

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

Table of Contents

Appendix C Locational Marginal Price	2
A. Locational Marginal Price for Energy	2
A.1 LMP Composition in the Day-Ahead Market and the Real-Time Market	2
A.2 Marginal Energy Cost Component of the LMP	3
A.3 Marginal Congestion Component of the LMP	3
A.4 Marginal Losses Component of the LMP	5
A.5 Marginal Greenhouse Gas Cost Component of the LMP	5
A.6 Trading Hub Price Calculation	6
A.7 Load Aggregation Point Price Calculation	6
A.8 Intertie Scheduling Point Price Calculation	6
A.8.1 Intertie Scheduling Point Price Calculation for IBAAAs	7
A.8.1.1 Scheduling Point Prices	7
A.8.1.2 Applicable Marginal Losses Adjustment	8
B. Locational Marginal Price for Imbalance Reserves	11
B.1. Locational IRU and IRD Price Composition	11
B.2. Marginal IRU and IRD Cost Component	12
B.3. Marginal Congestion Component for IRU and IRD	13
C. Locational Marginal Price for Reliability Capacity	14
C.1. Locational RCU and RCD Price Composition	14
C.2. Marginal Reliability Capacity Cost Component	15
C.3. Marginal Congestion Component for RCU and RCD	16
D. Marginal Loss Component for RCU and RCD	17

Appendix C

Locational Marginal Price

A. Locational Marginal Price for Energy

The CAISO shall calculate the price of Energy at Generation PNodes, Scheduling Points, and Aggregated Pricing Nodes, as provided in the CAISO Tariff. The CAISO establishes Trading Hub prices and LAPs as provided in the CAISO Tariff. The LMPs at PNodes, Scheduling Points, and Aggregated Pricing Nodes include separate components for the Marginal Energy Cost, Marginal Cost of Congestion, Marginal Cost of Losses, and Marginal GHG Cost. As provided in Sections 6.5.3.2.2 and 6.5.5.2.4, LMPs are calculated and posted for each hour of the Day-Ahead Market and for each interval of the Real-Time Market.

A.1 LMP Composition in the Day-Ahead Market and the Real-Time Market

In each hour of the Day-Ahead Market, each 15-minute interval of the Fifteen-Minute Market, and each 5-minute interval of the Real-Time Dispatch, the CAISO calculates the LMP for each PNode, which is based on the Bids of sellers and buyers selected in the Day-Ahead or Real-Time Market as calculated below. The CAISO uses a Reference Bus for the calculation of the Locational Marginal Prices. The Reference Bus in the base scenario is the distributed load in the Market Area used in the AC power flow solution to distribute the deviations for Transmission Losses between iterations, and in sensitivity calculations that yield rates for Marginal Losses and the Power Transfer Distribution Factors. If the CAISO Market solution reverts to a DC power flow solution, the Reference Bus is not used because Transmission Losses are not included. Nevertheless, the CAISO reflects the Transmission Losses for the Market Area in the DC power flow solution by adjusting the load by the average loss factor. The Locational Marginal Prices are not determined by resources that are not eligible to set the Locational Marginal Price as defined in Sections 31.3.1.4 and 34.20.2.3. For each PNode, the CAISO determines separate components of the LMP for the Marginal Energy Cost, Marginal Cost of Congestion, Marginal Cost of Losses, and Marginal GHG Cost, as follows:

$$LMP_i = MEC_i + MCC_i + MCL_i + MCG_i$$

where:

- i is the PNode index.
- MEC_i is the LMP component representing the Marginal Energy Cost at PNode i .

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

- MCC_i is the LMP component representing the Marginal Cost of Congestion at PNode i .
- MCL_i is the LMP component representing the Marginal Cost of Losses at PNode i .
- MCG_i is the LMP component representing the Marginal GHG Cost at PNode i .

A.2 Marginal Energy Cost Component of the LMP

The MEC is the same for all PNodes in each Balancing Authority Area in the Market Area. The MEC is the Shadow Price of the power balance constraint for the respective Balancing Authority Area at the optimal solution. The power balance constraint for each Balancing Authority Area in the Market Area ensures that the physical law of conservation of Energy (the sum of Generation and imports equals the sum of Demand, including exports and Transmission Losses, plus the Net Market Transfer) is accounted for in the market solution. The MEC for the Transfer System Resources (TSRs) on each side of the Market Transfer that they model is the MEC of the respective Balancing Authority Area. The MEC may be different between two Balancing Authority Areas in the Market Area when Market Transfers between these Balancing Authority Areas are scheduled at their respective scheduling limits. The MEC difference between the Balancing Authority Areas on either side of a specific Market Transfer generates Market Transfer revenue.

