California ISO

California Independent
System Operator Corporation

June 24, 2016

The Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: California Independent System Operator Corporation
Docket No. ER16- ___-000

Tariff Amendment to Implement Flexible Ramping Product

Dear Secretary Bose:

The California Independent System Operator Corporation (CAISO) submits this tariff amendment to implement the flexible ramping product.[1] The flexible ramping product replaces the existing flexible ramping constraint that the CAISO applies in its real-time market, including the Energy Imbalance Market (EIM). It will enhance the CAISO ability to manage the ramping capability necessary to meet changes in net load—both forecasted and unexpected.

The CAISO requests that the Commission accept the tariff revisions contained in this filing effective October 1, 2016. The CAISO respectfully requests an order by September 1, 2016, which, as explained further below, will provide the CAISO and market participants sufficient time to prepare for implementation of the new product.

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[1] The CAISO submits this filing pursuant to section 205 of the Federal Power Act, 16 U.S.C. § 824d. References to specific sections are references to existing sections in the current CAISO tariff ("existing tariff sections"), or to tariff sections as revised ("revised tariff sections") or proposed ("new tariff sections") in this filing, unless otherwise indicated.

I. Summary

Over the past several years, the CAISO has implemented several enhancements to its real-time market, which now includes the energy imbalance market (EIM), to manage effectively the integration of variable energy resources to support state and federal policies to decarbonize the grid. In 2011, the CAISO implemented a flexible ramping constraint to help ensure it positioned sufficient resources to meet forecast uncertainty for upward ramping needs. At that time, the CAISO committed to address limitations of the constraint through the design of a product that would more effectively dispatch resources to meet ramping needs. As California progresses toward implementing a 50 percent renewable portfolio, variable energy resources and behind the meter generation will play an increasing role in the CAISO's real-time market. This will require a greater need for ramping capability and the accurate settlement of such capability in conjunction with imbalance energy. After a robust stakeholder process, the CAISO is proposing a flexible ramping product that will ensure that sufficient upward and downward ramping capability is available and efficiently dispatched in the CAISO real-time market. The flexible ramping product as proposed will significantly improve the management of ramping capability and will enable the CAISO to support the environmental policy goals in the West more efficiently and economically.

The flexible ramping product is a significant enhancement from the flexible ramping constraint currently in place as it will procure and compensate resources for providing ramping capability for both the forecasted movement of net load, which is the gross load forecast less the wind and solar output, and uncertainty in the forecasted net load.

First, the flexible ramping product will procure ramping capability for the forecasted net load ramp, between the financially-binding interval and the subsequent advisory interval. Ramping of load, dispatchable resources, non-dispatchable resources, and interties can create both a demand for ramp and a supply for ramp. Load or supply resources that increase the need for ramping capability between intervals will be charged for the flexible ramping product. Load or supply resources that decrease the need for ramping capability between intervals will receive a payment for the flexible ramping product. Settling ramping capability directly between load or supply resources that consume ramping capability and those that provide ramping capability will help manage the ramping need by incentivizing load serving entities to have a portfolio of both dispatchable and non-dispatchable resources that can follow their load profile.

Second, in addition to procuring ramping capability for the change in forecasted net load, the flexible ramping product will procure an additional amount of ramping capability to cover uncertainty in the forecasted net load. Absent a flexible ramping product requirement, the market will solve only for expected load and system conditions. This limits the ability of the real-time dispatch to meet changes in system conditions between the fifteen-minute market and five-minute real-time dispatch, and between subsequent market runs of the five-minute dispatch. The flexible ramping product will address this forecasted net load uncertainty by procuring ramping capability in addition to that needed to meet the forecasted movement between intervals. It will only do this if the expected benefits of this additional ramping capability exceed its costs. The CAISO will determine this trade-off by calculating the probability of a power balance violation due to a deficiency in imbalance energy and the associated costs to the market and comparing this to the costs to procure ramping capability.

Unlike forecasted movement between intervals, there cannot be a direct settlement between those requiring ramping capability and those providing ramping capability to cover uncertainty in the forecasted net load. This is because the market may not need to use, and consequently attribute to a specific load or supply resource, the flexible ramping capability procured to cover uncertainty. Consequently, the market will allocate the costs of the ramping capability it procures to cover uncertainty based on a load's or a supply resource's contribution to this uncertainty. It will do this by evaluating each load's or supply resource's contribution to this uncertainty first daily and then recalculate those amounts for each month.

The CAISO developed the flexible ramping product over a four-year period and through a robust stakeholder process. The CAISO extended the stakeholder process to accommodate implementation of the fifteen-minute market and the Energy Imbalance Market in 2014. The CAISO took the necessary time to address stakeholder concerns and ensure the new product is appropriately tailored for the new market design. Stakeholders largely support the proposal, but have expressed concern regarding the need to evaluate whether the requirements setting tool will work as expected. As is normally the case with an enhancement of this importance, the CAISO will conduct a robust market simulation, which is scheduled to start in early August 2016. This will allow the CAISO to address this concern prior to implementing the new product.

II. Background

A. Need for Flexible Ramping Capability

The CAISO's real-time market, which is available to other balancing authority areas through the EIM, uses security constrained unit commitment and security constrained economic dispatch to commit and dispatch resources to serve forecasted demand in the real-time.[2] The CAISO will implement the flexible ramping product in the real-time market, which includes the fifteen-minute granularity short-term unit commitment and real-time unit commitment processes, and the five-minute granularity real-time dispatch. Each of these market runs optimizes over multiple time intervals. The CAISO financially settles the real-time market in the fifteen-minute market, based on schedules produced by the second interval of each run of the real-time unit commitment process, and dispatches produced by the first interval of each run of the five-minute real-time dispatch. These are referred to as "binding" intervals while the other intervals of each market run are referred to as "advisory" intervals. The CAISO must meet "forecasted net load" with dispatchable resources, which is the difference between total system demand and the demand met by non-dispatchable resources.[3] Because load and the output of variable energy resources are variable, the CAISO's real-time market must have resources available that can rapidly change their output to respond to a change in net forecasted system demand. This ability is called flexible ramping capability. The CAISO's experience in operating the markets shows that the fleet of resources committed in the fifteen-minute real-time unit commitment process to provide energy often does not provide sufficient flexible ramping capability in the five-minute real-time dispatch to meet the actual changes in net load that occur over every successive five-minute period.[4] When this occurs, the CAISO may have to relax the power balance constraint, dispatch units out of economic sequence, or dispatch units that are not in the market. Such measures impose additional costs on the system that are borne through uplift, and prices do not reflect such marginal costs.

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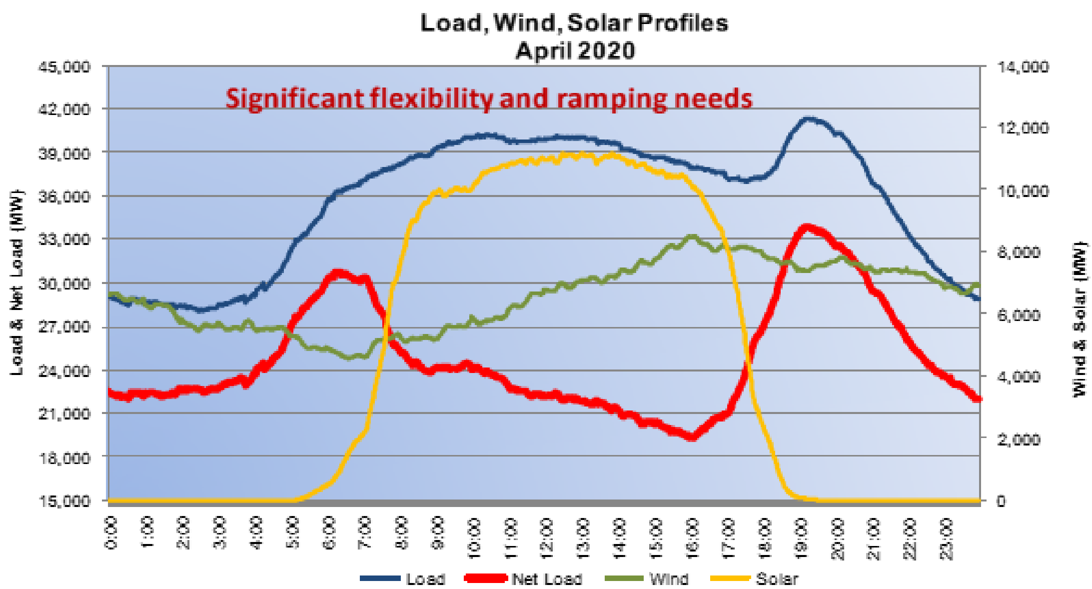
[2] Fewer resources generally are available for commitment in the real-time than in the day-ahead.

[3] Specifically, net system demand is load plus exports minus all resources' schedules that are not five-minute dispatchable, which may include variable energy resources, imports, and self-schedules.

[4] The need for enough flexible ramping capability should not be confused with the related need for sufficient flexible resource adequacy capacity, the latter of which the CAISO addressed in tariff revisions the Commission accepted in 2014. *See Cal. Indep. Sys. Operator Corp.*, 149 FERC ¶ 61,042 (2014). The relationship between the two needs is comparable to the relationship between resource adequacy and energy. Adequate resource capacity must first be available to ensure that system needs can be addressed, and then real-time market mechanisms must be in place to ensure efficient dispatch of energy from these resources. Similarly, sufficient flexible resource adequacy capacity must first be available to meet needs as they arise, and then sufficient flexible ramping capability must be in place to allow efficient dispatch of the available resources when such needs do arise.

Meeting ramping needs is becoming more challenging as California progresses toward its renewables portfolio standard requirement that load-serving entities meet 33 percent of their customers' annual electricity demand from variable energy resources by 2020. Moreover, the challenge will grow as more variable resources come online to meet the 50 percent renewables portfolio standard for 2030. Figure 1 below, which is a figure that the CAISO previously presented in support of the flexible ramping constraint amendment discussed below, remains relevant. It depicts the projected load, net load, and energy provided by wind- and solar-powered resources for the CAISO markets in April 2020.

Figure 1: Projected Load and Renewable Profiles in April 2020



In Figure 1, the net load (shown as a red line) equals the load (shown as a blue line) minus the variable energy resources' total wind and solar output (shown as a green and a yellow line, respectively). Figure 1 shows that the five-minute-to-five-minute net load change may triple in magnitude in the hours ending 18:00 and 19:00, with the variable energy resources' output moving in the opposite direction of the load. The variable energy resources' output may also reverse the direction of load ramping in the hours ending 7:00 and 8:00. These projections demonstrate the need for measures to maintain sufficient flexible ramping capability to ensure reliability.

B. Existing Mechanism for Providing Flexible Ramping Capability

The CAISO's market design, implemented in 2009, includes a multi-interval optimization in the unit commitment and dispatch processes that can look several intervals ahead to meet forecasted net load needs, including the ramping capability necessary to meet each successive interval's forecasted imbalance energy requirement. Specifically, at 7.5 minutes before interval t (*i.e.,* at t-7.5), the CAISO will run the optimization to determine the five-minute real-time dispatch for interval t, known as the "binding interval." The real-time dispatch forecasted net load for interval t is certain in the sense it is not subject to future changes in a subsequent market run. Similarly, the CAISO runs the optimization for the fifteen-minute real-time unit commitment process at 37.5 minutes before the binding interval. The optimization will take into account the forecasted net load over multiple successive intervals, or "advisory" intervals, to produce a feasible solution, *i.e.,* one that will meet forecasted net load over the series of intervals. The testimony of Donald Tretheway, Attachment C, explains the optimization in greater detail.

Mr. Tretheway uses a simplified two-resource example. His example shows that in a single interval dispatch, the market dispatches the supply needed to meet demand in that interval, without regard to the need to manage the ramping capability to meet demand in the next interval. In such a circumstance, the market may be unable to meet the demand in the advisory run and would need to take uneconomic measures, such as relaxing the power balance constraint and cause the CAISO to rely on regulation units or rely on the interconnection or dispatching units out-of-market or merit order.[5] In his example showing a two-interval optimization, the market meets the demand forecast for both the binding and advisory intervals simultaneously. To accomplish this, the market changes the dispatch composition in the binding interval and meets the demand in the advisory interval with two resources based on their ramping capability, ensuring there is sufficient ramping capability available to meet the forecasted net load increase.[6] Therefore, the multiple interval optimization enhances reliability by correctly positioning resources to meet forecasted system conditions in subsequent market runs.

C. Deficiency of Exclusive Reliance of Multi-Interval Dispatch for Meeting Flexible Ramping Needs.

The CAISO's experience has shown that the CAISO cannot rely exclusively on the multi-interval market optimization alone to meet net load needs because of the uncertainty in forecasts. Because the optimization does not include a margin of error between the forecasted ramping need and the actual ramping need, the optimization will generally commit and dispatch an amount of energy that exactly matches the forecasted net load. If the actual energy need is

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[5] Tretheway testimony at 5.

[6] Tretheway testimony at 14.

higher or lower than the forecast,[7] the supply may not be able meet demand, thus triggering a power balance violation.

A power balance violation can lead to three undesirable outcomes: (1) the system must rely on regulation services to resolve the issue in real-time after the imbalance has caused frequency deviation or area control error; (2) if there is insufficient regulation response the CAISO will be forced to rely on regulation energy from other balancing authority areas in the Western Interconnection to make up for the remaining shortage, which may affect the CAISO's ability to meet operational performance criteria required by North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC) reliability standards; and (3) administrative penalty prices rather than economic bids determine real-time dispatch energy prices.[8]

Although regulation services address forecast uncertainties, they are not a sufficient solution to address the ramping needs identified above. A deviation from forecasted net load may arise before the beginning of a trading interval or during the trading interval. The CAISO uses regulation services to address deviations that arise during the trading interval and compensates the provider for the energy at the corresponding real-time energy price (in addition to the ancillary services compensation for the regulation). Procuring additional regulation to address deviations that arise before the trading interval is problematic because the additional capacity reserved for regulation would not be available for dispatch as imbalance energy. This reduces the quantity of resources available for real-time dispatch and potentially can lead to more power balance violations. Although these power balance violations would not reflect actual operational issues, but rather over-procurement of regulation, they would trigger penalty prices related to the bid caps ($1000/MWh and -$155/MWh for incremental and decremental energy, respectively). The penalty prices would also apply to any energy dispatched from the regulation.

The CAISO could also obtain additional ramping capability by procuring additional spinning reserves, but this would be overly expensive as the price of spinning reserves includes the opportunity cost of not providing energy. The CAISO procures spinning reserves as capacity available to be dispatched in the event of a contingency, whereas the ramping capability under the flexible

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[7] This may occur for a variety of reasons, including five-minute interval granularity; resources shutting down without sufficient notice; variable energy resources delivering more or less than forecast, including sudden changes in expected deliveries; contingency events; high hydroelectric run-off decreasing resource flexibility; interties tagging and delivering less than amounts awarded in the hour-ahead scheduling process of the real-time market; and interchange ramp in and out between hours.

[8] *See* existing tariff sections 27.4.3.4, 39.6.1.1.

ramping product is available for dispatch independent of a contingency event. As the market often dispatches ramping capability to provide energy, resources providing ramping through spinning reserves would also receive an energy payment, such that the capacity would receive double compensation. In addition, there is no downward contingency reserve product.

Reliance on multi-interval dispatch to address flexible ramping needs also raises issues regarding the compensation of resources providing ramping capability. The market optimization makes resources whole by factoring in all of a resource's costs and revenues in earlier intervals when calculating prices for advisory intervals. It does not employ this information when an advisory interval becomes the upcoming binding interval. Mr. Tretheway demonstrates this deficiency, building on his simplified two-resource example. He demonstrates that the multi-interval optimization would have dispatched the first unit lower than it would have without the multi-interval optimization, and dispatched the second unit out-of-economic-order to simultaneously meet load in the binding and advisory intervals. In his example, we see that the financially binding price is set by the first unit, since it is the marginal unit, and that unit is adequately compensated for its dispatch since the marginal price reflects its bid price from its bid curve. The second resource, held out of economic merit order, however, experiences bid insufficiency, which under today's market design is recovered through bid cost recovery uplift to the extent its bid costs over the entire day exceed its revenues for the day. This mutes accurate price signals reflected in the market-clearing price for individual market intervals and poses the potential for increased uplift payments that are spread to the load.

The current design also raises compensation issues regarding the first resource in the financially binding interval in the example described above. The resource receives no payment for the flexible ramping capability that the optimization counting on in the binding interval to meet the next interval's net load forecast. As to energy, the first resource is indifferent to this result, because the marginal price reflects its bid, which is theoretically its marginal costs. Nonetheless, the resource provides a valuable service—its ramping capability—without compensation. As the example in Mr. Tretheway's testimony shows, under the CAISO's proposed flexible ramping product, this resource would receive a flexible ramping product payment for the value of this ramping capability, in addition to the locational marginal price for energy.[9]

The existing flexible ramping constraint, discussed below, partially addresses these issues, but it is limited to the real-time unit commitment process and upward ramping. The proposed flexible ramping product will also provide additional ramping capability to address the potential downward error in

[9] *See* Tretheway testimony at 21-22.

forecasted net load. It will also provide resources with compensation for the flexible ramping capability that they provide to address the forecasted movement issues identified above.

D. Interim Flexible Ramping Constraint

In 2011, following a stakeholder process, the CAISO proposed and, after settlement procedures, the Commission approved a tariff amendment to implement a flexible ramping constraint that would operate in the real-time unit commitment process as an interim measure for ensuring the commitment of sufficient upward ramping capability[10] of dispatchable resources.[11]

The flexible ramping constraint currently operates in the fifteen-minute unit commitment processes to ensure available capability from flexible dispatchable resources to meet upward ramping needs in the five-minute real-time dispatch. Specifically, the constraint reserves unloaded ramping capability from dispatchable resources that the CAISO has not designated to provide regulation or contingency reserves, and whose upward capability is not committed to meet forecasted net load needs, in the real-time unit commitment processes. This capability is then available for five-minute dispatch instructions from the real-time dispatch, and, if dispatched above minimum load, the capability is eligible to set real-time locational marginal prices (subject to other specified eligibility

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[10] The CAISO did not propose to apply the flexible ramping constraint to ensure sufficient downward ramping capability of dispatchable resources because it believed at the time that (1) maintaining sufficient upward ramping capability would more directly resolve reliability concerns; (2) enforcing a downward ramping constraint might not be effective in times of over-generation conditions, as commitment of additional resources to be available to ramp down may exacerbate over-generation conditions, and (3) the CAISO determined that other market-based measures being pursued through another stakeholder process would address over-generation concerns more appropriately.

[11] *See Cal. Indep. Sys. Operator Corp.*, 140 FERC ¶ 61,012 (2012); *Cal. Indep. Sys. Operator Corp.*, Commission letter order, Docket No. ER12-50-001 (Nov. 29, 2012) (accepting revised tariff records included in settlement); *California Indep. Sys. Operator Corp.*, Commission letter order, Docket No. ER12-50-002 (Feb. 19, 2013) (accepting revised tariff record to correct typographical error). Section 6.4 of the settlement included a provision stating that the settlement was not intended to prejudge or limit the CAISO's authority to make a filing with the Commission pursuant to section 205 of the FPA regarding any flexible ramping product or other measures, including to propose such new products or measures, that may be the same as or different from the revised tariff provisions. *See California Indep. Sys. Operator Corp.*, 140 FERC ¶ 63,019, at P 20 (2012).

provisions).[12] Resources whose ramping capability is used to resolve the flexible ramping constraint are compensated pursuant to a formula set forth in the tariff.[13]

The flexible ramping constraint only partially meets system ramping needs because it only operates in the unit commitment processes and only addresses upward ramping needs. The CAISO did not intend the constraint to be the final solution to ramping needs, but expected that the constraint would help alleviate the issues arising from the lack of flexible ramping capacity while the CAISO developed a flexible ramping product, which would be a new market product. In directing settlement procedures, the Commission acknowledged the need for a more robust solution, noting that the CAISO was developing the flexible ramping product with stakeholders and "strongly encourag[ing] CAISO to continue its work toward a bid-based flexible ramping product."[14]

E. Stakeholder Process for the Proposed Flexible Ramping Product

The CAISO conducted the stakeholder process to develop the flexible ramping product from 2011 to 2016. The CAISO issued fourteen papers and provided opportunities for stakeholders to submit written comments on each of the papers. The CAISO conducted nineteen stakeholder meetings and conference calls to discuss the CAISO papers and other matters related to the flexible ramping product. Materials regarding this stakeholder process are

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[12] *See* existing tariff section 27.10.

[13] *See* existing tariff section 11.25.

[14] *Cal. Indep. Sys. Operator Corp*., 137 FERC ¶ 61,191 at P 30 (2011). *See also id.* at P 27 n.46 ("The Commission encourages CAISO to continue developing its bid-based flexible ramping product."). From time to time, the CAISO has subsequently informed the Commission of progress made in the flexible ramping product stakeholder process. *See, e.g.*, *Cal. Indep. Sys. Operator Corp.*, 148 FERC ¶ 61,173, at P 17 (2014). The fully developed flexible ramping product relies on energy bids, but only for the portion that addresses uncertainty.

available on the CAISO website.[15] The Draft Final Proposal and Technical Appendix are provided as Attachments D and E to this filing.[16]

The CAISO Governing Board (Board) voted unanimously to authorize this filing during its public meeting held on February 3, 2016. Materials related to the Board's authorization, including the report of the Market Surveillance Committee, are available on the CAISO website.[17] The memorandum to the Board on the flexible ramping product is provided in Attachment I to this filing. The Market Surveillance Committee opinion is provided in Attachment J.

The CAISO published draft tariff language for comments on April 26, 2016. The CAISO responded to comments[18] on a web conference on May 10, 2016. The CAISO posted revised language on May 20, 2016, and discussed them with stakeholders on May 26, 2016.[19]

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15 *See* Flexible Ramping Product Stakeholder Process Webpage, http://www.caiso.com/informed/Pages/StakeholderProcesses/FlexibleRampingProduct.aspx.

16 In the middle of this period (from the fall of 2012 to the spring of 2014), the CAISO temporarily suspended the stakeholder process regarding the flexible ramping product to focus on the development of other significant market enhancements subsequently accepted by the Commission, including the CAISO's fifteen-minute market and the energy imbalance market. *See Cal. Indep. Sys. Operator Corp.*, 146 FERC ¶ 61,204 (2014) (conditionally accepting proposed tariff revisions to implement fifteen-minute market); *Cal. Indep. Sys. Operator Corp.*, 147 FERC ¶ 61,231 (2014) (conditionally accepting proposed tariff revisions to implement energy imbalance market). Further, in the spring of 2014, the CAISO and stakeholders developed a flexible ramping constraint relaxation parameter in the same stakeholder initiative that resulted in this tariff amendment filing. *See Cal. Indep. Sys. Operator Corp.*, 149 FERC ¶ 61,256 (2014) (accepting proposed tariff revisions to implement flexible ramping constraint relaxation parameter).

17 *See* CAISO Board of Governors Materials, http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=A32400DA-3AEC-4E21-ACD4-3816F0161F5E

18 See Stakeholder Comments on Proposed Tariff Language, *http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=7F4D1724-63A4-43AB-B1A5-8588F9EB2DC3*

19 See Stakeholder Comments on Proposed Tariff Language Matrix, *http://www.caiso.com/Documents/CommentsMatrix-FlexibleRampingProduct-DraftTariffLanguage.pdf*.

III. The Flexible Ramping Product

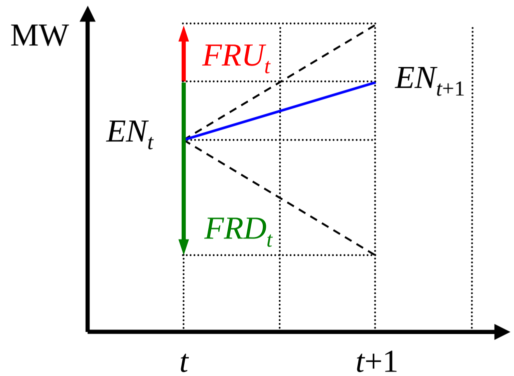
This section describes the CAISO's proposed implementation of the flexible ramping product. The CAISO explains conforming tariff provisions in the next section.

A. Overview

The flexible ramping product is an enhancement to the CAISO's real-time market that improves the management of ramping capability to meet changes in system conditions. It also financially settles the resources and loads that provide and consume ramping capability more appropriately by explicitly compensating for ramping capability and calculating the value of ramping distinct from the imbalance energy price. The flexible ramping product consists of upward ramping capability and downward ramping capability. The flexible ramping product will replace the existing flexible ramping constraint.

The flexible ramping product will enhance the CAISO's ability to address net load variation between market intervals. Because ramping capability procured under the flexible ramping product is not withheld from the market, the flexible ramping product will enhance the flexibility of dispatch. There are two components to the real-time ramping need. The first is the amount of ramping capability necessary to meet the changes in forecasted net load between market intervals of the same market run (the "forecasted movement"). The existing multi-interval optimization addresses this need, however, as described earlier, does not provide accurate price signals for this need. The second component is the amount of additional ramping capability necessary to meet net load if the forecast error materializes in a subsequent market run (the "uncertainty requirement"). Figure 2 illustrates these components, with the change in forecasted net load between t and t+1, shown as EN_t and En_{t+1}, being the forecasted movement up, the dotted lines representing the additional amounts necessary for uncertainty, with upward uncertainty requirement shown as FRU and downward uncertainty requirement shown as FRD.

Figure 2



The flexible ramping product will compensate resources for both components. In its market optimization, the CAISO will first procure the forecasted movement and uncertainty awards through the market's 15-minute market runs. Both the uncertainty awards and the energy schedules are financially binding at the fifteen-minute market price of the financially binding interval. The CAISO will also re-optimize the procurement of forecasted movement and uncertainty awards in the five-minute real-time dispatch and settle differences in the amount of flexible ramping procured at the five-minute real-time price.

The flexible ramping product is distinct from capacity products, such as ancillary services. Ancillary services in the CAISO's market are "standby" unloaded capacity available to meet net system demand deviations from assumed levels in the same trading interval. The unloaded capacity represents energy that is withheld from the market and not routinely available for dispatch. The CAISO deploys through automated generation control energy from regulation services after the real-time dispatch through automatic generation control, not through economic bids. The CAISO dispatches operating reserves through the real-time contingency dispatch only after a defined contingency event occurs.

B. Uncertainty Awards

Procurement of uncertainty requirements optimized through the use of a procurement curve.

The CAISO will determine uncertainty requirements for each balancing authority area in the EIM area[20] and for the EIM area as a whole. As previously explained, the uncertainty requirement is an amount of flexible ramping capability to cover the potential error in the real-time dispatch forecasted net load.[21]

The CAISO will only issue uncertainty awards to the extent that procuring for the uncertainty is economic. The CAISO will determine whether it is economic to do so by determining whether the cost of procurement is less than the avoided cost of relaxing the relevant power balance constraint. For this purpose, the CAISO will use a "procurement curve" to procure the flexible ramping product uncertainty requirement up to the expected cost of incurring a power balance violation, at which point the constraint will be relaxed. The CAISO will determine the likelihood of error through a probability distribution function of the historical forecasted net load errors and other appropriate data. The probability distribution of errors will use a specified confidence level. At this time, the CAISO expects the confidence interval to be at 95 percent. However, this may change over time as the CAISO obtains more experience with the use of the new tool.

The CAISO will calculate the forecasted net load error for each fifteen-minute unit commitment run interval and for each five-minute real-time dispatch interval. For a given fifteen-minute real-time unit commitment run interval, it will calculate the forecasted net load error as the difference between the forecasted net load the market used in the real-time unit commitment process for the first advisory real-time unit commitment interval and the maximum and minimum

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[20] The EIM area consists of the CAISO balancing authority area and the balancing authority areas participating in the EIM as a whole.

[21] In determining uncertainty awards, the CAISO will use its supply and demand forecasts, including variable energy resource forecasts. Variable energy resources may use their own forecasts for energy settlement, even though the CAISO uses its independent forecasts when clearing the market optimization. *See, e.g.,* § 29.11(j). For the flexible ramping product, since the ramping is calculated based upon what is used within the market optimization, the CAISO will not use these forecasts submitted by resources used solely for energy settlement for the purpose of awarding and settling the flexible ramping product. If a different forecast was used to determine flexible ramping awards than what was used in the market optimization, this could potentially lead to market manipulation by resources submitting inaccurate forecasts to inflate flexible ramping product payments, and the need for uplift charges resulting from forecasted movement settlement because buyers and sellers of ramping capability would not equal.

forecasted net load the market used for the three corresponding (*i.e.*, for the same time period) binding five-minute real-time dispatch intervals. The CAISO will calculate the forecasted net load error for a given five-minute interval as the difference between the forecasted net load the market used for the binding real-time dispatch interval and the forecasted net load for the corresponding advisory interval of the previous real-time dispatch run.

The CAISO will enforce the uncertainty requirement in all intervals of all the various components of the real-time market, which include the short-term unit commitment process, the real-time unit commitment process, and the real-time dispatch.

The CAISO will place limits on the procurement curve to preserve the priority of ancillary service necessary to meet NERC and WECC reliability criteria over flexible ramping capability. The CAISO will set the penalty price of relaxing the flexible ramping uncertainty requirement to a price lower than the penalty price of relaxing the ancillary services requirement. The CAISO will do this so that the CAISO will forgo procuring uncertainty awards before it forgoes procuring ancillary services. It will give a higher priority to ancillary services because these are required to meet NERC and WECC reliability criteria while there is no similar criteria for flexible ramping capability. The CAISO will limit the upward procurement curve to an amount (specified in the business practice manual) less than the CAISO's contingency reserves relaxation penalty pricing parameter. Mr. Tretheway indicates that at this time, the CAISO believes it will be necessary to set the flexible ramping product parameter to $3/MW less than the parameter for relaxing the upward and downward ancillary services requirement.[22] The CAISO will also limit the downward procurement curve to an amount (specified in the business practice manual) less than the CAISO's regulation down penalty pricing parameter.

The CAISO will describe in detail how it calculates the probability distribution functions, how it will specify the confidence interval, and how it will develop the procurement curve in the business practice manuals. The CAISO is requesting this level of flexibility because it will be necessary to modify the methodology over time, as it gains experience and determines better ways to refine the procurement requirement. For example, the CAISO may determine that under the chosen methodology it is procuring a greater or lesser amount than needed. While the CAISO expects to determine the probability distribution function for each hour of the day, the CAISO will evaluate whether hours with

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[22] *See* Business Practice Manual for Market Operations § 6.6.5. The parameter for the flexible ramping product will be specified in the same business practice manual.

similar ramping patterns could be combined to increase the sample size used in the historical analysis.

Any change in the methodology will be subject to the business practice manuals change management process. Under the change management process the CAISO will be required to stakeholder the changes and participants will have the ability to comment and appeal any decisions made.[23] This provides market participants with due process regarding the procurement requirements.

To the extent these procedures produce requirements that are anomalous and not consistent with actual conditions, the CAISO operators will have the ability to make adjustments that ensure the CAISO dispatches are reliable. These adjustments will be made consistent with good utility practice to ensure the market solution does not adversely impact reliability.

Flexible ramping product selected based on energy bids and no separate bids for the product will be required.

There will be no separate bids for the uncertainty awards. Rather, the CAISO will economically dispatch energy and determine uncertainty awards contemporaneously through the real-time market, using the energy bids submitted by suppliers. As explained further below, the flexible ramping product price will be based on the shadow price of the flexible ramping uncertainty requirement constraint, which can result from various factors, including costs when a resource is dispatched at an energy price lower than its energy bid price or opportunity costs when a resource is held back when the energy price is greater than its bid price. When the CAISO commenced the flexible ramping product stakeholder process, the CAISO and stakeholders anticipated that the flexible ramping product would be an economically bid capability product, that the CAISO would procure both upward and downward ramping capability, and procure the product in the day-ahead market.

As the stakeholder initiative progressed, the CAISO and stakeholders questioned the appropriateness of economic bidding in the real-time market because there is no additional cost for an out-of-merit dispatch beyond the cost of not being dispatched consistent with a resource's energy bid. In addition, the CAISO determined that the benefits of procuring the flexible ramping product in the day-ahead market were not significant enough to overcome the inefficiencies caused by different settlement and dispatch periods between the day-ahead and real-time market. These inefficiencies include significant flexible ramping product re-procurement in the real-time market. For example, the day-ahead market would potentially procure the same amount of flexible ramping product from two

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[23] *See* CAISO Tariff § 22.11.

60 MW resources, but one with a 100 MW/min ramp rate and the other with a 1 MW/minute rate. The day-ahead market would procure up to 60 MWh of flexible ramping product from both resources, while the resource with the 1 MW/minute ramp rate could only provide 5 MWh of flexible ramping product in each five-minute real-time dispatch interval.

Certain stakeholders expressed concern that any resource can be awarded flexible ramping product so long as they have an energy bid and that to avoid this there should be a separate bid to award them flexible ramping product. These stakeholders were concerned that their resource could be awarded flexible ramping product in the day-ahead market and they would incur additional costs for “buying-back” that flexible ramping capability in the real-time market, either because their resource would not be able to provide that capability or if they would want to self-schedule additional energy in the real-time market. However, absent procurement in the day-ahead, there is no need for a separate bid, because there are no costs incurred in the real-time market that need to be recovered through a bid-in price. As the Market Surveillance Committee noted:

> [T]he 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. 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 [real-time] markets.[24]

The Market Surveillance Committee also explained that with bids in the real-time market, it would be possible that resources offering ramp with a positive bid price not clear, despite their capability being available for dispatch in real-time. Then 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 capability and simply not pay the resources. The CAISO agrees with the Market Surveillance Committee that separate bids for the flexible ramping product would create inefficiencies and there is no evidence supporting the need for additional compensation.[25]

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[24] *See* Attachment J, California ISO Market Surveillance Committee, Opinion on Flexible Ramping Product at 10.

[25] *Id.* at 11.

No certification of ramping capability required.

The proposal does not require resources to have a certified flexible ramping capability, as is the case with the provision of ancillary services, The CAISO does, however, propose to limit eligibility for uncertainty awards to dispatchable resources that have economic bids in the real-time market. This includes variable energy resources who are economically bidding to be dispatched or scheduled at their forecasted output. Because uncertainty in the forecasted net load materializes in the real-time dispatch, a resource must be dispatchable in order to resolve forecasted net load errors. A resource cannot receive an uncertainty award if it is in a forbidden operating zone or during a multi-stage generator transition because resources have limits on their ramping ability under those conditions.

Uncertainty awards will be procured at regional levels for the individual balancing authority areas and EIM area as a whole.

The CAISO proposes to set the uncertainty requirement and procure uncertainty awards at a regional level for the individual balancing authority areas and the EIM area as a whole. Certain stakeholders also proposed the CAISO consider more granular procurement, expressing a concern that without a more locational, *i.e., sub-regional,* component, the CAISO may procure flexible ramping product that is ultimately stranded due to congestion and thus unable to serve the intended need. On the other hand, the Market Surveillance Committee stated that it is not possible to judge whether locational procurement will be needed until the CAISO gains experience with the flexible ramping product and the expansion of the EIM.[26] Other stakeholders argued that further delay in implementing the product to accommodate additional modifications is unreasonable and unwarranted. These stakeholders pointed out that the CAISO can track the "performance of the product, once implemented, through the CAISO's well established and rigorous market performance and monitoring safeguards, including through reports and oversights by the Department of Market Monitoring (where applicable) and through the regularly scheduled Market Performance and Planning Forum."[27] The CAISO agrees with these stakeholders and the Market Surveillance Committee, particularly because to provide more granular procurement would require significant enhancements that

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[26] *Id.* at 9.

[27] *See Stakeholder Comments to Draft Final Proposal, available at,* http://www.caiso.com/Documents/CESAComments-FlexibleRampingProduct-RevisedDraftFinalProposal.pdf.

would unnecessarily delay implementing the product. Therefore, the CAISO proposes to proceed without the more granular procurement at this time.

The CAISO will monitor ramping needs to refine procurement targets.

As noted above, the CAISO intends to draw upon actual market experience to refine the determination of ramping needs. This should respond to concerns expressed by its Department of Market Monitoring, the Market Surveillance Committee, and certain stakeholders stressing the importance of the determination of the amount of ramp capability that the fifteen-minute market and the real-time dispatch target for procurement. The CAISO agrees that it is necessary to ensure that the target is not too high relative to potential ramp requirements. If set too low, the CAISO will not procure sufficient ramping capability resulting in increased power balance violations, which the proposal is intended to avoid. Conversely, if it procures too much, capability procured would create incremental ramp capability in one interval will exceed the amount of capability needed to avoid power balance constraint relaxations in subsequent intervals.[28]

The Department of Market Monitoring recommends that the CAISO ensures that sufficient time and resources are made available to develop, review and refine the demand curve prior to implementing the flexible ramping product in the fall. Key to the Department of Market Monitoring's concerns is for the CAISO to ensure there is a sufficiently large sample of net load forecast errors used to estimate the procurement curve.[29]

One of the concerns expressed by the Department of Market Monitoring is that the CAISO's current intent to draw the probability distribution of errors hourly can result in the CAISO forgoing certain information that could be captured were the CAISO to draw the historical errors through a broader range such as daily or in groupings of hours. The CAISO believes that while it is possible that certain data points that cross the hours of a day may be missed, it is also possible that because system and other conditions vary through the day there may be historical events that provide no value or possibly even skew requirements in any given hour. For example, events and errors that are specific during the load pull are unlikely to be relevant for other hours of the day. Crossing over such hours could cause the CAISO to set its requirements inconsistent with actual need.

In any case, the CAISO intends to evaluate its current methodology and the parameters it sets for determining the procurement requirement during market simulation and plans on continuing to evaluate these after it implements

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[28] Market Surveillance Committee Opinion at 7.

[29] Department of Market Monitoring Comments, Attachment H, at 13.

the new feature. The CAISO will inform market participants of the performance of its procedures through the market simulation process and will document how it intends to proceed at the start in the business practice manuals. This evaluation process should provide the Department of Market Monitoring, the CAISO, and all market participants sufficient visibility into the performance of the probability function and opportunity to guide the setting of these requirements in a prudent manner.

C. Market Optimization

As is the case with the current energy and ancillary services market, the proposed tariff changes do not detail the optimization process for the flexible ramping product. Nonetheless, the CAISO will provide a general overview here to assist the Commission's evaluation of the overall proposal. Additional detail is available in the Technical Appendix included as Attachment E.

The CAISO's model will continue to optimize over multi-interval horizons. The CAISO will model the flexible ramping product by enforcing ramping constraints in each interval of the short-term unit commitment process, real-time unit commitment process and the real-time dispatch. Modeling in the advisory intervals will enable the optimization to anticipate and address ramping needs in those intervals.

The process modifies the optimization process to ensure that sufficient ramping capability is maintained in order to meet both forecasted movement and uncertainty requirements. The changes to the constraints involving flexible ramping are as follows:

- Upward ramping capability limit: This constraint enforces the sharing of a resource's upward ramping capability among the upward flexible ramping product and the upward reserve (regulation-up, spinning, and non-spinning) awards across market clearing intervals.

- Downward ramping capability limit: This constraint enforces the sharing of a resource's downward ramping capability among the downward flexible ramping product and regulation-down awards across market clearing intervals.

- Active power maximum limit: This constraint limits the resource's energy schedule, upward reserves, and upward flexible ramping product to be less than or equal to the resource's upper economic limit.

- Active power minimum limit: This constraint limits the energy schedule minus the award of regulation-down and the downward flexible ramping product to be greater than or equal to the resource's lower economic limit.

- Upward flexible ramping requirement: This constraint ensures that the total amount of upward uncertainty awards meets the upward uncertainty requirement based on the uncertainty demand curve.

- Downward flexible ramping requirement: This constraint ensures that the total amount of downward uncertainty awards meets the downward uncertainty requirement based on the uncertainty demand curve.

D. Settlement

1. Overview

The CAISO has designed the settlement principles to conform to principles of cost causation. Under well-settled law, a rate satisfies the cost-causation requirement if it allocates costs to customers in proportion to the benefits they derive from the incurrence of the costs *or* to their respective contribution to the need for those costs to be incurred.[30] To be sure, FERC need not "allocate costs with exacting precision,"[31] but it must adhere to the principle of cost-causation to the extent possible and may only depart from it in extraordinary circumstances and for a limited purpose.[32] As discussed below, in each instance, the CAISO has attempted to ensure that resources are adequately rewarded for services they provide, but not to an extent beyond the benefits that those services yield.

2. Resource Compensation Level

The CAISO will pay and charge resources a flexible ramping price, up or down, equal to the shadow price of the uncertainty requirement for the applicable constraint, as described below. This is the marginal production cost reduction from relaxing the constraint, which equals the marginal cost of procuring flexible ramping product. This is the appropriate price because it represents the marginal cost of obtaining flexible ramping capability. The CAISO will calculate separate prices for the fifteen-minute market and the real-time dispatch. The CAISO will discuss the use of these prices separately for uncertainty awards and forecasted movement. This is also consistent with the CAISO's locational marginal pricing

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30 *Midwest ISO Transmission Owners v. FERC*, 373 F.3d 1361, 1368 (D.C. Cir. 2004.

31 *Id*. at 1369.

32 *Transmission Access Policy Study Group v. FERC*, 225 F.3d 667, 707 (D.C. Cir. 2000)

principles, which also result in prices that reflect the marginal cost of meeting system requirements.

3 Uncertainty Awards

The CAISO will settle uncertainty awards to resources at the applicable flexible ramping price for each settlement interval. As described below, the CAISO will rescind amounts that represent double payment.

As discussed above, and in more detail in Mr. Tretheway's testimony,[33] in order to address uncertainty requirements, the real-time market may dispatch a resource inconsistent with its bid to position the system so that the forecasted net load plus uncertainty requirement are achievable if the forecast error materializes in the subsequent market run. In such circumstances, the resource will receive the locational marginal price for its energy, but may incur a loss due to the difference in its bid (reflecting its marginal costs) and the locational marginal price. By paying the unit an uncertainty award reflecting the marginal cost of the uncertainty requirement, the CAISO is making the resource whole.[34] This not only provides just compensation to the resource, but also reduces the need for real-time bid cost recovery, a major advantage.

Because the resource incurs no costs (in addition to the variable costs recovered through the energy price and the uncertainty award price), no additional compensation is necessary. The CAISO's Market Surveillance Committee agrees that there are no other costs incurred in this situation and no market participants put forth any reasonable costs to be recovered through the CAISO markets.[35]

Supply resources (including dynamically scheduled interties), static interties, and load other than five-minute metered load each contribute to the uncertainty requirement in similar ways.[36] Unlike forecasted movement between intervals, there cannot be a direct settlement between those requiring ramping capability and those providing ramping capability to cover uncertainty in the forecasted net load. This is because the market may not need to use, and consequently cannot attribute to a specific load or supply resource, the flexible ramping capability procured to cover uncertainty. Consequently, the CAISO determined it is best to allocate the costs of the ramping capability it procures to

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[33] Tretheway testimony at 18-19.

[34] Tretheway testimony at 27-28.

[35] Market Surveillance Committee Opinion at 10.

[36] Load is metered hourly, supply is metered in five-minute intervals, and interties are metered in fifteen-minute intervals.

cover uncertainty based on a load's or a supply resource's contribution to this uncertainty. This allocation follows the principles of cost causation as it assigns responsibility as close as possible to each category's contribution to the uncertainty.

The CAISO will allocate these costs in two-steps. First, it will allocate the costs in the first step pro-rata between load, generation, and imports/exports based upon the observed forecast error of each category relative to the other two categories. Second, it will allocate the costs in the second step for each category, load, generation, and imports/exports, an appropriate billing determinant for that category.

For the first step allocation, the CAISO will initially calculate the uncertainty movement for each supply and intertie resource as the difference between the dispatch instruction or real-time dispatch schedule, as applicable, in the binding interval and when it was the advisory interval in the previous market run. Then, for each of the three categories to be charged, the CAISO will calculate the total uncertainty movement for the interval. For the supply and intertie categories, this is the net sum of uncertainty movements initially calculated for each supply and intertie resource. For non-participating load, it is the change in forecast demand between the binding interval and the advisory interval. Then the CAISO will allocate the upward and downward charges to each category according to the ratio of the category's upward or downward uncertainty movement to the total upward or downward uncertainty movement. The CAISO will perform these calculations for each five-minute interval, and separately by balancing authority area and the EIM area as a whole. Having determined the categories' share of the uncertainty award costs, the CAISO will then allocates the amounts to scheduling coordinators to reflect, to the degree possible, their contribution to the need for the ramping capability, *i.e.,* the need for incremental and decremental imbalance energy.

In the second step, the CAISO will allocate costs assigned to non-participating load to each scheduling coordinator based on its pro-rata share of gross uninstructed imbalance energy (excluding the non-participating load of a metered subsystem that has elected to load-follow according to a metered subsystem), with no netting between settlement intervals. As discussed by Mr. Tretheway, the allocation reflects the fact that negative uninstructed energy reflects the need in real-time for upward imbalance energy and positive uninstructed energy reflects the need for downward imbalance energy. The CAISO will allocate upward flexible ramping product uncertainty costs to negative (increased consumption) uninstructed imbalance energy. It will allocate downward flexible ramp product uncertainty costs to positive (decreased consumption) uninstructed imbalance energy. Because load is metered on an hourly basis, the CAISO will perform these allocations on an hourly basis. The allocation will exclude the metered subsystem load following operational adjustment because they are metered on a five-minute basis.

The CAISO proposes to allocate costs assigned to supply based on both uncertainty movement and uninstructed imbalance energy. The CAISO will allocate these amounts on the five-minute basis, matching the metering intervals for supply resources. The use of uncertainty movement is appropriate because it is the materialization of forecast error between the advisory interval from the preceding market run and the binding interval of the subsequent market run. The CAISO also includes consideration of uninstructed imbalance energy in order to provide an additional incentive for dispatchable resources to follow their dispatch instructions. If uninstructed imbalance energy persists, this can increase the need for dispatch other resources for energy, which can change the dispatch between the two market runs. As noted by Mr. Tretheway, this reflects the fact that negative combined uncertainty movement and uninstructed imbalance energy creates the need for incremental imbalance energy above what the prior market run anticipated. Upward combined uncertainty movement and uninstructed imbalance energy create the need for decremental imbalance energy below what the prior market run anticipated.

The CAISO will first determine for each scheduling coordinator the positive or negative difference for each settlement interval between the positive or negative (*i.e.,* upward or downward) uncertainty movement and the positive or negative uninstructed imbalance energy. The CAISO will then sum all positive differences and all negative differences and allocate upward flexible ramping product uncertainty costs to each scheduling coordinator according to its pro rata share of the total positive differences. It will allocate downward flexible ramping product uncertainty costs to each scheduling coordinator according to its pro rata share of the total negative differences. The CAISO will use the same method for load-following metered subsystems, except that the CAISO will sum the non-participating load uninstructed imbalance energy, supply resources within the MSS uninstructed imbalance energy, load following energy, load following operational adjustments, and uncertainty movement.

The CAISO proposes to allocate costs assigned to the static intertie transactions (*i.e.,* those other than those dynamically scheduled) according operational adjustments. Operational adjustments for static interties are analogous to uninstructed imbalance energy for load, and similarly contributes to the need for additional dispatchable resources to cover changes between market runs. For upward uncertainty awards, the CAISO will allocate the costs to the ratio of the magnitude of the scheduling coordinator's negative operational adjustment for non-dynamic system resources, or positive operational adjustment for export resources, to the sum of the magnitudes of such operational adjustments in the balancing authority area or system-wide, without netting that sum across settlement intervals, to the total absolute value of such operational adjustments in the balancing authority area or system-wide, without netting that sum across settlement intervals. The methodology will be the same for downward uncertainty awards except that the CAISO will reverse the positive and negative designations. In the same manner as static interties are metered, the CAISO will make these allocations on a 15-minute basis. As descried by Mr. Tretheway, negative operational adjustment for non-dynamic system resources and positive operational adjustment for export resources are analogous to negative uninstructed energy and positive operational adjustment for non-dynamic system resources and negative operational adjustment for export resources are analogous to positive uninstructed imbalance energy.

Because the uncertainty requirement addresses the potential for differences between the forecasted net load for an advisory interval and the forecast when that interval becomes the binding interval in the subsequent market run, it is analogous to a form of insurance. For this reason, the CAISO concluded it is more appropriate to allocate the cost over a longer period and initially proposed to settle uncertainty awards to resources at the end of the month. In examining implementation issues, however, the CAISO recognized that, because it needed to include flexible ramping product compensation in bid cost recovery, it would need to compensate resources daily, which then necessitates the need to calculate the allocation on a daily basis. Therefore, the CAISO will do a first allocation of the cost of the uncertainty awards (*i.e.,* the compensation paid to resources) on a daily basis. The CAISO proposes to reallocate the cost (*i.e.,* the compensation paid to resources) at the end of the month.

In the monthly reallocations, the CAISO proposes to allocate the costs of the uncertainty awards into the same categories described above separately to peak and non-peak hours and for upward ramping and downward ramping. Peak hours are those from 7:00 a.m. to 11:00 p.m. All other hours are non-peak. This will be more consistent with cost causation by reflecting the fact that solar facilities do not contribute to uncertainty during evening hours.

One market participant expressed concern with the need to disaggregate the allocation into the two groups. Although that market participant also stated that it did not believe this issue poses a market problem, it argued that the disaggregation into the groups does not provide any benefits but does impose significant processing issues and difficulties for settlement validation. The CAISO disagrees. The grouping allows the CAISO to allocate the costs more consistently with cost causation principles, taking into account that solar generation does not contribute to uncertainty in the night hours. The CAISO will also provide the allocation by these two groups and the parties can validate the amounts based on the information provided and their own information on uninstructed imbalance energy.

Finally, if the settlement amounts for flexible ramping up uncertainty awards, flexible ramping down uncertainty awards, flexible ramping up uncertainty rescission amounts, flexible ramping down uncertainty rescission amounts, flexible ramping up uncertainty allocation amounts, and flexible ramping down uncertainty allocation amounts do not equal zero, the ISO will assess the resulting differences to all scheduling coordinators with metered demand within the balancing authority area and system-wide.

4. Forecasted Movement

Forecasted movement compensation addresses the compensation issues that arise from multi-level optimization, as discussed above. As with uncertainty awards, a dispatchable resource may be dispatched inconsistent with its economic bid to provide ramping capability necessary to meet the forecasted net load in the next market interval of the current market run. It is appropriate to compensate all resources that provide flexible ramping capability regardless if the resource is meeting forecasted movement or the uncertainty requirement because the value of the ramping capability is the same.

Forecasted movement has a buyer and seller for each binding interval just as there is a buyer and seller of imbalance energy resulting from the dispatch.

In the fifteen-minute market, the CAISO will determine the forecasted movement as the difference between the resource's non-binding fifteen-minute market schedule in the first advisory interval and its fifteen-minute schedule in the binding interval. The CAISO will settle the fifteen-minute market forecasted movement at the upward and downward fifteen-minute market price. In the real-time dispatch, the CAISO will determine the forecasted movement as the difference between the non-binding dispatch instruction for the first advisory interval and the dispatch instruction for the binding interval. Differences between the fifteen-minute market forecasted movement and the five-minute forecasted movement will be settled at the relevant upward and downward five-minute market price.

Consistent with this approach, for the forecasted movement, CAISO will compensate each resource and intertie schedule (for movement in the direction of total system movement) and charge (for movement opposite to the direction of total system movement) in each market at the directional flexible ramping price calculated for that market, which is the same price calculated for the uncertainty requirement discussed above. The CAISO will consider upward movement to be positive movement and downward movement to be negative movement. The remaining forecasted movement is the result of load movement as measured by the CAISO load forecast used to clear the market optimization. Since the load forecast is not performed by load serving entity, but rather load forecast zones, the remaining forecasted movement amount to be settled (charge or payment) will be allocated to metered demand.

This settlement of forecasted movement aligns with cost causation because the costs are charged to supply, interties, or load that add to the total system movement and the supply, interties, or load that provide ramping to meet the total system movement receive payments. This is the same way instructed imbalance energy is settled. It is appropriate to settle forecasted movement at the same price as the uncertainty awards because they provide the same service for meeting the next market runs forecasted net load and the price established by the uncertainty awards represents the marginal price for flexible ramping capability.

In EIM areas, the CAISO will treat base schedules of non-participating resources in the same manner as self-schedules for settling forecasted movement because the ramps between operating hours are managed through the real-time unit commitment process and real-time dispatch. The real-time unit commitments honor hourly base schedules. The CAISO will settle the flexible ramping payments and charges for changes in base schedules between operating hours from non-participating resources to the EIM entity scheduling coordinator, as is currently done for imbalance energy settlement.

5. Rescission

The flexible ramping product creates the potential for double payment if the CAISO were to compensate a resource for flexible ramping product and then subsequently compensate it for uninstructed imbalance energy. For example, if the CAISO compensates a resource with an energy bid of $40/MWh upward flexible ramping product and the locational marginal price is $50, the resource will receive no less than $10 for the flexible ramping up product. If the resource then generates above its binding dispatch, it would incur positive uninstructed imbalance energy and receive the $50 locational marginal price. This would constitute a profit of $10 which would be the same as, and in addition to, the compensation for the each megawatt hour of the flexible ramping up product, which is based on the assumption that the resource will be at its dispatch operating target.

The proposal thus includes provisions to prevent such double payment. For each settlement interval in which a resource receives a flexible ramping product payment, the CAISO will determine if the resource was double paid by comparing uninstructed imbalance energy to the award. If the resource has an uninstructed imbalance energy deviation or an operational adjustment that overlaps the flexible ramping product forecast movement and uncertainty awarded capacity, the CAISO will rescind the overlapping portion of the award at the real-time dispatch flexible ramping price. The CAISO will assess the amount first against the resource’s uncertainty award, and then against the forecasted movement compensation in the same settlement interval as the energy imbalance.

6. Stakeholder Settlement Concerns

Certain stakeholders argued that the CAISO should allocate flexible ramping product costs solely to load, citing, the allocation to load and exports that the Commission approved for the Midcontinent Independent System Operator's (MISO) flexible ramping capacity.[37] The MISO allocation methodology would not be just and reasonable for allocating the costs of the CAISO's flexible ramping product because it would be inconsistent with cost causation principles.[38] As discussed above, the CAISO's proposed compensation and cost allocation principles ensure categories of market participants are compensated for relieving the ramping burden and charged for contributing to it. The Commission approved allocating MISO's flexible capacity to load because 90% of the variability underlying the procurement of flexible capacity was caused by due to load and exports.[39] That is not the case here. The CAISO includes the forecast error of variable energy resources when determining the uncertainty requirement and allows load and variable energy resource error to offset each other which reduces the total requirement. When determining the split of uncertainty award costs to the each category, it is appropriate to allow all variable energy resources forecast errors to offset each other in the same manner all individual load serving entities' loads changes offset each other within the CAISO load forecast. This ensures that the supply category is only allocated for uncertainty movement of the total supply category. More importantly, since the uncertainty awards are determined using a procurement curve, variable energy resources benefit from the additional ramping capability being procured to cover their forecast error such that if it materializes a power balance violations will be avoided which limits the variable energy resource's exposing to prices at the bid cap when their forecast decreases unexpectedly and the prices at the bid floor when their forecast increases unexpectedly. Further, the MISO's product does not address ramping capability obtained through multi-interval scheduling, which, as discussed above, is attributable to supply.

The Department of Market Monitoring expressed concern with the CAISO's proposal to allocate flexible ramping product costs to uninstructed deviations of supply resources, which are the difference between a resource's real-time dispatch instruction and actual metered output of dispatchable resources (*i.e*., resources that economically bid and can be dispatched pursuant to such bids), because they can cause the CAISO to procure uncertainty awards. The Department of Market Monitoring recommends that if the CAISO allocates

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37 *See Midcontinent Indep. Sys. Operator, Inc.,* 149 FERC ¶ 61,095 (2014).

38 *See, e.g., PJM Interconnection, L.L.C.*, 119 FERC ¶ 61,063, at P 39 (2007).

39 149 FERC ¶ 61,095 at P 26.

such costs to uninstructed deviations, it should include them it in the uncertainty requirement and procurement curve. The Department of Market Monitoring believes that if the CAISO does not include uninstructed deviations in the target, then the CAISO is essentially not procuring flexible ramping product for uninstructed deviations and, therefore, should not be allocating costs to uninstructed deviations. The Department of Market Monitoring also argues that uninstructed deviations from non-dispatchable resources, such as variable energy resources, do not create any additional need for flexible ramping capability procurement, and, thus, the CAISO should not allocate flexible ramping capability costs to the uninstructed deviations of non-dispatchable resources.[40]

The CAISO disagrees with the Department of Market Monitoring that the calculation of the uncertainty requirement and the cost allocation must utilize the same approach and data. As described earlier, the ISO anticipates that it will strive to improve its method for determining the proper uncertainty requirement over time. This will likely result in changes to the methodology for determining the uncertainty requirement that the CAISO will document in the business practice manual. Initially, the ISO will look at historical forecasted net load error on an hourly basis, and as the Department of Market Monitoring pointed out, will consider potentially aggregating hours if that provides a more accurate forecast of the uncertainty requirement. There may be additional statistical analysis that could further improve the forecast of uncertainty requirements based upon the actual forecast of resources online at the time of the market optimization. Therefore, if the CAISO ties the cost allocation directly to the requirement determination, this will limit its ability to improve over time the calculation of the uncertainty requirement and procurement curve, which would be contrary to the Department of Market Monitoring's recommendation that this be improved with experience. The primary driver of the change in forecasted net load between market runs is forecast error which materializes in the subsequent market run, thus the CAISO believes that applying the similar metric across the three categories provides similar treatment for each category when initially dividing the costs. As discussed earlier, once the costs are appropriately divided into each of the categories, the billing determinant appropriate to the category can be used to provide similar treatment of all within the given category.

Finally, the Market Surveillance Committee agrees with the CAISO, stating that the CAISO's proposal balances the workability to approximate the cost causation and the allocation of such costs to sources of variability in net load that cause the need for additional ramping capability.[41]

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[40] *See* Attachment H, Department of Market Monitoring Comments at 16.

[41] Market Surveillance Committee Opinion at 14.

F. Energy Imbalance Market Ramping Sufficiency Test

The CAISO currently applies an hourly resource sufficiency evaluation in the energy imbalance market to assess the adequacy of upward ramping capability in an EIM entity balancing authority area and system-wide. If an EIM entity balancing authority area fails the ramping test the CAISO will exclude the EIM balancing authority area from the system-wide ramping constraint[42] and hold the EIM transfer limit into the EIM entity balancing authority area at the value of the last fifteen-minute interval.

With implementation of the flexible ramping product, the CAISO will also implement a downward ramping test to address real-time leaning due to over-supply of a balancing authority area in the EIM area. The test is symmetrical to the existing upward ramping test. The consequences of failing the test are similar to those for failing the upward test, except that the CAISO will hold the EIM transfer limit out of, rather than into, the EIM entity balancing authority area at the value of the last fifteen-minute interval.

