Adjustment to Inter-Tie Constraint Penalty Prices

November 11, 2021

Issue Paper/Straw Proposal

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Acronyms

BAA	Balancing Authority Area
CAISO	California Independent System Operator
ETC	Existing Transmission Contract
HASP	Hour Ahead Scheduling Process
HE	Hour Ending
IFM	Integrated Forward Market
ISL	Inter-Tie Scheduling Limit
ITC	Inter-Tie Constraint
LMP	Locational Marginal Price
MCC	Marginal Congestion Component
MLC	Marginal Loss Component
NOB	Nevada/Oregon Border
PBC	Power Balance Constraint
RUC	Residual Unit Commitment
SCUC	Security Constrained Unit Commitment
SMEC	System Marginal Energy Component
TOR	Transmission Operating Rights

Introduction

The California ISO regularly reports on the performance of its markets to provide timely and relevant information. Recent monthly reports have focused on the CAISO's market performance and system conditions during the 2021 summer months, when system conditions in the CAISO and across the Western Interconnection were more constrained than other times of the year.

Through that effort, the CAISO identified instances where market schedules exceeded the derated limit of the MALIN500_ISL (Malin) and Nevada/Oregon Border (NON_ITC "NOB") intertie in the real-time market. The overscheduling resulted because the intertie was largely derated due to transmission outages caused by the Bootleg fire, and because of the interplay of the scheduling priorities the CAISO uses in its market optimization. In real-time, the CAISO operators manually curtailed import schedules to comply with intertie limits. The CAISO also identified overscheduling on interties in the Residual Unit Commitment (RUC). The overscheduling of interties results in an overestimation of capacity actually available to the real-time market. To resolve this inconsistency between market results and actual conditions, the CAISO must manually curtail schedules to ensure flows are within operating limits.

This issue paper and straw proposal identifies the reasons why market overscheduling occurred, and proposes changes to specific penalty price parameters to ensure the market is able to resolve similar situations in the future consistent with actual physical conditions on the grid. The current hour ahead scheduling process (HASP) Inter-Tie Constraint (ITC) or Inter-Tie Scheduling Limit (ISL) relaxation parameter, which determine when the market optimization allows schedules to exceed stated limits, is $1,500/MWh. In this paper, the CAISO proposes to update this price to $2,900/MWh. The current RUC ITC/ISL relaxation penalty price is $1,250/MWh. In this paper, the CAISO proposes to similarly update this price to $3,200/MWh.

Background

There are four optimization elements that are foundational to the market clearing process and critical to understanding both the overscheduling issues and the analysis that informs the CAISO's proposal:

- **Market constraint relaxation parameter hierarchy:** As stated in the CAISO Business Practice Manual for Market Operations (referred to herein as "the BPM") Section 6.6.5:"Known in the jargon of mathematical optimization as 'penalty factors,' which are associated with constraints on the optimization and which govern the conditions under which constraints may be relaxed and the setting of market prices when any constraints are relaxed. Importantly, the magnitude of the penalty factor values in the tables for each market reflect the hierarchical priority order in which the associated constraint may be relaxed in that market by the market software."[1]

- **Locational Marginal Prices (LMP):** As stated in the CAISO Business Practice Manual for Market Operations Section 3.1, "The LMP is the marginal cost (expressed in $/MWh) of serving the next increment of Demand at that PNode." The LMP consists of three main parts including System Marginal Energy Component (SMEC), Marginal Loss component (MLC), and Marginal Congestion Component (MCC).

- **Power Balance Constraint (PBC) relaxation:** The PBC ensures that the sum of the demand and transmission losses is equal to the supply. In order to assess the need to relax the PBC, its penalty price is included in the objective function of the optimization problem. The use of penalty prices sets the priority level of the PBC relative to other priorities within the optimization.[2] The penalty price, as stated in the BPM, for real-time and HASP is $1,450 and in RUC is $1,600.

- **Inter-Tie Constraint (ITC) or Inter-Tie Scheduling Limit (ISL) relaxation:** An ITC is a scheduling constraint that is modeled in the market. An ISL is a group comprised of multiple ITCs. ITC's have a bi-directional limits for cleared intertie or system resource bids. An ITC constraint ensures intertie schedules, considering the net direction of the import schedules and export schedules, do not violate either the physical limit for import or exports. The directional

[1] CAISO Business Practice Manual for Market Operations, Section 6.6.5.
[2] Id. at section 6.6.5.4.

limits help ensure the accuracy of the power balance equation and scheduling within the CAISO, since the PBC includes net intertie schedules.[3] The penalty price, as stated in the BPM, for real-time and HASP is $1,500 and in RUC is $1,250.

HASP ITC and under-generation conditions

Issue Description

On July 9, 2021[4] operating and market conditions dictated the simultaneous relaxation of both the PBC and the ITC constraints. These relaxations were driven by two key factors:

- High demand with an hourly average load of 42,924 MW.