A.3 Marginal Congestion Component of the LMP

The CAISO calculates the Marginal Cost of Congestion at each PNode as the net contribution of the Shadow Prices of the binding Transmission Constraints at the optimal solution, weighed by the respective Power Transfer Distribution Factors, as follows:

$$MCC_i = - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k} \mu_{m,k} - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k}^{(IRU)} \mu_{m,k}^{(IRU)} - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k}^{(IRD)} \mu_{m,k}^{(IRD)}$$

Where:

- i is the PNode index.
- m is the Transmission Constraint index in the Market Area; transmission constraints outside the Market Area are not enforced.

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

- k is the constraint case index; zero (0) indicates the base case where all transmission and generation facilities are in service, whereas a positive case indicates a preventive transmission or generation contingency case, as applicable.
- j is the transmission component index of Transmission Constraint m . When Transmission Constraint m is a Nomogram, there can be more than one transmission components in it; otherwise, there is only one transmission component.
- K is the number of constraint cases, besides the base case.
- M is the number of Transmission Constraints.
- J_m is the number of transmission components of Transmission Constraint m .
- $PTDF_{i,j,m,k}$, $PTDF_{i,j,m,k}^{(IRU)}$, and $PTDF_{i,j,m,k}^{(IRD)}$ is the Power Transfer Distribution Factor (PTDF) for PNode i on transmission component j of Transmission Constraint m in constraint case k in the base, IRU deployment, or IRD deployment scenario, respectively; it is the flow contribution on that transmission component j when an increment of power is injected at PNode i and an equivalent amount of power is withdrawn at the Reference Bus. For Market Area Intertie Resources at a Scheduling Point, and TSRs at a Transfer Location, the PTDF to an intertie constraint or intertie scheduling limit at that Scheduling Point is +1 for an import and -1 for an export. The CAISO does not consider the effect of Transmission Losses in the calculation of PTDFs; they depend only on the network configuration. Furthermore, the difference between the PTDFs at two PNodes with respect to any binding Transmission Constraint, and thus the difference between the MCCs of the LMPs at these PNodes, is independent from the selection of the Reference Bus.
- $C_{j,m}$ is the constraint coefficient for transmission component j of Transmission Constraint m when Transmission Constraint m is a Nomogram; otherwise, this constraint coefficient is always one.
- $\mu_{m,k}$, $\mu_{m,k}^{(IRU)}$, and $\mu_{m,k}^{(IRD)}$ is the Shadow Price of Transmission Constraint m in constraint case k in the base, IRU deployment, or IRD deployment scenario, respectively.

A.4 Marginal Losses Component of the LMP

The CAISO calculates the Marginal Cost of Losses at each PNode as the product of the MEC and the rate for Marginal Losses at that PNode, as follows:

$$MCL_i = -MEC_i \frac{\partial L}{\partial P_i}$$

Where the rate for Marginal Losses at PNode i ($\partial L/\partial P_i$) is the sensitivity (partial derivative) of system losses (L) to an increment of power injected at that PNode (P_i) and absorbed by the Reference Bus. This calculation reflects the area interchange control feature of the AC power flow where the net scheduled interchange (NSI) of a Balancing Authority Area in the FNM is kept constant while the iterative solution distributes loss deviation from the previous iteration to the Reference Bus. Consequently, the rate for Marginal Losses of the TSRs that model a Market Transfer at a Transfer Location between two Balancing Authority Areas in the Market Area may be different because these TSRs belong to different Balancing Authority Areas. The CAISO sets the MCL for both of these TSRs to the average rate for Marginal Losses between the two so that there is no MCL difference between the TSRs on either side of a specific Market Transfer. The Marginal Losses on transmission facilities outside the Market Area are ignored in the calculation of the MCL.

