Appendix A

- Transmission Constraints

Physical and operational limitations on the transfer of electric power through transmission facilities, which include Contingencies and Nomograms.

- Contingency

A potential Outage that is unplanned, viewed as possible or eventually probable, which is taken into account when considering approval of other requested Outages or while operating the CAISO Balancing Authority Area or EIM Balancing Authority. Contingencies include potential Outages due to Remedial Action Schemes.

Commented [RS1]: Does this mean contingency or system events triggering RAS actions as one single contingency or are does it refer simply to a RAS action as a contingency? If it is the latter, PacifiCorp does not agree with it since that sounds like a 'RAS mis-operation' which we do not consider as a contingency event.

- Outage

Disconnection, separation or reduction in capacity, planned or forced, of one or more elements of an electric system.

- Congestion

A characteristic of the transmission system produced by a binding Transmission Constraint to the optimum economic dispatch to meet Demand such that the LMP, exclusive of Marginal Cost of Losses, at different Locations of the transmission system is not equal.

- Remedial Action Schemes (RAS)

Protective systems that typically utilize a combination of conventional protective relays, computer-based processors, and telecommunications to accomplish rapid, automated response (including Outages) to unplanned power system events. Also, details of RAS logic and any special requirements for arming of RAS schemes, or changes in RAS programming, that may be required. Remedial Action Schemes are also referred to as Special Protection Systems.

- Special Protection System (SPS)

An automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components to maintain System Reliability. Such action may include changes in Demand, Generation (MW and MVar), or system configuration to maintain system stability, acceptable voltage, or power flows. An SPS does not include (a) Underfrequency Load Shedding or undervoltage Load Shedding or (b) fault conditions that must be isolated or (c) out-of-step relaying (not designed as an integral part of an SPS). An SPS is also sometimes called a Remedial Action Scheme.

27.1.1 Locational Marginal Prices for Energy

As further described in Appendix C, the LMP for Energy at any PNode is the marginal cost of serving the next increment of Demand at that PNode calculated by the CAISO through the operations of the CAISO Markets considering, as described further in the CAISO Tariff, among other things, modeled Transmission Constraints (including Remedial Action Schemes), transmission losses, the performance characteristics of resources, and Bids submitted by Scheduling Coordinators and as modified through the Locational Market Power Mitigation process. The LMP at any given PNode is comprised of three marginal cost components: the System Marginal Energy Cost (SMEC); Marginal Cost of Losses (MCL); and Marginal Cost of Congestion (MCC). Through the IFM the CAISO calculates LMPs for each Trading Hour of the next Trading Day. Through the FMM the CAISO calculates distinct financially binding fifteen-minute LMPs for each of the four fifteen-minute intervals within a Trading Hour. Through the Real-Time Dispatch, the CAISO calculates five-minute LMPs for each of the twelve (12) five (5) minute~~t~~ Dispatch Intervals of each Trading Hour. The CAISO uses the FMM or RTD LMPs for Settlements of the Real-Time Market. In the event that a Pricing Node becomes electrically disconnected from the market model during a CAISO Market run, the LMP, including the SMEC, MCC and MCL, at the closest electrically connected Pricing Node will be used as the LMP at the affected location.

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27.1.1.3 Marginal Cost of Congestion

The Marginal Cost of Congestion at a PNode reflects a linear combination of the Shadow Prices of the binding Transmission Constraints (including Remedial Action Schemes) in the network, multiplied by the corresponding Power Transfer Distribution Factor (PTDF) and coefficient relevant to the transmission segment within that constraint, which is described in Appendix C. The Marginal Cost of Congestion for a Transmission Constraint may be positive or negative depending on whether a power injection at that Location marginally increases or decreases Congestion.

