Price Formation Enhancements

Stakeholder Workshop #3

03/20/2023

Housekeeping reminders

- This call is being recorded for informational and convenience purposes only. Any related transcriptions should not be reprinted without ISO's permission.
- Meeting is structured to stimulate dialogue and engage different perspectives.
- Please keep comments professional and respectful.
- Please try and be brief and refrain from repeating what has already been said so that we can manage the time efficiently.

Instructions to ask a question:

In person:

Please raise your hand for a mic and state your name and affiliation before making a comment.

Virtual Participation:

- Select the raise hand icon  located on the bottom-middle of your screen. Use #2 when dialed into the meeting.
  - Please remember to state your **name** and **affiliation** before making your comment.
- If you need technical assistance during the meeting, please send a chat to the event producer.

Proposed Mechanism to Incorporate Fast-Start Pricing into CAISO Market (for discussion purposes)

- Based on two examples from CAISO's supplemental comments in the Fast-Start Pricing NOPR proceeding
- Proposed mechanism intends to prevent undermining FRP while assuming fast-start generators are dispatchable below their minimum output level

! Remember: the marginal cost of repositioning (and hence, the FRP price) would have been zero in the pricing run, even though the need to reposition these generators actually existed in the scheduling run.

https://www.caiso.com/Documents/Aug18_2017_SupplementalComments-Fast-StartPricingNOPR_RM17-3.pdf

Alternative Approach to Implementing FSP

Fast-Start Generators in the binding interval

- Pricing dispatch assumes as though they could operate at any level between 0 MW and their maximum output level

Fast-Start Generators in the advisory intervals

- Pricing dispatch assumes they could operate at no less than their minimum output level

Fast-Start Generator Examples

- Example 1: FSG does not operate in the binding interval 
  - Alternative FSP produces FRP prices that reflect marginal opportunity costs; ordinary FSP would not

- Example 2: FSG operates in the binding interval and is needed to meet load 
  - Alternative FSP permits FSG's offer to set LMP while FRP prices reflect marginal opportunity costs

Assumptions

- Three generators: G1, G2, FSG
- G1 & G2 not fast-start, committed to operate in binding & advisory intervals
- FSG fast-start, can be started whenever to meet load

Resource	Ramp Rate (MW/min)	PMIN (MW)	PMAX (MW)	Energy Offer ($/MWh)
G1	2	0	500	25
G2	100	Varies by example		30
FSG	15	35	60	35

- No start-up costs
- Generators dispatched to minimize cost while meeting forecasted load and upward/downward uncertainty

Example 1: FSG does not operate in the binding interval

Additional Assumptions

Resource	Ramp Rate (MW/min)	Min Output (MW)	Max Output (MW)	Energy Offer ($/MWh)
G1	2	0	500	25
G2	100	320	345	30
FSG	15	35	60	35

Binding interval load requirement: 825 MW

Advisory interval load expectation: 855 MW

Uncertainty requirements: +/- 20MW

Terminology before we start

- Remember that fast-start pricing requires separating the physical dispatch from the pricing dispatch
  - CAISO → Scheduling Run and Pricing Run
- Status Quo – Physical Dispatch → represents the status quo CAISO market solution (dispatch and pricing) AND the physical dispatch solution under either fast-start pricing method
- Pricing Dispatch Ordinary FSP → represents the pricing dispatch solution under ordinary fast-start pricing
- Pricing Dispatch Alternative FSP → represents the pricing dispatch solution under alternative fast-start pricing

Example 1: FSG does not operate in the binding interval

Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	320	345	100	$30	0	335	20	320
FSG	35	60	15	$35	0	0	0	35
Total					**20**	**825**	**20**	**855**

G1 and G2 have combined capacity of 845 MW so FSG must be started in the advisory interval to meet load. FSG is not needed in the binding interval.

Example 1: FSG does not operate in the binding interval

Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	320	345	100	$30	0	335	20	320
FSG	35	60	15	$35	0	0	0	35
Total					**20**	**825**	**20**	**855**

G1's output in the binding interval must not exceed 490 MW, since it must be able to reduce its output to 480 MW in the advisory interval and G1 can only change output by 10 MW/interval (2 MW/min x 5 min/interval).

