# Addendum to

# the Retrospective Analysis of Local Market Power Mitigation Enhancements

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## A1. BACKGROUND

The Retrospective Analysis[1] compared the ISO's new Local Market Power Mitigation (LMPM) methodology and the current LMPM methodology using historical day-ahead market data. In response to stakeholders' comments, this addendum will discuss several topics beyond those that have been covered in the Retrospective Analysis from both a conceptual and an empirical point of view. By going from "how it works" to "why it works", this addendum seeks to provide a better understanding of the new LMPM approach. All the empirical analyses in the addendum were performed on the same study period as the Retrospective Analysis, i.e. day-ahead market from February 1, 2011 to March 31, 2011.

## A2. HOW DIFFERENT ARE THEY? THE NEW VS THE CURRENT

The mechanics of the current LMPM method and the new LMPM method seem different. The current LMPM method requires two runs, the competitive constraints run (CC run) and the all constraints run (AC run). The units that are dispatched in the upward direction from the CC run to the AC run will be subject to mitigation. The new method only requires one run, the AC run, and relies on the LMP decomposition to determine the locational advantage due to non-competitive constraints.

Despite the apparent difference, the current method and new method are both sensitivity type of approaches. Both methods try to determine the impact or sensitivity of non-competitive constraints. There are two types of sensitivity, namely the large change sensitivity and the marginal sensitivity. The large change sensitivity is the change in outcome due to large changes in parameters. The current LMPM is a large difference sensitivity method. The large change in parameters is with and without the non-competitive constraints enforced. The outcome is an upward unit dispatch.

In contrast, the marginal sensitivity is the changing rate in the outcome due to infinitesimal changes in parameters, i.e. outcome delta change divided by parameter change. Note that shift factors, constraint shadow prices, LMPs, and LMP components are all marginal sensitivities. The new LMPM method is also a marginal sensitivity approach, because the LMP non-competitive component is the shift factor weighted aggregated shadow prices from all non-competitive constraints.

Neither of these approaches is more "correct" than the other. Both are valid methods, and are seen in various applications in industry. Depending on the specific application, one might perform better

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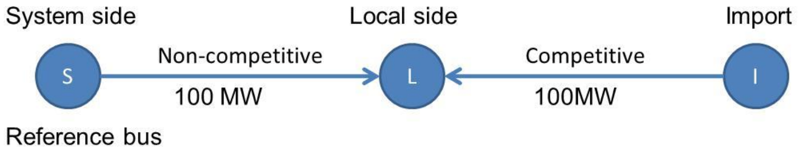
[1] A Retrospective Analysis of Local Market Power Mitigation Enhancements, http://www.caiso.com/2b79/2b79e5c95b260.pdf

than the other. For the purpose of LMPM, as demonstrated in the Retrospective Analysis, the current method (large change sensitivity) does not perform as well as the new method (marginal change sensitivity). One fundamental reason for that is because a deadband exists for any large change sensitivity, which means unless a change is sufficiently large, it cannot be observed. For the current LMPM method, enforcing the non-competitive constraints may not be a sufficiently large change to trigger an upward unit dispatch in the constrained local area. This happens when there is a more economical way to relieve the congestion on the non-competitive constraints than dispatching up the units in a local area. For example, if the units in a local area bid too high, they will not be dispatched in both the CC and AC run. In this case, the units inside the local area are within their deadband. An example is illustrated in Figure 1 to demonstrate this. As a convention in the paper, the resources listed under the corresponding node are connected to that node. In this example, generator G0 is connected to the system side, generator G1 and load L1 are connected to the local side, and import I2 is connected to the inter tie connection point.