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27.5.6 Management & Enforcement of Constraints in the CAISO Markets

The CAISO operates the CAISO Markets through the use of a market software system that utilizes various information including the Base Market Model, the State Estimator, submitted Bids including Self-Schedules, Generated Bids, Transmission Constraints, and transmission and generation Outages, including due to Remedial Action Schemes. The market model used in each of the CAISO Markets is derived from the most current Base Market Model available at that time. To create a more relevant time-specific network model for use in each of the CAISO Markets, the CAISO will adjust the Base Market Model to reflect Outages and derates that are known and applicable when the respective CAISO Market will operate, and to compensate for observed discrepancies between actual real-time power flows and flows calculated by the market software. Through this process the CAISO creates the market model to be used in each Day-Ahead Market and each process of the Real-Time Market. The CAISO will manage the enforcement of Transmission Constraints, consistent with good utility practice, to ensure, to the extent possible, that the market model used in each market accurately reflects all the factors that contribute to actual Real-Time flows on the CAISO Controlled Grid and that the CAISO Market results are better aligned with actual physical conditions on the CAISO Controlled Grid. In operating the CAISO Markets, the CAISO may take the following actions so that, to the extent possible, the CAISO Market solutions are feasible, accurate, and consistent with good utility practice:

(a) The CAISO may enforce, not enforce, or adjust flow-based Transmission Constraints if the CAISO observes that the CAISO Markets produce or may produce results that are inconsistent with observed or reasonably anticipated conditions or infeasible market solutions either because (a) the CAISO reasonably anticipates that the CAISO Market run will identify Congestion that is unlikely to materialize in Real-Time even if the Transmission Constraint were to be ignored in all the markets leading to Real-Time, or (b) the CAISO reasonably anticipates that the CAISO Market will fail to identify Congestion that is likely to appear in the Real-Time. The CAISO does not make such adjustments to intertie Scheduling Limits.

(b) The CAISO may enforce or not enforce Transmission Constraints (including those resulting from Remedial Action Schemes) if the CAISO has determined that non-enforcement or enforcement, respectively, of such Transmission Constraints may result in the unnecessary pre-commitment and scheduling of use-limited resources.

(c) The CAISO may not enforce Transmission Constraints if it has determined it lacks sufficient visibility to conditions on transmission facilities necessary to reliably ascertain constraint flows required for a feasible, accurate and reliable market solution.

(d) For the duration of a planned or unplanned Outage, the CAISO may create and apply alternative Transmission Constraints that may add to or replace certain originally defined constraints.

(e) The CAISO may adjust Transmission Constraints for the purpose of setting prudent operating margins consistent with good utility practice to ensure reliable operation under anticipated conditions of unpredictable and uncontrollable flow volatility consistent with the requirements of Section 7.

(f) The CAISO may adjust Transmission Constraints for the purpose of reserving internal transfer capability in the Day-Ahead or Real-Time Markets, based on anticipated conditions on the natural gas delivery system, to reliably serve load in specific geographic regions of the CAISO Balancing Authority Area, or to assure deliverability of Ancillary Services. The CAISO may or may not release such reserved internal transfer capability based on natural gas and electric system conditions, or observed market inefficiencies. Upon determining that an adjustment is necessary, the CAISO will issue a notification specifying the amount of the adjustment.

To the extent that particular Transmission Constraints are not enforced in the operations of the CAISO Markets, the CAISO will operate the CAISO Controlled Grid and manage any Congestion based on available information including the State Estimator solutions and available telemetry to Dispatch resources through Exceptional Dispatch to ensure the CAISO is operating the CAISO Controlled Grid consistent with the requirements of Section 7.

Appendix C

Locational Marginal Price

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D. Marginal Congestion Component Calculations (Day-Ahead and Real-Time)

The CAISO calculates the Marginal Costs of Congestion at each bus as a component of the bus-level LMP. The Marginal Cost of Congestion (MCCi) component of the LMP at ~~bus~~ node i is calculated in the Day-Ahead Market using the equation:

$$MCC_i = -\sum_{k}\sum_{j} C_{j,k}\, PTDF_{i,j}\, FSP_k$$

$$MCC_i = -\sum_{\cancel{k}m=1}^{\cancel{K}M}\sum_{j=1}^{J_m} c_{j,m}\, PTDF_{i,j}\, \mu_m \cancel{\sum_{j} C_{j,k}\cdot PTDF_{i,j}\cdot FSP_{k,j}} - \sum_{k=1}^{K}\sum_{m=1}^{M} PTDF_{i,m}^{k}\, \mu_m^{k}$$
$$-\sum_{g=1}^{K_g}\sum_{m=1}^{M}\left(PTDF_{i,m}^{g} + \delta_{O_g,i}\sum_{n=1}^{N} PTDF_{n,m}^{g}\, GLDF_{O_g,n}\right)\mu_m^{g}\cancel{\sum_{j}\Bigg(PTDF_{i,j}}$$
$$\cancel{+\,\delta_{i,O_g}\sum_{n}^{N} PTDF_{n,j}\cdot GLD_{n,O_g}\Bigg)\cdot FSP_{g,j}}$$

where:

- i is a node index.
- n is a node index.
- m is the constraint or monitored element index.
- k is the preventive contingency case.
- g is the generation contingency case.

