UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Fast-Start Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators	)))	**Docket No. RM17-3-000**

SUPPLEMENTAL COMMENTS OF THE CALIFORNIA INDEPENDENT SYSTEM OPERATOR CORPORATION

The California Independent System Operator Corporation (CAISO) submits the following supplemental comments in response to the Federal Energy Regulatory Commission's (Commission) Notice of Proposed Rulemaking (NOPR) issued in this docket on December 15, 2016. The NOPR proposes to revise the Commission's regulations to require that each Regional Transmission Organization (RTO) and Independent System Operator (ISO) incorporate market rules that meet certain requirements with respect to "fast-start" resources.

In its initial comments, submitted on February 28, 2017, the CAISO indicated that it supported the Commission's goals of enhancing price formation in energy and ancillary services markets operated by RTOs and ISOs. The CAISO agreed with the general principle that prices used in energy and ancillary services markets should reflect the true marginal cost of production, to the extent possible, and fully compensate resources for the marginal cost of providing service. The CAISO explained, however, that the measures proposed by the Commission in the NOPR would be unlikely to further those goals in the CAISO's markets. The CAISO's primary concerns are that under the proposed pricing rules (1) market prices will mask the proper price signal in numerous intervals; and (2) the CAISO will need to rely more extensively on out-of-market actions that increase, rather than minimize, market uplift. The CAISO also expressed concern that the proposed rules could undermine certain significant and carefully tailored market design changes the CAISO has made in recent years to address the challenges raised by the transformation of its resource fleet. In particular, the CAISO described conflicts between the proposals in the NOPR and market design improvements made by the CAISO over the past several years aimed at enhancing the dispatch and pricing of resources that are able to provide ramping capability, both upwards and downwards, over relatively short time periods, known as flexible ramping capability.

In order to address these concerns in more detail, the CAISO proposed that the Commission convene a technical workshop. The CAISO stated that it would be difficult to effectively and comprehensively communicate the CAISO's concerns in written comments on the NOPR, and that it would be much more informative and beneficial to engage in a dialogue in a targeted workshop. In May 2017, the CAISO met with Commission staff to discuss the NOPR and implications for the CAISO market specifically. At that meeting, CAISO and Department of Market Monitoring personnel presented their concerns and provided a numerical example of how the proposals in the NOPR would impact the CAISO's efforts to address ramping needs in its markets. Based on this exchange, the CAISO believes these comments will further inform the

Commission of the issues the NOPR raises in the CAISO markets and assist the Commission in its final rulemaking.

This additional material focuses on the issues caused by the interaction between the fast-start pricing rules proposed in the NOPR and the CAISO's flexible ramping product. The flexible ramping product is one of the key components of the CAISO's market design aimed at managing a generation fleet that is increasingly comprised of variable energy resources. The CAISO believes that these additional materials will assist the Commission in understanding the challenges that the CAISO is currently facing and the deleterious impacts that the NOPR rules would have on its markets were the Commission to require the CAISO to adopt the proposals. The CAISO, therefore, respectfully requests that the Commission include these comments in the record and consider them in developing its final rule on fast-start pricing.

I. SUPPLEMENTAL COMMENTS

A. Background on the CAISO's Efforts to Address the Increased Need for Resources with Flexible Ramping Capability

As the CAISO explained in its initial comments,[1] under renewable portfolio standards in California and other western states, variable energy resources will continue to play an increasing role in the CAISO's real-time markets. The increasing reliance on these resources to meet load requires a corresponding increase in capability from resources that can rapidly change their output to

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[1] CAISO Initial Comments at 4-7.

respond to changes in net forecasted system demand.[2] The CAISO refers to this ability to rapidly change output levels as “flexible ramping capability.” The CAISO’s experience in operating the market has shown that the energy from the fleet of resources committed in the fifteen-minute real-time unit commitment process may 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. 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 market prices do not reflect such costs.

The CAISO has undertaken a number of initiatives over the past several years in order to address the increased need for flexible ramping capability accompanying the growing number of variable energy resources on the CAISO’s system. The CAISO market optimizes over multiple intervals, meaning that the market simultaneously determines the necessary output of resources to meet forecasted net load over multiple intervals. An illustration of the benefits of a multi-interval optimization in addressing ramping capability needs is set forth in the testimony provided by Mr. Donald Tretheway as part of the CAISO’s 2016 flexible ramping product filing,[3] which is included as Attachment A to this filing.

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[2] The CAISO uses the terms “net forecasted system demand” or “net forecasted load” to refer to forecasted demand net of forecasted non-dispatchable supply such as variable energy resources like wind and solar.

[3] Direct Testimony of Donald Tretheway in Commission Docket ER16-2023, attached hereto as Attachment A, at 8-11 (“Attachment A”).

However, the multi-interval optimization is not in and of itself sufficient to capture fully the CAISO's ramping capability requirements. As Mr. Tretheway explained in his testimony, a multi-interval optimization produces schedules based on forecasted net load changes between market intervals, but such forecasts are inherently uncertain and subject to change in either direction (*i.e*., a need for more or less generation).[4]

In 2011, the CAISO first addressed uncertainty in forecasted net load by adding a flexible ramping constraint in its real-time unit commitment process to ensure that upward ramping capability is available in addition to the ramping capability that results from the multi-interval optimization, so as to address forecast uncertainties. In 2016, the CAISO filed tariff revisions to implement its flexible ramping product. The Commission accepted the CAISO's flexible ramping product amendment in an order issued on September 26, 2016.[5]

As with the flexible ramping constraint, the purpose of the flexible ramping product is to ensure that sufficient ramping capability is available from resources to meet the changes in forecasted net load between all intervals in a market run. However, unlike the flexible ramping constraint, the flexible ramping product models and procures both upward and downward ramping needs, and does so in all of the CAISO's real-time market processes, including the short-term unit commitment process, the fifteen-minute market, real-time unit commitment process, and the real-time dispatch. Also, the flexible ramping product only

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4 *Id.* at 12.

5 *Cal. Indep. Sys. Operator Corp.,* 156 FERC ¶ 61,226 (2016).

procures additional ramping capability if the marginal cost exceeds the expected benefit of additional ramping capability. Load and supply that increase the need for ramping capability between intervals are charged for the flexible ramping product, while 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 helps 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.

The flexible ramping product also represents an improvement over the flexible ramping constraint by separating energy prices and ramping prices, thereby providing more transparent price signals. Under the flexible ramping constraint pricing methodology that was established through a settlement process, the CAISO compensated resources based on calculated prices that reflected a composite of the energy and ramping price. A composite energy and ramping price may not in all cases be consistent with a resource's energy offer price and may trigger real-time bid cost recovery if the dispatch of the resource does not provide sufficient revenues to cover start-up and minimum load costs over the operating day. The settlement of forecasted movement through the flexible ramping product addresses this situation by reducing 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.[6] In addition, the CAISO did not compensate resources based on the first advisory interval. Prior to the adoption of the flexible ramping product, resources received no payment for the flexible ramping capability that the optimization counted on in the binding interval to meet the next interval's net load forecast. From an energy perspective, the resource may be indifferent because either the marginal price reflects their bid and marginal costs, or, the resource is eligible to receive bid cost recovery. The resource, however, provided a valuable service – its ramping capability – without compensation. As the example in Mr. Tretheway's testimony shows, under the CAISO's flexible ramping product, the same resource now receives a flexible ramping product payment for the value of this ramping capability, in addition to the locational marginal price (LMP) for energy.[7]

B. Illustration of How the Flexible Ramping Product Addresses Load and Generation Variability

In this section, the CAISO discusses how the CAISO prices and settles flexibility under its current market design, taking into account forecasted needs and the uncertainty in those forecasts. The discussion is based on several illustrative figures, which are taken from a presentation provided by the CAISO's Department of Market Monitoring (DMM) at the May 10, 2017 meeting with Commission Staff.[8]

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6 Attachment A at 25-26.

7 *Id.* at 21-26.

8 The CAISO Department of Market Monitoring's presentation from the May 10, 2017 meeting with Commission staff is attached hereto as Attachment B ("DMM Presentation" or "Attachment B").

The CAISO's market optimization dispatches generation to meet load. However, the market optimization cannot control all generation and load. Generation that the market optimization cannot dispatch, such as many renewable generation resources, is referred to as "non-dispatchable." As noted above, the CAISO's *net load* is the sum of all non-dispatchable load and generation. To maintain power balance, the CAISO's optimization must move dispatchable resources to meet net load. As the amount of renewable generation interconnected to the CAISO continues to increase, a primary concern for the CAISO is the ability to meet net load variability and uncertainty.

The CAISO's multi-interval optimization positions dispatchable resources not only to meet net load in the current market interval but also to meet the expected net load in the next market interval. Figure 1 below shows net load for two market intervals. The CAISO's market dispatch must meet the current net load and have enough ramping capability to make the next interval's expected net load feasible. As discussed in the previous section, the CAISO's market design now prices and settles this ramping capability.

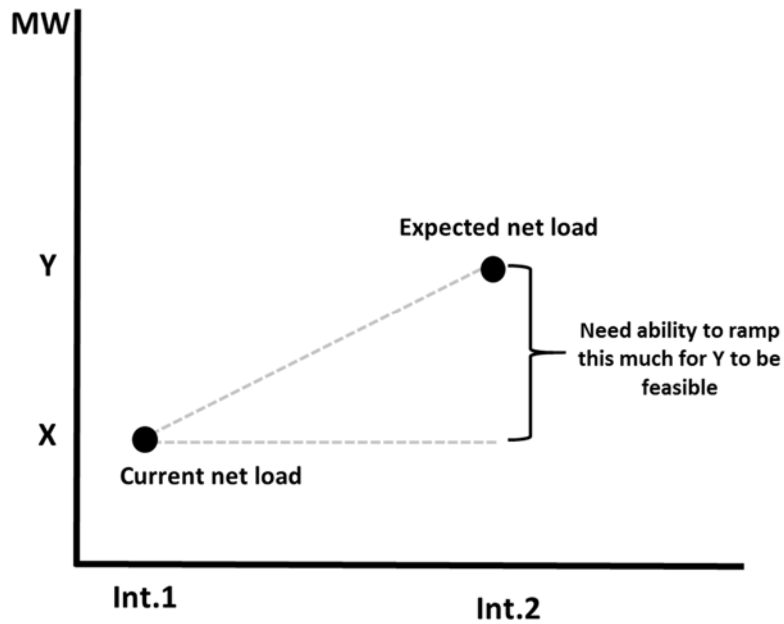

Figure 1

The flexible ramping product prices and settles ramping capability necessary to address both changes in forecasted net load and uncertainty in the forecasted net load. Further, the expected net load is broken out into changes that increase the expected ramp need and changes that decrease the expected ramp need. Generation or load that increase the need for additional flexible capability pay the generation and load that reduce the need or that provide flexibility. The flexible ramping price is set at the marginal cost of procuring flexible ramping capability.

Figure 2 below shows the breakdown of a net load forecast in the upward ramp direction. The dark and light blue bars shows the expected net load upward ramp needs that occur because of an increase in non-dispatchable load and a reduction in non-dispatchable generation. The light green bar shows a decrease in expected upward ramp needs from an increase rise in non-dispatchable generation. The dark green bar represents the ramp capability provided by dispatchable resources. Under the flexible ramping product design, resources and load increasing the need for upward flexibility, *i.e.,* the blue bar, pay resources and load reducing the need or providing flexibility, *i.e.,* the green bar, at the flexible ramping up price.

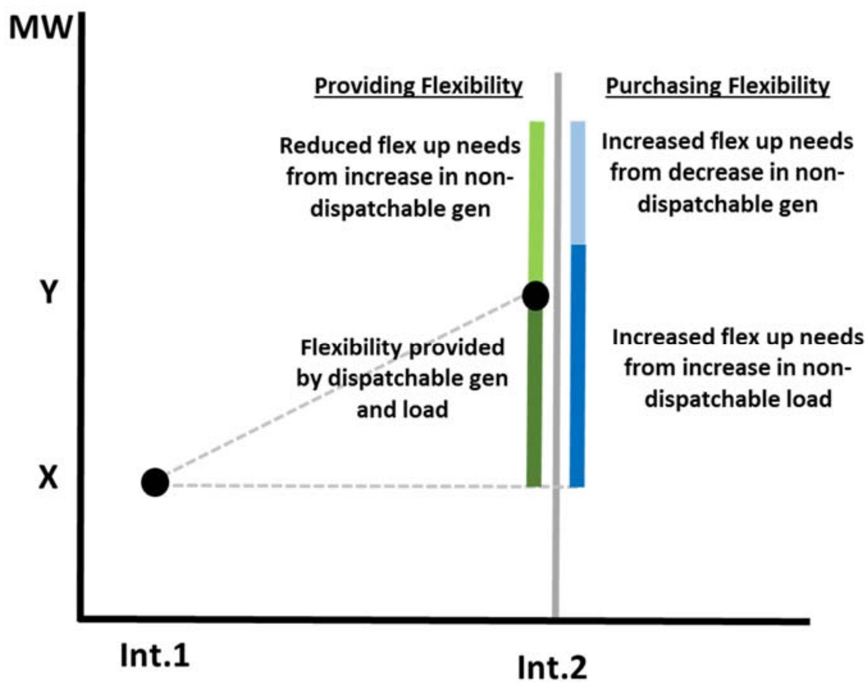

Figure 2

Because net load forecasts are uncertain and the actual net load may be different, the CAISO market optimization procures additional flexible ramping capability to enable the market to respond to potential forecast errors. The optimization procures flexible ramping capability until the marginal cost of additional capability equals the estimated marginal benefit of reduced power balance violations. Figure 3 below illustrates this optimization process.