- 3 out of 4 lines north of Malin on the Northwest AC intertie (NWACI) relayed due to the impact of the Bootleg fire, resulting in California Oregon Intertie (COI) de-rates from 2,967 MW to 1,800 MWs at Hour Ending (HE) 14 and later starting in HE 17 to 285 MWs. Pacific DC Intertie PDCI de-rates at the Nevada Oregon Border (NOB) started in HE 17 from 1,622 MWs to 785 MW.

Because of limitations of net imports into the CAISO balancing authority area, the high loads, and tight supply conditions, the CAISO market result relaxed ITC on the CAISO PACI_ITC constraint in HASP for HE 19. Figure 1 and Figure 2 below show the market schedules across the different markets at the Malin and NOB intertie scheduling points, respectively, compared to the ITC limits on July 9. The figures show the net intertie schedules for each market process, *i.e.* the day-ahead residual unit commitment (RUC), the hour-ahead scheduling process, the fifteen-minute market, and real-time dispatch compared to the import limit the market optimization used for each market process. The bar above the limit indicates the time periods where the CAISO market optimization relaxed the ITC. This resulted in the market overscheduling of the derated ITC limit.

[3] Id at Section 6.6.2.5.

[4] For more information on timelines and de-rates that occurred on July 9th, please see page 97 of the CAISO's Summer Market Performance Report for July 2021, **http://www.caiso.com/Documents/SummerMarketPerformanceReportforJuly2021.pdf**.

Figure 1: July 9 2021 Malin schedules by market in comparison to the limit

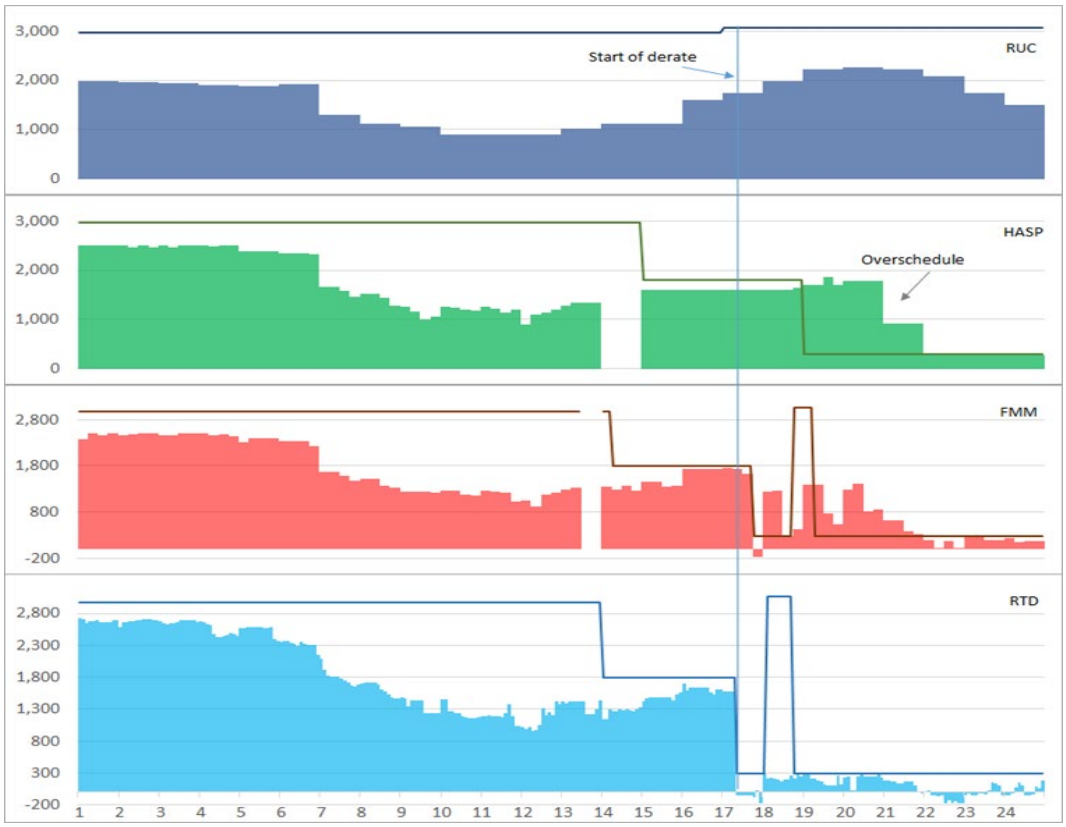
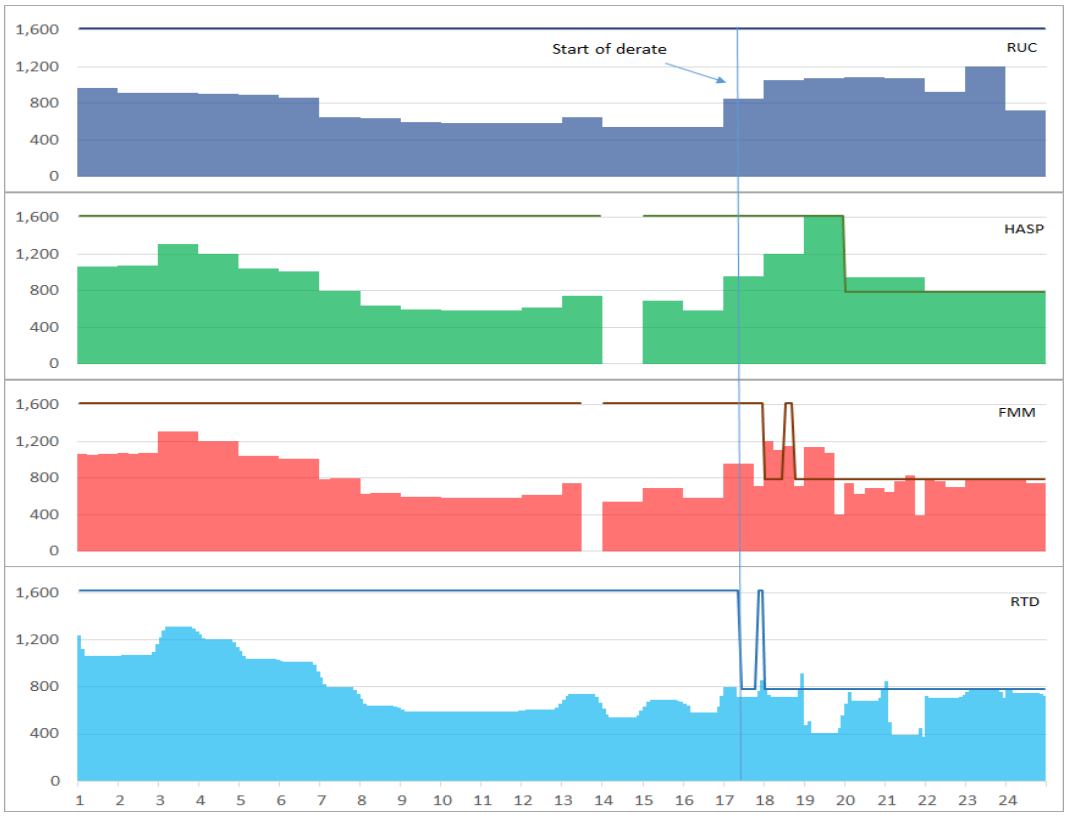