O_g is the node index associated with the generator ~~and Remedial Action Scheme~~ contingency case g.

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- ~~*K* is the Transmission Constraint index.~~
- j is the transmission component index of Transmission Constraint ~~*k*~~*m*. When Transmission Constraint *m*~~*k*~~ is a Nomogram, there can be more than one transmission component. When Transmission Constraint *m*~~*k*~~ is any other Transmission Constraint, there shall be only one transmission component.
- *N* is the number of network nodes.
- *M* is the number of constraints or monitored elements.
- *K* is the ~~Transmission Constraint~~number of preventive contingencies ~~index~~.
- K_g is the number of preventive generation contingencies.
- J_m is the number of transmission components for constraint *m*.
- $PTDF_{i,j}$ the Power Transfer Distribution Factor for the bus *i* on transmission component *j* of the Transmission Constraint *k* which represents the flow across that transmission component *j* when an increment of power is injected at bus *i* and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the determination of PTDFs.
- ~~C_j~~$C_{j,}$~~$_k$~~$_m$ is the constraint coefficient for the transmission component *j* in constraint *m*~~*k*~~. When constraint *m*~~*k*~~ is a Nomogram, this represents the relevant coefficient for that component. When constraint *m*~~*k*~~ is any other Transmission Constraint, this coefficient will always be 1.
- ~~*FSP*~~μ_m~~$_k$~~ is the constraint Shadow Price on constraint *m*~~*k*~~ in the base case and is equivalent to the reduction in system cost expressed in $/MWh that results from a marginal increase of the capacity on constraint *m*~~*k*~~. If the market-clearing problem is limited by any Transmission Constraint including Interties, branch groups, flowgates, nomograms, and Energy Imbalance Market-related transmission constraints (EIM Transfer constraints and power balance constraint for a Balancing Authority Area), the market clearing process would create a Shadow Price for the Transmission Constraint, only when the relaxation of the constraint would result in a reduction in the total cost to operate the system.
- μ_m^k is the constraint Shadow Price on constraint *m* in the preventive contingency case *k* and is equivalent to the reduction in system cost expressed in $/MWh that results from a marginal

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increase of the capacity on constraint m in the preventive contingency case k. If the market-clearing problem is limited by any Transmission Constraint including Interties, branch groups, flowgates, nomograms, and Energy Imbalance Market-related transmission constraints (EIM Transfer constraints and power balance constraint for a Balancing Authority Area), the market clearing process would create a Shadow Price for the Transmission Constraint, only when the relaxation of the constraint would result in a reduction in the total cost to operate the system.

- μ_m^g is the constraint Shadow Price on constraint m in the generator contingency case g and is equivalent to the reduction in system cost expressed in $/MWh that results from a marginal increase of the capacity on constraint m in the generator contingency case g. If the market-clearing problem is limited by any Transmission Constraint including Interties, branch groups, flowgates, nomograms, and Energy Imbalance Market-related transmission constraints (EIM Transfer constraints and power balance constraint for a Balancing Authority Area), the market clearing process would create a Shadow Price for the Transmission Constraint, only when the relaxation of the constraint would result in a reduction in the total cost to operate the system.

~~Kg is the Transmission Constraint index associated with generator and Remedial Action Scheme contingencies.~~

- ~~O_g is the node associated with generator and Remedial Action Scheme contingency g.~~
- $\delta_{i,O_g,i}$ is the binary parameter that identifies the node with a generator outage under generator ~~and Remedial Action Scheme~~ contingency case g. This parameter is one for all nodes in index i when i is the outage node O_g associated with a generator ~~and Remedial Action Scheme~~ contingency case g. This parameter is zero for all nodes in index i when i is not the outage node O_g associated with the generator ~~and Remedial Action Scheme~~ contingency case g.
-
- ~~N is an index of all nodes~~
- $PTDF_{i,m}^k$ is the Power Transfer Distribution Factor for the bus i on transmission component m under the preventive contingency case k, which represents the flow across that transmission component m when an increment of power is injected at bus i and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the

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determination of PTDFs.