As with the upward requirement, the CAISO will calculate the flexible ramping down requirement for each balancing authority area individually and for the EIM footprint, and will recognize the diversity benefits of the EIM. The CAISO will calculate separately the upward and downward EIM diversity benefit as the difference between the sum of the upward and downward uncertainty requirements for all balancing authority areas in the EIM area, and the uncertainty requirement for the EIM area. The total system requirement will not exceed the sum of the individual balancing authority area flexible ramping requirements because in such a case the requirement can be met with no transfers between balancing authority areas.

If an EIM entity balancing authority area has a net outgoing EIM transfer (net imbalance energy import with reference to the base net schedule interchange) before the operating hour, then it has partially fulfilled its flexible ramping up requirement for that hour because it can retract that EIM transfer during the hour as needed. In such cases, the CAISO will apply an upward flexible ramping requirement credit in the flexible ramping down sufficiency test equal to the net incoming EIM transfer before the operating hour. The same is true for net incoming EIM transfers and the downward flexible ramping requirement.

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[42] In phase 1 of the first year EIM enhancements, the CAISO eliminated the sufficiency test for combinations of EIM balancing authority areas and replaced it with a system-wide sufficiency test. In an oversight, the CAISO did not make a parallel change in describing the consequences of failing the EIM balancing authority area test. The CAISO is amending section 29.34(n)(1) in this filing to correct that oversight.

IV. Section by Section Description of Proposed Tariff Revisions

Proposed new section 11.5.9 adds the flexible ramping product to the list of real-time market settlements and specifies that the CAISO will settle it according to section 11.25.

The proposed revision to section 11.8.4.2 adds forecasted movement and uncertainty award settlement amounts to the real-time market revenue calculations for bid cost recovery. The CAISO will exclude amounts rescinded, forecasted movement compensation when there are changes to self-schedules across trading hours, and forecasted movement compensation when there are changes across trading hours without economic bids. The rescinded forecast movement payments are excluded from revenue because the CAISO does not what to unwind the rescission by then providing compensation through BCR. Forecasted movement from self-schedule and base schedule changes are excluded because self-schedules and base schedules are not eligible to receive bid cost recovery payment.

The CAISO deletes the current text in section 11.25 and its subsections, which provides for flexible ramping constraint compensation, because the amendment deletes the flexible ramping constraint. The CAISO replaces the text with the provisions governing settlement on the flexible ramping product, which the CAISO has described in detail above.

Proposed new section 11.25.1 sets forth the settlement of forecasted movement as determined in section 44.3 and described above. Proposed new section 11.25.1.1 address fifteen-minute market settlement and 11.25.1.2 addresses real-time dispatch settlement. Proposed new section 11.25.1.3 sets forth the allocation of imbalance between forecasted movement compensation and charges.

Proposed new section 11.25.2 sets forth the settlement of the uncertainty requirement. Proposed new section 11.25.2.1 describes the payment to resources and proposed new section 11.25.2.2 describes the allocation of costs. Proposed new section 11.25.2.3 provides for the rescission of double payment for imbalance energy and uncertainty awards.

The proposed revision to section 16.6.3 provides for charging scheduling coordinators for existing transmission contract self-schedules for the flexible ramping product, in the same manner as it charges for transmission losses and schedule schedules.

The proposed revision to section 17.3.3 provides for charging flexible ramping product to valid transmission owner rights self-schedules.

The proposed revision to section 27.4.1 includes the Flexible Ramping Product procedures among the purposes of security constrained unit commitment.

The CAISO proposes to delete section 27.10, which provided for the flexible ramping constraint, because the flexible ramping product will fulfill its purpose.

Proposed new subsection (o) of section 29.11 provides that settlement of the Flexible Ramping Product in the energy imbalance market is according to section 11.25.Revised section 29.34(m) establishes upward and downward ramping capability requirements for the energy imbalance market and the rules for testing the sufficiency of the capacity, as described in section III.F above. Currently, the only requirement is for upward capacity. This revision is discussed in greater detail above.

The proposed revision to section 29.34(n) sets forth the consequences of failing to meet the downward sufficiency test added to section 29.34(m), as also described in in greater detail above.

Proposed new section 29.44 provides that the CAISO will procure the flexible ramping product for the energy imbalance market according to proposed new section 44.

The proposed revision to section 34.4 adds the procurement and optimization of the flexible ramping product to the matters addressed in the fifteen-minute market.

The proposed revision to section 34.5 adds the procurement of the flexible ramping product to the matters addressed in real-time dispatch.

The proposed revision to section 34.7 adds the relevant provisions concerning the flexible ramping product to the CAISO's general dispatch principles.

The proposed revision to section 34.8 adds the flexible ramping product to the CAISO's matters for which the CAISO may issue dispatch instructions.

The proposed revision to section 34.9 adds the satisfaction of flexible ramping product requirements to the matters for which the CAISO may use energy bids.

The proposed revision to section 34.13.2 provides that during a time when a resource is noncompliant with dispatch instructions, the CAISO will suspend its eligibility for ancillary services and uncertainty awards.

Proposed section 44 and its subsections set forth the rules for determining forecast movement and procuring uncertainty awards. These are described in greater detail above.

Proposed section 44.1 provides that the CAISO will procure the flexible ramping product in the fifteen-minute market and real-time dispatch to meet the forecasted net demand for the next interval and cover upward and downward forecast errors or uncertainty of the next interval.

Proposed section 44.2 sets forth the rules for uncertainty awards. Proposed section 44.2.1 explains that the CAISO will optimize the procurement of uncertainty awards simultaneously with the procurement of energy and ancillary services and that the awards will not overlap with ancillary services awards or available balancing capacity. Proposed section 44.2.2 provides that the CAISO will use its own forecast to determine uncertainty awards and forecast movement for variable energy resources.

Proposed section 44.2.3 sets forth eligibility rules for uncertainty awards. Section 44.2.4 describes the determination of the uncertainty requirement, as discussed above, including the procurement curve and procurement curve cap.

Proposed section 44.3 sets for the determination of forecasted movement, as described above.

The proposed revision to Appendix A provides definitions for the tariff revisions, which are discussed above.

V. Effective Date

The CAISO requests that the Commission accept the tariff revisions contained in this filing effective as of October 1, 2016. The CAISO respectfully requests an order by September 22, 2016, to allow it and market participants sufficient time to determine how to proceed on October 1, 2016.

VI. Communications

Correspondence and other communications regarding this filing should be directed to:

Sean A. Atkins
Michael E. Ward
Alston & Bird LLP
The Atlantic Building
950 F Street, NW
Washington, DC 20004
Tel: (202) 239-3300
Fax: (202) 654-4875
michael.ward@alston.com

Roger E. Collanton
General Counsel
Anna A. McKenna
Assistant General Counsel
California Independent
System Operator
Corporation
250 Outcropping Way
Folsom, CA 95630
Tel: (916) 608-7287
Fax: (916) 608-7222
amckenna@caiso.com

VII. Service

The CAISO has served copies of this filing on the California Public Utilities Commission, the California Energy Commission, and all parties with scheduling coordinator agreements under the CAISO tariff. In addition, the CAISO has posted a copy of the filing on the CAISO website.

VIII. Contents of Filing

In addition to this transmittal letter, this filing includes the following attachments:

Attachment A	Clean CAISO tariff sheets incorporating this tariff amendment
Attachment B	Marked CAISO tariff sheets showing the revisions contained in this tariff amendment
Attachment C	Direct Testimony of Donald Tretheway
Attachment D	Revised Draft Final Proposal Flexible Ramping Product, December 17, 2015
Attachment E	Flexible Ramping Product Draft Final Technical Appendix, December 17, 2015
Attachment F	Addendum to Draft Final Technical Appendix

Attachment G	Matrix of Stakeholder Comments to Draft Tariff Language
Attachment H	Department of Market Monitoring Comments on Final Flexible Ramping Product Proposal, Department of Market Monitoring, June 24, 2016
Attachment I	Board Memorandum (including matrix of stakeholder comments)
Attachment J	Market Surveillance Committee Opinion

IX. Conclusion

For the reasons set forth in this filing, the CAISO respectfully requests that the Commission accept the tariff revisions proposed in this filing effective as of October 1, 2016.

Respectfully submitted,

/s/ Anna A. McKenna
Anna A. McKenna

Sean A. Atkins
Michael E. Ward
Alston & Bird LLP
The Atlantic Building
950 F Street, NW
Washington, DC 20004
Tel: (202) 239-3300
Fax: (202) 654-4875
michael.ward@alston.com

Roger E. Collanton
General Counsel
Anna A. McKenna
Assistant General Counsel
California Independent
System Operator
Corporation
250 Outcropping Way
Folsom, CA 95630
Tel: (916) 608-7287
Fax: (916) 608-7222
amckenna@caiso.com

Counsel for the California Independent System Operator Corporation

CERTIFICATE OF SERVICE

I certify that I have served the foregoing document upon the parties listed on the official service list in the captioned proceedings, in accordance with the requirements of Rule 2010 of the Commission's Rules of Practice and Procedure (18 C.F.R. § 385.2010).

Dated at Folsom, California this 24th day of June, 2016.

/s/ Martha Sedgley
Martha Sedgley

Attachment A – Clean Tariff Records

Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

11.5.9 Flexible Ramping Product

The CAISO will settle the Flexible Ramping Product as set forth in Section 11.25.

* * *

11.8.4 RTM Bid Cost Recovery Amount

* * *

11.8.4.2 RTM Market Revenue Calculations

11.8.4.2.1 For each Settlement Interval in a CAISO Real-Time Market Commitment Period, the RTM Market Revenue for a Bid Cost Recovery Eligible Resource is the algebraic sum of the elements listed below in this Section. For Multi-Stage Generating Resources the RTM Market Revenue calculations will be made at the Generating Unit level.

(a) The sum of the products of the FMM or RTD Instructed Imbalance Energy (including Minimum Load Energy of the Bid Cost Recovery Eligible Resource committed in RUC and where for Pumped-Storage Hydro Units and Participating Load operating in the pumping mode or serving Load, the MWh is negative), except Standard Ramping Energy, Residual Imbalance Energy, Exceptional Dispatch Energy, Derate Energy, MSS Load following Energy, Ramping Energy Deviation and Regulation Energy, with the relevant FMM and RTD LMP, for each Dispatch Interval in the Settlement Interval. These amounts are subject to the Real-Time Performance Metric and the Persistent Deviation Metric as described in Sections 11.8.4.4 and 11.17, respectively.

(b) The product of the Real-Time Market AS Award from each accepted Real-Time Market AS Bid in the Settlement Interval with the relevant ASMP, divided by the number of fifteen (15)-minute Commitment Intervals in a Trading Hour (4), and prorated to the duration of the Settlement Interval.

(c) The relevant tier-1 No Pay charges for that Bid Cost Recovery Eligible Resource in that Settlement Interval.

(d) The Forecasted Movement and Uncertainty Awards Settlement Amounts as calculated pursuant to Section 11.25 are included in the RTM Market Revenues calculation, not including:

(1) the amounts rescinded pursuant to Section 11.25.3;

(2) Forecasted Movement revenue when there are changes in Self-Schedules across consecutive Trading Hours; and

(3) Forecasted Movement revenue when there are changes in EIM Base Schedules across consecutive Trading Hours without Economic Bids.

11.8.4.2.2 For each Settlement Interval in a non-CAISO Real-Time Market Commitment Period, the Real- Time Market Revenue for a Bid Cost Recovery Eligible Resource is the algebraic sum of the following:

(a) The sum of the products of the FMM or RTD Instructed Imbalance Energy (excluding the Minimum Load Energy of Bid Cost Recovery Eligible Resources committed in RUC), except, Standard Ramping Energy, Residual Imbalance Energy, Exceptional Dispatch Energy, Derate Energy, MSS Load Following Energy, Ramping Energy Deviation and Regulating Energy, with the relevant FMM or RTD Market LMP, for each Dispatch Interval in the Settlement Interval. These amounts are subject to the Real-Time Performance Metric and the Persistent Deviation Metric as described in Sections 11.8.4.4 and 11.17, respectively.

(b) The product of the Real-Time Market AS Award from each accepted Real-Time Market AS Bid in the Settlement Interval with the relevant ASMP, divided by the number of fifteen (15)-minute Commitment Intervals in a Trading Hour (4), and prorated to the duration of the Settlement Interval.

(c) The relevant tier-1 No Pay charges for that Bid Cost Recovery Eligible Resource in that Settlement Interval.

(d) The Forecasted Movement and Uncertainty Awards Settlement Amounts as calculated pursuant to Section 11.25 are included in the RTM Market Revenues calculation, not including:

(1) the amounts rescinded pursuant to Section 11.25.3;

(2) Forecasted Movement revenue when there are changes in Self-Schedules across consecutive Trading Hours; and

(3) Forecasted Movement revenue when there are changes in EIM Base Schedules across consecutive Trading Hours without Economic Bids.

* * *

11.25. Settlement of Flexible Ramping Product

11.25.1 Settlement of Forecasted Movement

11.25.1.1 **FMM.** The CAISO will settle FMM Forecasted Movement with Scheduling Coordinators as follows, where upward movement is a positive amount and downward movement is a negative amount:

(a) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the FMM FRUP; plus

(b) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the product of the FMM FRDP and negative one.

11.25.1.2 **RTD.** The CAISO will settle RTD Forecasted Movement with Scheduling Coordinators as follows, where upward movement is a positive amount and downward movement is a negative amount:

(a) the product of the difference between the RTD Forecasted Movement and the FMM Forecasted Movement for the relevant Settlement Interval, both calculated for each resource pursuant to Section 44.3 in MWhs, and the RTD FRUP, less any rescission amounts pursuant to section 11.25.3; plus

(b) the product of the difference between the RTD Forecasted Movement and the FMM Forecasted Movement for the relevant Settlement Interval, both calculated for each resource pursuant to Section 44.3 in MWhs, and the product of the RTD FRDP and negative one, less any rescission amounts pursuant to section 11.25.3.

11.25.1.3 **Allocation of Residual Forecasted Movement Settlements.** The CAISO will settle amounts remaining after settlement of Forecasted Movement pursuant to Section 11.25.1 to each Scheduling Coordinator's metered EIM Demand or metered CAISO Demand in proportion to its share of the total metered EIM Demand and metered CAISO Demand.

11.25.2 Settlement of Uncertainty Requirement.

11.25.2.1 Payment to Resources. On a daily basis, the CAISO will settle awards to resources for providing the Uncertainty Requirement at the applicable FRUP or FRDP less any payment rescission for each interval pursuant to Section 11.25.3.

11.25.2.2 Allocation of Costs of Uncertainty Movement Procured.

11.25.2.2.1 Settlement Process.

(a) **Daily.** The CAISO will initially—

(1) allocate the cost of the Uncertainty Award within each Balancing Authority Area in the EIM Area and within the EIM Area on a daily basis according to the categories as set forth in this Section 11.25.2.2; and

(2) allocate the daily amounts to Scheduling Coordinators as set forth in this Section 11.25.2.2.

(b) **Monthly.** The CAISO will resettle the costs of the Uncertainty Awards by—

(1) reversing the daily allocation;

(2) assigning the monthly costs of the Uncertainty Awards to Peak Flexible Ramp Hours and Off-Peak Flexible Ramp Hours;

(3) separately allocating the monthly Peak Flexible Ramp Hours amounts and Off-Peak Flexible Ramp Hours amounts to the categories within each Balancing Authority Area in the EIM Area and within the EIM Area as set forth in this Section 11.25.2.2; and

(4) allocating the monthly amounts in each category to Scheduling Coordinators as set forth in this Section 11.25.2.2.

11.25.2.2.2 Allocation of Charges to Categories.

(a) **Determination of Uncertainty Movement For Resources.** For each interval, the CAISO will calculate the net Uncertainty Movement of each resource according to the following categories

(1) for Supply resources other than non-Dynamic System Resources as the difference between the Dispatch Instruction of the binding interval in the next RTD run and the first advisory RTD interval in the current run.

(2) for non-Dynamic System Resources and export schedules as the difference between the schedule used in the RTD (accounting for ramp) for the binding interval in the next RTD run and the scheduled use for the first advisory interval in the current RTD run.

(b) **RTD Uncertainty Movement by Balancing Authority Area and by EIM Area.** The CAISO will determine the total net RTD Uncertainty Movement for each category separately for each Balancing Authority Area in the EIM Area and by EIM Area—

(1) for the category of Supply resources, which shall not include non-Dynamic System Resources, as the net sum of the five-minute Uncertainty Movement determined pursuant to Section 11.25.2.2.2 of all the Supply resources in the category.

(2) for the category of Intertie resources, which shall comprise non-Dynamic System Resources and exports,

as the net sum of the five-minute Uncertainty Movement determined pursuant to Section 11.25.2.2 of all the non-Dynamic System resources and export schedules.

(3) for the non-Participating Load category, as the difference between-

(A) the CAISO Forecast of CAISO Demand, the CAISO forecast of Balancing Authority Area EIM Demand, or the CAISO forecast of EIM Area EIM Demand, as applicable, of the binding interval in the next RTD run; and

(B) the CAISO Forecast of CAISO Demand, the CAISO forecast of Balancing Authority Area EIM Demand, or the CAISO forecast of EIM Area EIM Demand, as applicable, for the first advisory interval in the current RTD run.

11.25.2.2.3 Assignment of Uncertainty Costs to Categories. The CAISO will allocate the total Uncertainty Award cost calculated pursuant to this section 11.25.2.2 to each category described in Section 11.25.2.2.2(b) based on—

(a) for upward Uncertainty Award cost, the ratio of such category's positive Uncertainty Movement to the sum of the positive Uncertainty Movements of all categories with positive Uncertainty Movement for each Balancing Authority Area in the EIM Area and the EIM Area; and.

(b) for downward Uncertainty Award costs, the ratio of such category's negative Uncertainty Movement to the sum of the negative Uncertainty Movements of all categories with negative

Uncertainty Movement for each Balancing Authority Area in the EIM Area and the EIM Area.

11.25.2.2.4 Allocation to Scheduling Coordinators.

(a) **Non-Participating Load Category.** The CAISO will allocate the Uncertainty Awards costs of the non-Participating Load category to Scheduling Coordinators—

(1) for upward Uncertainty Award cost in proportion to the Scheduling Coordinator's negative non-Participating Load UIE, excluding the non-Participating Load of an MSS that has elected to load-follow according to an MSS Agreement, without netting that UIE across Settlement Intervals, to the total of such negative non-Participating Load UIE, without netting that UIE across Settlement Intervals, in the Balancing Authority Area or EIM Area as applicable, and

(2) for downward Uncertainty Award cost calculated pursuant to Section 11.25, in proportion to the Scheduling Coordinator's daily positive non-Participating Load UIE, excluding the non-Participating Load of an MSS that has elected to load-follow according to an MSS Agreement, without netting that UIE across Settlement Intervals, to the total of such positive non-Participating Load UIE, without netting that UIE across Settlement Intervals, in the BAA or EIM Area as applicable.

(b) **Supply Category.** The CAISO will allocate the Uncertainty Awards costs of the Supply category to Scheduling Coordinators for each resource in the Supply category based on the sum of the resource's Uncertainty Movement and UIE—

(1) for upward Uncertainty Award cost in proportion to the Scheduling Coordinator's positive sum of the resource's Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, to the total positive sum of all resources' Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, in the BAA or EIM Area as applicable; and

(2) for downward Uncertainty Award cost in proportion to the Scheduling Coordinator's negative sum of the resource's Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, to the total negative sum of all resources' Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, in the Balancing Authority Area or EIM Area as applicable; except that

(3) for the MSS that have elected to load follow pursuant to an MSS Agreement, the CAISO will calculate the positive and negative sums specified above for each Settlement Interval as the sum of MSS non-Participating Load UIE, Supply resources within the MSS UIE, MSS Load Following Energy, MSS Load Following Operational Adjustments, and Uncertainty Movement of resources within the MSS Aggregation.

(c) **Intertie Category.** The CAISO will allocate the Uncertainty Awards costs of the Intertie category to Scheduling Coordinators for each non-Dynamic System Resource and export based on the sum of the resource's Uncertainty Movement and Operational Adjustment—

(1) for upward Uncertainty Award cost in proportion to the magnitude of the Scheduling Coordinator's negative Operational Adjustment for non-Dynamic System Resources, or positive Operational Adjustment for export resources, to the sum of the magnitudes of such Operational Adjustments in the Balancing Authority Area or EIM Area, without netting that sum across Settlement Intervals; and

(2) for downward Uncertainty Award cost in proportion to the magnitude of the Scheduling Coordinator's positive Operational Adjustment for non-Dynamic System Resources, or negative Operational Adjustment for export resources, to the sum of the magnitudes of such Operational Adjustments in the Balancing Authority Area or EIM Area, without netting that sum across Settlement Intervals; and

(3) for the purposes of the allocations specified above, the MSS Load Following Operational Adjustment is excluded.

(d) **Uncertainty Award Cost Offset**. If the sum of the settlement of Uncertainty Awards and the charges to Scheduling Coordinators for Uncertainty Award costs is nonzero, the CAISO will allocate such amounts to Scheduling Coordinators based on the ratio of their metered CAISO Demand and metered EIM Demand to the total EIM area metered demand.

11.25.3. Rescission

11.25.3.1 **Amount of Rescission.** For each Settlement Interval in which a resource has either a UIE deviation or Operational Adjustment and a Flexible Ramping Product settlement, separately for upward and downward, the CAISO will rescind Settlement Amount for the overlap of the UIE or Operational Adjustment and the sum of RTD Forecasted Movement and Uncertainty Award, at the RTD FRUP or FRDP.

11.25.3.2 **Order of Rescission.** The CAISO will apply any rescission amount first to any Uncertainty Award, in the applicable direction, and then apply any remaining rescission amount to Forecasted Movement, in the applicable direction.

* * *

16.6.3 Treatment Of Valid ETC Self-Schedules

The resulting valid ETC Self-Schedules shall have the following Settlement treatment:

(1) The CAISO will apply the ETC Settlement treatment in Sections 11.2.1.5 and 11.5.7.1.

(2) The CAISO shall base the Marginal Cost of Losses on LMP differentials at the Existing Contract source(s) and sink(s) identified in the valid ETC Self-Schedule.

(3) The holders of Existing Rights will not be entitled to an allocation of revenues from the CAISO, including Access Charge revenue related to those Existing Rights.

(4) Parties with Existing Rights shall continue to pay for Transmission Losses or Ancillary Services requirements in accordance with such Existing Contracts as they may be modified or changed in accordance with the terms of the Existing Contract. The Participating TOs shall continue to provide Transmission Losses and any other Ancillary Services to the holder of the rights under an Existing Contract as may be required by the Existing Contract. The CAISO will charge Scheduling Coordinators submitting the ETC Self-Schedule for Transmission

Losses, Ancillary Services, and Flexible Ramping Product, in accordance with the CAISO Tariff and any shortfall or surplus between the CAISO charges and the Existing Rights shall be settled bilaterally between the Existing Contract parties or through the relevant TO Tariff. To enable holders of Existing Rights to determine whether the CAISO's calculations result in any associated shortfall or surplus and to enable the parties to the Existing Contracts to settle the differences bilaterally or through the relevant TO Tariff, the CAISO shall calculate and provide the Scheduling Coordinator's Settlements the amounts paid for the MCL for the amounts of MWh submitted with a valid ETC Self-Schedule. Each Participating TO will be responsible for recovering any deficits or crediting any surpluses associated with differences in Transmission Losses and Transmission Loss requirements and/or Ancillary Services requirements, through its bilateral arrangements or its Transmission Owner Tariff.

*** * ***

17.3.3 Settlement Treatment Of Valid TOR Self-Schedules

The resulting valid TOR Self-Schedules shall have the following Settlement treatment:

(1) The CAISO will apply the TOR Settlement treatment in Sections 11.2.1.5 and 11.5.7.

(2) The CAISO shall base the Marginal Cost of Losses on LMP differentials at the Points of Receipt and Points of Delivery identified in the valid TOR Self-Schedule; provided, however, that if a specific loss percentage exists in an applicable agreement between the TOR holder and the CAISO or an existing agreement between the TOR holder and a Participating TO, the CAISO will apply the IFM and RTM Marginal Cost of Losses Credit as provided in Sections 11.2.1.7 and 11.5.7.2. In any case in which the TOR holder has an existing agreement regarding its TORs with either the CAISO or a Participating TO, the provisions of the agreement shall prevail over any conflicting provisions of this

Section 17.3.3(2). Where the provisions of this Section 17.3.3(2) do not conflict with the provisions of the agreement, the provisions of this Section 17.3.3(2) shall apply to the subject TORs.

(3) The CAISO will assess only charges applicable to Ancillary Services, Imbalance Energy, Transmission Losses, Flexible Ramping Product, and Grid Management Charges for the use of a TOR and will not assess charges for neutrality, UFE, transmission Access Charges, Minimum Load Costs, or other charges that might otherwise be applicable to the Demand or exports served solely over the TOR. The CAISO will assess charges applicable to Ancillary Services for the use of a TOR only to the extent that the CAISO must procure Ancillary Services for the TOR holder because Ancillary Services are not self-provided by the TOR holder. The CAISO will assess charges and provide payments for TOR Self-Schedules pursuant to the rules specified in Sections 11.2.1.5 and 11.5.7.2. The CAISO will assess charges applicable to Imbalance Energy for the use of a TOR only if the CAISO must procure Imbalance Energy for the TOR holder. The CAISO will assess Grid Management Charges for the use of a TOR only in accordance with the provisions of Section 11.22 and Appendix F, Schedule 1.

(4) The holders of TORs will not be entitled to an allocation of revenues from the CAISO, including Access Charge revenues; provided that the Scheduling Coordinator for the TOR holder shall be allocated the applicable amount of IFM Marginal Losses Surplus Credit in accordance with the provisions of Section 11.2.1.6, except for any TOR Self-Schedule that received the IFM Marginal Cost of Losses Credit.

(5) Parties with TORs shall continue to pay for Transmission Losses or Ancillary Services requirements in accordance with any Existing Contracts applicable to those TORs as they may be modified or changed in accordance with the terms of the Existing Contract. Any affected Participating TOs shall continue to provide Transmission Losses and any other Ancillary Services to the holder of a TOR

subject to an Existing Contract as may be required by the Existing Contract. As described in Section 17.3.3(3) above, the CAISO will charge Scheduling Coordinators submitting the TOR Self-Schedule the charges applicable to Transmission Losses, Ancillary Services, and Imbalance Energy in accordance with the CAISO Tariff (e.g., the Transmission Losses Charge based on the Marginal Cost of Losses), and any shortfall or surplus between the CAISO charges and the provisions of any applicable Existing Contract shall be settled bilaterally between the Existing Contract parties or through the relevant TO Tariff. To enable holders of TORs to determine whether the CAISO's calculations result in any associated shortfall or surplus and to enable the parties to the Existing Contracts to settle the differences bilaterally or through the relevant TO Tariff, the CAISO shall calculate and provide the Scheduling Coordinator's Settlements the amounts paid for the MCL for the amounts of MWh submitted with a valid TOR Self-Schedule. Each Participating TO will be responsible for recovering any deficits or crediting any surpluses associated with differences in Transmission Losses and Transmission Loss requirements and/or Ancillary Services requirements, through its bilateral arrangements or its Transmission Owner Tariff.

* * *

27.4.1 Security Constrained Unit Commitment

The CAISO uses SCUC to run the MPM process associated with the DAM and the RTM. SCUC is conducted over multiple varying intervals to commit and schedule resources as follows: (1) in the Day-Ahead time frame, to meet Demand reflected in Bids submitted in the Day-Ahead Market and considered in the MPM process and IFM, and to procure AS in the IFM; (2) to meet the CAISO Forecast Of CAISO Demand in the RUC, HASP, STUC and FMM, and in the MPM process utilized in the HASP and RTM; (3) to procure any incremental AS in the RTM, and (4) to procure Flexible Ramping Product in the RTM. In the Day-Ahead MPM, IFM and RUC processes, the SCUC commits resources over the twenty-four (24) hourly intervals of the next Trading Day. In the FMM, which runs every fifteen (15) minutes and commits resources for the RTM, the SCUC optimizes over a number of 15-minute intervals corresponding to the Trading Hours for which the Real-Time Markets have closed. The Trading Hours for which the Real-Time Markets have closed consist of (a) the Trading Hour in which the applicable run is conducted and (b) all the fifteen-minute intervals of the entire subsequent Trading Hour. In the HASP, which runs once per hour, the SCUC: 1) accepts and awards HASP Block Intertie Schedules for Energy and Ancillary Services, respectively; 2) provides HASP Advisory Schedules to Economic Hourly Block Bids with Intra-Hour Option that will change for economic reasons at most once in the Trading Hour; and 3) provides HASP Advisory Schedules to all other participants in the RTM. In the STUC, which runs once an hour, the SCUC commits resources over the last fifteen (15) minutes of the imminent Trading Hour and the entire next four Trading Hours. The CAISO will commit Extremely Long Start Resources, for which commitment in the DAM does not provide sufficient time to Start-Up and be available to supply Energy during the next Trading Day as provided in Section 31.7.

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29.11. Settlements And Billing For EIM Market Participants.

*** * ***

(g) **[Not Used]**

*** * ***

(p) **Flexible Ramping Product.** The CAISO will allocate and settle payments and charges for the Flexible Ramping Product according to Section 11.25, where the CAISO will consider EIM Base Schedules of non-participating resources as Self-Schedules.

*** * ***

29.34. EIM Operations

* * *

(l) EIM Resource Plan Evaluation.

(1) Requirement. The EIM Base Schedules for resources included in the EIM Resource Plan must balance the Demand Forecast for each EIM Entity Balancing Authority Area.

(2) Insufficient Supply. An EIM Resource Plan shall be deemed to have insufficient Supply if the sum of EIM Base Schedules from non-participating resources and the sum of the highest quantity offers in the Energy Bid range from EIM Participating Resources, including Interchange with other Balancing Authority Areas, is less than the total Demand Forecast that the EIM Entity Scheduling Coordinator has decided to use for the associated EIM Entity Balancing Authority Area.

(3) Excess Supply. An EIM Resource Plan shall be deemed to have excessive Supply if the sum of EIM Base Schedules from non-participating resources and the sum of the lowest quantity Bids in the Energy Bid range from EIM Participating Resources is greater than the total Demand Forecast that the EIM Entity Scheduling Coordinator has decided to use for the associated EIM Entity Balancing Authority Area.

(4) **Additional Hourly Capacity Requirements.**

(A) **In General.** If the CAISO determines under the procedures set forth in the Business Practice Manual for the Energy Imbalance Market that an Balancing Authority Area in the EIM Area has historically high import or export schedule changes between forty minutes and twenty minutes before the start of the Trading Hour, the CAISO will add to the Balancing Authority Area in the EIM Area's capacity requirements an additional requirement.

(B) **Additional Capacity Requirement**. On a monthly basis, according to procedures set forth in the Business Practice Manual for the Energy Imbalance Market, the CAISO will calculate for each Balancing Authority Area in the EIM Area histograms of the percentage of the difference between imports and exports scheduled at forty minutes before the start of the Trading Hour and the final imports and exports at twenty minutes before the start of the Trading Hour based on the submitted E-Tags at those times and calculate additional upward and downward requirements for the capacity test component of the resource sufficiency evaluation.

(m) **Flexible Ramping Sufficiency Determination.**

(1) **Review.**

(A) **EIM Entity Balancing Authority Areas.** The CAISO will review the EIM Resource Plan pursuant to the process set forth in the Business Practice Manual for the Energy Imbalance Market and verify that it has sufficient Bids for Ramping capability to meet the EIM Entity Balancing Authority Area upward and downward Ramping requirements, as adjusted pursuant to Sections 29.34(m)(2), (3), and (5).

(B) **CAISO Balancing Authority Area.** The CAISO will review the Day-Ahead Schedules in the CAISO Balancing Authority Area and verify that it has sufficient Bids for Ramping capability to meet the CAISO Balancing Authority Area upward and downward Ramping requirements, as adjusted pursuant to Sections 29.34(m)(2), (3), (5), and (6).

(2) **Determination of EIM Diversity Benefit.** The CAISO will calculate separately the upward and downward EIM diversity benefit as the difference between the sum of the upward and downward Uncertainty Requirements for all Balancing Authority Areas in the EIM Area, and the

Uncertainty Requirement for the EIM Area.

(3) **Effects of EIM Diversity Benefit.** For each Balancing Authority Area in the EIM Area, the CAISO will reduce the upward and downward Uncertainty Requirements by the Balancing Authority Area's pro rata share of the upward and downward EIM diversity benefit in the EIM Area as may be limited by—

(A) the available net import EIM Transfer capability into that Balancing Authority Area in the case of an upward Uncertainty Requirement; and

(B) the available net export EIM Transfer capability from that Balancing Authority Area in the case of a downward Uncertainty Requirement.

(4) **Determination of Flexible Ramping Sufficiency Credit.** The CAISO will calculate for each Balancing Authority Area in the EIM Area, the upward flexible Ramping sufficiency credit as the outgoing EIM Transfer from that area and the downward flexible Ramping sufficiency credit as the incoming EIM transfer into that area.

(5) **Effect of Flexible Ramping Sufficiency Credit.** The CAISO will reduce the upward Uncertainty Requirement of a Balancing Authority Area in the EIM Area by its upward flexible Ramping sufficiency credit, and will reduce the downward Uncertainty Requirement of a Balancing Authority Area in the EIM Area by its downward flexible Ramping sufficiency credit.

(4)

(6) **Incremental Requirements.**

(i) **In General.** If the CAISO determines under the procedures set forth in the Business Practice Manual for the Energy Imbalance Market that an EIM Balancing Authority Area has historically high import or export schedule changes between T-40 and T-20, the

CAISO will add to the EIM Entity's flexible capacity requirement an additional incremental requirement.

(ii) **Additional Incremental Requirement.** On a monthly basis, according to procedures set forth in the Business Practice Manual for the Energy Imbalance Market, the CAISO will calculate for each EIM Entity Balancing Authority Area histograms of the percentage of the difference between imports and exports scheduled at T-40 and the final imports at T-20 based on the E-Tags submitted at T-40 and T-20 and calculate additional incremental and decremental requirements for the capacity test component of the resource sufficiency evaluation.

(n) **Effect of Resource Plan Insufficiency.**

(1) **Resource Plan Balance.** If, after the final opportunity for the EIM Entity to revise hourly Real-Time EIM Base Schedules as provided in Section 29.34(f)(1)(c), the EIM Resource Plan has insufficient supply as determined according to Section 29.34(l)—

(A) the CAISO will not include the EIM Entity Balancing Authority Area in the Uncertainty Requirement of the EIM Area;

(B) the CAISO will hold the EIM Transfer limit into or from the EIM Entity Balancing Authority Area, as specified in Section 29.34(n)(2), at the value for the last 15-minute interval.

(2) **Flexible Ramping Insufficiency.** If, after the final opportunity for the EIM Entity to revise hourly Real-Time EIM Base Schedules as provided in Section 29.34(f)(1)(c), the CAISO determines—

(i) that an EIM Entity Balancing Authority Area has insufficient upward Ramping capacity according to Section 29.34(m), the CAISO will take the actions described in Section 29.34(n)(1)(A) and (B) in the upward and into the EIM Entity BAA direction; and

(ii) that an EIM Entity Balancing Authority Area has insufficient downward Ramping capacity according to Section 29.34(m), the CAISO will take the actions described in Section 29.34(n)(1)(A) and (B) in the downward and from the EIM Entity BAA direction.

* * *

29.44 Flexible Ramping Product. The CAISO will procure Flexible Ramping Product for the Energy Imbalance Market as set forth in Section 44, except that the CAISO will consider the EIM Base Schedules of non-participating resources as Self-Schedules for the calculation of Flexible Ramping Product requirements.

* * *

34.4 Fifteen Minute Market

The CAISO conducts the Fifteen Minute Market using the second interval of each RTUC run horizon as follows: (1) at approximately 7.5 minutes prior to the first Trading Hour, for T-45 minutes to T+60 minutes where the binding interval is T-30 to T-15; (2) at approximately 7.5 minutes into the current hour for T-30 minutes to T+60 minutes where the binding interval is T-15 to T; (3) at approximately 22.5 minutes into the current hour for T-15 minutes to T+60 minutes for the binding interval T to T+15; and (4) at approximately 37.5 minutes into the current hour for T to T+60 minutes for the binding interval T+15 to T+30, where T is the beginning of the next Trading Hour. In these intervals the CAISO conducts the FMM to (1) determine financially binding FMM Schedules and corresponding LMPs for all Pricing Nodes, including all Scheduling Points; (2) determine financially and operationally binding Ancillary Services Awards and corresponding ASMPs, procure required additional Ancillary Services, and calculate ASMP used for settling procured Ancillary Service capacity for the next fifteen-minute Real-Time Ancillary

Service interval for all Pricing Nodes, including Scheduling Points; (3) determine LAP LMPs that are the basis for settling Demand; and (4) determine FMM Uncertainty Awards. In any FMM interval that falls within a time period in which a Multi-Stage Generating Resource is transitioning from one MSG Configuration to another MSG Configuration, the CAISO: (1) will not award any incremental Ancillary Services; (2) will disqualify any Day-Ahead Ancillary Services Awards; (3) will disqualify Day-Ahead qualified Submissions to Self-Provide Ancillary Services Award, and (4) will disqualify Submissions to Self-Provide Ancillary Services in RTM. Each particular FMM market optimization produces binding settlement prices for Energy, Flexible Ramping Product, and Ancillary Services for the first FMM interval in the FMM horizon but the optimization considers the advisory results from subsequent market intervals within the FMM horizon. The CAISO settles Hourly Intertie Schedules and Hourly Ancillary Services Awards accepted in the HASP as FMM Schedules and FMM Ancillary Services Awards in accordance with Section 11.5 and 11.10.1.2, respectively. In the event that a FMM run fails, the CAISO reverts to Day-Ahead Market Ancillary Services Awards and RUC Schedules results corresponding to the same interval, or the corresponding interval from the previous RTUC. The FMM will clear Supply against the CAISO Forecast Of CAISO Demand and exports. The FMM issues Energy Schedules and Ancillary Services Awards by twenty-two and a half minutes prior to the binding fifteen-minute interval.

34.5 Real-Time Dispatch

The RTED uses a Security Constrained Economic Dispatch (SCED) algorithm every five (5) minutes throughout the Trading Hour to determine optimal Dispatch Instructions to balance Supply and Demand and determine Uncertainty Awards. The RTD can operate in three modes: RTED, RTCD and RTMD. In any given five-minute interval, the RTD optimization looks ahead over multiple five-minute intervals, but the CAISO issues Dispatch Instructions only for the next target five-minute interval. The CAISO will use the Real-Time Economic Dispatch (RTED) under most circumstances to optimally dispatch resources based on their Bids. The RTED can be used to Dispatch Contingency Only Operating Reserves, pursuant to Section 34.10, when needed to avoid an imminent System Emergency. The Real-Time Contingency Dispatch (RTCD) can be invoked in place of the RTED when a transmission or generation contingency occurs and will include all Contingency Only Operating Reserves in the optimization. If the CAISO awards a Non-Dynamic System Resource Ancillary Services in the IFM, HASP, or FMM and issues a Dispatch Instruction in the middle of the Trading Hour for Energy associated with its Ancillary Services (Operating Reserve) capacity, the CAISO will Dispatch the Non-Dynamic System Resource to operate at a constant level until the end of the Trading Hour. If the CAISO dispatches a Non-Dynamic System Resource such that the binding interval of the Dispatch is in the next Trading Hour, the CAISO will dispatch Energy from the Non-Dynamic System Resource at a constant level until the end of the next Trading Hour. The dispatched Energy will not exceed the awarded Operating Reserve capacity for the next Trading Hour and will be at a constant level for the entire next Trading Hour. The Real Time Manual Dispatch (RTMD) will be invoked as a fall-back mechanism only when the RTED or RTCD fails to provide a feasible Dispatch. These three (3) modes of the RTD are described in Sections 34.5.1, 34.5.2, and 34.5.3.

* * *

34.7 General Dispatch Principles

The CAISO shall conduct all Dispatch activities consistent with the following principles:

(1) The CAISO shall issue AGC instructions electronically as often as every four (4) seconds from its Energy Management System (EMS) to resources providing Regulation and on Automatic Generation Control to meet NERC and WECC performance requirements;

(2) In each run of the RTED or RTCD the objective will be to meet the projected Energy requirements and Uncertainty Requirements over the applicable forward-looking time period of that run, subject to transmission and resource operational constraints, taking into account the short term CAISO Forecast Of CAISO Demand or forecast of EIM Demand, adjusted as necessary by the CAISO or EIM Entity operator to reflect scheduled changes to Interchange and non-dispatchable resources in subsequent Dispatch Intervals;

(3) Dispatch Instructions will be based on Energy Bids for those resources that are capable of intra-hour adjustments and will be determined through the use of SCED except when the CAISO must utilize the RTDD and RTMD;

(4) When dispatching Energy from awarded Ancillary Service capacity the CAISO will not differentiate between Ancillary Services procured by the CAISO and Submissions to Self-Provide an Ancillary Service;

(5) The Dispatch Instructions of a resource for a subsequent Dispatch Interval shall take as a point of reference the actual output obtained from either the State Estimator solution or the last valid telemetry measurement and the resource's operational ramping capability. For Multi-Stage Generating Resources the determination of the point of reference is further affected by the MSG Configuration and the information contained in the Transition Matrix;

(6) In determining the Dispatch Instructions for a target Dispatch Interval while at the same time achieving the objective to minimize Dispatch costs to meet the forecasted conditions of the entire forward-looking time period, the Dispatch for the target Dispatch Interval will be affected by: (a) Dispatch Instructions in prior intervals, (b) actual output of the resource, (c) forecasted conditions in subsequent intervals within the forward-looking time period of the optimization, and (d) operational constraints of the resource, such that a resource may be dispatched in a direction for the immediate target Dispatch Interval that is different than the direction of change in Energy needs from the current Dispatch Interval to the next immediate Dispatch Interval, considering the applicable MSG Configuration;

(7) Through Start-Up Instructions the CAISO may instruct resources to start up or shut down, or may reduce Load for Participating Loads, Reliability Demand Response Resources, and Proxy Demand Resources, over the forward-looking

time period for the RTM based on submitted Bids, Start-Up Costs and Minimum Load Costs, Pumping Costs and Pump Shut-Down Costs, as appropriate for the resource, or for Multi-Stage Generating Resource as appropriate for the applicable MSG Configuration, consistent with operating characteristics of the resources that the SCED is able to enforce. In making Start-Up or Shut-Down decisions in the RTM, the CAISO may factor in limitations on number of run hours or Start-Ups of a resource to avoid exhausting its maximum number of run hours or Start-Ups during periods other than peak loading conditions;

(8) The CAISO shall only start up resources that can start within the applicable time periods of the various CAISO Markets Processes that comprise the RTM;

(9) The RTM optimization may result in resources being shut down consistent with their Bids and operating characteristics provided that: (a) the resource does not need to be on-line to provide Energy, (b) the resource is able to start up within the applicable time periods of the processes that comprise the RTM, (c) the Generating Unit is not providing Regulation or Spinning Reserve, and (d) Generating Units online providing Non-Spinning Reserve may be shut down if they can be brought up within ten (10) minutes as such resources are needed to be online to provide Non-Spinning Reserves;

(10) For resources that are both providing Regulation and have submitted Energy Bids for the RTM, Dispatch Instructions will be based on the Regulation Ramp Rate of the resource rather than the Operational Ramp Rate if the Dispatch Operating Point remains within the Regulating Range. The Regulating Range will limit the Ramping of Dispatch Instructions issued to resources that are providing Regulation;

(11) For Multi-Stage Generating Resources the CAISO will issue Dispatch Instructions by Resource ID and Configuration ID;

(12) The CAISO may issue Transition Instructions to instruct resources to transition from one MSG Configuration to another over the forward-looking time period for the RTM based on submitted Bids, Transition Costs and Minimum Load Costs, as appropriate for the MSG Configurations involved in the MSG Transition, consistent with Transition Matrix and operating characteristics of these MSG Configurations. The RTM optimization will factor in limitations on Minimum Run Time and Minimum Down Time defined for each MSG configuration and Minimum Run Time and Minimum Down Time at the Generating Unit.

34.8 Dispatch Instructions to Units, Participating Loads, PDRs and RDRRs

The CAISO may issue Dispatch Instructions covering:

(a) Ancillary Services;

(b) Energy, which may be used for:

(i) Congestion relief;

(ii) provision of Imbalance Energy; or

(iii) replacement of an Ancillary Service;

(c) agency operation of Generating Units, Participating Loads, Proxy Demand Resources, or Interconnection schedules, for example:

(i) output or Demand that can be Dispatched to meet Applicable Reliability Criteria;

(ii) Generating Units that can be Dispatched for Black Start;

(iii) Generating Units that can be Dispatched to maintain governor control regardless of their Energy schedules;

(d) the operation of voltage control equipment applied on Generating Units as described in this CAISO Tariff;

(e) MSS Load following instructions provided to the CAISO, which the CAISO incorporates to create their Dispatch Instructions;

(f) Dispatch necessary to respond to a System Emergency or imminent emergency;

(g) Transition Instructions;

(h) Dispatch of Reliability Demand Response Resources pursuant to Section 34.18; or

(i) Uncertainty Awards.

34.9 Utilization Of The Energy Bids

The CAISO uses Energy Bids for the following purposes: (i) satisfying Real-Time Energy needs; (ii) mitigating Congestion; (iii) maintaining aggregate Regulation reserve capability in Real-Time; (iv) allowing recovery of Operating Reserves utilized in Real-Time operations; (v) procuring Voltage Support required from resources beyond their power factor ranges in Real-Time; (vi) establishing LMPs; (vii) as the basis for Bid Cost Recovery; (viii) to the extent a Real-Time Energy Bid Curve is submitted starting at minimum operating level for a Short Start Unit that is scheduled to be on-line, the RTM may Dispatch such a resource down to its minimum operating level and may issue a Shut-Down Instruction to the resource based on its Minimum Load Energy costs; and (ix) satisfying Uncertainty Requirements.

* * *

34.13.2 Failure To Conform To Dispatch Instructions

In the event that, in carrying out the Dispatch Instruction, an unforeseen problem arises (relating to plant operations or equipment, personnel or the public safety), the recipient of the Dispatch Instruction must notify the CAISO or, in the case of a Generator, the relevant Scheduling Coordinator immediately. The relevant Scheduling Coordinator shall notify the CAISO of the problem immediately. If a resource is unavailable or incapable of responding to a Dispatch Instruction, or fails to respond to a Dispatch Instruction in accordance with its terms, the resource shall be considered to be non-conforming to the Dispatch Instruction unless the resource has notified the CAISO of an event that prevents it from performing its obligations within thirty (30) minutes of the onset of such event through a submission in the CAISO's outage management system pursuant to Section 9 log entry. Notification of non-compliance via the Automated Dispatch System (ADS) will not supplant nor serve as the official notification mechanism to the CAISO. If the resource is considered to be non-conforming as described above, the Scheduling Coordinator for the resource concerned shall be subject to Uninstructed Imbalance Energy as specified in Section 11.5.2 and Uninstructed Deviation Penalties as specified in Section 11.23. This applies whether any Ancillary Services concerned are contracted or Self-Provided. For a Non-Dynamic System Resource Dispatch Instruction prior to the Trading Hour, the Scheduling Coordinator shall inform the CAISO of its ability to conform to a Dispatch Instruction via ADS. The Non-Dynamic System Resource has the option to accept, partially accept, or decline the Dispatch Instruction, but in any case must respond within the timeframe specified in a Business Practice Manual. The Non-Dynamic System Resource can change its response within the indicated timeframe. If a Non-Dynamic System Resource does not respond within the indicated timeframe, the Dispatch Instruction will be considered declined. A decline of such a Non-Dynamic System Resource for a Dispatch Instruction received at least forty (40) minutes prior to the Trading Hour will be subject to Uninstructed Deviation Penalties as specific in Section 11.23. A decline of such a Non-Dynamic System Resource for a Dispatch Instruction received less than forty (40) minutes prior to the Trading Hour will not be subject to Uninstructed Deviation Penalties. A Non-Dynamic System Resource that only partially accepts a Dispatch Instruction is subject to Uninstructed Deviation Penalties for the portion of the Dispatch Instruction that is declined.

When a resource demonstrates that it is not following Dispatch Instructions, the RTM will no longer assume that the resource will ramp from its current output level. The RTM assumes the resource to be "non-compliant" if it is deviating its five (5)-minute Ramping capability for more than N intervals by a magnitude determined by the CAISO based on its determination that it is necessary to improve the calculation of the expected Imbalance Energy as further defined in the BPM. When a resource is identified as "non-compliant," RTM will set the Dispatch operating target for that resource equal to its actual output in the Market Clearing software such that the persistent error does not cause excessive AGC action and consequently require CAISO to take additional action to comply with reliability requirements. Such a resource will be considered to have returned to compliance when the resource's State Estimator or telemetry value (whichever is applicable) is within the above specified criteria. During the time when the resource is "non-compliant", the last applicable Dispatch target shall be communicated to the Scheduling Coordinator as the Dispatch operating target. The last applicable Dispatch target may be (i) the last Dispatch operating target within the current Trading Hour that was instructed prior to the resource becoming "non-compliant," or (ii) the Day-Ahead Schedule, or (iii) awarded Self-Schedule Hourly Block depending on whether the resource submitted a Bid and the length of time the resource was "non-compliant," or (iv) for a Dynamic System Resource or a Pseudo-Tie Generating Unit that is an Eligible Intermittent Resource, the most recently available telemetry for the actual output. During the time the resource is deemed to be "non-compliant" the CAISO will suspend the resource's eligibility for Ancillary Services and Uncertainty Awards.

* * *

44. Flexible Ramping Product

44.1 In General. The CAISO may enforce flexible ramping constraints in the Real-time Market to meet Forecasted Movement and Uncertainty Requirements, using tools as further described in the Business Practice Manual that estimate the Demand Forecast and Supply forecast error, as set forth in this Section 44. **44.2 Uncertainty Awards.**

44.2.1 Optimization. The CAISO will optimize the procurement of Uncertainty Awards in the Real-Time Market simultaneously with the procurement of Energy and Ancillary Services, as applicable. Uncertainty Awards do not overlap with Ancillary Services Awards or Available Balancing Capacity.

44.2.2 Variable Energy Resources. The CAISO will use the CAISO's own forecast (Independent Third Party Forecast) to determine the Uncertainty Awards and Forecast Movement for Variable Energy Resources.

44.2.3 Eligibility for Uncertainty Award.

44.2.3.1 Generally. All resources that have Economic Bids in the RTM that can be dispatched on a five-minute basis by RTD are eligible for receiving Uncertainty Awards.

44.2.3.2 Suspension. If the CAISO deems the resource to be non-compliant, the CAISO will suspend the resource's eligibility as specified in Section 34.13.2.

44.2.3.3 Ineligible Operating States. A resource is not eligible for an Uncertainty Award if it is in a Forbidden Operating Region or during an MSG Transition.

44.2.4 Determination of Uncertainty Requirement.

44.2.4.1 Requirement. The CAISO will determine the Uncertainty Requirement for each Real-Time Market run, by each BAA and for the EIM Area overall.

44.2.4.2 Procurement Curve.

(a) Generally. Based on statistical analysis of the Uncertainty Requirement, the CAISO will calculate constraint relaxation parameters to ensure the total cost of the Uncertainty Awards will not exceed the cost of expected power balance violations in absence of the Uncertainty Award, by each Balancing Authority Area and for the EIM Area overall, as set forth in the Business Practice Manual.

(b) Procurement Curve Cap. The CAISO will establish in the Business Practice Manual a limit on the procurement curve—

(1) at an amount less than the contingency relaxation penalty pricing parameter specified in the Business Practice Manual for market operations, in the case of an upward demand curve; and

(2) at an amount more than the regulation down relaxation penalty pricing parameter specified in the Business Practice Manual for market operations, in the case of a downward demand curve.

44.3 Forecasted Movement

44.3.1 Generally. The CAISO will determine the Forecasted Movement for each Generating Unit, System Resource, Pumped Storage, Pseudo-Tie, Non-generating Resource, PDR, Participating Load, and any other resource that has a schedule or dispatch change in the Real-Time Market as described below.

44.3.2 RTD Forecasted Movement. For the RTD, the Forecasted Movement for the resource will be the MW difference between the resource's non-binding dispatch instruction in the first five-minute advisory RTD interval and its Dispatch Instruction in the financially binding RTD interval, in the same RTD run.

44.3.3 FMM Forecasted Movement. For FMM the Forecasted Movement will be the difference between the resource's advisory FMM schedule in the first advisory FMM interval and its FMM Schedule in the financially binding FMM interval for the same applicable FMM run.

* * *

Appendix A

-Peak Flexible Ramp Hours

Trading Hours from hour ending 7 through hour ending 22.

- **Flexible Ramp Up Price (FRUP)**

The Shadow Price of the upward Uncertainty Requirement constraint, which is the cost sensitivity of relaxing the upward Uncertainty Requirement constraint ($/MWh).

-Flexible Ramp Down Price (FRDP)

The Shadow Price of the downward Uncertainty Requirement constraint, which is the cost sensitivity of relaxing the downward Uncertainty Requirement constraint ($/MWh).

-Off Peak Flexible Ramp Hours

Trading Hours from hour ending 1 through hour ending 6 and from hour ending 23 through hour ending 25.

Forecasted Movement

A resource's change in forecasted output between market intervals as described in Section 44.3.

Uncertainty Award

A resource’s awards for meeting Uncertainty Requirements as described in Section 44.2.

Uncertainty Requirement

Flexible ramping capability to meet the requirements as specified in Section 44.2.4.

- Supply

The Energy delivered from a Generating Unit, System Unit, Physical Scheduling Plant, System Resource, the Curtailable Demand provided by a Participating Load, the Demand Response Services provided by a Proxy Demand Resource or a Reliability Demand Response Resource, or Non-Generator Resources.

Attachment B – Marked Tariff Records

Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

11.5.9 Flexible Ramping Product

The CAISO will settle the Flexible Ramping Product as set forth in Section 11.25.

* * *

11.8.4 RTM Bid Cost Recovery Amount

* * *

11.8.4.2 RTM Market Revenue Calculations

~~The RTM Market Revenue calculations are subject to the Real-Time Performance Metric and the Persistent Deviation Metric as described in Sections 11.8.4.4 and 11.17, respectively.~~

11.8.4.2.1 For each Settlement Interval in a CAISO Real-Time Market Commitment Period, the RTM Market Revenue for a Bid Cost Recovery Eligible Resource is the algebraic sum of the elements listed below in this Section. For Multi-Stage Generating Resources the RTM Market Revenue calculations will be made at the Generating Unit level.

(a) The sum of the products of the FMM or RTD Instructed Imbalance Energy (including Minimum Load Energy of the Bid Cost Recovery Eligible Resource committed in RUC and where for Pumped-Storage Hydro Units and Participating Load operating in the pumping mode or serving Load, the MWh is negative), except Standard Ramping Energy, Residual Imbalance Energy, Exceptional Dispatch Energy, Derate Energy, MSS Load following Energy, Ramping Energy Deviation and Regulation Energy, with the relevant FMM and RTD LMP, for each Dispatch Interval in the Settlement Interval. These amounts are subject to the Real-Time Performance Metric and the Persistent Deviation Metric as described in Sections 11.8.4.4 and 11.17, respectively.

(b) The product of the Real-Time Market AS Award from each accepted Real-Time Market AS Bid in the Settlement Interval with the relevant ASMP, divided by the number of fifteen (15)-minute Commitment Intervals in a Trading Hour (4), and prorated to the duration of the Settlement Interval.

(c) The relevant tier-1 No Pay charges for that Bid Cost Recovery Eligible Resource in that Settlement Interval.

(d) The Forecasted Movement and Uncertainty Awards Settlement Amounts as calculated pursuant to Section 11.25 are included in the RTM Market Revenues calculation, not including:

(1) the amounts rescinded pursuant to Section 11.25.3;

(2) Forecasted Movement revenue when there are changes in Self-Schedules across consecutive Trading Hours; and

(3) Forecasted Movement revenue when there are changes in EIM Base Schedules across consecutive Trading Hours without Economic Bids.

11.8.4.2.2 For each Settlement Interval in a non-CAISO Real-Time Market Commitment Period, the Real-Time Market Revenue for a Bid Cost Recovery Eligible Resource ~~is subject to the Real-Time Performance Metric and~~ is the algebraic sum of the following:

(a) The sum of the products of the FMM or RTD Instructed Imbalance Energy (excluding the Minimum Load Energy of Bid Cost Recovery Eligible Resources committed in RUC), except, Standard Ramping Energy, Residual Imbalance Energy, Exceptional Dispatch Energy, Derate Energy, MSS Load Following Energy, Ramping Energy Deviation and Regulating Energy, with the relevant FMM or RTD Market LMP, for each Dispatch Interval in the Settlement Interval. These amounts are subject to the Real-Time Performance Metric and the Persistent Deviation Metric as described in Sections 11.8.4.4 and 11.17, respectively.

(b) The product of the Real-Time Market AS Award from each accepted Real-Time Market AS Bid in the Settlement Interval with the relevant ASMP, divided by the number of fifteen (15)-minute Commitment Intervals in a Trading Hour (4), and prorated to the duration of the Settlement Interval.

(c) The relevant tier-1 No Pay charges for that Bid Cost Recovery Eligible Resource in that Settlement Interval.

(d) The Forecasted Movement and Uncertainty Awards Settlement Amounts as calculated pursuant to Section 11.25 are included in the RTM Market Revenues calculation, not including:

(1) the amounts rescinded pursuant to Section 11.25.3;

(2) Forecasted Movement revenue when there are changes in Self-Schedules across consecutive Trading Hours; and

(3) Forecasted Movement revenue when there are changes in EIM Base Schedules across consecutive Trading Hours without Economic Bids.