Example 1: FSG does not operate in the binding interval

Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	320	345	100	$30	0	336	20	320
FSG	35	60	15	$35	0	0	0	35
Total					**20**	**836**	**20**	**855**

G2 sets the LMP for the binding interval ($30/MWh) since G1 cannot increase output in the binding interval and maintain ability to decrease output to 480 MW in the advisory interval

Example 1: FSG does not operate in the binding interval

Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	489	0	499
G2	320	345	100	$30	1	336	20	321
FSG	35	60	15	$35	0	0	0	35
Total					**21**	**825**	**20**	**855**

FRD marginal price is $10/MWh since an increase in downward uncertainty would necessitate a reduction in G1's output and an offsetting increase in G2's output in both the binding and advisory intervals, increasing the cost of the dispatch by $10/MWh

Example 1: FSG does not operate in the binding interval

Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	320	345	100	$30	0	335	21	320
FSG	35	60	15	$35	0	0	0	35
Total					**21**	**825**	**21**	**855**

FRU marginal price is $0/MWh since an increase in upward uncertainty has no impact on the energy schedules.

Upcoming example

- Upcoming example illustrates concern CAISO raised to FERC that fast-start pricing resulted in inappropriate price signal for FRP
  - Applying ordinary FSP would prevent G1 from being paid the opportunity costs that it incurs in the binding interval
- These examples do not (yet) incorporate commitment costs into LMPs via modified offer curves for the FSG

Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	10	325	0	345
FSG	0	60	15	$35	10	0	20	10
Total					**20**	**825**	**20**	**855**

**Remember that the dispatches/awards are only relevant for pricing purposes*

***Assumes offline FSG not eligible to set price*

Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	10	325	0	345
FSG	0	60	15	$35	10	0	20	10
Total					**20**	**825**	**20**	**855**

G1 and G2 have combined capacity of 845 MW so FSG must be started in the advisory interval to meet load. However, FSG is no longer required to operate at minimum of 35 MW.

Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	10	325	0	345
FSG	0	60	15	$35	10	0	20	10
Total					**20**	**825**	**20**	**855**

No need for G1 to reduce its output to balance load in the downward uncertainty scenario.

Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	10	326	0	345
FSG	0	60	15	$35	10	0	20	10
Total					**20**	**826**	**20**	**855**

G2 sets the LMP for the binding interval ($30/MWh)

Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	11	325	0	345
FSG	0	60	15	$35	10	0	20	10
Total					**21**	**825**	**20**	**855**

FRD marginal price is $0/MWh since an increase in downward uncertainty has no impact on the energy schedules

Example 1: FSG does not operate in the binding interval

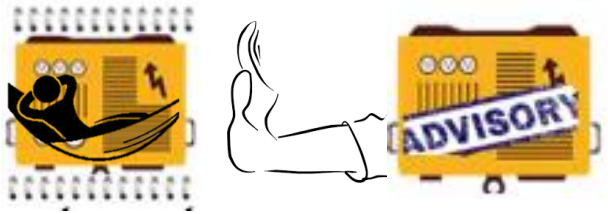
Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	320	345	100	$30	10	325	0	345
FSG	0	60	15	$35	10	0	21	10
Total					**20**	**825**	**21**	**855**

FRU marginal price is $0/MWh since an increase in upward uncertainty has no impact on the energy schedules

Alternative Fast-Start Pricing

- Alternative FSP would relax the minimum output constraint in the **binding interval** of the pricing dispatch, but continue to enforce the minimum output constraint during the **advisory intervals** of the pricing dispatch



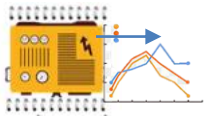
Example 1: FSG does not operate in the binding interval

Pricing Dispatch – Alternative FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	320	345	100	$30	0	335	20	320
FSG	35	60	15	$35	0	0	0	35
Total					**20**	**825**	**20**	**855**

Pricing dispatch is the same as the physical dispatch since FSG is not scheduled to operate in the binding interval in this example. FRP prices remain the same under alternative FSP proposal, avoiding problems that would arise from ordinary FSP.