Bids:

| | | |
|---|---|---|
| G0: 180MW at $40/MWh | G1: 200MW at $500/MWh<br>L1: 150MW | I2: 160MW at $300/MWh |

Schedules:

| | | |
|---|---|---|
| CC run: 150MW at $40<br>AC run: 100MW at $40 | CC run: 0MW at $40<br>AC run: 0MW at $300 | CC run: 0MW at $40<br>AC run: 50MW at $300 |

FIGURE 1: HIGH BID CREATED DEADBAND

In the example, G1 bids very high ($500) and create a deadband such that G1 will not be dispatched in either CC run or AC run. This example also demonstrates that import bids can also “crowd out” generator bids similar to the effect produced by virtual bids. In the example, import I2 “crowds out” generator G1. Because the combination of bidding behavior and the “crowding out” effect, G1 is not dispatched in either the CC or AC run resulting in a lack of mitigation.

In the study period, among all hours that the new LMPM method had identified units for mitigation, 26% of time these identified units are inside the deadband of the current LMPM method. In other words, 26% of time, the AC run did not dispatch up any units in the local areas compared with the CC run.

## A3. WHAT DOES A GOOD MITIGATION REFERENCE BUS LOOK LIKE?

Generally speaking, a good reference bus should be electrically close to the supply side of any non-competitive constraint if the ‘to’ side of the constraint is truly a load pocket. However, today some constraints are deemed non-competitive by default even if it is the outlet of a generation pocket. In this case, the reference bus may be electrically closer to the ‘to’ side of the constraint, because the ‘to’ side is actually the system side in this case. This just means the constraint is constrained in the direction from the generation to the system.

For radial constraints, the reference bus on the supply side can be verified when the 'from' bus shift factor close to 0. Similarly, the reference bus on the 'to' side can be verified when the 'from' bus shift factor close to 1. However, for looped networks, these properties may not hold. In order to characterize if the reference bus is close to the 'from' side or the 'to' side, we need to define a new measure.

One can determine how radial a constraint is in the following way. Assume $r$ is the flow on the constraint by injecting 1 MW at the 'from' side of the constraint, and withdrawing 1 MW at the 'to' side of the constraint. By definition, $r$ is independent of the reference choice. The value of $r$ is the shift factor difference between the 'from' bus and the 'to' bus of the constraint, and is typically between 0 and 1.[2]

$r$ is a measure of how radial a constraint is. If $r$ is equal to 1, the constraint is radial. By definition, $r = 1$ implies 100% of the power injected at the 'from' bus will flow through the constraint to reach the 'to' side. There are no other paths between the 'from' side and the 'to' side. If $r < 1$, only $100*r$ percent of the power injected at the 'from' side will flow through the constraint to reach the 'to' side. This also implies the $(1-r)*100$ percent of power goes through other paths, i.e. there are loops between the 'from' side and the 'to' side.

To measure whether the reference bus is relatively closer to the 'from' side of the constraint or the 'to' side of the constraint, we can define another parameter $ds = SF\_from / r$, where $SF\_from$ is the 'from' side shift factor. Because the reference bus has a shift factor equal to 0, $SF\_from$ is actually the distance between the 'from' side and the reference bus measured by shift factor. $ds$ is a number from 0 to 1. If $ds$ is equal to 0 the reference bus is exactly at the 'from' side. If $ds$ is equal to 1, the reference bus is exactly at the 'to' side. If $ds$ is equal to 0.5 the reference bus is exactly in the middle of the 'from' side and the 'to' side.

Now we can characterize what a good reference looks like. First, we need to verify the constraints with $ds < 0.5$ are indeed load pockets, and the constraints with $ds > 0.5$ are indeed generation pockets.[3] Second, for a load pocket, the closer to 0 $ds$ is, the better reference bus it is; the closer to 0.5 $ds$ is, the worse the reference bus is.

The binding constraints in the study period versus the relative location of the reference bus (Midway 500 KV or Vincent 500KV) are summarized in Table 1. The load pockets are shaded dark red, and the generation pockets are dark blue. We can verify that the $ds > 0.5$ corresponds to generation pockets and $ds < 0.5$ corresponds to load pockets. For example, SDGE_PCT_UF_IMP_BG has $r = 0.98$, which means it is almost radial, and $ds = 0$, which means the reference bus is exactly on

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[2] Generally speaking, for Nomogram constraints, the value of $r$ depends on the Nomogram coefficient, and may not be between 0 to 1 if absolute value of the Nomogram coefficient is greater than 1.