Figure 2: July 9th 2021 NOB schedules by market in comparison to the limit



To understand how the relaxation parameters worked together on July 9 there are several market design elements to consider. First, the bid floor and bid cap at -$150/MWh and $1,000/MWh, respectively, an import or export resource could bid into the market at any price point on that range. Alternatively, they could also self-schedule. The penalty prices for self-schedules for imports in HASP, as well as the other penalty price constraints relevant to this scenario, are listed below in Table 1.

Table 1: Applicable HASP Penalty Prices

Penalty Price Description	Scheduling Run Value Based on $1000 Cap	Pricing Run Value Based on $1000 Cap	Scheduling Run Value Based on $2000 Cap	Pricing Run Value Based on $2000 Cap	Comment
Real-time price-taker self-schedule import with RUC schedule and import leg of high priority wheel through self-schedule with RUC schedule	-1200	-150	-2400	-150	For hourly bids in HASP and fifteen- minute bids in FMM, a RUC scheduled import self-schedule Has a higher priority than over-generation energy slack
Real-time price-taker self-schedule import without RUC schedule and import leg of high priority wheel through self-schedule without RUC schedule	-1100	-150	-2200	-150	For hourly bids in HASP and fifteen-minute bid in FMM, a real time submitted self-schedule with no RUC schedule has a higher priority than over-generation energy slack
Energy balance/Load curtailment, RUC cleared self-scheduled export using identified non-RA capacity. RUC cleared export leg of a wheel through self-schedule. Real-time export leg of a wheel through self-schedule. Real-time market self-scheduled export using identified non-RA capacity.	1450	1000	2900	2000	Scheduling run penalty price is set high to achieve high priority in serving forecast load and exports that utilize non-RA capacity. Energy bid cap as pricing run parameter reflects energy supply shortage.
Transmission constraints: Intertie scheduling	1500	1000	3000	2000	The highest among all constraints in scheduling run, penalty price reflects its priority over load serving. Energy bid cap as pricing run parameter reflects energy supply shortage.

Imports are cleared based upon a supply curve. If the price goes below the bid in offer, the bid will not clear. This same principle applies to import self-schedules at a scheduling point: to be cut, the price at the scheduling point has to be more negative than the penalty price parameter used for adjusting the self-schedule.

On July 9, the reduction on the Malin and NOB scheduling limit occurred in the import direction. With the de-rate limit imposed, the market needed to reduce imports on these interties in the HASP to recognize the new limit. The order that this would be done in the optimization is as follows: First, the CAISO market clears economic imports and schedules in decreasing merit order (from most expensive to least) against the amount of import capacity. Should the market exhaust the bid stack, the next step is to reduce self-schedules. The market will first reduce real-time import self-schedules,

followed by self-schedules that cleared RUC and have submitted self-schedules in real-time up to the RUC cleared level. In addition to these priorities, the formulation of the price at the scheduling point during each level of relaxation has to be considered to understand the impact on the market outcome.