Example 2: FSG operates in the binding interval and is needed to meet load



Additional Assumptions

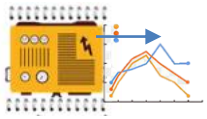
Resource	Ramp Rate (MW/min)	Min Output (MW)	Max Output (MW)	Energy Offer ($/MWh)
G1	2	0	500	25
G2	100	↓300	↓325	30
FSG	15	35	60	35

Binding interval requirements: ↑830 MW

Advisory interval load expectations: ↓845 MW

Uncertainty requirements: +/- 30 MW

Example 2: FSG operates in the binding interval and is needed to meet load

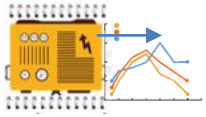


Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	305	15	310
FSG	35	60	15	$35	0	35	15	35
Total					**30**	**830**	**30**	**845**

G1 and G2 have combined capacity of 825 MW so FSG must be started in the binding interval to meet load

Example 2: FSG operates in the binding interval and is needed to meet load



Status Quo - Physical Dispatch

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Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
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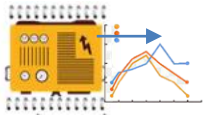
G2	300	325	100	$30	10	305	15	310
FSG	35	60	15	$35	0	35	15	35
Total					**30**	**830**	**30**	**845**

G1's output in the binding interval must not exceed 490 MW, since it must be able to reduce its output to 480 MW in the advisory interval and G1 can only change output by 10 MW/interval (2 MW/min x 5 min/interval)

Example 2: FSG operates in the binding interval and is needed to meet load

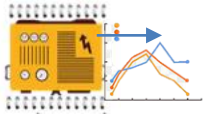


Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	306	15	310
FSG	35	60	15	$35	0	35	15	35
Total					**30**	**831**	**30**	**845**

G2 sets the LMP for the binding interval ($30/MWh) since G1 cannot increase output in the binding interval and maintain ability to decrease output to 480 MW in the advisory interval

Example 2: FSG operates in the binding interval and is needed to meet load



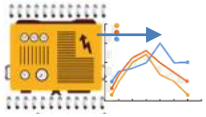
Status Quo - Physical Dispatch

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	489	0	499
G2	300	325	100	$30	11	306	15	311
FSG	35	60	15	$35	0	35	15	35
Total					**31**	**830**	**30**	**845**

FRD marginal price is $10/MWh since an increase in downward uncertainty would necessitate a reduction in G1's output and an offsetting increase in G2's output in the binding and advisory intervals, increasing the cost of the dispatch by $10/MWh

Example 2: FSG operates in the binding interval and is needed to meet load

Status Quo - Physical Dispatch



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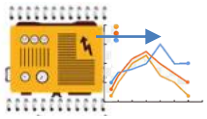
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	305	16	310
FSG	35	60	15	$35	0	35	15	35
Total					**30**	**830**	**31**	**845**

FRU marginal price is $0/MWh since an increase in upward uncertainty has no impact on the energy schedules

Example 2: FSG operates in the binding interval and is needed to meet load

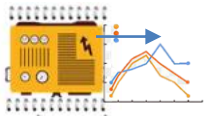


Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	10	325	0	325
FSG	0	60	15	$35	20	5	30	20
Total					**30**	**830**	**30**	**845**

**Assumes offline FSG not eligible to set price*

Example 2: FSG operates in the binding interval and is needed to meet load



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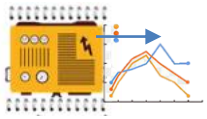
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	10	325	0	325
FSG	0	60	15	$35	20	5	30	20
Total					**30**	**830**	**30**	**845**

G1 and G2 have combined capacity of 825 MW so FSG must be started in the binding interval to meet load. However, FSG is no longer required to operate at minimum of 35 MW, so its pricing dispatch differs from the physical dispatch.

Example 2: FSG operates in the binding interval and is needed to meet load



Pricing Dispatch – Ordinary FSP

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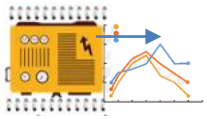
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	10	325	0	325
FSG	0	60	15	$35	20	5	30	20
Total					**30**	**830**	**30**	**845**

No need for G1 to reduce its output to balance load in the downward uncertainty scenario.

Example 2: FSG operates in the binding interval and is needed to meet load



Pricing Dispatch – Ordinary FSP

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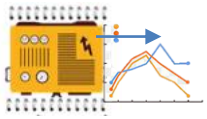
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	10	325	0	325
FSG	0	60	15	$35	20	6	30	20
Total					**30**	**831**	**30**	**845**

FSG sets the LMP for the binding interval ($35/MWh). This is the intended outcome of FSP.

