Technical Status Report on:
AC Power Flow under Convergence Bidding – Summary of Factory Test Results

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Background

One of the identified technical challenges for the implementation of convergence bidding is the difficulty of achieving alternate-current (AC) power flow solution in the day-ahead (DA) market application due to over-scheduling of convergence bids. A previous technical bulletin, http://www.caiso.com/2437/243786845a9d0.pdf, was published by the ISO to describe a proposed algorithm to deal with the potential AC power flow divergence due to:

1. Branch angle divergence due to the excessive flow of MW on a particular branch or branches
2. Voltage divergence due to voltage magnitude at a bus or group of buses

Recently, the ISO completed extensive testing of the day-ahead application after the implementation of the convergence bidding feature and the implemented approach to maintain AC power flow convergence in the day-ahead market. The purpose of this Test Summary Report is to describe the different test activities related to the convergence bidding in the day-ahead market application with focus on the market optimization application.

Brief Description of SCUC-NA Iteration Process

The current Integrated Forward Market (IFM) market application includes the Security Constrained Unit Commitment (SCUC) module and the Network Application (NA) module. The SCUC module optimizes generation, load, import, and export schedules and clears energy and AS supply and demand bids to manage congestion while respecting linearized transmission constraints and inter-temporal constraints. The NA module uses the optimal solution obtained from the SCUC module and performs AC power flow to determine the feasibility of the SCUC module solution. The NA module switches automatically to DC power flow if AC power flow can't be achieved. The NA module then formulate linear transmission constraints for overloaded branches, as well as nodal group limit constraints if AC solution is not obtained, and send them back to the SCUC module to be included in the second round of optimization performed in the SCUC-module. This iterative process between SCUC and NA modules (SCUC-NA) continues till no overloads are detected or maximum number of iterations reached.

1st SCUC – Optimize without network constraints and nodal limit group constraints but with already defined and active nomograms and inter-tie scheduling limit constraints

1st NA – Using the 1st SCUC optimal commitment results, run power flow to identify critical transmission constraints, nodal group limit constraints if AC solution is not acheived, and calculate shift-factors, and loss factors.
2nd SCUC – Optimize with constraints from 1st NA
2nd NA – Using the 2nd SCUC results, run power flow to identify unresolved constraints and feed back to 3rd SCUC.
3rd SCUC – Optimize with constraints from 2nd NA
3rd NA – Using the 3rd SCUC results, run power flow to make sure that all constraints are resolved.
Repeat iterative process between SCUC and NA until convergence criteria is established when no overloads are detected or maximum number of iterations is achieved.

Test Summary Results:

During the different stages of testing, the ISO gave special attention to the IFM bid processing, handling of additional intertie constraints representing virtual flow, calculation of new nodal limits, handling of nodal constraints in the optimization, and the LMP calculation considering the impact of nodal constraints.

Composite Virtual Bids

The ISO used all production physical bids corresponding to trading day May 12, 2010 and augmented the physical bid set with virtual bids on single and aggregate price locations as described below. This bid set also includes some virtual bids given by market participants.

The ISO used a diversified set of virtual bids covering every pricing location (single and aggregated Pnodes) allowed for virtual bidding by the Master File inside the ISO balancing authority area footprint. The ISO used approximately 20,000 virtual bids with most of them having two segments and some having up to 10 segments. Below is the example of aggregated locations the ISO used for virtual bidding (supply and demand).

- Price Nodes with physical resources
- Aggregated Generators (AGR)
- Aggregated System Resources (ASR)
- Trading Hubs (THs)
- DLAPs

- PODs

At each location (aggregated and not) supply and demand were submitted. The ISO verified that composite bid curves calculated based on same location individual virtual bids are built correctly with respect to the bid type and location, processed correctly by the market application, and transferred correctly to Network Application / Power Flow module. Detailed verification was conducted to ensure the correct distribution of composite virtual bids at the aggregated locations to the corresponding individual pnode locations included in the aggregate location.

The ISO also verified that virtual bids at Point of Delivery (POD) locations are processed correctly consistent to current ISO rules used for physical POD bids.

Disaggregation of composite virtual awards to individual virtual bids was examined very carefully. The ISO testers verified that the award is distributed correctly to the individual virtual components consistent with bid-in price and MW.

Virtual Bids Processing

The ISO created multiple scenarios to verify bid processing. The following is a brief overview of the performed tasks:

- Multiple virtual demand and supply bids at single pnode to build a composite virtual bid curve with large amount of segments.
- Same for aggregated virtual bids at different aggregated location types (TH, DLAP, POD, AGR, ASR)
- Insured that individual bids have price overlaps. Insured that supply and demand bids processed separately.
- Verified that virtual composite virtual bids are used by market application with no discrimination and dispatched economically.
- Verified that composite virtual bid award is disaggregated correctly.

Nodal Group Limits Constraints and AC Power Flow

In all test cases where large injection/withdrawal was created at different pricing locations, the software managed to solve AC power flow in the second SCUC-NA iteration after the introduction of the nodal group limits constraints in the optimization in the second SCUC-NA iteration and forward. The nodal group limit constraints are only enforced after the first detection of AC divergence. This same observation of achieving AC power flow in the second iteration is also true for the run performed using the sample virtual bids submitted by the market participants.

