



California ISO

PacifiCorp's Nodal Pricing Model in the CAISO Day-Ahead Market

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Prepared by: Power Systems & Market Technology
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Executive Summary

PacifiCorp has contracted with the California Independent System Operator (CAISO) to provide a Nodal Pricing Model (NPM) day-ahead service that economically clears energy supply and demand bids for the PacifiCorp one day ahead. PacifiCorp intends to use the nodal prices produced by the model to calculate the Net Power Cost (NPC) for each state under its service territory. PacifiCorp system is currently model with two separate balancing areas PACW and PACE.

To ensure that the NPM balancing and congestion management solution is not impacted by the CAISO Day-Ahead Market footprint solution and vice versa, and to isolate marginal transmission losses between PacifiCorp and CISO, the CAISO implemented balancing authority area (BAA) specific calculation of loss penalty factors (LPFs) with reference to the distributed load in each BAA. Using BAA-specific LPFs separates the marginal cost of losses between PacifiCorp and CISO. Similarly, to isolate congestion management between PacifiCorp and CISO, the CAISO's day-ahead market (DAM) software does not consider the cross-BAA shift factors between PacifiCorp and CISO. This is achieved in two steps: i) shift factors of CAISO resources on transmission constraints in PACW and PACE are ignored; ii) conversely, shift factors of PACW and PACE resources on transmission constraints in CISO are ignored. Ignoring the cross-BAA shift factors in the formulation of transmission constraints isolates the marginal cost of transmission congestion between PacifiCorp and CISO to be solely based on transmission congestion inside the PACE and PACW BAAs for PacifiCorp's resources, and transmission congestion inside the CAISO BAA for CAISO's resources.

Parallel operation Day-Ahead Market cases are used in this report to demonstrate the decoupled market solutions of CAISO market footprint and the PacifiCorp area (PACE and PACW BAAs). The results show complete isolation/decoupling of CAISO and PacifiCorp BAAs.

Background

PacifiCorp has contracted with the California Independent System Operator (CAISO) to provide a Nodal Pricing Model (NPM) day-ahead service that economically clears energy supply and demand bids for the PacifiCorp one day ahead. PacifiCorp intends to use the nodal prices produced by the model to calculate the Net Power Cost (NPC) for each state under its service territory. The CAISO's NPM service leverages the its existing Day-Ahead Market technology platform, the ISO's full network model, and data interfaces available in the real-time Energy Imbalance Market (EIM) to provide the NPM solution. PacifiCorp is currently an EIM Entity participating in the EIM and has already developed systems and data interfaces with the EIM in submitting data and receiving settlement statements. Consequently, the proposed solution would only require a modest

expansion of PacifiCorp's bidding, scheduling, and settlement systems for NPM service participation, while gaining access to the state-of-art and up-to-date production version of CAISO's advanced security-constrained unit-commitment market software. Furthermore, the proposed technology solution will automatically inherit all new features and Day-Ahead market design enhancements in any future initiative.

The NPM solution development would uniquely benefit PacifiCorp because it allows for seamless participation in the future Extended Day-Ahead Market (EDAM), if and when, PacifiCorp decides to join. The NPM approach also provides PacifiCorp with the platform it needs to calculate the NPC for each state in its service territory on a faster pace while awaiting the outcome of CAISO's western EDAM stakeholder process.

Nodal Pricing Model Solution

Currently, before offering the NPM service, the CAISO's DAM market footprint is limited to the CAISO BAA (CISO). Other BAAs are modeled as external BAAs, similarly to non-EIM BAAs in the real-time EIM. Although supply and demand schedules in the external BAAs are not optimized, they are modeled as fixed in the CAISO's DAM to produce an accurate market and power flow solution. The CAISO, as the Reliability Coordinator of the West (RC WEST), receives the demand forecast and generation schedules for the next day from EIM BAAs and external BAAs, as well as the Area-To-Area Net Schedule Interchange (AANSI) between BAAs.

For the NPM solution, the CAISO proposes to include in the DAM market footprint the PacifiCorp BAAs, i.e. PACW and PACE, which are modeled as individual BAAs in the same way they are modeled currently in the EIM. Using similar market features and the optimization algorithm employed in the EIM, the DAM will produce optimal unit commitment and hourly energy schedules for supply resources in PACW and PACE, subject to a power balance constraint for each of these BAAs and active transmission network constraints in PACE and PACW. Energy transfers between PACW and PACE will be optimally scheduled, subject to applicable scheduling limits, whereas the net energy transfer between CISO and PAC will be fixed at zero, to prevent energy exchange between CISO and PacifiCorp that may impact the CAISO's DAM solution. This zero-net-energy-transfer constraint provides marginal energy price isolation between CISO and PacifiCorp, while permitting wheel through schedules to occur.