A.5 Marginal Greenhouse Gas Cost Component of the LMP

The CAISO employs a GHG model in the DAM and RTM as described in Sections 29.32 and 33.32. The GHG model calculates an optimal GHG Transfer for each GHG Regulation Area. If the GHG Transfer for a GHG Regulation Area is an import, it is allocated optimally to resources outside that GHG Regulation Area based on those resources' GHG Bid Adders. In that case, the Marginal GHG Cost for all PNodes in a specific GHG Regulation Area is the Shadow Price of the GHG Transfer allocation constraint for that GHG Regulation Area and it represents the marginal cost of GHG regulation for net import transfer into that GHG Regulation Area. If the GHG Transfer is an export, the GHG Transfer allocation constraint is not binding, all GHG attributions are zero for that GHG Regulation Area, and the Marginal GHG Cost for all PNodes in that GHG Regulation Area is zero. The Marginal GHG Cost outside of all GHG Regulation Areas is always zero. Furthermore, the Marginal GHG Cost of a TSR is always zero, even when its Transfer Location is within or at the border of a GHG Regulation Area, because the associated GHG

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

regulation cost is collected from the LMP settlement of all physical resources within the GHG Regulation Area and paid explicitly to the respective resources outside the GHG Regulation Area with GHG Attributions for that GHG Regulation Area.

A.6 Trading Hub Price Calculation

The CAISO calculates Existing Zone Generation Trading Hub prices, as provided in Section 27.3, based on the LMP calculations described in this Attachment and in Section 27.2.

A.7 Load Aggregation Point Price Calculation

The CAISO calculates LAP prices as described in Section 27.2.2.

A.8 Intertie Scheduling Point Price Calculation

The CAISO calculates LMPs for intertie resources at Scheduling Points, which are represented in the FNM as PNodes or aggregations of PNodes external to the Market Area (*i.e.*, at the boundary of a Balancing Authority Area inside the Market Area with a Balancing Authority Area outside the Market Area), through the same process that is used to calculate LMPs for PNodes within the Market Area. In some cases, facilities that are part of the CAISO Controlled Grid but are external to the CAISO Balancing Authority Area connect some intertie Scheduling Points to the CAISO Balancing Authority Area, and in these cases, the Scheduling Points are within external Balancing Authority Areas. In these cases, the Scheduling Points are represented in the FNM at the relevant Locations and used to schedule imports and exports to/from the CAISO Balancing Authority Area. The MCC of the LMP at a Scheduling Point includes contributions from binding intertie constraints and intertie scheduling limits that constrain import/export Schedules at the relevant Scheduling Point.

In most cases, System Resources are registered at a Scheduling Point to a Balancing Authority Area in the Market Area to model Energy or capacity imports/exports from/to another Balancing Authority Area. When the Balancing Authority Area in the Market Area is not the CAISO Balancing Authority Area and the System Resource is not a Resource Adequacy Resource, the CAISO distributes the import/export Energy Schedule or capacity award of the System Resource to the associated GAP and the MCL and MCC of the LMP of the System Resource reflect the Marginal Losses and Congestion at the relevant GAP.

When the Balancing Authority Area in the Market Area is the CAISO Balancing Authority Area or if Balancing Authority Area in the Market Area is not the CAISO Balancing Authority Area but the System

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

Resource is a Resource Adequacy Resource, the CAISO distributes the import/export Energy Schedule or capacity award of the System Resource to the relevant Scheduling Point and the MCL and MCC of the LMP of the System Resource reflects the Marginal Losses and Congestion at the relevant Scheduling Point.

In certain cases, System Resources are registered at a Scheduling Point to a Balancing Authority Area in the Market Area to model Energy imports/exports from/to another Balancing Authority Area inside the Market Area. This occurs because of differences in the Market Area between the Day-Ahead Market and the Real-Time Market when a Balancing Authority Area is outside the EDAM Area in the Day-Ahead Market, but inside the EIM Area in the Real-Time Market. In this case, the day-ahead Energy schedule of the relevant System Resource is distributed in the Real-Time Market to the Scheduling Point, for a CAISO Balancing Authority Area intertie, or the relevant DGAP of the source/sink Balancing Authority Area that is in the EIM Area, but cancelled with an opposite base Energy schedule of an EIM Mirror System Resource at the same Scheduling Point with the same distribution. The EIM Mirror System Resource belongs to the source/sink Balancing Authority Area and its base Energy schedule matches the day-ahead Energy schedule of the System Resource it mirrors. The EIM Mirror System Resource that mirrors a System Resource has an export base schedule that matches the day-ahead import schedule of its mirrored System Resource, or a base import schedule that matches the day-ahead export schedule of its mirrored System Resource. The LMPs of the EIM Mirror System Resource and the System Resource it mirrors are different in general because the MEC, MCL, and MCC components differ since the two resources belong to different Balancing Authority Areas in the Market Area.