The following series of examples highlight these issues, using the components of the Locational Marginal Price (LMP), including System Marginal Energy Component (SMEC), Marginal Loss component (MLC), and Marginal Congestion Component (MCC) through a series of decreasing import limits. For simplification, assume the loss component is $0/MWh. Assume the SMEC is $25/MWh. Four import resources bid at the tie location, each with 10 MW offers. There are two import economic bids, Bid A at $24/MWh and Bid B at -$10/MWh. Along with the two economic bids, there are two self-schedules: Bid C is a real-time self-schedule and Bid D is a self-schedule that cleared RUC.

- **Example 1:** This example demonstrate full availability at the scheduling point. Assuming a 50MW transfer limit on the scheduling point and SMEC being higher than all import bid offers. Assume the total imports bids at that scheduling point totals 40MW. Since all intertie bids are infra-marginal, all bid offers would be accepted and the total amount of schedules at the tie point would be 40 MW, which is lower than the ITC limit. Consequently, the ITC is not congested (is not binding).

- **Example 2:** This example shows a derated import limit. As a result, not all the economic bids are accepted due to reduced available transfer capability. It illustrates the impact of congestion on the priority of cleared economic bids, the determination of a shadow price, and the formulation of the LMP.

  Consider two scenarios with different import limits: 35 MW and 25 MW. For the larger transfer limit (35 MW) the marginal resource that clears at the limit is Bid A at 5 MW and the rest of the bids accepted at full capacity for a total schedule at the limits of 35 MWs. At the intertie location with Bid A is the marginal bid at a price of $24/MWh, this would result in a shadow price on the ITC of -$1/MWh. The MCC for the resource would also be -$1/MWh resulting in a LMP at the tie point of $24/MWh.

  If the intertie was de-rated further to 25 MW: Bid A would not clear, Bid B would clear at 5 MW, and the two self-schedules are cleared at full capacity of 10 MW each for a total schedule of 25 MW. Because Bid B is the marginal bid, the shadow

price would be -$35/MWh resulting in a MCC at the point of -$35/MWh for a price of -$10/MWh.

- **Example 3:** The third example further reduces the scheduling limit of the intertie beyond economic bids to highlight how the cuts on the tie must be performed via scheduling priority, with cuts applied first to the lowest priority of self-schedules. The lowest priority of import self-schedule is the real-time self-schedules that did not clear in RUC, represented in these examples by Bid C. The penalty price for this type of self-schedule is -$1,100, as stated in Table 1. If the limit is now reduced to 15 MW, Bids A and B would not clear. Bid C would clear at 5 MW and Bid D would clear at full capacity of 10 MW, for a total schedule cleared of 15 MW. The partial quantity for Bid C clearing is due to its lower scheduling priority. In this example the shadow price at the ITC would be -$1,125/MWh and the MCC at that tie point would be -$1,125/MWh. With the SMEC of $25/MWh this results in a LMP at the intertie point of -$1,100/MWh.

- **Example 4:** The fourth example highlights economic cuts that occur to a higher priority schedule scheduling on the intertie; specifically self-schedules that have cleared RUC. The penalty price for this type of self-schedule is -$1,200 MWh. For this example the import limit is now 5 MW. At this limit, Bid A, B, and C would not clear. Bid D would be the highest priority cleared at 5 MW for a total schedule cleared of 5 MW. The shadow price at the ITC would be -$1,225/MWh and the MCC at that tie point would be -$1,225/MWh. With the SMEC of $25/MWh this results in a LMP at the tie point of -$1,200/MWh.