Example 2: FSG operates in the binding interval and is needed to meet load

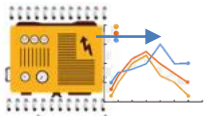


Pricing Dispatch – Ordinary FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	11	325	0	325
FSG	0	60	15	$35	20	5	30	20
Total					**31**	**830**	**30**	**845**

FRD marginal price is $0/MWh since an increase in downward uncertainty has no impact on the energy schedules

Example 2: FSG operates in the binding interval and is needed to meet load



Pricing Dispatch – Ordinary FSP

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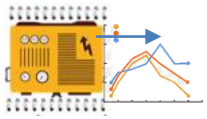
G1	0	500	2	$25	0	500	0	500
G2	300	325	100	$30	10	325	0	325
FSG	0	60	15	$35	20	5	31	20
Total					**30**	**830**	**31**	**845**

FRU marginal price is $0/MWh since an increase in upward uncertainty has no impact on the energy schedules

Example 2: FSG operates in the binding interval and is needed to meet load

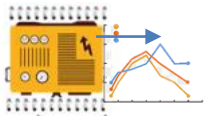


Pricing Dispatch – Alternative FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	325	15	310
FSG	35	60	15	$35	0	15	15	35
Total					**30**	**830**	**30**	**845**

FSG's minimum operating level of 35 MW is not enforced in the binding interval for the pricing dispatch and is instead dispatched at 15 MW.

Example 2: FSG operates in the binding interval and is needed to meet load

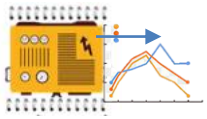


Pricing Dispatch – Alternative FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	325	15	310
FSG	35	60	15	$35	0	16	15	35
Total					**30**	**831**	**30**	**845**

FSG sets the LMP for the binding interval ($35/MWh). This is the intended outcome of FSP.

Example 2: FSG operates in the binding interval and is needed to meet load

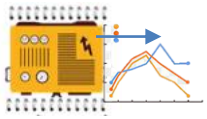


Pricing Dispatch – Alternative FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	489	0	499
G2	300	325	100	$30	11	325	14	311
FSG	35	60	15	$35	0	16	16	35
Total					**31**	**830**	**30**	**845**

FRD marginal price is $15/MWh since an increase in downward uncertainty would necessitate a reduction in G1's output and an offsetting increase in FSG's output (G2 is at max gen) in the binding interval, and a reduction in G1's output in the advisory interval with an offsetting increase in G2's output, increasing the cost of the dispatch by $15/MWh

Example 2: FSG operates in the binding interval and is needed to meet load



Pricing Dispatch – Alternative FSP

					Binding Interval			Advisory Interval
Resource	**PMIN (MW)**	**PMAX (MW)**	**Ramp (MW/min)**	**Energy Offer ($/MWh)**	FRD (MW)	Energy Schedule (MW)	FRU (MW)	Energy Schedule (MW)
G1	0	500	2	$25	20	490	0	500
G2	300	325	100	$30	10	325	15	310
FSG	35	60	15	$35	0	15	16	35
Total					**30**	**830**	**31**	**845**

FRU marginal price is $0/MWh since an increase in upward uncertainty has no impact on the energy schedules

Discussion points

- Changes the price formation of FRP by extension of changing the energy price
  - If one agrees with the principles of fast-start pricing (minus the commitment cost portion) generally then one may also agree the FRP compensation is fair in these scenarios since the opportunity cost is properly accounted for
- Relaxation of the min output constraint in the advisory interval may be limited by the resource's ramp constraint
  - It would be necessary to relax the ramping constraint of the FSG between binding and advisory intervals on portions below PMIN
  - We have explored other examples and have not identified any issues

Discussion points

- FRP payments seem to be sufficient to incent following dispatch
- These examples do not (yet) incorporate commitment costs into LMPs via modified offer curves for the FSG

Next Steps

All related information for the Price Formation Enhancements Initiative related materials are available on the California ISO - Price formation enhancements (caiso.com)

- Send email to ISOstakeholderaffairs@caiso.com
  Subject: Price Formation Enhancements