[3] A good dynamic competitive path assessment (CPA) should not deem a generation pocket constraint non-competitive. Doing so may result in over mitigation. The new LMPM method is able to protect those units with non-positive LMP non-competitive component from being mitigated. For example, if $ds = 1$ for a generation pocket constraint, the new LMPM will not mitigate any unit for this constraint even it is deemed non-competitive. However, more generally, if $ds < 1$, the new LMPM will not be able to completely correct the CPA false positive. It is expected that the dynamic CPA would significantly reduce the amount the false positives.

the 'from' side. Next, we can verify that for every load pocket constraint (in dark red color), *ds* is closer to 0 (the maximum of *ds* is 0.1) than 0.5. This means for every generator that has a positive shift factor on a load pocket constraint, the shift factor value must be very small (bounded by *r*ds* ). Therefore, they can only have relatively small negative LMP non-competitive components relative to the Midway 500KV bus or the Vincent 500KV bus. This confirms the validity of using the Midway 500KV bus or Vincent 500KV bus as the reference bus for mitigation.

| Constraint | Type | Description | *r* | *ds* | Ref. bus location |
|---|---|---|---|---|---|
| SDGE_PCT_UF_IMP_BG | Flowgate | Flow into SDGE | 0.98 | 0.00 | 'from' side |
| SLIC 1417897_IV_CB_7022_OUT_NG | Nomogram | Flow on Imperial Valley bank into SDGE | 0.90 | 0.71 | 'to' side |
| 36957_MCSN TP1_230_36961_MOCCASIN_230_BR_1 _1 | Flowgate | Moccasin generation into Newark | 1.00 | 1.00 | 'to' side |
| 32228_PLACER _115_32238_BELL PGE_115_BR_1 _1 | Flowgate | Drum, Higgins, and etc flow from Bell to Placer | 0.98 | 0.75 | 'to' side |
| SLIC 1446790 EGL_SLV_FLTN SOL-1 | Nomogram | North Geysers flow on Eagle Rock-Silverado-Fulton | 0.67 | 0.96 | 'to' side |
| SLIC 1368530_SDGE_IV_CB_7022 | Nomogram | Flow on Imperial Valley bank into SDGE | 0.90 | 0.75 | 'to' side |
| SSONGS_BG | Flowgate | Path 44 from Songs to SDGE | 0.88 | 0.07 | 'from' side |
| SLIC 1434491_Moorpark_Pardee_NG | Nomogram | Flow from Pardee into Santa Clara | 0.65 | 0.10 | 'from' side |
| 22716_SANLUSRY_230_24131_S.ONOFRE_230_BR_3 _1 | Flowgate | Part of path 44 into SDGE | 0.81 | 0.05 | 'from' side |

TABLE 1: BINDING NON-COMPETITIVE CONSTRAINTS AND REFERENCE BUS (MIDWAY OR VINCENT) RELATIVE LOCATION

## A4. MITIGATE BASED ON INDIVIDUAL CONSTRAINT OR ALL NON-COMPETITIVE CONSTRAINTS?

PG&E and SCE commented that mitigation should be based on the shift factor for each individual constraint. They suggest that a unit should be mitigated if it has a negative shift factor on at least one non-competitive constraint. Doing so may cause over-mitigation as demonstrated in the following example.