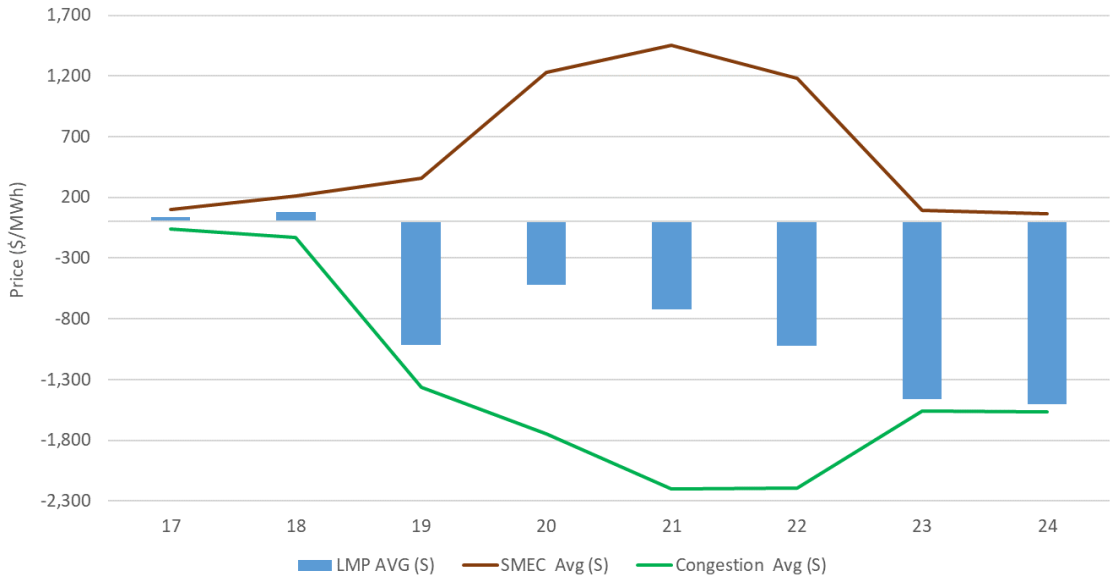
These example demonstrate how self-schedule cuts work through the use of the LMPS and each component. This also demonstrates how when the PBC constraint and an ITC are at the level of price relaxation that overloads can occur on the ITC. In the examples above the SMEC was clearing at a price of $25/MWh. If the PBC was relaxed in the CAISO, this results in a SMEC of $1,450. The ITC penalty price is relaxed at -$1,500 penalty price. When these two constraints (ITC and PBC) bind, the price being set at that intertie scheduling point would be the SMEC plus the MCC, not considering loss, only the ITC congestion, the price at that location would be -$50/MW. As a result of both constraints being relaxed the net prices is not low enough to make the necessary cuts. This price will allow import bids to clear and will not reduce any self-schedules. This interaction is the result of the cleared price at the location being higher than any bid from -$50/MWh to the minimum bid price of -$150 MWh. All self-schedule would also clear because the penalty price is lower than the -$50/MWhs. This last example illustrates why the ITC is

relaxed when the PBC binds when import limit cuts occur and also demonstrates the need for an updated ITC penalty price.

While these examples are illustrative, the overscheduling of the Malin and NOB intertie scheduling points that occurred on July 9 has additional complexities. Because the ITC penalty price was not high enough, there was still overscheduling. Figure 3 shows the scheduling run prices in the HASP hours of July 9 at the Malin scheduling point. The LMPs for this time frame were well below the -$50/MWh price. This was due to the fact that the SMEC did not reach PBC relaxation penalty for all the four of the intervals of HASP along with other system conditions that occurred.

Similarly, the prices in hour ending HE 19 to HE 22 were well above the self-schedule penalty price of -$1,100 identified in Table 1. This was also due to the fact that SMEC did not reach PBC relaxation penalty price for all intervals of the hour. Further, in HE 23 and 24 prices decreased to approximately -$1,200/MWh, when the DA self-schedules are marginal. This is due to a combination of two factors: first, the SMEC decreases to a range of $100/MWh to $200/MWh. This indicates that the ITC and PBC constraints are no longer in conflict and binding at the same time. Second, there was additional congestion from relatively close transmission constraint for this time and contributed to the higher congestion component that is reflected in the LMP.

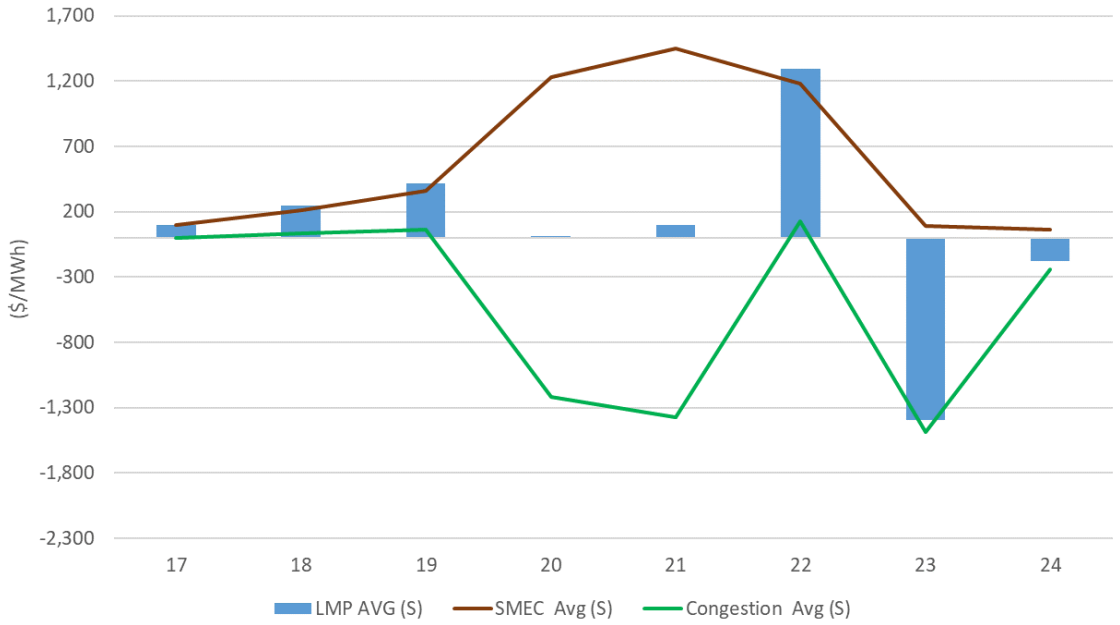
Figure 3: HASP scheduling prices at Malin on July 9, 2021



The NOB_ITC overloads occurred in HE 20 and 21 as indicated in Figure 4. For these two hours, the ITC and PBC relaxation penalties are closer to the -$50 /MWh. With the average LMP, which for these hours were $10.85/MWh and $98.38/MWh. This was due to an

average SMEC being closer to PBC relaxation penalty price and the congestion component only being influenced by the ITC relaxation penalty price.