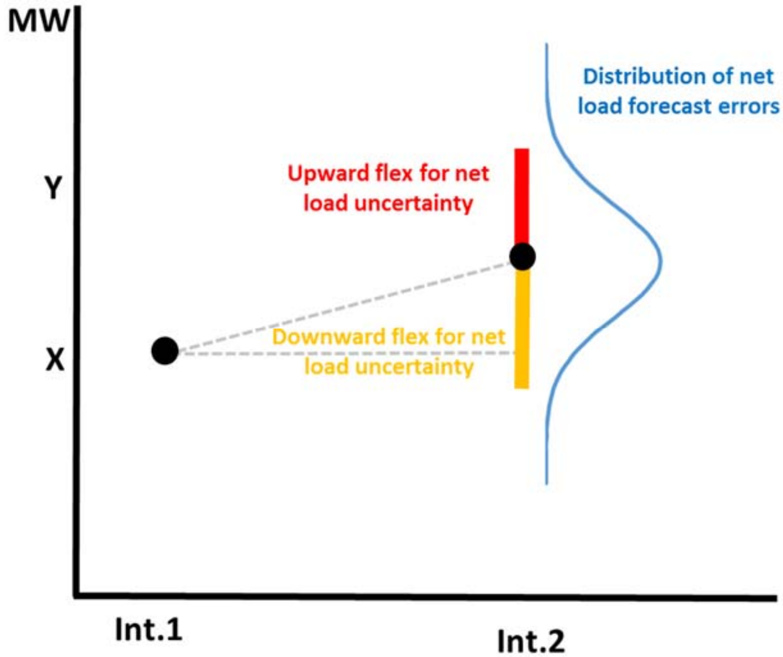

Figure 3

The CAISO pays the resources procured in order to address upward uncertainty the flexible ramping up price, and pays the resources procured in order to address downward uncertainty the flexible ramping down price. Figure 4 below illustrates this concept. The CAISO then charges resources and load with net load forecast errors for the cost of the flexible ramping capability procured to respond to this uncertainty in expected ramping needs.

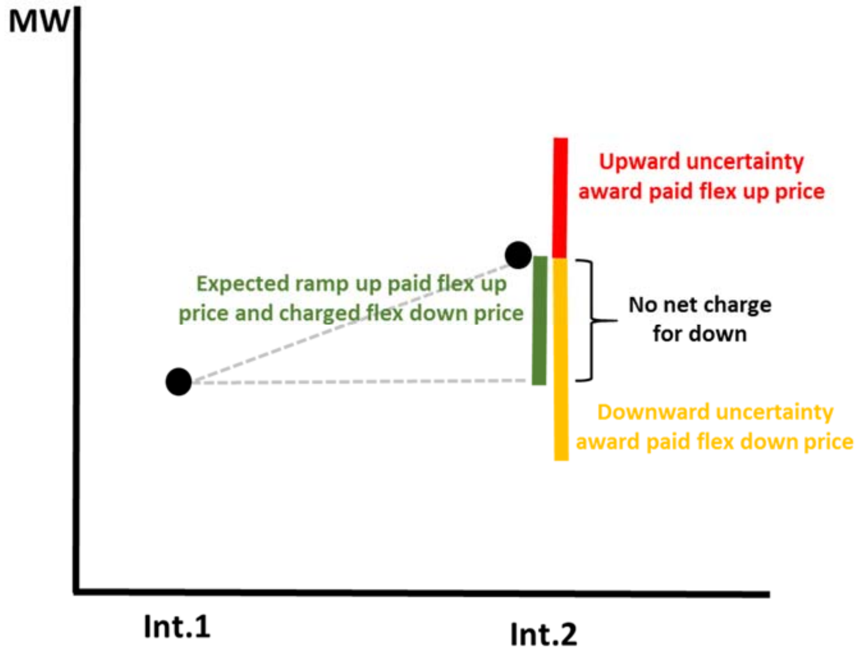

Figure 4

C. Illustration of the CAISO's Concerns Regarding the Interaction Between the NOPR Proposal and the CAISO's Flexible Ramping Product

As the CAISO explained in its initial comments, relaxing the economic minimum operating limit of a fast-start resource to zero as proposed in the NOPR will permit an inflexible or mostly inflexible fast-start resource to be treated as dispatchable during the pricing run of its market.[9] The CAISO is concerned that this will have the effect of undermining the flexible ramping price signals that the CAISO designed and implemented as part of its flexible ramping product amendment.

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[9] The CAISO uses the pricing run to generate binding schedules and prices. Including an assumption that the CAISO can dispatch a fast-start resource between zero and its Pmin in that run will distort price signals and potentially generate infeasible schedules.

In its briefing to Commission Staff in May of this year, the CAISO provided a slide presentation to provide additional details regarding these impacts.[10] This presentation contrasts two scenarios showing how the CAISO market dispatches and compensates generation to address ramping requirements between two successive intervals, a binding interval and the following advisory interval. The first scenario demonstrates the application of the CAISO's existing market rules, including the multi-interval optimization process, the flexible ramping product, and that the prices and dispatches are consistent and from the same market optimization run.[11] The second scenario shows how the fast-start pricing rules proposed in the NOPR would interact with the CAISO's market rules to change the pricing and settlement results. The starting conditions for these two scenarios are identical, and involve three generators with the following characteristics:

Resource	Pmin (MW)	Pmax (MW)	Ramp Rate (MW/Minute)	Energy Bid ($/MWh)
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

10 Interaction between flexible ramping product and fast-start pricing NOPR, Briefing for Commission Staff, May 2017, attached hereto as Attachment C ("CAISO Presentation" or "Attachment C").

11 In 2013, the CAISO proposed and the Commission accepted a tariff amendment to establish both awards and settlement prices in the CAISO's pricing run. Tariff Amendment to Enhance Price Consistency, Docket No. ER13-957-000 (February 19, 2013).

The net load forecasted for the two intervals is as follows:

	Binding Interval	Advisory Interval		Forecasted Movement Requirement
Net Load	800	845		45 U

For the binding interval units G1 and G2 are dispatched to meet all of the net load in that interval (800 MW), and the LMP is $30/MWh based on the energy bid of the marginal unit, G2.[12]

Resource	Binding Interval			
G1	500			
G2	300			
Fast Start	0			
LMP	**$30**			

For purposes of the advisory interval, the Fast Start unit is required to meet the forecasted increase to 845 MW of net load. Due to the minimum operating limit (Pmin) of the Fast Start unit, the market must reduce the output of G1 or G2. Because G2 is already at its Pmin of 300, G1 is dispatched down 5 MW between the two intervals. Because G1 is the marginal unit in the advisory interval, its bid of $25/MWh sets the price for that interval.[13]

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12 *Id*. at Slide 6.

13 *Id*. at Slides 7-11.

Resource	Binding Interval	Advisory Interval		
G1		495		
G2		300		
Fast Start		50		
LMP		**$25**		

Under this dispatch scenario, the ramp between the two intervals is feasible. The ramp capability from the multi-interval optimization is settled as forecasted movement.[14]

Resource	Binding Interval	Advisory Interval		Forecasted Movement
G1	500	495		5 D
G2	300	300		0
Fast Start	0	50		50 U
LMP	**$30**	**$25**		**$0 U $0 D**

The next ten slides in the presentation demonstrate how the flexible ramping product accounts for forecast uncertainty.[15] This example uses the same initial assumptions regarding available generation and net load conditions, however, there is uncertainty in the net load forecast such that the forecast could be up to 10 MW lower (835 MW). Therefore, the market must position dispatchable generation so that it is able to meet lower net load if the forecast uncertainty materializes.

[14] *Id*. at Slides 12-13.

[15] *Id*. at Slides 14-23.

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

The awards for the advisory interval remain the same. G1 remains the marginal resource and sets the price based on its $25/MWh energy bid.[16]

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1		495		
G2		300		
Fast Start		50		
LMP		**$25**		

However, only G1 can reduce its output by 10 MW in the advisory interval, which would be necessary if the 10 MW of forecast uncertainty were to materialize. Due to its ramp rate, this means that it will need be scheduled 10 MW lower in the binding interval, with the difference made up by G2. G2 is still the marginal resource in the binding interval because G1 cannot be dispatched up another MW and still meet the ramping requirement between the two intervals.[17]

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	490	495	10	
G2	310	300		
Fast Start	0	50		
LMP	**$30**	**$25**		

16 *Id*. at Slide16.

17 *Id*. at Slides 18-20.

This dispatch solution creates a $5/MWh opportunity cost associated with the downward uncertainty requirement. This opportunity cost reflects the trade-off associated with marginally increasing flexible ramping procurement. Here, the trade-off is between decreasing G1's output ($25/MWh) and correspondingly increasing G2's output ($30/MWh), which increases overall production costs by $5/MWh. As such, there is a $5/MWh price associated with the forecast movement down, resulting in the following dispatches and prices:[18]

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	490	495	10	5 U
G2	310	300		10 D
Fast Start	0	50		50 U
LMP	**$30**	**$25**	**$5**	**$0 U $5 D**

The next example illustrates the CAISO's concerns with respect to how the NOPR's proposal to relax the Pmin for fast-start resources affects the CAISO's existing pricing and market rules. This example uses the same assumptions regarding available generation, forecast net load, and forecast uncertainty as the example discussed above.[19]

Under the NOPR rules, the pricing run would not observe the Fast Start generator's Pmin. The CAISO's pricing run would dispatch units G1 and G2 to their maximum operating limit (Pmax) levels to meet load in the advisory interval, while dispatching the Fast Start generator to 20 MW. The advisory interval

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18 *Id*. at Slides 21-23.

19 *Id.* at Slides 24-30.

energy price is $35/MWh because the Fast Start generator's adjusted dispatchable range appears to be marginal in the pricing run under the NOPR rules:[20]

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1		500		
G2		325		
Fast Start		20		
LMP		**$35**		

The Fast Start generator receives an award for addressing the 10 MW of downward uncertainty associated with the forecasted movement between the binding and advisory intervals in this scenario. The NOPR rule would require that the CAISO market treat the Fast Start unit as being able to operate below its Pmin and its advisory interval energy dispatch for purposes of the pricing run. This would forces the CAISO market software to ignore that constraint and makes the market software think that there is no need to dispatch units out of their normal merit order in the binding interval in order to meet the ramp requirement needed to meet the advisory interval potential net load. The least-expensive unit, G1, would be dispatched to its Pmax and there would be no price associated with the downward uncertainty requirement, because there is no opportunity cost to meet that uncertainty:[21]

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20 *Id*. at Slides 24-25.

21 *Id*. at Slides 26-28.

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	500	500		
G2	300	325		
Fast Start	0	20	10	
LMP	**$30**	**$35**	**$0**	

Applying the NOPR pricing rules in this scenario results in forecasted movement that is also different from the physically feasible dispatch for the generators:

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	500	500		0
G2	300	325		25 U
Fast Start	0	20	10	20 U
LMP	**$30**	**$35**	**$0**	**$0 U $0 D**

This is problematic because the binding prices do not reflect the actual, physical need to position the generators in these scenarios differently in order to have the dispatch capability to meet uncertainty in the forecasted net load in the advisory interval (835 MW *versus* 845 MW). This also means that the market will not compensate G1 or G2 for providing the flexibility needed to ramp between the two intervals.

The next two tables compare the settlement of flexible ramping product under the current market optimization and under the proposed NOPR market optimization based on the same example used above. Under the NOPR, the binding dispatch would be determined in a separate pricing run in which the CAISO would have to consider the fast-start resource as dispatchable between zero and its Pmin. As a result, the pricing run thinks the entire capacity of the fast-start resource could meet the flexible ramping product uncertainty requirement even though in actuality the fast-start resource cannot be dispatched below its Pmin when the advisory interval becomes binding. This infeasible dispatch reduces the price signal to flexible resources because under the NOPR the pricing run does not capture the $5.00 opportunity cost to dispatch G1 out of merit order. Instead, this dispatch results in a zero dollar flexible ramping down price even though the system needs downward flexibility.