A.8.1 Intertie Scheduling Point Price Calculation for IBAA's

A.8.1.1 Scheduling Point Prices

As described in Section 27.5.3, the CAISO's FNM includes a full model of the network topology of each IBAA. The CAISO will specify Resource IDs that associate Intertie Scheduling Point Bids and Schedules with supporting injection and withdrawal locations on the FNM. These Resource IDs may be specified by the CAISO based on the information available to it, or developed pursuant to a Market Efficiency Enhancement Agreement. Once these Resource IDs are established, the CAISO will determine Intertie Scheduling Point LMPs based on the injection and withdrawal locations associated with each Intertie

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

Scheduling Point Bid and Schedule by the appropriate Resource ID. In calculating these LMPs the CAISO follows the provisions specified in Section 27.5.3 regarding the treatment of Transmission Constraints and losses on the IBAA network facilities. Unless otherwise required pursuant to an effective MEEA, the default pricing for all imports from the IBAA(s) to the CAISO Balancing Authority Area will be based on the SMUD/TID IBAA Import LMP and all exports to the IBAA(s) from the CAISO Balancing Authority Area will be based on the SMUD/TID IBAA Export LMP. The SMUD/TID IBAA Import LMP will be calculated based on modeling of supply resources that assumes all supply is from the Captain Jack substation as defined by WECC. The SMUD/TID IBAA Export LMP will be calculated based on the Sacramento Municipal Utility District hub that reflects Intertie distribution factors developed from a seasonal power flow base case study of the WECC region using an equivalencing technique that requires the Sacramento Municipal Utility District hub to be equivalenced to only the buses that comprise the aggregated set of load resources in the IBAA, with all generation also being retained at its buses within the IBAA. The resulting load distribution within each aggregated set of load resources within the IBAA defines the Intertie distribution factors for exports from the CAISO Balancing Authority Area.

A.8.1.2 Applicable Marginal Losses Adjustment

For import Schedules to the CAISO Balancing Authority Area at the southern terminus of the California-Oregon Transmission Project at the Tracy substation or at the applicable Scheduling Point that connects the CAISO Balancing Authority and the Western Area Power Administration system, the CAISO will replace the Marginal Cost of Losses at the otherwise applicable source for such Schedules with the Marginal Cost of Losses at the Tracy substation or at the applicable Scheduling point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system, provided that the Scheduling Coordinators certify as discussed further below that the Schedules originate from transactions that use: (a) the California-Oregon Transmission Project; or (b) transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA. In addition, as described further below, the Scheduling Coordinator must certify that the Schedules are subject to: (a) charges for losses by the Western Area Power Administration for the use of transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA; or (b) charges for losses by the Transmission Agency of Northern California for the use of the California-Oregon Transmission Project. The CAISO will establish

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

Resource IDs that are to be used only to submit Bids, including Self-Schedules, for the purpose of establishing Schedules that are eligible for this loss adjustment.

Prior to obtaining such Resource IDs, the relevant Scheduling Coordinator shall certify that it will only use this established Resource ID for Bids, including Self-Schedules, that originate from transactions that use: (a) the California-Oregon Transmission Project; or (b) transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA. In addition, the Scheduling Coordinator must certify that the Schedules are subject to: (a) charges for losses by the Western Area Power Administration for the use of transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA; or (b) Transmission Agency of Northern California for the use of the California-Oregon Transmission Project. Further, by actually using such Resource ID, the Scheduling Coordinator represents that such Bids, including Self-Schedules, that originate from transactions that use: (a) the California-Oregon Transmission Project; or (b) transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA. Schedules and Dispatches settled under such Resource IDs shall be subject to an LMP which has accounted for the Marginal Cost of Losses as if there were an actual physical generation facility at the Tracy Scheduling Point or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system as opposed to the Marginal Cost of Losses under the IBAA LMPs specified in Section I.1.1 of this Appendix. The CAISO may request information on a monthly basis from such Scheduling Coordinators to verify these certifications. Any such request shall be limited to transactions that use the designated Resource IDs during the six month prior period to the date of the request. The CAISO will calculate a re-adjustment of the Marginal Cost of Losses at the Tracy substation or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system to reflect the otherwise applicable source for such Schedules for any Settlement Interval in which the CAISO has determined that the Scheduling Coordinator's payments did not reflect transactions that meet the above specified certification requirements. Any amounts owed to the CAISO for such Marginal Cost of Losses re-adjustments will be recovered by the CAISO from the affected Scheduling Coordinator by netting the amounts owed from payments due in subsequent Settlements Statements until the outstanding amounts are fully recovered.