* * *

~~**11.25 Flexible Ramping Constraint Compensation**~~

~~**11.25.1 Determination of Flexible Ramping Constraint Shadow Price**~~

~~The CAISO will determine a Flexible Ramping Constraint Shadow Price as the reduction of the total Energy and Ancillary Services procurement cost associated with a marginal change at each constraint for the individual Balancing Authority Areas in the EIM Area and applicable groupings of those areas in which the constraint is enforced, which will be equal to zero (0) if the Flexible Ramping Constraint is not binding.~~

~~**11.25.2 Compensation of Resources**~~

~~(a) The CAISO will award Flexible Ramping Constraint capacity to all resources identified as resolving the Flexible Ramping Constraint in the applicable RTUC interval and will pay the resource's Scheduling Coordinator, for each RTUC interval, whether or not the Flexible Ramping Constraint is binding, limited by the quantity of Flexible Ramping Constraint requirements.~~

~~(b) The CAISO will calculate the payment as the product of~~

~~(1) the upward MW of capacity identified to satisfy the constraint(s) in the groupings and individual Balancing Authority Areas in the EIM Area in which it participates to relieve the constraints in the groupings and individual Balancing Authority Areas in the EIM Area in which it participates to relieve the constraint(s), multiplied by 0.25 hours, and~~

~~(2) the Flexible Ramping Constraint Derived Price calculated for each applicable fifteen-minute FMM interval.~~

~~**11.25.2.1 Flexible Ramping Constraint Derived Price**~~

~~(a) For each applicable fifteen-minute FMM interval, the Flexible Ramping Constraint Derived Price is equal to the lesser of—~~

~~(1) $800/MWh; or~~

~~(2) the greater of~~

~~(i) the Real-Time ASMP for Spinning Reserves for the applicable fifteen-minute FMM interval; or~~

~~(ii) the total Flexible Ramping Constraint Shadow Price,~~

~~but not less than zero.~~

~~(b) The CAISO will determine the total Flexible Ramping Constraint Shadow Price as the sum of the Flexible Ramping Constraint Shadow Prices for the groupings and individual Balancing Authority Areas in the EIM Area in which the resource is deemed to have contributed to the constraint, minus seventy-five (75) percent of the greater of~~

~~(1) zero (0), or~~

~~(2) the Real-Time System Marginal Energy Cost, calculated as the simple average of the System Marginal Energy Cost for each of the three five-minute RTD intervals in the applicable fifteen-minute FMM interval.~~

~~11.25.3 Rescission of Payment for Non-Performance~~

~~(a) The CAISO will rescind payments to Scheduling Coordinators for the quantity of MW of undelivered Flexible Ramping Constraint capacity determined as the 15-minute sum of the Settlement Interval amounts calculated as the minimum of—~~

~~(1) the Flexible Ramping Constraint capacity identified as having contributed to the relief of the Flexible Ramping Constraint, or~~

~~(2) the difference between~~

~~(i) the absolute value of the negative UIE and~~

~~(ii) the upward MW identified as Undelivered Ancillary Services Capacity as required in Section 11.10.9.3 but not less than zero.~~

~~(b) The CAISO will determine rescinded amounts as the product of—~~

~~(1) the MW quantities to be rescinded determined as described in this Section 11.25.3; and~~

~~(2) the Flexible Ramping Constraint Derived Price as described in Section 11.25.2.~~

~~**11.25.4 Apportionment of Flexible Ramping Constraint Costs**~~

~~(a) The CAISO will determine the Flexible Ramping Constraint costs for each constraint as the product of—~~

~~(1) the resource-specific total Flexible Ramping Constraint costs, calculated as the total compensation in Section 11.25.2(b), net of rescission of payments, and~~

~~(2) the ratio of each Flexible Ramping Constraint Shadow Price to the sum of the Flexible Ramping Constraint Shadow Prices for the groupings and individual Balancing Authority Areas in the EIM Area in which the resource is deemed to have contributed to the constraint.~~

~~(b) For each constraint and each Balancing Authority Area in the EIM Area, the CAISO will determine the Flexible Ramping Constraint costs attributable to that Balancing Authority Area for which the applicable constraint(s) were binding in the applicable interval, based on the ratio of the Balancing Authority Area's requirement to its contribution to the individual constraint or group of constraints to which that Balancing Authority Area contributes.~~

~~(c) The CAISO will determine each Balancing Authority Area's apportionment of Flexible Ramping Constraint costs as the sum for that Balancing Authority Area of the amounts determined in Section 11.25.4(b).~~

~~**11.25.5 Allocation of Flexible Ramping Constraint Costs**~~

~~(a) For the CAISO Balancing Authority Area, the CAISO will allocate total Flexible Ramping Constraint costs described in Sections 11.25.5.1 and 11.25.5.2.~~

~~(b) The CAISO will allocate total Flexible Ramping Constraint costs for each EIM Entity Balancing Authority Area to the applicable EIM Entity Scheduling Coordinator.~~

~~**11.25.5.1 Allocation to Measured Demand**~~

~~Seventy five (75) percent of the total Flexible Ramping Constraint costs apportioned to the CAISO Balancing Authority Area and netted as described in Section 11.25.4, are allocated to Scheduling~~

~~Coordinators based on their Measured Demand for each applicable Trading Hour. Each Scheduling Coordinator is assessed a portion of seventy-five (75) percent share of the total costs equal to the Scheduling Coordinator's Measured Demand for the applicable Trading Hour divided by total market Measured Demand for the applicable Trading Hour.~~

~~**11.25.5.2 Allocation to Supply Deviations**~~

~~Twenty-five (25) percent of the total Flexible Ramping Constraint costs apportioned to the CAISO Balancing Authority Area and netted as described in Section 11.25.4, are allocated to Scheduling Coordinators based on their gross negative Supply deviations as follows, using a two-step process. First, on a daily basis, the CAISO determines a daily rate equal to twenty-five (25) percent of the total daily Flexible Ramping Constraint costs divided by total daily gross Supply negative deviations for the applicable Trading Day. Each Scheduling Coordinator is assessed its share of these daily costs based on its daily gross negative deviations calculated by resource as described below. Second, at the end of each Trading Month, the CAISO reverses the daily amounts assessed to Scheduling Coordinators and calculates a monthly rate equal to twenty-five (25) percent of the tot;al monthly Flexible Ramping Constraint costs divided by the total monthly gross Supply negative deviations. Each Scheduling Coordinator is assessed its share of these monthly costs based on its monthly gross negative deviations calculated by resource as described below. The gross Supply negative deviations are determined by resource based on the sum of: (1) the resource's total negative Settlement Interval UIE deviations, which are determined as specified in Section 11.5.2, and (2) any negative import Operational Adjustments. Gross Supply negative deviations determined for this purpose are not netted across Settlement Intervals. The CAISO will provide the ability for Scheduling Coordinators to see daily or monthly Flexible Ramping Constraint cost allocation by resource for their resources in their regularly released Settlement Statements.~~

11.25. Settlement of Flexible Ramping Product

11.25.1 Settlement of Forecasted Movement

11.25.1.1 FMM. The CAISO will settle FMM Forecasted Movement with Scheduling Coordinators as follows, where upward movement is a positive amount and downward movement is a negative amount:

(a) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the FMM FRUP; plus

(b) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the product of the FMM FRDP and negative one.

11.25.1.2 RTD. The CAISO will settle RTD Forecasted Movement with Scheduling Coordinators as follows, where upward movement is a positive amount and downward movement is a negative amount:

(a) the product of the difference between the RTD Forecasted Movement and the FMM Forecasted Movement for the relevant Settlement Interval, both calculated for each resource pursuant to Section 44.3 in MWhs, and the RTD FRUP, less any rescission amounts pursuant to section 11.25.3; plus

(b) the product of the difference between the RTD Forecasted Movement and the FMM Forecasted Movement for the relevant Settlement Interval, both calculated for each resource pursuant to Section 44.3 in MWhs, and the product of the RTD FRDP and negative one, less any rescission amounts pursuant to section 11.25.3.

11.25.1.3 Allocation of Residual Forecasted Movement Settlements.

The CAISO will settle amounts remaining after settlement of Forecasted Movement pursuant to Section 11.25.1 to each Scheduling Coordinator's metered EIM Demand or metered CAISO Demand in proportion to its share of the total metered EIM Demand and metered CAISO Demand.

11.25.2 Settlement of Uncertainty Requirement.

11.25.2.1 Payment to Resources. On a daily basis, the CAISO will settle awards to resources for providing the Uncertainty Requirement at the applicable

FRUP or FRDP less any payment rescission for each interval pursuant to Section 11.25.3.

11.25.2.2 Allocation of Costs of Uncertainty Movement Procured.

11.25.2.2.1 Settlement Process.

(a) **Daily.** The CAISO will initially—

(1) allocate the cost of the Uncertainty Award within each Balancing Authority Area in the EIM Area and within the EIM Area on a daily basis according to the categories as set forth in this Section 11.25.2.2; and

(2) allocate the daily amounts to Scheduling Coordinators as set forth in this Section 11.25.2.2.

(b) **Monthly.** The CAISO will resettle the costs of the Uncertainty Awards by—

(1) reversing the daily allocation;

(2) assigning the monthly costs of the Uncertainty Awards to Peak Flexible Ramp Hours and Off-Peak Flexible Ramp Hours;

(3) separately allocating the monthly Peak Flexible Ramp Hours amounts and Off-Peak Flexible Ramp Hours amounts to the categories within each Balancing Authority Area in the EIM Area and within the EIM Area as set forth in this Section 11.25.2.2; and

(4) allocating the monthly amounts in each category to Scheduling Coordinators as set forth in this Section 11.25.2.2.

11.25.2.2.2 Allocation of Charges to Categories.

(a) **Determination of Uncertainty Movement For Resources.** For each interval, the CAISO will calculate the net Uncertainty

Movement of each resource according to the following categories~~.~~

(1) for Supply resources other than non-Dynamic System Resources as the difference between the Dispatch Instruction of the binding interval in the next RTD run and the first advisory RTD interval in the current run.

(2) for non-Dynamic System Resources and export schedules as the difference between the schedule used in the RTD (accounting for ramp) for the binding interval in the next RTD run and the scheduled use for the first advisory interval in the current RTD run.

(b) RTD Uncertainty Movement by Balancing Authority Area and by EIM Area. The CAISO will determine the total net RTD Uncertainty Movement for each category separately for each Balancing Authority Area in the EIM Area and by EIM Area—

(1) for the category of Supply resources, which shall not include non-Dynamic System Resources, as the net sum of the five-minute Uncertainty Movement determined pursuant to Section 11.25.2.2.2 of all the Supply resources in the category.

(2) for the category of Intertie resources, which shall comprise non-Dynamic System Resources and exports, as the net sum of the five-minute Uncertainty Movement determined pursuant to Section 11.25.2.2 of all the non-Dynamic System resources and export schedules.

(3) for the non-Participating Load category, as the difference between-

(A) the CAISO Forecast of CAISO Demand, the CAISO forecast of Balancing Authority Area EIM Demand, or the CAISO forecast of EIM Area EIM Demand, as applicable, of the binding interval in the next RTD run; and

(B) the CAISO Forecast of CAISO Demand, the CAISO forecast of Balancing Authority Area EIM Demand, or the CAISO forecast of EIM Area EIM Demand, as applicable, for the first advisory interval in the current RTD run.

11.25.2.2.3 Assignment of Uncertainty Costs~~.~~ to Categories. The CAISO will allocate the total Uncertainty Award cost calculated pursuant to this section 11.25.2.2 to each category described in Section 11.25.2.2.2(b) based on—

(a) for upward Uncertainty Award cost, the ratio of such category's positive Uncertainty Movement to the sum of the positive Uncertainty Movements of all categories with positive Uncertainty Movement for each Balancing Authority Area in the EIM Area and the EIM Area; and.

(b) for downward Uncertainty Award costs, the ratio of such category's negative Uncertainty Movement to the sum of the negative Uncertainty Movements of all categories with negative Uncertainty Movement for each Balancing Authority Area in the EIM Area and the EIM Area.

11.25.2.2.4 Allocation to Scheduling Coordinators.

(a) **Non-Participating Load Category.** The CAISO will allocate the Uncertainty Awards costs of the non-Participating Load category to Scheduling Coordinators—

(1) for upward Uncertainty Award cost in proportion to the Scheduling Coordinator's negative non-Participating Load UIE, excluding the non-Participating Load of an MSS that has elected to load-follow according to an MSS Agreement, without netting that UIE across Settlement Intervals, to the total of such negative non-Participating Load UIE, without netting that UIE across Settlement Intervals, in the Balancing Authority Area or EIM Area as applicable, and

(2) for downward Uncertainty Award cost calculated pursuant to Section 11.25, in proportion to the Scheduling Coordinator's daily positive non-Participating Load UIE, excluding the non-Participating Load of an MSS that has elected to load-follow according to an MSS Agreement, without netting that UIE across Settlement Intervals, to the total of such positive non-Participating Load UIE, without netting that UIE across Settlement Intervals, in the BAA or EIM Area as applicable.

(b) **Supply Category.** The CAISO will allocate the Uncertainty Awards costs of the Supply category to Scheduling Coordinators for each resource in the Supply category based on the sum of the resource's Uncertainty Movement and UIE––

(1) for upward Uncertainty Award cost in proportion to the Scheduling Coordinator's positive sum of the resource's Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, to the total positive sum of all resources' Uncertainty Movement and UIE, without

netting that sum across Settlement Intervals, in the BAA or EIM Area as applicable; and

(2) for downward Uncertainty Award cost in proportion to the Scheduling Coordinator's negative sum of the resource's Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, to the total negative sum of all resources' Uncertainty Movement and UIE, without netting that sum across Settlement Intervals, in the Balancing Authority Area or EIM Area as applicable; except that

(3) for the MSS that have elected to load follow pursuant to an MSS Agreement, the CAISO will calculate the positive and negative sums specified above for each Settlement Interval as the sum of MSS non-Participating Load UIE, Supply resources within the MSS UIE, MSS Load Following Energy, MSS Load Following Operational Adjustments, and Uncertainty Movement of resources within the MSS Aggregation.

(c) **Intertie Category.** The CAISO will allocate the Uncertainty Awards costs of the Intertie category to Scheduling Coordinators for each non-Dynamic System Resource and export based on the sum of the resource's Uncertainty Movement and Operational Adjustment—

(1) for upward Uncertainty Award cost in proportion to the magnitude of the Scheduling Coordinator's negative Operational Adjustment for non-Dynamic System Resources, or positive Operational Adjustment for export resources, to the sum of the magnitudes of such

Operational Adjustments in the Balancing Authority Area or EIM Area, without netting that sum across Settlement Intervals; and

(2) for downward Uncertainty Award cost in proportion to the magnitude of the Scheduling Coordinator's positive Operational Adjustment for non-Dynamic System Resources, or negative Operational Adjustment for export resources, to the sum of the magnitudes of such Operational Adjustments in the Balancing Authority Area or EIM Area, without netting that sum across Settlement Intervals; and

(3) for the purposes of the allocations specified above, the MSS Load Following Operational Adjustment is excluded.

(d) Uncertainty Award Cost Offset. If the sum of the settlement of Uncertainty Awards and the charges to Scheduling Coordinators for Uncertainty Award costs is nonzero, the CAISO will allocate such amounts to Scheduling Coordinators based on the ratio of their metered CAISO Demand and metered EIM Demand to the total EIM area metered demand.

11.25.3. Rescission

11.25.3.1 Amount of Rescission. For each Settlement Interval in which a resource has either a UIE deviation or Operational Adjustment and a Flexible Ramping Product settlement, separately for upward and downward, the CAISO will rescind Settlement Amount for the overlap of the UIE or Operational Adjustment and the sum of RTD Forecasted Movement and Uncertainty Award, at the RTD FRUP or FRDP.

11.25.3.2 Order of Rescission. The CAISO will apply any rescission amount first to any Uncertainty Award, in the applicable direction, and then apply any remaining rescission amount to Forecasted Movement, in the applicable direction.

* * *

16.6.3 Treatment Of Valid ETC Self-Schedules

The resulting valid ETC Self-Schedules shall have the following Settlement treatment:

(1) The CAISO will apply the ETC Settlement treatment in Sections 11.2.1.5 and 11.5.7.1.

(2) The CAISO shall base the Marginal Cost of Losses on LMP differentials at the Existing Contract source(s) and sink(s) identified in the valid ETC Self-Schedule.

(3) The holders of Existing Rights will not be entitled to an allocation of revenues from the CAISO, including Access Charge revenue related to those Existing Rights.

(4) Parties with Existing Rights shall continue to pay for Transmission Losses or Ancillary Services requirements in accordance with such Existing Contracts as they may be modified or changed in accordance with the terms of the Existing Contract. The Participating TOs shall continue to provide Transmission Losses and any other Ancillary Services to the holder of the rights under an Existing Contract as may be required by the Existing Contract. The CAISO will charge Scheduling Coordinators submitting the ETC Self-Schedule for Transmission Losses ~~and~~, Ancillary Services, and Flexible Ramping Product, in accordance with the CAISO Tariff and any shortfall or surplus between the CAISO charges and the Existing Rights shall be settled bilaterally between the Existing Contract parties or through the relevant TO Tariff. To enable holders of Existing Rights to determine whether the CAISO's calculations result in any associated shortfall or surplus and to enable the parties to the Existing Contracts to settle the

differences bilaterally or through the relevant TO Tariff, the CAISO shall calculate and provide the Scheduling Coordinator's Settlements the amounts paid for the MCL for the amounts of MWh submitted with a valid ETC Self-Schedule. Each Participating TO will be responsible for recovering any deficits or crediting any surpluses associated with differences in Transmission Losses and Transmission Loss requirements and/or Ancillary Services requirements, through its bilateral arrangements or its Transmission Owner Tariff.

* * *

17.3.3 Settlement Treatment Of Valid TOR Self-Schedules

The resulting valid TOR Self-Schedules shall have the following Settlement treatment:

(1) The CAISO will apply the TOR Settlement treatment in Sections 11.2.1.5 and 11.5.7.

(2) The CAISO shall base the Marginal Cost of Losses on LMP differentials at the Points of Receipt and Points of Delivery identified in the valid TOR Self-Schedule; provided, however, that if a specific loss percentage exists in an applicable agreement between the TOR holder and the CAISO or an existing agreement between the TOR holder and a Participating TO, the CAISO will apply the IFM and RTM Marginal Cost of Losses Credit as provided in Sections 11.2.1.7 and 11.5.7.2. In any case in which the TOR holder has an existing agreement regarding its TORs with either the CAISO or a Participating TO, the provisions of the agreement shall prevail over any conflicting provisions of this Section 17.3.3(2). Where the provisions of this Section 17.3.3(2) do not conflict with the provisions of the agreement, the provisions of this Section 17.3.3(2) shall apply to the subject TORs.

(3) The CAISO will assess only charges applicable to Ancillary Services, Imbalance Energy, Transmission Losses, Flexible Ramping Product, and Grid Management Charges for the use of a TOR and will not assess charges for neutrality, UFE,

transmission Access Charges, Minimum Load Costs, or other charges that might otherwise be applicable to the Demand or exports served solely over the TOR. The CAISO will assess charges applicable to Ancillary Services for the use of a TOR only to the extent that the CAISO must procure Ancillary Services for the TOR holder because Ancillary Services are not self-provided by the TOR holder. The CAISO will assess charges and provide payments for TOR Self-Schedules pursuant to the rules specified in Sections 11.2.1.5 and 11.5.7.2. The CAISO will assess charges applicable to Imbalance Energy for the use of a TOR only if the CAISO must procure Imbalance Energy for the TOR holder. The CAISO will assess Grid Management Charges for the use of a TOR only in accordance with the provisions of Section 11.22 and Appendix F, Schedule 1.

(4) The holders of TORs will not be entitled to an allocation of revenues from the CAISO, including Access Charge revenues; provided that the Scheduling Coordinator for the TOR holder shall be allocated the applicable amount of IFM Marginal Losses Surplus Credit in accordance with the provisions of Section 11.2.1.6, except for any TOR Self-Schedule that received the IFM Marginal Cost of Losses Credit.

(5) Parties with TORs shall continue to pay for Transmission Losses or Ancillary Services requirements in accordance with any Existing Contracts applicable to those TORs as they may be modified or changed in accordance with the terms of the Existing Contract. Any affected Participating TOs shall continue to provide Transmission Losses and any other Ancillary Services to the holder of a TOR subject to an Existing Contract as may be required by the Existing Contract. As described in Section 17.3.3(3) above, the CAISO will charge Scheduling Coordinators submitting the TOR Self-Schedule the charges applicable to Transmission Losses, Ancillary Services, and Imbalance Energy in accordance with the CAISO Tariff (e.g., the Transmission Losses Charge based on the Marginal Cost of Losses), and any shortfall or surplus between the CAISO

charges and the provisions of any applicable Existing Contract shall be settled bilaterally between the Existing Contract parties or through the relevant TO Tariff. To enable holders of TORs to determine whether the CAISO's calculations result in any associated shortfall or surplus and to enable the parties to the Existing Contracts to settle the differences bilaterally or through the relevant TO Tariff, the CAISO shall calculate and provide the Scheduling Coordinator's Settlements the amounts paid for the MCL for the amounts of MWh submitted with a valid TOR Self-Schedule. Each Participating TO will be responsible for recovering any deficits or crediting any surpluses associated with differences in Transmission Losses and Transmission Loss requirements and/or Ancillary Services requirements, through its bilateral arrangements or its Transmission Owner Tariff.

* * *

27.4.1 Security Constrained Unit Commitment

The CAISO uses SCUC to run the MPM process associated with the DAM and the RTM. SCUC is conducted over multiple varying intervals to commit and schedule resources as follows: (1) in the Day-Ahead time frame, to meet Demand reflected in Bids submitted in the Day-Ahead Market and considered in the MPM process and IFM, and to procure AS in the IFM; (2) to meet the CAISO Forecast Of CAISO Demand in the RUC, HASP, STUC and FMM, and in the MPM process utilized in the HASP and RTM; ~~and~~ (3) to procure any incremental AS in the RTM, and (4) to procure Flexible Ramping Product in the RTM. In the Day-Ahead MPM, IFM and RUC processes, the SCUC commits resources over the twenty-four (24) hourly intervals of the next Trading Day. In the FMM, which runs every fifteen (15) minutes and commits resources for the RTM, the SCUC optimizes over a number of 15-minute intervals corresponding to the Trading Hours for which the Real-Time Markets have closed. The Trading Hours for which the Real-Time Markets have closed consist of (a) the Trading Hour in which the applicable run is conducted and (b) all the fifteen-minute intervals of the entire subsequent Trading Hour. In the HASP, which runs once per hour, the SCUC: 1) accepts and awards HASP Block Intertie Schedules for Energy and Ancillary

Services, respectively; 2) provides HASP Advisory Schedules to Economic Hourly Block Bids with Intra-Hour Option that will change for economic reasons at most once in the Trading Hour; and 3) provides HASP Advisory Schedules to all other participants in the RTM. In the STUC, which runs once an hour, the SCUC commits resources over the last fifteen (15) minutes of the imminent Trading Hour and the entire next four Trading Hours. The CAISO will commit Extremely Long Start Resources, for which commitment in the DAM does not provide sufficient time to Start-Up and be available to supply Energy during the next Trading Day as provided in Section 31.7.

* * *

~~27.10 Flexible Ramping Constraint~~

~~The CAISO may enforce a Flexible Ramping Constraint in the RTM. Any flexible Dispatch capacity constrained to be available as a result of the Flexible Ramping Constraint in RTM will come from capacity that is not designated to provide Regulation or Operating Reserves, and will not offset the required procurement of Regulation or Operating Reserves in RTUC. To the extent a resource incurs an opportunity cost for not providing Energy or Ancillary Services in the FMM or RTD interval as a result of a binding Flexible Ramping Constraint, all resources resolving that Flexible Ramping Constraint will be compensated pursuant to Section 11.25. In the FMM or RTD the resources identified as resolving the Flexible Ramping Constraint in the corresponding RTUC run will be the only resources used to resolve the Flexible Ramping Constraint enforced in FMM or RTD. The Flexible Ramping Constraint can be satisfied only by committed online dispatchable Generating Units, Participating Load, and Proxy Demand Response resources with ramping capability for which a Scheduling Coordinator has submitted Economic Bids for Energy for the applicable Trading Hour, and Dynamic System resources as specified below. This constraint cannot be satisfied by System Resources that are not Dynamic System Resources. Dynamic System Resources can become eligible to participate in relieving the Flexible Ramping Constraint if the Scheduling Coordinator scheduling that Resource can demonstrate that it has firm transmission service to the CAISO Balancing Authority Area intertie that allows the resource to deliver additional Energy in Real-Time, consistent with the requirements of Section 1.5 of the Dynamic Scheduling Protocol in Appendix M. This Dynamic System Resource must demonstrate that the~~

~~Dynamic System Resource has acquired sufficient firm transmission to support the total quantity of Energy and Ancillary Services offered in the Real-Time Market by submitting an E-Tag with a transmission profile that reflects the necessary transmission reservation(s) outside the CAISO Balancing Authority Area.~~

~~Procurement of Flexible Ramping Constraint capacity from Dynamic System Resources is limited by the available capacity in Real-Time for the applicable interval on the applicable intertie transmission constraint with which the Dynamic System Resource is associated. The quantity of the flexible ramping capacity for each applicable CAISO Market run will be determined by CAISO operators using tools that estimate the: 1) expected level of imbalance variability; 2) uncertainty due to forecast error; and 3) differences between the hourly, fifteen (15) minute average and historical five (5) minute Demand levels. The Flexible Ramping Constraint relaxation parameter is $60.~~

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29.11. Settlements And Billing For EIM Market Participants.

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(g) **[Not Used]~~Flexible Ramping Constraint Allocation.~~**

~~(1) **Calculation.** The CAISO will calculate awards for Flexible Ramping Constraint capacity according to Section 11.25.2 and rescission for non-performance in accordance with 11.25.3, except that the Real-Time Ancillary Service Market Price for Spinning Reserves will be deemed to be zero in determining awards to EIM Participating Resources.~~

~~(2) **Apportionment of Costs.** The CAISO will apportion Flexible Ramping Constraint costs to each EIM Entity Balancing Authority Area and the CAISO Balancing Authority Area in accordance with Section 11.25.4.~~

~~(3) **Cost Allocation.** The CAISO will allocate each EIM Entity's Flexible Ramping Constraint costs to the applicable EIM Entity Scheduling Coordinator in accordance with Section 11.25.5(b).~~

* * *

(p) **Flexible Ramping Product.** The CAISO will allocate and settle payments and charges for the Flexible Ramping Product according to Section 11.25, where the CAISO will consider EIM Base Schedules of non-participating resources as Self-Schedules.

* * *

29.34. EIM Operations

* * *

(l) EIM Resource Plan Evaluation.

(1) Requirement. The EIM Base Schedules for resources included in the EIM Resource Plan must balance the Demand Forecast for each EIM Entity Balancing Authority Area.

(2) Insufficient Supply. An EIM Resource Plan shall be deemed to have insufficient Supply if the sum of EIM Base Schedules from non-participating resources and the sum of the highest quantity offers in the Energy Bid range from EIM Participating Resources, including Interchange with other Balancing Authority Areas, is less than the total Demand Forecast that the EIM Entity Scheduling Coordinator has decided to use for the associated EIM Entity Balancing Authority Area.

(3) Excess Supply. An EIM Resource Plan shall be deemed to have excessive Supply if the sum of EIM Base Schedules from non-participating resources and the sum of the lowest quantity Bids in the Energy Bid range from EIM Participating Resources is greater than the total Demand Forecast that the EIM Entity Scheduling Coordinator has decided to use for the associated EIM Entity Balancing Authority Area.

(4) Additional Hourly Capacity Requirements.

(A) In General. If the CAISO determines under the procedures set forth in the Business Practice Manual for the Energy Imbalance Market that an

Balancing Authority Area in the EIM Area has historically high import or export schedule changes between forty minutes and twenty minutes before the start of the Trading Hour, the CAISO will add to the Balancing Authority Area in the EIM Area's capacity requirements an additional requirement.

(B) **Additional Capacity Requirement**. On a monthly basis, according to procedures set forth in the Business Practice Manual for the Energy Imbalance Market, the CAISO will calculate for each Balancing Authority Area in the EIM Area histograms of the percentage of the difference between imports and exports scheduled at forty minutes before the start of the Trading Hour and the final imports and exports at twenty minutes before the start of the Trading Hour based on the submitted E-Tags at those times and calculate additional upward and downward requirements for the capacity test component of the resource sufficiency evaluation.

(m) **Flexible Ramping** ~~**Constraint Requirement.**~~

~~(1) **Responsibility.** Each EIM Entity Balancing Authority Area and the CAISO Balancing Authority Area will be responsible for meeting its own portion of the combined Flexible Ramping Constraint capacity requirements for the next hour as determined by Section 29.34(m).~~

~~(2) **Nature.** The Flexible Ramping Constraint capacity requirement is a minimum requirement for each Balancing Authority Area in the EIM Area and on a system wide basis based upon the EIM Transfer limit between Balancing Authority Areas.~~

~~(3) **Determination.** Under the provisions of Section 29.34(m) and the procedures set forth in the Business Practice Manual for the Energy Imbalance Market, the CAISO will determine the Flexible Ramping Constraint capacity requirement using the CAISO Demand Forecast and~~

~~CAISO Variable Energy Resource forecast for each Balancing Authority Area in the EIM Area and system wide.~~

~~(4)~~ **Sufficiency Determination.**

(1~~A~~) **Review.**

(A~~i~~) **EIM Entity Balancing Authority Areas.** The CAISO will review the EIM Resource Plan pursuant to the process set forth in the Business Practice Manual for the Energy Imbalance Market and verify that it has sufficient Bids for Ramping capability to meet the EIM Entity Balancing Authority Area upward and downward ~~Flexible~~ Ramping requirements~~Constraint capacity requirement~~, as adjusted pursuant to Sections 29.34(m)~~(4)~~(2~~B~~), (3~~C~~), and (5~~E~~).

(B~~ii~~) **CAISO Balancing Authority Area.** The CAISO will review the Day-Ahead Schedules in the CAISO Balancing Authority Area and verify that it has sufficient Bids for Ramping capability to meet the CAISO Balancing Authority Area upward and downward ~~Flexible~~ Ramping ~~Constraint capacity~~ requirements, as adjusted pursuant to Sections 29.34(m)(2), (3), (5), and (6)~~4)(B), (C), and (E)~~.

(2~~B~~) Determination ~~Pro Rata Reduction and~~ of EIM Diversity Benefit ~~Limit~~. The CAISO will calculate separately the upward and downward EIM diversity benefit as the difference between the sum of the upward and downward Uncertainty Requirements for all Balancing Authority Areas in the EIM Area, and the Uncertainty Requirement for the EIM Area.

(3) Effects of EIM Diversity Benefit. For e~~E~~ach ~~EIM Entity~~ Balancing Authority Area in the EIM Area, the CAISO will reduce the upward and downward Uncertainty ~~Flexible Ramping Constraint capacity~~

~~R~~Requirement~~s~~ ~~shall be reduced~~ by the Balancing Authority Area's ~~its~~ pro rata share of the upward and downward EIM diversity benefit in the EIM Area as may be limited by—

(A) the available net import EIM Transfer capability into that ~~EIM Entity~~ Balancing Authority Area in the case of an upward Uncertainty Requirement; and

(B) the available net export EIM Transfer capability from that Balancing Authority Area in the case of a downward Uncertainty Requirement.

(4~~C~~) **Determination of Flexible Ramping Sufficiency Credit.** The CAISO will calculate for each Balancing Authority Area in the EIM Area, the upward flexible Ramping sufficiency credit as the outgoing EIM Transfer from that area and the downward flexible Ramping sufficiency credit as the incoming EIM transfer into that area.

(5) **Effect of Flexible Ramping Sufficiency Credit ~~of an EIM Entity Balancing Authority Area with a Net Outgoing EIM Transfer~~.** ~~If an EIM Entity Balancing Authority Area has a net outgoing EIM Transfer (net export with reference to the EIM Base Schedule) before the Operating Hour, then~~

~~(1)~~ ~~t~~The CAISO will reduce the upward Uncertainty Requirement of a Balancing Authority Area in the EIM Area by its ~~apply a~~ upward ~~f~~Flexible Ramping sufficiency ~~Constraint capacity requirement~~ credit, ~~in determining the sufficiency of the Flexible Ramping Constraint capacity for that EIM Entity Balancing Authority Area equal to the net outgoing EIM Transfer before the Operating Hour~~ and will reduce the downward Uncertainty Requirement of a Balancing Authority Area in the EIM Area by its downward flexible Ramping sufficiency credit.

(4~~D~~) ~~**Sufficiency of an EIM Entity Balancing Authority Area with a Net**~~

~~**Ingoing EIM Transfer.** If an EIM Entity Balancing Authority Area has a net incoming EIM Transfer (net import with reference to the EIM Base Schedule) before the Operating Hour; then~~

~~(i)~~ ~~the Flexible Ramping Constraint capacity for that EIM Entity Balancing Authority Area will be considered sufficient if it meets its own upward Flexible Ramping Constraint capacity requirement, irrespective of the incoming EIM Transfer that results from Real-Time Dispatch in the EIM Area.~~

(6~~E~~) **Incremental Requirements.**

(i) **In General.** If the CAISO determines under the procedures set forth in the Business Practice Manual for the Energy Imbalance Market that an EIM Balancing Authority Area has historically high import or export schedule changes between T-40 and T-20, the CAISO will add to the EIM Entity's flexible capacity requirement an additional incremental requirement.

(ii) **Additional Incremental Requirement.** On a monthly basis, according to procedures set forth in the Business Practice Manual for the Energy Imbalance Market, the CAISO will calculate for each EIM Entity Balancing Authority Area histograms of the percentage of the difference between imports and exports scheduled at T-40 and the final imports at T-20 based on the E-Tags submitted at T-40 and T-20 and calculate additional incremental and decremental requirements for the capacity test component of the resource sufficiency evaluation.

~~(5)~~ ~~**System Wide Constraints.** The CAISO shall determine the Flexible Ramping Constraint capacity requirement system wide, including~~

~~requirements for individual Balancing Authority Areas in the system wide constraint, by reducing the total Flexible Ramping Constraint capacity requirement for each Balancing Authority Area by the total amount of EIM Internal Intertie import capability to that Balancing Authority Area from each Balancing Authority Area in the EIM Area.~~

(n) **Effect of Resource Plan Insufficiency.**

(1) **Resource Plan Balance.** If, after the final opportunity for the EIM Entity to revise hourly Real-Time EIM Base Schedules as provided in Section 29.34(f)(1)(c), the EIM Resource Plan has insufficient supply as determined according to Section 29.34(l)—

(A) the CAISO will not include the EIM Entity Balancing Authority Area in ~~any~~ the Uncertainty Requirement of the EIM Area~~Flexible Ramping Constraints for any combination of Balancing Authority Areas~~;

~~(B) the CAISO will formulate only individual constraints for the EIM Entity Balancing Authority Area's individual Flexible Ramping Constraint capacity requirements; and~~

(B~~C~~) the CAISO will hold the EIM Transfer limit into or from the EIM Entity Balancing Authority Area, as specified in Section 29.34(n)(2), at the value for the last 15-minute interval.

(2) **Flexible Ramping Insufficiency.** If, after the final opportunity for the EIM Entity to revise hourly Real-Time EIM Base Schedules as provided in Section 29.34(f)(1)(c), the CAISO determines—

(i) that an EIM Entity Balancing Authority Area has insufficient upward ~~Flexible~~ Ramping ~~Constraint~~ capacity according to Section 29.34(m), the CAISO will take the actions described in Section 29.34(n)(1)(A) and (B) in the upward and into the EIM

Entity BAA direction; and

(ii) that an EIM Entity Balancing Authority Area has insufficient downward Ramping capacity according to Section 29.34(m), the CAISO will take the actions described in Section 29.34(n)(1)(A) and (B) in the downward and from the EIM Entity BAA direction.

* * *

29.44 ~~**[Not Used]**~~**Flexible Ramping Product.** The CAISO will procure Flexible Ramping Product for the Energy Imbalance Market as set forth in Section 44, except that the CAISO will consider the EIM Base Schedules of non-participating resources as Self-Schedules for the calculation of Flexible Ramping Product requirements.

* * *

34.4 Fifteen Minute Market

The CAISO conducts the Fifteen Minute Market using the second interval of each RTUC run horizon as follows: (1) at approximately 7.5 minutes prior to the first Trading Hour, for T-45 minutes to T+60 minutes where the binding interval is T-30 to T-15; (2) at approximately 7.5 minutes into the current hour for T-30 minutes to T+60 minutes where the binding interval is T-15 to T; (3) at approximately 22.5 minutes into the current hour for T-15 minutes to T+60 minutes for the binding interval T to T+15; and (4) at approximately 37.5 minutes into the current hour for T to T+60 minutes for the binding interval T+15 to T+30, where T is the beginning of the next Trading Hour. In these intervals the CAISO conducts the FMM to~~;~~ (1) determine financially binding FMM Schedules and corresponding LMPs for all Pricing Nodes, including all Scheduling Points; (2) determine financially and operationally binding Ancillary Services Awards and corresponding ASMPs, procure required additional Ancillary Services, and calculate ASMP used for settling procured Ancillary Service capacity for the next fifteen-minute Real-Time Ancillary Service interval for all Pricing Nodes, including Scheduling Points; ~~and~~ (3) determine LAP LMPs that are the basis for settling Demand; and (4) determine FMM Uncertainty Awards. In any FMM interval that falls within a time period in which a Multi-Stage Generating Resource is transitioning from one MSG

Configuration to another MSG Configuration, the CAISO: (1) will not award any incremental Ancillary Services; (2) will disqualify any Day-Ahead Ancillary Services Awards; (3) will disqualify Day-Ahead qualified Submissions to Self-Provide Ancillary Services Award, and (4) will disqualify Submissions to Self-Provide Ancillary Services in RTM. Each particular FMM market optimization produces binding settlement prices for Energy, Flexible Ramping Product, and Ancillary Services for the first FMM interval in the FMM horizon but the optimization considers the advisory results from subsequent market intervals within the FMM horizon. The CAISO settles Hourly Intertie Schedules and Hourly Ancillary Services Awards accepted in the HASP as FMM Schedules and FMM Ancillary Services Awards in accordance with Section 11.5 and 11.10.1.2, respectively. In the event that a FMM run fails, the CAISO reverts to Day-Ahead Market Ancillary Services Awards and RUC Schedules results corresponding to the same interval, or the corresponding interval from the previous RTUC. The FMM will clear Supply against the CAISO Forecast Of CAISO Demand and exports. The FMM issues Energy Schedules and Ancillary Services Awards by twenty-two and a half minutes prior to the binding fifteen-minute interval.

34.5 Real-Time Dispatch

The RTED uses a Security Constrained Economic Dispatch (SCED) algorithm every five (5) minutes throughout the Trading Hour to determine optimal Dispatch Instructions to balance Supply and Demand and determine Uncertainty Awards. The RTD can operate in three modes: RTED, RTCD and RTMD. In any given five-minute interval, the RTD optimization looks ahead over multiple five-minute intervals, but the CAISO issues Dispatch Instructions only for the next target five-minute interval. The CAISO will use the Real-Time Economic Dispatch (RTED) under most circumstances to optimally dispatch resources based on their Bids. The RTED can be used to Dispatch Contingency Only Operating Reserves, pursuant to Section 34.10, when needed to avoid an imminent System Emergency. The Real-Time Contingency Dispatch (RTCD) can be invoked in place of the RTED when a transmission or generation contingency occurs and will include all Contingency Only Operating Reserves in the optimization. If the CAISO awards a Non-Dynamic System Resource Ancillary Services in the IFM, HASP, or FMM and issues a Dispatch Instruction in the middle of the Trading Hour for Energy associated with its Ancillary Services (Operating Reserve) capacity, the CAISO will Dispatch the Non-Dynamic System Resource to operate at a constant level until the end of the Trading Hour. If the CAISO dispatches a Non-Dynamic

System Resource such that the binding interval of the Dispatch is in the next Trading Hour, the CAISO will dispatch Energy from the Non-Dynamic System Resource at a constant level until the end of the next Trading Hour. The dispatched Energy will not exceed the awarded Operating Reserve capacity for the next Trading Hour and will be at a constant level for the entire next Trading Hour. The Real Time Manual Dispatch (RTMD) will be invoked as a fall-back mechanism only when the RTED or RTCD fails to provide a feasible Dispatch. These three (3) modes of the RTD are described in Sections 34.5.1, 34.5.2, and 34.5.3.

* * *

34.7 General Dispatch Principles

The CAISO shall conduct all Dispatch activities consistent with the following principles:

(1) The CAISO shall issue AGC instructions electronically as often as every four (4) seconds from its Energy Management System (EMS) to resources providing Regulation and on Automatic Generation Control to meet NERC and WECC performance requirements;

(2) In each run of the RTED or RTCD the objective will be to meet the projected Energy requirements and Uncertainty R~~r~~equirements over the applicable forward-looking time period of that run, subject to transmission and resource operational constraints, taking into account the short term CAISO Forecast Of CAISO Demand or forecast of EIM Demand, adjusted as necessary by the CAISO or EIM Entity o~~O~~perator to reflect scheduled changes to Interchange and non-dispatchable resources in subsequent Dispatch Intervals;

(3) Dispatch Instructions will be based on Energy Bids for those resources that are capable of intra-hour adjustments and will be determined through the use of SCED except when the CAISO must utilize the RTDD and RTMD;

(4) When dispatching Energy from awarded Ancillary Service capacity the CAISO will not differentiate between Ancillary Services procured by the CAISO and Submissions to Self-Provide an Ancillary Service;

(5) The Dispatch Instructions of a resource for a subsequent Dispatch Interval shall take as a point of reference the actual output obtained from either the State Estimator solution or the last valid telemetry measurement and the resource's operational ramping capability. For Multi-Stage Generating Resources the determination of the point of reference is further affected by the MSG Configuration and the information contained in the Transition Matrix;

(6) In determining the Dispatch Instructions for a target Dispatch Interval while at the same time achieving the objective to minimize Dispatch costs to meet the forecasted conditions of the entire forward-looking time period, the Dispatch for the target Dispatch Interval will be affected by: (a) Dispatch Instructions in prior intervals, (b) actual output of the resource, (c) forecasted conditions in subsequent intervals within the forward-looking time period of the optimization, and (d) operational constraints of the resource, such that a resource may be dispatched in a direction for the immediate target Dispatch Interval that is different than the direction of change in Energy needs from the current Dispatch Interval to the next immediate Dispatch Interval, considering the applicable MSG Configuration;

(7) Through Start-Up Instructions the CAISO may instruct resources to start up or shut down, or may reduce Load for Participating Loads, Reliability Demand Response Resources, and Proxy Demand Resources, over the forward-looking time period for the RTM based on submitted Bids, Start-Up Costs and Minimum Load Costs, Pumping Costs and Pump Shut-Down Costs, as appropriate for the resource, or for Multi-Stage Generating Resource as appropriate for the applicable MSG Configuration, consistent with operating characteristics of the

resources that the SCED is able to enforce. In making Start-Up or Shut-Down decisions in the RTM, the CAISO may factor in limitations on number of run hours or Start-Ups of a resource to avoid exhausting its maximum number of run hours or Start-Ups during periods other than peak loading conditions;

(8) The CAISO shall only start up resources that can start within the applicable time periods of the various CAISO Markets Processes that comprise the RTM;

(9) The RTM optimization may result in resources being shut down consistent with their Bids and operating characteristics provided that: (a) the resource does not need to be on-line to provide Energy, (b) the resource is able to start up within the applicable time periods of the processes that comprise the RTM, (c) the Generating Unit is not providing Regulation or Spinning Reserve, and (d) Generating Units online providing Non-Spinning Reserve may be shut down if they can be brought up within ten (10) minutes as such resources are needed to be online to provide Non-Spinning Reserves;

(10) For resources that are both providing Regulation and have submitted Energy Bids for the RTM, Dispatch Instructions will be based on the Regulation Ramp Rate of the resource rather than the Operational Ramp Rate if the Dispatch Operating Point remains within the Regulating Range. The Regulating Range will limit the Ramping of Dispatch Instructions issued to resources that are providing Regulation;

(11) For Multi-Stage Generating Resources the CAISO will issue Dispatch Instructions by Resource ID and Configuration ID;

(12) The CAISO may issue Transition Instructions to instruct resources to transition from one MSG Configuration to another over the forward-looking time period for the RTM based on submitted Bids, Transition Costs and Minimum Load Costs, as appropriate for the MSG Configurations involved in the MSG Transition,

consistent with Transition Matrix and operating characteristics of these MSG Configurations. The RTM optimization will factor in limitations on Minimum Run Time and Minimum Down Time defined for each MSG configuration and

34.8 Dispatch Instructions to Units, Participating Loads, PDRs and RDRRs

The CAISO may issue Dispatch Instructions covering:

(a) Ancillary Services;

(b) Energy, which may be used for:

(i) Congestion relief;

(ii) provision of Imbalance Energy; or

(iii) replacement of an Ancillary Service;

(c) agency operation of Generating Units, Participating Loads, Proxy Demand Resources, or Interconnection schedules, for example:

(i) output or Demand that can be Dispatched to meet Applicable Reliability Criteria;

(ii) Generating Units that can be Dispatched for Black Start;

(iii) Generating Units that can be Dispatched to maintain governor control regardless of their Energy schedules;

(d) the operation of voltage control equipment applied on Generating Units as described in this CAISO Tariff;

(e) MSS Load following instructions provided to the CAISO, which the CAISO incorporates to create their Dispatch Instructions;

(f) Dispatch necessary to respond to a System Emergency or imminent emergency;

(g) Transition Instructions; ~~or~~

(h) Dispatch of Reliability Demand Response Resources pursuant to Section 34.18; or

(i) Uncertainty Awards.

34.9 Utilization Of The Energy Bids

The CAISO uses Energy Bids for the following purposes: (i) satisfying Real-Time Energy needs; (ii) mitigating Congestion; (iii) maintaining aggregate Regulation reserve capability in Real-Time; (iv) allowing recovery of Operating Reserves utilized in Real-Time operations; (v) procuring Voltage Support required from resources beyond their power factor ranges in Real-Time; (vi) establishing LMPs; (vii) as the basis for Bid Cost Recovery; ~~and~~ (viii) to the extent a Real-Time Energy Bid Curve is submitted starting at minimum operating level for a Short Start Unit that is scheduled to be on-line, the RTM may Dispatch such a resource down to its minimum operating level and may issue a Shut-Down Instruction to the resource based on its Minimum Load Energy costs; and (ix) satisfying Uncertainty Requirements.

* * *

34.13.2 Failure To Conform To Dispatch Instructions

In the event that, in carrying out the Dispatch Instruction, an unforeseen problem arises (relating to plant operations or equipment, personnel or the public safety), the recipient of the Dispatch Instruction must notify the CAISO or, in the case of a Generator, the relevant Scheduling Coordinator immediately. The relevant Scheduling Coordinator shall notify the CAISO of the problem immediately. If a resource is unavailable or incapable of responding to a Dispatch Instruction, or fails to respond to a Dispatch Instruction in accordance with its terms, the resource shall be considered to be non-conforming to the Dispatch Instruction unless the resource has notified the CAISO of an event that prevents it from performing its obligations within thirty (30) minutes of the onset of such event through a submission in the CAISO's outage management system pursuant to Section 9 log entry. Notification of non-compliance via the Automated Dispatch System (ADS) will not supplant nor serve as the official notification mechanism to the CAISO. If the resource is considered to be non-conforming as described above, the Scheduling

Coordinator for the resource concerned shall be subject to Uninstructed Imbalance Energy as specified in Section 11.5.2 and Uninstructed Deviation Penalties as specified in Section 11.23. This applies whether any Ancillary Services concerned are contracted or Self-Provided. For a Non-Dynamic System Resource Dispatch Instruction prior to the Trading Hour, the Scheduling Coordinator shall inform the CAISO of its ability to conform to a Dispatch Instruction via ADS. The Non-Dynamic System Resource has the option to accept, partially accept, or decline the Dispatch Instruction, but in any case must respond within the timeframe specified in a Business Practice Manual. The Non-Dynamic System Resource can change its response within the indicated timeframe. If a Non-Dynamic System Resource does not respond within the indicated timeframe, the Dispatch Instruction will be considered declined. A decline of such a Non-Dynamic System Resource for a Dispatch Instruction received at least forty (40) minutes prior to the Trading Hour will be subject to Uninstructed Deviation Penalties as specific in Section 11.23. A decline of such a Non-Dynamic System Resource for a Dispatch Instruction received less than forty (40) minutes prior to the Trading Hour will not be subject to Uninstructed Deviation Penalties. A Non-Dynamic System Resource that only partially accepts a Dispatch Instruction is subject to Uninstructed Deviation Penalties for the portion of the Dispatch Instruction that is declined.

When a resource demonstrates that it is not following Dispatch Instructions, the RTM will no longer assume that the resource will ramp from its current output level. The RTM assumes the resource to be "non-compliant" if it is deviating its five (5)-minute Ramping capability for more than N intervals by a magnitude determined by the CAISO based on its determination that it is necessary to improve the calculation of the expected Imbalance Energy as further defined in the BPM. When a resource is identified as "non-compliant," RTM will set the Dispatch operating target for that resource equal to its actual output in the Market Clearing software such that the persistent error does not cause excessive AGC action and consequently require CAISO to take additional action to comply with reliability requirements. Such a resource will be considered to have returned to compliance when the resource's State Estimator or telemetry value (whichever is applicable) is within the above specified criteria. During the time when the resource is "non-compliant", the last applicable Dispatch target shall be communicated to the Scheduling Coordinator as the Dispatch operating target. The last applicable Dispatch target may be (i) the last Dispatch operating target within the current Trading Hour that was instructed prior to the resource becoming "non-compliant," or (ii) the Day-Ahead Schedule, or (iii) awarded Self-Schedule Hourly Block depending on whether the resource submitted a Bid and the length of time the resource was "non-compliant," or (iv) for a Dynamic System Resource or a Pseudo-Tie Generating Unit that is an Eligible Intermittent Resource, the most recently available telemetry for the actual output. During the time the resource is deemed to be "non-compliant" the CAISO will suspend the resource's eligibility for Ancillary Services and Uncertainty Awards.

* * *

44. Flexible Ramping Product

44.1 In General. The CAISO may enforce flexible ramping constraints in the Real-time Market to meet Forecasted Movement and Uncertainty Requirements, using tools as further described in the Business Practice Manual that estimate the Demand Forecast and Supply forecast error, as set forth in this Section 44.

44.2 Uncertainty Awards.

44.2.1 Optimization. The CAISO will optimize the procurement of Uncertainty Awards in the Real-Time Market simultaneously with the procurement of Energy and Ancillary Services, as applicable. Uncertainty Awards do not overlap with Ancillary Services Awards or Available Balancing Capacity.

44.2.2 Variable Energy Resources. The CAISO will use the CAISO's own forecast (Independent Third Party Forecast) to determine the Uncertainty Awards and Forecast Movement for Variable Energy Resources.

44.2.3 Eligibility for Uncertainty Award.

44.2.3.1 Generally. All resources that have Economic Bids in the RTM that can be dispatched on a five-minute basis by RTD are eligible for receiving Uncertainty Awards.

44.2.3.2 Suspension. If the CAISO deems the resource to be non-compliant, the CAISO will suspend the resource's eligibility as specified in Section 34.13.2.

44.2.3.3 Ineligible Operating States. A resource is not eligible for an Uncertainty Award if it is in a Forbidden Operating Region or during an MSG Transition.

44.2.4 Determination of Uncertainty Requirement.

44.2.4.1 Requirement. The CAISO will determine the Uncertainty Requirement for each Real-Time Market run, by each BAA and for the EIM Area overall.

44.2.4.2 Procurement Curve.

(a) Generally. Based on statistical analysis of the Uncertainty Requirement, the CAISO will calculate constraint relaxation parameters to ensure the total cost of the Uncertainty Awards will not exceed the cost of expected power balance violations in absence of the Uncertainty Award, by each Balancing Authority Area and for the EIM Area overall, as set forth in the Business Practice Manual.

(b) Procurement Curve Cap. The CAISO will establish in the Business Practice Manual a limit on the procurement curve—

(1) at an amount less than the contingency relaxation penalty pricing parameter specified in the Business Practice Manual for market operations, in the case of an upward demand curve; and

(2) at an amount more than the regulation down relaxation penalty pricing parameter specified in the Business Practice Manual for market operations, in the case of a downward demand curve.

44.3 Forecasted Movement

44.3.1 Generally. The CAISO will determine the Forecasted Movement for each Generating Unit, System Resource, Pumped Storage, Pseudo-Tie, Non-generating Resource, PDR, Participating Load, and any other resource that has a schedule or dispatch change in the Real-Time Market as described below.

44.3.2 RTD Forecasted Movement. For the RTD, the Forecasted Movement for the resource will be the MW difference between the resource's non-binding dispatch instruction in the first five-minute advisory RTD interval and its Dispatch Instruction in the financially binding RTD interval, in the same RTD run.

44.3.3 FMM Forecasted Movement. For FMM the Forecasted Movement will be the difference between the resource's advisory FMM schedule in the first advisory FMM interval and its FMM Schedule in the financially binding FMM interval for the same applicable FMM run.

* * *

Appendix A

-Peak Flexible Ramp Hours

Trading Hours from hour ending 7 through hour ending 22.

- Flexible Ramp Up Price (FRUP)

The Shadow Price of the upward Uncertainty Requirement constraint, which is the cost sensitivity of relaxing the upward Uncertainty Requirement constraint ($/MWh).

-Flexible Ramp Down Price (FRDP)

The Shadow Price of the downward Uncertainty Requirement constraint, which is the cost sensitivity of relaxing the downward Uncertainty Requirement constraint ($/MWh).

-Off Peak Flexible Ramp Hours

Trading Hours from hour ending 1 through hour ending 6 and from hour ending 23 through hour ending 25.

Forecasted Movement

A resource's change in forecasted output between market intervals as described in Section 44.3.

Uncertainty Award

A resource’s awards for meeting Uncertainty Requirements as described in Section 44.2.

Uncertainty Requirement

Flexible ramping capability to meet the requirements as specified in Section 44.2.4.

- Supply

The Energy delivered from a Generating Unit, System Unit, Physical Scheduling Plant, System Resource, the Curtailable Demand provided by a Participating Load, ~~or~~ the Demand Response Services provided by a Proxy Demand Resource or a Reliability Demand Response Resource, or Non-Generator Resources.

Attachment C – Direct Testimony of Donald Tretheway

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

California Independent System Operator Corporation	))	**Docket No. ER16-____-000**

DIRECT TESTIMONY OF
DONALD TRETHEWAY
ON BEHALF OF THE
CALIFORNIA INDEPENDENT SYSTEM
OPERATOR CORPORATION

Q. Please state your name, title, and business address.

A. My name is Donald Tretheway. I am employed as a Senior Advisor for Market Design and Regulatory Policy for the California Independent System Operator Corporation (CAISO). My business address is 250 Outcropping Way, Folsom, CA 95630.

Q. Please describe your educational background.

A. I have a Bachelor of Arts in Economics, with a specialization in Computing, from the University of California, Los Angeles and a Masters of Business Administration, Finance & Technology Management, from the University of California, Davis - Graduate School of Management.

Q. What are your responsibilities as Senior Advisor for Market Design and Regulatory Policy?

A. I am responsible for developing enhancements to the wholesale electricity markets administered by the CAISO with an objective of improving the efficiency of those markets and realizing regulatory and public policy objectives in the region.

Q. What is your previous experience at the CAISO?

A. I began working at the CAISO in June 2009 and have worked on a number of significant market design issues. Since 2013, I have been the policy lead on the Energy Imbalance Market (EIM), which includes a number of stakeholder efforts to develop and enhance expansion of the CAISO's real-time market to accommodate participation by balancing authority areas other than the CAISO's balancing authority area.

I was the policy lead on the CAISO stakeholder process to develop its fifteen-minute scheduling and settlement and related market design enhancements to satisfy the intra-hour scheduling requirements established by the Commission in Order No. 764. These enhancements allow the CAISO's real-time market to more efficiently integrate large amounts of renewable variable energy resources into the fleet of resources serving customers in the CAISO's balancing authority area.

I also led stakeholder initiatives to evaluate changes to market products to facilitate the participation of new resources in the CAISO market, such as modifications to the CAISO ancillary services product to allow non-generator resources to provide these services and regulation energy management, which enabled short duration energy storage resources to provide regulation up and down. In addition, I was the policy lead on the CAISO's initiative to comply with the requirements established by the Commission in Order No. 755 concerning procurement of frequency regulation in the organized wholesale electric markets.

Q. What is the purpose of your testimony?

A. My testimony supports the CAISO's proposed tariff provisions establishing a flexible ramping product and explains its function and the manner in which it will operate.

I. BACKGROUND

A. Need for Flexible Ramping Capability

Q. What is the flexible ramping product?

A. The flexible ramping product is an enhancement to the CAISO's real-time market that will improve the management of ramping capability to meet changes in system conditions and to financially settle the resources and loads that provide and consume the ramping capability more accurately.

Q. What do you mean by ramping capability to meet changes in system conditions?

A. The CAISO uses its real-time market to dispatch imbalance energy to meet the difference between real-time demand and generation scheduled in the day-ahead market. The CAISO real-time market dispatches this imbalance energy on a fifteen-minute and five-minute basis through its fifteen- and five minute markets, respectively. In forecasting needed imbalance energy, the CAISO targets the forecasted demand, net of forecasted supply from variable energy resources, such as wind and solar. I refer to this as the forecasted net load. This element of the CAISO's dispatch is foundational for understanding the design of the flexible ramping product and the related rules, which I will describe further below. Both total demand and the output of variable energy resources are continually changing. To meet those changes the CAISO must dispatch supply resources to change their output. For example, if the total demand forecast in a given interval is 1000 megawatts, and the forecasted output for variable energy resources is 200 megawatts, the CAISO will dispatch enough generation to meet the remaining 800 megawatts.

Q. What is the ramping capability to which you refer?

A. Ramping capability is a resource's ability to move from one energy output to a higher (upward ramp) or lower (downward ramp) energy output. Different resources have different ramping capabilities. For example, one resource, which I will call G1, may be able to increase its output by 100 MW per minute, while another, G2, may only be able to increase its output by 10 MW per minute. Thus, the change in output within a 5-minute interval for G1 is 500 megawatts and G2 is 50 megawatts. In order to manage the grid reliably through the market, the CAISO must have sufficient dispatchable ramping capability available to meet forecasted net load changes between market intervals.

B. Multi-Interval Optimization

Q. How does the CAISO real-time market currently address ramping needs?

A. The CAISO's real-time market currently addresses ramping needs through a multi-interval optimization and, since 2012, an upward flexible ramping constraint.

Q. Please explain the real-time market's multi-interval optimization.

A. Each run of the CAISO's real-time market simultaneously determines the necessary output of dispatchable resources to meet forecasted net load over multiple intervals, not just in the next, "financially binding." interval. The subsequent intervals are "advisory" intervals. The CAISO real-time market consists of the short-term unit commitment process, the real-time unit commitment process (which includes an interval of each run that is used for fifteen-minute market and also is used for the hour-ahead scheduling process) and the real-time dispatch process. The various real-time processes have different horizons: (1) the short-term unit commitment process looks ahead for 4.5 hours of fifteen-minute intervals; (2) the real-time unit commitment process looks ahead up to 7 fifteen-minute intervals; and (3) the real-time dispatch looks ahead up to 14 five-minute intervals. The CAISO will enforce the flexible ramping requirements in all of these processes. As is the case with all market products, the financially binding awards will be based on the fifteen-minute market and real-time market dispatch binding market interval. There is no financial obligation associated with the schedules or dispatches for the advisory intervals.

The optimization produces feasible schedules and dispatches for all of the intervals included in the market run, and in doing so, it takes into account the ramp rates of the available resources. Thus, it may schedule or dispatch resources in a given interval out of economic merit order to the extent necessary to ensure sufficient ramping to provide the least cost solution over the market horizon.