CURRENT MARKET OPTIMIZATION DISPATCH AND PRICES

Resource	Binding Interval Dispatch	Uncertainty Award Down	Forecasted Movement
G1	490	10	5 U
G2	310		10 D
Fast Start	0		50 U
LMP	**$30**	**$5**	**$0 U $5 D**

NOPR MARKET OPTIMIZATION DISPATCH AND PRICES

Resource	Binding Interval Dispatch	Uncertainty Award Down	Forecasted Movement
G1	490	10	5 U
G2	310		10 D
Fast Start	0		50 U
LMP	**$30**	**$0**	**$0 U $0 D**

DMM's presentation also shows the rules proposed in the NOPR's would adversely affect the way in which the CAISO market dispatches and compensates resources for flexible ramping capability. DMM's presentation shows that relaxing the minimum operating limit of Fast Start units results in an apparent reduction in downward ramping needs based on what appears to the market as less non-dispatchable minimum load generation.[22] This reduction is reflected by the hollow grey portion of the bar on the right of Figure 5.

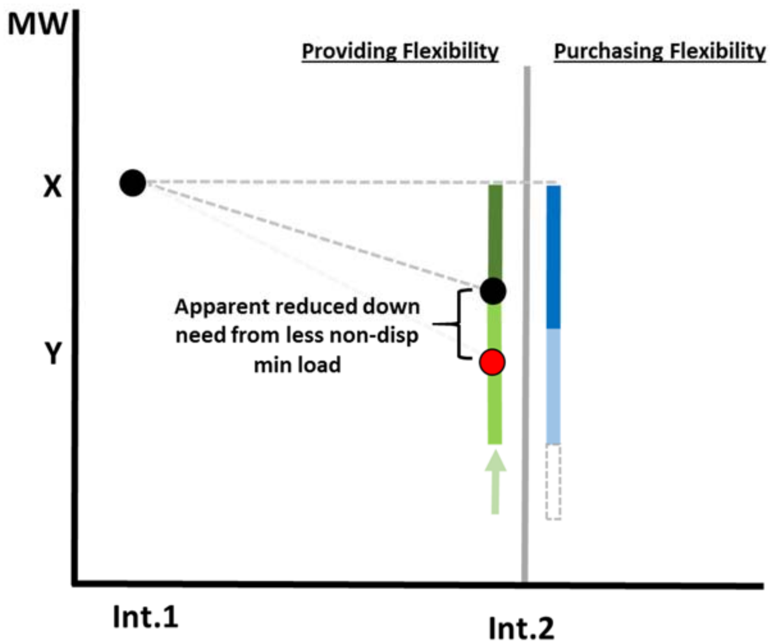

Figure 5

In this example, downward flexibility appears less valuable and upward flexibility appears more valuable than is actually the case based on the physical state of the system. Figure 6 illustrates this outcome.

[22] Attachment B at Slides 14-16.

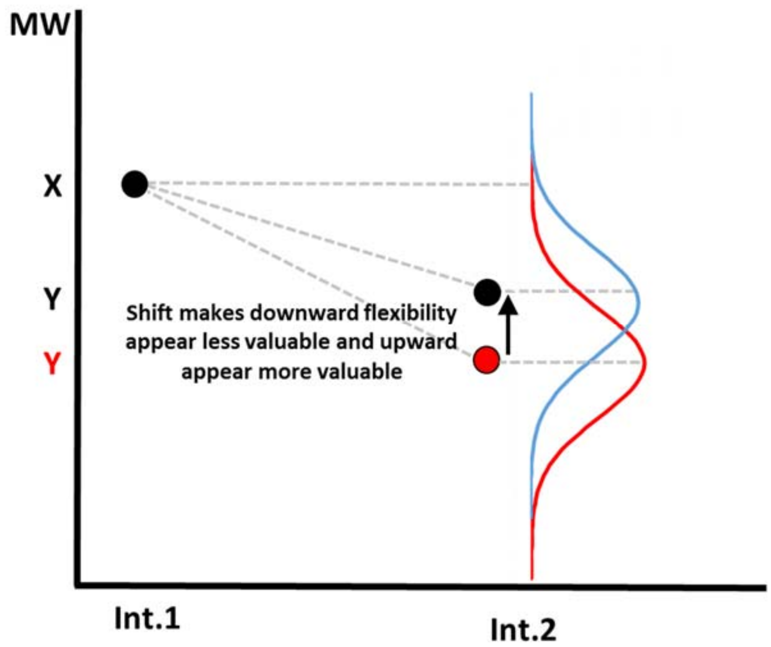

Figure 6

Both the DMM and CAISO presentations illustrate concerns that adopting the pricing proposals set forth in the NOPR will result in incorrect price signals. The CAISO believes that over the longer term, these incorrect price signals will result in the over-procurement of inflexible resources, and the under-procurement of resources with flexible ramping capability. This outcome would exacerbate rather than help to address the operational challenges the CAISO faces in managing a generation fleet that is increasingly composed of variable resources.

It is important that the Commission carefully consider and address these implications, along with the other concerns expressed in the CAISO's initial comments, in preparing its final rule on fast-start pricing. The final rule must be structured so as not to undermine the CAISO's current market structure, particularly the market mechanisms devoted to procuring and incentivizing the development of resources with flexible ramping capabilities. The CAISO and its stakeholders have devoted significant time, effort and expense to improving the CAISO's market design in order to meet the challenges associated with continuing changes to the resource mix in California and the West. Moreover, the Commission, in accepting the tariff amendment to implement the flexible ramping product, explicitly found these improvements to be just and reasonable.

> We find that CAISO's proposal to implement the flexible ramping product in the instant filing is just and reasonable and is an improvement over the existing flexible ramping constraint. We find that the flexible ramping product will enhance CAISO's ability to manage ramping capability to address changes in system conditions by extending CAISO's ability to procure ramping capability in both the upward and downward directions and to account for forecasted net load movement and forecast uncertainty in all processes of the real-time market. Thus, the flexible ramping product will ensure that CAISO has sufficient dispatchable ramping capability to meet net load changes in all market intervals. We also find that CAISO's proposal will ensure that flexible ramping capability is valued and compensated properly in CAISO's markets, as discussed below.[23]

It would be unjust and unreasonable as well as arbitrary and capricious to now require the CAISO to adopt market rules that conflict with and undermine the CAISO's current market design, which the fast-start pricing rules as proposed in the NOPR would do. The Commission should therefore make whatever modifications are necessary to the NOPR proposal in its final rule in order to avoid this outcome. At a minimum, the Commission should decline to adopt a broad mandate that all ISO/RTOs adopt the pricing rules proposed in the NOPR. Rather, the CAISO requests that the Commission's final rule at least provide sufficient flexibility so that each ISO and RTO has the opportunity to make a

[23] *California Indep. Sys. Op. Corp*., 156 FERC ¶ 61,226 at P 36 (2016).

demonstration, on compliance, that the pricing mechanisms proposed in the NOPR are not necessary or appropriate in its markets, given its individual market structure.

II. CONCLUSION

The CAISO respectfully request that the Commission accept these supplemental comments, as they will enhance the record in this proceeding and assist the Commission in developing its final rule on fast-start pricing.

Respectfully submitted,

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Counsel for the California Independent System Operator Corporation

Dated: August 18, 2017

Attachment A – Direct Testimony of Donald Tretheway

Supplemental Comments to the Fast-Start Pricing Notice of Proposed Rulemaking

California Independent System Operator Corporation

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:

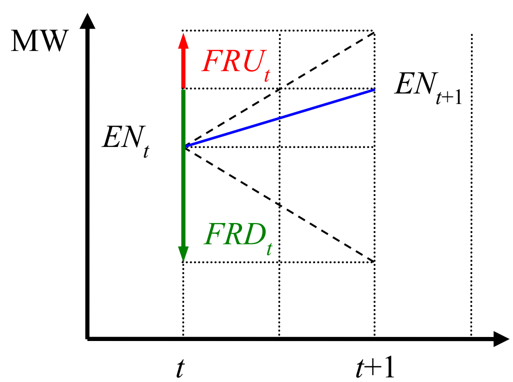


Figure 1

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 B – Department of Market Monitoring Presentation dated May 10, 2017

