



California ISO

System Market Power Mitigation

Appendix B: Draft Technical Description

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Power System Technology Development

Version 1.0

June 5, 2020

Technical Description

TABLE OF CONTENTS

1	Introduction	1
2	Assumptions.....	1
3	Notation	2
4	Mathematical Formulation	4

Technical Description

1 INTRODUCTION

This technical paper describes the calculation of the Residual Supply Index (RSI) with three pivotal suppliers for System Market Power Mitigation (SMPM) in the Real-Time Market (RTM). The SMPM will mitigate the energy bids of pivotal suppliers in the CAISO Balancing Authority Area (CISO) if the market is not competitive. Whether the market is competitive or not is determined by the RSI, similar to how the Dynamic Competitive Path Assessment (DCPA) method determines whether a binding transmission constraint is competitive in the market solution for Local Market Power Mitigation (LMPM). For SMPM, the binding constraint is the power balance constraint for the CISO, or the group of Balancing Authority Areas (BAAs) that includes the CISO and separates from the rest of the BAAs in the Energy Imbalance Market (EIM) due to binding import transfer constraints. The latter result in a higher marginal energy price within the importing BAA group compared to marginal energy prices outside the group. The SMPM assessment will be triggered when the CISO is in the highest-priced BAA group in the EIM Area, ranked in descending order by the shadow price of the power balance constraint for each BAA.

The RSI is the ratio of the available supply counter flow for the binding constraint over the demand for counter flow for that constraint. The demand for counter flow is the power flow on the binding constraint. The available supply counter flow is derived as the maximum supply counter flow from Fringe Competitive Suppliers (FCS) plus the minimum supply counter flow from the three largest Potentially Pivotal Suppliers (PPS). The latter are determined in decreasing order of the supply counter flow that they can withhold. The remaining suppliers are classified as FCS. When the RSI is less than one, the binding constraint is not competitive. For SMPM, the demand for counter flow for the power balance constraint is simply the demand in the highest-priced BAA group, and the supply for counter flow is simply the supply in that BAA group.

2 ASSUMPTIONS

The following assumptions are made in this paper:

- The mathematical formulation is general assuming that the RSI is calculated at the solution of the Market Power Mitigation (MPM) pass for each interval in the Fifteen-Minute Market (FMM)¹ and for each interval in the Real-Time Dispatch (RTD) for potential independent SMPM at each of these intervals. FMM has a designated MPM pass, but RTD does not; for RTD, the previous RTD run advisory intervals serve as the MPM pass solution. The SMPM can be configured to apply only for selected intervals and market runs.
- The highest-priced BAA group is determined by grouping the BAAs in the EIM Area with the highest shadow price for their power balance constraint; these BAAs separate from the rest of the BAAs in the EIM Area because of binding transfer limits

¹ Except for the buffer interval.

Technical Description

across the dividing interface. SMPM applies only in intervals where the CISO is included in the highest-priced BAA group.

- Import/export bids at CISO interties are treated similarly to resource bids inside the CISO, but they are constrained by the relevant ITC/ISL limits at the respective interties, taking into account any transfers that clear on these interties.
- Hourly intertie resources at CISO interties are considered fixed in FMM and RTD intervals; bids from these resources are considered only in the four 15min intervals for the next hour of the Hour-Ahead Scheduling Process (HASP).
- The net import base schedules to EIM BAAs in the highest-priced BAA group from non-EIM BAAs are considered as fixed FCS.
- The cleared net import transfers into the highest-priced BAA group from EIM BAAs outside the group are considered as fixed FCS.
- Transmission and transfer constraints inside the highest-priced BAA group are ignored.
- Ancillary services self-provision and base schedules are considered reserved capacity not available for supply. Similarly, ancillary services awards in RTD are considered reserved capacity not available for supply. Flexible Ramp Up and Down cannot be self-provided, hence they are ignored. Ancillary services cannot be self-provided from import resources at CISO interties, and ancillary services awards from these resources are ignored in RTD for simplicity.
- Ramp capability constraints are considered in the calculation of available supply.
- Exceptional and Manual Dispatch Instructions are considered in the calculation of available supply.
- Startup, shutdown, and Multi-State Generator (MSG) transitions are ignored in the calculation of available supply for simplicity.
- Scheduling Coordinators (SCs) are grouped by affiliates in the determination of PPS.
- SC affiliate groups may include intertie bids at CISO interties.
- The determination of PPS for SC affiliate groups considers only supply in excess of the SC affiliate group demand, determined from historical hourly meter data submission.
- The EIM Entity SC affiliate group includes the corresponding merchant SC and all third-party suppliers with no resources within the CISO. Furthermore, the determination of PPS for an EIM Entity SC affiliate group considers only supply in excess of the corresponding EIM BAA demand forecast. This is an approximation because third party demand information is not currently available for EIM BAAs.