Q. Can you give an example of how ramping capacity would affect the CAISO's ability to match generation and demand without the multi-interval optimization?

A. Consider the two resources I introduced above. As shown in table 1, G1 has a ramp rate of 100 megawatts per minute, energy bid of $25/MWh and has a maximum output of 500 megawatts. G2 has a ramp rate of 10 megawatts per minute, an energy bid of $30 per megawatt, and has a maximum output of 500 megawatts. The initial state for both resources is zero megawatts.

Table 1

RESOURCE	MAXIMUM OUTPUT (MW)	RAMP RATE (MW/MIN)	ENERGY BID ($/MWh)
G1	500	100	$25
G2	500	10	$30

Also, assume forecasted net load for interval t of 420 megawatts and for interval t+1, of 590 megawatts. The CAISO will need 170 megawatts of ramping capability in order to meet forecasted net load in interval t+1 after the two resources have met the 420 MW net load in interval t.

As shown in table 2, in a single interval optimization, the market would dispatch G1 to serve the entire 420 megawatts of demand and its bid would set the energy price at $25 per megawatt-hour. G1 would have no profit because its bid would reflect its marginal costs.

Table 2

RESOURCE	INTERVAL t DISPATCH (MW)	INTERAVAL t PROFIT
G1	420	$0.00
G2	0	$0.00
MARGINAL PRICE	$25.00	

As shown in table 3 in the next market run, for interval t+1, the market would only be able to increase the dispatch of G1 by 80 megawatts (up to its maximum output) and would only be able to dispatch G2 for 50 megawatts (its maximum ramp in five minutes). The market would be unable to meet the demand in the interval t+1 market run and the CAISO would thus need to dispatch units out of market, and cause prices to be based on the penalty price, which is set to the bid cap (*i.e.*, $1000 per megawatt-hour) for having to relax the power balance constraint.

Table 3

RESOURCE	INITIAL STATE (MW)	DISPATCH INTERVAL t+1 (MW)
G1	420	500
G2	0	50
Load	420	590
Power Balance Constraint Relaxation		-40
Marginal Price		**$1000**

Q. Can you illustrate the benefit of a multi-interval optimization?

A. Yes, I will do so using the same two resources in the example above. Under a multi-interval optimization, the market must meet the forecasted net load for both t and t+1 simultaneously. As shown in table 4, in order to meet the 590 megawatt demand in interval t+1, G2 must be dispatched in interval t so that it will not be limited by its ramping ability, which would prevent the resource from reaching 90 megawatts of output. Thus, in interval t, the CAISO would dispatch G1 for 380 megawatts and G2 for 40 megawatts to meet the 420 megawatt demand. The CAISO would then have 170 megawatts of ramping capability (120 megawatts to the maximum output of G1 and 50 megawatts maximum ramp of

G2) available for meeting the forecasted net load increase in interval t+1. This enhances the market's ability to dispatch sufficient supply to meet forecasted system conditions in subsequent market run.

Table 4

RESOURCE	DISPATCH INTERVAL t (MW)	DISPATCH INTERVAL t+1 (MW)	PROFIT INTERVAL t
G1	380	500	$0.00
G2	40	90	-$16.67
Load	420	590	
Marginal Price	**$25.00/MWh**	**$35.00/MWh**	

Q. **Are the prices different as a result of having a multi-interval optimization?**

A. Yes.

Q. **Please explain the pricing in a single interval optimization**

A. In the binding market run for interval t, under a single interval optimization, G1 is the marginal unit and sets the price at $25.00 per megawatt-hour. In the single interval optimization all resources are dispatched consistent with their bids. As I noted, however, in interval t+5 the market would have insufficient supply to meet demand because of a lack of ramping capability. The price would thus be set at the power balance constraint parameter, currently $1000 per megawatt-hour.

Q. **How does this change in a multi-interval optimization?**

A. Under a multi-interval optimization, both prices are determined for each interval. In interval t, the marginal energy price would be G1's bid price of $25 per megawatt-hour. G1 is the marginal resource because it is the unit that the CAISO would have dispatched if the forecasted load had been one megawatt greater, that is, 421 megawatts. G2 is dispatched uneconomically in the binding interval, because the market needs to position the resource such that its ramping capability can meet the load in the advisory interval.

The optimization ensures that resources are scheduled and dispatched consistent with their bid over the entire market horizon, not for each individual interval. The market would reflect G2's uneconomic dispatch cost of $5 per megawatt-hour from interval t in the advisory price for interval t+1. G2 would be the marginal unit in interval t+1 because G1 would be at its maximum output. The advisory marginal price would thus consist of G2's bid of $30 per megawatt-hour per megawatt plus the $5 per megawatt hour cost for the scheduling inconsistent with its bid in interval t, for a total of $35 per megawatt-hour. However, in each market run there is only one financially binding price. In this example, only the price for interval t is financially binding.

Q. Will G2 receive market revenues that cover its costs for interval t and interval t+1?

A. Not necessarily. As I mentioned above, the CAISO does not settle advisory prices. When the financially binding market run for interval t+1 determines prices, it does not observe the uneconomic dispatch for G2 that occurred previously. If the forecasted net load for interval t+1 remains the same as the prior advisory forecast, G2 remains the marginal resource to serve the 590 megawatts of demand and sets the price at $30 per megawatt hour. As a result, G2 does not recover its revenue shortfall incurred in interval t through the local marginal price in interval t+1. It could potentially recover this shortfall through bid cost recovery, but only to the extent it has a shortfall over the entire day.

Q. Does the multi-interval optimization fully meet ramping requirements?

A. Not entirely. As I discussed above, the multi-interval optimization produces feasible schedules based on the forecasted net load change between multiple intervals in a single market run. The forecasts used for the advisory intervals, however, are subject to change. We refer to this potential change in forecasted net load as uncertainty. Ramping capability can be used to address both forecasted movement and uncertainty. Consider the following illustration:

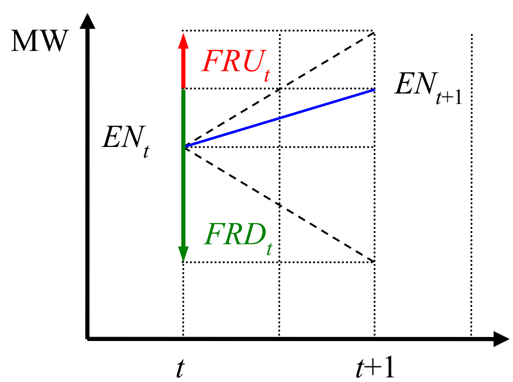

Figure 1

The center solid blue line represents the forecasted net load change between interval t and interval t+1, which the multi-interval optimization addresses. We call this the forecasted movement. The dotted lines represent potential error, or uncertainty, in the forecasted net load for interval t+1 of the subsequent market run. This is called uncertainty movement.

C. Flexible Ramping Constraint

Q. You mentioned the flexible ramping constraint. Before we turn to the flexible ramping product, please explain the flexible ramping constraint.

A. In 2011, the CAISO implemented a new flexible ramping constraint to help address the uncertainty. The constraint operates in the market optimization's real-time unit commitment process to provide upward ramping capability in addition to the capability resulting from multi-interval optimization. Section 27.10 of the CAISO tariff authorizes this constraint.

Q. Why did the CAISO believe it required additional upward ramping capacity to cover potential error of the net load forecast?

A. As I discussed above, the CAISO dispatches resources to meet its forecasted net load, which is the demand forecast less the variable energy forecast. As the reliance on variable energy resources increases, so too does the potential for error in the forecasted net load.

The multi-interval optimization can solve so precisely that it does not leave unused ramping capability that would be needed if the forecasted net load changes. When ramping capability is exhausted, the CAISO must price the market using relaxation parameters tied to the bid cap and bid floor. However, if the market had secured additional ramping capability in recognition that that the forecasted net load may can change in a subsequent market run, the CAISO could clear the market using economic bids.

Q. **How does the current flexible ramping constraint impact the multi-interval optimization example above?**

A. In the example above, the forecasted net load for interval t+1 is 590 megawatts. But when the financially binding market run for interval t+1 is performed, the forecasted net load might be different, for example 600 megawatts. If G2 were scheduled in interval t at 40 megawatts, the market would be unable to meet 600 MW of forecasted net load, and the optimization would be forced to relax the power balance constraint and establish prices based upon the $1000 bid cap. If G2 were scheduled in interval t at 50 MW, the resource would have sufficient ramping capability to reach 100 MW output, which is the additional supply needed in the event the forecast error materializes.

Q. **How does the flexible ramping constraint work?**

A. The CAISO applies a flexible ramping constraint in its real-time unit commitment process to ensure necessary ramping capacity is available in addition to that preserved through the multi-interval optimization. If the shadow price exceeds sixty dollars per megawatt hour, however, the CAISO will relax the constraint. The CAISO determines the necessary quantity of flexible ramping capacity using tools that estimate the expected level of imbalance variability, the uncertainty due to forecast error, and the differences between the hourly, fifteen-minute average and historical five-minute demand levels. This capacity is fully available to the CAISO in the real-time dispatch in the financially binding interval and gradually held back in the advisory intervals.

Q. Does the CAISO compensate resources for the capacity withheld by the flexible ramping constraint?

A. Yes, but only for the additional ramping capability to address uncertainty in the forecasted net load. Also, the CAISO does not compensate the units at the marginal cost of addressing the constraint. The CAISO compensates resources that provide this additional ramping capability according to a formula developed through a FERC-approved settlement process. As was the case before implementing the flexible ramping constraint, there is no compensation for ramping capability that the multi-interval optimization uses to meet the changes in forecasted net load between intervals in the same market run.

Q. Did the CAISO believe that the section 27.10 flexible ramping constraint was a durable solution to this need?

A. No. As the CAISO informed the Commission at the time, the CAISO considered the section 27.10 flexible ramping constraint to be an interim measure while the CAISO worked on developing a market-based flexible ramping product, which is the subject of the current filing.

II. PROPOSED FLEXIBLE RAMPING PRODUCT

A. Operation of the Flexible Ramping Product.

Q. How will the flexible ramping product address the ramping needs?

A. The CAISO has designed the flexible ramping product to improve its ability to ensure that there is sufficient ramping capability available to meet the forecasted net load and to cover the potential error in the forecasted net load.

Q. How does the CAISO intend to implement the flexible ramping product?

A. Instead of using the section 27.10 upward flexible ramping constraint, which applies only in the real-time unit commitment process, the CAISO will model both an upward and downward ramping constraint in all processes of the real-time market, which includes the short-term unit commitment process, the real-time unit commitment process, and the real-time dispatch. Financially binding schedules for both energy and the flexible ramping product will be determined in the fifteen-minute market. Financially binding dispatches for energy and the flexible ramping product will be re-optimized through five-minute market

Q. How will the CAISO determine the ramping need to be included in the modeling?

A. The CAISO will continue to use the multi-interval optimization to ensure ramping capability is available from resources to meet the changes forecasted net load between all intervals in a market run. The proposed tariff identifies this ramping capability as forecasted movement.

In addition to accounting for and compensating for a resource's forecasted movement, the flexible ramping product allows the CAISO to procure an additional amount of ramping capability necessary to address uncertainty, *i.e.,* as discussed above, potential errors in the forecasted net load that may materialize in a subsequent market run. The current constraint partially performs this function, but only in the upward direction and then not in the real-time dispatch.

Q. How will the CAISO obtain the ramping capability to meet the uncertainty requirement?

A. The CAISO will procure the ramping capability to meet the uncertainty requirement in both the upward and downward direction. The calculation of the uncertainty requirement will be similar to the current flexible ramping constraint. However, the flexible ramping product will meet the uncertainty requirement only to the extent the benefits exceed the costs of procuring it. The CAISO will not procure an additional MW of ramping capability if the marginal cost exceeds the expected benefit of the additional MW of ramping capability. Under the current flexible ramping constraint, the market software procures flexible ramping capacity if the cost of doing so does not exceed $60.00 per megawatt hour.

Q. Do the ancillary services bids or procurement of ancillary services impact the cost of the flexible ramping product?

A. Yes. The flexible ramping product is co-optimized with both energy and ancillary services. Therefore, both energy and ancillary services can result in an opportunity cost, which will be reflected in the shadow price of the flexible ramping up and down uncertainty requirement constraints.

Q. Will resources submit bids for uncertainty awards?

A. No. During the stakeholder process, the CAISO considered a bidding process for uncertainty awards, but it determined that the use of energy and ancillary services bids is sufficient to reflect the costs of providing ramping capability. These bids reflect the costs at which a resource is willing to be scheduled or dispatched for energy or ancillary services in a given interval. Therefore, if the market procures ramping capability from a resource, its costs are the opportunity cost or the profit it would have earned if the market had instead procured energy or ancillary services from that resource in that market interval. Note that the market would only use ancillary services bids to make uncertainty awards in the real-time unit commitment process because the real-time market only procures ancillary services through the real-time unit commitment process. During the stakeholder process, the CAISO considered if there were any costs in addition to the opportunity cost of providing energy or ancillary services and concluded that there were none.

Q. Does that mean that a resource can be held back for ramping capability at the cost of procuring incremental ancillary services?

A. No. The CAISO will not prioritize flexible ramping capability over the need to ensure it has procured sufficient ancillary services to meet its NERC/WECC requirements. The CAISO will limit the upward procurement curve to an amount (specified in the business practice manual) less than the CAISO's contingency reserves relaxation penalty pricing parameter. Because ramping does not have a higher priority than ancillary services, the CAISO will also limit the downward procurement curve to an amount (specified in the business practice manual) less than the CAISO's regulation down penalty pricing parameter. These penalty pricing parameters are specified in the business practice manual.

Q. How will the CAISO compensate uncertainty awards?

A. By enforcing an upward and a downward uncertainty requirement constraint in the real-time market, the CAISO will be able to determine a shadow price for the ramping capability. As discussed above, the market will consider each resource's cost to provide ramping capability to be its opportunity costs of foregoing providing energy or ancillary services or an out of merit economic schedule or dispatch. Thus, the market will determine the shadow price for the uncertainty requirement. The shadow price is the marginal production cost reduction from relaxing the constraint which equals the marginal cost of procuring flexible ramping product. The CAISO will establish both an upward and downward ramping price based upon the relevant shadow price.

Q. How will the CAISO determine the amount of uncertainty awards it will procure?

A. The CAISO will use the tools available to it to develop a probability distribution of forecasted net load errors by observing the changes in forecasted net load between the binding interval and first advisory interval in successive market runs over a specified historical period. The CAISO will initially develop the probability distributions for each hour, separately for upward and downward ramping needs and separately for real-time dispatch and real-time unit commitment. Although the CAISO discussed specific tools in the policy portion of the stakeholder process, it concluded that it is preferable to keep those details in the business practice manual. This will allow the CAISO to enhance the determination of uncertainty requirements based upon operational experience and statistical analysis.

The CAISO will use the probability distributions and the power balance constraint relaxation parameters to develop a procurement curve that will establish a constraint relaxation price to ensure that the procurement cost will not exceed the benefits of the additional capacity, which I explained is the avoided cost of the power balance violation that the additional ramping capacity will protect against. The CAISO will develop uncertainty requirements and procurement curves for each balancing authority area in the EIM area as well as for the EIM area as a whole.

Q. Are there restrictions on the resources that can receive uncertainty awards?

A. Yes. Only resources with economic energy bids available for 5-minute dispatch in real-time dispatch are eligible for uncertainty awards. This requirement is necessary because uncertainty in the forecasted net load materializes in the real-time dispatch. If the CAISO cannot dispatch a resource, then the resource cannot resolve forecasted net load errors. Because the CAISO does not schedule static imports and exports in the real-time dispatch, they cannot receive uncertainty awards even if they have submitted an economic bid that allows a fifteen-minute schedule change. In contrast, the CAISO can dispatch dynamic transfers, so they can receive uncertainty awards. In addition, because resources in a forbidden operating zone or a multi-stage generator transition have limits on their ramping ability, they are ineligible for the awards. The CAISO may also suspend the eligibility of a resource that the CAISO has deemed noncompliant with dispatch instructions.

Q. Will flexible ramping resources be subject to any form of mitigation?

A. No. Since there is no explicit flexible ramping product bid, there is no need for mitigation measures. The price for the flexible ramping product is based upon the marginal opportunity cost resulting from a resource being dispatched inconsistent with its economic bids. In the event of local market power, the CAISO will mitigate the energy bids to the resource's default energy bids. The CAISO then uses these mitigated to clear the market and determine the flexible ramping product prices.

Q. Will the CAISO procure flexible ramping product sub-regionally?

A. No. The CAISO will procure uncertainty requirements on a system basis and for each balancing authority area in the EIM. Some parties expressed concern that without sub-regional requirements, there could be instances where a resource receives an uncertainty award, but due to congestion cannot be dispatched if the uncertainty materializes. This concern is not relevant for forecasted movement because the energy schedules and dispatches to meet forecasted net load in the advisory intervals respect transmission limits. The CAISO recognizes that ensuring deliverability in a subsequent run could be beneficial; however, such procurement would require significant software enhancements that would delay the implementation of the product. The CAISO sees no reason to forgo the benefits that will accrue with the product as currently contemplated especially since we are enforcing a constraint for each balancing authority area in the EIM footprint.

Q. Please explain why the CAISO would only implement the flexible ramping product in the real-time market and not in the day-ahead market.

A. Initially, the CAISO contemplated procuring the flexible ramping product in the day-ahead market as well as the real-time market. But as the CAISO and stakeholders continued to evaluate the implications of doing so, the CAISO determined that including the flexible ramping product in the day-ahead market would impose costs without adding sufficient additional benefits. In the day-ahead market, ramping capability is considered on an hourly basis, whereas in the real-time market it is considered on fifteen-minute and five-minute bases. This would result in the settlement of difference in forecasted movement and uncertainty awards between the day-ahead and real-time market that is the result of the granularity difference in addition to changes in system conditions. While a similar granularity difference exists between the 15-minute market and the 5-minute market, the CAISO believes the benefit of the uncertainty requirement to impact real-time unit commitment overcomes the issues with settlement of granularity differences.

Q. **Can you provide an example of the operation of the use of uncertainty awards?**

A. Let's go back to the previous example. For simplicity, I will not include a downward uncertainty requirement in this example. Under the current multi-interval design, in the binding interval t, the market would dispatch G1 to 380 megawatts and G2 to 40 megawatts in order to maintain the ramping capability to meet the additional 170 megawatts of forecasted net load in the advisory interval t+1. The optimization would produce a marginal price of $25 per megawatt-hour for interval t and an advisory marginal price of $35 per megawatt hour for the interval t+1. Since the ramping capability in this example is using megawatt-hours, the quantity must be divided by 12 to convert a single 5-minute interval value into an hourly value. G2 will incur a cost of $16.67 ($5 per megawatt-hour multiplied by 40 megawatt hours and divided by 12 intervals per hour) in interval t because its bid cost is $30 per megawatt hour but the locational marginal price is $25/MWh. G1 will incur no financial disadvantage, but it will not receive compensation for the fast ramping capacity it provides.

With the flexible ramping product, the CAISO will include an upward uncertainty requirement based on the demand curve, assume 10 megawatts. The market optimization will need the ability to move from 420 megawatts to 600 MWs, an increase in its potential ramping need to 180 megawatts. As shown in table 5, because G1 is at its maximum output in interval t+1, G2 must be positioned in interval t such that it could reach an output of 100 megawatts in the event the 10 megawatts of uncertainty materialized. This results in G2 being dispatched higher at 50 megawatts in interval t and to maintain power balance in interval t G1 is dispatched lower at 370 megawatts. Because the energy marginal price is unchanged at $25 per megawatt-hour, G1's energy profit is unchanged at zero and G2's energy loss for the out of merit dispatch in interval t increases by $5 per megawatt-hour for the 10 megawatt dispatch above its energy dispatch absent an upward uncertainty requirement. This yields a price for upward ramping of $5/MWh.

Under the flexible ramping product we will settle both forecasted movement and uncertainty awards. For the purpose of this illustration, I have assumed that the flexible ramping down price is $0. G1 will receive an additional $54.17 ($5 per megawatt hour multiplied by 130 megawatts of ramping capability divided by 12) for its upward forecasted movement and be charged $0 ($0 per megawatt-hour multiplied by 130 per megawatt hour of ramping capability divided by 12) for its downward forecasted movement. G2 will receive $16.67 ($5/megawatt-hour multiplied by 40 megawatts divided by 12) for its upward forecasted movement, a charge for $0 ($0/megawatt-hour multiplied by 40 megawatts divided by 12), and a payment of $4.17 ($5/megawatt-hour multiplied by 10 megawatts divided by 12) for the 10 megawatts for the uncertainty award. Thus, G2 recovers its $20.83 cost for being scheduled inconsistent with its economic bid. This results in the combined payments for ramping capability and energy that is consistent with its economic bid of $30/megawatt-hour. Load will be charged an additional $70.83 ($5/megawatt-hour multiplied by 170 megawatts divided by 12) for its upward forecasted movement and paid $0 ($0/megawatt-hour multiplied by 170 megawatts divided by 12) for its downward forecasted movement. The $4.17 paid to address uncertainty in the load forecasted will be allocated as discussed below. Table 5 illustrates this.

Table 5

RESOURCE	**MAXIMUM OUTPUT (MW)**	**RAMP RATE (MW/MIN)**	**ENERGY BID ($/MWH)**
G1	500	100	25
G2	500	10	30

Without Flexible Ramping Produce

Resource	*Binding Dispatch (MW)*	*Advisory Dispatch (MW)*	*Uncertainty Requirem’t (MW)*	*Uncertainty Award (MW)*	*Forecasted Movement (MW)*	*Profit ($/MWH)*
Forecasted Net Load	420	590			170	
G1	380	500			120	0
G2	40	90			50	16.67 (5x40 /12)
Marginal Price ($/MWh)	25	35 (30+5)				

With Flexible Ramping Product

Resource	*Binding Dispatch (MW)*	*Advisory Dispatch (MW)*	*Uncertainty Requirem't (MW)*	*Uncertainty Award (MW)*	*Forecasted Movement (MW)*	*Profit ($/MWh)*
Forecasted Net Load	420	590	10		170	
G1	370	500			130	54.17 (5x130 /12)
G2	50	90		10	40	0 (-20.83 +((5x10) /12)) + (5x 40/12))
Marginal Price ($/MWh)	25	30				

Q. Why are these compensation mechanisms preferable to the existing compensation mechanism?

A. The flexible ramping product decomposes the pure energy price and ramping prices, and provides more transparent and less volatile price signals. The market's multi-interval optimization currently produces a "composite" energy price, which consists of a pure energy price and a ramping price.

Because the CAISO only settles the binding interval, the composite energy price may not be consistent with the resource's energy offer price. This may trigger real-time bid cost recovery because the dispatch does not provide sufficient revenues to cover start-up and minimum load costs over the operating day. The settlement of forecasted movement addresses this situation. These prices are also more consistent with the energy offers and reduce the need for bid cost recovery because the forecasted movement is settled directly through the market between providers of ramping capability and consumers of ramping capability. This direct settlement of ramping capability is far more accurate than settling shortfalls from flexible resources through bid cost recovery and allocating the costs through a market uplift. These would be advantages even if forecasted net load could be predicted with high accuracy.

In addition, the energy price is very sensitive to deviations from the forecasted net load because there is no margin built into the optimization for forecast error. Without carrying additional ramping capability, the energy price can be very volatile. The procurement of additional ramping capability to meet uncertainty address the volatility and appropriately compensates resources that provide the additional ramping capability.

SETTLEMENT

Q. How will the CAISO settle with resources for uncertainty awards?

A. The CAISO will settle the megawatts hours specified in the upward uncertainty award for each interval at the upward flexible ramping price and the downward uncertainty award at the downward price. The CAISO will settle uncertainty awards in the fifteen-minute market at the fifteen-minute market price.

Differences between fifteen-minute market uncertainty awards and five-minute market uncertainty awards will be settled at the five-minute market price.

Q. You mentioned that the CAISO will settle with resources and intertie schedules for ramping capability reserved through the multi-interval optimization. How will the CAISO do this?

A. The CAISO will settle forecasted movement, which is ramping capability reserved through the multi-interval optimization, at the ramping price it determines for uncertainty awards. For each interval, all resources and intertie schedules will receive a settlement for both upward and downward forecasted movement. For example, if the resource has 10 megawatt-hours of forecasted movement upward, with an upward ramping price of $10 per megawatt-hour and a downward ramping price of $4 per megawatt hour, the CAISO will pay the resource $100 and charge it $40. Similarly, if the resource has 10 megawatts-hours of forecasted movement downward, with the same prices, the CAISO will charge the resource $100 and pay it $40.

The forecast movement will be settled in the fifteen-minute market at the fifteen-minute market price. Differences between fifteen-minute market forecast movement and five-minute market forecast movement will be settled at the five-minute market price.

Q. Can compensation for ramping be rescinded?

A. Yes. It is possible for a resource to receive uninstructed imbalance energy revenues from capacity for which it will receive flexible ramping product compensation. The CAISO settles uninstructed imbalance energy at the five-minute interval's financially binding price. Because the flexible ramping product price represents the marginal cost of not being dispatched for energy consistent with its economic bid, it is equivalent to the profit the resource would have received had it been dispatched consistent with its economic bid. If the resource then deviates and receives the energy settlement from uninstructed imbalance energy, the resource's profit will be double. In that case, the CAISO will rescind the double payment. The CAISO will apply the rescission first to uncertainty awards, and then to forecasted movement.

Q. After the CAISO settles forecasted movement and payment rescissions, how will it settle the remaining amounts?

A. The CAISO will recover the residual amounts from scheduling coordinators with EIM demand or CAISO metered demand in proportion to their share of total metered EIM demand and CAISO metered demand. This residual amount represents the forecasted movement from changes in the CAISO's forecasted load across the EIM area.

Q. How will the CAISO recover the costs of the uncertainty awards?

A. The uncertainty requirement protects against potential error in the forecasted net load between market runs. As such, it is analogous to a form of insurance. For this reason, the CAISO concluded it is more appropriate to allocate the cost over a longer period. During the policy portion of the stakeholder process, the CAISO proposed to make all uncertainty award payments to resources and allocate the costs to scheduling coordinators at the end of the month. In developing the procedures to implement the settlement policy, the CAISO recognized that, because it needed to include flexible ramping product compensation in bid cost recovery, it would need to settle daily with resources and calculate the allocation on a daily basis to remain financially neutral. The CAISO, therefore, decided to allocate the costs daily and then perform a monthly reallocation. Stakeholders had the opportunity to address this during the tariff portion of the stakeholder process and there were no objections.

Q. What is the CAISO's proposed allocation of the costs of the uncertainty awards?

A. The CAISO has designed the allocation of the costs of the uncertainty awards to scheduling coordinators to reflect their contribution to errors in the forecasted net load. In doing so, the CAISO recognized that it was not possible to use a single billing determinant across load, supply, and interties. Therefore, the CAISO will calculate realized forecasted errors by determining the uncertainty movement for load, supply, and interties. Uncertainty movement is the change in the five-minute forecast of the advisory interval from the prior market run and the forecast used to establish the financially binding dispatch.

Q. How does the CAISO accomplish this?

A. The CAISO has identified three categories for allocating the costs: non-participating load, supply resources other than non-dynamic system resources, and intertie transactions, which comprise non-dynamic system resources and exports. The first step is to determine the uncertainty movement for each category for each five-minute interval. For non-participating load, that is simply the difference between the total demand forecast for the balancing authority area or the EIM area in the binding interval and the total in the advisory interval. For supply resources, it is the net sum for all resources in the balancing authority area of each variable energy resource's forecasted output in the binding interval and the advisory interval. For interties, it is the net sum for all non-dynamic system resources and exports in the balancing authority area of each non-dynamic system resource's and export's difference between the schedule used in real-time dispatch for the binding interval and for the advisory interval. Then the CAISO will determine the total upward uncertainty movement for those categories that have upward uncertainty movement and the total downward uncertainty movement for those categories that have downward uncertainty movement.

Q. What is the next step?

A. For each balancing authority area and the EIM area as a whole, the CAISO will allocate the upward uncertainty costs to categories that have upward uncertainty movement in proportion to their share of the total upward uncertainty movement and will allocate the downward uncertainty costs to categories that have downward uncertainty movement in proportion to their share of the total downward uncertainty movement.

Q. How does the CAISO propose to allocate these costs to scheduling coordinators?

A. Again, the CAISO has designed the allocation of the costs assigned to each category to reflect cost causation and the CAISO's cost allocation guiding principles. The metric varies according to category because the available measurements differ.

In 2012, the CAISO worked with stakeholders to develop a set of guiding principles to help shape cost allocation decisions, and the CAISO follows these principles in developing cost allocation rules for its market modifications. Since developing these principles, the CAISO has applied them in developing new cost allocation procedures and in considering the need to change any existing cost allocation procedures. At a high level, these principals are as follows:

- Causation – Costs will be charged to resources and/or market participants that benefit from and/or drive the costs.
- Comparable Treatment – Similarly situated resources and/or market participants should receive similar allocation of costs and not be unduly discriminated against.
- Accurate Price Signals – The cost allocation design supports the economically efficient achievement of state and federal policy goals by providing accurate price signals from the CAISO market.
- Incentivize Behavior – Providing appropriate incentives is key to an economically efficient market.
- Manageable - Market participants should have the ability to manage exposure to the allocation.
- Synchronized – The cost drivers of the allocation should align as closely as possible to the selected billing determinant.

- Rational - Implementation costs/complexity should not exceed the benefits that are intended to be achieved by allocating costs.

With respect to cost allocation, the CAISO discusses and considers these guiding principles through stakeholder initiatives on an ongoing basis.

Q. How does the CAISO propose to allocate the costs assigned to non-participating load?

A. The CAISO proposes to allocate upward uncertainty award costs for this category in proportion to the scheduling coordinator's share of the total negative non-participating load uninstructed imbalance energy in the balancing authority area, without netting across settlement intervals. The CAISO will exclude the non-participating load of a metered subsystem. The CAISO proposes to allocate downward uncertainty award costs similarly, except that it will use positive uninstructed imbalance energy. The allocation reflects the fact that negative uninstructed energy reflects the need in real-time for upward load imbalance and positive uninstructed energy reflects the need for downward load imbalance energy.

Q. How does the CAISO propose to allocate the costs assigned to supply resources?

A. The CAISO proposes to allocate uncertainty award costs for this category based on both uncertainty movement and uninstructed imbalance energy combined. Consideration of uninstructed imbalance energy provides additional incentive for dispatchable resources to follow their dispatch instructions, which should help indirectly control the need for ramping capability. The CAISO proposes to allocate upward uncertainty award costs for this category in proportion to the resources share of the total negative combined uncertainty movement and uninstructed imbalance energy of the supply category in the balancing authority area, without netting. It will allocate downward flexible ramping product uncertainty costs similarly. This reflects the fact that negative combined uncertainty movement and uninstructed imbalance energy creates the need for incremental imbalance energy above what the prior market run anticipated. Upward combined uncertainty movement and uninstructed imbalance energy creates the need for decremental imbalance energy below what the prior market run anticipated.

The CAISO will use the same method for load-following metered subsystems, except that the CAISO will sum the non-participating load uninstructed imbalance energy, supply resources within the MSS uninstructed imbalance energy, load following energy, load following operational adjustments, and uncertainty movement.

Q. How does the CAISO propose to allocate the costs assigned to interties?

A. The CAISO will allocate these costs in a similar manner as for the other categories, except that it will use operational adjustments, which is the difference between energy scheduled in the balancing authority area check out process and the fifteen-minute schedule. For upward uncertainty awards, the CAISO will allocate the costs in proportion to the scheduling coordinator's share of the sum of the absolute values of the negative operational adjustment for non-dynamic system resources and positive operational adjustment for export resources in the balancing authority area or EIM Area. It will allocate down uncertainty costs in the same manner, but will use positive operational adjustment for non-dynamic system resources and negative operational adjustment for export resources. Negative operational adjustment for non-dynamic system resources and positive operational adjustment for export resources are analogous to negative uninstructed energy and positive operational adjustment for non-dynamic system resources and negative operational adjustment for export resources are analogous to positive uninstructed imbalance energy.

Q. Will the monthly allocation differ in any way from the daily allocation?

A. Yes. The daily allocation is performed hourly. When it performs the monthly reallocation the CAISO will separately aggregate costs incurred during peak periods, from 7:00 a.m. to 10:00 p.m., and incurred in off-peak periods and will allocate each type separately. This recognizes that solar resources do not need insurance to meet their forecast error during nighttime hours.

Q. Thank you. I have no further questions.

I, Donald Tretheway, declare under penalty of perjury that the statements in this testimony are true and correct to the best of my knowledge, information, and belief.

/s/ Donald Trethaway
Donald Tretheway

Executed this 24th day of June, 2016, in Folsom, California.

Attachment D – Revised Draft Final Proposal Flexible Ramping Product
December 17, 2015

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

California ISO

Flexible Ramping Product

Revised Draft Final Proposal

December 17, 2015

Flexible Ramping Product
Revised Draft Final Proposal

Table of Contents

1 Introduction

This paper describes the ISO's market design proposal for the upward and downward flexible ramping products (FRP). This stakeholder effort develops market-based flexible ramping products to address the operational challenges of maintaining power balance in the real-time dispatch. The ISO has observed that the fleet of units determined in the real-time unit commitment process (RTUC), also known as the real-time pre-dispatch (RTPD) process, sometimes is not positioned with sufficient ramping capability and flexibility in real-time dispatch (RTD) to handle the 5-minute to 5-minute system load and supply changes. Insufficient ramping capability sometimes manifests itself in triggering power balance violations, which means the there is no feasible system wide RTD schedule to maintain supply and demand power balance. Here, there are at least three undesirable outcomes:

- The system must rely on regulation services to resolve the issue in real-time after the imbalance has caused frequency deviation or area control error (ACE)
- When power balance is violated, the RTD energy price is not priced by economic bids, but by administrative penalty prices. This would eventually create market inefficiency since the imbalance energy of resources providing regulation services is priced using the administrative penalty prices from RTD.
- Insufficient regulation service results in leaning on the interconnection, which may affect the ability to meet required operational performance criteria.

Since the new nodal market was implemented in 2009, the ISO has had a multi-interval optimization in the unit commitment and dispatch process. The multi-interval optimization can look several intervals ahead to meet forecasted ramping needs. The ISO has observed that the optimization would create the exact amount of ramping capacity according to the imbalance forecast. When the future system conditions materialize, the actual ramping need may differ from the forecast. If the actual ramping need is higher than the forecast, the net supply cannot meet the net demand and a power balance violation is triggered. This develops because there is no margin of error between the interval ramping needs in a multi-interval optimization. A deviation beyond the forecasted ramping need that occurs in a subsequent market run could result in a spurious price spike. FRP creates a ramping margin on top of the forecasted movement between interval ramping need and reduces the frequency of spurious power balance violations. The FRP would compensate resources based on the marginal opportunity cost from out of merit dispatch in the financially binding market interval.

2 Background

With increasing levels of variable energy resources and behind the meter generation, the operational challenge of ramping capability is even more prominent. The variable outputs of the renewable resources may increase the magnitude of the 5-minute to 5-minute net load changes. In Figure 1, the net load equals the load minus the renewable resources' total output. As shown in Figure 1, the 5-minute to 5-minute net load change may triple its magnitude in hour-ending 18 and 19 with renewable generation output moving in the opposite direction of load. It may also reverse the direction of load ramping in hour-ending 7 and 8.

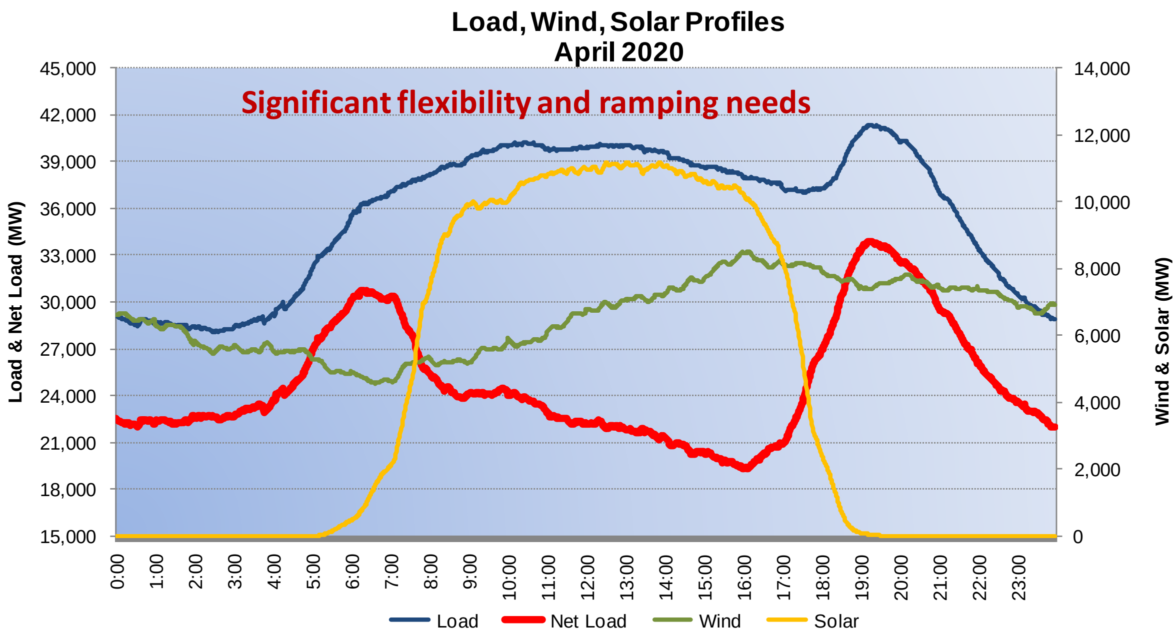

Figure 1: Projected load and Renewable profiles in April 2020[1]

Stakeholders have questioned why the ISO must design a new ramping product while regulation services are standard products to deal with the forecast uncertainties. Two types of uncertainties are accounted for based on timing that uncertainties are realized: one is realized before the binding RTD interval and the other is realized during the binding RTD interval. Uncertainties realized before the binding RTD interval affect the RTD energy price in the binding RTD interval. While uncertainties realized during the binding RTD interval would not impact the RTD energy price. Regulation services are the standard products that address uncertainties that exist during the binding RTD interval. Energy produced by regulation services will be compensated at the corresponding RTD energy price and the resource is also compensated for the provision of the regulation service separately. Procuring more regulation is problematic for uncertainties realized before the binding RTD interval because having additional capacity in an interval locked as regulation service, which cannot be dispatched in RTD as energy, will reduce the resources available to RTD and would lead to more power balance violations, causing prices to be set by the penalty prices related to the bid caps ($1000/MWh and -$155/MWh). In addition, when regulation services are dispatched, they would be paid the RTD prices. If more regulation is procured to handle uncertainties, the additional dispatched energy would be

1 Operating flexibility analysis for R.12-03-014, Mark Rothleder, Shucheng Liu, and Clyde Loutan, CPUC workshop, June 4, 2012.

compensated at the penalty prices. Even when there is no actual operational issue, but just an artificial power balance issue in RTD created by the over-procurement of regulation. That is why it is inappropriate to procure more regulation services to deal with the uncertainties realized before the binding RTD interval. FRP addresses uncertainties realized before the binding RTD interval. While the flexible ramping procurement and deployment would also influence the energy prices, while doing so in a more efficient manner to best reflect the system conditions.

Stakeholders have also questioned whether procuring more non-contingent spinning reserve can achieve what the FRP would achieve. The problem with procuring more non-contingent reserves and dispatching them in RTD is the false opportunity cost payment. When spinning reserve is procured, its price already includes the energy opportunity cost. If the capacity is dispatched in RTD, then the resource will also receive the energy payment. Therefore, the same capacity would be compensated twice for the energy profit. The ramping capacity should be procured and deployed frequently. Using non-contingent spinning reserve for this purpose is problematic from the due to the double compensation.

Prior to these market-based full flexible ramping products, the ISO has implemented a flexible ramping constraint to address certain reliability and operational issues observed in the ISO's operation of the grid.[2] Upon completing the Flexible Ramping Constraint stakeholder process, the ISO Board of Governors agreed with stakeholder and the ISO that greater market efficiency can be gained by developing market-based products that allow for the identification, commoditization, and compensation for the need of flexible capability.

FRP would help the system to maintain and use dispatchable flexibility. FRP is the 5-minute ramping capability, which will be dispatched to meet 5-minute to 5-minute net system demand changes or net system movement in RTD. The net system demand is defined as the load plus export minus all resources' schedules that are not 5-minute dispatchable, which may include renewable resources, imports, and self-schedules. We will refer to the potential 5-minute to 5-minute net system movement in RTD as the Real Ramping Need. The Real Ramping Need is illustrated in Figure 2. Assume the current time is t–7.5 minutes, and the ISO is running RTD for the binding interval t (the 5-minute interval from t to t+5). From the market point of view, RTD interval t's net system demand is certain in the sense it is not subject to future changes in the market. However, the RTD net system demand for the advisory interval t+5 (the 5-minute interval from t+5 to t+10) is still subject to change (from t–7.5 to t–2.5). Consequently, we view RTD advisory interval t+5's net system demand as a random variable with a spread from a lower limit to an upper limit. The lower limit and upper limit are illustrated in Figure 2. FRP is able to cover the random net system demand in interval t+5 with a spread from the lower limit to the upper limit. Note that the spread from the lower limit to the upper limit only reflects the ISO's intended coverage of the next interval's net system demand. It may not be able to cover all

[2] See CAISO Technical Bulletin "Flexible Ramping Constraint" for detailed discussion of the constraint, http://www.caiso.com/Documents/TechnicalBulletin-FlexibleRampingConstraint_UpdatedApr19_2011.pdf, February 2011. See California ISO Tariff Amendment Proposing the Flexible Ramping Constraint and Related Compensation: http://www.caiso.com/Documents/2011-10-07_FlexiRampConstraint_Amend.pdf

possible net system demand levels that may be realized when interval t+5 becomes the binding interval. The flexible ramping capability is met with separate products in the upward and downward directions as the ramp needs may be in both directions. The Real ramping need is:

- Upward: max{ [upper limit at t+5] – [RTD net system demand at t], 0 }
- Downward: max{ [RTD net system demand at t] – [lower limit at t+5], 0 }

Note that the actual net system demand may differ from the RTD energy binding interval load, and the difference is covered by regulation services.

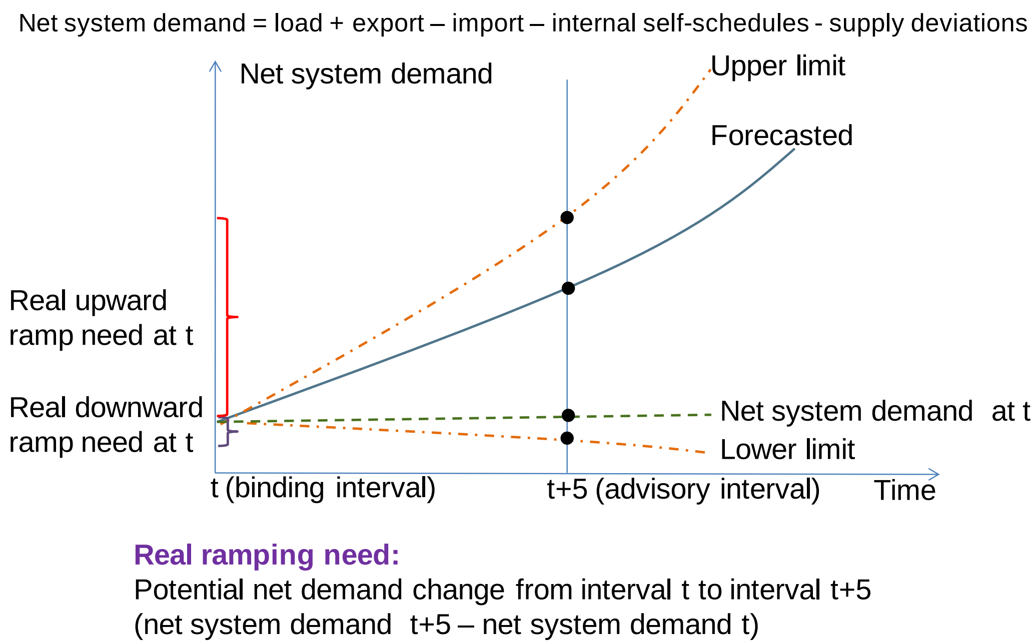

Figure 2: Real ramping need

Stakeholders have questioned why the procurement target is real ramping need, not the unexpected ramping need on top of the expected ramping. Arguing that we should not compensate the resources that meet the expected ramping and should only compensate resources that meet unexpected ramping. As discussed by the Market Surveillance Committee[3], there is no operational difference between resources that meet expected ramping and resources that meet unexpected ramping. There may be resources in either category dispatched out of merit to provide flexible ramping capability. It is inappropriate to treat and compensate the resources under the two categories differently. In addition, there is improved market efficiency. As the opportunity costs for out-of-merit dispatches is compensated in the binding RTD interval. Rather than assumed covered in the advisory RTD intervals, as illustrated in the settlement examples later in the draft final proposal.

[3] Scott Harvey, Flexi Ramp Product Design Issues, http://www.caiso.com/Documents/FlexiRampProductDesignIssues-MSCPresentation.pdf

The latest market design changes separate the settlement of forecasted movement and uncertainty. This change recognizes forecasted movement between intervals would be providers of ramping capability and consumers of ramping capability. Which can be directly settled as energy where forecasted demand and dispatched supply are equal. This improves market efficiency as forecasted movement can be settled in each binding interval which minimizes flexible ramping costs that must be allocated through a monthly uplift. To allocate uncertainty costs, it is appropriate to use monthly data since the need for uncertainty is not based upon a given financially binding interval. Rather, estimates of net load forecast error is used with historical observations.

3 Market Design

This section describes and discusses the FRP design regarding the real-time market. With the introduction of the new fifteen-minute market, the energy schedule from enforcing flexible ramping requirement during RTUC is financially binding. This is beneficial because the opportunity cost of out of merit dispatch is actually realized by resources providing FRP in RTUC.

Two characteristics distinguish FRP from capacity products, such as ancillary services.

> **Capability preserved for between interval changes:** All ancillary services in the ISO's market are "standby" capacity in the sense they are unloaded capacity to meet net system demand deviations from assumed level in the same interval. FRP is the only market product targeting between intervals net system demand changes.
>
> **Regularly dispatched in RTD:** FRP is a 5-minute ramping capability product, which is continuously procured and dispatched in RTD, to meet the net system movement. No similar capacity product currently exists in the ISO's market. Regulation services are dispatched after RTD by automatic generation control (AGC), not through economic bids. Operating reserves are dispatched through the real-time contingency dispatch only after a defined contingency event occurs. FRP can improve the ISO's dispatch flexibility in RTD, while ancillary services awards reduce the RTD flexibility because capacity is held by ancillary service awards.

FRP will be modeled as ramping capability constraints. Modeling flexible ramping in RTUC helps real-time unit commitment make the correct decisions in creating ramping headroom if it is necessary. The real-time unit commitment decisions are binding if such decisions cannot be revisited in later runs due to physical commitment time constraints. With the introduction of the fifteen-minute market, both the flexible ramping headroom and energy schedules in RTUC are financially binding at the FMM price. The ISO will also re-optimize the procurement of flexible ramping capability in RTD and awards will be compensated according to the marginal prices in RTD where the energy awards are also financially binding.

3.1 Bidding Rules

There is no bidding of FRP and the ISO will not procure FRP in the day-ahead market. All resources can provide forecasted movement between market intervals in both the FMM and RTD. Only resources that have an economic bid and are dispatchable in RTD can have a flexible ramping award in excess of its forecasted movement. Flexible ramping awards over the forecasted movement between intervals is procured to meet uncertainty in the 5-minute net load forecast. Resources have no certified flexible ramping capability as done with ancillary services. The ISO will use the internal DOT to evaluate and award the FRP. For instance, if a variable energy resource is using its own 5-minute forecast for settlement of energy. Ramping capability on this resource will be based upon the ISO forecast of the resources. The ISO forecast, not the resource's forecast, is used to clear both FMM and RTD. The FRP price will be based on marginal opportunity cost of meeting the forecasted movement and uncertainty.

Since there is no economic bidding, there is no self-provision of FRP or market power mitigation rules applied to flexible ramping awards.

3.2 Co-optimizing Flexible Ramping Products with Energy and Ancillary Services

This section will cover the stylized optimization model of co-optimizing FRP with energy and ancillary services. The stylized model is for illustration purpose only, and additional information is provided in the technical appendix. The optimization model applies to both RTUC and RTD. RTUC and RTD both optimize over multi-interval horizons. FRP will be modeled by enforcing ramping constraints in each interval of RTUC and RTD. Modeling FRP in advisory intervals enables the optimization to foresee potential problems and take actions accordingly. As is the case for energy dispatches, only the flexible ramping award in the first RTD interval is financially binding. Additional detail is provided in the final technical appendix.

The objective function is modified to ensure sufficient ramping capability is maintained in order to meet both forecasted movement and uncertainty. The changes to the constraints involving flexible ramping are as follows.

Upward ramping capability limit: This constraint ensures that a resource's upward ramping award plus the total amount of upward reserves (regulation-up, spinning, and non-spinning) awards does not exceed its upward ramping capability over the market clearing interval.

Downward ramping capability limit: This constraint ensures that a resource's downward ramping award plus the regulation-down award does not exceed its downward ramping capability over the market clearing interval.

Active power maximum limit: This constraint limits the awards of energy schedule, upward reserves and upward FRP to be less than or equal to the resource's maximum operating capability.

Active power minimum limit: This constraint limits the energy schedule minus the awards of regulation-down and downward FRP to be greater than or equal to the resource's minimum operating level.

Upward flexible ramping requirement: This constraint ensures that the total amount of upward FRP awards at least meets the requirement.

Downward flexible ramping requirement: This constraint ensures that the total amount of downward FRP awards at least meets the requirement.

FRP is a 5-minute ramping capability based on the dispatch level and the resource's ramp rate. The RTUC and RTD have different market clearing interval granularity:

- RTUC has 15-minute market clearing interval, and
- RTD has 5-minute market clearing interval.

In the optimization, the ISO will model the average 5-minute ramping capability over the applicable market clearing interval. The ramping capability over the market clearing interval will be converted to the average 5-minute ramping capability by dividing it by an averaging factor AF (AF = 3 for RTUC, and AF=1 for RTD). If resource A has 60 MW capacity and 1 MW/minute ramp rate, it can be awarded 15 MW ramping capability over in an FMM interval. This can be converted to an average of 5 MW 5-minute ramping capability. The difference between the FMM 5 MW award will be settled at the RTD flexible ramping price. If the resource is awarded 4 MW 5-minute ramping capability in RTD, the resource must pay back the 1 MW at the RTD flexible ramping price.

4 Demand Curve to Meet Uncertainty

Besides procuring FRP to meet net forecast demand within the respective interval, the ISO will procure additional flexible ramping capability using the demand curve which is based on the net demand forecast uncertainty of the next interval. If the price of supply is lower, more FRP will be procured to cover the ramping requirement uncertainty. If the price of supply is higher, less FRP will be procured to cover the ramping requirement uncertainty.

Figure 3 illustrates an interval where the maximum expected downward forecast error (max is greater than the FRU minimum requirement. The ISO will procure the portion between the maximum expected forecast error and net load forecast at time t using a demand curve. This is illustrated as the difference between the dashed green line and the dashed orange line.

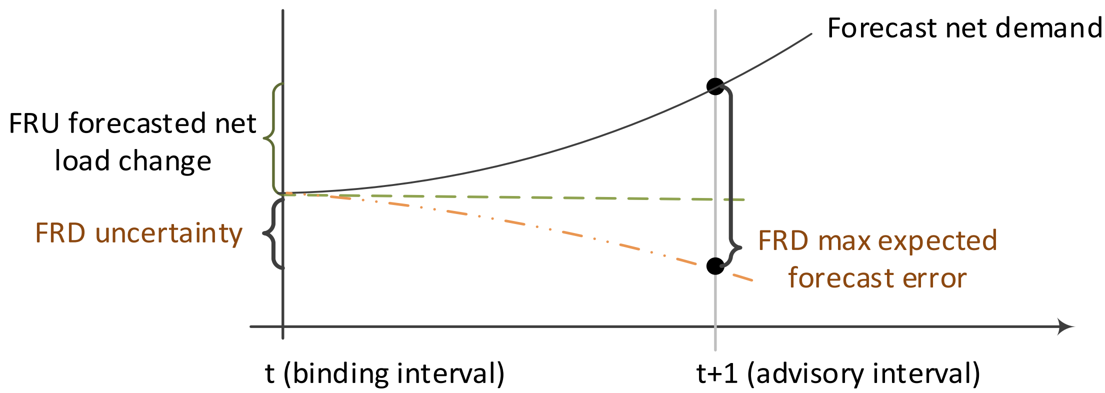

Figure 3 Flexible Ramping Product Requirement due to uncertainty

Figure 4, below, illustrates an interval where the maximum expected downward forecast error is less than the FRU minimum requirement. In this situation the ISO will not need additional FRD capacity.

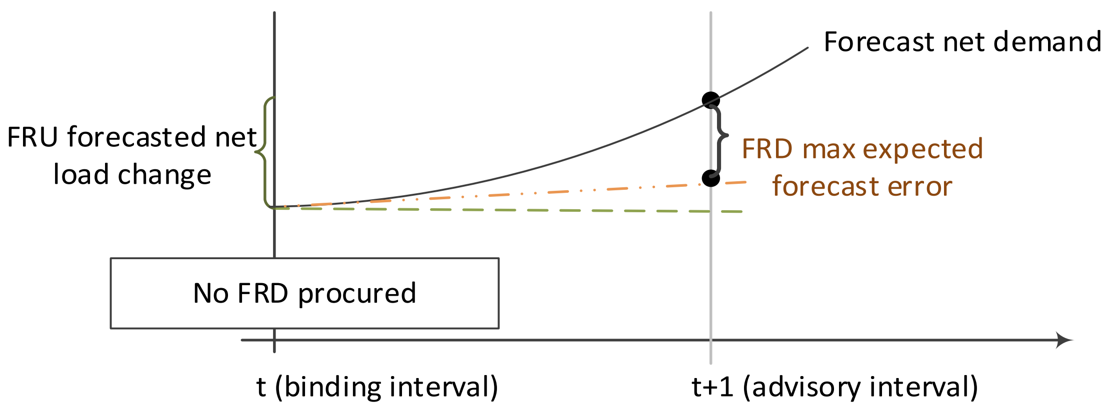

Figure 4 Flexible Ramping product with no flexible ramping down minimum or demand requirement

The ISO will construct histograms as an approximation of the probability distribution of net demand forecast errors to be used to procure for uncertainty. It will construct separate histograms for FRU and FRD for each hour, separately for RTD and FMM.

The histogram for RTD will be constructed by comparing the net demand for the first advisory RTD interval to the net load in the same time interval for the next financially binding RTD run. Figure 5 shows two consecutive RTD 5-minute market runs, RTD_1 and RTD_2. The ISO will construct the histograms by subtracting the net demand from the first market run used for the first advisory interval (A1) from the net demand the second market run used for the binding interval (B_2).

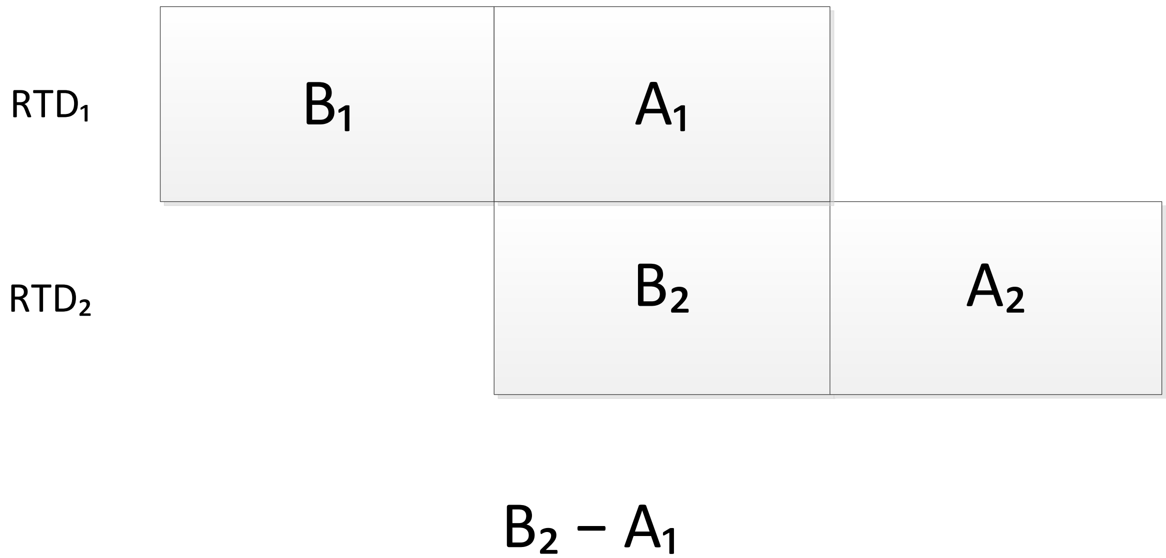

Figure 5: RTD Histogram Construction

For FMM, the ISO will construct separate histograms for FRU and FRD.

- For FRU, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the maximum net demand the market used for the three corresponding RTD intervals.
- For FRD, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the minimum net demand the market used for the three corresponding RTD intervals.

Figure 6 shows two RTUC intervals: the FMM (i.e. the RTUC binding interval) and the first advisory interval (labeled “A”). It illustrates how the FRU histogram will be constructed by comparing the net demand the FMM used for first advisory RTUC interval to the maximum net demand the market used for the corresponding three RTD binding intervals (b_1,b_2,b_3).

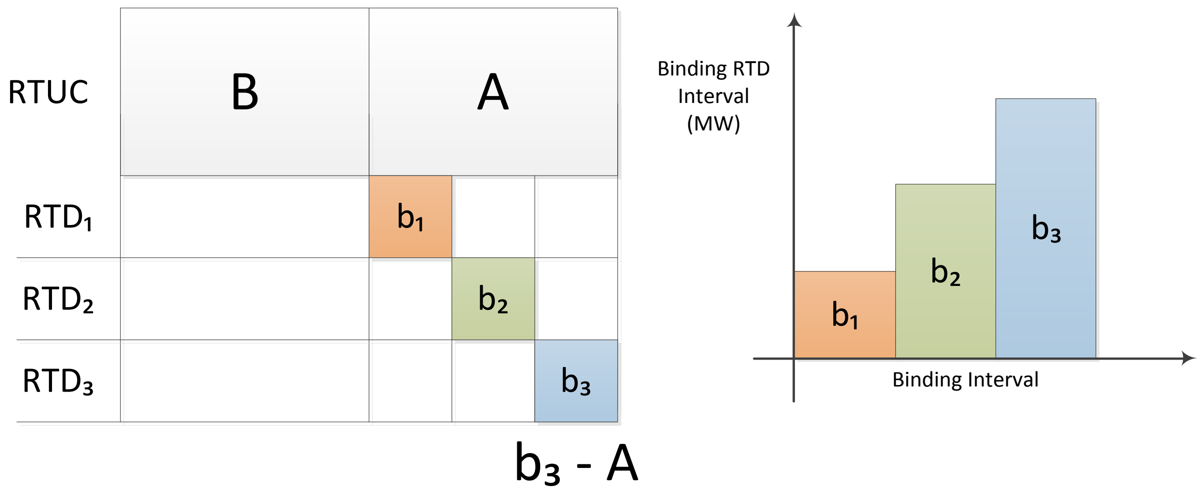

Figure 6: Histogram construction in FMM

The FRU histogram will use the observation b_3 – A. This represents the maximum ramping need. The variable b_3, represents the maximum net load in the three RTD intervals. The FRD histogram will use observation b_1 – A as this is the minimum ramping need. Ultimately in this example, the FRD observation is positive and therefore will not be used directly in the demand curve creation. It will however be used to calculate the 95th percentile load forecast error and therefore needs to be captured in the histogram.