Supplemental Comments to the Fast-Start Pricing Notice of Proposed Rulemaking

California Independent System Operator Corporation

Flexible Ramping Product Overview

Briefing for FERC staff

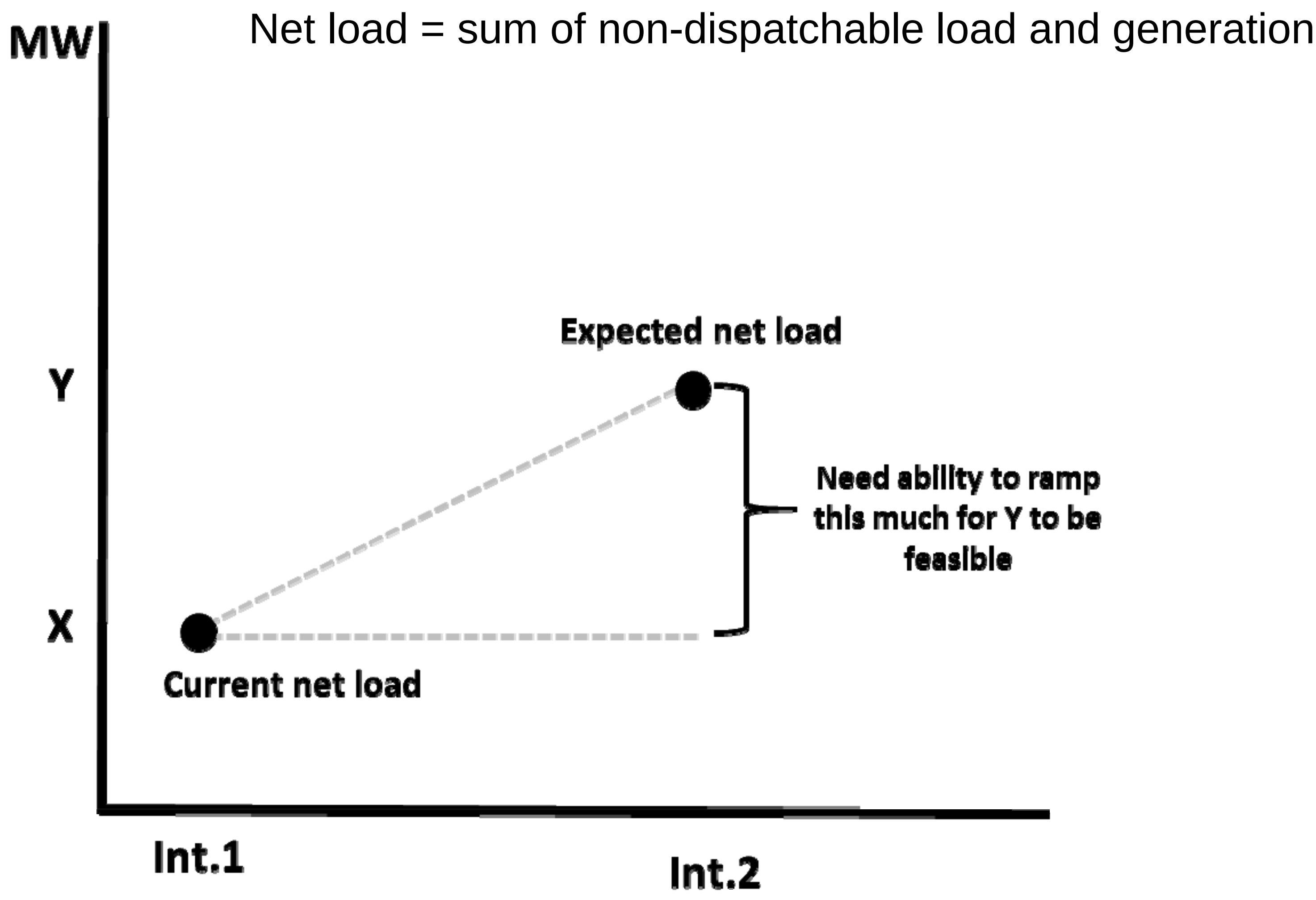
May 10th, 2017

Department of Market Monitoring

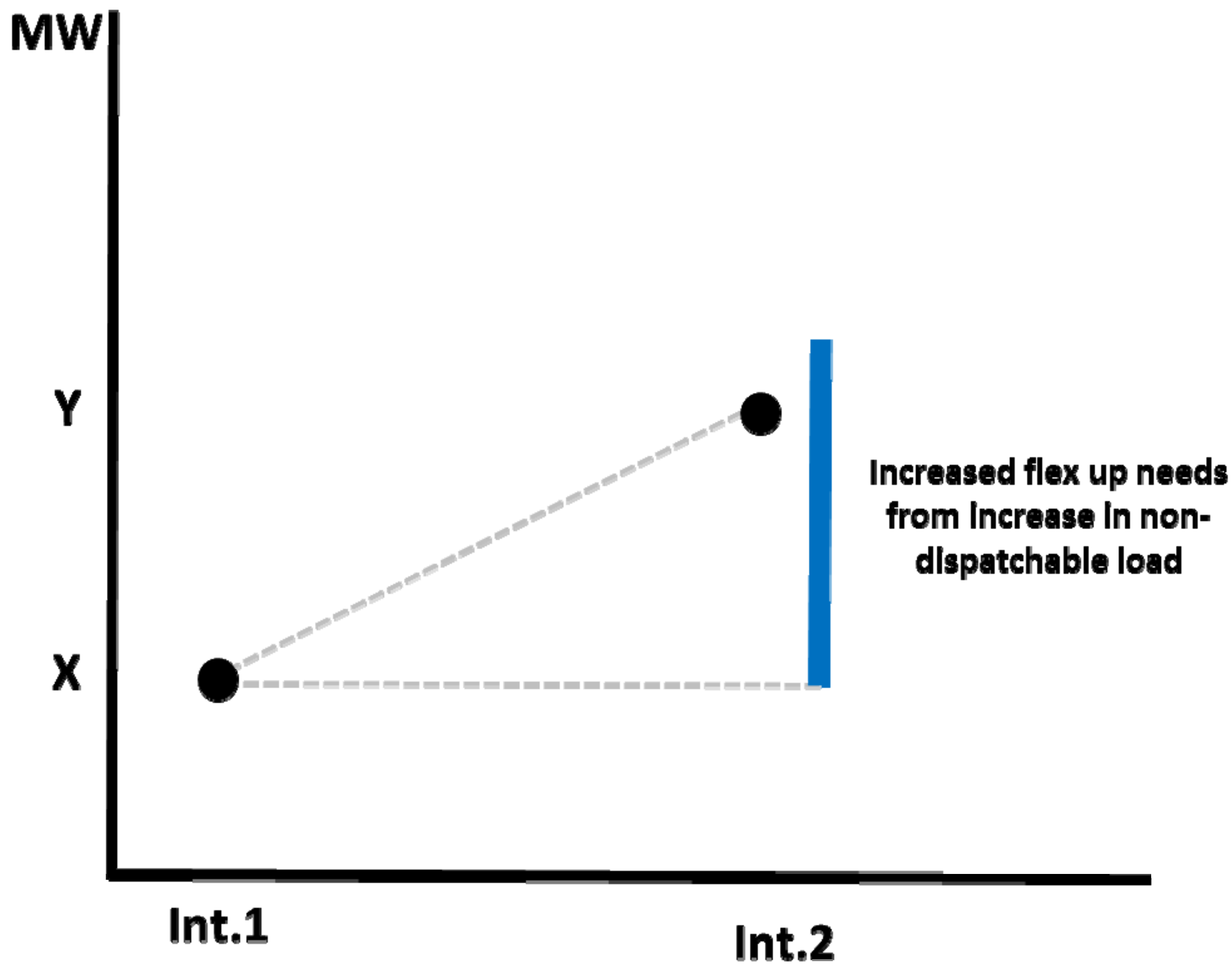
Roger Avalos

Lead Analyst

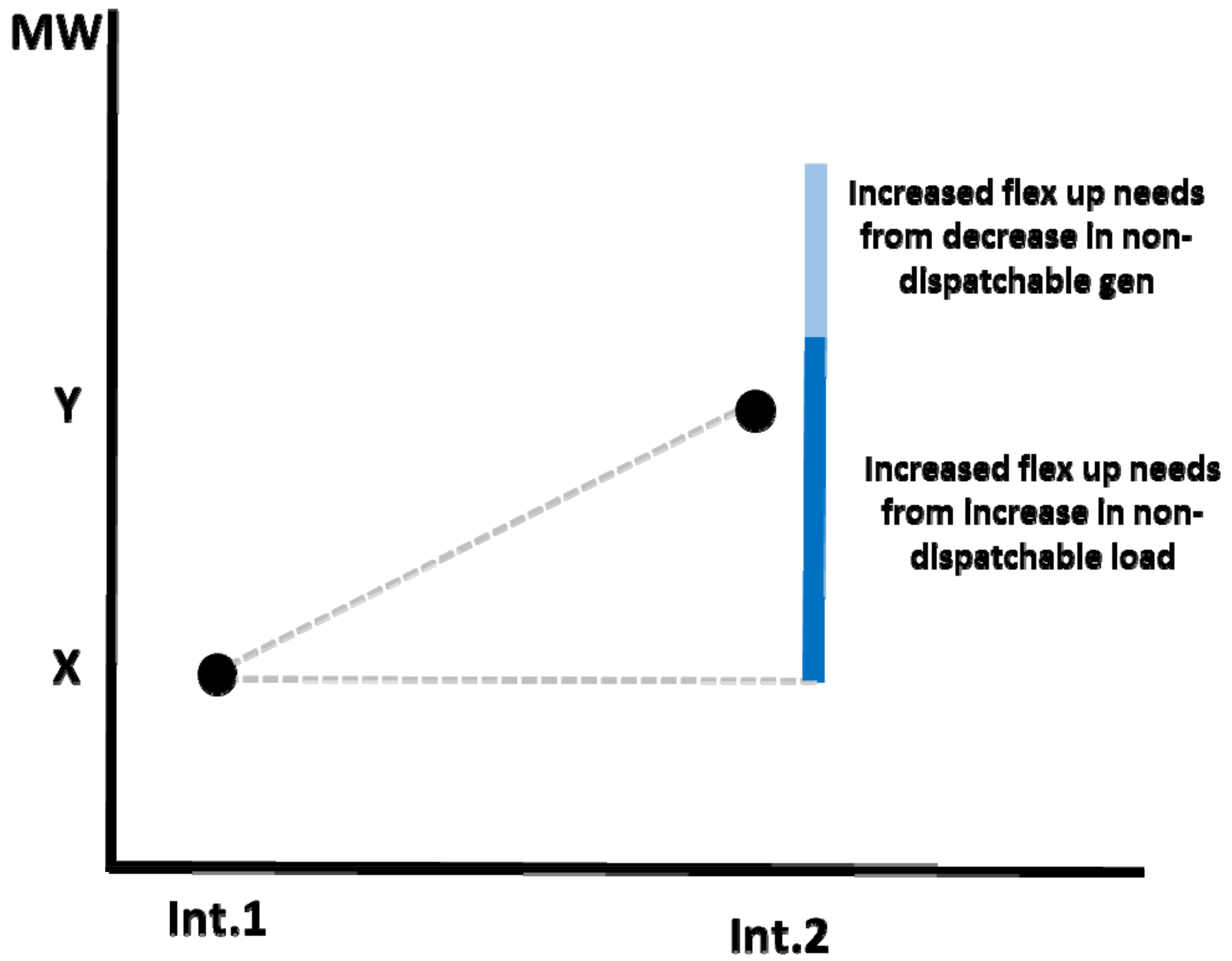
Market dispatch considers current and future conditions