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

For export Schedules from the CAISO Balancing Authority Area at the southern terminus of the California-Oregon Transmission Project at the Tracy substation or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system, the CAISO will replace the Marginal Cost of Losses at the otherwise applicable sink for such Schedules with the Marginal Cost of Losses at the Tracy substation or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system, provided that the Scheduling Coordinator certifies, as discussed below, where the export Schedules use: (a) the California-Oregon Transmission Project; or (b) any transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA. In addition, the Scheduling Coordinator must certify that the affected Schedules are charged losses by: (a) the Western Area Power Administration for the use of transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA; or (b) Transmission Agency of Northern California for the use of the California-Oregon Transmission Project. The CAISO will establish Resource IDs that are to be used only to submit Bids, including Self-Schedules, for the purpose of establishing Schedules that are eligible for this loss adjustment. Prior to obtaining such Resource IDs, the relevant Scheduling Coordinator shall certify that it will only use this established Resource ID for Bids, including Self-Schedules, where the export Schedules use: (a) the California-Oregon Transmission Project; or (b) any transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA. In addition the Scheduling Coordinator must certify that the affected Schedules are charged losses by: (a) the Western Area Power Administration for the use of transmission facilities owned by the Western Area Power Administration within the SMUD/TID IBAA; or (b) Transmission Agency of Northern California for the use of the California-Oregon Transmission Project. Further, by actually using such Resource ID, the Scheduling Coordinator represents that such Bids, including Self-Schedules, are used for the above specified conditions.

Schedules and Dispatches settled under such Resource IDs shall be subject to an LMP which has accounted for the Marginal Cost of Losses as if there were an actual physical generation facility at the Tracy Scheduling Point or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system as opposed to the Marginal Cost of Losses under the IBAA LMPs specified in Section I.1.1 of this Appendix. The CAISO may request

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

information on a monthly basis from such Scheduling Coordinators to verify that schedules for such Resource IDs meet the above specified conditions. Any such request shall be limited to transactions that use the designated Resource IDs during the six month prior period to the date of the request.

The CAISO will calculate a re-adjustment of the Marginal Cost of Losses at the Tracy substation or at the applicable Scheduling Point that connects the CAISO Balancing Authority Area and the Western Area Power Administration system to reflect the otherwise applicable sink for such Schedules for any Settlement Interval in which the CAISO has determined that the Scheduling Coordinator's payments did not reflect transactions that met the above specified conditions. Any amounts owed to the CAISO for such Marginal Cost of Losses re-adjustments will be recovered by the CAISO from the affected Scheduling Coordinator by netting the amounts owed from payments due in subsequent Settlements Statements until the outstanding amounts are fully recovered.

B. Locational Marginal Price for Imbalance Reserves

The CAISO shall calculate the Locational IRU Price and Locational IRD Price at Generation PNodes, Scheduling Points, and Aggregated Pricing Nodes, as provided in the CAISO Tariff. The Locational IRU Price and Locational IRD Price at PNodes, Scheduling Points, and Aggregated Pricing Nodes include separate components for the Marginal IRU or IRD Cost, and the Marginal IRU or IRD Cost of Congestion, respectively. As provided in Section 6.5.3.2.2, Locational IRU Prices and Locational IRD Prices are calculated and posted for each hour of the Day-Ahead Market. There are different Locational Marginal Prices for IRU and IRD at any given Location in the Market Area.