The ISO proposes to use a rolling 30 days, with a separate histogram for weekends and holidays, to evaluate the historical advisory RTUC imbalance energy requirement error pattern for each RTUC hour. The ISO will also evaluate if hours with similar ramping patterns could be combined to increase the sample size used in the historical analysis. The ISO expects that the estimate of uncertainty will improve over time. Therefore, the actual method of calculating the demand curve will be included in the business practice manual versus including these details in the tariff.

5 Settlement of Forecasted Movement

Forecasted movement will be settled in FMM at the FMM price. Any difference between FRP procured for the FMM forecasted movement and the RTD forecasted movement will be settled at the RTD FRP price. Note that the granularity difference between FMM and RTD can cause differences between the FMM awards and RTD awards. The same issue exists with energy settlements today.

For dispatchable and non-dispatchable supply, the settlement is calculated by resource for each 15-minute FMM and 5-minute RTD settlement interval. The ISO uses its forecast[4] for variable energy resources' output to clear the market but provides the option for variable energy resources to use their own forecast to schedule energy. The ISO will only use the ISO's forecast to calculate ramping awards for variable energy resources. This is to mitigate against variable energy resources adjusting the forecast of the advisory interval to receive payment for ramp. VERs could do this without financial cost because the advisory energy schedules are not financially binding.

For interties, the settlement is calculated for each schedule for each 15-minute and 5-minute settlement interval based upon the prescribed ramps. Hourly schedule changes have a 20 minute ramp. 15-minute schedule changes have a 10 minute ramp. The granularity differences between FMM and RTD will result in ramp settlement even if though a static intertie schedule cannot be changed in RTD. In addition, operational adjustments should be reflected prior to the start of the RTD optimization covering the relevant FMM interval; therefore, this change can be reflected in the forecasted movement of RTD is not a cause of uncertainty.

Unlike supply and interties, load cannot be settled directly for forecasted movement with a Scheduling Coordinator (SC) because the ISO load forecast used to clear the market is aggregated for each balancing authority area. Therefore, all payments and charges to load based upon the ISO market forecast will be charged/paid based on load ratio share for each 5-minute settlement interval for each balancing authority area.

6 Monthly Settlement and Allocation of Uncertainty

Unlike forecasted movement, there is no counterparty to directly charge in the financially binding interval for FRP procured for uncertainty. Uncertainty is procured to address the potential for differences in net load when the advisory interval becomes financially binding in the subsequent market run. This difference occurs when uncertainty is realized in a future interval. Since the additional ramping capability is similar to insurance, it is appropriate to not allocate cost for a given realization of uncertainty, but over a period of time. Therefore, the cost (payment to dispatchable resources) will be allocated at the end of the month through an uplift.

The FRP for uncertainty awards will be settled with dispatchable resources at the applicable binding interval FMM or RTD price at the end of the <u>month</u>. By not paying the uncertainty awards immediately, there is no need to perform a monthly resettlement because the payment to a resource and the cost allocation will occur in the same settlement period. This is a significant simplification of the settlements implementation.

In addition, payment rescissions to dispatchable resources for uninstructed imbalance energy that would provide a double payment as discussed in the subsequent section will be charged at

[4] In the energy imbalance market, the EIM entity must provide an independent third party forecast. This forecast is then used in the market. If the EIM entity does not have an independent third party forecast, the ISO will use its forecast provider.

the end of the month. The payment rescission will be settled at applicable binding interval RTD price in which the payment rescission occurred.

If the settlement amounts for Flexible Ramp Up Uncertainty Settlement Amount, Flexible Ramp Down Uncertainty Settlement Amount, Flexible Ramp Up Uncertainty Rescission Amount, Flexible Ramp Down Uncertainty Rescission Amount, Flexible Ramp Up Uncertainty Allocation Amount, and Flexible Ramp Down Uncertainty Allocation Amount does not equal zero, the ISO will assess the resulting differences to all SCs with metered demand within the balancing authority area.

The ISO proposes settling the uncertainty for two groups of trade hours. In the assessment of grid management charge (GMC) prior to the 2010 GMC redesign, the ISO identified a GMC bucket for charging load based upon Non-Coincident Peak hours and Non-Coincident Off Peak Hours. Non-Coincident Peak Hours is defined as trading hours ending 7 through 22 for all trading days within a trading month, whereas Non-Coincident Off Peak Hours is defined as trading hours ending 1 through 6 and trading hours 23 through 25 for all trading days within a trading month. For each group of the hour, the FRP for uncertainty uplift cost is the sum of the monthly payments to dispatchable resources less monthly payment rescissions charges to dispatchable resources in the each bucket of trading hours. The total FRP for uncertainty uplift cost is first allocated between the load, supply, and intertie categories. The respective uplift costs allocated to the load, supply, and intertie categories are then allocated to individual resources or loads using a different billing determinate method for each category.

The initial allocation of FRP uncertainty uplift costs between the load, supply, and intertie categories is determined by calculating the “vertical” binding – advisory as shown in figure 7. This difference will be calculated for all non-dispatchable[5] changes in supply resources, interties[6] and load for each 5-minute interval. There is no netting between 5-minute intervals, so in each 5-minute interval there will be either a FRU value or an FRD value. Table 2 below illustrates whether the observed net load error will split FRU or FRD costs. “A” is the advisory interval in the first RTD run and “B” is the binding interval from the second RTD run.

5 Only non-dispatchable resources can have forecast errors between the two market runs. A dispatchable resource could have differences between the two market runs, but this is in response to market instructions not a result a forecast error of that resources.

6 Only operational adjustments that occur after RTD initializes will result in a forecast error. Once the operational adjustment is reflected in RTD, it is settled as part of the forecasted movement.

Figure 7: Binding and advisory interval representation

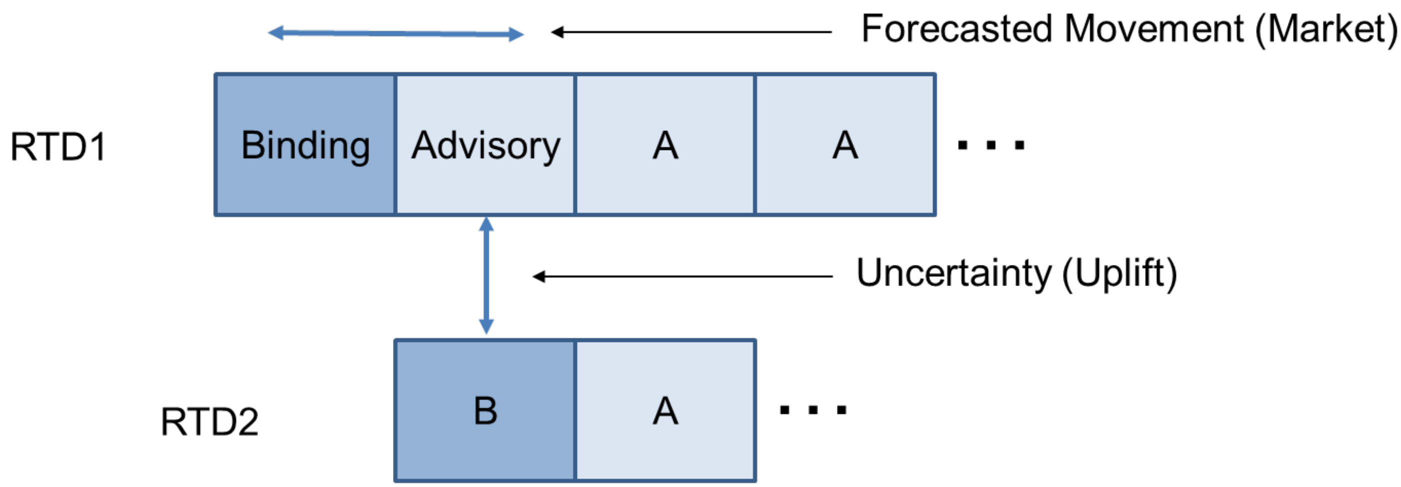

Table 1 Allocation of uncertainty uplift costs between FRU and FRD

	FRU	FRD
Load	A-B > 0	A-B < 0
Supply	A-B < 0	A-B > 0
Interties (Net import in B)	A-B < 0	A-B > 0
Interties (Net export in B)	A-B > 0	A-B < 0

*For load and exports the values of A and B are negative

The load forecast is a single value for each balancing authority area, therefore the forecast error nets errors resulting from individual load serving entities. The load will have a single FRU or FRD value for each settlement interval per balancing authority area based on the ISO forecast between "vertical" advisory – binding interval shown in Figure 7. When splitting the costs into each category, supply and interties must also have a single FRU or FRD value for each settlement interval per balancing authority area. This is accomplished by netting all resources within the supply category and separately netting all intertie schedules within the intertie category to then calculate a single value for each of the categories.

There will be 4 monthly costs that will be allocated: FRU Peak, FRD Peak, FRU Off Peak, and FRD Off Peak. The FRU and FRD values in each 5-minute interval for each category are summed for the month over each range of trading hours. Then each category is allocated its pro-rata share of the monthly FRP costs. The each category allocates its four costs according to its own billing determinant.

1. Load is allocated to each SC based on the pro-rata share of gross UIE over the month. There is no netting between settlement intervals. Negative (increased consumption) UIE is allocated FRU and positive (decreased consumption) UIE is allocated FRD. If a load

uses five minute metering, such as load following metered sub-systems, then the load would be included within the supply category.

2. Supply is allocated by calculating the observed forecast error (the vertical advisory – binding) plus any uninstructed imbalance energy. Each resource is allocated its pro-rata share of gross (A-B-UIE) for over the month for each cost bucket. There is no netting between settlement intervals. Positive (A-B-UIE) is allocated FRU and negative (A-B-UIE) is allocated FRD. Uninstructed imbalance energy was included to provide an additional incentive for dispatchable resources to follow their dispatch instruction. If UIE persists, this can increase the need for ramping capability.
3. Intertie category is allocated to each SC based upon the pro-rata share of gross operational adjustment in each cost bucket over the month. Uncertainty costs for interties will be small. The uncertainty is realized only if an operational adjustment occurs after the binding RTD interval prior to the start of the next RTD interval. Otherwise, the operational adjustment will be resettled as a forecasted movement in RTD. Most operational adjustments occur prior to the start of the operating hour and will be settled through the forecasted movement deviation between FMM and RTD.

7 Rule to Address Double Payment

Since dispatchable resources, non-dispatchable resources, interties, and load will all be awarded and compensated for FRP, the ISO is proposing a consistent approach to address the potential double payment of opportunity costs. The double payment arises when a resource is awarded FRP and is then subsequently settled for uninstructed imbalance energy. Assume a resource's energy bid is $30/MWh and the market clearing LMP was $40. If the resource was awarded FRU, it would be paid no less than $10 for the FRU award. If the resource then deviated above its binding dispatch, the resource would incur positive uninstructed imbalance energy and be paid at the 5-minute LMP of $40. This would cause a profit of $10 which would be the same as the opportunity cost used to compensate the FRU award which assumed the resource would be at it dispatch operating target.

For each settlement interval in which a resource is awarded FRP, the ISO will determine if the resource was double paid by comparing uninstructed imbalance energy (UIE) to the FRP award. If the resource's final meter indicates that the resource has uninstructed imbalance energy deviation or operational adjustment that overlaps with the reserved FRP awarded capacity, the ISO will rescind this portion of the FRP award. The FRP rescission quantity will be charged at the five-minute market FRP price. The FRP rescission quantity will be first assessed against the resource's FRP uncertainty awards and then against the FRP movement awards.

The rescinded FRP amount for forecasted movement will be charged in each settlement interval with the same settlement timing as energy imbalances. The rescinded FRP amount for uncertainty will be charged at the end of the month to eliminate the need for a monthly resettlement since uncertainty costs are allocated monthly.

The rescinded FRP amounts for forecasted movement will be paid to the resources directly charged in proration to their forecasted movement in the binding RTD interval. The rescinded

FRP amounts for uncertainty will be netted against the FRP uncertainty payments prior to monthly allocation to load, supply, and interties as discussed in the next section.

8 EIM Resource Sufficiency Evaluation

With introducing FRP, the ISO will introduce a downward ramping sufficiency evaluation to address real-time leaning due to over-supply in the energy imbalance market (EIM). If the EIM entity balancing authority area (BAA) fails the flexible ramping down sufficiency incremental EIM transfers out of that BAA will not be allowed. The test is symmetrical to the upward ramping sufficiency test currently implemented in the EIM and applied to all BAAs in the EIM[7].

In addition, the settlement to both EIM participating resources and EIM non-participating resources will be settled as any resource in the ISO BAA. The base schedules of non-participating resources will be considered self-schedules when calculating forecasted movement and for allocating the monthly uncertainty cots. The EIM entity scheduling coordinator will be allocated flexible ramping costs for changes in base schedules from non-participating resources because the ramps between hourly base schedules must be honored by RTD.

The ISO will calculate the flexible ramping down requirement for each BAA individually and for the EIM footprint, which recognizes the diversity benefits of the EIM. The diversity benefit will then be allocated pro rata to individual EIM entity BAA for the flexible ramping down sufficiency test. The total system requirement will not exceed the sum of the individual BAA flexible ramping requirements, since in this case the requirement can be met with no transfers between BAAs.

If an EIM entity BAA has a net incoming EIM transfer (net imbalance energy import with reference to the base net schedule interchange) before the operating hour, then it has partially fulfilled its flexible ramping down requirement for that hour because it can retract that EIM transfer during the hour as needed. Here, the ISO will apply a flexible ramping down requirement credit in the flexible ramping down sufficiency test for that EIM entity BAA equal to the net incoming EIM transfer before the operating hour. There will be no such credit for an EIM Entity BAA with a net outgoing EIM transfer (net imbalance energy export with reference to the base net schedule interchange) before the operating hour; the flexible ramping down requirement for that EIM entity BAA in the flexible ramping down sufficiency test will not be affected by the net outgoing EIM transfer. That EIM entity BAA will be sufficient if it meets its own flexible ramping down requirement, with any EIM diversity benefit, irrespective of the outgoing EIM transfer, which results from optimal dispatch in the EIM.

The ISO will perform a series of flexible ramping down sufficiency tests prior to commencing the EIM. The sufficiency test is cumulative. The EIM Entity BAA must meet flexible ramping down requirements for each 15 minute interval of the hour:

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[7] See section 3.4.3 of the EIM draft final proposal at http://www.caiso.com/Documents/EnergyImbalanceMarket-DraftFinalProposal092313.pdf

- Interval 1: 15-minute ramp from T−7.5 to T+7.5
- Interval 2: 30-minute ramp from T−7.5 to T+22.5
- Interval 3: 45-minute ramp from T−7.5 to T+37.5
- Interval 4: 60-minute ramp from T−7.5 to T+52.5

Upon completion of the flexible ramping down sufficiency test, the ISO will enforce separate flexible ramping down constraints in the market optimization for each BAA in EIM and the entire EIM footprint. EIM entity BAAs that fail the flexible ramping down sufficiency test will not be included in EIM footprint constraint. The only constraint to be formulated for these EIM entity BAAs will be for their individual flexible ramping down requirements.

The ISO will calculate a total BAA uncertainty cost before performing the monthly cost allocation to the three categories. The uncertainty costs will include the BAA specific constraint uncertainty costs and the pro-rata share, based upon the individual BAA requirements, of the EIM footprint constraint when the BAA has passed the resource sufficiency evaluations.

9 Next Steps

The ISO plans to discuss this revised draft final proposal and updated technical appendix with stakeholders during a stakeholder conference call to be held on January 5th. The ISO requests comments from stakeholders on the proposed market design changes described in this revised draft final proposal. Stakeholders should submit written comments by January 12th to initiativecomments@caiso.com.

Table 2 - Schedule for Flexible Ramping Product Stakeholder Initiative

Item	Date
Post Revised Draft Final Proposal and Technical Appendix	December 17, 2015
Stakeholder Conference Call	January 5, 2015
Stakeholder Comments Due	January 12, 2015
Board of Governors Decision	February 11-12, 2015

Attachment E – Flexible Ramping Product Draft Final Technical Appendix
December 17, 2015

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Flexible Ramping Product

Draft Final Technical Appendix

December 17, 2015

Table of Contents

1. Introduction

This technical appendix documents the proposed design for a market-based flexible ramping product (FRP). The ISO is proposing the FRP to maintain power balance in the real-time dispatch and appropriately compensate ramping capability.

The ISO issued a revised draft technical appendix on November 16, 2015. This draft final technical appendix includes clarifications and minor edits from the revised draft. The following clarifications and changes to the FRP design from the June 10, 2015 draft have been included:

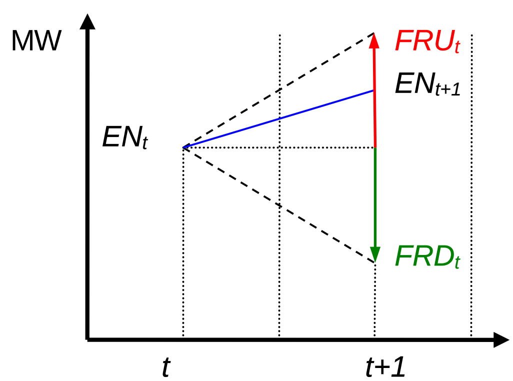
- Modified the capacity constraints (see section 5.2) to allow netting of FRU and FRD to allow for a more flexible dispatch.
- Corrected table 11 which shows the settlement of intertie schedule changes in both FMM and RTD due to hourly schedule changes.

2. Generalized flexible ramping capacity model

This section provides a brief overview of the flexible ramping capacity model in order to illustrate the flexible ramping procurement concept. For simplicity, the ISO does not include any ancillary services below; however, the full model will include ancillary service constraints.

Figure 1 shows the potential flexible ramping up and down awards for an online resource in time period *t* that can be procured based on the resource's ramping capability from t to t+1.

FIGURE 1: SIMPLIFIED FRP ILLUSTRATION OF CONCEPTUAL MODEL



The dashed lines represent the upward and downward ramping capability of the resource from its energy schedule in time period t. The flexible ramping up and down awards are limited by the ramping capability of the resource. The flexible ramping award may also include capacity that is needed to meet the scheduled ramping needs between t and t+1.

Both energy schedules (EN_t, EN_{t+1}) and flexible ramp awards (FRU_t, FRD_t) are calculated simultaneously by the market optimization engine. The only exception is the initial point (EN_0) of where the resource is scheduled in t-1, which is a fixed input for the ramp to the resource's energy schedule in time period t. These control variables are constrained by the following set of capacity and ramp constraints:

$$\max(EN_t + FRU_t, EN_{t+1}) \le UEL_{t+1}$$
$$\min(EN_t + FRD_t, EN_{t+1}) \ge LEL_{t+1}$$
$$RRD(EN_t, T) \le FRD_t \le 0$$
$$0 \le FRU_t \le RRU(EN_t, T)$$
$$RRD(EN_t, T) \le EN_{t+1} - EN_t \le RRU(EN_t, T)$$

$EN_{i,t}$	Energy schedule of dispatchable Resource *i* in time period *t* (positive for supply and negative for demand).
$FRU_{i,t}$	Flexible Ramp Up award of Resource i in time period t.
$FRD_{i,t}$	Flexible Ramp Down award (non-positive) of Resource i in time period t.
$UEL_{i,t}$	Upper Economic Limit of Resource i in time period t.
$LEL_{i,t}$	Lower Economic Limit of Resource i in time period t.
$RRU_i(EN, T)$	Piecewise linear ramp up capability function of Resource *i* for time interval duration *T*.
$RRD_i(EN, T)$	Piecewise linear ramp down capability function (non-positive) of Resource *i* for time interval duration *T*.

The FRP will help the system to maintain and use dispatchable capacity. It will be procured to meet five minute to five minute net system demand changes plus uncertainty[1] and will be modeled as a ramping capability constraint. Both the five-minute RTD and fifteen-minute real time unit commitment (RTUC) will schedule FRP throughout their dispatch horizon. Awards will be compensated according to marginal FRP prices in the financially binding RTD interval (the first interval) and in the FMM, which is the financially binding RTUC interval (the second interval). Modeling FRP in RTUC enables the market to commit or de-commit resources as needed to obtain sufficient upward or downward ramping capability.

3. Flexible ramping product summary

FRP will be procured and dispatched in both the RTD and RTUC using similar methodologies. FRP is designed with specific constraints and ramping requirements to ensure that there is sufficient ramping capability available in the financially binding interval to meet the forecasted net load for the next interval and cover upwards and downwards forecast error or uncertainty of the next interval.

In RTD, the FRU and FRD requirements are determined using the forecasted five minute net demand variation. The forecasted net demand variation is made up of (1) the forecasted net load movement between the binding and first advisory interval and (2) the expected error in the

[1] Only resources that are 5-minute dispatchable can be used to meet the uncertainty portion of FRP. For non-dispatchable resources, a resource constraint will limit FRP award to forecasted movement. For interties, FRP awards in FMM will not exceed the forecasted movement because the schedule changes are fixed in RTD.

advisory intervals RTD net demand forecast within a 95% confidence interval. The uncertainty for both FRU and FRD will be procured using a demand curve. The upward demand curve will be capped at $247/MW, which is $3/MW less than the contingency reserve relaxation parameter. The downward demand curve will be capped at ($155/MW) with is $3/MW higher than regulation down relaxation parameter.

The probability distribution function for the five minute net demand forecast error is approximated by a histogram constructed from historical observations obtained from consecutive RTD runs over time periods that represents similar real-time conditions. While the historical observations for five minute net demand errors are the foundational data for forecasting the flexible ramping requirement, additional information may be used as the ISO continuously improves the forecast of ramping capability needed. The ISO will describe any additional factors that scale the historical observations in the business practice manual. The net load forecast error sample for a given five-minute interval is calculated as the difference between observed net demand for the binding RTD solution for that interval and forecasted net demand for the corresponding advisory interval of the previous RTD run.

Figure 2 illustrates the FRP requirement when net load is ramping upward in the RTD.

FIGURE 2 FLEXIBLE RAMPING PRODUCT RTD REQUIREMENT ILLUSTRATIVE SINGLE INTERVAL EXAMPLE

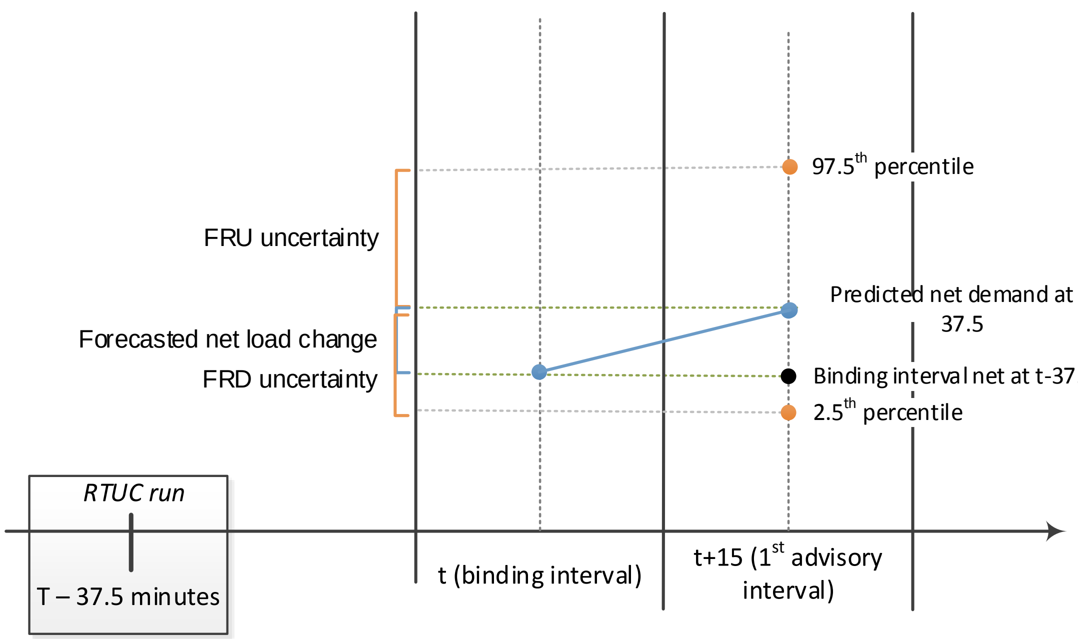


Figure 3 illustrates how the multi-interval optimization will treat FRP in each subsequent advisory interval in the real-time outlook.[2] Each advisory interval will reserve the forecasted net load

[2] RTD looks out between 9 and 13 intervals.

change between successive advisory intervals and a portion of the predicted net load forecast error uncertainty, using an interval specific demand curve. If the outlook period is within the same hour and therefore the same histogram as the binding interval, the uncertainty portion of the demand curve will be the same in the binding and advisory FRP procurement. Outside of the hour, the uncertainty portion of the demand curve may change because the underlying histogram may be different (e.g. the histogram for 8:00 am may be different than the histogram for 9:00 am.) Therefore, there will be the same uncertainty in each subsequent advisory interval within hour 10:00, but in hour 11:00 the underlying demand curve may change.

The expected net load forecast change will be the difference between each subsequent advisory interval's and the previous adjacent interval's net load. The uncertainty for each advisory interval will be calculated using a net demand forecast within a 95% confidence interval.

FIGURE 3 FLEXIBLE RAMPING PRODUCT RTD REQUIREMENT ILLUSTRATIVE MULTI-INTERVAL EXAMPLE

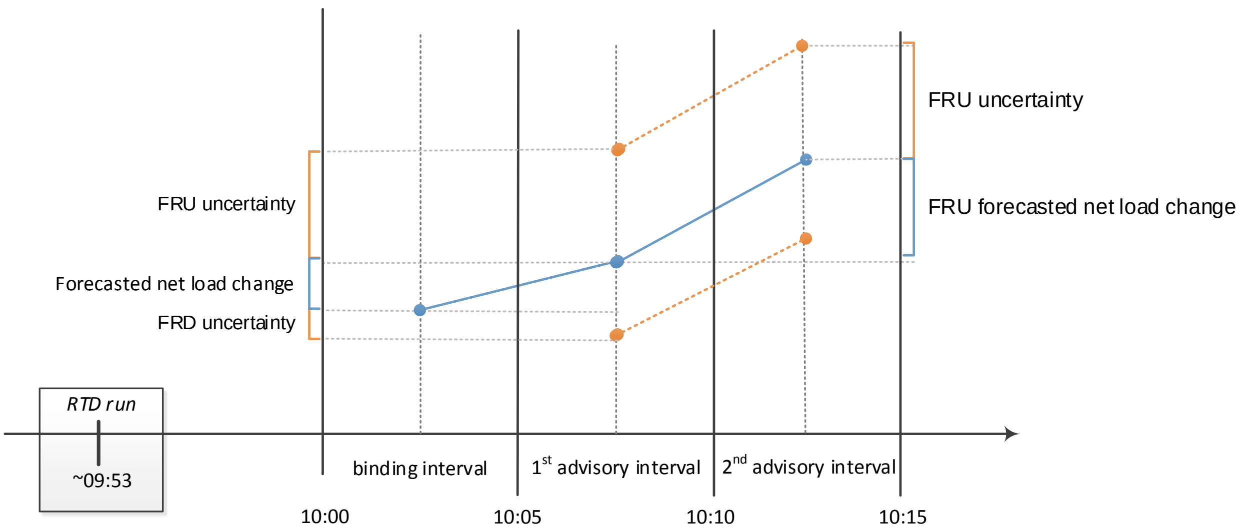
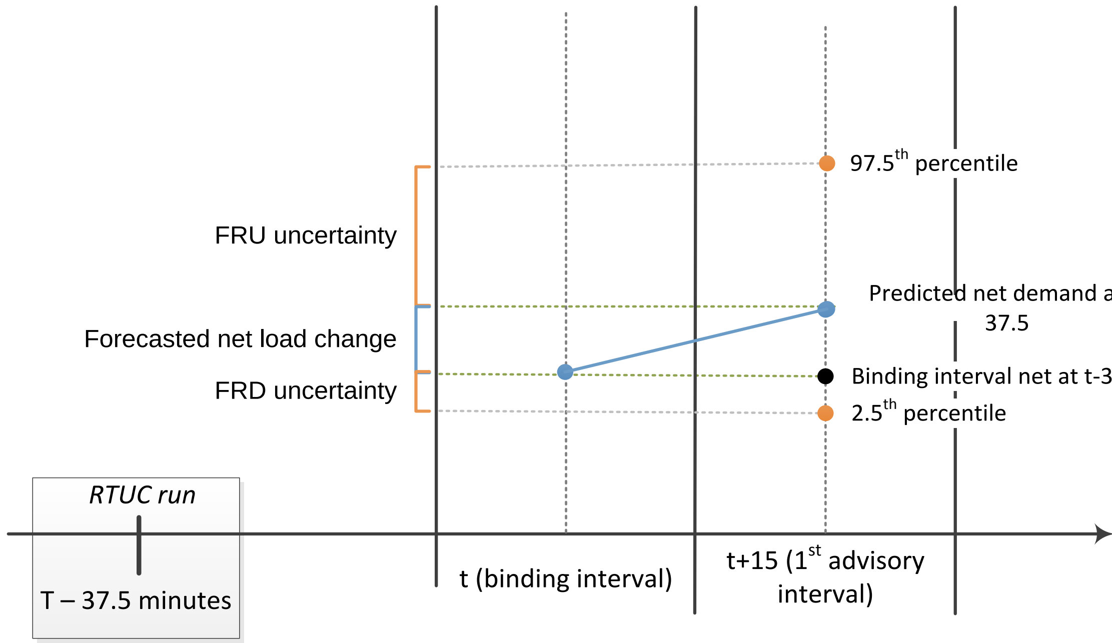


Figure 4 illustrates RTUC FRP procurement for the binding interval. Similar to RTD, in RTUC the FRU and FRD requirements are determined by the forecasted 15-minute net demand variation. The forecasted net demand variation is made up of (1) the forecasted net load change between the binding and first advisory interval and (2) the highest expected error between the RTUC first advisory interval and the associated RTD binding interval within a 95% confidence interval.

FIGURE 4 FLEXIBLE RAMPING PRODUCT RTUC REQUIREMENT ILLUSTRATIVE EXAMPLE



4. Flexible ramping requirement

4.1 Flexible ramping product total requirement

The FRP total requirement is calculated as the sum of the net demand forecast change across intervals and an additional amount for uncertainty within a 95% confidence interval. The uncertainty will be determined using historical net demand forecast errors and incorporated into a histogram. The histogram will be used to construct a demand curve that the market will use to procure FRP. The market will enforce FRP requirements in all binding and advisory intervals of the RTD and RTUC runs:

$$\left.\begin{aligned} FRUR_t &= FRUR_{\mathrm{ND}t} + FRUR_{\mathrm{U}t} \\ FRDR_t &= FRDR_{\mathrm{ND}t} + FRDR_{\mathrm{U}t} \end{aligned}\right\}, t = 1,2, \dots, N-1$$

t	Time period (interval) index.
N	The number of time periods in the time horizon.
$FRUR_t$	Total Flexible Ramp Up requirement in time period *t*.
$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRUR_{\mathrm{U}t}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_t$	Total Flexible Ramp Down requirement (non-positive) in time period *t*.

$FRDR_{\mathrm{ND}t}$	Flexible Ramp Down requirement (non-positive) due to net demand forecast change in time period *t*.
$FRDR_{\mathrm{U}t}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.

4.2 Flexible ramping requirement for net demand forecast movement

The minimum FRP requirement is the forecasted real ramping need between intervals. For each binding interval, the market will use the requirement below to procure enough flexible ramping need to meet the forecasted net demand in the next advisory interval. Below is the mathematical representation of the minimum ramping requirement.

The flexible ramp requirement due to net demand forecast change exists only in the direction the net demand forecast is changing; it is zero in the opposite direction:

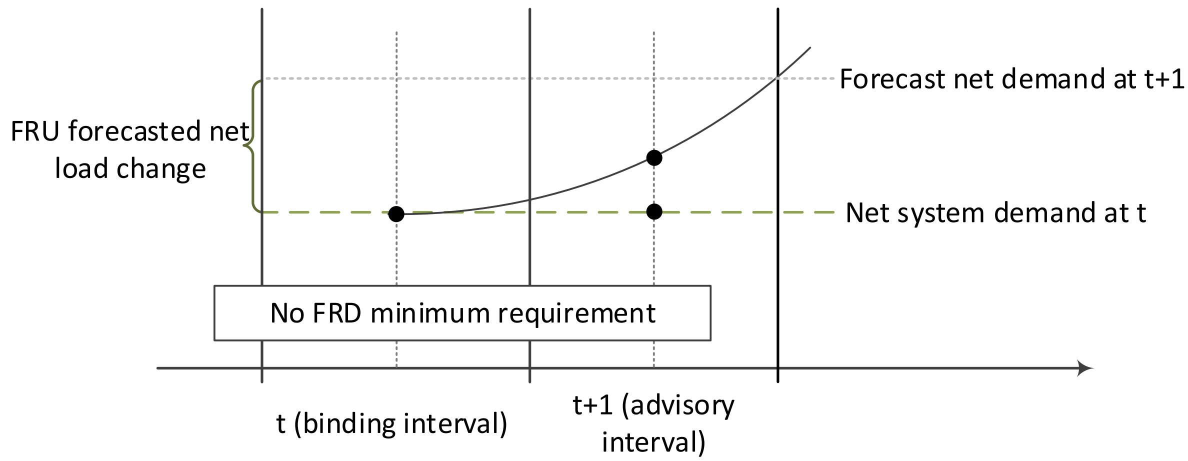
$$\left.\begin{array}{l} FRUR_{\mathrm{ND}t} = \max(0, \Delta ND_t) \\ FRDR_{\mathrm{ND}t} = \min(0, \Delta ND_t) \end{array}\right\}, t = 1,2, \dots, N-1$$

$$\textbf{Where}: \Delta \mathrm{ND_t} = ND_{t+1} - ND_t$$

ND_t	Net demand forecast in time period *t*.
$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRDR_{Ut}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period t.

The ISO market will only set a FRU or FRD minimum requirement in the event that the forecasted net demand is moving in the same direction as the up or down requirement. Therefore, when the net demand is ramping upward there will not be a minimum FRD requirement, and vice versa. Figure 5 shows an illustrative example of a minimum FRU requirement. In this situation, there is no minimum FRD requirement.

FIGURE 5 FLEXIBLE RAMPING PRODUCT MINIMUM REQUIREMENT



4.3 Flexible ramping requirement due to uncertainty

The ISO market will procure additional flexible ramping capability using the demand curve based on net demand forecast uncertainty of the next interval. If the supply price is lower, FRP will be procured closer to the maximum ramping requirement. If the supply price is higher, FRP will be procured closer to the minimum requirement.

The flexible ramp requirement due to uncertainty is calculated as follows:

$$\left.\begin{aligned} FRUR_{Ut} &= \max(0, EU_t + FRDR_{\mathrm{ND}t}) \\ FRDR_{Ut} &= \min(0, ED_t + FRUR_{\mathrm{ND}t}) \end{aligned}\right\}, t = 1,2, \ldots, N-1$$

Where:

$$\left.\begin{aligned} &EU_t = \max(0, PU_t) \\ &\int_{-\infty}^{PU_t} p_t(\varepsilon)\, d\varepsilon = CLU \end{aligned}\right\}, t = 1,2, \ldots, N-1$$

$$\left.\begin{aligned} &ED_t = \min(0, PD_t) \\ &\int_{-\infty}^{PD_t} p_t(\varepsilon)\, d\varepsilon = CLD \end{aligned}\right\}, t = 1,2, \ldots, N-1$$

$FRUR_{\mathrm{U}t}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_{\mathrm{U}t}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.

$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRDR_{\mathrm{ND}t}$	Flexible Ramp Down requirement (non-positive) due to net demand forecast change in time period *t*.
EU_t	Flexible Ramp Up uncertainty at the upper confidence level in time period t.
ED_t	Flexible Ramp Down uncertainty (negative) at the lower confidence level in time period t.
$p_t(\varepsilon)$	Probability distribution function for the average five minute net demand forecast error in time period t, approximated by a histogram compiled from historical observations.
PU_t	Cumulative probability of net demand forecast error at or below the upper confidence level in time period *t*.
PD_t	Cumulative probability of net demand forecast error at or below the lower confidence level in time period *t*.
CLU	Flexible ramp uncertainty upper confidence level, e.g., 97.5%.
CLD	Flexible ramp uncertainty lower confidence level, e.g., 2.5%.

The above formula is illustrated in Figure 6 and Figure 7.

FIGURE 6 FLEXIBLE RAMPING PRODUCT REQUIREMENT DUE TO UNCERTAINTY

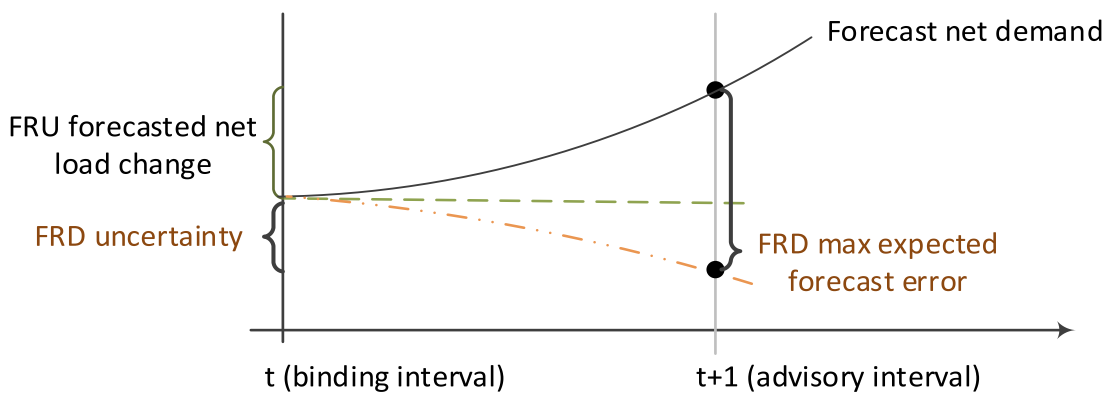
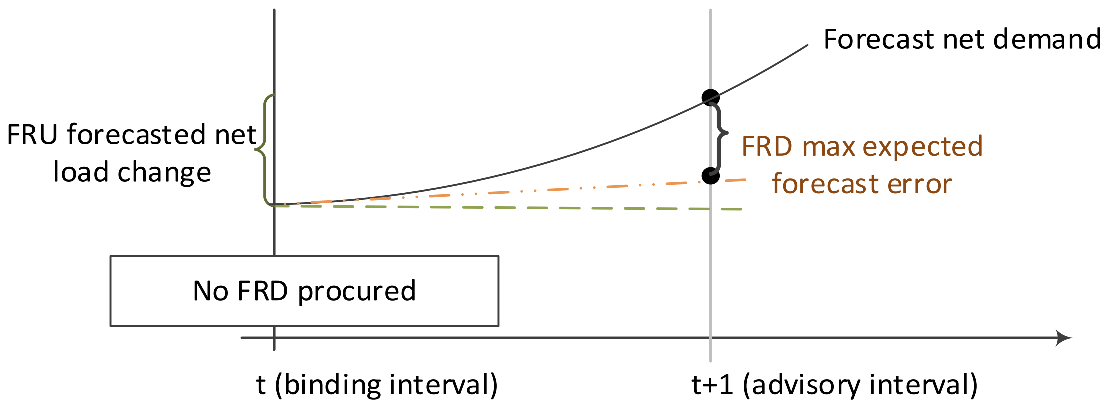


Figure 6 illustrates an interval where the maximum expected downward forecast error (max {ED_t}) is greater than the FRU minimum requirement. The ISO will then procure the portion between the maximum expected forecast error and net load forecast at time t using a demand curve. This is illustrated as the difference between the dashed green line and the dashed orange line.

Figure 7, below, illustrates an interval where the maximum expected downward forecast error (max {ED_t}) is less than the FRU minimum requirement. In this situation the ISO will not need additional FRD capacity.

FIGURE 7: FLEXIBLE RAMPING PRODUCT WITH NO FLEXIBLE RAMPING DOWN MINIMUM OR DEMAND REQUIREMENT

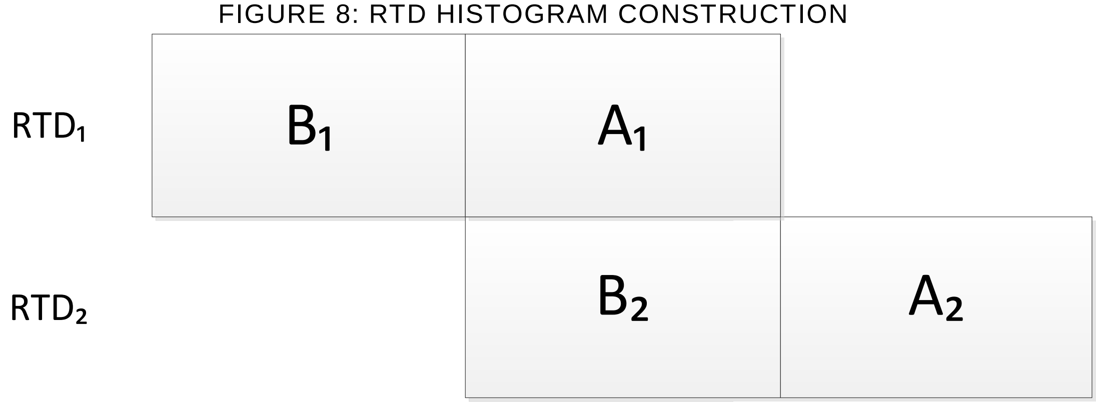


4.3.1 Using historical data to forecast uncertainty

The ISO will construct histograms as an approximation of the probability distribution of net demand forecast errors to be used to procure for uncertainty. It will construct separate histograms for FRU and FRD for each hour, separately for RTD and RTUC.

The histogram for RTD will be constructed by comparing the net demand for the first advisory RTD interval to the net load in the same time interval for the next financially binding RTD run. For example, Figure 8 shows two consecutive RTD 5-minute market runs, RTD_1 and RTD_2. The ISO will construct the histograms by subtracting the net demand from the first market run used for the first advisory interval (A1) from the net demand the second market run used for the binding interval (B_2).

FIGURE 8: RTD HISTOGRAM CONSTRUCTION



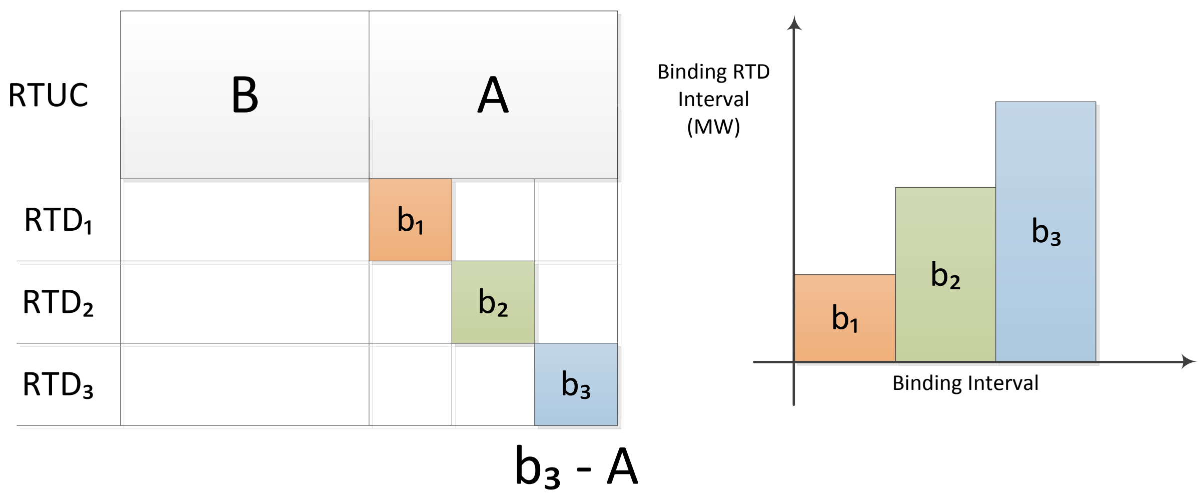
$$B_2 - A_1$$

For RTUC, the ISO will construct separate histograms for FRU and FRD as follows:

- For FRU, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the maximum net demand the market used for the three corresponding RTD intervals.
- For FRD, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the minimum net demand the market used for the three corresponding RTD intervals.

Figure 9 shows two RTUC intervals: the FMM (i.e. the RTUC binding interval) and the first advisory interval (labeled “A”). It illustrates how the FRU histogram will be constructed by comparing the net demand the FMM used for first advisory RTUC interval to the maximum net demand the market used for the corresponding three RTD binding intervals (b_1,b_2,b_3).

FIGURE 9: HISTOGRAM CONSTRUCTION IN RTUC



The FRU histogram will use the observation b_3 – A. This represents the maximum ramping need. The variable b_3, represents the maximum net load in the three RTD intervals. The FRD histogram will use observation b_1 – A as this is the minimum ramping need. Ultimately in this example, the FRD observation is positive and therefore will not be used directly in the demand curve creation. It will however be used to calculate the 95th percentile load forecast error and therefore needs to be captured in the histogram.

The ISO proposes to use a rolling 30 days, with a separate histogram for weekends and holidays, to evaluate the historical advisory RTUC imbalance energy requirement error pattern for each RTUC hour. The ISO will also evaluate if hours with similar ramping patterns could be combined to increase the sample size used in the historical analysis.

4.4 Flexible ramping product requirement constraints

The requirement constraints for the procurement of FRU/FRD are as follows:

$$\left.\begin{aligned}\sum_i FRU_{i,t} + FRUS_t = FRUR_t \\ \sum_i FRD_{i,t} + FRDS_t = FRDR_t\end{aligned}\right\}, t = 1,2,\dots,N-1$$

i	Resource index.
$FRU_{i,t}$	Flexible Ramp Up award of Resource *i* in time period *t*.
$FRD_{i,t}$	Flexible Ramp Down award (non-positive) of Resource *i* in time period *t*.
$FRUS_t$	Flexible Ramp Up surplus in time period *t*.
$FRDS_t$	Flexible Ramp Down surplus (non-positive) in time period *t*.
$FRUR_t$	Total Flexible Ramp Up requirement in time period *t*.
$FRDR_t$	Total Flexible Ramp Down requirement (non-positive) in time period *t*.

Where the FRU/FRD surplus variables provide flexible ramp demand response for the entire flexible ramp requirement at an appropriate cost:

$$\left.\begin{aligned}0 \le FRUS_t \le FRUR_t \\ 0 \ge FRDS_t \ge FRDR_t\end{aligned}\right\}, t = 1,2,\dots,N-1$$

4.5 Flexible ramping product objective function

This section describes the objective and cost function of the FRP. The FRP will be procured to meet the predicted net demand variation and uncertainty requirements using a demand curve at the cost of expected power balance violations in absence of FRP.

$$C = \dots + \sum_{t=1}^{N} \int_0^{FRUS_t} C\dot{S}U_t(FRUS_t)\, de + \sum_{t=1}^{N} \int_0^{FRDS_t} C\dot{S}D_t(FRDS_t)\, de$$

A surplus variable is used to determine the expected cost of not procuring a portion of the uncertainty. The FRU/FRD surplus cost function for the flexible ramp requirement due to uncertainty is the expected uncertainty multiplied by the relevant price cap:

$$\left.\begin{aligned}CSU_t(FRUS_t) = PC \int_{EU_t - FRUS_t}^{EU_t} \big(e - (EU_t - FRUS_t)\big) * \ p_t(e)\, de, 0 \le FRUS_t \le FRUR_{Ut} \\ CSD_t(FRDS_t) = -PF \int_{ED_t - FRDS_t}^{ED_t} \big(e - (ED_t - FRDS_t)\big) * \ p_t(e)\, de, 0 \ge FRDS_t \ge FRDR_{Ut}\end{aligned}\right\},$$
$$t = 1,2,\dots,N-1$$

And the incremental FRU/FRD surplus cost function is extended to the total flexible ramp requirement:

$$\left.\begin{aligned}C\dot{S}U_t(FRUS_t) = C\dot{S}U_t(FRUR_{Ut}), FRUR_{Ut} < FRUS_t \le FRUR_t \\ C\dot{S}D_t(FRDS_t) = C\dot{S}D_t(FRDR_{Ut}), FRDR_{Ut} > FRUS_t \ge FRDR_t\end{aligned}\right\}, t = 1,2,\dots,N-1$$

e	Average 5min net demand forecast error
$p_t(e)$	Probability distribution function for the average 5min net demand forecast error in time period *t*, approximated by a histogram compiled from historical observations.
$FRUS_t$	Flexible Ramp Up surplus in time period *t*.
$FRDS_t$	Flexible Ramp Down surplus in time period *t*.
$CSU_t(FRUS_t)$	Flexible Ramp Up surplus cost function in time period *t*.
$CSD_t(FRDS_t)$	Flexible Ramp Down surplus cost function in time period *t*.
$FRUR_{Ut}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_{Ut}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.
C	Objective function.
PC	Bid Price ceiling, currently $1,000/MWh.
PF	Bid Price floor, currently –$155/MWh.
EU_t	Flexible Ramp Up uncertainty at the upper confidence level in time period t.
ED_t	Flexible Ramp Down uncertainty (negative) at the lower confidence level in time period t.

The cost functions and their derivatives above can be approximated using the relevant histogram compiled from historical observations, leading to a stepwise incremental cost function that must be forced to be monotonically increasing for *FRUS* and monotonically decreasing for *FRDS*, as required by market optimization solvers for convergence.

4.5.1 Demand curve will be used to procure FRP to meet uncertainty

The power balance penalty cost function:

Power Balance MW violation	Penalty ($/MWh)
-300 to 0	$-155
0 to 400	$1000

The net load forecast error probability distribution function:

Net Load Forecast Error MW bin	Probability
-300 to -200	1%
-200 to -100	2%
-100 to 0	44.8%
0 to 100	50%
100 - 200	1.4%
200 - 300	0.5%
300 - 400	0.3%

For optimization efficiency, it is better to construct the demand curve as a demand response (requirement reduction) assigned to a surplus variable as shown in the objective function formula above. This is the mirror image of the demand curve across the vertical axis and can be constructed integrating the histogram from the maximum surplus towards the center.

The cost function for the FRU/FRD surplus is derived from the histogram as follows:

FRP (MW)		Surplus (MW)		Probability	Penalty ($/MWh)	Demand Curve Price ($/MWh)
-200	-300	0	-100	0.01	–155	(.01/2) (-155) = –$.79
-100	–200	-100	-200	0.02	–155	(.02/2 + .01) (-155) = -$3.10
0	–100	-200	-300	0.448	–155	(.448/2 + .02 + .01) (–155) = –$39.37
0	100	300	400	0.5	1,000	(.5/2 + .014 +.005 +.003) 1000 = $272.00
100	200	200	300	0.014	1,000	(.014/2 +.005 +.003) 1000 = $15.00
200	300	100	200	0.005	1,000	(.005/2 + .003) 1000 = $5.50
300	400	0	100	0.003	1,000	(.003/2) 1000 = $1.50
Start	End	Start	End	Probability	Penalty ($/MWh)	Demand Curve Price ($/MWh)

The step size that is used to discretize the net load forecast error distribution function and the corresponding flexible ramping product demand curve may change size depending on the distribution of errors. In the event the demand curve is non-monotonic, the ISO will set each non-monotonic price segment at the last monotonic segment price.

5. Flexible ramping resource constraints

5.1 Resource ramping capability constraints

FRP will be procured based on a constraint by its ramping capability within an interval:

$$\left.\begin{array}{l} 0 \leq FRU_{i,t} \leq RRU_i(EN_t, T_5) \\ RRD_i(EN_t, T_5) \leq FRD_{i,t} \leq 0 \end{array}\right\} \forall i, t = 1,2, \dots, N-1$$

For implementation, it is advantageous to use the same time domain for the *RRU*() and *RRD*() dynamic ramp functions, and since the energy schedules are constrained by cross-interval ramps, the FRU/FRD ramp constraints can be expressed on the same time domain for all market applications as follows:

$$\left.\begin{array}{l} 0 \leq AF\ FRU_{i,t} \leq RRU_i(EN_t, T) \\ RRD_i(EN_t, T) \leq AF\ FRD_{i,t} \leq 0 \end{array}\right\} \forall i, t = 1,2, \dots, N-1$$

Where *T* is the relevant market interval duration:

$$T = \begin{cases} T_5 & \text{in RTD} \\ T_{15} & \text{in RTUC} \end{cases}$$

And the averaging factor is defined as follows:

$$AF = \begin{cases} 1 & \text{in RTD} \\ \dfrac{T_{15}}{T_5} & \text{in RTUC} \end{cases}$$

T	Time interval.
T_5	RTD time interval (5min).
T_{15}	RTUC time interval (15min).
AF	Averaging factor.
$FRU_{i,t}$	Flexible Ramp Up award of Resource *i* in time period *t*.
$FRD_{i,t}$	Flexible Ramp Down award (non-positive) of Resource *i* in time period *t*.
$RRU_i(EN,T)$	Piecewise linear ramp up capability function of Resource i for time interval T.
$RRD_i(EN,T)$	Piecewise linear ramp down capability function (non-positive) of Resource i for time interval T.

5.2 Resource capacity constraints

A resource must have an energy bid to be eligible for FRP. Also, the resource's schedule must not be in a forbidden operating region or in a state of transition if it is a multi-stage generator.

The relevant capacity constraints for an online resource on regulation are as follows:

$$\left.\begin{array}{l}\max\left(LOL_{i,t+1}, LRL_{i,t+1}\right) \leq EN_{i,t} + AF\ FRD_{i,t} + RD_{i,t+1} \\ EN_{i,t} + AF\ FRU_{i,t} + NR_{i,t+1} + SR_{i,t+1} + RU_{i,t+1} \leq \min\left(UOL_{i,t+1}, URL_{i,t+1}, CL_{i,t+1}\right) \\ LEL_{i,t+1} - AF\ FRD_{i,t} \leq EN_{i,t} \leq UEL_{i,t+1} - AF\ FRU_{i,t}\end{array}\right\} \forall i, t$$
$$= 1,2, \ldots, N-1$$

The relevant capacity constraints for an online resource not on regulation are as follows:

$$\left.\begin{array}{l}LOL_{i,t+1} \leq EN_{i,t} + AF\ \left(FRU_{i,t} + FRD_{i,t}\right) \\ EN_{i,t} + AF\ \left(FRU_{i,t} + FRD_{i,t}\right) + NR_{i,t+1} + SR_{i,t+1} \leq \min\left(UOL_{i,t+1}, CL_{i,t+1}\right) \\ LEL_{i,t+1} - AF\ \left(FRU_{i,t} + FRD_{i,t}\right) \leq EN_{i,t} \leq UEL_{i,t+1} - AF\ \left(FRU_{i,t} + FRD_{i,t}\right)\end{array}\right\} \forall i, t$$
$$= 1,2, \ldots, N-1$$

AF	Averaging factor.
$UOL_{i,t}$	Upper Operating Limit of Resource *i* in time period *t*.
$LOL_{i,t}$	Lower Operating Limit of Resource *i* in time period *t*.
$URL_{i,t}$	Upper Regulating Limit of Resource *i* in time period *t*.
$LRL_{i,t}$	Lower Regulating Limit of Resource *i* in time period *t*.
$UEL_{i,t}$	Upper Economic Limit of Resource *i* in time period *t*.
$LEL_{i,t}$	Lower Economic Limit of Resource *i* in time period *t*.
$CL_{i,t}$	Capacity Limit for Resource *i* in time period *t*; $LOL_{i,t} \leq CL_{i,t} \leq UOL_{i,t}$; it defaults to $UOL_{i,t}$.
$EN_{i,t}$	Energy schedule of Resource *i* in time period *t* (positive for supply and negative for demand).
$RU_{i,t}$	Regulation Up award of Resource *i* in time period *t*.
$RD_{i,t}$	Regulation Down award (non-positive) of Resource *i* in time period *t*.
$SR_{i,t}$	Spinning Reserve award of Resource *i* in time period *t*.
$NR_{i,t}$	Non-Spinning Reserve award of Resource *i* in time period *t*.
$FRU_{i,t}$	Flexible Ramp Up award of Resource *i* in time period *t*.
$FRD_{i,t}$	Flexible Ramp Down award (non-positive) of Resource *i* in time period *t*.

6. Properties of flexible ramping

This section presents simple examples of FRP to demonstrate the properties and benefits of flexible ramping under the assumption that net load is accurately predicted.

These examples will show:

- The market's multi-interval look-ahead optimization, which currently produces a "composite" energy price, which consists of a pure energy price and a ramping price. The composite energy price may not be consistent with the resource's energy offer price if only the binding interval is settled, and may trigger bid cost recovery. The composite energy price is also very sensitive to deviations from the expected net system demand level because there is no dispatch margin built in the optimization. The composite energy price can be very volatile.
- FRP can decompose the pure energy price and flexible ramping prices, and provide more transparent and less volatile price signals. These prices are also more consistent with the energy offers, and reduce the need for bid cost recovery. These are advantages of FRP even if net system demand could be predicted with high accuracy.

For simplicity, the examples will only consider the interaction between energy and the flexible ramping product, and ignore ancillary services.

6.1 Upward flexible ramping

Assume there are two 500 MW online resources in the system that could provide FRU. The bids and parameters of the two generators are listed in Table 1. G1 has 100 MW/minute ramp rate, and G2 has 10 MW/minute ramp rate. G1 is more economic in energy than G2. They both have zero cost bids for providing flexible ramping.

TABLE 1: RESOURCE BIDS, INITIAL CONDITION AND OPERATIONAL PARAMETERS

Generation	Energy Bid	Initial Energy	Ramp Rate	Pmin	Pmax
G1	$25	400 MW	100 MW	0	500 MW
G2	$30	0	10 MW	0	500 MW

Scenario 1: Single interval RTD optimization without upward flexible ramping with load at 420 MW.

In scenario 1, load is met by the most economic resource G1, and G1 sets the LMP at $25.