3 NOTATION

The following notation is used in this paper:

Technical Description

i	Resource index.
j	BAA index, zero for CISO.
k	CISO aggregate inertia index; inertias are aggregated by the highest (innermost) hierarchical ITC/ISL.
l	Generic index for inertias between BAAs in the EIM Area with transfers (ETSRs).
m	EIM BAA to non-EIM BAA inertia index.
t	Time interval index (zero for initial condition).
n	Supplier affiliate group index.
PS	Potentially pivotal supplier index.
\forall	For all...
\in	Member of...
\cup	Union...
\cap	Intersection...
T	Number of intervals in the time horizon.
N	The total number of supplier affiliates.
S_{GR}	Set of Generating Resources.
S_{NGR}	Set of Non-Generator Resources.
S_I	Set of Import Resources.
S_E	Set of Export Resources.
S_T	Set of Transfer Resources (ETSRs).
BAA	Set of EIM inertias for a BAA (empty for CISO).
BHP	Set of BAAs in the highest-priced BAA group.
THP	Set of boundary transfers for the highest-priced BAA group.
S	Set of resources of a supplier affiliate group in the highest-priced BAA group.
PPS	Set of resources of potential pivotal suppliers.
FCS	Set of resources of fringe competitive suppliers.
δ	Global binary option (1/0) to adjust ED/MD for ancillary services self-provision in RTM.
η	Binary variable (1/0) that is set if the resource is must-run because of energy self-schedule, or regulation, spin, or online non-spin self-provision, or inter-temporal constraints.
UOL	Upper Operating Limit reflecting derates.
LOL	Lower Operating Limit reflecting rerates.
URL	Upper Regulating Limit.
LRL	Lower Regulating Limit.
UEL	Upper Economic Limit (top of energy bid).
ESS	Energy Self-Schedule for Generating Resource (GR) (bottom of energy bid or LOL).
GSS	Generating Self-Schedule for Non-Generator Resource (NGR) (bottom of energy bid or zero).
CL	Capacity Limit; $UEL \leq CL \leq UOL$; it defaults to UOL ; it is used to limit regulation awards.
UCL	Upper Capacity Limit.
LCL	Lower Capacity Limit.

Technical Description

EN	Resource Energy schedule (positive for supply and negative for participating load or NGR in load mode).
I	Import schedule.
E	Export schedule.
IT	Import Transfer (ETSR) schedule.
ET	Export Transfer (ETSR) schedule.
RU	Regulation Up self-provision or base schedule.
RD	Regulation Down self-provision or base schedule.
SR	Spinning Reserve self-provision or base schedule.
NR	Non-Spinning Reserve self-provision or base schedule.
$RRU(p, \tau)$	Piecewise linear upward ramp capability function from output p for a ramping period τ , reflecting derates.
$RRD(p, \tau)$	Piecewise linear downward ramp capability function from output p for a ramping period τ , reflecting derates.
Δt	Time interval duration.
\overline{ED}	Maximum effective (MAXGOTO) ED/MD.
\underline{ED}	Minimum effective (MINGOTO) ED/MD.
\overline{ITC}	ITC/ISL import limit.
\underline{ITC}	ITC/ISL export limit (negative).
WC	Withheld supply.
\overline{SCF}	Maximum supply.
\underline{SCF}	Minimum supply.
D	Demand forecast.
L	Metered Load.
RSI	Residual supply index.