B.1. Locational IRU and IRD Price Composition

In each hour of the Day-Ahead Market, the CAISO calculates the Locational IRU Price and Locational IRD Price for each PNode, which is based on the IRU and IRD Bids of sellers selected in the Day-Ahead Market as calculated below. The CAISO uses a Reference Bus for the calculation of the Locational IRU Price and Locational IRD Price. The Reference Bus for the Locational IRU Price is the distributed IRU requirement in the Market Area, whereas the Reference Bus for the Locational IRD Price is the distributed IRD requirement in the Market Area. The Reference Bus is used in sensitivity calculations that yield the Power Transfer Distribution Factors. The CAISO does not employ an AC power flow in the IRU and IRD deployment scenarios in the IFM. The Transmission Constraints in the IRU and IRD deployment

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

scenarios are formulated as linear extensions of the Transmission Constraints in the base scenario using the AC power flow solution for the base scenario. Therefore, there is no marginal loss component in the Locational IRU Price and Locational IRD Price. For each PNode, the CAISO determines separate components of the Locational IRU Price and Locational IRD Price for the Marginal IRU and IRD Cost, and the Marginal Cost of Congestion for IRU and IRD, as follows:

$$LMP_i^{(IRU)} = MEC_i^{(IRU)} + MCC_i^{(IRU)}$$

$$LMP_i^{(IRD)} = MEC_i^{(IRD)} + MCC_i^{(IRD)}$$

where:

- i is the PNode index.
- $MEC_i^{(IRU)}$ is the Locational IRU Price component representing the Marginal IRU Cost at PNode i .
- $MCC_i^{(IRU)}$ is the Locational IRU Price component representing the Marginal Cost of Congestion for IRU at PNode i .
- $MEC_i^{(IRD)}$ is the Locational IRD Price component representing the Marginal IRD Cost at PNode i .
- $MCC_i^{(IRD)}$ is the Locational IRD Price component representing the Marginal Cost of Congestion for IRD at PNode i .

B.2. Marginal IRU and IRD Cost Component

The Marginal IRU and IRD Cost Component is the same for all PNodes in each Balancing Authority Area in the Market Area. It is the Shadow Price of the power balance constraint in the IRU or IRD deployment scenario for the respective Balancing Authority Area at the optimal solution in the IFM. The power balance constraint for each Balancing Authority Area in the Market Area ensures that the physical law of conservation of Energy and deployed capacity (the sum of physical resource energy schedules from the base scenario plus the deployed IRU or IRD awards equals the IRU or IRD requirement minus the IRU or IRD demand relaxation plus the Net IRU or IRD Transfer) is accounted for in the solution of the IRU or IRD deployment scenario. The Marginal IRU or IRD Cost for the Transfer System Resources (TSRs) on each side of an EDAM Transfer is the Marginal IRU or IRD Cost of the respective Balancing Authority Area. The Marginal IRU or IRD Cost may be different between two Balancing Authority Areas in the Market Area when EDAM Transfers between these Balancing Authority Areas are scheduled at their

respective scheduling limits. The Marginal IRU or IRD Cost difference between the Balancing Authority Areas on either side of a specific EDAM Transfer generates EDAM Transfer revenue.

B.3. Marginal Congestion Component for IRU and IRD

The CAISO calculates the Marginal Cost of Congestion for IRU and IRD at each PNode as the net contribution of the Shadow Prices of the binding Transmission Constraints in the IRU or IRD deployment scenarios at the optimal solution for IFM, weighed by the respective Power Transfer Distribution Factors, as follows:

$$MCC_i^{(IRU)} = - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k}^{(IRU)} \mu_{m,k}^{(IRU)}$$

$$MCC_i^{(IRD)} = - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k}^{(IRD)} \mu_{m,k}^{(IRD)}$$

Where:

- i is the Pnode index.
- m is the Transmission Constraint index in the Market Area; transmission constraints outside the Market Area are not enforced.
- k is the constraint case index; zero (0) indicates the base case where all transmission and generation facilities are in service, whereas a positive case indicates a preventive transmission or generation contingency case, as applicable.
- j is the transmission component index of Transmission Constraint m . When Transmission Constraint m is a Nomogram, there can be more than one transmission components in it; otherwise, there is only one transmission component.
- K is the number of constraint cases, besides the base case.
- M is the number of Transmission Constraints.
- J_m is the number of transmission components of Transmission Constraint m .
- $PTDF_{i,j,m,k}^{(IRU)}$ and $PTDF_{i,j,m,k}^{(IRD)}$ is the Power Transfer Distribution Factor (PTDF) for PNode i on transmission component j of Transmission Constraint m in constraint case k in the IRU or IRD deployment scenario; it is the power flow contribution on that transmission

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

component j when an increment of power is injected at PNode i and an equivalent amount of power is withdrawn at the Reference Bus. For Market Area Intertie resources at a Scheduling Point, and TSRs at a Transfer Location, the PTDF to an intertie constraint or intertie scheduling limit at that Scheduling Point is +1 for an import and -1 for an export. The CAISO does not consider the effect of Transmission Losses in the calculation of PTDFs; they depend only on the network configuration. Furthermore, the difference between the PTDFs at two PNodes with respect to any binding Transmission Constraint, and thus the difference between the Marginal Cost of Congestion for IRU or IRD at these PNodes, is independent from the selection of the Reference Bus. The PTDFs in the IRU or IRD deployment scenarios are different from the ones in the base scenario of the IFM because although the network configuration is the same, the Reference Bus is different; furthermore, the binding constraints in the base and the IRU or IRD deployment scenarios may be different.