TABLE 2: SINGLE-INTERVAL RTD DISPATCH WITHOUT UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$25)	
Generation	**Energy**	**Flex-ramp up**
G1	420 MW	-
G2	0 MW	-

Scenario 2: Single interval RTD optimization with upward flexible ramping with load at 420 MW

and an upward flexible ramping requirement at 170 MW.

The solution for scenario 2 is listed in Table 3. In scenario 2, in order to meet 170 MW upward flexible ramping, G1 is not dispatched for as much energy to make room for upward flexible ramping. As a result, G1 does not have extra capacity to meet extra load, and LMP is set by G2 at $30. The upward flexible ramping requirement caused the LMP to increase compared with scenario 1. FRU price is set by G1's energy opportunity cost $30 – $25= $5.

TABLE 3: SINGLE-INTERVAL RTD DISPATCH WITH UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$30, FRUP=$5)	
Generation	**Energy**	**Flex-ramp up**
G1	380 MW	120 MW
G2	40 MW	50 MW

Scenario 3: Two-interval RTD optimization without upward flexible ramping with load (t) at 420 MW and load (t+5) at 590 MW.

The solution for scenario 3 is listed in Table 4. In scenario 3, there is no flexible ramping requirement. However, the look-ahead optimization projects a 170 MW of upward load ramp from interval t to t+5, which equals the upward flexible ramping requirement in scenario 2. The look-ahead optimization produces the same dispatch for interval t as in scenario 2, but different LMPs. The LMPs are different because there is an interaction between the energy price and flexible ramping price. Without the flexible ramping product, the look-ahead optimization still holds G1 back in interval t to meet the load in interval t+5, but G1 is still the marginal unit in interval t and sets the LMP at $25. G2 is the marginal unit for interval t+5 and sets the non-binding LMP for interval t+5 at $35 ($30 bid cost in interval t+5 plus $5 not bid cost not recovered in interval t).

TABLE 4: LOOK-AHEAD RTD DISPATCH WITHOUT UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$25)	**Interval t+5 (LMP=$35)**
Generation	**Energy**	**Energy**
G1	380 MW	500 MW
G2	40 MW	90 MW

Scenario 4: Two-interval RTD optimization with upward flexible ramping with load (t) at 420 MW and load (t+5) at 590 MW. The upward flexible ramping requirement at (t) is 170.01 MW.

In scenario 4, both flexible ramping and look-ahead are modeled in the optimization. In order to have uniquely determined prices, we set upward flexible ramping requirement slightly higher than expected load ramp 170 MW. The results are listed in Table 5 which converge to scenario 2 in the first interval. If the flexible ramping requirement is slightly lower than the expected load ramp, the solution would converge to scenario 3.

TABLE 5: LOOK-AHEAD RTD DISPATCH WITH FRU REQUIREMENT SLIGHTLY HIGHER THAN EXPECTED UPWARD LOAD RAMP

	Interval t (LMP=$30, FRUP=$5)		Interval t+5 (LMP=$30)	
Generation	**Energy**	**Flex-ramp up**	**Energy**	**Flex-ramp up**
G1	379.99 MW	120.01 MW	500 MW	-
G2	40.01 MW	50 MW	90 MW	-

TABLE 6: POSSIBLE LOOK-AHEAD RTD DISPATCH WITHOUT FLEXIBLE RAMPING IN INTERVAL T+5

Interval t+5	Load = 589.99 MW	Load = 590.01 MW
G1	500 MW	500 MW
G2	89.99 MW	90 MW
LMP	$30/MWh	$1000/MWh

6.2 Downward flexible ramping

Assume two 500 MW resources are online in the system that can provide flexible ramping. The bids and parameters of the two generators are listed in Table 7. G1 has 10 MW/minute ramp rate, and G2 has 100 MW/minute ramp rate. G1 is more economic in energy than G2. They both have zero cost for providing flexible ramping.

TABLE 7: RESOURCE BIDS, INITIAL CONDITION AND OPERATIONAL PARAMETERS

Generation	Energy Bid	Flex Ramp Up	Flex Ramp Down	Energy Initial	Ramp rate	Pmin	Pmax
G1	$25	0	0	300 MW	10 MW/min	0	500 MW
G2	$30	0	0	100 MW	100 MW/min	0	500 MW

Scenario 1: Single interval RTD optimization without downward flexible ramping with load at t = 380 MW

The solution for scenario 1 is listed in Table 8. In scenario 1, load is met by both G1 and G2, and G2 sets the LMP at $30. Although G1 is more economic than G2, its output 350 MW has been limited by its ramp rate 10 MW/minute from its initial condition 300 MW, so it cannot set the LMP.

TABLE 8: SINGLE-INTERVAL RTD DISPATCH WITHOUT DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$30)	
Generation	**Energy**	**Flex-ramp down**
G1	350 MW	-
G2	30 MW	-

Scenario 2: Single interval RTD optimization with downward flexible ramping with load at t = 380 MW and downward flexible ramping requirement at t = 170 MW

The solution for scenario 2 is listed in Table 9. In scenario 2, in order to meet 170 MW downward flexible ramping, G2 needs to be dispatched up in order to provide downward flexible ramping. As a result, G1's output will be reduced in order to maintain the power balance, and G1 sets the LMP at $25. Note the downward flexible ramping requirement causes the LMP to decrease compared with scenario 1. The downward flexible ramping price FRDP is set by G2's energy price deficit $30 – $25= $5. The FRDP price is to compensate G2 such that G2's revenue including both energy and FRD can cover its energy bid cost $30. As a result, there is no revenue shortage for G2, and no need for bid cost recovery.

TABLE 9: SINGLE-INTERVAL RTD DISPATCH WITH DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$25, FRDP=$5)	
Generation	**Energy**	**Flex-ramp down**
G1	260 MW	50 MW
G2	120 MW	120 MW

Scenario 3: Two-interval RTD optimization without downward flexible ramping with load at t = 380 MW and load at t+5 = 210 MW.

The solution for scenario 3 is listed in Table 10. In scenario 3, there is no FRD requirement. However, the look-ahead optimization projects a 170 MW of downward load ramp from interval t to t+5, which equals the downward flexible ramping requirement in scenario 2. The look-ahead optimization produces the same dispatch for interval t as in scenario 2, but different LMPs. The dispatch is the same because the look-ahead load ramp also requires the same amount of ramping capability as the flexible ramping requirement in interval t. The LMPs are different because there is an interaction between the energy price and flexible ramping price. When net system demand is decreasing, which creates more downward ramp need, the look-ahead optimization will increase the energy price in the binding interval (for similar but opposite reasons as described in the FRU example in scenario 3 in the preceding section 6.1).

TABLE 10: LOOK-AHEAD RTD DISPATCH WITHOUT DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$30)		Interval t+5 (LMP=$20)	
Generation	**Energy**	**Flex-ramp down**	**Energy**	**Flex-ramp down**
G1	260 MW	-	210 MW	-
G2	120 MW	-	0	-

Scenario 4: Two-interval RTD optimization with downward flexible ramping with load t = 380 MW and load at t+5 = 210 MW. The downward flexible ramping requirement at (t) is 170.01.

In scenario 4, both flexible ramping and look-ahead are modeled in the optimization. In order to have uniquely determined prices, we set downward flexible ramping requirement slightly higher than expected load ramp 170 MW. The solution for scenario 4 is listed as Table 11.

TABLE 11: LOOK-AHEAD RTD DISPATCH WITH FRD REQUIREMENT SLIGHTLY HIGHER THAN EXPECTED DOWNWARD LOAD RAMP

	Interval t (LMP= $25 , FRDP= $5)		Interval t+5 (LMP=$25 , FRDP= $0)	
Generation	**Energy**	**Flex-ramp down**	**Energy**	**Flex-ramp down**
G1	259.99 MW	50 MW	210 MW	-
G2	120.01 MW	120.01 MW	0 MW	-

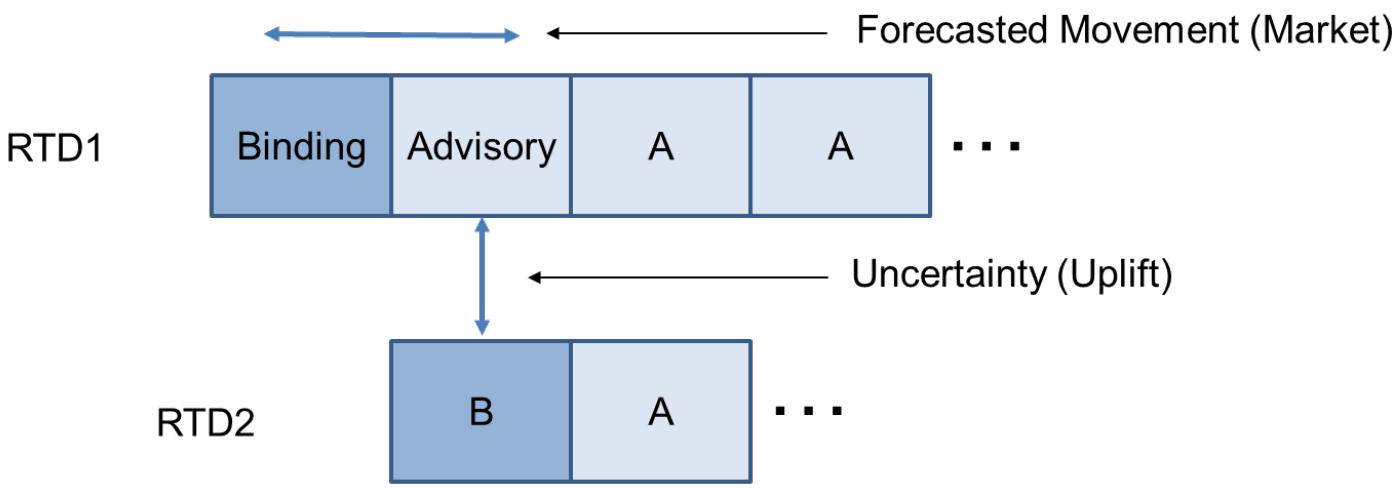
7. Settlement

The ISO will financially settle FRP in the fifteen-minute market and the five-minute market. The financial settlement of FRP is separated into two settlement calculations:

- A direct settlement in the market for all forecasted movement.
- A settlement for FRP procured for uncertainty, based on observed load and non-dispatchable resource forecast error, allocated at the end of the month through an uplift.

Figure 10 below shows two RTD runs and illustrates the difference between the FRP procured for forecasted movement settled directly in the market and the FRP procured for uncertainty allocated at the end of the month through an uplift. The forecasted movement will be settled in every FMM or RTD settlement interval and will be the difference between the "horizontal" binding and advisory intervals. Uncertainty will be settled monthly through the difference of the "vertical" binding and advisory intervals.

FIGURE 10 BINDING AND ADVISORY INTERVAL REPRESENTATION



The market will enforce a single requirement for each direction of the flexible ramping product (i.e. FRU, FRD) which covers both forecasted movement and uncertainty. This results in a single price for ramping capability to cover both forecasted movement and uncertainty.

The FRP settlement for forecasted movement will be paid and charge in each settlement interval with the same settlement timing as energy imbalances. The FRP settlement for uncertainty will be paid and charged at the end of the month to eliminate the need for a monthly resettlement.

7.1 Direct settlement for forecasted movement

Forecasted movement will be settled in FMM at the FMM price. Any difference between FRP procured for the FMM forecasted movement and the RTD forecasted movement will be settled at the RTD FRP price. Note that the granularity difference between FMM and RTD can cause differences between the FMM awards and RTD awards. The same issue exists with energy settlements today.

For dispatchable and non-dispatchable supply, the settlement is calculated by resource for each 15-minute FMM and 5-minute RTD settlement interval. The ISO uses its forecast[3] for variable energy resources' output to clear the market but provides the option for variable energy

[3] In the energy imbalance market, the EIM entity must provide an independent third party forecast. This forecast is then used in the market. If the EIM entity does not have an independent third party forecast, the ISO will use its forecast provider.

resources to use their own forecast to schedule energy. The ISO will only use the ISO's forecast to calculate ramping awards for variable energy resources. This is to mitigate against variable energy resources adjusting the forecast of the advisory interval to receive payment for ramp. VERs could do this without financial cost because the advisory energy schedules are not financially binding.

For interties, the settlement is calculated for each schedule for each 15-minute and 5-minute settlement interval based upon the prescribed ramps. Hourly schedule changes have a 20 minute ramp. 15-minute schedule changes have a 10 minute ramp. The granularity differences between FMM and RTD will result in ramp settlement even if though a static intertie schedule cannot be changed in RTD. In addition, operational adjustments should be reflected prior to the start of the RTD optimization covering the relevant FMM interval; therefore, this change can be reflected in the forecasted movement of RTD is not a cause of uncertainty.

Table 11 illustrates the upward FRP settlement in both FMM and RTD for an hourly intertie schedule that is ramping from 100 MW in HE 02 to 150 MW in HE 03. The schedule change will result in settlements at both the FMM and RTD FRU price. This accurately reflects the upward ramping value the hourly intertie change provides, as the real-time market schedules and dispatches resources to meet current system conditions.

TABLE 11 INTERTIE MOVEMENT SETTLEMENT IN RTD AND FMM

	HE 02						HE 03					
	RTD7	RTD8	RTD9	RTD10	RTD11	RTD12	RTD1	RTD2	RTD3	RTD4	RTD5	RTD6
Prescribed hourly ramp (Avg. MW)	100.00	100.00	100.00	100.00	106.25	118.75	131.25	143.75	150.00	150.00	150.00	150.00
	FMM3			FMM4			FMM1			FMM2		
FMM Non-Dispatchable Energy	100.00			108.33			141.67			150.00		
FMM Ramp Award (MW)	8.33			33.33			8.33			0.00		
FMM Ramp Award (MW)	2.78	2.78	2.78	11.11	11.11	11.11	2.78	2.78	2.78	0.00	0.00	0.00
RTD Incremental Ramp Award (MW)	-2.78	-2.78	-2.78	-4.86	1.39	1.39	9.72	3.47	-2.78	0.00	0.00	0.00
Final Ramp	0.0	0.0	0.0	6.25	12.5	12.5	12.5	6.25	0.00	0.00	0.00	0.00

Unlike supply and interties, load cannot be settled directly for forecasted movement with a Scheduling Coordinator (SC) because the ISO load forecast that is used to clear the market is aggregated for each balancing authority area. Therefore, all payments and charges to load based upon the ISO market forecast will be allocated based on load ratio share for each 5-minute settlement interval for each balancing authority area.

7.2 Rescission of payments for FRP awards

Since dispatchable resources, non-dispatchable resources, interties, and load will all be awarded and compensated for FRP, the ISO is proposing a consistent approach to address the potential double payment of opportunity costs. The double payment arises when a resource is awarded FRP and is then subsequently settled for uninstructed imbalance energy. For example, assume a resource's energy bid is $30/MWh and the market clearing LMP was $40. If the resource was awarded FRU, it would be paid no less than $10 for the FRU award. If the resource then deviated above its binding dispatch, the resource would incur positive uninstructed imbalance energy and be paid at the 5-minute LMP of $40. This would result in a profit of $10 which would be the same as the opportunity cost used to compensate the FRU award which assumed the resource would be at it dispatch operating target.

For each settlement interval in which a resource is awarded FRP, the ISO will determine if the resource was double paid by comparing uninstructed imbalance energy (UIE) to the FRP award. If the resource's final meter indicates that the resource has uninstructed imbalance energy deviation or operational adjustment that overlaps with the reserved FRP awarded capacity, the ISO will rescind this portion of the FRP award. The FRP rescission quantity will be charged at the five-minute market FRP price. The FRP rescission quantity will be first assessed against the resource's FRP uncertainty awards and then against the FRP movement awards.

The rescinded FRP amount for forecasted movement will be charged in each settlement interval with the same settlement timing as energy imbalances. The rescinded FRP amount for uncertainty will be charged at the end of the month to eliminate the need for a monthly resettlement since uncertainty costs are allocated monthly.

The rescinded FRP amounts for forecasted movement will be paid to the resources which were directly charged in proration to their forecasted movement in the binding RTD interval. The rescinded FRP amounts for uncertainty will be netted against the FRP uncertainty payments prior to monthly allocation to load, supply, and interties as discussed in the next section.

7.3 Monthly settlement of uncertainty

Unlike forecasted movement, there is no counterparty to directly charge in the financially binding interval for FRP procured for uncertainty. Uncertainty is procured to address the potential for differences in net load when the advisory interval becomes financially binding in the subsequent market run. This difference occurs when uncertainty is realized in a future interval. Since the additional ramping capability is similar to insurance, it is appropriate to not allocate cost for a given realization of uncertainty, but over a period of time. Therefore, the cost (payment to dispatchable resources) will be allocated at the end of the month through an uplift.

The FRP for uncertainty awards will be settled with dispatchable resources at the applicable binding interval FMM or RTD price at the end of the month. The ISO had previously proposed settling these on a daily basis and initially allocating the costs to load and resources according to the relevant billing determinant. By not paying the uncertainty awards immediately, there is no need to perform a monthly resettlement because the payment to a resource and the cost allocation will occur in the same settlement period. This is a significant simplification of the settlements implementation.

In addition, payment rescissions to dispatchable resources for uninstructed imbalance energy that would provide a double payment as discussed in the previous section will be charged at the end of the month. The payment rescission will be settled at applicable binding interval RTD price in which the payment rescission occurred.

To the extent that the sum of the Settlement amounts for Flexible Ramp Up Uncertainty Settlement Amount, Flexible Ramp Down Uncertainty Settlement Amount, Flexible Ramp Up

Uncertainty Rescission Amount, Flexible Ramp Down Uncertainty Rescission Amount, Flexible Ramp Up Uncertainty Allocation Amount, and Flexible Ramp Down Uncertainty Allocation Amount does not equal zero, the ISO will assess the resulting differences to all SCs with metered demand within the balancing authority area.

7.3.1 Allocation of uncertainty

The ISO proposes settling the uncertainty for two groups of trade hours. In the assessment of grid management charge (GMC) prior to the 2010 GMC redesign, the ISO identified a GMC bucket for charging load based upon Non-Coincident Peak hours and Non-Coincident Off Peak Hours. Non-Coincident Peak Hours is defined as trading hours ending 7 through 22 for all trading days within a trading month, whereas Non-Coincident Off Peak Hours is defined as trading hours ending 1 through 6 and trading hours 23 through 25 for all trading days within a trading month. For each group of the hour, the FRP for uncertainty uplift cost is the sum of the monthly payments to dispatchable resources less monthly payment rescissions charges to dispatchable resources in the each bucket of trading hours. The total FRP for uncertainty uplift cost is first allocated between the load, supply, and intertie categories. The respective uplift costs allocated to the load, supply, and intertie categories are then allocated to individual resources or loads using a different billing determinate method for each category.

The initial allocation of FRP uncertainty uplift costs between the load, supply, and intertie categories is determined by calculating the “vertical” binding – advisory as shown in figure 10. This difference will be calculated for all non-dispatchable[4] changes in supply resources, interties[5] and load for each 5-minute interval. There is no netting between 5-minute intervals, so in each 5-minute interval there will be either a FRU value or an FRD value. Table 12 below illustrates whether the observed net load error will split FRU or FRD costs. “A” is the advisory interval in the first RTD run and “B” is the binding interval from the second RTD run.

The initial allocation of FRP uncertainty uplift costs between the load, supply, and intertie categories is determined by calculating the “vertical” binding – advisory as shown in Figure 10. This difference will be calculated for all non-dispatchable resources, interties and load for each 5-minute interval. There is no netting between 5-minute intervals, so in each 5-minute interval there will be either a FRU value or an FRD value. Table 12 below illustrates whether the observed net load error will be used to split FRU or FRD costs. “A” is the advisory interval in the first RTD run and “B” is the binding interval from the second RTD run.

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4 Only non-dispatchable resources can have forecast errors between the two market runs. A dispatchable resource could have differences between the two market runs, but this is in response to market instructions not a result a forecast error of that resources.

5 Only operational adjustments that occur after RTD initializes will result in a forecast error. Once the operational adjustment is reflected in RTD, it is settled as part of the forecasted movement.

TABLE 12 ALLOCATION OF UNCERTAINTY UPLIFT COSTS BETWEEN FRU AND FRD

	FRU	FRD
Load	A-B > 0	A-B < 0
Supply	A-B < 0	A-B > 0
Interties (Net import in B)	A-B < 0	A-B > 0
Interties (Net export in B)	A-B > 0	A-B < 0

*For load and exports the values of A and B are negative

The load forecast is a single value for each balancing authority area, therefore the forecast error nets errors resulting from individual load serving entities. The load will have a single FRU or FRD value for each settlement interval per balancing authority area based on the ISO forecast between "vertical" advisory – binding interval shown in Figure 10. When splitting the costs into each category, supply and interties must also have a single FRU or FRD value for each settlement interval per balancing authority area. This is accomplished by netting all resources within the supply category and separately netting all intertie schedules within the intertie category to then calculate a single value for each of the categories.

There will be 4 monthly costs that will be allocated: FRU Peak, FRD Peak, FRU Off Peak, and FRD Off Peak. The FRU and FRD values in each 5-minute interval for each category are summed for the month over each range of trading hours. Then each category is allocated its pro-rata share of the monthly FRP costs. The each category allocates its four costs according to its own billing determinant.

1. Load is allocated to each SC based on the pro-rata share of gross UIE over the month. There is no netting between settlement intervals. Negative (increased consumption) UIE is allocated FRU and positive (decreased consumption) UIE is allocated FRD. If a load uses five minute metering, such as load following metered sub-systems, then the load would be included within the supply category.
2. Supply is allocated by calculating the observed forecast error (the vertical advisory – binding) plus any uninstructed imbalance energy. Each resource is allocated its pro-rata share of gross (A-B-UIE) for over the month for each cost bucket. There is no netting between settlement intervals. Positive (A-B-UIE) is allocated FRU and negative (A-B-UIE) is allocated FRD. Uninstructed imbalance energy was included to provide an additional incentive for dispatchable resources to follow their dispatch instruction. If UIE persists, this can increase the need for ramping capability.
3. Intertie category is allocated to each SC based upon the pro-rata share of gross operational adjustment in each cost bucket over the month. Uncertainty costs for interties will be small. The uncertainty is realized only if an operational adjustment occurs after the binding RTD interval prior to the start of the next RTD interval. Otherwise, the operational adjustment will be resettled as a forecasted movement in RTD. Most operational adjustments occur prior to the start of the operating hour and will be settled through the forecasted movement deviation between FMM and RTD.

7.4 Settlement Examples

The examples in tables 13-16 show the energy and FRP settlement for supply, load and interties scheduled for energy and awarded FRP.

Table 13 illustrates the real-time market energy settlement for each resource type for FRU when load is increasing. Generator 1 is awarded 100 MW of FRU but provided an additional 50 MW which was reported by the meter. Therefore, Generator 1 will be paid 100 MW of the FRU award and charged 50 MW as a payment rescission. Generator 2 is awarded 50 MW of FRU uncertainty and 900 MW of FRU movement. The meter showed that Generator 2 produced 75 MW which is 25 MW more than the awarded uncertainty, in which 25 MW will be charged to the generator as a payment rescission. Load is charged 1000 MW of FRU but will also be paid the 75 MW that was rescinded from generators 1 and 2.

Table 14 illustrates the real-time market energy settlement for each resource type for FRU when actual metered load was lower than what was forecasted. In this example, load was forecasted at 1000 MW but the meter showed that it was 150 MW lower than what was forecasted. Load will be paid 1000 MW FRU but charged 150 MW rescission. The generators will be allocated pro-rata share of this 150 MW rescission charge from load. The payment rescission basis for generators 1 and 2 will be the product of the 150 MW that was below forecast and the amount of FRU awarded to the generator divided by the total FRU awarded.

Tables 15 and 16 illustrate the real-time market energy settlement for FRD under the same scenario for load changes. The results of each resource types' awards and rescissions are calculated in a similar manner as tables 13 and 14.

Table 13 Flexible Ramp Up Settlement with Rescission (Load Forecast Increase)

Resource Type	FRU Uncertainty Award (MW)	FRU Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRU Uncertainty Rescission Quantity (MW)	FRU Movement Rescission Quantity (MW)	FRU Uncertainty Settlement ($)*	FRU Uncertainty Rescission ($)*	FRU Movement Settlement ($)	FRU Movement Rescission ($)
Gen 1	0	100	50	0	50	0	0	100 MW FRU Payment	50 MW FRU Rescission Charge
Gen 2	50	900	75	50	25	50 MW FRU Payment	50 MW FRU Rescission Charge	900 MW FRU Payment	25 MW FRU Rescission Charge
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	0			0	0	1000 MW FRU Charge	75 MW FRU Rescission Payment

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

TABLE 14 FLEXIBLE RAMP UP SETTLEMENT WITH RESCISSION (LOAD FORECAST DECREASE)

Resource Type	FRU Uncertainty Award (MW)	FRU Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRU Uncertainty Rescission Quantity (MW)	FRU Movement Rescission Quantity (MW)	FRU Uncertainty Settlement ($)*	FRU Uncertainty Rescission ($)*	FRU Movement Settlement ($)	FRU Movement Rescission ($)
Gen 1	0	100	0	0	0	0	0	100 MW FRU Charge	150 MW * (100/1000) FRU Rescission Payment
Gen 2	0	900	0	0	0	0	0	900 MW FRU Charge	150 MW * (900/1000) FRU Rescission Payment
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	150	0	150**	0	0	1000 MW FRU Payment	150 MW FRU Rescission Charge

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.
** The Actual Meter Load change was less than forecasted.

TABLE 15 FLEXIBLE RAMP DOWN SETTLEMENT WITH RESCISSION (LOAD FORECAST INCREASE)

Resource Type	FRD Uncertainty Award (MW)	FRD Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRD Uncertainty Rescission Quantity (MW)	FRD Movement Rescission Quantity (MW)	FRD Uncertainty Settlement ($)*	FRD Uncertainty Rescission ($)*	FRD Movement Settlement ($)	FRD Movement Rescission ($)
Gen 1	0	100	-50	0	50	0	0	100 MW FRD Payment	50 MW FRD Rescission Charge
Gen 2	50	900	-75	50	25	50 MW FRD Payment	50 MW FRD Rescission Charge	900 MW FRD Payment	25 MW FRD Rescission Charge
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	0			0	0	1000 MW FRU Charge	75 MW FRU Rescission Payment

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

TABLE 16 FLEXIBLE RAMP DOWN SETTLEMENT WITH RESCISSION (LOAD FORECAST INCREASE)

Resource Type	FRD Uncertainty Award (MW)	FRD Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRD Uncertainty Rescission Quantity (MW)	FRD Movement Rescission Quantity (MW)	FRD Uncertainty Settlement ($)*	FRD Uncertainty Rescission ($)*	FRD Movement Settlement ($)	FRD Movement Rescission ($)
Gen 1	0	100	0	0	0	0	0	100 MW FRD Charge	150 MW * (100/1000) FRD Rescission Payment
Gen 2	0	900	0	0	0	0	0	900 MW FRD Charge	150 MW * (900/1000) FRD Rescission Payment
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	-150	0	150**	0	0	1000 MW FRD Payment	150 MW FRD Rescission Charge

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

** The Meter Load change was greater than forecasted.

Attachment F – Addendum to Draft Final Technical Appendix
January 25, 2016

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Flexible Ramping Product

Draft Final Technical Appendix

January 25, 2016

Table of Contents

1. Introduction

This technical appendix documents the proposed design for a market-based flexible ramping product (FRP). The ISO is proposing the FRP to maintain power balance in the real-time dispatch and appropriately compensate ramping capability.

The ISO issued a ~~revised~~ draft final technical appendix on ~~November 16~~December 17, 2015. This addendum to the draft final technical appendix includes ~~clarifications and minor edits from the revised draft.~~ a proposed modification to the formulation for capacity constraints to ensure sufficient ramp is procured to support the projected change in dispatch without over-constraining the dispatch if it is reduced as a result of economic or limit changes. The following clarifications and changes to the FRP design from the ~~June 10~~December 17, 2015 draft have been included:

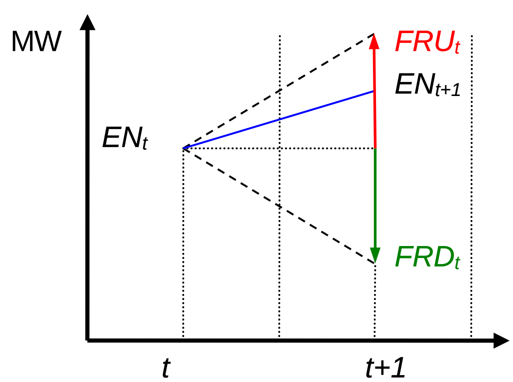
- Modified the capacity constraints (see section 5.2) to allow netting of FRU and FRD to allow for a more flexible dispatch.
- Corrected table 11 which shows the settlement of intertie schedule changes in both FMM and RTD due to hourly schedule changes.

2. Generalized flexible ramping capacity model

This section provides a brief overview of the flexible ramping capacity model in order to illustrate the flexible ramping procurement concept. For simplicity, the ISO does not include any ancillary services below; however, the full model will include ancillary service constraints.

Figure 1 shows the potential flexible ramping up and down awards for an online resource in time period *t* that can be procured based on the resource's ramping capability from t to t+1.

FIGURE 1: SIMPLIFIED FRP ILLUSTRATION OF CONCEPTUAL MODEL



The dashed lines represent the upward and downward ramping capability of the resource from its energy schedule in time period t. The flexible ramping up and down awards are limited by the ramping capability of the resource. The flexible ramping award may also include capacity that is needed to meet the scheduled ramping needs between t and t+1.

Both energy schedules (EN_t, EN_{t+1}) and flexible ramp awards (FRU_t, FRD_t) are calculated simultaneously by the market optimization engine. The only exception is the initial point (EN_0) of where the resource is scheduled in t-1, which is a fixed input for the ramp to the resource's energy schedule in time period t. These control variables are constrained by the following set of capacity and ramp constraints:

$\cancel{\max(EN_t + FRU_t, EN_{t+1}) \le UEL_{t+1}}$ $\max(EN_t + FRU_t, EN_{t+1}) \le UEL_{t+1}$

$\cancel{\min(EN_t + FRD_t, EN_{t+1}) \ge LEL_{t+1}}$ $\min(EN_t + FRD_t, EN_{t+1}) \ge LEL_{t+1}$

$\cancel{RRD(EN_t, T) \le FRD_t \le 0}$ $RRD(EN_t, T) \le FRD_t \le EN_{i,t+1} - EN_{i,t}$

$\cancel{0 \le FRU_t \le RRU(EN_t, T)}$ $EN_{i,t+1} - EN_{i,t} \le FRU_t \le RRU(EN_t, T)$

$\cancel{RRD(EN_t, T) \le EN_{t+1} - EN_t \le RRU(EN_t, T)}$ $RRD(EN_t, T) \le EN_{t+1} - EN_t \le RRU(EN_t, T)$

$EN_{i,t}$	Energy schedule of dispatchable Resource *i* in time period *t* (positive for supply and negative for demand).
$FRU_{i,t}$	Flexible Ramp Up award (algebraic) of Resource i in time period t.
$FRD_{i,t}$	Flexible Ramp Down award (~~non-positive~~algebraic) of Resource i in time period t.
$UEL_{i,t}$	Upper Economic Limit of Resource i in time period t.
$LEL_{i,t}$	Lower Economic Limit of Resource i in time period t.
$RRU_i(EN, T)$	Piecewise linear ramp up capability function of Resource *i* for time interval duration *T*.
$RRD_i(EN, T)$	Piecewise linear ramp down capability function (non-positive) of Resource *i* for time interval duration *T*.

The FRP will help the system to maintain and use dispatchable capacity. It will be procured to meet five minute to five minute net system demand changes plus uncertainty[1] and will be modeled as a ramping capability constraint. Both the five-minute RTD and fifteen-minute real time unit commitment (RTUC) will schedule FRP throughout their dispatch horizon. Awards will be compensated according to marginal FRP prices in the financially binding RTD interval (the first interval) and in the FMM, which is the financially binding RTUC interval (the second interval). Modeling FRP in RTUC enables the market to commit or de-commit resources as needed to obtain sufficient upward or downward ramping capability.

FRU is allowed to be negative when the resource must be dispatched lower in the next interval because of an upper operating limit derate; similarly, FRD is allowed to be positive when the resource must be dispatched higher in the next interval because of a lower operating limit uprate.

3. Flexible ramping product summary

FRP will be procured and dispatched in both the RTD and RTUC using similar methodologies.

[1] Only resources that are 5-minute dispatchable can be used to meet the uncertainty portion of FRP. For non-dispatchable resources, a resource constraint will limit FRP award to forecasted movement. For interties, FRP awards in FMM will not exceed the forecasted movement because the schedule changes are fixed in RTD.

FRP is designed with specific constraints and ramping requirements to ensure that there is sufficient ramping capability available in the financially binding interval to meet the forecasted net load for the next interval and cover upwards and downwards forecast error or uncertainty of the next interval.

In RTD, the FRU and FRD requirements are determined using the forecasted five minute net demand variation. The forecasted net demand variation is made up of (1) the forecasted net load movement between the binding and first advisory interval and (2) the expected error in the advisory intervals RTD net demand forecast within a 95% confidence interval. The uncertainty for both FRU and FRD will be procured using a demand curve. The upward demand curve will be capped at $247/MW, which is $3/MW less than the contingency reserve relaxation parameter. The downward demand curve will be capped at ($155/MW) with is $3/MW higher than regulation down relaxation parameter.

The probability distribution function for the five minute net demand forecast error is approximated by a histogram constructed from historical observations obtained from consecutive RTD runs over time periods that represents similar real-time conditions. While the historical observations for five minute net demand errors are the foundational data for forecasting the flexible ramping requirement, additional information may be used as the ISO continuously improves the forecast of ramping capability needed. The ISO will describe any additional factors that scale the historical observations in the business practice manual. The net load forecast error sample for a given five-minute interval is calculated as the difference between observed net demand for the binding RTD solution for that interval and forecasted net demand for the corresponding advisory interval of the previous RTD run.

Figure 2 illustrates the FRP requirement when net load is ramping upward in the RTD.

FIGURE 2 FLEXIBLE RAMPING PRODUCT RTD REQUIREMENT ILLUSTRATIVE SINGLE INTERVAL EXAMPLE

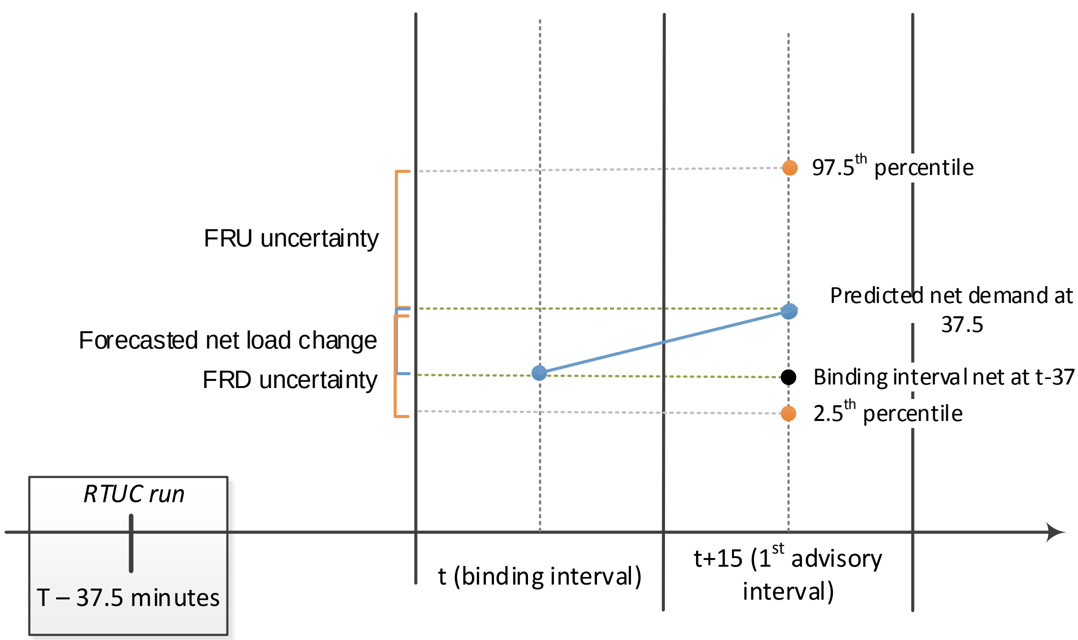


Figure 3 illustrates how the multi-interval optimization will treat FRP in each subsequent advisory interval in the real-time outlook.[2] Each advisory interval will reserve the forecasted net load change between successive advisory intervals and a portion of the predicted net load forecast error uncertainty, using an interval specific demand curve. If the outlook period is within the same hour and therefore the same histogram as the binding interval, the uncertainty portion of the demand curve will be the same in the binding and advisory FRP procurement. Outside of the hour, the uncertainty portion of the demand curve may change because the underlying histogram may be different (e.g. the histogram for 8:00 am may be different than the histogram for 9:00 am.) Therefore, there will be the same uncertainty in each subsequent advisory interval within hour 10:00, but in hour 11:00 the underlying demand curve may change.

The expected net load forecast change will be the difference between each subsequent advisory interval's and the previous adjacent interval's net load. The uncertainty for each advisory interval will be calculated using a net demand forecast within a 95% confidence interval.

FIGURE 3 FLEXIBLE RAMPING PRODUCT RTD REQUIREMENT ILLUSTRATIVE MULTI-INTERVAL EXAMPLE

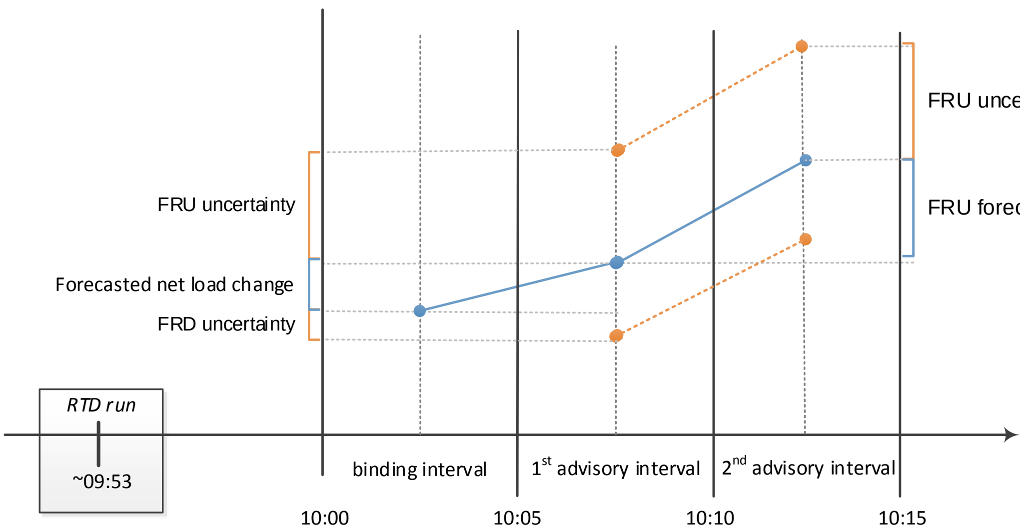
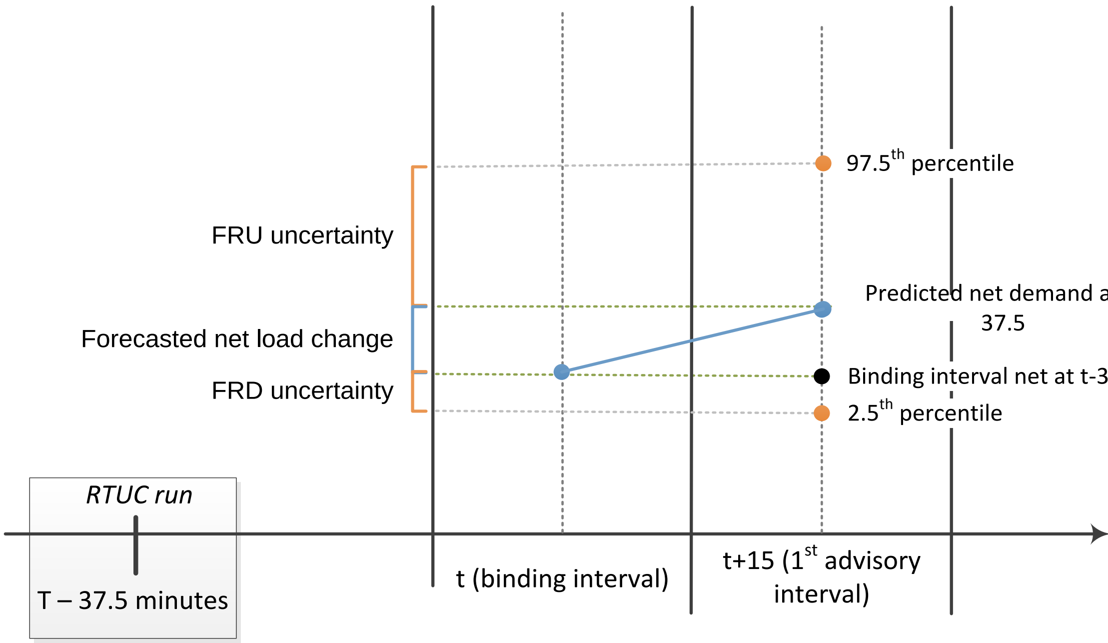


Figure 4 illustrates RTUC FRP procurement for the binding interval. Similar to RTD, in RTUC the FRU and FRD requirements are determined by the forecasted 15-minute net demand variation. The forecasted net demand variation is made up of (1) the forecasted net load change between the binding and first advisory interval and (2) the highest expected error between the RTUC first advisory interval and the associated RTD binding interval within a 95% confidence interval.

[2] RTD looks out between 9 and 13 intervals.

FIGURE 4 FLEXIBLE RAMPING PRODUCT RTUC REQUIREMENT ILLUSTRATIVE EXAMPLE



4. Flexible ramping requirement

4.1 Flexible ramping product total requirement

The FRP total requirement is calculated as the sum of the net demand forecast change across intervals and an additional amount for uncertainty within a 95% confidence interval. The uncertainty will be determined using historical net demand forecast errors and incorporated into a histogram. The histogram will be used to construct a demand curve that the market will use to procure FRP. The market will enforce FRP requirements in all binding and advisory intervals of the RTD and RTUC runs:

$$\left.\begin{array}{l} FRUR_t = FRUR_{\mathrm{ND}t} + FRUR_{\mathrm{U}t} \\ FRDR_t = FRDR_{\mathrm{ND}t} + FRDR_{\mathrm{U}t} \end{array}\right\}, t = 1,2, \dots, N-1$$

t	Time period (interval) index.
N	The number of time periods in the time horizon.
$FRUR_t$	Total Flexible Ramp Up requirement in time period *t*.
$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRUR_{\mathrm{U}t}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_t$	Total Flexible Ramp Down requirement (non-positive) in time period *t*.

$FRDR_{\mathrm{ND}t}$	Flexible Ramp Down requirement (non-positive) due to net demand forecast change in time period *t*.
$FRDR_{\mathrm{U}t}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.

4.2 Flexible ramping requirement for net demand forecast movement

The minimum FRP requirement is the forecasted real ramping need between intervals. For each binding interval, the market will use the requirement below to procure enough flexible ramping need to meet the forecasted net demand in the next advisory interval. Below is the mathematical representation of the minimum ramping requirement.

The flexible ramp requirement due to net demand forecast change exists only in the direction the net demand forecast is changing; it is zero in the opposite direction:

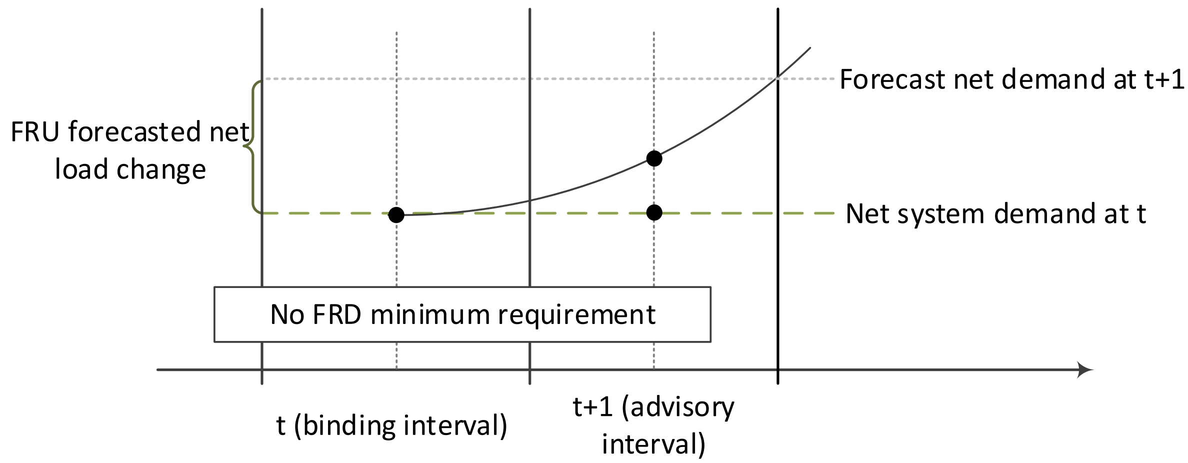
$$\left.\begin{aligned} FRUR_{\mathrm{ND}t} &= \max(0, \Delta ND_t) \\ FRDR_{\mathrm{ND}t} &= \min(0, \Delta ND_t) \end{aligned}\right\}, t = 1,2, \ldots, N-1$$

$$\textbf{Where}: \Delta\mathrm{ND_t} = ND_{t+1} - ND_t$$

ND_t	Net demand forecast in time period *t*.
$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRDR_{Ut}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period t.

The ISO market will only set a FRU or FRD minimum requirement in the event that the forecasted net demand is moving in the same direction as the up or down requirement. Therefore, when the net demand is ramping upward there will not be a minimum FRD requirement, and vice versa. Figure 5 shows an illustrative example of a minimum FRU requirement. In this situation, there is no minimum FRD requirement.

FIGURE 5 FLEXIBLE RAMPING PRODUCT MINIMUM REQUIREMENT



4.3 Flexible ramping requirement due to uncertainty

The ISO market will procure additional flexible ramping capability using the demand curve based on net demand forecast uncertainty of the next interval. If the supply price is lower, FRP will be procured closer to the maximum ramping requirement. If the supply price is higher, FRP will be procured closer to the minimum requirement.

The flexible ramp requirement due to uncertainty is calculated as follows:

$$\left.\begin{array}{l} FRUR_{Ut} = \max(0, EU_t + FRDR_{\mathrm{ND}t}) \\ FRDR_{Ut} = \min(0, ED_t + FRUR_{\mathrm{ND}t}) \end{array}\right\}, t = 1,2,\dots,N-1$$

Where:

$$\left.\begin{array}{l} EU_t = \max(0, PU_t) \\ \displaystyle\int_{-\infty}^{PU_t} p_t(\varepsilon)\, d\varepsilon = CLU \end{array}\right\}, t = 1,2,\dots,N-1$$

$$\left.\begin{array}{l} ED_t = \min(0, PD_t) \\ \displaystyle\int_{-\infty}^{PD_t} p_t(\varepsilon)\, d\varepsilon = CLD \end{array}\right\}, t = 1,2,\dots,N-1$$

$FRUR_{\mathrm{U}t}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_{\mathrm{U}t}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.

$FRUR_{\mathrm{ND}t}$	Flexible Ramp Up requirement due to net demand forecast change in time period *t*.
$FRDR_{\mathrm{ND}t}$	Flexible Ramp Down requirement (non-positive) due to net demand forecast change in time period *t*.
EU_t	Flexible Ramp Up uncertainty at the upper confidence level in time period t.
ED_t	Flexible Ramp Down uncertainty (negative) at the lower confidence level in time period t.
$p_t(\varepsilon)$	Probability distribution function for the average five minute net demand forecast error in time period t, approximated by a histogram compiled from historical observations.
PU_t	Cumulative probability of net demand forecast error at or below the upper confidence level in time period *t*.
PD_t	Cumulative probability of net demand forecast error at or below the lower confidence level in time period *t*.
CLU	Flexible ramp uncertainty upper confidence level, e.g., 97.5%.
CLD	Flexible ramp uncertainty lower confidence level, e.g., 2.5%.

The above formula is illustrated in Figure 6 and Figure 7.

FIGURE 6 FLEXIBLE RAMPING PRODUCT REQUIREMENT DUE TO UNCERTAINTY

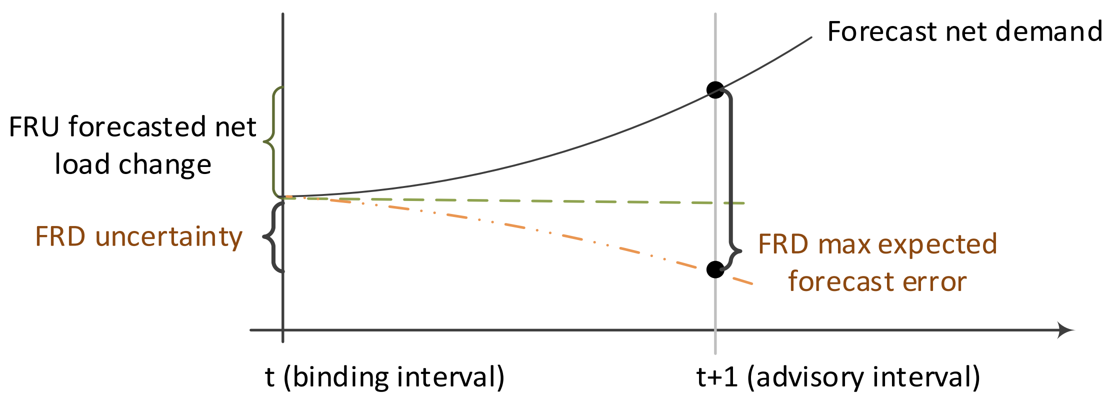
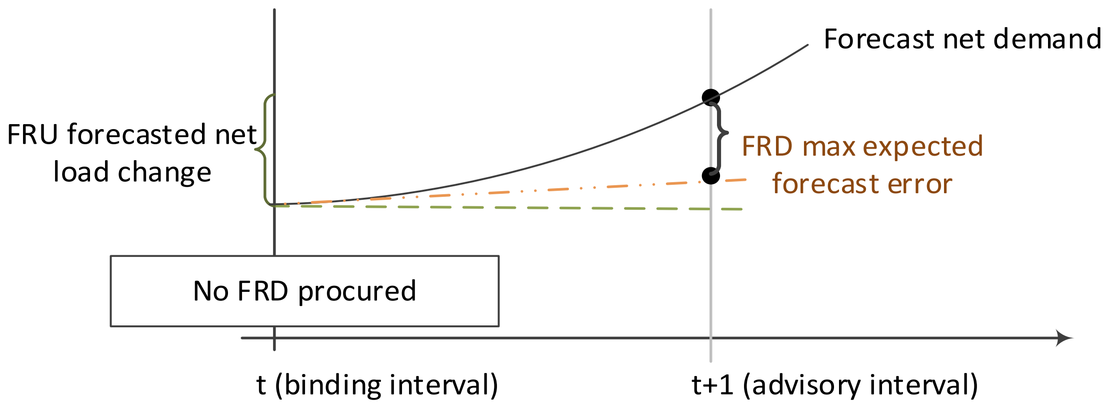


Figure 6 illustrates an interval where the maximum expected downward forecast error (max {ED_t}) is greater than the FRU minimum requirement. The ISO will then procure the portion between the maximum expected forecast error and net load forecast at time t using a demand curve. This is illustrated as the difference between the dashed green line and the dashed orange line.

Figure 7, below, illustrates an interval where the maximum expected downward forecast error (max {ED_t}) is less than the FRU minimum requirement. In this situation the ISO will not need additional FRD capacity.

FIGURE 7: FLEXIBLE RAMPING PRODUCT WITH NO FLEXIBLE RAMPING DOWN MINIMUM OR DEMAND REQUIREMENT

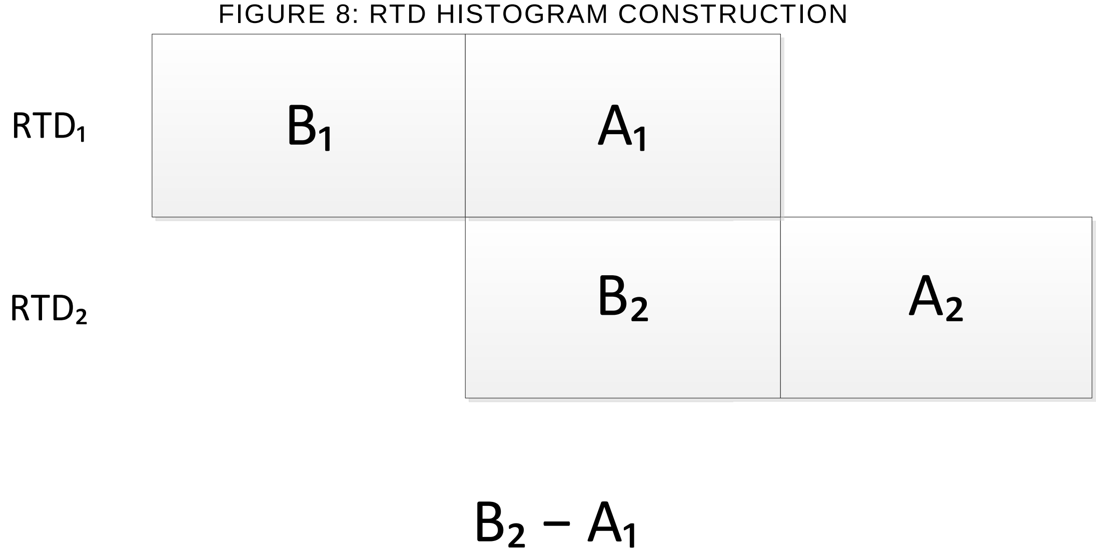


4.3.1 Using historical data to forecast uncertainty

The ISO will construct histograms as an approximation of the probability distribution of net demand forecast errors to be used to procure for uncertainty. It will construct separate histograms for FRU and FRD for each hour, separately for RTD and RTUC.

The histogram for RTD will be constructed by comparing the net demand for the first advisory RTD interval to the net load in the same time interval for the next financially binding RTD run. For example, Figure 8 shows two consecutive RTD 5-minute market runs, RTD_1 and RTD_2. The ISO will construct the histograms by subtracting the net demand from the first market run used for the first advisory interval (A1) from the net demand the second market run used for the binding interval (B_2).

FIGURE 8: RTD HISTOGRAM CONSTRUCTION

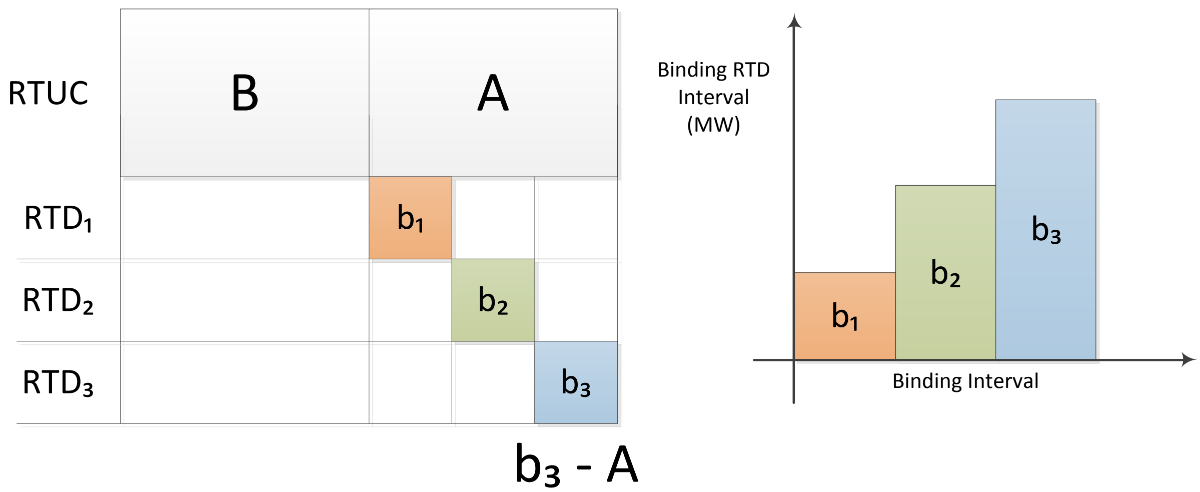


For RTUC, the ISO will construct separate histograms for FRU and FRD as follows:

- For FRU, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the maximum net demand the market used for the three corresponding RTD intervals.
- For FRD, the histograms will be constructed based on the difference of the net demand the market used in the FMM for the first advisory RTUC interval and the minimum net demand the market used for the three corresponding RTD intervals.

Figure 9 shows two RTUC intervals: the FMM (i.e. the RTUC binding interval) and the first advisory interval (labeled "A"). It illustrates how the FRU histogram will be constructed by comparing the net demand the FMM used for first advisory RTUC interval to the maximum net demand the market used for the corresponding three RTD binding intervals (b_1,b_2,b_3).

FIGURE 9: HISTOGRAM CONSTRUCTION IN RTUC



The FRU histogram will use the observation b_3 – A. This represents the maximum ramping need. The variable b_3, represents the maximum net load in the three RTD intervals. The FRD histogram will use observation b_1 – A as this is the minimum ramping need. Ultimately in this example, the FRD observation is positive and therefore will not be used directly in the demand curve creation. It will however be used to calculate the 95th percentile load forecast error and therefore needs to be captured in the histogram.

The ISO proposes to use a rolling 30 days, with a separate histogram for weekends and holidays, to evaluate the historical advisory RTUC imbalance energy requirement error pattern for each RTUC hour. The ISO will also evaluate if hours with similar ramping patterns could be combined to increase the sample size used in the historical analysis.

4.4 Market interval and Averaging Factor

To present the same mathematical formulation for both RTUC and RTD for simplicity, in the following sections we ignore the buffer interval in RTUC assuming there are *N*–1 FRU/FRD awards in both RTUC and RTD. Furthermore, to make the formulation agnostic to the particular market application, the market interval is defined as follows:

$$T = \begin{cases} T_5 & \text{in RTD} \\ T_{15} & \text{in RTUC} \end{cases}$$

For the same reason, since the FRU/FRD awards in RTUC are three 5min back-to-back awards covering the 15min ramp from one 15min interval to the next, it is convenient to define an averaging factor as follows:

$$AF = \begin{cases} 1 & \text{in RTD} \\ \dfrac{T_{15}}{T_5} & \text{in RTUC} \end{cases}$$

T	Application time interval.
T_5	RTD time interval (5min).
T_{15}	RTUC time interval (15min).
AF	Averaging factor.

Consequently, multiplying the FRU/FRD awards with the averaging factor makes the mathematical formulation applicable to both RTUC and RTD.