Figure 4: HASP scheduling prices at NOB on July 9, 2021



Proposed Solution

In the BPM Section 6.6.5 and Tariff Section 27.4.3.2.1 the penalty price for the ITC in the real-time market is $1,500/MWh.

The CAISO proposes to increase the ITC penalty price from $1,500/MWh to $2,900/MWh for $1,000 bid cap and $5,800 for $2,000 bid cap so that under any conditions, the market does not overschedule interties. At this penalty price, the market will respect both the intertie scheduling limits and the PBC relaxation.

The methodology to set the price must consider other constraints binding in order to produce a price reflective of the necessary priorities. In this case, if there is a reduction in ITC limits and a PBC violation, the resultant penalty price must be lower than the highest priority self-schedule. When PBC is being relaxed and import limits have been reduced to the level of cutting import RUC cleared IFM schedules that penalty price in real-time needs to be less than -$1,200.

The new penalty price is determined as follows. Under the current self-schedule penalty price structure for imports and exports, the minimum penalty price on the import side would need to be the lowest ITC penalty price minus the highest import penalty price, excluding ETC or TORs. That would lead the minimum penalty price to be (-$1,200-$1,450 = -$2,650). Following sensitivity analysis performed by the CAISO we recommend there be a margin of difference among the penalty prices to account for interplay with other constraints and other components of the LMP. For instance, the CAISO needs to consider

the loss component because the losses at scheduling points can vary in either direction. The testing showed the largest losses are in the range of plus or minus $150, so this is used a starting point. An additional $100 is added to provide additional margin for the possibility of larger losses and to create separation in the priorities. The CAISO determined that the proposed penalty price to addresses this interplay is at least $2,900/MWh for the export and -$2,900/MWh for the import direction.

As part of any penalty price change, the CAISO must coordinate such a change relative to other penalty prices in order to preserve the relative scheduling priority in the market optimization. Consequently, as part of this proposal for adjusting the ITC penalty price, there are other adjustments proposed, as listed in Table 2.

Table 2: Additional HASP Penalty Price for priority adjustment

Penalty Price Description	Scheduling Run Value Based on $1000 Cap	Pricing Run Value Based on $1000 Cap	Scheduling Run Value Based on $2000 Cap	Pricing Run Value Based on $2000 Cap	Comment
Exceptional Dispatch for Tie Generators	1600	1000	3200	2000	Priority to exceptional dispatches made by operators for Tie generators
EIM Base scheduled exports	1550	1000	3100	2000	EIM base scheduling priority for export when tagged schedules do not exist
Tagged Quantity for exports	1550	1000	3100	2000	After clearing in the real time market, Inter-tie tagged priority for exports. Higher priority than load in real time.
EIM Base scheduled imports	-1250	-150	-2500	-150	EIM base scheduling priority for import when tagged schedules do not exist
Tagged Quantity for imports	-1250	-150	-2500	-150	After clearing in the real time market, Inter-tie tagged priority for imports. Higher priority than over-generation energy slack
EIM Transfer Constraint	1500	1000	3000	2000	Penalty price and pricing parameter consistent with the transmission constraint;

These penalty prices are used to clear base schedules and tagged quantities in the energy imbalance market (EIM), exceptional dispatches on tie generators, and for internal CAISO tagged transactions that have already cleared the HASP or FMM markets. These scheduling priorities need to remain above the ITC relaxation penalty price in subsequent market runs because these become tagged (fixed) values that should not be cut in the markets. This is the responsibility of each Balancing Authority Area (BAA) to maintain through its scheduling process. Table 3 has the proposed adjustments to the additional penalty prices.

Table 3: Proposed additional HASP Penalty Price for priority adjustment

Penalty Price Description	Scheduling Run Value Based on $1000 Cap	Pricing Run Value Based on $1000 Cap	Scheduling Run Value Based on $2000 Cap	Pricing Run Value Based on $2000 Cap	Comment
Exceptional Dispatch for Tie Generators	3200	1000	6400	2000	Priority to exceptional dispatches made by operators for Tie generators
EIM Base scheduled exports	3100	1000	6200	2000	EIM base scheduling priority for export when tagged schedules do not exist
Tagged Quantity for exports	3100	1000	6200	2000	After clearing in the real time market, Inter-tie tagged priority for exports. Higher priority than load in real time.
EIM Base scheduled imports	-3100	-150	-6200	-150	EIM base scheduling priority for import when tagged schedules do not exist
Tagged Quantity for imports	-3100	-150	-6200	-150	After clearing in the real time market, Inter-tie tagged priority for imports. Higher priority than over-generation energy slack
EIM Transfer Constraint	2900	1000	5800	2000	Penalty price and pricing parameter consistent with the transmission constraint;