4 MATHEMATICAL FORMULATION

This section contains the mathematical formulation for the calculation of the RSI. This calculation takes place only for time intervals where the CISO is a member of the highest-priced BAA group ($0 \in BHP_t$). The highest-priced BAA group is the union of BAAs in the EIM Area that have the highest shadow price for their power balance constraint.

It is convenient to define the following capacity limits for a resource depending on its regulation self-provision:

$$\left. \begin{aligned}
 RU_{i,t} + RD_{i,t} > 0 &\rightarrow \left\{ \begin{aligned}
 UCL_{i,t} &\equiv \min(UOL_{i,t}, URL_{i,t}, CL_{i,t}) \\
 LCL_{i,t} &\equiv \max(LOL_{i,t}, LRL_{i,t})
 \end{aligned} \right\} \\
 RU_{i,t} + RD_{i,t} = 0 &\rightarrow \left\{ \begin{aligned}
 UCL_{i,t} &\equiv UOL_{i,t} \\
 LCL_{i,t} &\equiv LOL_{i,t}
 \end{aligned} \right\}
 \end{aligned} \right\}, \forall i \in S_{GR} \cup S_{NGR}, t = 1, 2, \dots, T$$

These definitions reflect the fact that regulation self-provision places the resource on regulation and restricts its operating capacity range between the corresponding regulating limits, as opposed to between the operating limits. For resources without bids, like EIM Non-

Technical Description

Participating Resources, the upper and lower capacity limits are equal to the energy schedule in the MPM pass.

The maximum and minimum supply from a resource is calculated for each resource type, as follows:

$$\begin{aligned}
 \overline{SCF}_{i,t} &= \min \left(\begin{array}{c} UCL_{i,t} - RU_{i,t} - SR_{i,t} - NR_{i,t}, \\ UEL_{i,t} - SR_{i,t} - NR_{i,t}, \\ \overline{ED}_{i,t} - \delta (RU_{i,t} + SR_{i,t} + NR_{i,t}), \\ EN_{i,t-1} + RRU_{i,t}(EN_{i,t-1}, \Delta t) \end{array} \right) \\
 \underline{SCF}_{i,t} &= \eta_{i,t} \max \left(\begin{array}{c} LCL_{i,t} + RD_{i,t}, ESS_{i,t} \\ \underline{ED}_{i,t} + \delta RD_{i,t}, \\ EN_{i,t-1} - RRD_{i,t}(EN_{i,t-1}, \Delta t) \end{array} \right) \\
 \overline{SCF}_{i,t} &= \min \left(\begin{array}{c} UCL_{i,t} - RU_{i,t} - SR_{i,t} - NR_{i,t}, \\ UEL_{i,t} - SR_{i,t} - NR_{i,t}, \\ \overline{ED}_{i,t} - \delta (RU_{i,t} + SR_{i,t} + NR_{i,t}), \\ EN_{i,t-1} + RRU_{i,t}(EN_{i,t-1}, \Delta t) \end{array} \right) \\
 \underline{SCF}_{i,t} &= \max \left(\begin{array}{c} LCL_{i,t} + RD_{i,t}, GSS_{i,t} \\ \underline{ED}_{i,t} + \delta RD_{i,t}, \\ EN_{i,t-1} - RRD_{i,t}(EN_{i,t-1}, \Delta t) \end{array} \right) \\
 \overline{SCF}_{i,k,t} &= UEL_{i,k,t} \\
 \underline{SCF}_{i,k,t} &= ESS_{i,k,t} \\
 \overline{SCF}_{i,k,t} &= -ESS_{i,k,t} \\
 \underline{SCF}_{i,k,t} &= -UEL_{i,k,t}
 \end{aligned}
 \left. \vphantom{\begin{aligned} \overline{SCF}_{i,t} \\ \underline{SCF}_{i,t} \\ \overline{SCF}_{i,t} \\ \underline{SCF}_{i,t} \\ \overline{SCF}_{i,k,t} \\ \underline{SCF}_{i,k,t} \\ \overline{SCF}_{i,k,t} \\ \underline{SCF}_{i,k,t} \end{aligned}} \right\} \forall i \in S_{GR}, t = 1, 2 \dots, T$$