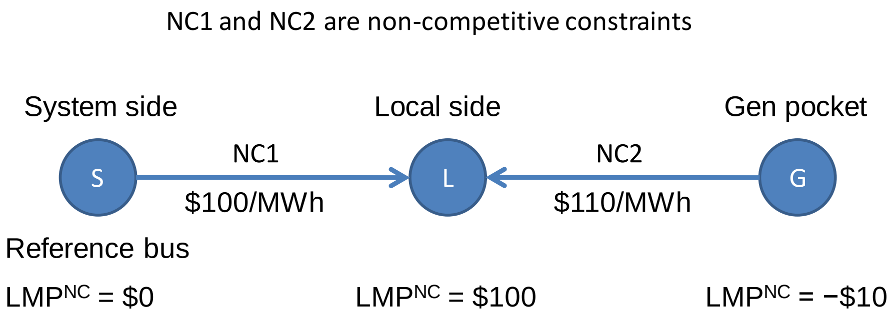


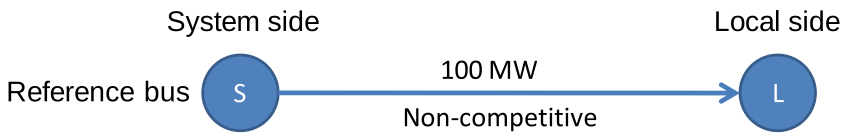
FIGURE 2: A GENERATION POCKET EXAMPLE

A load pocket L is connected to the system side S via a non-competitive constraint NC1. A generation pocket G is located on the local side, and is connected to L by another non-competitive constraint NC2. Suppose in the AC run, NC1 has a $100 shadow price and NC2 has a $110 shadow price. Assume the reference bus is on the system side. G has LMP non-competitive component equal to –$10 (=$100 – 110). Therefore, the ISO proposed method will not mitigate generators in G. However, because G has –1 shift factor, PG&E and SCE proposed shift factor test will mitigate generators in G. This is over-mitigation, because generators in G are unable to inflate the local pocket price.

## A5. THE COMPETITIVE LMP VS THE CC RUN LMP

A unit subject to mitigation should not be mitigated under a competitive baseline price, which is an estimate of the market price when the locational advantage due to non-competitive constraints is absent. The current LMPM method establishes this competitive baseline by running a CC run relaxing all non-competitive constraints. The CC run LMP protects the units from being mitigated below the competitive baseline price. The ISO's proposed new LMPM method establishes the competitive baseline by recalculating the AC run LMP after zeroing out the shadow prices on all non-competitive constraints. This is called the competitive LMP, and is equal to the AC run LMP minus the LMP non-competitive component.

PG&E commented the CC run LMP provides a better competitive baseline than the ISO proposed method. In order to reduce the extra CC run execution time, which may impact dynamic competitive path assessment (CPA) performance, PG&E proposes to carry out the CC run with fixed unit commitment from the AC run. However, under certain conditions, the CC run price calculated in the manner proposed by PG&E could be inflated by local market power as demonstrated in the following example in Figure 3.



Bids:

G0: 120MW at $40/MWh

G1: 100MW at $500/MWh
L1: 150MW

Schedules:

G0 CC run: 120MW at $500
G0 AC run: 100MW at $40

G1 CC run: 30MW at $500
G1 AC run: 50MW at $500

CC run price is not competitive

FIGURE 3: A PIVOTAL EXAMPLE

In this example, in the CC run, generator G1 on the local side has to be dispatched to meet the local load, because the system side supply is not sufficient. In this case, G1 is "pivotal".[4] G1's bid sets the CC run LMP at $500. If the CC run price $500 is used as the competitive price, then G1 cannot be mitigated. In a pivotal case, the CC run LMP over-estimates the competitive LMP.

The ISO's proposal will correctly estimate the true competitive price. The AC run will clear 100MW from G0 on the system side at an LMP equal to $40, and 50MW from G1 on the local side at an LMP equal to $500. Therefore, the local side has the LMP non-competitive component at $460, the competitive LMP at $40, which equals the system side LMP. G1 will be mitigated to the higher of $40 and its DEB.

As demonstrated in the example, in a pivotal case, the CC run LMP cannot correctly estimate the competitive LMP, while the LMP decomposition can.

The distribution of the difference between the competitive LMP and the CC run LMP in the study period is plotted in Figure 4. The price differences are hourly averages over the units with positive non-competitive LMP components.

- 79% percent of time, the competitive LMP is lower than the CC run LMP. On average, the competitive LMP is $5 lower than the CC run LMP.
- The competitive LMP and the CC run LMP are typically close. 85% percent of time, the difference is between –$6 to $3.
- In extreme cases, they can be very different.