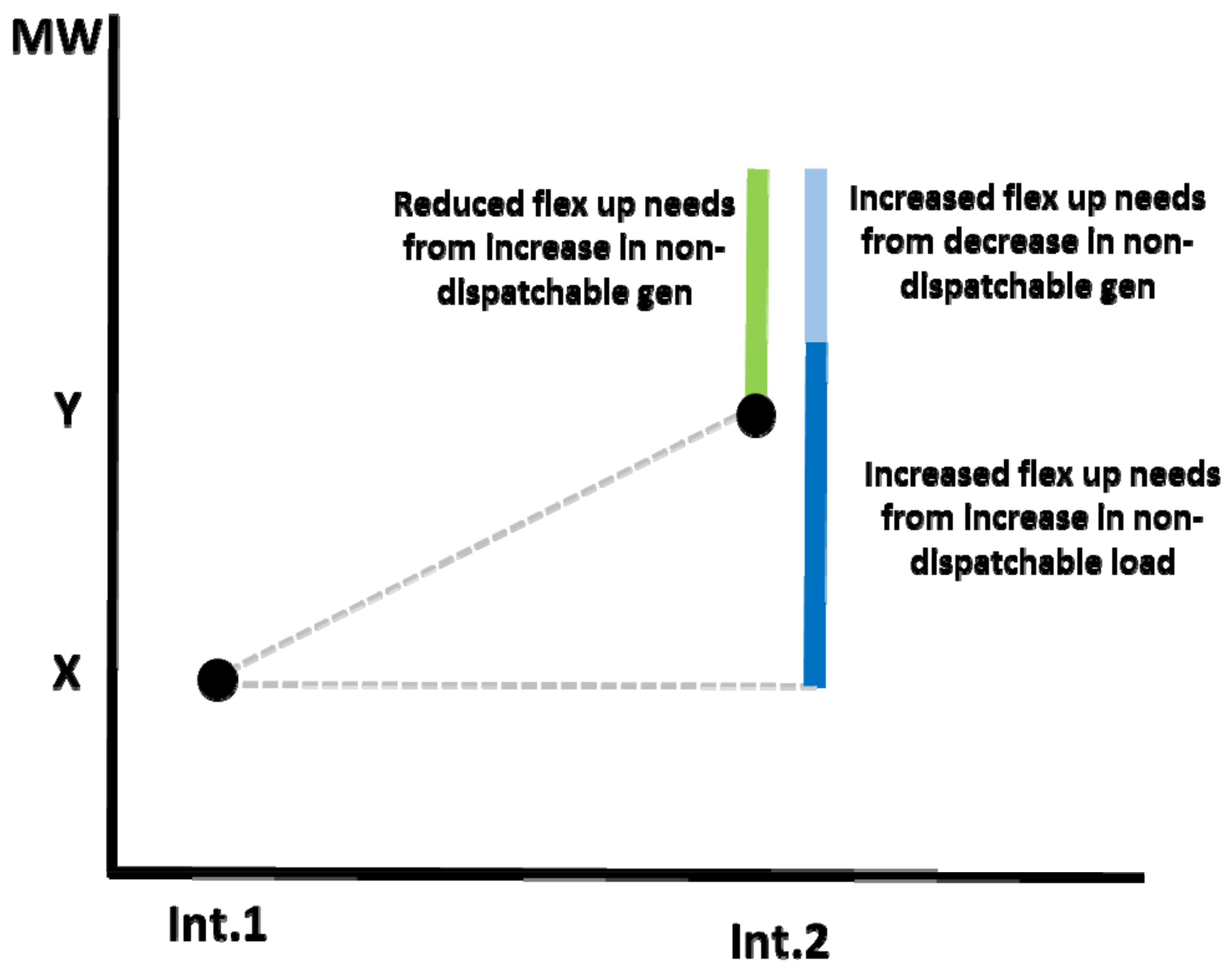
Components of net load change



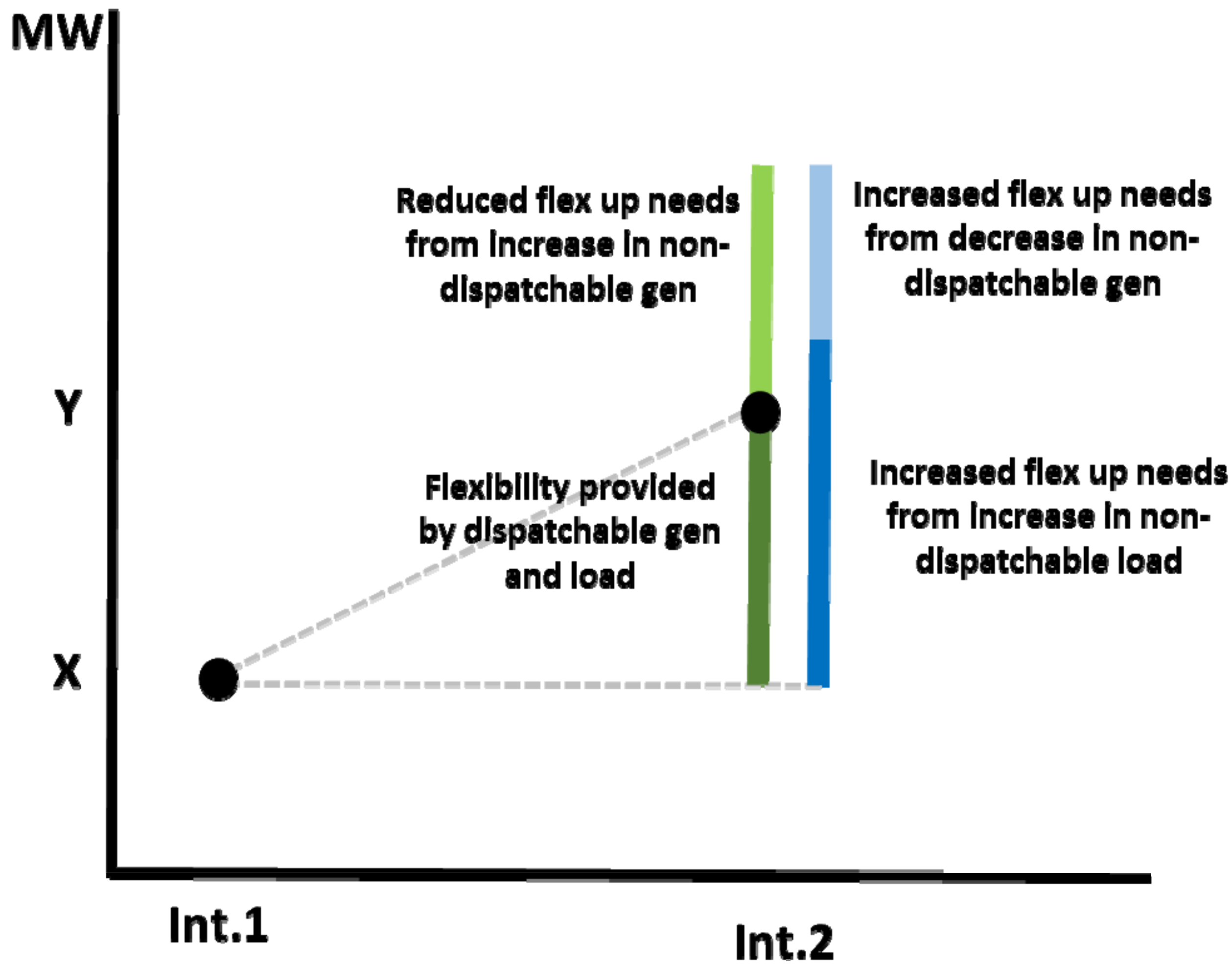
Components of net load change



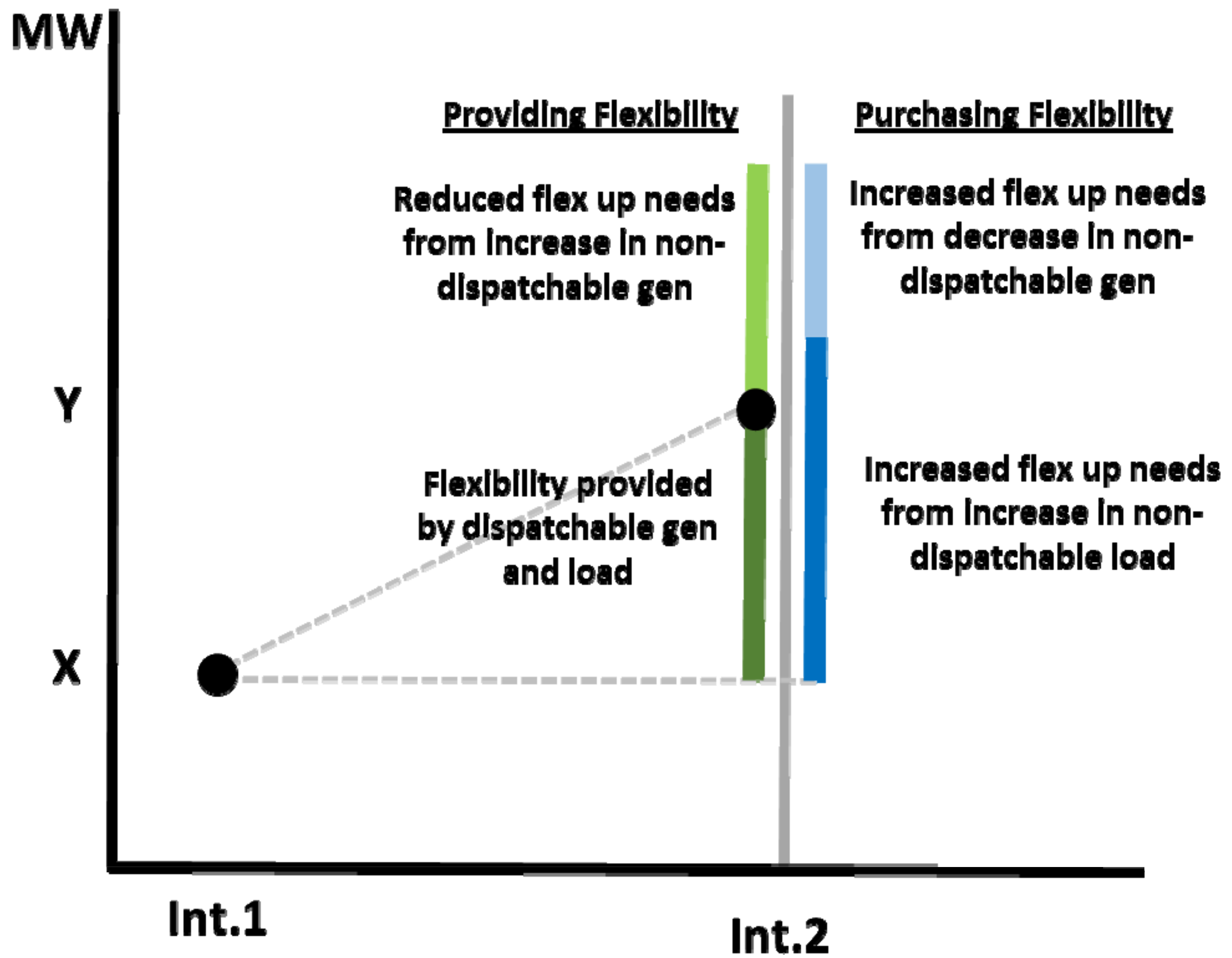
Components of net load change



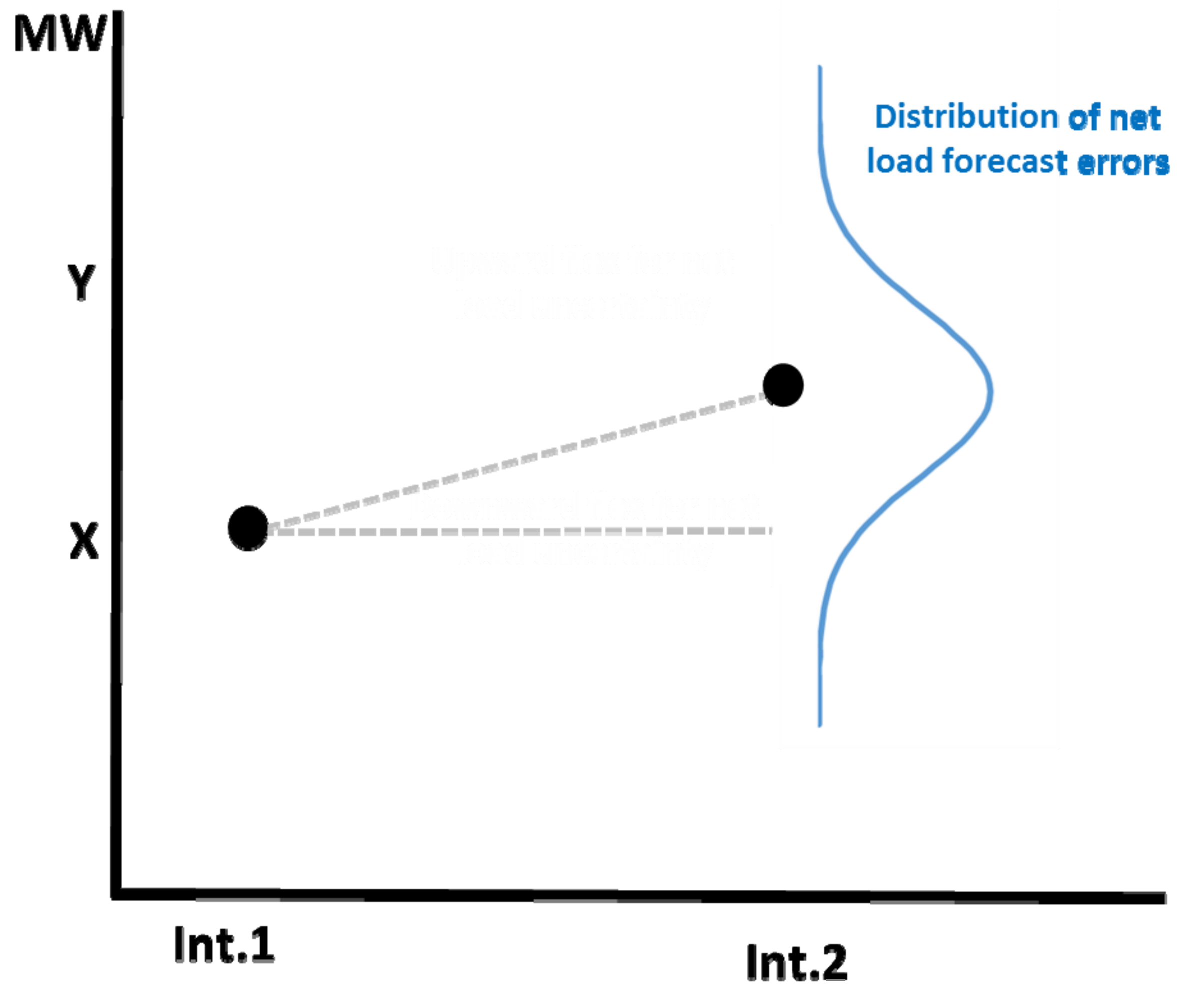
Flexible capacity needed to meet net load