- $PTDF_{i,m}^{g}$ is the Power Transfer Distribution Factor for the bus i on transmission component m under the generator contingency case g, which represents the flow across that transmission component m when an increment of power is injected at bus i and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the determination of PTDFs.
- $PTDF_{n,m}^{g}$ is the Power Transfer Distribution Factor for the bus n on transmission component m under the generator contingency case g, which represents the flow across that transmission component m when an increment of power is injected at bus n and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the determination of PTDFs.
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- $GLDF_{i,O_g,n}$ is the net injectiongeneration loss distribution factor in the generator and Remedial Action Scheme contingency case g. This value is negative one when in is O_g. This value is zero when in is not O_g and when in is not associated with a frequency response capable generator. This value is the committed generator output at in divided by the sum of the output from all committed frequency response capable generators when in is not O_g and in is associated with a frequency response capable generator.
- $PTDF_{i,m}^{g}$ is the Power Transfer Distribution Factor for the bus i on transmission component m under the generator contingency case g, which represents the flow across that transmission component m when an increment of power is injected at bus i and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the determination of PTDFs.
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- $PTDF_{n,m}^{g}$ is the Power Transfer Distribution Factor for the bus n on transmission component m under the generator contingency case g, which represents the flow across that transmission component m when an increment of power is injected at bus n and an equivalent amount of power is withdrawn at the Reference Bus. The CAISO does not consider the effect of losses in the

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~~determination of PTDFs.~~

The MCC at PNodes in an EIM Entity Balancing Authority Area *j* in the Real Time Market includes an additional contribution from the shadow price of the power balance constraint for that Balancing Authority Area, λ_j, as follows:

$$\mathrm{MCC}_i = \lambda_j - \sum_{k=1}^{K} PTDF_{jk}\, FSP_k$$

$$MCC_i = \lambda_j - \sum_{mk=1}^{KM} PTDF_{ijk} \cdot \mu_{km} - \sum_{k=1}^{K} \sum_{m=1}^{M} PTDF_{i,m}^{k}\, \mu_m^k - \sum_{g=1}^{K_g} \sum_{m=1}^{M} \left(PTDF_{i,m}^{g} + \delta_{O_g,i} \sum_{n=1}^{N} PTDF_{n,m}^{g}\, GLDF_{O_g,n} \right) \mu_m^g$$

$$- \sum_{g}^{K_g} \sum_{j} \left(PTDF_{i,j} + \delta_{i,O_g} \sum_{n}^{N} PTDF_{n,j} \cdot GLD_{n,O_g} \right) \cdot FSP_{g,j}$$

A power balance constraint is not formulated for the CAISO Balancing Authority Area alone in the RTM. The shadow price of the power balance constraint for EIM Entity Balancing Authority Area *j* (λ_j) has the following contributions:

a) the shadow price of the EIM Transfer distribution constraint (φ_j), which distributes the EIM Transfer for Balancing Authority Area *j* to Energy transfers on interties with other Balancing Authority Areas in the EIM Area; and

b) the shadow price of the EIM Transfer scheduling limit for Balancing Authority Area *j*, upper (ν_j) or lower (ξ_j):

$$\lambda_j = \varphi_j - \nu_j + \xi_j$$

Where λ_j is zero for the CAISO Balancing Authority Area since the power balance constraint is not formulated for it.

The difference between the shadow prices of the EIM Transfer distribution constraints for two Balancing Authority Areas *j* and *k* in the EIM Area has the following contributions from any intertie *l* used for energy transfers between these two Balancing Authority Areas:

a) the EIM Transfer schedule costs that applies to that intertie *l* (c_l);

b) the shadow price of the Energy transfer schedule limit from Balancing Authority Area *j* to

Balancing Authority Area *k* that applies to that intertie *l*, upper limit (ρ_l) or lower limit (σ_l); and

c) the shadow price of the scheduling limit that constrains both Energy transfers and additional schedules to Balancing Authority Area *j* on that intertie *l*, upper limit (ζ_l) or lower limit (η_l):

$$\varphi_j - \varphi_k = -c_l - \rho_l + \sigma_l + \zeta_l - \eta_l$$

There may be multiple scheduling limits under (c) above that constrain schedules on a given EIM Intertie.