~~4.4~~4.5 Flexible ramping product requirement constraints

The requirement constraints for the procurement of FRU/FRD are as follows:

$$\cancel{\left.\begin{array}{l} \sum_i FRU_{i,t} + FRUS_t = FRUR_t \\ \sum_i FRD_{i,t} + FRDS_t = FRDR_t \end{array}\right\}, t = 1,2,\ldots,N-1}$$

$$\left.\begin{array}{l} AF \sum_i FRU_{i,t} + FRUS_t \geq FRUR_t \\ AF \sum_i FRD_{i,t} + FRDS_t \leq FRDR_t \end{array}\right\}, t = 1,2,\ldots,N-1$$

i	Resource index.
AF	Averaging factor.
$FRU_{i,t}$	Flexible Ramp Up award (algebraic) of Resource i in time period t.
$FRD_{i,t}$	Flexible Ramp Down award (~~non-positive~~algebraic) of Resource i in time period t.
$FRUS_t$	Flexible Ramp Up surplus in time period t.
$FRDS_t$	Flexible Ramp Down surplus (non-positive) in time period t.
$FRUR_t$	Total Flexible Ramp Up requirement in time period t.
$FRDR_t$	Total Flexible Ramp Down requirement (non-positive) in time period t.

Where the FRU/FRD surplus variables provide flexible ramp demand response for the entire flexible ramp requirement at an appropriate cost:

$$\left.\begin{array}{l} 0 \leq FRUS_t \leq FRUR_t \\ 0 \geq FRDS_t \geq FRDR_t \end{array}\right\}, t = 1,2,\dots,N-1$$

~~4.5~~4.6 Flexible ramping product objective function

This section describes the objective and cost function of the FRP. The FRP will be procured to meet the predicted net demand variation and uncertainty requirements using a demand curve at the cost of expected power balance violations in absence of FRP.

$$C = \cdots + \sum_{t=1}^{N} \int_{0}^{FRUS_t} C\dot{S}U_t(FRUS_t)\, de + \sum_{t=1}^{N} \int_{0}^{FRDS_t} C\dot{S}D_t(FRDS_t)\, de$$

A surplus variable is used to determine the expected cost of not procuring a portion of the uncertainty. The FRU/FRD surplus cost function for the flexible ramp requirement due to uncertainty is the expected uncertainty multiplied by the relevant energy price cap:

$$\left.\begin{array}{l} CSU_t(FRUS_t) = PC \displaystyle\int_{EU_t - FRUS_t}^{EU_t} \big(e - (EU_t - FRUS_t)\big) * p_t(e)\, de, 0 \leq FRUS_t \leq FRUR_{Ut} \\ CSD_t(FRDS_t) = -PF \displaystyle\int_{ED_t - FRDS_t}^{ED_t} \big(e - (ED_t - FRDS_t)\big) * p_t(e)\, de, 0 \geq FRDS_t \geq FRDR_{Ut} \end{array}\right\},$$

$$t = 1,2,\dots,N-1$$

~~And~~The FRU/FRD demand curve is the incremental FRU/FRD surplus cost function, capped by the applicable FRU/FRD insufficiency administrative price:

$$\left.\begin{array}{l} \left.\begin{array}{l} CDU_t(FRUS_t) = \min\left(FRUP, C\dot{S}U_t(FRUS_t)\right) = \\ \qquad \min\left(FRUP, PC \displaystyle\int_{EU_t - FRUS_t}^{EU_t} p_t(e)\, de\right) \end{array}\right\}, \quad 0 \leq FRUS_t \leq FRUR_{Ut} \\ \left.\begin{array}{l} CDD_t(FRDS_t) = \min\left(FRDP, C\dot{S}D_t(FRDS_t)\right) = \\ \qquad \max\left(FRDP, PF \displaystyle\int_{ED_t - FRDS_t}^{ED_t} p_t(e)\, de\right) \end{array}\right\}, \quad 0 \geq FRDS_t \geq FRDR_{Ut} \end{array}\right\}, t$$

$$= 1,2,\dots,N-1$$

The FRU/FRD demand curve is extended to the total flexible ramp requirement at the applicable FRU/FRD insufficiency administrative price:

$$\cancel{\left.\begin{array}{l}C\dot{S}U_t(FRUS_t) = C\dot{S}U_t(FRUR_{Ut}), FRUR_{Ut} < FRUS_t \leq FRUR_t \\ C\dot{S}D_t(FRDS_t) = C\dot{S}D_t(FRDR_{Ut}), FRDR_{Ut} > FRUS_t \geq FRDR_t\end{array}\right\}, t = 1,2,\ldots,N-1}$$

$$\left.\begin{array}{l}CDU_t(FRUS_t) = FRUP, FRUR_{Ut} < FRUS_t \leq FRUR_t \\ CDD_t(FRDS_t) = FRDP, FRDR_{Ut} > FRUS_t \geq FRDR_t\end{array}\right\}, t = 1,2,\ldots,N-1$$

e	Average 5min net demand forecast error
$p_t(e)$	Probability distribution function for the average 5min net demand forecast error in time period *t*, approximated by a histogram compiled from historical observations.
$\cdot$	Denotes derivative.
$FRUS_t$	Flexible Ramp Up surplus in time period *t*.
$FRDS_t$	Flexible Ramp Down surplus (non-positive) in time period *t*.
$CSU_t(FRUS_t)$	Flexible Ramp Up surplus cost function in time period *t*.
$CSD_t(FRDS_t)$	Flexible Ramp Down surplus cost function in time period *t*.
$FRUR_{Ut}$	Flexible Ramp Up requirement due to uncertainty within specified confidence interval in time period *t*.
$FRDR_{Ut}$	Flexible Ramp Down requirement due to uncertainty within specified confidence interval in time period *t*.
C	Objective function.
PC	Bid Price ceiling, currently $1,000/MWh.
PF	Bid Price floor, currently –$155/MWh.
EU_t	Flexible Ramp Up uncertainty at the upper confidence level in time period t.
ED_t	Flexible Ramp Down uncertainty (negative) at the lower confidence level in time period t.
$CDU_t(FRUS_t)$	Flexible Ramp Up demand curve in time period t.
$CDD_t(FRDS_t)$	Flexible Ramp Down demand curve in time period t.
$FRUP$	Flexible Ramp Up insufficiency administrative price.
$FRDP$	Flexible Ramp Down insufficiency administrative price (negative).
$FRUR_t$	Total Flexible Ramp Up requirement in time period t.
$FRDR_t$	Total Flexible Ramp Down requirement (non-positive) in time period t.

The cost functions and their derivatives above can be approximated using the relevant histogram compiled from historical observations, leading to a stepwise incremental cost function that must be forced to be monotonically increasing for *FRUS* and monotonically decreasing for *FRDS*, as required by market optimization solvers for convergence.

~~4.5.1~~4.6.1 Demand curve will be used to procure FRP to meet uncertainty

The power balance penalty cost function:

Power Balance MW violation	Penalty ($/MWh)
-300 to 0	$-155
0 to 400	$1000

The net load forecast error probability distribution function:

Net Load Forecast Error MW bin	Probability
-300 to -200	1%
-200 to -100	2%
-100 to 0	44.8%
0 to 100	50%
100 - 200	1.4%
200 - 300	0.5%
300 - 400	0.3%

For optimization efficiency, it is better to construct the demand curve as a demand response (requirement reduction) assigned to a surplus variable as shown in the objective function formula above. This is the mirror image of the demand curve across the vertical axis and can be constructed integrating the histogram from the maximum surplus towards the center.

The cost function for the FRU/FRD surplus is derived from the histogram as follows:

FRP (MW)		Surplus (MW)		Probability	Penalty ($/MWh)	Demand Curve Price ($/MWh)
-200	-300	0	-100	0.01	–155	(.01/2) (-155) = –$.79
-100	–200	-100	-200	0.02	–155	(.02/2 + .01) (-155) = -$3.10
0	–100	-200	-300	0.448	–155	(.448/2 + .02 + .01) (–155) = –$39.37
0	100	300	400	0.5	1,000	(.5/2 + .014 +.005 +.003) 1000 = $272.00
100	200	200	300	0.014	1,000	(.014/2 +.005 +.003) 1000 = $15.00
200	300	100	200	0.005	1,000	(.005/2 + .003) 1000 = $5.50
300	400	0	100	0.003	1,000	(.003/2) 1000 = $1.50
Start	End	Start	End	Probability	Penalty ($/MWh)	Demand Curve Price ($/MWh)

The step size that is used to discretize the net load forecast error distribution function and the corresponding flexible ramping product demand curve may change size depending on the distribution of errors. In the event the demand curve is non-monotonic, the ISO will set each non-monotonic price segment at the last monotonic segment price.

5. Flexible ramping resource constraints

5.1 Resource ramping capability constraints

FRP will be procured based on a constraint by its ramping capability within an interval:

$$\cancel{\left.\begin{array}{l} 0 \le FRU_{i,t} \le RRU_i(EN_t, T_5) \\ RRD_i(EN_t, T_5) \le FRD_{i,t} \le 0 \end{array}\right\} \forall i, t = 1,2, \ldots, N-1}$$

~~For implementation, it is advantageous to use the same time domain for the *RRU*() and *RRD*() dynamic ramp functions, and since the energy schedules are constrained by cross-interval ramps, the FRU/FRD ramp constraints can be expressed on the same time domain for all market applications as follows:~~

$$\cancel{\left.\begin{array}{l} 0 \le AF\ FRU_{i,t} \le RRU_i(EN_t, T) \\ RRD_i(EN_t, T) \le AF\ FRD_{i,t} \le 0 \end{array}\right\} \forall i, t = 1,2, \ldots, N-1}$$

~~Where *T* is the relevant market interval duration:~~

$$\cancel{T = \begin{cases} T_5 & \text{in RTD} \\ T_{15} & \text{in RTUC} \end{cases}}$$

~~And the averaging factor is defined as follows:~~

$$\cancel{AF = \begin{cases} 1 & \text{in RTD} \\ \dfrac{T_{15}}{T_5} & \text{in RTUC} \end{cases}}$$

$$\left.\begin{array}{l} EN_{i,t+1} - EN_{i,t} \le AF\ FRU_{i,t} \le RRU_i(EN_t, T) \\ RRD_i(EN_t, T) \le AF\ FRD_{i,t} \le EN_{i,t+1} - EN_{i,t} \end{array}\right\} \forall i, t = 1,2,\dots,N-1$$

$\cancel{T}$	~~Time interval.~~
$\cancel{T_5}\underline{T}$	~~RTD~~Application time interval~~ (5min).~~.
$\cancel{T_{15}}$	~~RTUC time interval (15min).~~
AF	Averaging factor.
$FRU_{i,t}$	Flexible Ramp Up award (algebraic) of Resource *i* in time period *t*.
$FRD_{i,t}$	Flexible Ramp Down award (~~non-positive~~algebraic) of Resource *i* in time period *t*.
$RRU_i(EN,T)$	Piecewise linear ramp up capability function of Resource i for time interval T.
$RRD_i(EN,T)$	Piecewise linear ramp down capability function (non-positive) of Resource i for time interval T.

5.2 Resource capacity constraints

A resource must have an energy bid to be eligible for FRP. Also, the resource's schedule must not be in a forbidden operating region or in a state of transition if it is a multi-stage generator.

The relevant capacity constraints for an online resource on regulation are as follows:

$$\left.\begin{array}{l} \max(LOL_{i,t+1}, LRL_{i,t+1}) \le EN_{i,t} + AF\ FRD_{i,t} + RD_{i,t+1} \\ EN_{i,t} + AF\ FRU_{i,t} + NR_{i,t+1} + SR_{i,t+1} + RU_{i,t+1} \le \min(UOL_{i,t+1}, URL_{i,t+1}, CL_{i,t+1}) \\ LEL_{i,t+1} - AF\ FRD_{i,t} \le EN_{i,t} \le UEL_{i,t+1} - AF\ FRU_{i,t} \end{array}\right\} \forall i, t = 1,2,\dots,N-1$$

The relevant capacity constraints for an online resource not on regulation are as follows:

$$\cancel{\left.\begin{array}{l} LOL_{i,t+1} \le EN_{i,t} + AF\left(FRU_{i,t} + FRD_{i,t}\right) \\ EN_{i,t} + AF\left(FRU_{i,t} + FRD_{i,t}\right) + NR_{i,t+1} + SR_{i,t+1} \le \min(UOL_{i,t+1}, CL_{i,t+1}) \\ LEL_{i,t+1} - AF\left(FRU_{i,t} + FRD_{i,t}\right) \le EN_{i,t} \le UEL_{i,t+1} - AF\left(FRU_{i,t} + FRD_{i,t}\right) \end{array}\right\} \forall i, t = 1,2,\dots,N}\ \cancel{-1}$$

$$\left.\begin{array}{l} LOL_{i,t+1} \le EN_{i,t} + AF\ FRD_{i,t} \\ EN_{i,t} + AF\ FRU_{i,t} + NR_{i,t+1} + SR_{i,t+1} \le \min(UOL_{i,t+1}, CL_{i,t+1}) \\ LEL_{i,t+1} - AF\ FRD_{i,t} \le EN_{i,t} \le UEL_{i,t+1} - AF\ FRU_{i,t} \end{array}\right\} \forall i, t = 1,2,\dots,N-1$$

AF	Averaging factor.
$UOL_{i,t}$	Upper Operating Limit of Resource *i* in time period *t*.
$LOL_{i,t}$	Lower Operating Limit of Resource *i* in time period *t*.
$URL_{i,t}$	Upper Regulating Limit of Resource *i* in time period *t*.
$LRL_{i,t}$	Lower Regulating Limit of Resource *i* in time period *t*.
$UEL_{i,t}$	Upper Economic Limit of Resource *i* in time period *t*.
$LEL_{i,t}$	Lower Economic Limit of Resource *i* in time period *t*.
$CL_{i,t}$	Capacity Limit for Resource *i* in time period *t*; $LOL_{i,t} \leq CL_{i,t} \leq UOL_{i,t}$; it defaults to $UOL_{i,t}$.
$EN_{i,t}$	Energy schedule of Resource *i* in time period *t* (positive for supply and negative for demand).
$RU_{i,t}$	Regulation Up award of Resource *i* in time period *t*.
$RD_{i,t}$	Regulation Down award (non-positive) of Resource *i* in time period *t*.
$SR_{i,t}$	Spinning Reserve award of Resource *i* in time period *t*.
$NR_{i,t}$	Non-Spinning Reserve award of Resource *i* in time period *t*.
$FRU_{i,t}$	Flexible Ramp Up award (algebraic) of Resource *i* in time period *t*.
$FRD_{i,t}$	Flexible Ramp Down award (~~non-positive~~algebraic) of Resource *i* in time period *t*.

6. Properties of flexible ramping

This section presents simple examples of FRP to demonstrate the properties and benefits of flexible ramping under the assumption that net load is accurately predicted.

These examples will show:

- The market's multi-interval look-ahead optimization, which currently produces a "composite" energy price, which consists of a pure energy price and a ramping price. The composite energy price may not be consistent with the resource's energy offer price if only the binding interval is settled, and may trigger bid cost recovery. The composite energy price is also very sensitive to deviations from the expected net system demand level because there is no dispatch margin built in the optimization. The composite energy price can be very volatile.

- FRP can decompose the pure energy price and flexible ramping prices, and provide more transparent and less volatile price signals. These prices are also more consistent with the energy offers, and reduce the need for bid cost recovery. These are advantages of FRP even if net system demand could be predicted with high accuracy.

For simplicity, the examples will only consider the interaction between energy and the flexible ramping product, and ignore ancillary services.

6.1 Upward flexible ramping

Assume there are two 500 MW online resources in the system that could provide FRU. The bids and parameters of the two generators are listed in Table 1. G1 has 100 MW/minute ramp rate, and G2 has 10 MW/minute ramp rate. G1 is more economic in energy than G2. They both have zero cost bids for providing flexible ramping.

TABLE 1: RESOURCE BIDS, INITIAL CONDITION AND OPERATIONAL PARAMETERS

Generation	Energy Bid	Initial Energy	Ramp Rate	Pmin	Pmax
G1	$25	400 MW	100 MW	0	500 MW
G2	$30	0	10 MW	0	500 MW

Scenario 1: Single interval RTD optimization without upward flexible ramping with load at 420 MW.

In scenario 1, load is met by the most economic resource G1, and G1 sets the LMP at $25.

TABLE 2: SINGLE-INTERVAL RTD DISPATCH WITHOUT UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$25)	
Generation	**Energy**	**Flex-ramp up**
G1	420 MW	-
G2	0 MW	-

Scenario 2: Single interval RTD optimization with upward flexible ramping with load at 420 MW and an upward flexible ramping requirement at 170 MW.

The solution for scenario 2 is listed in Table 3. In scenario 2, in order to meet 170 MW upward flexible ramping, G1 is not dispatched for as much energy to make room for upward flexible ramping. As a result, G1 does not have extra capacity to meet extra load, and LMP is set by G2 at $30. The upward flexible ramping requirement caused the LMP to increase compared with scenario 1. FRU price is set by G1's energy opportunity cost $30 – $25= $5.

TABLE 3: SINGLE-INTERVAL RTD DISPATCH WITH UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$30, FRUP=$5)

Generation	Energy	Flex-ramp up
G1	380 MW	120 MW
G2	40 MW	50 MW

Scenario 3: Two-interval RTD optimization without upward flexible ramping with load (t) at 420 MW and load (t+5) at 590 MW.

The solution for scenario 3 is listed in Table 4. In scenario 3, there is no flexible ramping requirement. However, the look-ahead optimization projects a 170 MW of upward load ramp from interval t to t+5, which equals the upward flexible ramping requirement in scenario 2. The look-ahead optimization produces the same dispatch for interval t as in scenario 2, but different LMPs. The LMPs are different because there is an interaction between the energy price and flexible ramping price. Without the flexible ramping product, the look-ahead optimization still holds G1 back in interval t to meet the load in interval t+5, but G1 is still the marginal unit in interval t and sets the LMP at $25. G2 is the marginal unit for interval t+5 and sets the non-binding LMP for interval t+5 at $35 ($30 bid cost in interval t+5 plus $5 not bid cost not recovered in interval t).

TABLE 4: LOOK-AHEAD RTD DISPATCH WITHOUT UPWARD FLEXIBLE RAMPING

	Interval t (LMP=$25)	**Interval t+5 (LMP=$35)**
Generation	**Energy**	**Energy**
G1	380 MW	500 MW
G2	40 MW	90 MW

Scenario 4: Two-interval RTD optimization with upward flexible ramping with load (t) at 420 MW and load (t+5) at 590 MW. The upward flexible ramping requirement at (t) is 170.01 MW.

In scenario 4, both flexible ramping and look-ahead are modeled in the optimization. In order to have uniquely determined prices, we set upward flexible ramping requirement slightly higher than expected load ramp 170 MW. The results are listed in Table 5 which converge to scenario 2 in the first interval. If the flexible ramping requirement is slightly lower than the expected load ramp, the solution would converge to scenario 3.

TABLE 5: LOOK-AHEAD RTD DISPATCH WITH FRU REQUIREMENT SLIGHTLY HIGHER THAN EXPECTED UPWARD LOAD RAMP

	Interval t (LMP=$30, FRUP=$5)		**Interval t+5 (LMP=$30)**	
Generation	**Energy**	**Flex-ramp up**	**Energy**	**Flex-ramp up**
G1	379.99 MW	120.01 MW	500 MW	-

G2	40.01 MW	50 MW	90 MW	-

TABLE 6: POSSIBLE LOOK-AHEAD RTD DISPATCH WITHOUT FLEXIBLE RAMPING IN INTERVAL T+5

Interval t+5	Load = 589.99 MW	Load = 590.01 MW
G1	500 MW	500 MW
G2	89.99 MW	90 MW
LMP	$30/MWh	$1000/MWh

6.2 Downward flexible ramping

Assume two 500 MW resources are online in the system that can provide flexible ramping. The bids and parameters of the two generators are listed in Table 7. G1 has 10 MW/minute ramp rate, and G2 has 100 MW/minute ramp rate. G1 is more economic in energy than G2. They both have zero cost for providing flexible ramping.

TABLE 7: RESOURCE BIDS, INITIAL CONDITION AND OPERATIONAL PARAMETERS

Generation	Energy Bid	Flex Ramp Up	Flex Ramp Down	Energy Initial	Ramp rate	Pmin	Pmax
G1	$25	0	0	300 MW	10 MW/min	0	500 MW
G2	$30	0	0	100 MW	100 MW/min	0	500 MW

Scenario 1: Single interval RTD optimization without downward flexible ramping with load at t = 380 MW

The solution for scenario 1 is listed in Table 8. In scenario 1, load is met by both G1 and G2, and G2 sets the LMP at $30. Although G1 is more economic than G2, its output 350 MW has been limited by its ramp rate 10 MW/minute from its initial condition 300 MW, so it cannot set the LMP.

TABLE 8: SINGLE-INTERVAL RTD DISPATCH WITHOUT DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$30)	
Generation	**Energy**	**Flex-ramp down**
G1	350 MW	-
G2	30 MW	-

Scenario 2: Single interval RTD optimization with downward flexible ramping with load at t =

380 MW and downward flexible ramping requirement at t = 170 MW

The solution for scenario 2 is listed in Table 9. In scenario 2, in order to meet 170 MW downward flexible ramping, G2 needs to be dispatched up in order to provide downward flexible ramping. As a result, G1's output will be reduced in order to maintain the power balance, and G1 sets the LMP at $25. Note the downward flexible ramping requirement causes the LMP to decrease compared with scenario 1. The downward flexible ramping price FRDP is set by G2's energy price deficit $30 – $25= $5. The FRDP price is to compensate G2 such that G2's revenue including both energy and FRD can cover its energy bid cost $30. As a result, there is no revenue shortage for G2, and no need for bid cost recovery.

TABLE 9: SINGLE-INTERVAL RTD DISPATCH WITH DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$25, FRDP=$5)	
Generation	**Energy**	**Flex-ramp down**
G1	260 MW	50 MW
G2	120 MW	120 MW

Scenario 3: Two-interval RTD optimization without downward flexible ramping with load at t = 380 MW and load at t+5 = 210 MW.

The solution for scenario 3 is listed in Table 10. In scenario 3, there is no FRD requirement. However, the look-ahead optimization projects a 170 MW of downward load ramp from interval t to t+5, which equals the downward flexible ramping requirement in scenario 2. The look-ahead optimization produces the same dispatch for interval t as in scenario 2, but different LMPs. The dispatch is the same because the look-ahead load ramp also requires the same amount of ramping capability as the flexible ramping requirement in interval t. The LMPs are different because there is an interaction between the energy price and flexible ramping price. When net system demand is decreasing, which creates more downward ramp need, the look-ahead optimization will increase the energy price in the binding interval (for similar but opposite reasons as described in the FRU example in scenario 3 in the preceding section 6.1).

TABLE 10: LOOK-AHEAD RTD DISPATCH WITHOUT DOWNWARD FLEXIBLE RAMPING

	Interval t (LMP=$30)		**Interval t+5 (LMP=$20)**	
Generation	**Energy**	**Flex-ramp down**	**Energy**	**Flex-ramp down**
G1	260 MW	-	210 MW	-
G2	120 MW	-	0	-

Scenario 4: Two-interval RTD optimization with downward flexible ramping with load t = 380 MW and load at t+5 = 210 MW. The downward flexible ramping requirement at (t) is 170.01.

In scenario 4, both flexible ramping and look-ahead are modeled in the optimization. In order to have uniquely determined prices, we set downward flexible ramping requirement slightly higher than expected load ramp 170 MW. The solution for scenario 4 is listed as Table 11.

TABLE 11: LOOK-AHEAD RTD DISPATCH WITH FRD REQUIREMENT SLIGHTLY HIGHER THAN EXPECTED DOWNWARD LOAD RAMP

	Interval t (LMP= $25 , FRDP= $5)		Interval t+5 (LMP=$25 , FRDP= $0)	
Generation	**Energy**	**Flex-ramp down**	**Energy**	**Flex-ramp down**
G1	259.99 MW	50 MW	210 MW	-
G2	120.01 MW	120.01 MW	0 MW	-

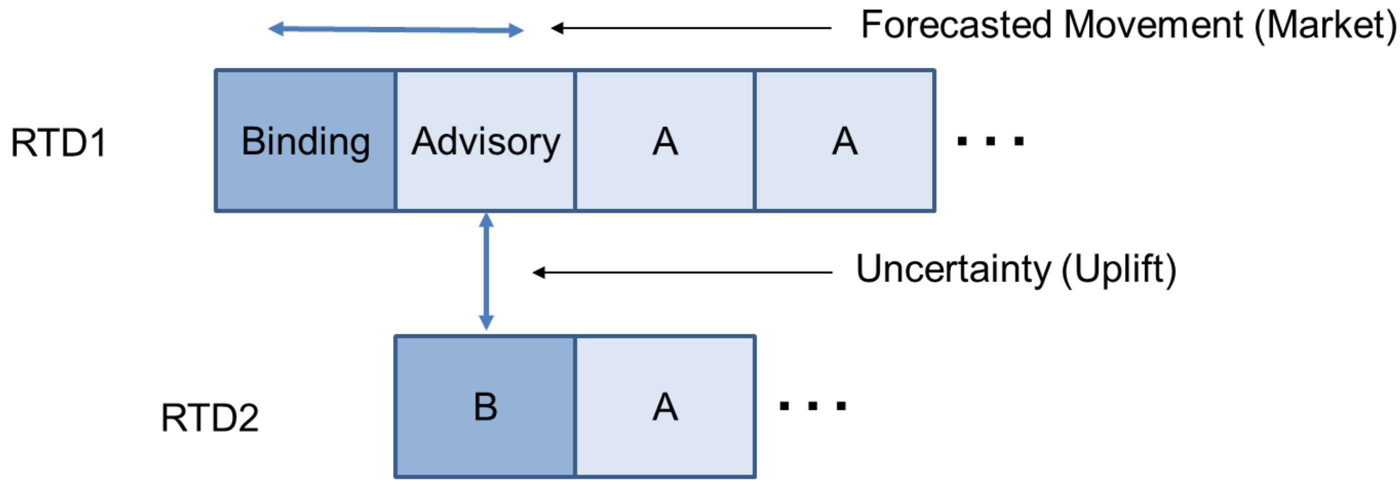
7. Settlement

The ISO will financially settle FRP in the fifteen-minute market and the five-minute market. The financial settlement of FRP is separated into two settlement calculations:

- A direct settlement in the market for all forecasted movement.
- A settlement for FRP procured for uncertainty, based on observed load and non-dispatchable resource forecast error, allocated at the end of the month through an uplift.

Figure 10 below shows two RTD runs and illustrates the difference between the FRP procured for forecasted movement settled directly in the market and the FRP procured for uncertainty allocated at the end of the month through an uplift. The forecasted movement will be settled in every FMM or RTD settlement interval and will be the difference between the “horizontal” binding and advisory intervals. Uncertainty will be settled monthly through the difference of the “vertical” binding and advisory intervals.

FIGURE 10 BINDING AND ADVISORY INTERVAL REPRESENTATION



The market will enforce a single requirement for each direction of the flexible ramping product (i.e. FRU, FRD) which covers both forecasted movement and uncertainty. This results in a single price for ramping capability to cover both forecasted movement and uncertainty.

The FRP settlement for forecasted movement will be paid and charge in each settlement interval with the same settlement timing as energy imbalances. The FRP settlement for uncertainty will be paid and charged at the end of the month to eliminate the need for a monthly resettlement.

7.1 Direct settlement for forecasted movement

Forecasted movement will be settled in FMM at the FMM price. Any difference between FRP procured for the FMM forecasted movement and the RTD forecasted movement will be settled at the RTD FRP price. Note that the granularity difference between FMM and RTD can cause differences between the FMM awards and RTD awards. The same issue exists with energy settlements today.

For dispatchable and non-dispatchable supply, the settlement is calculated by resource for each 15-minute FMM and 5-minute RTD settlement interval. The ISO uses its forecast[3] for variable energy resources' output to clear the market but provides the option for variable energy resources to use their own forecast to schedule energy. The ISO will only use the ISO's forecast to calculate ramping awards for variable energy resources. This is to mitigate against variable energy resources adjusting the forecast of the advisory interval to receive payment for ramp. VERs could do this without financial cost because the advisory energy schedules are not

[3] In the energy imbalance market, the EIM entity must provide an independent third party forecast. This forecast is then used in the market. If the EIM entity does not have an independent third party forecast, the ISO will use its forecast provider.

financially binding.

For interties, the settlement is calculated for each schedule for each 15-minute and 5-minute settlement interval based upon the prescribed ramps. Hourly schedule changes have a 20 minute ramp. 15-minute schedule changes have a 10 minute ramp.   The granularity differences between FMM and RTD will result in ramp settlement even if though a static intertie schedule cannot be changed in RTD. In addition, operational adjustments should be reflected prior to the start of the RTD optimization covering the relevant FMM interval; therefore, this change can be reflected in the forecasted movement of RTD is not a cause of uncertainty.

Table 11 illustrates the upward FRP settlement in both FMM and RTD for an hourly intertie schedule that is ramping from 100 MW in HE 02 to 150 MW in HE 03. The schedule change will result in settlements at both the FMM and RTD FRU price. This accurately reflects the upward ramping value the hourly intertie change provides, as the real-time market schedules and dispatches resources to meet current system conditions.

TABLE 11 INTERTIE MOVEMENT SETTLEMENT IN RTD AND FMM

	HE 02						HE 03					
	RTD7	RTD8	RTD9	RTD10	RTD11	RTD12	RTD1	RTD2	RTD3	RTD4	RTD5	RTD6
Prescribed hourly ramp (Avg. MW)	100.00	100.00	100.00	100.00	106.25	118.75	131.25	143.75	150.00	150.00	150.00	150.00
	FMM3			FMM4			FMM1			FMM2		
FMM Non-Dispatchable Energy	100.00			108.33			141.67			150.00		
FMM Ramp Award (MW)	8.33			33.33			8.33			0.00		
FMM Ramp Award (MW)	2.78	2.78	2.78	11.11	11.11	11.11	2.78	2.78	2.78	0.00	0.00	0.00
RTD Incremental Ramp Award (MW)	-2.78	-2.78	-2.78	-4.86	1.39	1.39	9.72	3.47	-2.78	0.00	0.00	0.00
Final Ramp	0.0	0.0	0.0	6.25	12.5	12.5	12.5	6.25	0.00	0.00	0.00	0.00

Unlike supply and interties, load cannot be settled directly for forecasted movement with a Scheduling Coordinator (SC) because the ISO load forecast that is used to clear the market is aggregated for each balancing authority area. Therefore, all payments and charges to load based upon the ISO market forecast will be allocated based on load ratio share for each 5-minute settlement interval for each balancing authority area.

7.2 Rescission of payments for FRP awards

Since dispatchable resources, non-dispatchable resources, interties, and load will all be awarded and compensated for FRP, the ISO is proposing a consistent approach to address the potential double payment of opportunity costs. The double payment arises when a resource is awarded FRP and is then subsequently settled for uninstructed imbalance energy. For example, assume a resource's energy bid is $30/MWh and the market clearing LMP was $40. If the resource was awarded FRU, it would be paid no less than $10 for the FRU award. If the resource then deviated above its binding dispatch, the resource would incur positive uninstructed imbalance energy and be paid at the 5-minute LMP of $40. This would result in a profit of $10 which would be the same as the opportunity cost used to compensate the FRU award which assumed the resource would be at it dispatch operating target.

For each settlement interval in which a resource is awarded FRP, the ISO will determine if the resource was double paid by comparing uninstructed imbalance energy (UIE) to the FRP award. If the resource's final meter indicates that the resource has uninstructed imbalance energy deviation or operational adjustment that overlaps with the reserved FRP awarded capacity, the ISO will rescind this portion of the FRP award. The FRP rescission quantity will be charged at the five-minute market FRP price. The FRP rescission quantity will be first assessed against the resource's FRP uncertainty awards and then against the FRP movement awards.

The rescinded FRP amount for forecasted movement will be charged in each settlement interval with the same settlement timing as energy imbalances. The rescinded FRP amount for uncertainty will be charged at the end of the month to eliminate the need for a monthly resettlement since uncertainty costs are allocated monthly.

The rescinded FRP amounts for forecasted movement will be paid to the resources which were directly charged in proration to their forecasted movement in the binding RTD interval. The rescinded FRP amounts for uncertainty will be netted against the FRP uncertainty payments prior to monthly allocation to load, supply, and interties as discussed in the next section.

7.3 Monthly settlement of uncertainty

Unlike forecasted movement, there is no counterparty to directly charge in the financially binding interval for FRP procured for uncertainty. Uncertainty is procured to address the potential for differences in net load when the advisory interval becomes financially binding in the subsequent market run. This difference occurs when uncertainty is realized in a future interval. Since the additional ramping capability is similar to insurance, it is appropriate to not allocate cost for a given realization of uncertainty, but over a period of time. Therefore, the cost (payment to dispatchable resources) will be allocated at the end of the month through an uplift.

The FRP for uncertainty awards will be settled with dispatchable resources at the applicable binding interval FMM or RTD price at the end of the month. The ISO had previously proposed settling these on a daily basis and initially allocating the costs to load and resources according to the relevant billing determinant. By not paying the uncertainty awards immediately, there is no need to perform a monthly resettlement because the payment to a resource and the cost allocation will occur in the same settlement period. This is a significant simplification of the settlements implementation.

In addition, payment rescissions to dispatchable resources for uninstructed imbalance energy that would provide a double payment as discussed in the previous section will be charged at the end of the month. The payment rescission will be settled at applicable binding interval RTD price in which the payment rescission occurred.

To the extent that the sum of the Settlement amounts for Flexible Ramp Up Uncertainty Settlement Amount, Flexible Ramp Down Uncertainty Settlement Amount, Flexible Ramp Up Uncertainty Rescission Amount, Flexible Ramp Down Uncertainty Rescission Amount, Flexible Ramp Up Uncertainty Allocation Amount, and Flexible Ramp Down Uncertainty Allocation Amount does not equal zero, the ISO will assess the resulting differences to all SCs with metered demand within the balancing authority area.

7.3.1 Allocation of uncertainty

The ISO proposes settling the uncertainty for two groups of trade hours. In the assessment of grid management charge (GMC) prior to the 2010 GMC redesign, the ISO identified a GMC bucket for charging load based upon Non-Coincident Peak hours and Non-Coincident Off Peak Hours. Non-Coincident Peak Hours is defined as trading hours ending 7 through 22 for all trading days within a trading month, whereas Non-Coincident Off Peak Hours is defined as trading hours ending 1 through 6 and trading hours 23 through 25 for all trading days within a trading month. For each group of the hour, the FRP for uncertainty uplift cost is the sum of the monthly payments to dispatchable resources less monthly payment rescissions charges to dispatchable resources in the each bucket of trading hours. The total FRP for uncertainty uplift cost is first allocated between the load, supply, and intertie categories. The respective uplift costs allocated to the load, supply, and intertie categories are then allocated to individual resources or loads using a different billing determinate method for each category.

The initial allocation of FRP uncertainty uplift costs between the load, supply, and intertie categories is determined by calculating the “vertical” binding – advisory as shown in figure 10. This difference will be calculated for all non-dispatchable[4] changes in supply resources, interties[5] and load for each 5-minute interval. There is no netting between 5-minute intervals, so in each 5-minute interval there will be either a FRU value or an FRD value. Table 12 below illustrates whether the observed net load error will split FRU or FRD costs. “A” is the advisory interval in the first RTD run and “B” is the binding interval from the second RTD run.

The initial allocation of FRP uncertainty uplift costs between the load, supply, and intertie categories is determined by calculating the “vertical” binding – advisory as shown in Figure 10. This difference will be calculated for all non-dispatchable resources, interties and load for each 5-minute interval. There is no netting between 5-minute intervals, so in each 5-minute interval there will be either a FRU value or an FRD value. Table 12 below illustrates whether the observed net load error will be used to split FRU or FRD costs. “A” is the advisory interval in the first RTD run and “B” is the binding interval from the second RTD run.

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[4] Only non-dispatchable resources can have forecast errors between the two market runs. A dispatchable resource could have differences between the two market runs, but this is in response to market instructions not a result a forecast error of that resources.

[5] Only operational adjustments that occur after RTD initializes will result in a forecast error. Once the operational adjustment is reflected in RTD, it is settled as part of the forecasted movement.

TABLE 12 ALLOCATION OF UNCERTAINTY UPLIFT COSTS BETWEEN FRU AND FRD

	FRU	FRD
Load	A-B > 0	A-B < 0
Supply	A-B < 0	A-B > 0
Interties (Net import in B)	A-B < 0	A-B > 0
Interties (Net export in B)	A-B > 0	A-B < 0

*For load and exports the values of A and B are negative

The load forecast is a single value for each balancing authority area, therefore the forecast error nets errors resulting from individual load serving entities. The load will have a single FRU or FRD value for each settlement interval per balancing authority area based on the ISO forecast between “vertical” advisory – binding interval shown in Figure 10. When splitting the costs into each category, supply and interties must also have a single FRU or FRD value for each settlement interval per balancing authority area. This is accomplished by netting all resources within the supply category and separately netting all intertie schedules within the intertie category to then calculate a single value for each of the categories.

There will be 4 monthly costs that will be allocated: FRU Peak, FRD Peak, FRU Off Peak, and FRD Off Peak. The FRU and FRD values in each 5-minute interval for each category are summed for the month over each range of trading hours. Then each category is allocated its pro-rata share of the monthly FRP costs. The each category allocates its four costs according to its own billing determinant.

1. Load is allocated to each SC based on the pro-rata share of gross UIE over the month. There is no netting between settlement intervals. Negative (increased consumption) UIE is allocated FRU and positive (decreased consumption) UIE is allocated FRD. If a load uses five minute metering, such as load following metered sub-systems, then the load would be included within the supply category.
2. Supply is allocated by calculating the observed forecast error (the vertical advisory – binding) plus any uninstructed imbalance energy. Each resource is allocated its pro-rata share of gross (A-B-UIE) for over the month for each cost bucket. There is no netting between settlement intervals. Positive (A-B-UIE) is allocated FRU and negative (A-B-UIE) is allocated FRD. Uninstructed imbalance energy was included to provide an additional incentive for dispatchable resources to follow their dispatch instruction. If UIE persists, this can increase the need for ramping capability.
3. Intertie category is allocated to each SC based upon the pro-rata share of gross operational adjustment in each cost bucket over the month. Uncertainty costs for interties will be small. The uncertainty is realized only if an operational adjustment occurs after the binding RTD interval prior to the start of the next RTD interval. Otherwise, the operational adjustment will be resettled as a forecasted movement in RTD. Most operational adjustments occur prior to the start of the operating hour and will be settled through the forecasted movement deviation between FMM and RTD.

7.4 Settlement Examples

The examples in tables 13-16 show the energy and FRP settlement for supply, load and interties scheduled for energy and awarded FRP.

Table 13 illustrates the real-time market energy settlement for each resource type for FRU when load is increasing. Generator 1 is awarded 100 MW of FRU but provided an additional 50 MW which was reported by the meter. Therefore, Generator 1 will be paid 100 MW of the FRU award and charged 50 MW as a payment rescission. Generator 2 is awarded 50 MW of FRU uncertainty and 900 MW of FRU movement. The meter showed that Generator 2 produced 75 MW which is 25 MW more than the awarded uncertainty, in which 25 MW will be charged to the generator as a payment rescission. Load is charged 1000 MW of FRU but will also be paid the 75 MW that was rescinded from generators 1 and 2.

Table 14 illustrates the real-time market energy settlement for each resource type for FRU when actual metered load was lower than what was forecasted. In this example, load was forecasted at 1000 MW but the meter showed that it was 150 MW lower than what was forecasted. Load will be paid 1000 MW FRU but charged 150 MW rescission. The generators will be allocated pro-rata share of this 150 MW rescission charge from load. The payment rescission basis for generators 1 and 2 will be the product of the 150 MW that was below forecast and the amount of FRU awarded to the generator divided by the total FRU awarded.

Tables 15 and 16 illustrate the real-time market energy settlement for FRD under the same scenario for load changes. The results of each resource types' awards and rescissions are calculated in a similar manner as tables 13 and 14.

Table 13 Flexible Ramp Up Settlement with Rescission (Load Forecast Increase)

Resource Type	FRU Uncertainty Award (MW)	FRU Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRU Uncertainty Rescission Quantity (MW)	FRU Movement Rescission Quantity (MW)	FRU Uncertainty Settlement ($)*	FRU Uncertainty Rescission ($)*	FRU Movement Settlement ($)	FRU Movement Rescission ($)
Gen 1	0	100	50	0	50	0	0	100 MW FRU Payment	50 MW FRU Rescission Charge
Gen 2	50	900	75	50	25	50 MW FRU Payment	50 MW FRU Rescission Charge	900 MW FRU Payment	25 MW FRU Rescission Charge
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	0			0	0	1000 MW FRU Charge	75 MW FRU Rescission Payment

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

TABLE 14 FLEXIBLE RAMP UP SETTLEMENT WITH RESCISSION (LOAD FORECAST DECREASE)

Resource Type	FRU Uncertainty Award (MW)	FRU Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRU Uncertainty Rescission Quantity (MW)	FRU Movement Rescission Quantity (MW)	FRU Uncertainty Settlement ($)*	FRU Uncertainty Rescission ($)*	FRU Movement Settlement ($)	FRU Movement Rescission ($)
Gen 1	0	100	0	0	0	0	0	100 MW FRU Charge	150 MW * (100/1000) FRU Rescission Payment
Gen 2	0	900	0	0	0	0	0	900 MW FRU Charge	150 MW * (900/1000) FRU Rescission Payment
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	150	0	150**	0	0	1000 MW FRU Payment	150 MW FRU Rescission Charge

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.
** The Actual Meter Load change was less than forecasted.

TABLE 15 FLEXIBLE RAMP DOWN SETTLEMENT WITH RESCISSION (LOAD FORECAST INCREASE)

Resource Type	FRD Uncertainty Award (MW)	FRD Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRD Uncertainty Rescission Quantity (MW)	FRD Movement Rescission Quantity (MW)	FRD Uncertainty Settlement ($)*	FRD Uncertainty Rescission ($)*	FRD Movement Settlement ($)	FRD Movement Rescission ($)
Gen 1	0	100	-50	0	50	0	0	100 MW FRD Payment	50 MW FRD Rescission Charge
Gen 2	50	900	-75	50	25	50 MW FRD Payment	50 MW FRD Rescission Charge	900 MW FRD Payment	25 MW FRD Rescission Charge
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	0			0	0	1000 MW FRU Charge	75 MW FRU Rescission Payment

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

TABLE 16 FLEXIBLE RAMP DOWN SETTLEMENT WITH RESCISSION (LOAD FORECAST INCREASE)

Resource Type	FRD Uncertainty Award (MW)	FRD Movement Award (MW)	Meter – Total Expected Energy or Load Forecast	FRD Uncertainty Rescission Quantity (MW)	FRD Movement Rescission Quantity (MW)	FRD Uncertainty Settlement ($)*	FRD Uncertainty Rescission ($)*	FRD Movement Settlement ($)	FRD Movement Rescission ($)
Gen 1	0	100	0	0	0	0	0	100 MW FRD Charge	150 MW * (100/1000) FRD Rescission Payment
Gen 2	0	900	0	0	0	0	0	900 MW FRD Charge	150 MW * (900/1000) FRD Rescission Payment
Import	0	0	0	0	0	0	0	0	0
Export	0	0	0	0	0	0	0	0	0
Load	0	1000	-150	0	150**	0	0	1000 MW FRD Payment	150 MW FRD Rescission Charge

* FRU Uncertainty Payment and Rescission Charge is netted together over the month and allocated to load, supply, and interties.

** The Meter Load change was greater than forecasted.

Attachment G – Matrix of Stakeholder Comments to Draft Tariff Language

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Section number	Party	Comment	ISO Response
Definition of Forecasted Movement	Six Cities	Change “resources” to “resource’s”.	Accept
11.25.2.3.1(a)(2)	Puget Sound Energy	EIM Area on a daily basis according to the categories as set forth in this Section 11.25.2.3; and (2) allocate the daily amounts to Scheduling Coordinators as set forth in this ~~s~~Section 11.25.2.3. Delete section 27.10, Flexible Ramping Constraint	Accept
11.25.2.3.2(a)(2)	Six Cities	In the first line, change “Resource” to “Resources” and change “schedule” to “schedules”.	Accept
11.25.2.3.4(a)(2)	Six Cities	In the second line, delete “to” after “Section 11.25,”.	Accept
11.25.2.2.2(a)(1)	ISO	We will clarify that uncertainty movement is only calculated for resources that are being scheduled based upon a forecast.	
11.25.1	Six Cities	With respect to sub-sections 11.25.1.1.1 and 11.25.1.1.2, please explain why FRDP would be used in settling upward Forecasted Movement? Similarly, with respect to sub-sections 11.25.1.2.1 and 11.25.1.2.2, why would FRUP be used in settling downward Forecasted Movement? Is it not the case that Forecasted Movement for a particular resource occurs in only one direction within a given interval? If that is so, it would seem that only FRUP would apply to upward Forecasted Movement, and only FRDP would apply to downward Forecasted Movement.	The FRP design is that upward forecasted movement is paid the FRUP and charged the FRDP and that downward forecasted movement is paid the FRDP and charges the FRUP. Though a resource can only move in one direction in an interval, both FRUP and FRDP may be non-zero prices.

11.25.2	Puget Sound Energy	**11.25.2 Settlement of Uncertainty Requirement.** **11.25.2.1 Payment to Resources.** On a daily basis, the CAISO will settle awards to resources for providing the Uncertainty Requirement at the applicable FRUP or FRDP less any payment rescission for each interval pursuant to ~~s~~Section 11.25.3.	Accept
11.25.1.1 11.25.1.2 44.3	PG&E	Sections 11.25.1.1 and 11.25.1.2 both refer to Forecasted Movement for a resource calculated pursuant to Section 44.3. Section 44.3 does not separate Forecast Movement into movement up and movement down but only calculates movement. Consequently, the settlements calculations in Sections 11.25.1.1 and 11.25.1.2 are identical and will settle movement either up or down. The sections are repetitious and could be construed to pay a resource twice for forecast movement. It is suggested skipping 11.25.1.2 and retitling 11.25.1.1 to "Forecasted Movement".	The CAISO has combined and clarified these sections.
11.25.1.2	Puget Sound Energy	**11.25.1.2 Downward Forecasted Movement** **11.25.1.2.1 FMM.** The CAISO will settle downward FMM Forecasted Movement with Scheduling Coordinators as follows: (a) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the FMM FRUP; and (b) the product of the Forecasted Movement calculated for each resource pursuant to Section 44.3 in MWhs and the product of the FMM FRDP and negative one.	Accept
11.25.1.3	Six Cities	Please explain the source or sources of any residual Forecasted Movement settlement amounts. In the second line, change "the Section 11.25.1 to Scheduling Coordinator metered" to "Section 11.25.1 to each Scheduling Coordinator's metered". In the third line, insert "of" after "share".	This is a neutrality account for any residual amounts due to rescission of forecasted movement at the RTD price, which was originally procured at the FMM price and was not allocated to metered demand.

			Accepting grammatical changes.
11.25.1.3		**11.25.1.3 Allocation of Residual Forecasted Movement Settlements.** The CAISO will settle amounts remaining after settlement of Forecasted Movement pursuant to the Section 11.25.1 to Scheduling Coordinator metered EIM Demand or metered CAISO Demand in proportion to its share the total metered EIM Demand and metered CAISO Demand. Formatted: Indent: First line: 0" Formatted: Font: (Default) Arial Formatted: Font: (Default) Arial Comment [ZGS2]: Is this intended to be settled with the EIM Entity Scheduling Coordinator or all Scheduling Coordinators, including Participating Resource Scheduling Coordinators, with metered demand in the EIM area? Formatted: Font: (Default) Arial **.25.2 Settlement of Uncertainty Requirement.**	The CAISO will not settle with the SC for a participating resource because they do not represent metered demand. The EIM Entity SC will be allocated this amount.
11.25.2.3.1	Puget Sound Energy	Authority Area in the EIM Area and within the EIM Area as set forth in this Section 11.25.2.3; and (4) allocating the monthly amounts in each category to Scheduling Coordinators as set forth in this Section 11.25.2.3. Comment [ZGS3]: Missing decimal point **25.2.3.2 Allocation of Charges to Categories.**	Accept
11.25.2.3.2	Puget Sound Energy	**(3)** for the non-Participating Load category, as the difference between- **(A)** the CAISO Forecast of CAISO Demand, the CAISO forecast ~~-~~ of Balancing Authority Area EIM Demand, or the CAISO forecast of EIM Area EIM Demand, as applicable, of the binding interval in the next RTD run; and	Accept

		Demand, ~~and~~or the CAISO forecast of EIM Area EIM Demand, as applicable, for the first advisory interval in the current RTD run.	
11.25.2.3.4(d)	Six Cities	In the fifth line, change "ration" to "ratio" and change "its" to "their".	Accept
11.25.2.3.4	ISO	1) Take out "Uncertainty Movement and " in section 11.25.2.3.4 (c), which now reads: (c) **Intertie Category.** The CAISO will allocate the Uncertainty Awards costs of the Intertie category to Scheduling Coordinators for each non-Dynamic System Resource and export based on the sum of the resource's Operational Adjustment— 2) Include qualification to use "magnitude of" negative values in section 11.25.2.3.4 and subsections. This is because the different positive and negative values across resources for the same interval should not be netted together. Also in two cases, replaced "absolute value" with "magnitude of", to make it consistent. e.g. **11.25.2.3.4 Allocation to Scheduling Coordinators.** (a) **Non-Participating Load Category.** The CAISO will allocate the Uncertainty Awards costs of the non-Participating Load category to Scheduling Coordinators— (1) for upward Uncertainty Award cost in proportion to the Scheduling Coordinator's magnitude of negative non-Participating Load UIE, excluding the non-Participating Load of an MSS that has elected to load-follow according to an MSS Agreement, without netting	

		that UIE across Settlement Intervals, to the total magnitude of such negative non-Participating Load UIE, without netting that UIE across Settlement Intervals, in the Balancing Authority Area or EIM Area as applicable, and	
11.25.2.3.1.4	PG&E	Per Section 7.3 of the January 25, 2016 Addendum Draft Final Technical Appendix, the CAISO had proposed eliminating the daily settling in favor of a single monthly settlement; explicitly identifying it as a significant simplification over the resettlement process identified here. Thus, this would appear to be in contrast to proposed language in section 11.25.2.3.1.4.	The CAISO recognizes that previously the CAISO expected to implement the more simplified monthly settlement for these amounts. However, as it proceeded towards implementation it determined that, because it calculates the bid cost recovery amounts on a daily basis, it must first conduct the daily settlement and then resettle the amounts monthly. This does not change the value of the monthly settlement.
11.8.4.2	Puget Sound Energy	(d) The Forecasted Movement and Uncertainty Awards Settlement Amounts as calculated pursuant to Section 11.25 are included in the RTM Market Revenues calculation, not including: (1) the amounts rescinded pursuant to Section 11.~~2.5~~25.3; (2) Forecasted Movement revenue when there are changes in Self-Schedules across consecutive Trading Hours; and (3) Forecasted Movement revenue when there are changes in EIM Base Schedules across consecutive Trading Hours without Economic Bids. Comment [ZGS1]: Reference should be Section 11.25.3 not Section 11.2.5.3 Formatted: Indent: First line: 0"	Accept
11.8.4.2	CAISO	Clarifying application of the Real-time Peformance Metric and Persistent Deviation Metric applies only to imbalance energy related revenue and not FRP or Ancillary Services related revenue.	
29.34(m)(5)	Six Cities	In the eleventh line, insert "and" before "will".	Accept

29.34(l)(4)(A)	Six Cities	In the fourth line, change “minute” to “minutes”. In the fifth and sixth lines, add “capacity requirements of the” before “Balancing” and change “EIM Area’s capacity requirements” to “EIM Area”.	Accept.
29.34(n)(1)	Puget Sound Energy	~~Constraint capacity requirements; and~~ (B~~C~~) the CAISO will hold the EIM Transfer limit into ~~and~~or from the EIM Entity Balancing Authority Area, as specified in Section 29.34(n)(2) at the value for the last 15-minute ~~Trading Interval~~interval. **Comment [ZGS5]:** Clarify language to limit transfer only in the direction corresponding to the direction of the flex test failure	Accept
29.11	Puget Sound Energy	**29.11. Settlements And Billing For EIM Market Participants.** * * * ~~**(g) Flexible Ramping Constraint Allocation.**~~ ~~**(1) Calculation.** The CAISO will calculate awards for Flexible Ramping Constraint capacity according to Section 11.25.2 and rescission for non-performance in accordance with 11.25.3, except that the Real Time Ancillary Service Market Price for Spinning Reserves will be deemed to be zero in determining awards to EIM Participating Resources.~~ ~~**(2) Apportionment of Costs.** The CAISO will apportion Flexible Ramping Constraint costs to each EIM Entity Balancing Authority Area and the CAISO Balancing Authority Area in accordance with Section 11.25.4.~~ ~~**(3) Cost Allocation.** The CAISO will allocate each EIM Entity’s Flexible Ramping Constraint costs to the applicable EIM Entity Scheduling Coordinator in accordance with Section 11.25.5(b).~~ * * * **Formatted:** Strikethrough **Comment [ZGS4]:** Existing Section 2[illegible] should be removed	Accept
16 and 17	ISO	Update the Tariff Sections for Existing Transmission Contracts and Transmission Ownership Rights to include Flexible Ramp Product settlement. They are both responsible for Imbalance Energy Settlement, and Ancillary Service Settlement. Review the tariff language for the calculation of Uncertainty Movement of Supply. Based upon a recent update to the BRS. Uncertainty Movement will only be calculated for subset of Variable Energy Resources. We will not calculate Uncertainty Movement for other Generators.	Added language to new draft.
44.3.1	Six Cities	In the second and third lines, to make clear that all Forecasted Movement calculations are made on an individual resource basis, change “System Resources” to “System Resource”; change “Pseudo-Ties” to	Accept

		"Pseudo-Tie"; change Non-generating Resources" to "Non-generating Resource"; and change "PDRs" to "PDR".	
44.3.1.1	Six Cities	In the fourth line, change "it's" to "its".	Accept
44.3.1.2	Six Cities	In the second and third lines, insert "the" before "difference" and before "first".	Accept
44.2.3.1	Puget Sound Energy	**44.2.3 Eligibility for Uncertainty Award.** **44.2.3.1 Generally.** ~~All~~Each resource~~s~~ that ~~have~~has an Economic Bid~~s~~ in the RTM ~~that~~and can be dispatched on a five-minute basis by RTD ~~are~~is eligible for receiving Uncertainty Awards satisfying the Uncertainty Requirement for the BAA in which the resource is located. **44.2.3.2 Suspension.** If the CAISO deems the resource to be non-compliant, the CAISO will suspend the resource's eligibility as specified in Section 34.13.2. **Formatted:** Font: Bold **Comment [ZGS6]:** Please specify the relationship between Uncertainty Awards and Uncertainty Requirements and which awards meet which requirements (i.e. resource award meets its BAA requirement) **Formatted:** Font: Bold	

Attachment H – Comments on Final Flexible Ramping Product Proposal
Department of Market Monitoring, June 24, 2016

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Comments on Final Flexible Ramping Product Proposal

Department of Market Monitoring

June 24, 2016

Summary

The Department of Market Monitoring (DMM) supports the ISO's final Flexible Ramping Product (FRP) proposal. The FRP is an important improvement over the current flexible ramping constraint, and is a significant market design innovation which the ISO can continue to enhance as the ISO power grid evolves. This proposal was developed through an extensive market design and stakeholder process dating back to late 2011. Over this period, DMM worked closely with the ISO, stakeholders and the Market Surveillance Committee on developing and refining this proposal.

The ISO made a variety of key changes to the proposal to address specific concerns and recommendations by DMM.

- Under the ISO's initial proposal, participants would submit bids (or offer prices) for FRP in the real-time market that would be used to determine FRP prices and the scheduling of FRP capacity. This element was dropped from the proposal after DMM provided extensive analysis of the economic theory underlying this design element.
- The proposal was also modified so that costs for the flexible ramping product are directly charged to participants based on the flexible ramping product price and the expected ramp of each resource, rather than by allocating costs through an out-of-market uplift. DMM strongly advocated for this change as a major improvement that provides better price signals to the market participants reflecting the value of upward and downward flexibility.
- DMM also developed a detailed methodology for procuring FRP capacity based on a demand curve which reflects the expected value of avoiding power balance constraint violations due to incremental flexible capacity. This feature is incorporated in the ISO's final proposal, and – if implemented well – will increase market efficiency by allowing an explicit trade-off between the costs and benefits of procuring more or less FRP capacity.

While DMM strongly supports approval of the ISO's final proposal, DMM notes that the effectiveness of the FRP will depend on key implementation details, such as the specific demand curve used to procure FRP. Under the ISO proposal, a separate demand curve for each hour will be calculated based on data for that hour over the prior 20 days. DMM recommends that the ISO initially use the net load forecast errors from all hours across the day to estimate one distribution of net load forecast errors for each day. DMM believes this is necessary to ensure that the demand curve is based on a sufficiently large sample to avoid the problematic volatility of the requirement for the current flexible ramping constraint. As the ISO gets more experience in estimating distributions, it can attempt to estimate different distributions of net load forecast errors for different periods of the day by accounting more directly for the variables causing any potential differences in distributions.

DMM also believes that the number of different net load forecast error distributions that the ISO should try to estimate should not be prescribed in the BPM. Estimating the net load forecast error distribution is analogous to forecasting load. This is something the ISO should frequently review and adjust as

necessary, without having to provide specific details of the forecasting formula in the BPM. DMM has also provided recommendations for further potential refinements to the way in which costs of this new product are allocated.

Section 1 of these comments summarizes some of the key aspects and benefits of the FRP design leading DMM to support the ISO's final proposal. Section 2 explains in further detail DMM's reasoning for supporting the ISO's decisions on several aspects of the proposal on which some stakeholders have raised concerns: (1) no separate bidding for FRP, (2) no procurement of FRP in the day-ahead market, and (3) the decision not to delay the proposal due to interactions with virtual bidding. Section 3 provides recommendations concerning the implementation of the FRP demand curve and potential future refinements to the uncertainty FRP cost allocation.

1. Key provisions of proposal

The ISO's FRP design is a significant improvement over the current flexible ramping constraint, and DMM strongly supports approval of the ISO's final proposal. Some of the most important improvements are described below.

1.1 Settlement based on expected ramps of non-dispatchable resources

Under the current flexible ramping constraint, payments made to generators scheduled to provide flexible capacity are allocated to other participants based on their scheduled load. A key improvement incorporated in the FRP design is that the financial settlement of this product will closely reflect how different non-dispatchable load and supply schedules affect the amount of flexible capacity that will be procured under the FRP. Rather than allocating FRP costs as an uplift, the FRP is designed so that the costs of procuring the needed amount of flexible capacity are allocated directly through the market clearing price for the FRP. This is more equitable and provides price signals that can increase efficiency by providing economic incentives for load and supply schedules which reduce – rather than increase – the need for flexible ramping capacity.

