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Proposed Solution to Mitigate Concerns Regarding AC Power Flow under Convergence Bidding

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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, see discussion of the technical challenges on the public CAISO site http://www.caiso.com/240a/240a7ace60860.pdf.

To mitigate this specific risk, CAISO has embarked an internal effort to determine the impact of over-scheduling due to convergence bidding on convergence power flow solution.

Since the existing DA market application does not have the convergence bidding feature implemented yet, CAISO used physical bids in its testing effort at locations where network resources are connected to the associated market connectivity node(s).

The intent of this transmittal is to describe the steps performed by CAISO to test the validity of the proposed CAISO solution to deal with the two types of AC power flow divergence:

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

Brief Description of SCUC-NA Iteration Process

The current 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 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. In summary, 1st SCUC – Optimize without network constraints but with already known nomograms and inter-tie scheduling limit constraints

1st NA – Using the 1st SCUC optimal commitment results, run Power flow to identify critical transmission constraints 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 1st NA

3rd NA – Using the 3rd SCUC results, run Power flow to make sure that all constraints are resolved.

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Test Case Description

1. Start from a DA production save case and target a specific connectivity node that has physical load connected to it.
2. Confirm that the original save case is solving with converged AC Power flow in all Security Constrained Unit Commitment-Network Application (SCUC-NA) iterations between the optimization module and the network application power flow module of the DA market software application.
3. Pick one of the time intervals at the peak hours and run Power flow in Power flow mode only. Verify that the initial solution is in fact AC power flow.
4. Keep increasing the load at the target node to the point that AC power flow is no longer converging (angular divergence) and DC solution is obtained.
5. Start from the market application inputs and increase the self-schedule on the target node to the level where AC solution was not obtained in step 4 above.
6. Run the whole market and verify that the first iteration of SCUC-NA resulted is a diverged AC power flow and that the software switched automatically to DC power flow solution for the first iteration.
7. Using a CAISO developed script, reset the power flow parameter that controls the algorithm choice to force power flow module to first try AC solution at every SCUC-NA iteration before switching to DC solution. Current implementation of

the software is for power flow to stay DC in the subsequent iterations once it solves DC in one of the iterations.

8. Observe the result of the power flow in subsequent SCUC-NA iterations to see if the solution is AC or continued to be DC
9. Keep increasing the amount of self schedule on the target node till you hit voltage divergence of AC power flow and software switched to DC solution in the first iteration of SCUC-NA.
10. First, try enforcing more constraints around the area where the target node is located, and rerun with same conditions that caused the voltage divergence but with the additional enforced constraints.
11. Second, instead of enforcing additional constraints, limit the net nodal injection on the target node and re-execute with same conditions that caused voltage divergence.

Test Case Results

1. The increase in allocated MW to the target node caused power flow to diverge due to the excessive amount of MW that is flowing on the branch leading to the target node, i.e. branch angle difference divergence. Hence, the first SCUC-NA ended up solving with DC power flow. A transmission constraint corresponding to the overloaded branch was created by the power flow module (NA module) and communicated to the optimization module (SCUC module).
2. In the second SCUC-NA iteration, the SCUC module re-optimized the bids taking into account the overloaded constraint, and the software automatically communicated the optimization results back to the NA module to run power flow.
3. The developed CAISO script reset the power flow parameter to force software to try AC power flow in the second iteration (first iterations was DC before the re-optimization)
4. It was observed that the power flow in the second iteration converged with AC solution due to the re-optimization of the bids. This observation continued to be true for the many test cases that were executed by increasing the cleared MW amount at the target node up to a specific MW level where all subsequent SCUC-NA iterations were solving with DC power flow. The source of the divergence in this case was identified to be voltage divergence, i.e. voltage at the bus dropped to 0.1pu.
5. The same set-up in step 4 above was re-executed but with enforcing/activating more branch constraints around the target node. The intent here is to capture

more information about the overloads around the target node that can be communicated from NA module to the SCUC module to include in the re-optimization to make it more effective to resolve the overloads around the target node. This approach with the increased active constraints helped the software to re-optimize the bids and the AC power flow was observed again in the second SCUC-NA iteration and forward.

6. Instead of activating more constraints in the target node area, the net nodal injection at the target node was limited in the second iteration and forward. Note that the enforcement of the limit was done manually since the software is not yet developed to handle this new constraint. The enforcement of the nodal limit resulted in AC power flow solution in the second SCUC-NA iteration and forward.

Analysis of Results

1. For areas of the transmission network model where we have good observability and reasonable branch ratings, the test cases showed that AC solution can be achieved in the second SCUC-NA iteration and subsequent iterations as long as enough information about the overloaded branches around the node with net excessive MW are communicated to the optimization module from the DC power flow solution in the first iteration.

2. For areas of the transmission network model where CAISO does not have good observability nor reasonable ratings, a nodal limit constraint will be enforced only when software runs into power flow issues that prevents the convergence of AC solution. This constraint is needed to provide software control to reduce the loading of the target node to reasonable MW levels that will enable convergence AC solution in the second SCUC-NA iteration and forward.

3. Once the nodal constraint is enforced in an 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.

4. The nodal constraint, if binding, will have direct impact on the LMP of the target node. The impact of the target node LMP on the LAP LMP depends on the LDF of the target node with respect to the LAP bid.

5. The nodal convergence bids on the target node are more efficient in resolving the nodal limit constraint because they have effective factor of one, compared to the LAP bids which have small impact determined by the corresponding LDF of the target node with respect to the default LAP bid.

6. The nodal limit constraint gives the optimization module more controls to target specific congestion around the target node. The optimization module can relieve the congestion by re-optimizing nodal bids rather than moving the LAP bids. The LAP bids have wide system impact by nature and their movement could result in unrealistic optimization results if large MW LAP MW is moved to relief small congestion near the target node.

Conclusion

1. The nodal limit constraints are needed regardless of the decision to allow nodal or LAP-only convergence bidding.
2. The nodal convergence bids on the target node are more efficient in resolving the nodal limit constraint because they have effective factor of one, compared to the LAP bids which have small impact determined by the corresponding LDF of the target node with respect to the default LAP bid.
3. The nodal limit constraints shall only be enforced to the extent that transmission constraints are not active in the area causing the AC power flow divergence. The basis of the nodal limit will be an adjustable factor of the physical load/supply connected to the node.
4. Once the nodal 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.
5. The nodal constraint shadow cost, if binding, shall be included in the LMP of the corresponding node.