RUC ITC and under-generation conditions

Issue Description

The RUC scheduling priority penalty price for ITC and PBC is very similar to the HASP, but is slightly different in scale due to the size of the scheduling run PBC. An example of the over-scheduling of the ITC in RUC occurred on August 19, 2020. The MALIN500_ISL was overscheduled in RUC by approximately 530 MW in HE 17 through 21. The NOB_ITC was overscheduled on this day by approximately 195 MW in HE 17 through 21.

In RUC the PBC relaxation penalty price is set to $1600 and the ITC penalty price is -$1250 for import, as described in Table 4.

Table 4: Applicable RUC Penalty Prices

Penalty Price Description	Scheduling Run Value	Pricing Run Value	Comment
Market energy balance - under procurement. IFM cleared self-scheduled exports using identified non-RA capacity. IFM cleared export leg of a wheel through self-schedule	1600	250	The RUC procurement may be less than the Demand forecast if the CAISO has committed all available generation and accepted intertie bids up to the intertie capacity.
Transmission constraints: branch, corridor, nomogram (base case and contingency analysis)	1250	250	These constraints affect the final dispatch in the Real-Time Market, when conditions may differ from Day-Ahead.
IFM cleared supply schedules	Min(energy bid price -$250, or $0)	0	These values preserve schedules established in IFM in both the RUC scheduling run and pricing run.
IFM cleared economical exports	IFM bid-in price +300	0	Export adder priority for IFM schedules

The supply that clears in the IFM is the base quantity of commitment and schedules determined in RUC, and is protected with a penalty price. For supply, this penalty price is a negative adder to the bid value used in IFM. For exports, it is a positive adder to the cleared IFM schedules. This is done to maintain the relative scheduling priority in RUC of schedules that cleared in the IFM.

Table 5: IFM intertie penalty prices

Penalty Price Description	Scheduling Run Value Based on $1000 Cap	Pricing Run Value Based on $1000 Cap	Scheduling Run Value Based on $2000 Cap	Pricing Run Value Based on $2000 Cap	Comment
Import price-taker self-schedule. Import leg of a high priority wheel through self-schedule.	-1100	-150	-2200	-150	Generic self-schedules for supply receive higher priority than Economic Bids at the bid floor.
Import leg of a low priority wheel through self-schedule	0	0	0	0	Import side of a low priority wheel self-schedule
Self-scheduled exports not using identified non-RA capacity, Exports leg of a low priority wheel through self-schedule	1050	1000	2100	2000	The scheduling parameter for self-scheduled exports not using identified non-RA capacity is set below the parameter for generic self-schedules for demand.

Exports supported by non-RA capacity do not have the adder applied due to these resources having the same priority as load. For example, if an import self-schedule clears

10 MW in the IFM at $0, that 10 MW would be protected in RUC at a -$250 penalty price. For self-schedules, the market uses the same adder on top of the import self-schedule penalty price used in the IFM. Those penalty prices are located in Table 5.

Based on these penalty prices, the highest import price that would occur in RUC would be -$1,350/MWh, this is the IFM -$1100 plus the -$250 adder. The largest export penalty price would be $1,600 at PBC and the lower priority penalty price would be $1,350. So when the PBC is relaxed in RUC the SMEC will be set to $1,600. At this point if an ITC or ISL is at the limit in IFM cuts to the exports schedule will be made at the lower priority first then PBC and higher priority. When these cuts occur this leads to ITC limits potentially binding or being overloaded due to lack of counter flow, if the penalty price is not set high enough, it's is less costly to overload that constraint. This is why a -$1,250 ITC penalty price in RUC results in the market optimization relaxing the PBC, ITC and reducing exports. A larger penalty price for the ITC would eliminate this undesired interaction. Figures 5 and 6 provide an example of this occurring; By looking at the scheduling run LMP prices that cleared at Malin and NOB on August 19, 2020 (Figure 5 and Figure 6), the -$1,250 ITC penalty price was not large enough to prevent the market optimization from relaxing it and allowing overscheduling of these interties.

Figure 5: RUC scheduling prices at Malin on August 19, 2020.