- $c_{j,m}$ is the constraint coefficient for transmission component j of Transmission Constraint m when Transmission Constraint m is a Nomogram; otherwise, this constraint coefficient is always one.
- $\mu_{m,k}^{(IRU)}$ and $\mu_{m,k}^{(IRD)}$ is the Shadow Price of Transmission Constraint m in constraint case k at the IRU or IRD deployment scenario in the optimal solution of the IFM.

C. Locational Marginal Price for Reliability Capacity

The CAISO shall calculate the Locational RCU Price and Locational RCD Price at Generation PNodes, Scheduling Points, and Aggregated Pricing Nodes, as provided in the CAISO Tariff. The Locational RCU Price and Locational RCD Price at PNodes, Scheduling Points, and Aggregated Pricing Nodes include separate components for the Marginal RCU or RCD Cost, Marginal RCU or RCD Cost of Congestion, and Marginal RCU or RCD Cost of Losses, respectively. As provided in Section 6.5.3.2.2, Locational RCU Prices and Locational RCD Prices are calculated and posted for each hour of the Day-Ahead Market. There is a single Locational Marginal Price for Reliability Capacity that applies to both Reliability Capacity Up and Reliability Capacity Down at any given Location in the Market Area.

C.1. Locational RCU and RCD Price Composition

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

In each hour of the Day-Ahead Market, the CAISO calculates the Locational RCU Price and Locational RCD Price for each PNode, which is based on the RCU and RCD Bids of sellers selected in the Day-Ahead Market as calculated below. The CAISO uses a Reference Bus for the calculation of the Locational RCU Price and Locational RCD Price. The Reference Bus is the distributed demand forecast in the Market Area, used in the AC power flow solution in RUC to distribute the deviations for Transmission Losses between iterations, and in sensitivity calculations that yield rates for Marginal Losses and the Power Transfer Distribution Factors. If the CAISO Market solution reverts to a DC power flow solution, the Reference Bus is not used because Transmission Losses are not included. Nevertheless, the CAISO reflects the Transmission Losses for the Market Area in the DC power flow solution by adjusting the load by the average loss factor. For each PNode, the CAISO determines separate components of the Locational RCU Price and Locational RCD Price for the Marginal RCU and RCD Cost, Marginal Cost of Congestion for RCU and RCD, and Marginal Cost of Losses for RCU and RCD, as follows:

$$LMP_i^{(RUC)} = MEC_i^{(RUC)} + MCC_i^{(RUC)} + MCL_i^{(RUC)}$$

where:

- i is the PNode index.
- $MEC_i^{(RUC)}$ is the Locational RCU Price and Locational RCD Price component representing the Marginal Reliability Capacity Cost at PNode i .
- $MCC_i^{(RUC)}$ is the Locational RCU Price and Locational RCD Price component representing the Marginal Cost of Congestion for RCU and RCD at PNode i .
- $MCL_i^{(RUC)}$ is the Locational RCU Price and Locational RCD Price component representing the Marginal Cost of Losses for RCU and RCD at PNode i .

C.2. Marginal Reliability Capacity Cost Component

The Marginal Reliability Capacity Cost Component is the same for all PNodes in each Balancing Authority Area in the Market Area. It is the Shadow Price of the power balance constraint for the respective Balancing Authority Area at the optimal solution in the RUC. The power balance constraint for each Balancing Authority Area in the Market Area ensures that the physical law of conservation of Energy (the sum of physical resource energy schedules from the IFM plus the deployed Reliability Capacity awards

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

equals the demand forecast plus the Net Reliability Capacity Transfer) is accounted for in the RUC solution. The Marginal Reliability Capacity Cost for the Transfer System Resources (TSRs) on each side of an EDAM Transfer is the Marginal Reliability Capacity Cost of the respective Balancing Authority Area. The Marginal Reliability Capacity Cost may be different between two Balancing Authority Areas in the Market Area when EDAM Transfers between these Balancing Authority Areas are scheduled at their respective scheduling limits. The Marginal Reliability Capacity Cost difference between the Balancing Authority Areas on either side of a specific EDAM Transfer generates EDAM Transfer revenue.