These calculations reflect the fact that spinning and non-spinning reserve self-provision require an energy bid in RTM, whereas regulation self-provision does not require an energy bid. NGRs are continuous resources without inter-temporal constraints; hence, they are modelled as always online. Ancillary services awards in RTD are treated similarly to ancillary services self-provision. Intertie resources may not self-provide ancillary services. Ancillary services awards from intertie resources are ignored in RTD for simplicity. If the SMPM applies to any interval other than the four 15min intervals of the next hour in the HASP run, hourly intertie resources at CISO interties are fixed to their hourly schedules from previous HASP runs.

All EIM intertie resources, including Mirror System Resources, are fixed at their cleared values in the MPM pass because they have no energy bids:

$$\overline{SCF}_{m,t} = \sum_{i \in S_I \cup S_E} (I_{i,m,t} - E_{i,m,t}) = \underline{SCF}_{m,t}, \forall m, t = 1, 2 \dots, T$$

For CISO aggregate interties, the net supply for an SC affiliate group is limited by the respective ITC/ISL:

Technical Description

$$\overline{SCF}_{n,k,t} = \min \left(\begin{array}{l} \overline{ITC}_k - \sum_{i \in S_T} (IT_{i,k,t} - ET_{i,k,t}) - \sum_{i \in S_I - S_{n,t}} I_{i,k,t} + \sum_{i \in S_E - S_{n,t}} E_{i,k,t} \\ \sum_{i \in S_I \cap S_{n,t}} \overline{SCF}_{i,k,t} + \sum_{i \in S_E \cap S_{n,t}} \overline{SCF}_{i,k,t} \end{array} \right),$$

$$\underline{SCF}_{n,k,t} = \max \left(\begin{array}{l} \overline{ITC}_k - \sum_{i \in S_T} (IT_{i,k,t} - ET_{i,k,t}) - \sum_{i \in S_I - S_{n,t}} I_{i,k,t} + \sum_{i \in S_E - S_{n,t}} E_{i,k,t} \\ \sum_{i \in S_I \cap S_{n,t}} \underline{SCF}_{i,k,t} + \sum_{i \in S_E \cap S_{n,t}} \underline{SCF}_{i,k,t} \end{array} \right),$$

$$\forall k, t = 1, 2, \dots, T$$

The maximum supply that can be withheld by supplier affiliate groups in excess of their metered load is derived as follows:

$$WC_{n,t} = \max \left(0, \sum_{i \in (S_{GR} \cup S_{NGR}) \cap S_{n,t}} (\overline{SCF}_{i,t} - \underline{SCF}_{i,t}) + \sum_k (\overline{SCF}_{n,k,t} - \underline{SCF}_{n,k,t}) - L_{n,t} \right),$$

$$t = 1, 2, \dots, T$$

The metered load for a SC affiliate group is estimated by historical meter data submission. The SC affiliate group for an EIM Entity includes all EIM Non-Participating Resources, including intertie resources, and the EIM Participating Resources for the corresponding merchant and all third party generators in the respective EIM BAA, unless they represent resources within the CISO. The metered load for the EIM Entity SC affiliate group is estimated as the demand forecast for the respective EIM BAA. These approximations are necessary because there is no breakdown information for the demand in an EIM BAA.