Although the CAISO's net energy transfer will be constrained to zero, the PacifiCorp Merchant will be able to continue to participate in the CAISO DAM with import/export bids at any CAISO Scheduling Point as is the case today before NPM. These schedules are not part of any energy transfer, but they are mirrored at Mirror System Resources (MSRs) that are defined for PacifiCorp at CAISO Scheduling Points. Schedules at these MSRs are included in the PACW or PACE power balance constraints; hence, the energy associated with the imports/exports

to/from CISO will be generated/consumed in PACW or PACE, accordingly. To facilitate the scheduling of MSRs, they will be defined with the Auto-Mirror functionality so that their schedules will be automatically calculated by the DAM to match associated import/export bids from PacifiCorp as they clear the DAM at the corresponding CAISO Scheduling Points. The MW schedules of the mirror resources will be calculated optimally in the DA Local Market Power Mitigation (LMPM) and fixed in the integrated forward market (IFM) at these optimal MW values.

The DAM optimization engine is a Security Constrained Unit Commitment (SCUC) application employing a Mixed-Integer Linear Programming (MILP) solver that iterates with an AC power flow (ACPF) to linearize the system equations for each hourly interval in the Trading Day market horizon. Transmission losses are accounted within each BAA in the ACPF via the Area Interchange Control feature that adjusts the distributed load slack in each BAA to maintain the optimal Net Scheduled Interchange (NSI) while correcting for linearization error. Then, LPFs are used to account for the marginal transmission losses in the linearized power balance constraints enforced in the SCUC. The LPFs are computed based on loss sensitivities that are currently calculated at the ACPF solution with reference to the distributed load over the market footprint. To isolate marginal transmission losses between PacifiCorp and CAISO, CAISO implemented BAA-specific LPFs with reference to the distributed load in each BAA. Using BAA-specific LPFs isolates the marginal cost of losses between PacifiCorp and CISO.

The linearized transmission constraints enforced in SCUC use shift factors that are linear sensitivities, which depend on the transmission network configuration. The shift factors to a binding transmission constraint are currently calculated with reference to the distributed load over the market footprint. To isolate congestion management between PacifiCorp and CISO, CAISO's DAM software ignores the cross-BAA shift factors between PacifiCorp and CISO. This is achieved in two steps: i) shift factors of CAISO resources on transmission constraints in PACW and PACE are ignored; ii) conversely, shift factors of PACW and PACE resources on transmission constraints in CISO are ignored. Ignoring the cross-BAA shift factors in the formulation of transmission constraints isolates the marginal cost of transmission congestion between PacifiCorp and CISO to be solely based on transmission congestion inside the PACE and PACW BAAs for PacifiCorp's resources, and transmission congestion inside the CAISO BAA for CAISO's resources.

With the implemented changes in the DAM, as discussed above, the CAISO is able to optimize generation schedules in PACW and PACE while maintaining complete pricing and scheduling separation with CISO.

As a standard feature of the DAM, the CAISO will also be able to procure ancillary services (AS) optimally to meet the corresponding requirements in PACW and PACE, by designating these BAAs as separate AS regions with distinct requirements. The regional ancillary services procurement would isolate the marginal ancillary services prices between PacifiCorp and CISO. Optimal

procurement of ancillary services in PACE and PACW BAAs is deferred to the NPM phase 2 scope.

It should be noted that the day ahead settlement for the NPM is advisory, *i.e.* no real dollars will be paid or charged. The day ahead energy schedules and ancillary services awards for NPM resources are ignored in the EIM. SIBR will not impose must-offer obligation of the PacifiCorp's day ahead schedules in the EIM.

Day-ahead energy (in phase 1) and ancillary services (in phase 2) prices for PacifiCorp resources will be published in CMRI for PacifiCorp, but they will not be published publicly in OASIS. Also PAC's LMPs will not be published in OASIS. Furthermore, the day-ahead energy bids of PacifiCorp resources will not be published in the six-month old reports under the Public Bids tab on OASIS.