C.3. Marginal Congestion Component for RCU and RCD

The CAISO calculates the Marginal Cost of Congestion for RCU and RCD at each PNode as the net contribution of the Shadow Prices of the binding Transmission Constraints at the optimal solution for RUC, weighed by the respective Power Transfer Distribution Factors, as follows:

$$MCC_i^{(RUC)} = - \sum_{k=0}^K \sum_{m=1}^M \sum_{j=1}^{J_m} c_{j,m} PTDF_{i,j,m,k} \mu_{m,k}^{(RUC)}$$

where:

- i is the PNode index.
- m is the Transmission Constraint index in the Market Area; transmission constraints outside the Market Area are not enforced.
- k is the constraint case index; zero (0) indicates the base case where all transmission and generation facilities are in service, whereas a positive case indicates a preventive transmission or generation contingency case, as applicable.
- j is the transmission component index of Transmission Constraint m . When Transmission Constraint m is a Nomogram, there can be more than one transmission components in it; otherwise, there is only one transmission component.
- K is the number of constraint cases, besides the base case.
- M is the number of Transmission Constraints.
- J_m is the number of transmission components of Transmission Constraint m .
- $PTDF_{i,j,m,k}$ is the Power Transfer Distribution Factor (PTDF) for PNode i on transmission component j of Transmission Constraint m in constraint case k ; it is the power flow

California Independent System Operator Corporation
Fifth Replacement Electronic Tariff

contribution on that transmission component j when an increment of power is injected at PNode i and an equivalent amount of power is withdrawn at the Reference Bus. For Market Area Intertie resources at a Scheduling Point, and TSRs at a Transfer Location, the PTDF to an intertie constraint or intertie scheduling limit at that Scheduling Point is +1 for an import and -1 for an export. The CAISO does not consider the effect of Transmission Losses in the calculation of PTDFs; they depend only on the network configuration. Furthermore, the difference between the PTDFs at two PNodes with respect to any binding Transmission Constraint, and thus the difference between the Marginal Cost of Congestion for RCU and RCD at these PNodes, is independent from the selection of the Reference Bus. The PTDFs in the RUC are the same as the ones in the IFM base scenario because the network configuration is the same; however, the binding constraints in the RUC may be different from the ones in the IFM.

- $c_{j,m}$ is the constraint coefficient for transmission component j of Transmission Constraint m when Transmission Constraint m is a Nomogram; otherwise, this constraint coefficient is always one.
- $\mu_{m,k}^{(RUC)}$ is the Shadow Price of Transmission Constraint m in constraint case k at the optimal solution of the RUC.

D. Marginal Loss Component for RCU and RCD

The CAISO calculates the Marginal Cost of Losses for RCU and RCD at each PNode as the product of the Marginal Reliability Capacity Cost Component and the rate for Marginal Losses at that PNode, as follows:

$$MCL_i^{(RUC)} = -MEC_i^{(RUC)} \frac{\partial L}{\partial P_i}$$

Where the rate for Marginal Losses at PNode i ($\partial L / \partial P_i$) is the sensitivity (partial derivative) of system losses (L) to an increment of power injected at that PNode (P_i) and absorbed by the Reference Bus for the RUC. This calculation reflects the area interchange control feature of the AC power flow where the net scheduled interchange (NSI) of a Balancing Authority Area in the FNM is kept constant while the iterative solution distributes loss deviation from the previous iteration to the Reference Bus for the RUC.

California Independent System Operator Corporation
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Consequently, the Marginal Cost of Losses for RCU and RCD of the TSRs that model a Market Transfer at a Transfer Location between two Balancing Authority Areas in the Market Area may be different because these TSRs belong to different Balancing Authority Areas. The CAISO sets the Marginal Cost of Losses for RCU and RCD for both of these TSRs to the average rate for Marginal Losses between the two so that there is no difference between the Marginal Cost of Losses for RCU and RCD between the TSRs on either side of a specific Market Transfer. The Marginal Losses on transmission facilities outside the Market Area are ignored in the calculation of the Marginal Cost of Losses for RCU an