A significant portion of real-time market schedules are referred to as *non-dispatchable*. These non-dispatchable schedules are provided to the market software as inputs rather than outputs determined by the optimization and provided to resources as dispatches. For example, most real-time load schedules and many variable energy resources are non-dispatchable. The sum of all non-dispatchable load and generation is referred to as *net load*.

To meet net load in each 5-minute interval, the ISO's market software must dispatch enough dispatchable generation and load resources to meet net load in the current market interval, as well as to meet net load in the next market interval. For example, consider a scenario in which net load is 100 MW in the current 5-minute interval and forecast to be 120 MW in the next 5-minute interval. To ensure feasible market solutions in both 5-minute intervals without a power balance violation, the market software must dispatch 100 MW of dispatchable energy in the first 5-minute interval along with at least 20 MW of upward flexible capacity.

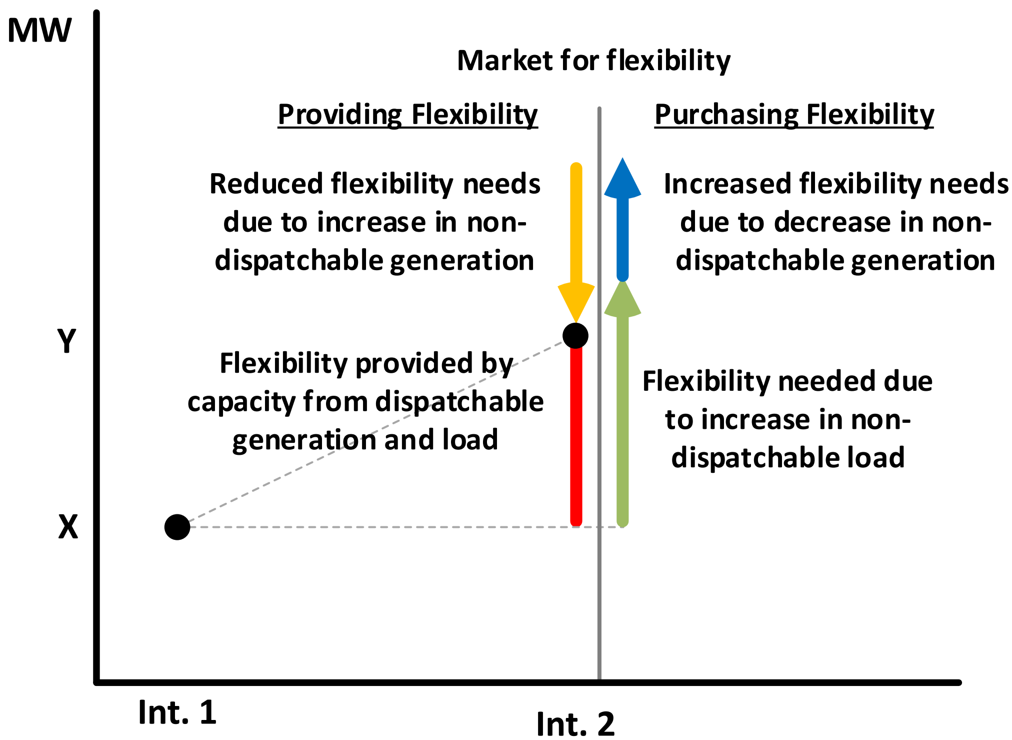
Figure 1-1 shows a scenario with an increase in projected net load from one interval to the next (i.e. from X MW in the current binding market interval to Y MW of forecasted net load in the next advisory interval). Flexible upward capacity is procured from dispatchable resources to meet the projected increase in net load change (shown by the red bar). Some non-dispatchable resources or loads comprising net load may be moving in a direction that increases the flexibility needed, while others may be moving in a direction that decreases the flexibility needed.

In this scenario, the need for upward flexibility is increased by a projected increase in non-dispatchable load (green arrow) and by a projected decrease in non-dispatchable generation (blue arrow). Meanwhile, the need for flexible ramping capacity is decreased by an increase in non-dispatchable generation (yellow arrow). The net demand for flexibility is met by procuring flexible capacity from dispatchable generation (red bar). Since decreasing the need for flexibility is just as valuable as providing flexibility, the non-dispatchable generation that is projected to increase (yellow arrow) and the upward ramping capacity of dispatchable generation capacity (red bar) are paid the upward FRP price.[1]

The upward FRP price is charged to schedules increasing the need for flexibility. In this example, the increasing non-dispatchable load and the decreasing non-dispatchable generation are both charged the upward FRP price. As shown in Figure 1-1, the payments and charges are balanced and settled in market without an uplift cost.

[1] Even though the advisory interval forecast for this non-dispatchable resource may differ from its binding interval schedule, the yellow arrow is still the decrease in overall flexibility needs to cover *expected* net load changes. For a non-dispatchable resource, the relevant forecast uncertainty for FRP is the difference between the resource's advisory interval forecast and the resource's binding interval schedule. The uncertainty in the non-dispatchable resource's binding interval schedule relative to its actual production is irrelevant for FRP. FRP needs created by the resource's forecast uncertainty will be captured in the FRP uncertainty demand curve. The non-dispatchable resource will be charged for FRP needs created by its forecast uncertainty based on its forecast errors (assuming supplier UIE is not included in the allocation formulas for uncertainty FRP costs).

Figure 1-1. Expected ramp settlement and trading of flexibility



Settling expected ramps in this manner will resolve another current issue in the real-time markets. The real-time markets use a multi-interval optimization where only the first interval has binding prices and schedules. The subsequent intervals of the optimization are advisory. Even though the advisory intervals do not have binding prices or schedules, they can affect the binding interval. Total power injections and withdrawals must be balanced in both the binding and advisory intervals. The multi-interval optimization may reserve capacity in the binding interval to make balanced advisory interval schedules feasible. A resource could incur opportunity costs by providing this capacity and forgoing energy sales in the binding interval. However, this resource would currently not be compensated for incurring this opportunity cost.[2] Under the flexible ramping product proposal, resources will be compensated for the opportunity cost of forgoing energy sales in order to provide capacity for the next interval.

1.2 Use of a demand curve allows an explicit trade-off between the costs and benefits of procuring additional FRP capacity

Another key feature of the FRP design is that – rather than procuring a fixed amount of flexible ramping capacity – the ISO will procure FRP capacity based on a demand curve. If implemented well, this approach can increase market efficiency by allowing an explicit trade-off between the costs and benefits

[2] This is not a day-ahead market issue as there is no advisory interval concept and all intervals (hours) are settled.

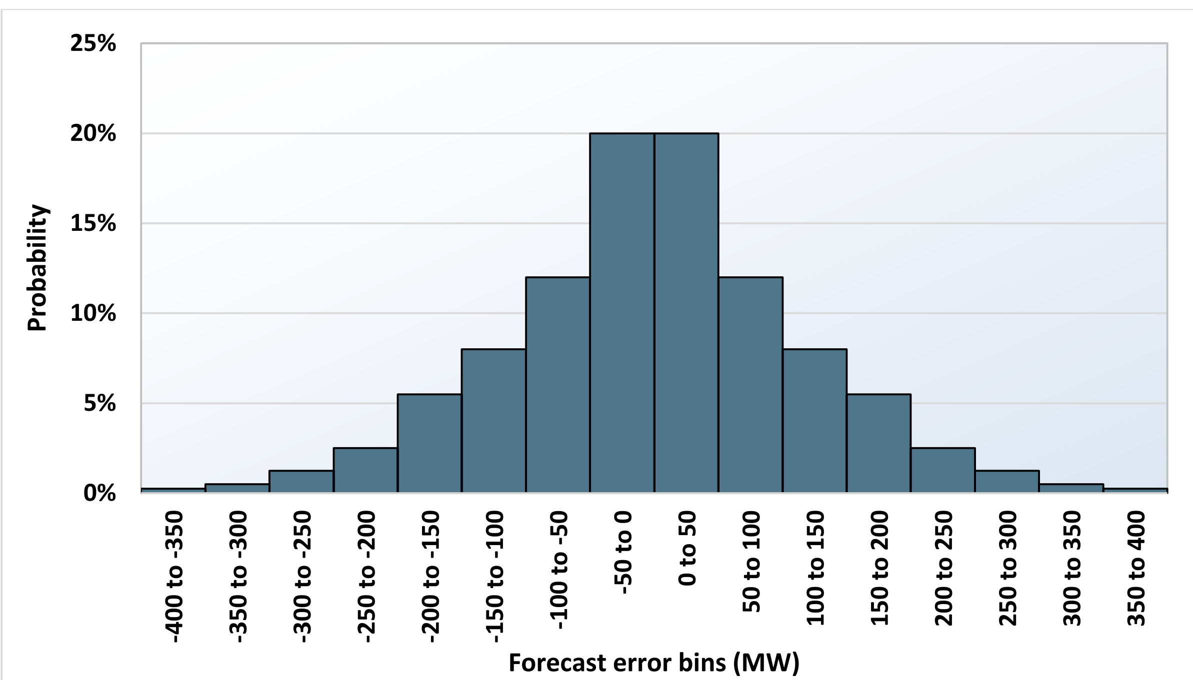
of procuring more or less FRP capacity. DMM developed and recommended this feature of the ISO's final proposal.

When the market software runs the optimization for the current binding interval, the net load in future advisory intervals is not known. The market software must use a forecast for the net load in these future advisory intervals. However, the net load in those future intervals may differ from the best forecast that had to be used for those advisory intervals in the software run for the current binding interval. Therefore, flexibility is needed not only to make the advisory interval's forecasted net load feasible but also to make a range of potential net loads in the advisory interval feasible.

This is shown in Figure 1-2. The distribution of net load forecast errors in Figure 1-2 shows an example of a potential range of net load above and below the advisory interval's forecasted net load. The quantity of this potential net load range that should be made feasible by dispatchable resource capacity depends on the costs of procuring more FRP capacity and the benefits of the additional flexibility.

The market optimization determines the cost of additional FRP capacity by evaluating the increase in minimized production costs due to procuring more capacity. This increase in minimized production costs represents the *marginal cost* of procuring flexible capacity. Rather than procuring FRP based on a fixed requirement, the ISO will procure FRP capacity based on a demand curve, which allows an explicit trade-off between the costs and benefits of procuring more or less FRP capacity. [3]

Figure 1-2. Example histogram of net load forecast errors



[3] DMM proposed the methodology for determining the demand curve in *Comments on Flexible Ramping Products Straw Proposal Incorporating FMM and EIM,* Department of Market Monitoring, July 7, 2014: http://www.caiso.com/Documents/DMM-CommentsFlexibleRampingProductsStrawProposal.pdf

Table 1-1 shows only the positive forecast errors from the histogram in Figure 1-2. The flexible ramping up demand curve can be calculated from the positive forecast errors. The "Histogram" column in Table 1-1 shows the probability a forecast error is between two points. For example, there is a 20 percent probability of a forecast error between 0 and 50 megawatts. The "Cumulative Probability" column shows the probability that an error is greater than the beginning of the histogram segment. For example, there is a 50% probability of a forecast error greater than 0 megawatts. The flexible ramping up marginal value is the cumulative probability at a point times $1,000 per MWh.

Table 1-1. Example histogram of forecast errors – positive only

Error MW Beg	Error MW End	Histogram	Cumulative Probability	Marginal FRU Value
0	50	20.00%	50.00%	$500.00
50	100	12.00%	30.00%	$300.00
100	150	8.00%	18.00%	$180.00
150	200	5.50%	10.00%	$100.00
200	250	2.50%	4.50%	$45.00
250	300	1.25%	2.00%	$20.00
300	350	0.50%	0.75%	$7.50
350	400	0.25%	0.25%	$2.50

Figure 1-3 below expands the cumulative probability function over all points for the histogram. Figure 1-4 shows the flexible ramping up marginal value over these points. For example, the flexible ramping up marginal value at 150 MW is 10 percent times $1,000 per MWh, or $100 per MWh.

[5] The marginal value is derived in *Comments on Demand Curves in the Flexible Ramping Product Draft Technical Appendix*, Department of Market Monitoring, June 15, 2015: http://www.caiso.com/Documents/DMMComments_FlexibleRampingProductTechnicalAppendix_DemandCurves.pdf

Figure 1-3. Positive error cumulative probability

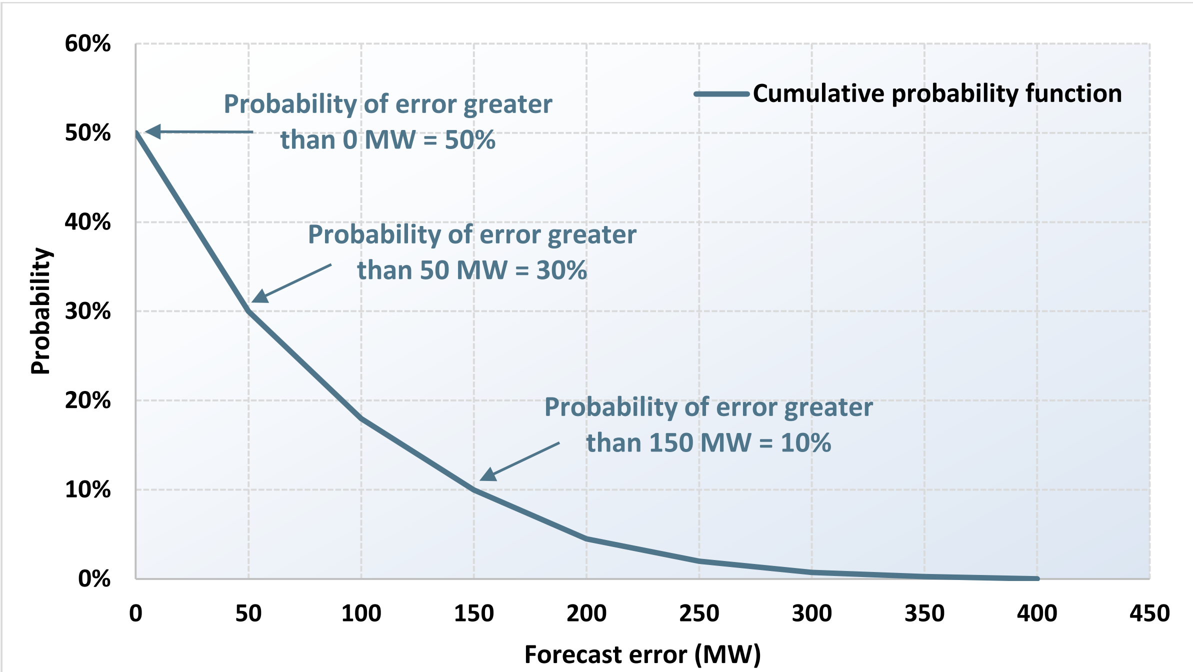
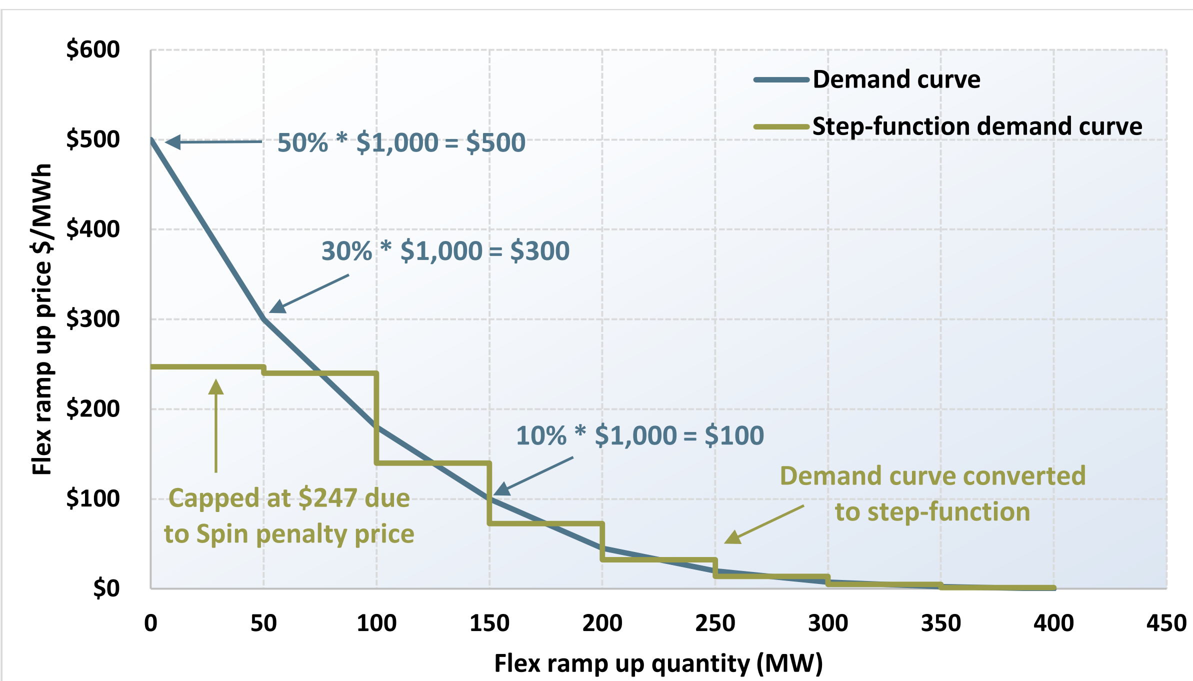


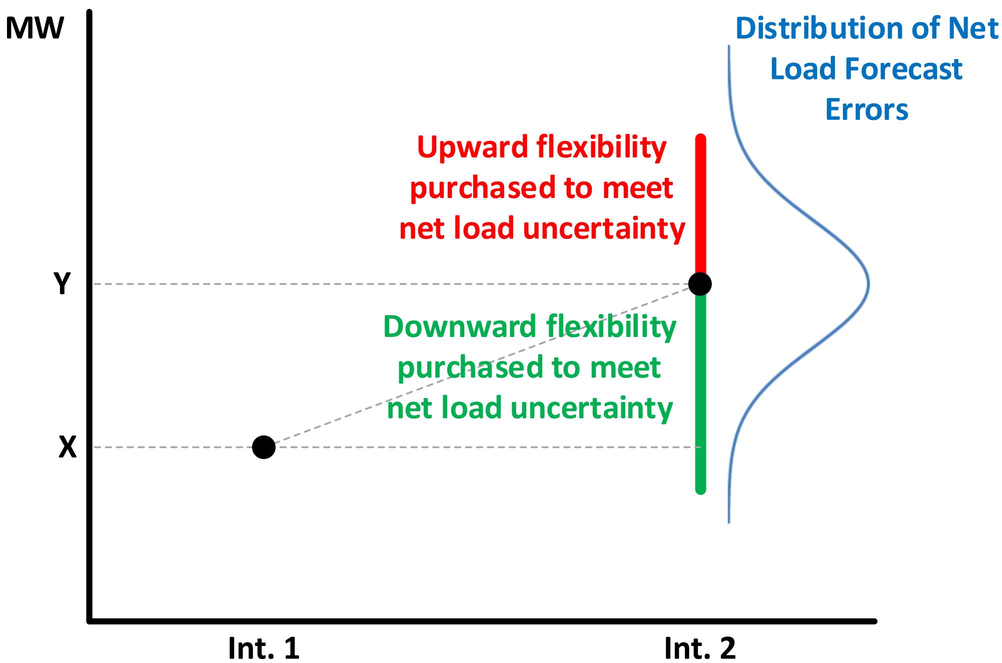
Figure 1-4. Flexible ramping up demand curve calculation



The entire blue curve in Figure 1-4 is the demand curve for flexible ramping up capacity. However, the FRP implementation uses a step function demand curve. Taking the marginal value at the midpoint of each segment converts the demand curve into the green step function. The marginal value at the midpoint is the average marginal value of all points within the histogram segment. The demand curve is also capped at $247 in order to keep the value of flexible ramping capacity below the spinning reserve penalty price.[7]

With the upward and downward FRP demand curves included in the optimization, the market optimization can trade off the value and cost of procuring additional upward and downward FRP capacity.

Figure 1-5. Expected ramp settlement and trading of flexibility



In the scenario illustrated in Figure 1-5, the entire range of net loads across the green and red bars is feasible due to the procurement of uncertainty FRP capacity. If no uncertainty FRP capacity were procured, the binding interval dispatch could result in only the expected net load (black dot) in interval two being feasible. The optimization will not necessarily make the entire potential range of net loads (represented by the distribution of net load forecast errors around the forecast) feasible. Instead, the optimization will procure FRP in order to make feasible only the range of potential net loads for which the benefits outweigh the costs.

As described in section 1.1 above, the costs of procuring FRP capacity to meet expected ramp is directly settled between the market participants who supply and demand the capacity each interval. This is not the case for uncertainty FRP. The amount of uncertainty FRP capacity purchased is determined by a demand curve that is created prior to the market optimization run. This demand curve is derived using historical data of the forecast errors of net load schedules. Therefore, allocating the uncertainty FRP

[7] In practice, the ISO will implement this demand curve as a series of constraint relaxation parameters.

capacity costs to entities in proportion to their net load forecast errors allocates the costs to those entities for whom the capacity was procured. This more closely resembles an in-market settlement than an out-of-market uplift.[8]

1.3 Procuring both upward and downward flexible capacity

The flexible ramping constraint only procures upward capacity. The flexible ramping product will constitute a significant improvement over the constraint simply by procuring downward capacity in addition to upward capacity. The downward flexible capacity will enable the market software to better position resources to respond to net load forecasts that are too high. This will reduce instances of power balance constraint violations caused by excess generation. This will also reduce the reliance on regulation down to prevent over generation.

1.4 Procuring FRP capacity in real-time dispatch

The current flexible ramping constraint only procures flexible capacity in the fifteen-minute market. There is no mechanism to ensure that the flexible capacity procured in the fifteen-minute market will be held and made available for use in the real-time dispatch intervals for which the capacity was procured. Instead, capacity procured in the fifteen-minute market corresponding to three particular real-time dispatch intervals may be dispatched for energy in real-time dispatch intervals that occur between the end of the fifteen-minute market run that procures the capacity and the start of the first real-time dispatch interval for which the capacity was procured. Therefore, even though flexible capacity was procured in the fifteen-minute market, there may not be enough flexible capacity in the real-time dispatch to respond to net load forecast deviations.[9]

The flexible ramping product improves upon the constraint by procuring capacity in both the fifteen-minute market and real-time dispatch. The real-time dispatch optimization will use current generation and net load conditions at the start of each real-time dispatch market run to re-determine the appropriate amount of flexible ramping capacity that should be procured for that specific real-time dispatch interval. Therefore, flexible capacity procured in the fifteen-minute market should only be released and used for energy by the real-time dispatch when it is cost-effective to do so.

1.5 Settling flexible capacity on the correct price

The flexible ramping constraint compensates resources through a complex formula for which the constraint's shadow price is only one input. The FRP capacity will be settled directly on the FRP constraint shadow price. This shadow price is precisely the marginal cost of procuring flexible capacity.

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[8] The ISO's final proposal does include uplifting a portion of the cost to dispatchable and non-dispatchable resource uninstructed imbalance energy. This uplift is discussed in the final section of these comments below.

[9] This issue is described in further detail by the ISO in *Flexible Ramping Constraint Penalty Price in the Fifteen Minute Market,* April 14, 2014: http://www.caiso.com/Documents/TechnicalBulletin-FlexibleRampingConstraintPenaltyPrice-FifteenMinuteMarket.pdf

Also see the Market Surveillance Committee presentation *Order 764 Market Design, Flexiramp and Ancillary Services*, Scott Harvey, March 11, 2014: http://www.caiso.com/Documents/Order764Implementation-MSC_Presentation.pdf

The marginal cost of procuring a product is the price at which the product should be transacted in a market in order to maximize market efficiency.

2. Further explanation of support for specific design elements

2.1 Separate FRP bids are not supported by costs and could create inefficiencies

Under the ISO's final proposal, generators will not submit any bids for FRP capacity. Energy bids will be used to determine FRP procurement. DMM supports the decision to not have separate FRP capacity bids for several reasons.

First, there are not any direct marginal costs of providing FRP that a separate FRP bid would represent. The FRP price in the ISO's proposal is determined by resources' energy bids. Units with energy bids below their locational energy price may have their capacity held for FRP. The foregone energy sale profits would result in an opportunity cost for these units. The market clearing FRP price will equal or exceed the opportunity costs for each unit providing FRP capacity. Therefore, this FRP price is sufficient to cover the opportunity costs of providing FRP capacity.

A separate FRP capacity bid would be appropriate only if it represented a marginal cost of providing FRP capacity. The ISO and stakeholders could not demonstrate a specific cost that a separate capacity bid would represent.[10] Furthermore, the ISO's Market Surveillance Committee could not find real-time marginal costs that a separate capacity bid would cover.[11]

Second, allowing entities to submit separate bids that do not represent marginal costs could create market inefficiencies. As noted by the ISO's Market Surveillance Committee, resources awarded FRP in the ISO real-time markets would "not incur any costs that should be reflected in an offer price in order to achieve an efficient market outcome."[12] This is because only marginal costs are needed to determine an efficient market outcome. Separate FRP bids would not represent marginal costs.

Third, allowing separate bids for FRP capacity could allow the exercise of market power and raise the FRP price above marginal cost. While DMM expects the FRP market to be competitive overall, real-time market ramping capacity might be tight at times. Market power could be exercised fairly easily with a separate capacity bid under tight ramping capacity conditions.

[10] DMM explored several potential costs, including finding that export sales to markets outside the ISO are not opportunity costs in *The Role of Separate Capacity Offers in Spot Capacity Reserve Markets*, Department of Market Monitoring, July 31, 2014: http://www.caiso.com/Documents/RoleSeparateCapacityOffers-SpotCapacityReserveMarkets.pdf

[11] *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 10: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

[12] *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 10: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

Finally, the ISO's Market Surveillance Committee noted several other potential inefficiencies and inconsistencies from allowing separate FRP bids.[13] The Committee notes that a unit with a positive FRP offer price might not clear FRP capacity in the market despite the fact that the capacity is still available to produce energy in the next market interval. This would result in the market software not accounting for all available capacity to meet flexibility needs. Therefore, the market software could procure more capacity than necessary. This would create a disconnect between the FRP procurement and actual conditions. This would also create scenarios in which units would provide capacity for which they were not compensated.

To avoid over procuring capacity, the optimization could count the unit's ramp capability but not provide it an FRP award or settlement. However, such an adjustment would result in lower compensation for the unit than if the unit had not submitted a separate FRP bid.

Another option would be to not count the capacity towards meeting the FRP requirement but still pay the unit for the capacity. This would create strong incentives for units to submit high offer prices for FRP capacity. The high offer prices would be intended to withhold capacity from the FRP requirement while still receiving payment for the withheld capacity.

A final option would be to both count the capacity towards meeting the FRP requirement and to pay the resource. However, this would effectively void the FRP bid which was higher than the market clearing price. In this situation, the ISO could provide bid cost recovery to pay the unit the difference between the FRP price and its bid. Bid cost recovery would create the same problematic incentives to submit high FRP bid prices described above. Units would have the incentive to bid high in order to be compensated at their high bid price for FRP capacity that would not clear the market. Therefore, separate FRP capacity bids would create some form of inconsistency or inefficiency.

2.2 FRP design would not be consistent with day-ahead market procurement

The ISO's final FRP proposal does not include day-ahead procurement. The ISO presented a day-ahead procurement design in a December 2014 proposal. However, the design contained several significant flaws that adversely impacted the effectiveness of procuring flexibility and that created potential inefficiencies.[14] DMM therefore supports the ISO's decision to drop day-ahead FRP procurement from the current proposal and to continue to work on a framework to include day-ahead procurement in future proposals.

The day-ahead FRP design in the 2014 proposal would have procured FRP based on net load ramps in previous day-ahead market runs. This could systematically under procure day-ahead FRP during periods when the net load ramp is increasing day-to-day. This could systematically over procure day-ahead FRP during periods when the net load ramp is decreasing day-to-day. This would significantly reduce the effectiveness and efficiency of procuring FRP in the day-ahead market.

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[13] *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 11: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

[14] See *Comments on Flexible Ramping Products Incorporating FMM and EIM Draft Final Proposal*, Department of Market Monitoring, December 31, 2014: http://www.caiso.com/Documents/DMMComments_FlexibleRampingProduct-DraftFinalProposal.pdf

Furthermore, the real-time market FRP design procures capacity in the current market interval in order to make a subsequent market interval's uncertain net load feasible. This is done using the expected net load for the advisory interval and the demand curve derived from the distribution of net load forecast errors. In the day-ahead market there are no advisory intervals. The net load that will clear each market interval (hour) is known. The basic structure underlying the real-time market FRP design does not exist in the day-ahead market.

Moreover, the difference between the granularity of the intervals in the day-ahead and real-time markets creates inefficiencies in the day-ahead procurement. The day-ahead market would see a 50 MW resource that could only ramp 1 MW per minute as being equivalent to a 50 MW resource that could ramp 4 MW per minute. This is because each could provide 50 MWs of day-ahead ramp. Procuring day-ahead flexible capacity from the slower ramping resource would be inefficient because the faster resource clearly provides more fifteen-minute market flexibility.

Structural differences between day-ahead and real-time markets make FRP capacity different between the markets. The day-ahead and real-time FRP would not be the same product. Therefore, settling real-time FRP capacity awards against the day-ahead awards would have been inconsistent. It could have potentially created various market inefficiencies and costs to market participants, including generators awarded day-ahead FRP.

2.3 FRP and virtual bid interaction is not a reason to delay FRP proposal

The FRP is only incorporated in the real-time markets. Differences between day-ahead and real-time market modeling can create opportunities for virtual bids to be profitable while creating uplift costs and having no impact on market efficiency.

However, the current flexible ramping constraint is only modeled in the fifteen-minute market. Therefore, the current flexible ramping constraint already creates a modeling difference between the day-ahead market and fifteen-minute market. As a result, the FRP proposal will not introduce a fundamental new modeling difference between the day-ahead and fifteen-minute markets.

To date, the current flexible ramping constraint has not been shown to create a significant incentive for inefficient virtual bidding. DMM has considered the potential for the FRP to create such an incentive, but has yet to find a significant one. The ISO's Market Surveillance Committee also "evaluated this concern and concluded that no such potential exists." [15] Therefore, DMM does not believe there is reason to delay the FRP design due to potential interactions between FRP and virtual bidding.

[15] *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 11: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

3. Recommendations to increase effectiveness of FRP proposal

3.1 Implementation of the demand curve can significantly affect market outcomes

While DMM supports the design and theory underlying the FRP demand curve, the implementation of this feature can have significant impacts on the final demand curves used in the market software. DMM emphasizes the importance of this issue since DMM has had numerous analogous concerns with how the ISO has calculated the demand requirement for the current flexible ramping constraint. DMM's recommendations concerning these calculations dating back to 2014 were not implemented. Given the fall 2016 target implementation date for the FRP, DMM recommends the ISO ensure that sufficient time and resources are made available to develop, review and refine the demand curve before and after the fall 2016 implementation date.

DMM's major recommendation concerning implementation of the demand curve involves ensuring that a sufficiently large sample of net load forecast errors is used to estimate the demand curve. The current flexible ramping constraint requirement is set by taking the 95th percentile of historic net load differences between the real-time dispatch and fifteen-minute market. However, the sample from which the 95th percentile is determined has a maximum of 40 observations. As a result, the second highest observation out of the sample of 40 observations sets the requirement. As highlighted in prior DMM reports, using such a small sample size creates a volatile requirement that does not necessarily represent the 95th percentile of the true distribution of ramp needs.[16] The Market Surveillance Committee similarly pointed out that "the 95th percentile is defined by 2 extreme data points which is much too small a sample to reliably estimate the variability of the distribution."[17]

DMM and the Market Surveillance Committee have raised concerns over the flexible ramping constraint requirement calculation since 2014. However, over the last year the ISO has only made several smaller intermediate fixes to this calculation.[18] The ISO partially addressed DMM's recommendations on this issue by setting a minimum and maximum bound that is used to truncate results of the calculation based on the sample of 40 observations currently used to determine the requirements.

However, the underlying problems of using such a small sample persist. Figure 3-1 shows the volatility of the flexible ramping constraint requirements across a typical recent day. As shown in this figure, the approach currently used to determine the requirement for the current flexible ramping constraint yields a very volatile demand requirement from one 15-minute interval to the next. During many intervals, the requirement calculated based on the small sample of intervals on prior days falls outside of the bounds established by the ISO, so that the requirement is actually set directly at the upper or lower bound set by the ISO.

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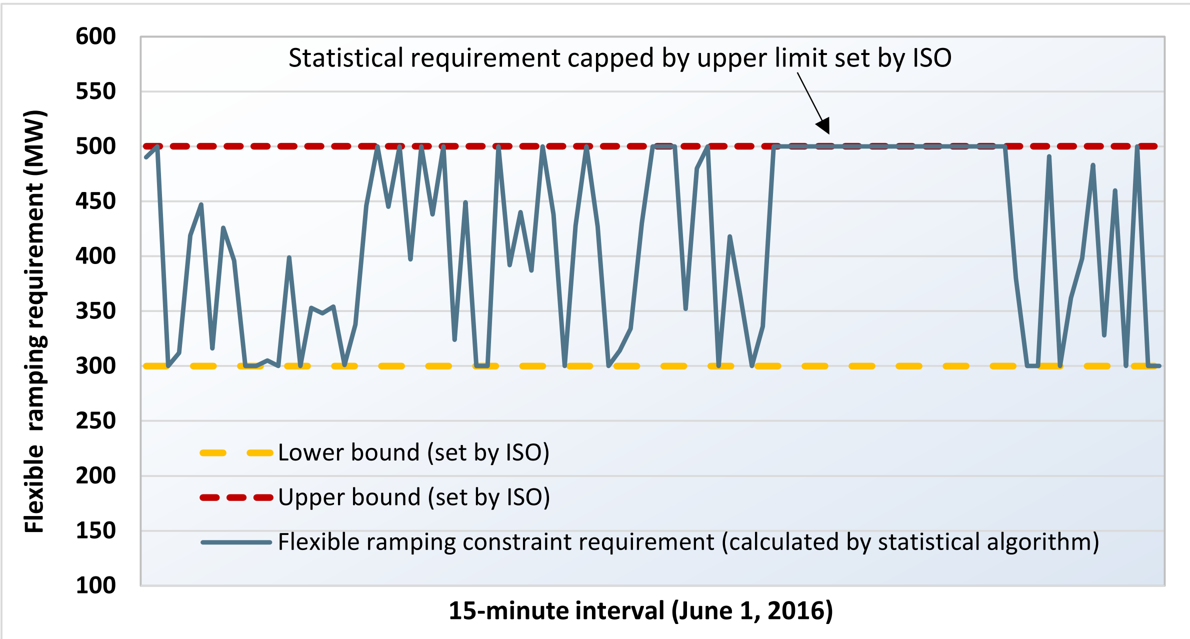
[16] *Q2 2015 Report on Market Issues and Performance*, Department of Market Monitoring, August 2015, p. 43: http://www.caiso.com/Documents/2015_SecondQuarterReport-MarketIssues_Performance-August2015.pdf

[17] *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 8: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

[18] These include increasing the sample size from 20 to 40 observations, correcting some data processing errors, and adjusting the upper and lower bounds on the balancing area specific requirements to limit volatility.

Figure 3-1. Example of current flexible ramping constraint requirements



The accuracy and level of the FRP demand curve will be even more sensitive to sample size than the flexible ramping constraint requirement. With the FRP, the distribution of net load forecast errors will be used to estimate demand curve prices across multiple segments, rather than just one fixed level of demand requirement.

In addition, the FRP demand curve will be a more important factor in FRP procurement and pricing than the demand requirement for the current flexible ramping constraint. The FRP price will have greater market impacts than the current flexible ramping constraint price for several reasons:

- The flexible ramping constraint only settles capacity incremental to the FMM energy schedules. FRP will settle both the expected ramp and incremental capacity for uncertainty.
- The flexible ramping constraint only settles capacity for dispatchable resources. The FRP will create settlements for both dispatchable and non-dispatchable resources.
- The constraint procures capacity in the fifteen-minute market only. FRP capacity will be procured in both the fifteen-minute and real-time dispatch markets.
- The constraint shadow price is only one of several inputs into the settlement price calculation for capacity. The FRP shadow price will be directly used to settle FRP capacity.

For these reasons, it is important that the ISO implements a robust FRP demand curve with a large enough sample of historic data to have a statistically sensible estimate of the distribution of net load forecast errors.

It is DMM's understanding that when calculating the FRP demand curve, the ISO plans to use the historical net load forecast errors from all intervals in an hour in order to estimate a different distribution of net load forecast errors for each hour. The sample size for each hour is likely to be too small to obtain a statistically significant estimate of the distribution. As the Market Surveillance Committee points out, this small increase in the sample to around 90 observations would "likely not do much to improve predictions relative to the current method."[19]

Therefore, DMM recommends that the ISO initially use the net load forecast errors from all intervals across the day to estimate one distribution of net load forecast errors for a day. As the ISO gets more experience in estimating distributions, it can attempt to estimate different distributions of net load forecast errors for different periods of the day by accounting more directly for the variables causing any potential differences in distributions.

DMM also believes that the number of different net load forecast error distributions that the ISO should try to estimate should not be prescribed in the BPM. Estimating the net load forecast error distribution is analogous to forecasting load. This is something the ISO should frequently review and adjust as necessary, without having to provide specific details of the forecasting formula in the BPM.

3.2 Allocation of FRP costs from net load uncertainty to generation uninstructed imbalance energy

DMM has also provided the ISO with recommendations for further potential refinements to the way in which costs of this new product are allocated.

Uninstructed deviations (the difference between a resource's real-time dispatch schedule and actual metered output) of dispatchable resources can create a need for procuring uncertainty FRP. DMM has described a method for incorporating uninstructed deviations into the FRP demand curve.[20] The ISO has not incorporated any effects of dispatchable resource uninstructed deviations into its FRP demand curve proposal. Therefore, no FRP will be procured as a result of these uninstructed deviations. However, the ISO proposes to allocate FRP costs to resource uninstructed imbalance energy (UIE) even though no FRP capacity will be procured for it.

Because uninstructed deviations from dispatchable resources do create a need to procure FRP, there may be some justification for allocating some FRP costs to dispatchable resources based on their uninstructed deviations. However, the quantity of FRP that should be procured due to uninstructed deviations is not equal to the UIE value. Moreover, allocating FRP costs based on UIE that did not cause any FRP procurement blunts more optimal behavioral incentives. Instead, the ISO could create more optimal behavioral incentives by allocating costs to entities in proportion to the actions that caused those costs.

[19] The 90 observation figure refers to the fifteen-minute market with about a 20 day lookback. See *Opinion on the Flexible Ramping Product*, Market Surveillance Committee, January 20, 2016, p. 8: http://www.caiso.com/Documents/Draft_MSC_Opinion_FlexibleRampingProduct-Jan2016.pdf

[20] See *Comments on Flexible Ramping Product Revised Draft Technical Appendix*, Department of Market Monitoring, December 1, 2015: http://www.caiso.com/Documents/DMMComments-FlexibleRampingProduct-RevisedDraftTechnicalAppendix.pdf. DMM notes that meter data could be used as a less optimal substitute for telemetry data if there were implementation concerns over using telemetry data.

Uninstructed deviations from non-dispatchable resources, such as variable energy resources, do not create any additional need for FRP procurement. The error in a non-dispatchable resource's advisory interval forecast relative to its binding interval schedule captures all non-dispatchable resource contributions to the need to procure uncertainty FRP. This type of forecast error is included in the demand curve. Allocating FRP costs to this type of forecast error therefore causes the correct amount of FRP costs to be allocated to non-dispatchable resources. The error in a non-dispatchable resource's binding interval schedule relative to its actual production (i.e., the resource's UIE) does not result in any need to procure FRP. Instead, this second type of forecast error results in the use of regulation. Allocating *regulation costs* to non-dispatchable resource UIE would be appropriate. The ISO does not seem to support its proposal to allocate *FRP costs* to non-dispatchable resource UIE.

If the ISO were to not allocate uncertainty FRP costs to resource UIE, it would not adversely affect, or require changes to, the rest of the FRP design. Therefore, the ISO could improve its FRP proposal by simply not allocating uncertainty FRP costs to dispatchable or non-dispatchable resource UIE. After the ISO incorporates dispatchable resource uninstructed deviations into the FRP demand curve, it would be appropriate to begin allocating FRP costs to dispatchable resources based on the contribution of each dispatchable resource's uninstructed deviations to FRP procurement.

Attachment I – Board Memorandum (including matrix of stakeholder comments)

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Memorandum

To: ISO Board of Governors

From: Keith Casey, Vice President, Market & Infrastructure Development

Date: January 27, 2016

Re: **Decision on flexible ramping product proposal**

This memorandum requires Board action.

EXECUTIVE SUMMARY

Over the past several years, the ISO has implemented several enhancements to its real-time market, which now includes the energy imbalance market (EIM), to effectively manage the integration of variable energy renewable resources to support state and federal policies to decarbonize the grid. In 2011, the ISO implemented a flexible ramping constraint to help ensure sufficient resources were positioned to meet forecast upward ramping needs. At that time, the ISO committed to address limitations of the constraint through the design of a product that would more effectively dispatch resources to meet forecast ramping needs. As a result, Management proposes the flexible ramping product, a key market design enhancement to further ensure that sufficient upward and downward flexible capacity is available and efficiently dispatched in the ISO real-time market.

The flexible ramping product is designed to compensate resources for providing ramping capability as well as incentivize loads, resources, and interties to reduce the significant ramps illustrated by the well-known “duck curve” diagram. If load or supply resources increase the forecast ramp, the market will charge the load or supply resource for the flexible ramping product. If load or supply resources decrease the forecasted ramp, the market will compensate the load or supply resource. In addition, the flexible ramping product is designed to procure additional ramping capacity to meet uncertainty in the net load[1] forecast when it is economic to do so. The market will allocate the cost for the flexible ramping product to cover uncertainty based on a load or supply resource’s forecast error.

[1] Net load is gross load less wind and solar resource output.

The proposed design significantly improves the management of ramping capacity in the real-time market. As a result, the environmental policy goals across the West can be achieved more efficiently and economically.

Management recommends the following motion:

> ***Moved, that the ISO Board of Governors approves the flexible ramping product proposal, as described in the memorandum dated January 27, 2016; and***
>
> ***Moved, that the ISO Board of Governors authorizes Management to make all necessary and appropriate filings with the Federal Energy Regulatory Commission to implement the proposed tariff change.***

DISCUSSION AND ANALYSIS

The ISO's real-time market optimizations seeks to ensure sufficient capacity is committed and positioned to allow for efficient and economic load following during each five-minute dispatch interval. Its objective is for these commitments and dispatches to be feasible and sufficient to address a reasonable range of unexpected outcomes. The ISO currently enforces a constraint in the fifteen-minute market that accounts for and awards upward flexible ramping capacity to resources to ensure there is sufficient ramping capacity available to the five-minute real-time dispatch.

Despite this constraint, Management has observed instances where there is insufficient flexible ramping capacity in the five-minute real-time dispatch. In addition, the current constraint does not ensure there is sufficient downward ramping capacity. To address these issues and improve how the ISO compensates resources for providing ramping capacity, Management proposes to replace the flexible ramping constraint with the flexible ramping product.

Background

In December 2011, the ISO implemented the flexible ramping constraint in the real-time market optimization to address frequent occurrences of insufficient ramping capacity in the five-minute real-time dispatch. At that time, Management committed to start a stakeholder process to develop a flexible ramping product that would address both upward and downward ramping needs. This stakeholder process was initiated in November 2011, however, Management suspended the stakeholder process to develop the fifteen-minute market in response to FERC Order No. 764. This was done to ensure that the flexible ramping product was ultimately compatible with the new fifteen-minute market. The ISO reinitiated the flexible ramping product stakeholder initiative in June 2014.

Compensating resources for ramping capacity

The flexible ramping product improves on the ISO market's compensation for ramping capacity by explicitly compensating resources for ramping capacity. The real-time market often dispatches resources out of economic merit order for a projected need in a future interval. Under the flexible ramping product, the resource will receive a separate payment in the financially binding interval for this ramping capacity to meet the projected future need. The market will award, price, and settle the flexible ramping product in both the fifteen- and five-minute market.

Currently with the flexible ramping constraint, the market often fails to compensate resources adequately when it is ramping them for a need in a future interval as a result of its multi-interval optimization. The ISO's market is especially advanced in this regard; it performs a multi-interval optimization for every respective run of the fifteen- and five-minute markets that dispatches resources economically over the entire market horizon. However, only a single initial interval is financially binding. The other intervals are only advisory, and the real-time market typically dispatches a resource differently for a given interval as conditions change in successive market runs.

This process often results in the real-time market dispatching a resource to begin ramping in the upcoming financially-binding interval, or holding a resource back, because the market sees that it needs the resource to be at a certain output level in a future interval. In this situation, the financially-binding interval's locational marginal price may not support the resource's bid price, or the resource may not be dispatched for energy for which it is economic, but the market projects the price in this future interval will make up for the shortfall or opportunity cost. However, conditions typically change in successive market runs, where even a small a change can cause the future interval advisory price to not materialize. In such cases, the market undercompensates the resource for ramping to meet the projected need in a future interval.

The flexible ramping product also helps the market avoid spurious price excursions associated with insufficient ramping margin because of forecast errors. These price excursions occur because there is little margin of error between the interval ramping needs in a multi-interval optimization. The flexible ramping product addresses this by maintaining additional ramping capacity on resources, when economic to do so, to ensure sufficient upward and downward flexibility is available.

Forecast ramping between intervals

As described above, the flexible ramping product procures ramping capacity for both the forecast net load ramp and ramping uncertainty. This first element, the forecast net load ramp, consists of the forecast net load ramp between the financially-binding interval and the subsequent advisory interval. Ramping of load, dispatchable resources, non-dispatchable resources, and interties can create both a demand for ramp and a supply for ramp.

Load or supply resources that increase the forecast ramp between intervals will be charged for the flexible ramping product. Load or supply resources that decrease the forecast ramp between intervals will receive a payment for the flexible ramping product. Settling ramping capacity directly between load or supply resources that consume ramping capacity and those that provide ramping capacity will help manage the ramping need illustrated by the "duck curve" diagram by incentivizing load serving entities to have a portfolio of both dispatchable and non-dispatchable resources that can follow their load profile.

Ramping uncertainty

In addition to procuring ramping capacity for the forecast net load ramp, the flexible ramping product will procure an additional amount of ramping capacity for ramping uncertainty. Absent a flexible ramping product requirement, the market will solve only for expected load and system conditions. This limits the ability of the real-time dispatch to meet changes in system conditions between the fifteen-minute market and five-minute real-time dispatch, and between subsequent market runs of the five-minute dispatch.

To address this forecast uncertainty, the flexible ramping product procures ramping capacity in addition to that needed to meet the forecast net load ramp. It will only do this if the expected benefits of this additional ramping capacity exceed its costs. This is determined by calculating the probability of a power balance violation due to a deficiency in ramping energy and the associated costs to the market and comparing this to the costs to procure ramping capacity. For example, assume there is a 5 percent probability that a shortage in supply will trigger a power balance violation and trigger the upward power balance relaxation parameter of $1,000/MWh used by the market. The flexible ramping product will assume it is economic to procure additional flexible ramping up capacity until the cost of doing so is greater than $50.00/MWh (5% x $1000/MWh). All supply and demand that cause forecast uncertainty economically benefit from the market procuring additional flexible ramping capacity at a price up to $50.00/MWh.

Unlike forecast ramping between intervals, there cannot be a direct settlement between those requiring ramping capacity and those providing ramping capacity to cover uncertainty in the net load forecast. This is because the market may not need to use, and consequently attribute to a specific load or supply resource, the flexible ramping capacity procured to cover uncertainty.

Consequently, the market will allocate the costs of the ramping capacity it procures to cover uncertainty based on a load's or a supply resource's contribution to this uncertainty. It will do this by evaluating each load's or supply resource's contribution to this uncertainty over each month. The market will do this in two-tiers:

- It will allocate the costs in the first tier pro-rata between load, generation, and imports/exports based upon the observed forecast error of each category relative to the other two categories.

- It will allocate the costs in the second tier using a different methodology for load, generation, and imports/exports, respectively. It will allocate costs to load based on gross uninstructed imbalance energy. It will allocate costs to generation based on gross observed forecast error plus uninstructed imbalance energy. It will allocate costs to imports/exports to deviations from schedules. The cost allocation for generation considers uninstructed imbalance energy to provide an additional incentive to follow dispatch instructions.

Energy imbalance market

The energy imbalance market includes an hourly resource sufficiency evaluation to ensure balancing authorities in the EIM have sufficient participating resources within their balancing authority area to meet their expected energy imbalances prior to benefiting from using more economic resources outside their balancing authority area. The current resource sufficiency evaluation only considers upward ramping capacity. Since the flexible ramping product will also manage downward ramping capacity, Management proposes to add a downward ramping test to the hourly resource sufficiency evaluation. If a balancing authority fails the downward ramping test, incremental EIM transfers out of the balancing authority area will not be allowed.

The costs of meeting the flexible ramping constraint are allocated directly to the EIM entity and the EIM entity subsequently allocates the costs to its customers according to the EIM entity's Open Access Transmission Tariff. This was appropriate initially with the flexible ramping constraint because both the compensation and cost allocation in the ISO was based upon a FERC settlement. However, with the redesign of the flexible ramping constraint into the flexible ramping product, resource compensation and cost allocation are key design elements that should apply across the real-time market footprint to ensure resources respond to ISO dispatches equally. Therefore, Management proposes that all loads, resources, and interties will be settled in the same manner *i.e.,* based on forecast ramping between intervals. In addition, the cost allocation of ramping capacity to meet uncertainty within an EIM balancing authority area will be allocated to both participating and non-participating resources in the same manner across the entire EIM footprint.

POSITIONS OF THE PARTIES

Stakeholders support the flexible ramping product proposal which is the result of a lengthy stakeholder process. The Market Surveillance Committee has provided a formal option on Management's proposal and the Department of Market Monitoring has provided comments in their Market Monitoring Report. A stakeholder comment matrix is included in appendix A.

When the ISO started the flexible ramping product stakeholder process, the ISO and stakeholders anticipated that the flexible ramping product would be an economically bid capacity product, allow procurement of both upward and downward ramping capacity, and procure the product in the day-ahead market. As the stakeholder initiative progressed, the ISO and stakeholders challenged the appropriateness of economic bidding because in the real-time market, the need for a capacity bid could not be justified since there is no additional cost for an out-of-merit dispatch beyond the opportunity cost of not being dispatched when the energy bid is economic.

In addition, the ISO determined that the benefits of procuring the flexible ramping product in the day-ahead market were not significant enough to overcome the inefficiencies caused by different settlement and dispatch periods between the day-ahead and real-time market. Therefore, Management does not propose to include these features in the day-ahead market; instead, the flexible ramping product is focused on improving managing ramping capacity in the real-time market by including a downward product, maintaining ramping capacity in the 5-minute real-time dispatch, and replacing the settlement and cost allocation of the current flexible ramping constraint.

CONCLUSION

Management seeks Board approval of the flexible ramping product proposal as described in this memorandum. The flexible ramping product enhances the ISO's advance real-time market by improving the management of ramping capacity, accurately compensating flexible resources, and appropriately allocating ramping costs. These features will incentivize greater participation of flexible resources, which will improve the ability of the market optimization to manage increasing levels of variable energy resources.

Attachment A

Stakeholder Process: Flexible Ramping Product

Summary of Submitted Comments

Stakeholders submitted eighteen rounds of written comments to the ISO on the following dates:

- Round one, 11/14/11
- Round two,12/12/11
- Round three, 01/19/12
- Round four, 03/21/12
- Round five, 03/29/12
- Round six, 04/16/12
- Round seven, 04/24/12
- Round eight, 07/24/12
- Round nine, 08/23/12
- Round ten, 09/25/12
- Round eleven, 10/09/12
- Round twelve, 06/23/14
- Round thirteen, 09/03/14
- Round fourteen, 10/14/14
- Round fifteen, 01/02/15
- Round sixteen, 07/01/15
- Round seventeen, 12/02/15
- Round eighteen, 01/12/16

Stakeholder comments were received from:

Brookfield Renewable Energy Group, California Department of Water Resources, California Energy Storage Alliance, California Municipal Utilities Association, California Public Utilities Commission, California Wind Energy Association, Calpine, Center for Energy Efficiency and Renewable Technologies, Department of Market Monitoring, Dynegy, Energy Curtailment Specialists, GenOn Energy Inc., Iberdrola, Independent Energy Producers, J.P. Morgan, Large-scale Solar Association, NRG Energy Inc., Pacific Gas & Electric, PacifiCorp, Powerex Corp., San Diego Gas & Electric, Sempra US Gas and Power, Southern California Edison, Viasyn, Wärtsilä, Wellhead, and Western Power Trading Forum.

Stakeholder comments are posted at:
http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=49027DBE-83C3-44EF-8E93-24AC285F7AA6

Other stakeholder efforts include:

- Meeting, 11/07/11
- Meeting, 12/05/11
- Meeting, 01/12/12
- Meeting, 03/14/12
- Workshop, 05/25/12
- Conference call, 07/02/12
- Meeting, 07/17/12
- Meeting, 08/16/12
- Technical workshop, 09/18/12
- Technical workshop, 10/02/12
- Meeting, 10/30/12
- Conference call, 04/21/14
- Meeting, 06/09/14
- Meeting, 08/20/14
- Conference call, 12/11/14
- Conference call, 04/21/15
- Technical workshop, 06/17/15
- Technical workshop, 11/18/15
- Conference call, 01/05/16

	Management Proposal: Prioritize market design elements needed to replace the current flexible ramping constraint.				
	Compensate all ramping capability	Procuring only in the real time market	Downward procurement	Explicit bidding not needed	Evaluate future need for more localized procurement
CDWR	Support	Support Recommends at least one year of operational experience before considering FRP in the day-ahead market.	Support	No comment	No comment
CESA	Support FRP will create a more efficient market solution.	Support	Support	No comment	No comment
LSA	Oppose Overly complex and opportunity-cost-based compensation is insufficient.	No comment	No comment	Oppose Lack of bidding results in compensation not covering costs for generators.	No comment
PG&E	Support	Support Building block to gaining operation experience for consideration of day-ahead market procurement.	Support	Support	Support Need for local requirements should be monitored
			Support	Support	Support

	Management Proposal: Prioritize market design elements needed to replace the current flexible ramping constraint.				
	Compensate all ramping capability	**Procuring only in the real time market**	**Downward procurement**	**Explicit bidding not needed**	**Evaluate future need for more localized procurement**
Powerex Corp	Support Sound conceptual framework that provides the appropriate price signals to minimize flexible ramping need.	Support Important step towards meeting challenges of balancing system but should consider day-ahead market procurement.			
SCE	Support	Support	Support	Support	Oppose Procure FRP through existing ancillary services (AS) regions.
WPTF	Support Inclusion of interties to provide forecasted movement is a key aspect.	Oppose Should include day-ahead procurement	Support	Oppose Difficult to consider design a product when bidding is not allowed.	Support
Management Response	Management has worked closely with stakeholders over the past four years to develop the flexible ramping product. The design compensates all resources that provide ramping capability and charges resources that contribute to ramping needs. The proposed design also includes the downward procurement of the flexible ramping product which addresses the operational challenges of over-generation, and enhances the EIM resources sufficiency evaluation. A majority of stakeholders are in favor of replacing the current flexible ramping constraint with the goal of making incremental changes to the flexible ramping product as the ISO gains more operational experience. Management determined that the benefits of procuring the flexible ramping product in the day-ahead market were not significant enough to overcome the inefficiencies caused by different settlement and dispatch periods between the day-ahead and real-time market. Without day-ahead procurement, Management, DMM, and the MSC could not identify additional costs, which would require an explicit flexible ramping product bid, that are not already reflected in the energy bid. Management will procure the flexible ramping product within each balancing authority area in the EIM footprint. However, due to increased implementation complexity, Management does not propose to support locational procurement within a balancing authority area.				

	Management Proposal: Improve settlement of ramping capability by compensating both forecasted ramp and additional ramp to meet uncertainty in net load forecast. Better align cost allocation with those that drive the requirement and benefit from ramp procurement.				
	Separate settlement for forecasted ramp and uncertainty	Procure uncertainty through demand curve	Allocate cost for uncertainty monthly	FRP award deviations between RTPD and RTD by settling at RTD price	Rescission of double payment
CDWR	Support	Support	Support	Support	Support
CESA	Support	Support	Support	Support	Support
LSA	Oppose Generator schedules should be used to settle costs rather than ISO forecast.	No comment	No comment	No comment	No comment
NV Energy	No comment	Conditional Request ISO commitment to inform market participants of any calculation changes prior to making updates in the system, and to give notice of the timing of those updates.	No comment	No comment	No comment

PG&E	Support Results in more transparency for market participants on the drivers of FRP costs	Support Requests ISO to state criteria it will use to determine when it will revisit method to set demand curve.	Support	Support	Support
Powerex Corp	Support Requesting additional examples illustrating settlement of uncertainty.	Support Continue to fine tune approach as the ISO gains experience with FRP.	Support	Support	No comment
SCE	Conditional Supports settling the payment to resources and allocating the cost at the same time but not the grouping of uncertainty costs to on-peak and off-peak periods.	Support	Oppose No advantage gained from summing gross positive and gross negative uninstructed imbalance energy of each category over the on-peak and off–peak periods.	Support	Support
WPTF	Support	Do not oppose	Support Cost allocation is a fair balance between incentivizing individual behavior and cost causation.	Support	Support

Management Response	Management proposes that the flexible ramping product will be settled in two segments. The settlement of forecast ramp between market intervals will be directly settled between resources providing ramp and resources consuming ramp. Additional ramping capability procured to meet uncertainty of the net load forecast will be settled and allocated on a monthly basis. The cost allocation on a monthly basis is appropriate because it is procured based upon potential forecast differences and not the actual realization of forecast error in a given settlement interval. Over the course of a month, observed forecast errors should be consistent with how the requirement was calculated using historical information regarding forecast errors. In addition, having separate allocations for off-peak and on-peak hours is appropriate because the cost of procuring the flexible ramping product may differ and there are resources, such as solar, which cannot impact the requirement when unable to produce energy. Management will document the methodology for calculating the flexible ramping product requirement and demand curves in the business practice manuals. Any change to the methodology will follow the business practice manual change process, which allows for stakeholder input prior to the methodology change being implemented.

Attachment J – Market Surveillance Committee Opinion

Tariff Amendment to Implement Flexible Ramping Product

California Independent System Operator Corporation

June 24, 2016

Opinion on
Flexible Ramping Product

by

James Bushnell, Member
Scott M. Harvey, Member
Benjamin F. Hobbs, Chair

Members of the Market Surveillance Committee of the California ISO

Final
January 26, 2016

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 FRAC-MOO 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]

[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

[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

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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.