The ISO conducted extensive verification of the nodal group limits constraints logic. The following is an overview of the performed tasks:

1. Verified that nodal limit for every individual pricing location is calculated correctly with respect to the distribution factors and load forecast or Pmax of generators under different network model conditions.
2. Verified that submitted virtual and physical bids at single pnode locations are large enough to produce injection/withdrawal resulting in DC power flow solution after the first SCUC iteration due to voltage magnitude drop or branch angle difference divergence.
3. Verified that submitted combination of virtual and physical bids (injections/withdrawal) at aggregated locations as well as single pnodes are large enough such that the combined injection from these bids at the individual pnodes result in DC power flow solution, and verified that nodal limit that includes all the pnodes connected to the impacted bus are passed back to the SCUC and added as an additional constraint at the next SCUC optimization.
4. Verified the use of LDFs as the basis for calculation of the nodal limits corresponding to the load resources pnodes. For pnodes corresponding to load resources, the nodal limit is calculated as MW corresponding to the distribution of the system load forecast to the pnode location, i.e LDF times load forecast, and increased by a configurable % parameter that is set at 130% of the load forecast distributed MW for the pnode.
5. Created a scenario where physical bids caused power flow to solve DC. Verified that if there is no virtual bids at the bus where power flow has diverged nodal limits are not created.
6. Created a scenario where there is combination of virtual injections/withdrawals and physical injections/withdrawals causing power flow to solve DC. Verified that nodal limit is created for the location and all bids are adjusted based on submitted bids to satisfy the nodal constraint with no discrimination between physical and virtual bids.

LMP calculation

1. Created a scenario where a pnode with virtual bids is participating in transmission congestion. Verified that congestion component of LMP at the pnode is calculated correctly based on participation in transmission, inter-tie, nomogram, and nodal limit constraints.
2. Created a scenario where some of the pnodes that are part of an aggregate node are participating in resolving nodal limit constraint, tie, transmission congestion. Verified that congestion component for apnode is calculated correctly.

3. Created scenario with no tie, and no transmission congestion. Verified nodal congestion component is equal to final congestion components for pnodes and apnodes.
4. Then introduced an inter-tie congestion caused by physical schedules at the tie and verified that congestion component for the pnode is now calculated based on the inter-tie congestion.
5. Then modified the scenario such that the congestion is caused by virtual bids instead of the physical bids, and verified that congestion component for involved pnodes and apnode are recalculated taking into account the inter-tie congestion.
6. Verified shadow price calculation for nodal limit constraints by increasing nodal limits and measuring the impact on the objective function value while ensuring the same commitment pattern.

New Inter-Tie Constraints

1. Created a scenario where virtual bids caused congestion across an inter-tie, and verified that IFM resolves the congestion economically.
2. Verified the creation of physical-only scheduling constraints as well as physical plus virtual scheduling constraints.
3. Verified that congestion cost component due to physical plus virtual inter-tie constraint is the one used for LMP pricing.
4. Created a scenario where there was an inter-tie congestion and both physical and virtual resources are marginal at the same price. Verified pro-rata calculation is applied to both virtual and physical based on the current pro-rata rules.

MPM and RUC General Regression Testing

1. Verified that no virtual bids are used in MPM or impacted the MPM solution.

2. Verified RUC energy net short calculation uses IFM physical cleared load versus CAISO Forecast of CAISO Demand

3. Verified that only physical supply bids are used in the calculation of the "Quick Start Resources" available for RUC

4. Verified that only physical supply bids are used to calculate the RUC "Max Energy Constraint or Min-load constraint"

5. Verified that RUC results does not include any virtual bids

6. Verified that RUC pricing results are within normal based on the physical bids corresponding to May 12, 2010 and the market participants submitted sample virtual bids.

Conclusions

1. The enforced transmission constraints together with the new nodal group limit constraints, which are only enforced after the first detection of AC power flow divergence, are effective design measures to achieve AC power flow convergence. All test cases with various virtual bids created by the ISO test team, as well as the test case created using the sample virtual bids submitted by market participants, all these cases solved with AC power flow due to the effectiveness of the enforced transmission constraints, and the nodal group limits constraints in mitigating the source of the AC power flow divergence.

2. Nodal group limits constraints are needed to provide software more controls to reduce the loading of the offended node(s) to reasonable MW levels that will enable AC power flow convergence solution in the second SCUC-NA iteration and forward. The nodal group limits constraints are needed regardless of the decision to allow nodal or LAP-only convergence bidding.

3. Once a nodal group limit constraint is enforced in SCUC-NA iteration, it will stay in the optimization module for the subsequent SCUC-NA iterations of that market run only; similar to the current implemented method for the overloaded transmission constraints. It should be noted that nodal group limits constraints are not carried over to new market runs.

4. The nodal constraint, if binding, has direct impact on the LMP of the offended node as well as the corresponding aggregate node based on the LDF or the GDF of the offending node within the aggregation. Therefore if an aggregate has 30% distribution on the offending node then this aggregate has a 30% effectiveness to the nodal limit constraint.

5. The nodal group limit constraint gives the optimization module more controls to target specific congestion around the offended node(s). The optimization module can relieve the congestion by re-optimizing nodal bids, if any, rather than performing expensive moves of LAP bids.