The aggregate withheld supply by supplier affiliate groups in excess of their metered load is used to rank supplier affiliate groups to determine the top three potentially pivotal suppliers:

$$\left\{ \begin{array}{l} PPS_t = S_{PS_{1,t}} \cup S_{PS_{2,t}} \cup S_{PS_{3,t}} \\ WC_{PS_{1,t}} = \max(\{WC_{n,t}, n = 1, 2, \dots, N\}) \\ WC_{PS_{2,t}} = \max(\{WC_{n,t}, n = 1, 2, \dots, N \wedge n \neq PS_{1,t}\}) \\ WC_{PS_{3,t}} = \max(\{WC_{n,t}, n = 1, 2, \dots, N \wedge n \neq PS_{1,t} \wedge n \neq PS_{2,t}\}) \end{array} \right\}, t = 1, 2, \dots, T$$

All the remaining supplier affiliate groups are classified as fringe competitive suppliers:

$$FCS_t = \cup \{S_{n,t}, n = 1, 2, \dots, N \wedge n \neq PS_{1,t} \wedge n \neq PS_{2,t} \wedge n \neq PS_{3,t}\}, t = 1, 2, \dots, T$$

The available supply from internal resources within the highest-priced BAA group is derived as follows:

$$SCF_{R,t} = \sum_{i \in (S_{GR} \cup S_{NGR}) \cap FCS_t} \overline{SCF}_{i,t} + \sum_{i \in (S_{GR} \cup S_{NGR}) \cap PPS_t} \underline{SCF}_{i,t}, t = 1, 2, \dots, T$$

The net available supply from CISO intertie resources is derived as follows:

Technical Description

$$SCF_{K,t} = \sum_k \max \left(\frac{ITC_k}{ITC_k}, \min \left(\overline{ITC}_k, \left(\sum_{i \in S_T} (IT_{i,k,t} - ET_{i,k,t}) + \sum_{n \in FCS_t} \sum_{i \in (S_I \cup S_E) \cap S_{n,t}} \overline{SCF}_{i,k,t} + \sum_{n \in PPS_t} \sum_{i \in (S_I \cup S_E) \cap S_{n,t}} \underline{SCF}_{i,k,t} \right) \right) \right), t = 1, 2, \dots, T$$

The net available supply from EIM intertie resources is derived as follows:

$$SCF_{M,t} = \sum_{j \in BHP_t} \sum_{m \in BAA_j} \overline{SCF}_{m,t}, t = 1, 2, \dots, T$$

The net available supply from boundary transfers is derived as follows:

$$SCF_{T,t} = \sum_{l \in \cap THP_t} \sum_{i \in S_T} (IT_{i,l,t} - ET_{i,l,t}), t = 1, 2, \dots, T$$

Finally, the Residual Supply Index is calculated as follows:

$$RSI_t = \frac{SCF_{R,t} + SCF_{K,t} + SCF_{M,t} + SCF_{T,t}}{\sum_{j \in BHP_t} D_{j,t}}, t = 1, 2, \dots, T$$

This metric determines whether the demand in the highest-priced BAA group can be met by the maximum supply from fringe competitive suppliers while the potentially pivotal suppliers withhold their supply providing only the minimum possible. If the Residual Supply Index is less than one, the highest-priced BAA group is deemed uncompetitive because its demand cannot be met without selecting at least one bid from a pivotal supplier who can then exercise market power. In this case, the energy bids from resources within the CISO that belong to pivotal suppliers will be mitigated for the next market run. If SMPM is applied only to the four 15min intervals of the next hour in the HASP run, any mitigated bids in these intervals will persist in subsequent FMM/RTD market runs for the corresponding intervals.

The list of pivotal suppliers is identified by expanding the three pivotal suppliers by adding additional suppliers in descending order of withheld capacity while the following condition holds:

- Replacing the third pivotal supplier with the next supplier in descending order of withheld capacity, results in a Residual Supply Index of less than one.

The mitigated energy bid above the Competitive Marginal Energy Price for a given resource is determined on a segment-by-segment basis as the lower of the originally submitted energy bid or the respective Default Energy Bid (DEB), while respecting monotonicity. The Competitive Marginal Energy Price is determined as the shadow price of the power balance constraint in the next lower-priced EIM BAA.