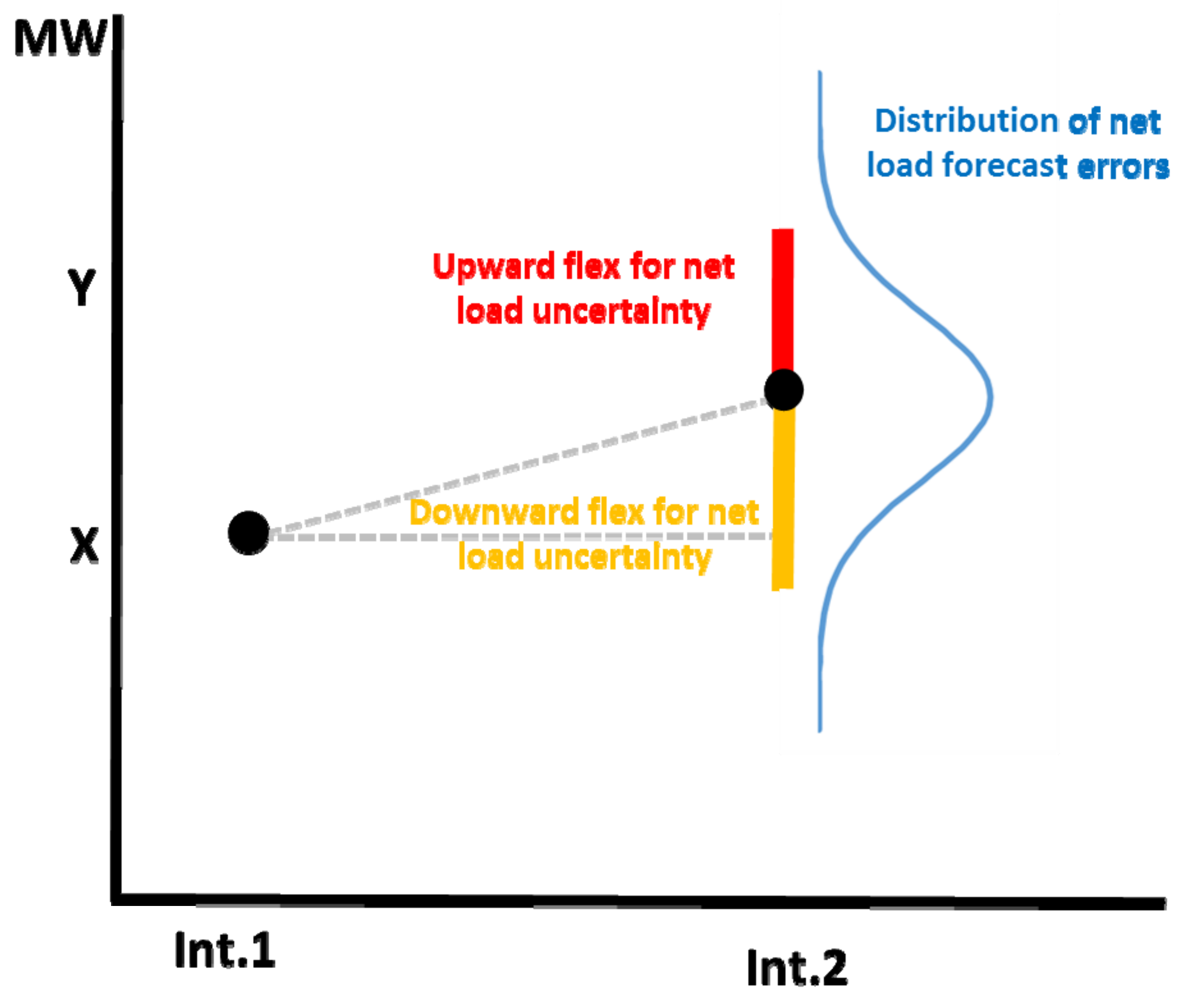
A market for flexibility



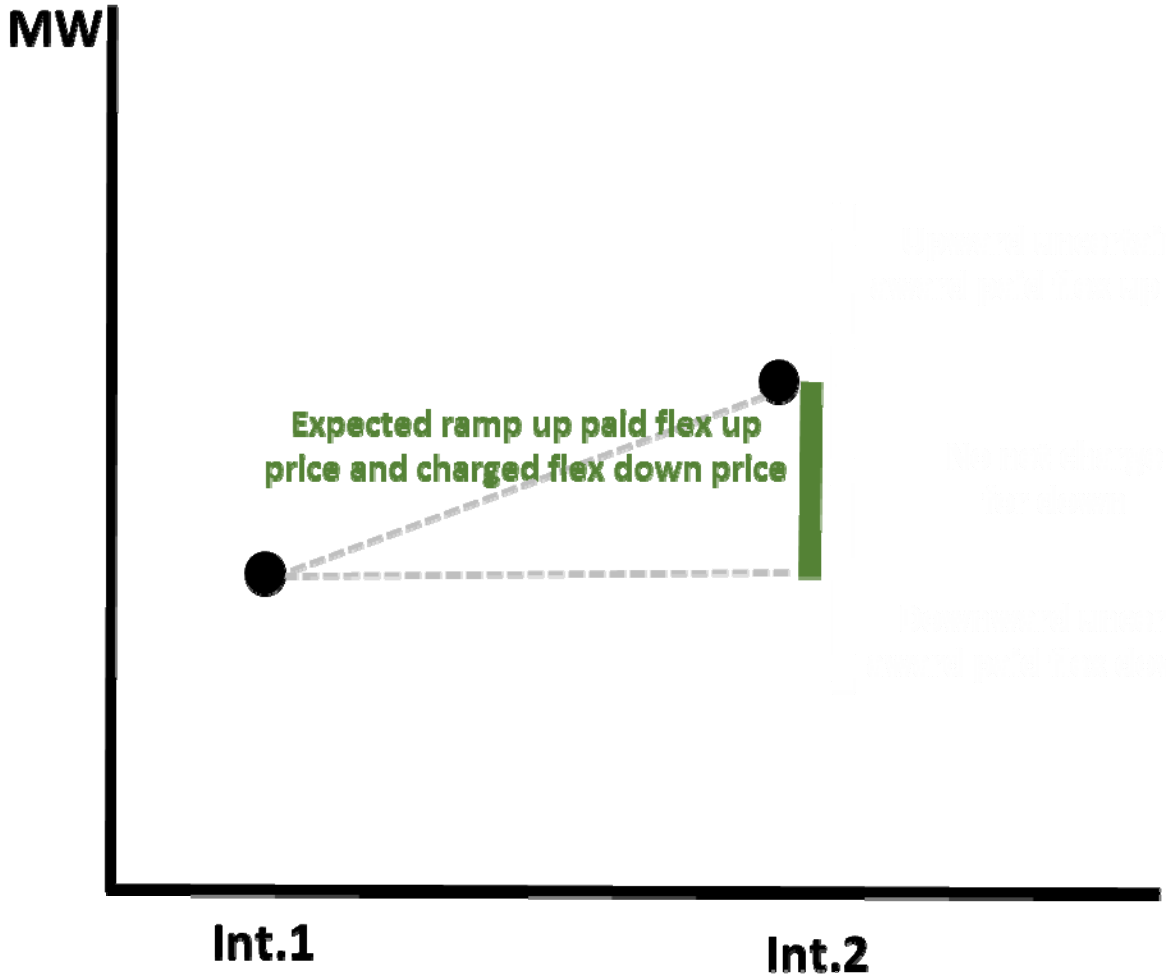
Uncertainty surrounding expected net load



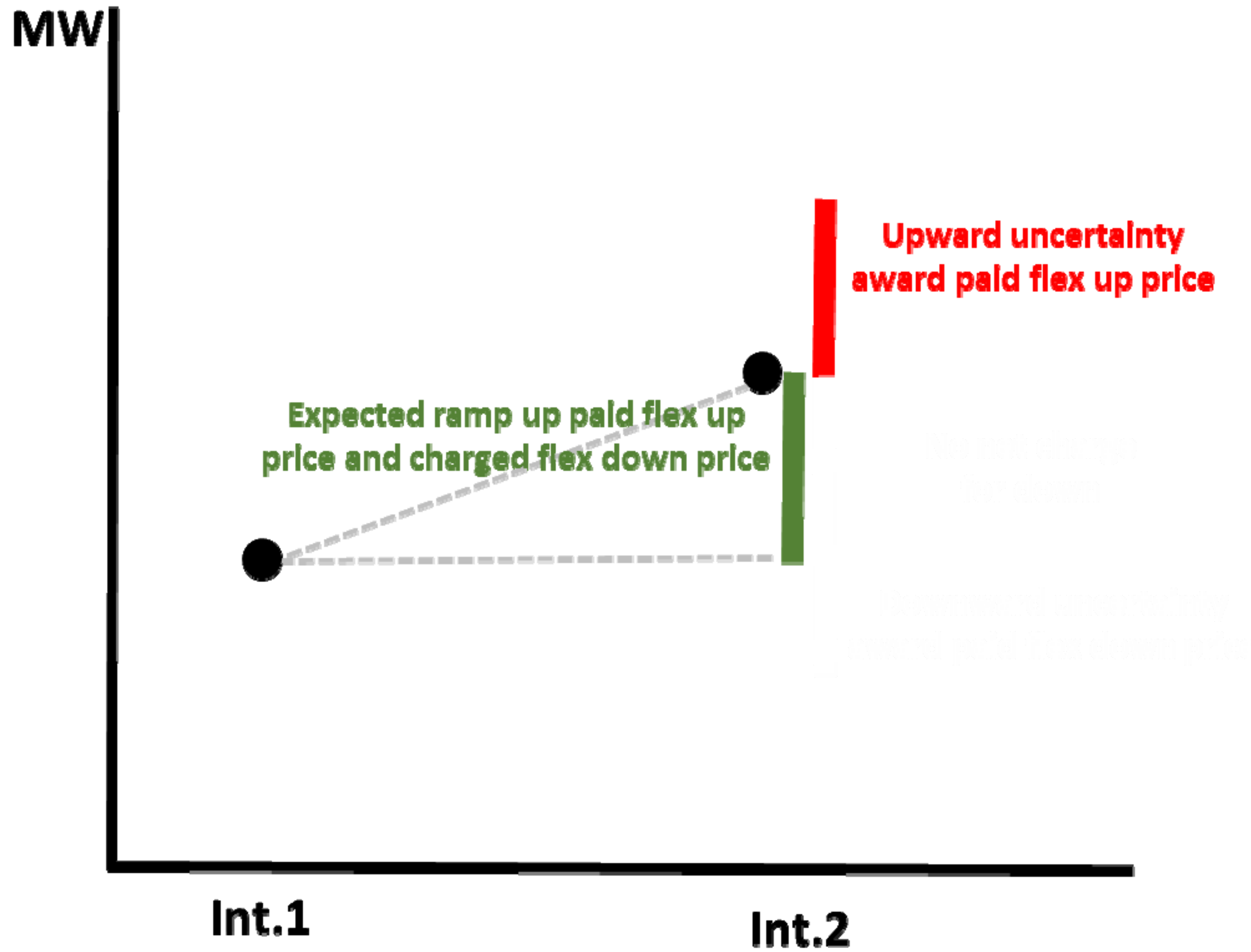
Additional flexibility procured to respond to uncertainty