Day-ahead price correction will apply to the day-ahead energy and ancillary services prices for PacifiCorp resources, and any corrected prices will be re-published after any corrections based on effective CAISO tariff and applicable BPM(s) related to price correction timelines.

The CIDI system and CAISO settlement dispute process will be available for PacifiCorp regarding the advisory day-ahead settlement in the NPM

Purpose and Scope

This report provides technical analysis and evidence to show the capability of CAISO DAM to produce DA nodal prices and MW dispatches for PacifiCorp resources with no impact on CAISO's DAM solution. The examples provided in the Analysis Section of this report demonstrate there is no impact on CAISO's DAM by verifying:

- the results of marginal energy cost at CISO locations with NPM On, and with NPM Off (current CAISO market footprint without NPM) are the same within numerical tolerances.
- the shift factors of CAISO's resources on transmission constraints in PACW and PACE are ignored; conversely, shift factors of PACW and PACE resources on transmission constraints in CISO are ignored. Ignoring the cross-BAA shift factors in the formulation of transmission constraints isolates the marginal cost of transmission congestion between PacifiCorp and CAISO to be solely based on transmission congestion inside the PACE and PACW BAAs for PacifiCorp's resources, and transmission congestion inside the CAISO BAA for CAISO's resources.
- the calculation of BAA-specific LPFs based on distributed load in each BAA to isolate marginal transmission losses between PacifiCorp and CISO. The use of BAA-specific LPFs isolates the marginal cost of losses between PacifiCorp and CISO.
- the computation performance to ensure that DAM timelines are still feasible.

Analysis

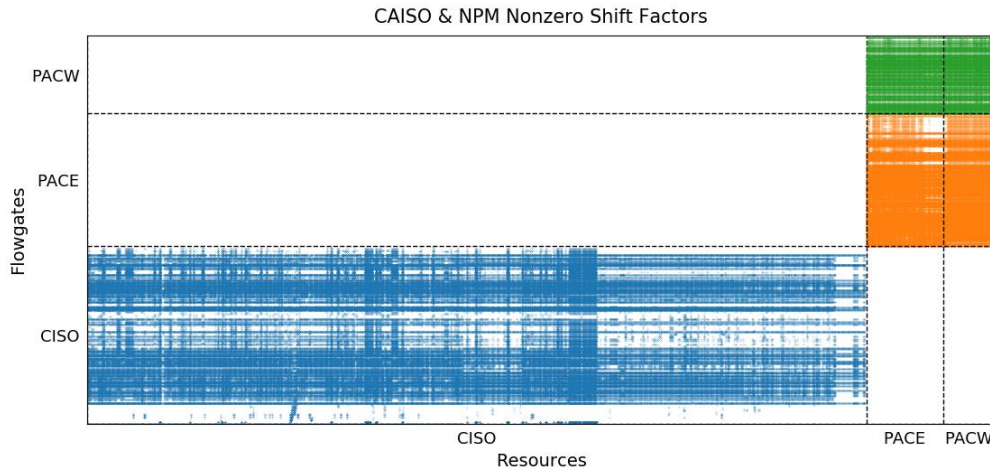
This section describes some test cases that verifies the decoupling of the market results and the LMP calculation for CAISO and PACE, PACW BAAs. There are three places that resources in different BAAs are coupled together in the optimization:

Power Balance Constraint (PBC)

The NPM project introduced separate PBC for each BAA in the market footprint, one for CISO, and separate one for PACE and another separate one for PACW with each PBC containing the corresponding resources belonging to the associated BAA. The separate PBCs enable the decoupling of the marginal energy cost component of the LMP. A test case was performed to run the market optimization (SCUC module) and the marginal energy cost component of the LMPs in the CAISO BAA was compared when NPM feature was enabled and when NPM feature was disabled (existing CAISO market footprint without NPM). The difference of the marginal energy cost calculation between the two sets of results is confirmed to be zero for the pricing locations inside CISO BAA.

Isolated Congestion Management for the NPM Area

Using a DAM case executed with the NPM feature ON, the following graph depicts all transmission constraints in the critical list for CISO, PACE and PACW BAAs. The X-axis represents a list of CISO, PACE, and PACW generation-only resources, respectively. The Y-axis represents the list of enforced flowgates in CISO, PACE, and PCW respectively. The different colors on the graph represent non-zero shift factors associated with flowgates from CISO, PACW, and PACE, respectively. The no/white color means that the shift factor calculation is skipped because the resource and the transmission constraints are in different NPM groups or zeroed out because they fall below the shift factor numerical threshold. It has been verified that there is no non-zero shift factors for generation resources in CISO BAA associated with a flowgate in PACE or PACW. Similarly, there is no non-zero shift factor for generation resources in PACE or PACW associated with CISO flowgates. The different colors in PACE and PACW is just indication that the generation resources in PACE are not effective in resolving congestion in PACW and vice versa. Please note that PACE and PACW are in one NPM group, and CISO is in another NPM group. The NPM grouping concept enable expansion of the NPM day-ahead service to other BAAs if needed.