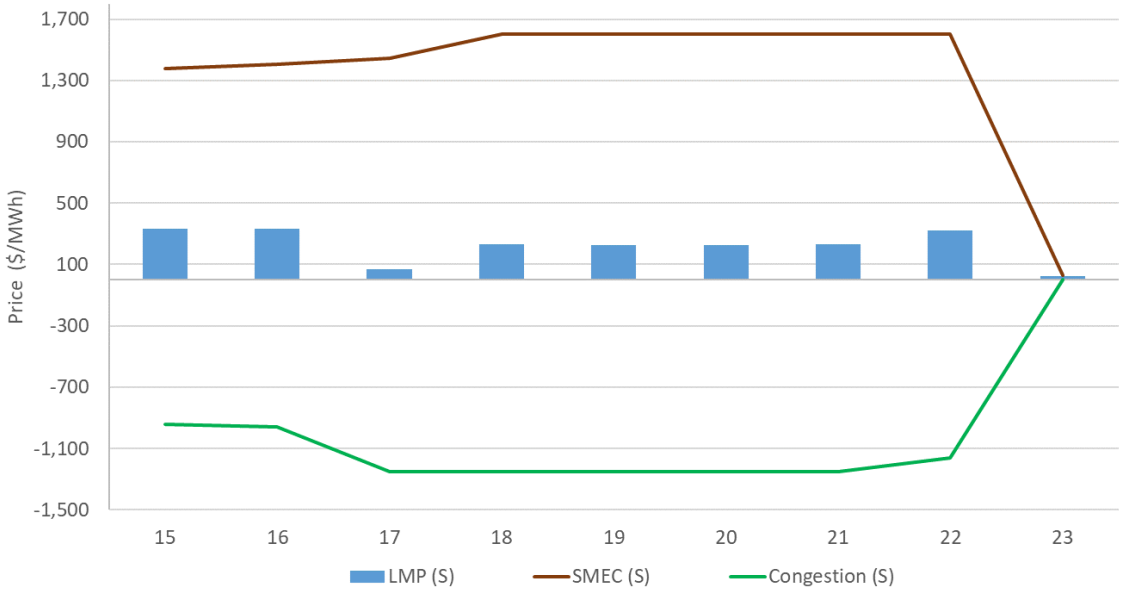
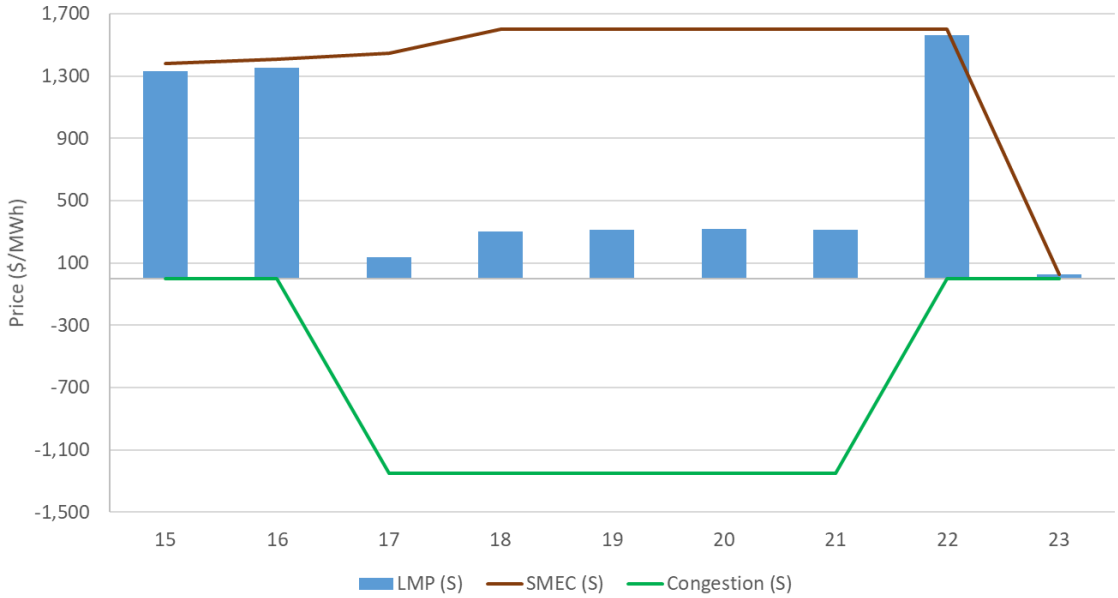


Figure 6: RUC scheduling prices at NOB on August 19, 2020.



Proposed Solution

In the BPM Section 6.6.5 and Tariff Section 27.4.3.2.1 the price for the ITC is $1,250/MWh. The CAISO proposes to adjust this amount to $3,200/MWh.

Similar to HASP, the penalty price adjustment for RUC ITC will be based on the highest import self-schedule, not including ETC/TOR, and the PBC relaxation penalty price. Therefore, the lower level for PT self-schedule price would be -$1,350 less the PBC relaxation or (-$1,350-$1,600) or -$2,950. Taking into consideration the loss component, which observations from testing indicate can range up to plus or minus $150 along with a $100 of margin the proposed price is -$3,200 for imports and $3,200 for exports. The CAISO identified that there are no other penalty price adjustments needed with the newly proposed ITC penalty price.

Next Steps

Date	Milestone
Issue Paper / Straw Proposal	November 11, 2021
Stakeholder Meeting	November 19, 2021
Comments Due	December 3, 2021
Draft Tariff / Draft Final Proposal	December 2021
Final Proposal	January 2022
ISO Board of Governors	February 2022
FERC Filing	March 2022