Note that the CC run today is a full optimization, while the PG&E proposal would have fixed unit commitment decisions (from the AC run) in the CC run. Generally speaking, fixing unit commitments will restrict the ability to alleviate congestion, and thus result in higher load pocket prices. Therefore, it is expected that the percentage of time when the competitive LMP is lower than the CC run LMP will increase with PG&E's proposal.

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[4] A pivotal case is more likely to happen in real-time markets due to the resource ramping limitation, forced outages, renewable resources output volatility, and etc.

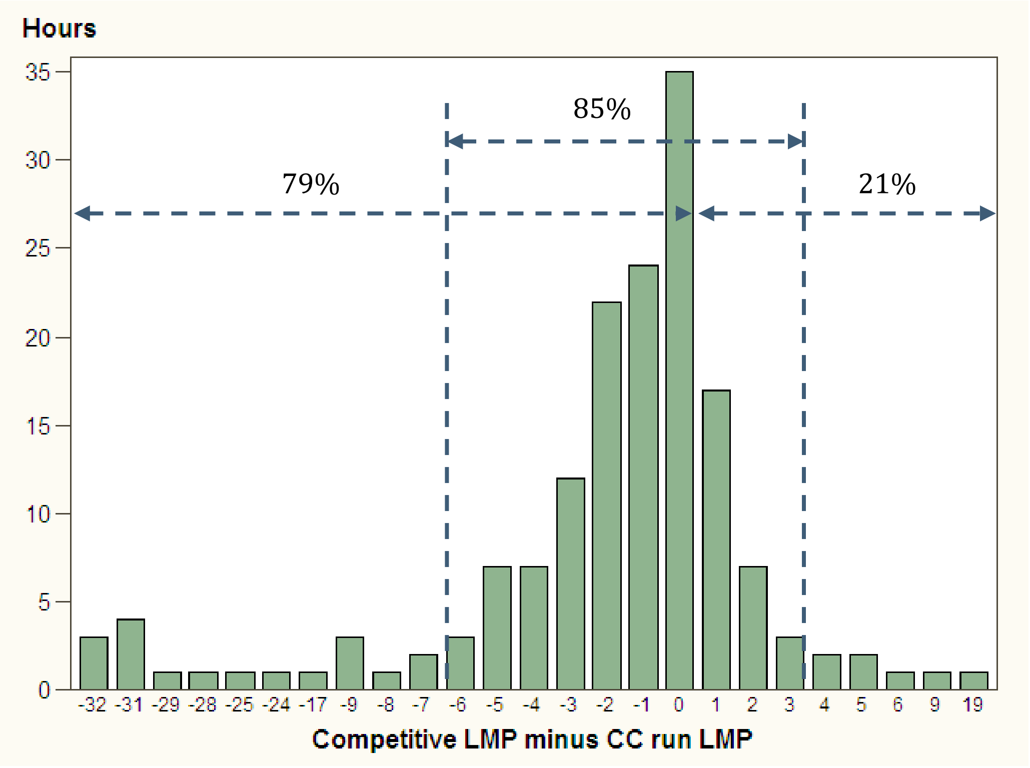

FIGURE 4: DISTRIBUTION OF THE DIFFERENCE BETWEEN THE COMPETITIVE LMP AND THE CC RUN LMP

# 4. SUMMARY

In this addendum, the fundamental difference between the new LMPM method and the current LMPM method is characterized as the marginal sensitivity vs the large change sensitivity. Due to the existence of deadband for dispatching units from the CC run to the AC run in the upward direction, the current method does not perform as well as the new method.

The reference bus plays a very important role in the new LMPM method. We verified the validity of using the Midway 500KV bus or Vincent 500KV bus against the binding non-competitive constraints in the study period. In the future, the ISO will monitor the reference bus performance.

In addition, two variations of the new LMPM method, namely mitigating based on individual constraint shift factor and using the CC run LMP to establish the competitive baseline price, have been demonstrated to cause problems under certain conditions.