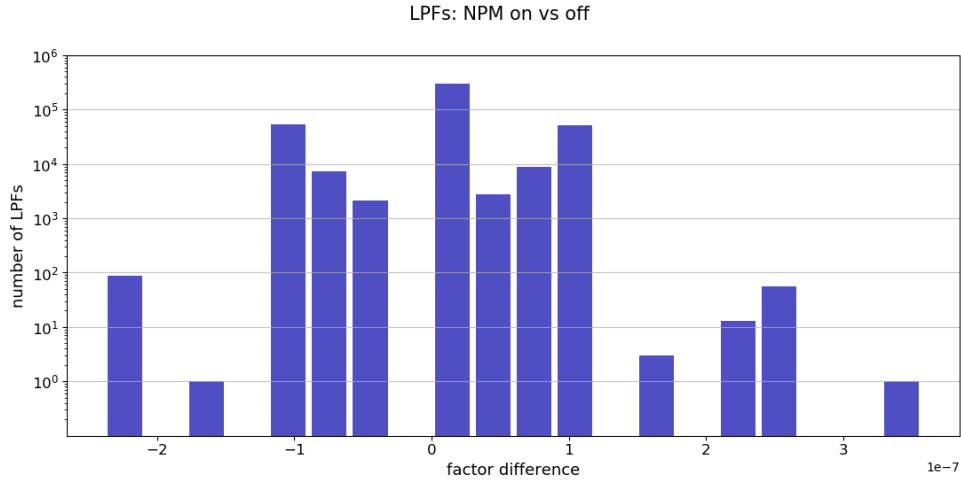


Calculation of Multiple Sets of Loss Sensitivities and Loss Penalty Factors

A change in the active power injection at a bus leads to a change in all the bus angles and voltage magnitudes. These changes will lead to changes in all branch flows, and therefore in the branch losses. The desired loss sensitivity at a specific node is given by a change of MW losses with respect to a power injection at that node. In the existing CAISO market footprint, the loss sensitivities are calculated based on the CAISO flowgates and the CAISO market footprint load since the day ahead market is using distributed load slack as reference.

Under the NPM project, a new loss sensitivity calculation is developed to generate loss sensitivities based on the associated NPM group load and flowgates. Therefore, when NPM feature is enabled, loss sensitivities and their corresponding loss penalty factors are calculated for CAISO locations based on CAISO load and CISO flowgates only. Another set of loss sensitivities and their corresponding loss penalty factors are also calculated for PACE and PACW load and flowgates.

A test case was performed by running a Day-Ahead case from the parallel production environment when the NPM feature is enabled and the new BAA-specific loss sensitivity calculation method is active to generate loss sensitivities for the CISO BAA and the results of the calculation is saved as reference solution for comparison purposes. The same reference case is used after the NPM feature was disabled, truncating previous loss sensitivities tables, and fixing the previous market solution in terms of injections in the network. Then, the power flow and loss sensitivities module is manually triggered to calculate the loss sensitivities similar to how it is done before NPM based on CAISO market footprint load and flowgates (NPM Off). Next, the new NPM Off case loss sensitivities and loss penalty factors are saved. The comparison of the reference NPM On results for CISO BAA locations with the NPM Off results indicates similar results with maximum absolute difference within numerical tolerances, see below graph considering the 10E-7 factor of the x-axis.



Computational Performance

The table below shows the increase in solution time due to adding the NPM solution for PACE and PACW BAAs with the same MIP gap setting in both cases. However, the increase in time is minimal and does not preclude satisfying the existing DAM timelines.

Table 1: Execution times in minutes

Market Pass	NPM Off	NPM On
LMPM	10	13
IFM	7	8
RUC	8	9

Conclusions

Parallel operation Day-Ahead Market cases are used in this report to demonstrate the decoupled market solutions of BAAs located in different NPM groups. The results show complete isolation/decoupling of CISO and PacifiCorp BAAs in the DAM process