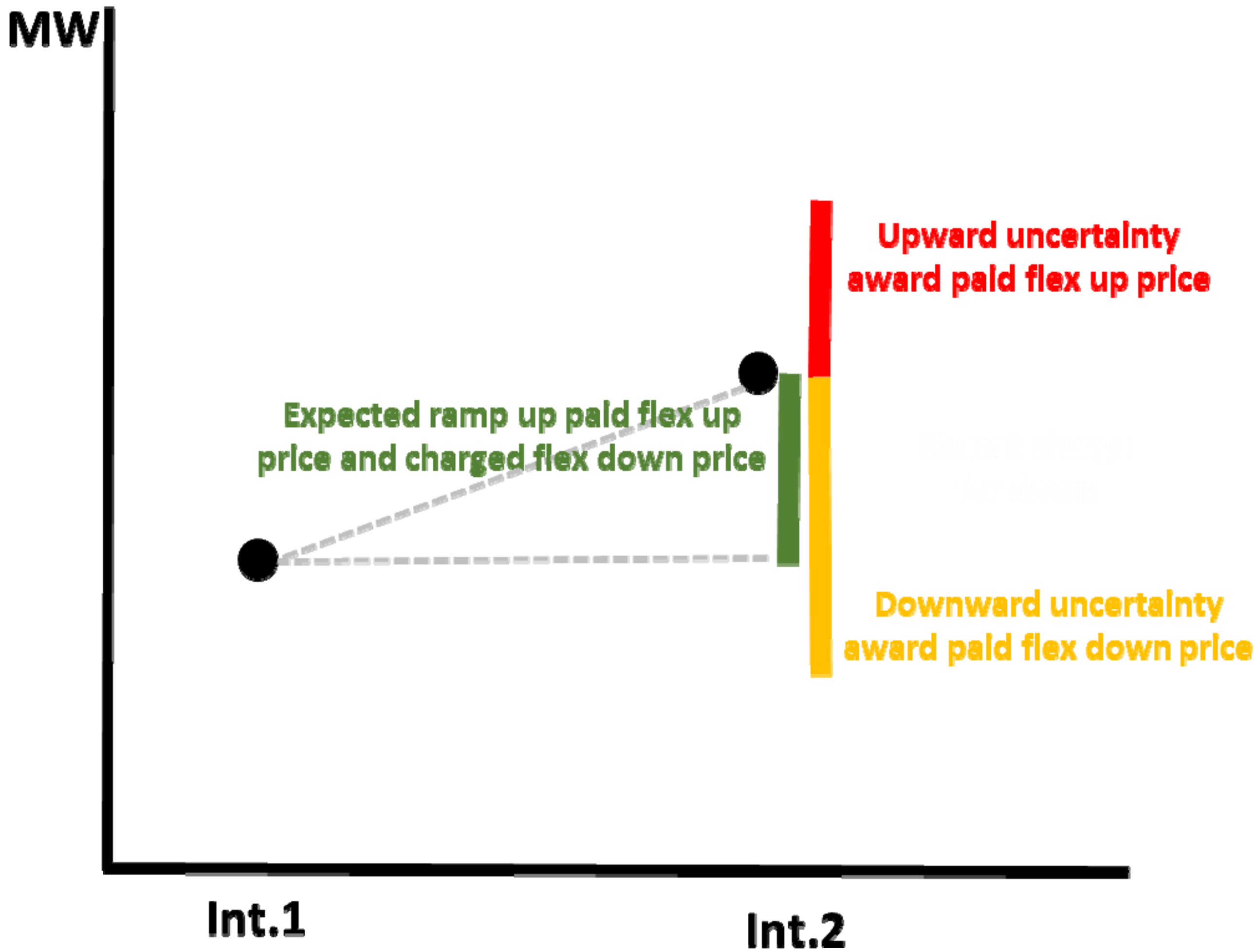
Individual resource awards



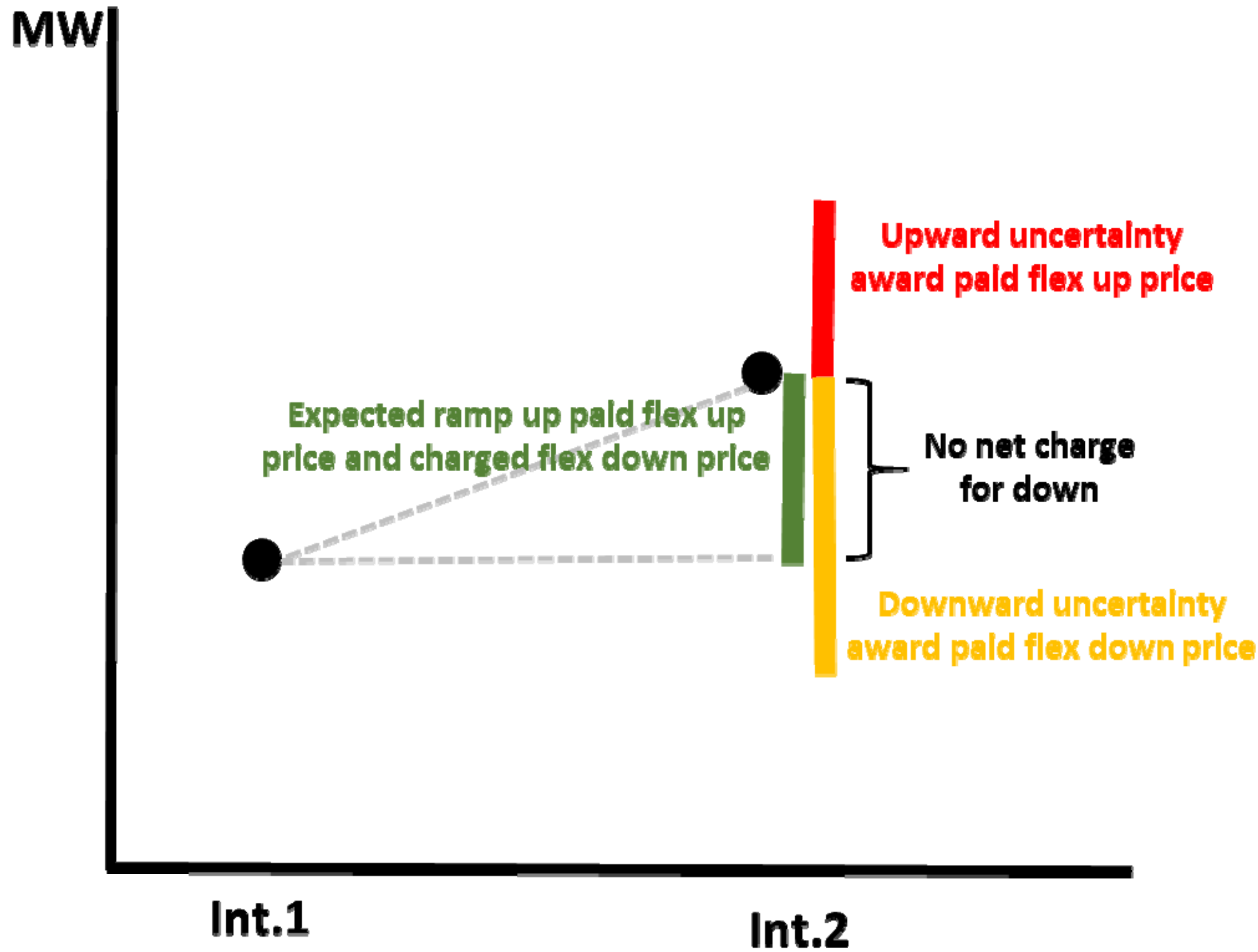
Individual dispatchable resource awards



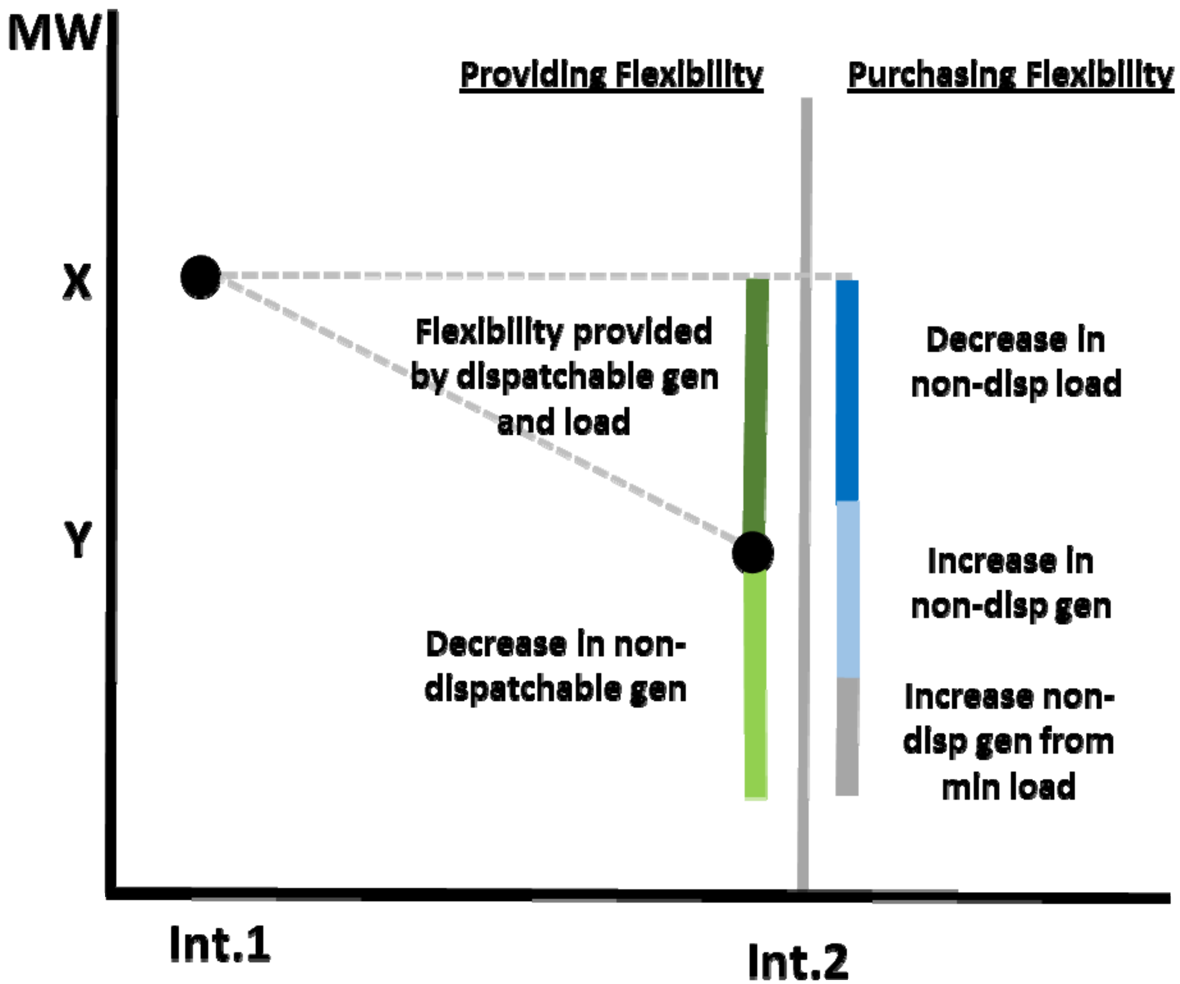
Individual dispatchable resource awards



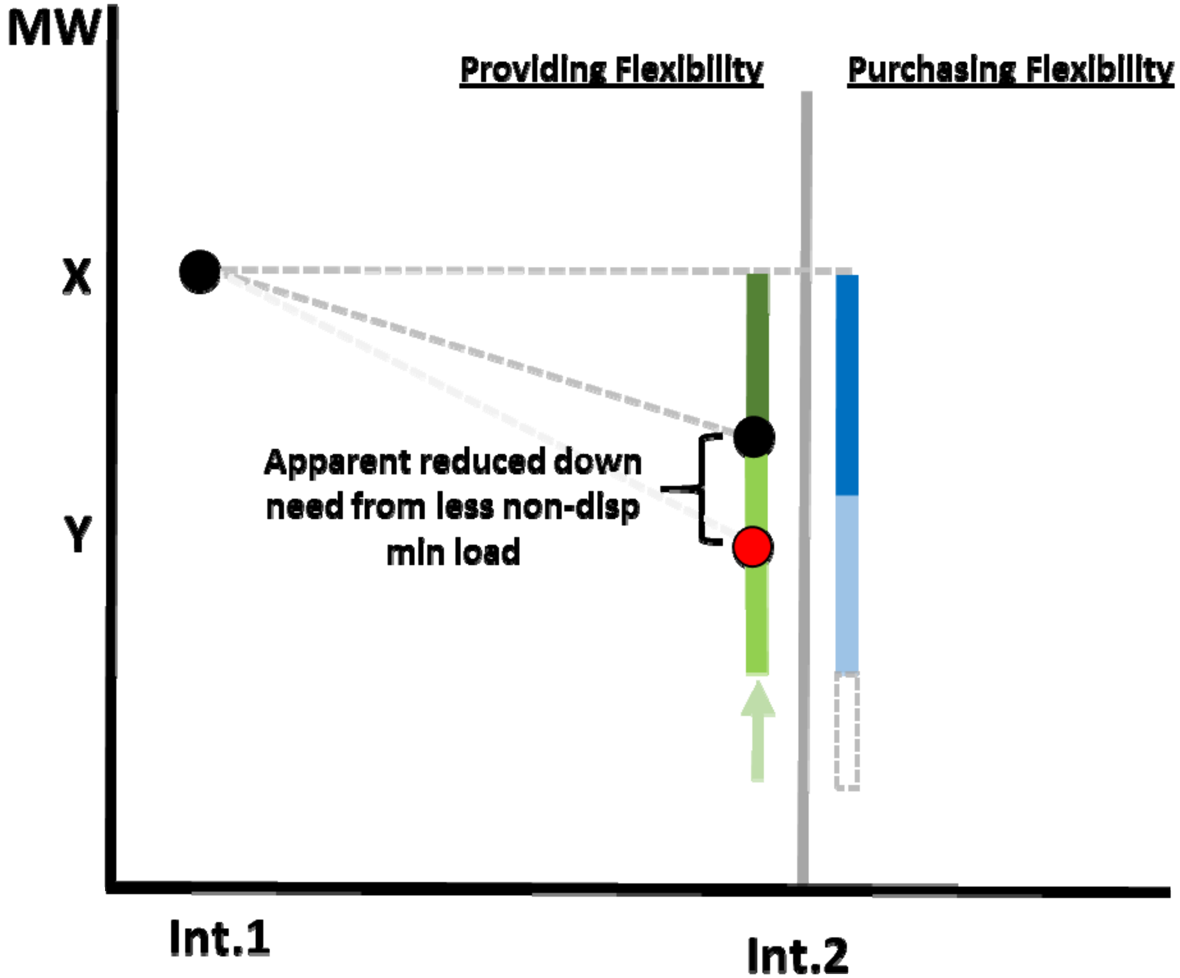
Individual dispatchable resource awards



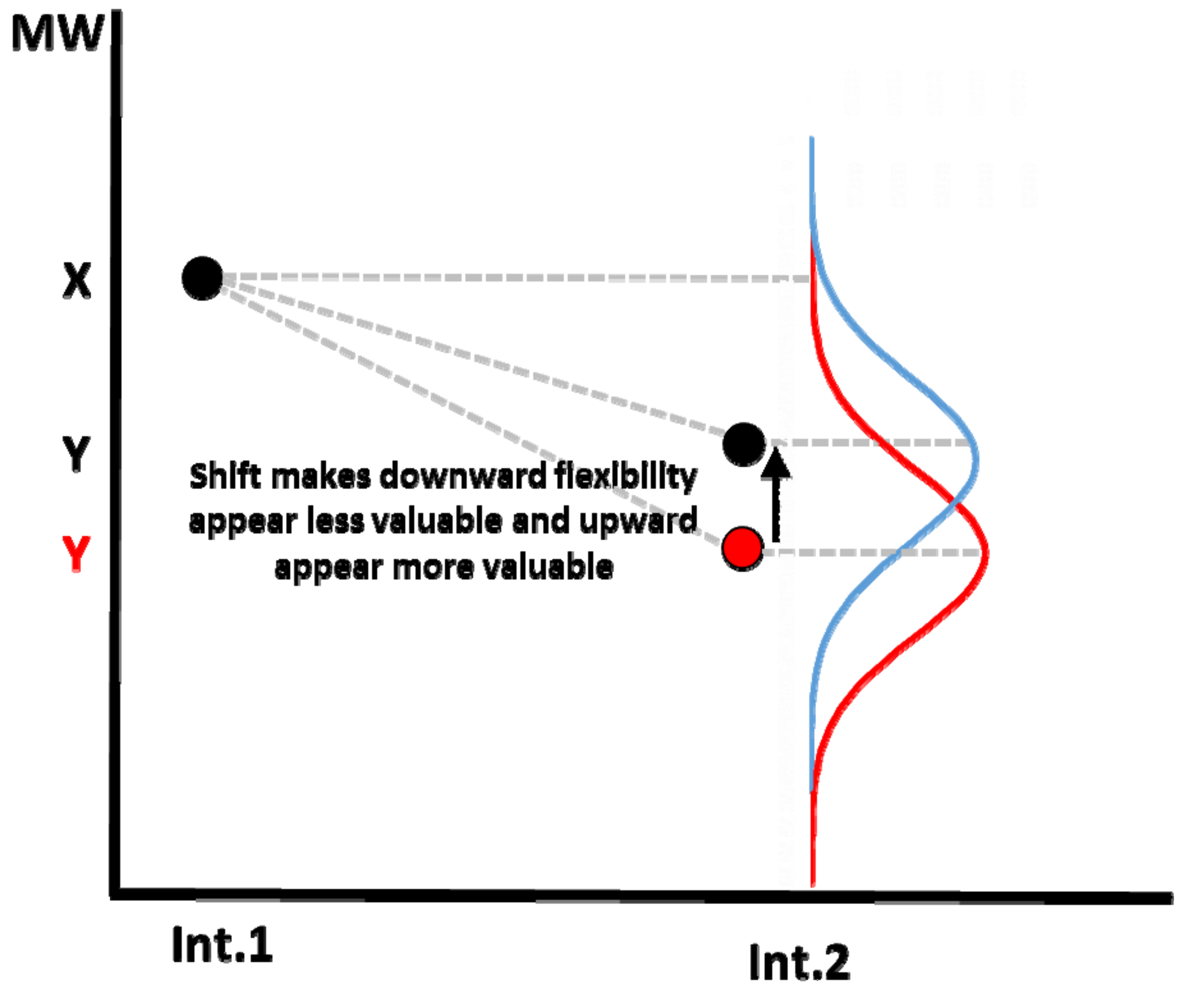
Downward flexibility example (expected ramps)



Downward flexibility in NOPR pricing run



Downward flexibility in NOPR pricing run



Attachment C – Federal Ramping Product Presentation dated May 2017

Supplemental Comments to the Fast-Start Pricing Notice of Proposed Rulemaking

California Independent System Operator Corporation

Interaction between flexible ramping product and fast start pricing NOPR

Briefing for FERC Staff

May 2017

Agenda

- Solution for binding interval optimization
- Solution for advisory interval optimization
- Solution for multi-interval optimization
- Solution for multi-interval optimization with uncertainty
- Solution using NOPR fast start pricing logic in pricing run

Incorrect determination of ramping need undermines the recently implemented flexible ramping product

Actual

	Interval 1	Interval 2	Forcasted Movement Up	Forecasted Movement Down
Load	1000	1040	-40	40
VER	-200	-195	-5	5
Pmin	0	-50	50	-50
Net Load	800	795	5	-5
Dispatchable Gen	800	795	-5	5

Fast Start NOPR

	Interval 1	Interval 2	Forcasted Movement Up	Forecasted Movement Down
Load	1000	1040	-40	40
VER	-200	-195	-5	5
Pmin	0	0	0	0
Net Load	800	845	-45	45
Dispatchable Gen	800	845	45	-45

- FRP down positive price
- FRP up zero price

- FRP down zero price
- FRP up positive price

Flexible ramping product no longer provides correct incentives and will need to be removed from ISO market optimization

(Charged) / Paid

Example – flexible ramping product down

Assume three dispatchable generators:

Resource	Pmin (MW)	Pmax (MW)	Ramp Rate (MW/Minute)	Energy Bid ($/MWh)
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

Currently, ISO creates financially binding dispatch and prices in same market run.

Solution for binding interval (1 of 2)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval			
Net Load	800			

We need to dispatch 800 MW of generation to balance Load - VERs

Resource	Binding Interval			
G1				
G2				
Fast Start				
LMP				

Solution for binding interval (2 of 2)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval			
Net Load	800			

Resource	Binding Interval			
G1	500			
G2	300			
Fast Start	0			
LMP	**$30**			

G2 is marginal and sets the LMP at $30

Solution for advisory interval (1 of 5)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55		

	Binding Interval	Advisory Interval		
Net Load	800	845		

We need to dispatch 845 MW of generation to balance Load - VERs

Resource	Binding Interval	Advisory Interval		
G1				
G2				
Fast Start				
LMP				

Solution for advisory interval (2 of 5)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval		
Net Load	800	845		

Resource	Binding Interval	Advisory Interval		
G1				
G2				
Fast Start		50		
LMP				

The Fast Start resource needs to be committed since G1+G2 can't meet demand

Solution for advisory interval (3 of 5)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval		
Net Load	800	845		

Resource	Binding Interval	Advisory Interval		
G1				
G2		300		
Fast Start		50		
LMP				

G2 scheduled to Pmin to create headroom for Fast Start Pmin burden

Solution for advisory interval (4 of 5)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval		
Net Load	800	845		

Resource	Binding Interval	Advisory Interval		
G1		495		
G2		300		
Fast Start		50		
LMP				

G1 dispatched below Pmax to provide additional headroom for Pmin burden of both G2 and Fast Start

Solution for advisory interval (5 of 5)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval		
Net Load	800	845		

Resource	Binding Interval	Advisory Interval		
G1		495		
G2		300		
Fast Start		50		
LMP		**$25**		

G1 is the marginal resource and sets the LMP at $25

Solution for multi-interval optimization (1 of 2)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval		Forecasted Movement Requirement
Net Load	800	845		45 U

Resource	Binding Interval	Advisory Interval		
G1	500	495		
G2	300	300		
Fast Start	0	50		
LMP	**$30**	**$25**		

The binding interval dispatch is ramp feasible to the advisory interval dispatch

Solution for multi-interval optimization (2 of 2)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	[illegible]	[illegible]	[illegible]0	$30
Fast Start	[illegible]	[illegible]	[illegible]	$35

The ramp capability from the multi-interval optimization is settled as forecasted movement

	[illegible] Interval	[illegible] Interval	[illegible]	Forecasted Movement Requirement
Net Load	800	845	[illegible]	45 U

Resource	Binding Interval	Advisory Interval		Forecasted Movement
G1	500	495		5 D
G2	300	300		0
Fast Start	0	50		50 U
LMP	**$30**	**$25**		**$0 U $0 D**

Solution for multi-interval demand and uncertainty (1 of 10)

The advisory interval net load could be as low as 835 MW in the next market run. Must position dispatchable generation so that they are able to meet lower net load if forecast error materializes.

Resource	Pmin	[illegible]	[illegible]	[illegible]
G1	0	[illegible]	[illegible]	[illegible]
G2	300	[illegible]	[illegible]	[illegible]
Fast Start	50	[illegible]	[illegible]	[illegible]

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1				
G2				
Fast Start				
LMP				

Solution for multi-interval demand and uncertainty (2 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertain Award Do	
G1				
G2		300		
Fast Start		50		
LMP				

G2 and Fast Start must be committed to meet 845 MW net load

California ISO

Solution for multi-interval demand and uncertainty (3 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertain Award Do	
G1		495		
G2		300		
Fast Start		50		
LMP		**$25**		

G1 is the marginal resource and sets the price at $25

Solution for multi-interval demand and uncertainty (4 of 10)

Resource	[illegible]	[illegible]ax	Ramp Rate	Energy Bid
G1	[illegible]	[illegible]0	1	$25
G2	[illegible]	[illegible]5	100	$30
Fast Start	[illegible]	[illegible]	10	$35

Only G1 can reduce its output if net load materializes at 835 MW since others are at Pmin

	Binding Interval	A[illegible]y In[illegible]	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1		495	10	
G2		300		
Fast Start		50		
LMP		**$25**		

Solution for multi-interval demand and uncertainty (5 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval	[illegible]
Net Load	800	845	[illegible]

But, G1 can only reach a dispatch of 485 MW in the advisory interval if we schedule it at 490 MW in the binding interval.

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	490	495	10	
G2		300		
Fast Start		50		
LMP		**$25**		

Solution for multi-interval demand and uncertainty (6 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	55	10	$35

	Binding Interval	Advisory Interval	[illegible]	[illegible]
Net Load	800	845	[illegible]	[illegible]

G2 provides the balance of the binding interval dispatch

Resource	Binding Interval	Advisory Interval	[illegible] Award Down	Forecasted Movement
G1	490	[illegible]	10	
G2	310	300		
Fast Start	0	50		
LMP		**$25**		

Solution for multi-interval demand and uncertainty (7 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	50	[illegible]	[illegible]	[illegible]

	Binding Interval	Advisory Interval	[illegible]	[illegible]
Net Load	800	845	[illegible]	45 U

> G2 is the marginal resource and sets the LMP at $30 because if you dispatch G1 up 1 MW you cannot meet the downward uncertainty requirement

Resource	Binding Interval	Advisory Interva[illegible]	[illegible]ertainty [illegible]ward Down	Forecasted Movement
G1	490	49[illegible]	10	
G2	310	[illegible]0		
Fast Start	0	50		
LMP	**$30**	**$25**		

Solution for multi-interval demand and uncertainty (8 of 10)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	10	$25
G2	300	325	100	$30
Fast Start	50	55	[illegible]	[illegible]

	Binding Interval	Advisory Interval	Uncertainty Requiremen Down	[illegible]
Net Load	800	845	10	[illegible]

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	…recasted …ovement
G1	490	495	10	
G2	310	300		
Fast Start	0	50		
LMP	**$30**	**$25**	**$5**	

Holding G1 back in the binding interval creates a $5 opportunity cost ($30 - $25)

Solution for multi-interval demand and uncertainty (9 of 10)

Resource	P[illegible]	[illegible]	Ramp Rate	Energy Bid
G1	[illegible]	[illegible]	10	$25
G2	[illegible]	[illegible]	100	$30
Fast Start	[illegible]	[illegible]	10	$35

Forecasted movement down also has a non-zero price which reflects the value of ramping capability

	Binding Interval	Advisory Interval	[illegible]tainty R[illegible]ment [illegible]n	Forecasted Movement Requirement
Net Load	800	845	[illegible]	45 U

Resource	Binding Interval	Advisory Interval	Uncert[illegible]y Award D[illegible]n	Forecasted Movement
G1	490	495	10	5 U
G2	310	300		10 D
Fast Start	0	50		50 U
LMP	**$30**	**$25**	**$5**	**$0 U $5 D**

Solution for multi-interval demand and uncertainty (10 of 10)

Re[illegible]	[illegible]	[illegible]	[illegible]	[illegible]ergy Bid
G1	[illegible]	[illegible]	[illegible]	$25
G2	[illegible]	[illegible]	[illegible]	$30
Fast S[illegible]	[illegible]	[illegible]	[illegible]	$35

The fleet is positioned to meet the binding interval demand and to meet advisory demand between 835 MW and 845 MW

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	490	495	10	5 U
G2	310	300		10 D
Fast Start	0	50		50 U
LMP	**$30**	**$25**	**$5**	**$0 U $5 D**

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (1 of 7)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325		
Fast Start	N/A	55		

Since we don't observe the Fast Start resource's Pmin, we dispatch G1 and G2 to Pmax

	Binding Interval	Advisory Interval	Uncert Requir D	Forecasted Movement Requirement
Net Load	800	845		45 U

Resource	Binding Interval	Advisory Interval	certainty ward Down	Forecasted Movement
G1		500		
G2		325		
Fast Start		20		
LMP				

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (2 of 7)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	N/A	55	10	$35

	Binding Interval	Advisory Interval	[illegible]	[illegible]
Net Load	800	845	1[illegible]	45 U

The Fast Start resource is marginal and sets the LMP at $35 in the pricing run

Resource	Binding Interval	Advisory Interval	Un[illegible]ty A[illegible] Down	Forecasted Movement
G1		500		
G2		325		
Fast Start		20		
LMP		**$35**		

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (3 of 7)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	[illegible]	[illegible]	1	$25
G2	[illegible]	[illegible]	100	$30
Fast Start	N/A	55	10	$35

The Fast Start is the most expensive unit that can reduce its output in the advisory interval

	Binding Interval	Advisory Interval	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	84[illegible]	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1		500		
G2		325		
Fast Start		20	10	
LMP		**$35**		

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (4 of 7)

Resource	Pm[illegible]	[illegible]	[illegible]	Energy Bid
G1	0			$25
G2	30			$30
Fast Start	N/A	5	10	$35

No out of merit dispatch needed to create ramping capability to cover uncertainty requirement

	Binding Interval	[illegible]y [illegible]al	Uncertainty Requirement Down	Forecasted Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	500	500		
G2	300	325		
Fast Start	0	20	10	
LMP	**$30**	**$35**		

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (5 of 7)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	0	500	1	$25
G2	300	325	100	$30
Fast Start	N/A	55		

Clearing price is zero because there is no opportunity cost

	Binding Interval	Advisory Interval	Uncertai… Requirement Down		…ement …uirement
Net Load	800	845	10		45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Dow…	Forecasted Movement
G1	500	500		
G2	300	325		
Fast Start	0	20	10	
LMP	**$30**	**$35**	**$0**	

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (6 of 7)

Resource	Pmin	Pmax	Ramp Rate	Energy Bid
G1	[illegible]	[illegible]	1	$25
G2	[illegible]	[illegible]	100	$30
Fast Start	[illegible]	[illegible]	10	$35

Forecasted movement is different than the physically feasible dispatch for generators.

	Binding Interval	Advis[illegible] Interval	[illegible]ncertainty [illegible]uirement [illegible]own	Forecasted Movement Requirement
Net Load	800	845	[illegible]	45 U

Resource	Binding Interval	Advisory Interval	Uncert[illegible]ty Award Do[illegible]n	Forecasted Movement
G1	500	500		0
G2	300	325		25 U
Fast Start	0	20	10	20 U
LMP	**$30**	**$35**	**$0**	**$0 U $0 D**

Pricing run solution for multi-interval demand and uncertainty using fast start pricing logic (7 of 7)

R
G1
G2
Fas

The binding prices do not reflect the need to position the fleet in the in the binding interval differently in order to meet net load in the advisory interval between 835 MW and 845 MW

We are not compensating G1 or G2 for providing the flexibility needed to ramp between the two intervals.

	Interval	Interval	Requirement Down	Movement Requirement
Net Load	800	845	10	45 U

Resource	Binding Interval	Advisory Interval	Uncertainty Award Down	Forecasted Movement
G1	500	500		0
G2	300	325		25 U
Fast Start	0	20	10	20 U
LMP	**$30**	**$35**	**$0**	**$0 U $0 D**

Summary

Current market optimization dispatch and prices

Resource	Binding Interval Dispatch	Uncertainty Award Down	Forecasted Movement
G1	490	10	5 U
G2	310		10 D
Fast Start	0		50 U
LMP	**$30**	**$5**	**$0 U $5 D**

Fast Start logic market optimization dispatch and prices

Resource	Binding Interval Dispatch	Uncertainty Award Down	Forecasted Movement
G1	490	10	5 U
G2	310		10 D
Fast Start	0		50 U
LMP	**$30**	**$0**	**$0 U $0 D**

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 18th day of August, 2017.

/s/ *Grace Clark*
Grace Clark