Single Schedule Market Pricing Issues

Presented by

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Phase 1 - Session 2

Module D: Multi-Interval Optimization and Pricing

June 2, 2017

Toronto, Ontario

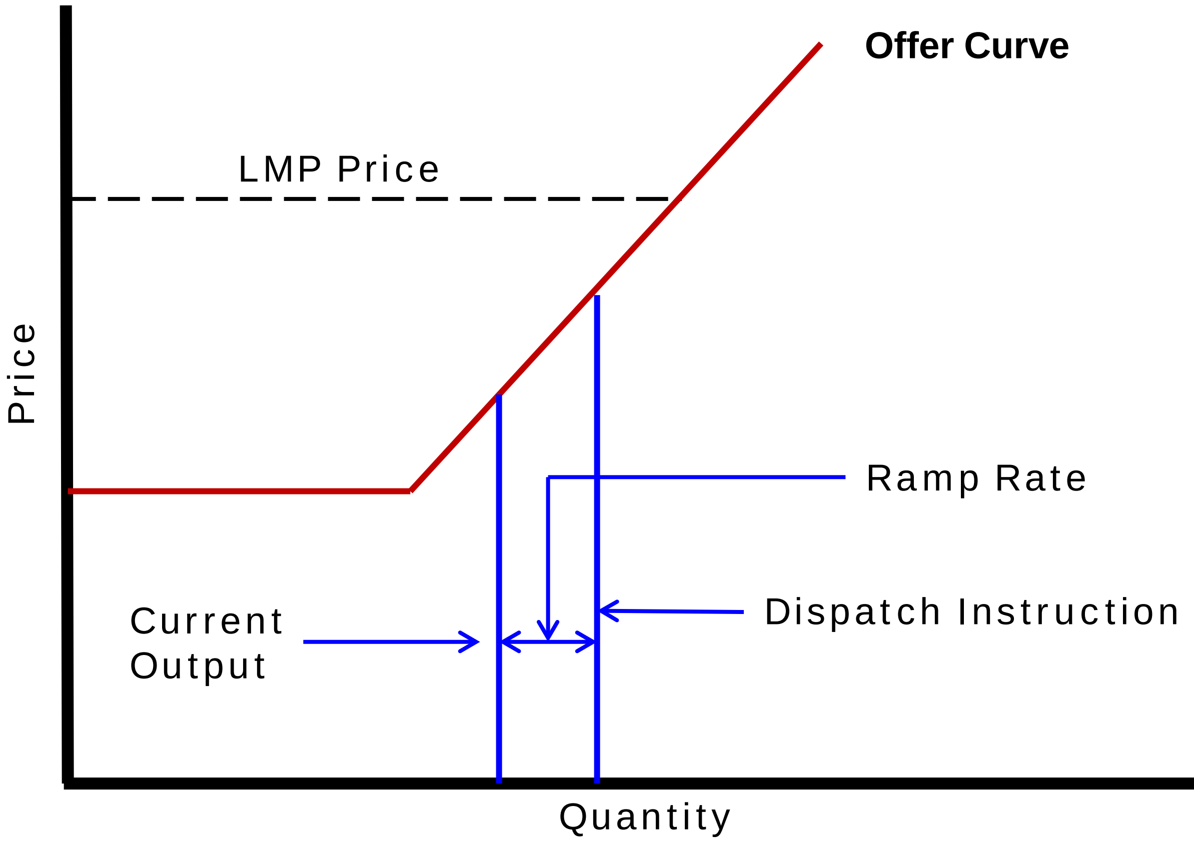
FTI

Module D: Multi-Interval Optimization and Pricing

TOPICS

Module D: Multi-interval Optimization and Pricing

- Multi-interval Optimization
- Ex Ante Pricing


Offer Curve
LMP Price
Price
Ramp Rate
Dispatch Instruction
Current
Output
Quantity

MULTI-INTERVAL OPTIMIZATION

The IESO constrained schedule, like the dispatch of other system operators, dispatches generation to meet load taking account of the ramp rate of each generation resource so that load and generation can be balanced within the time frame of the economic dispatch.

- When net load is rising rapidly, ramp constraints may result in a suboptimal dispatch of resources or an inability to meet the load following requirement.
- The converse situation can exist when net load is falling rapidly.

MULTI-INTERVAL OPTIMIZATION

Traditional security constrained least cost dispatch minimized the cost of meeting load over a five- or ten-minute dispatch period, without regard to the cost of meeting load in future dispatch intervals and even without regard to the potential to be unable to balance load and generation in future dispatch intervals.

- While operators might make ad hoc adjustments to generator dispatch points or to the load forecast in order to better manage expected future conditions, these are ad hoc adjustments outside the dispatch optimization.
- Multi-interval optimization of real-time dispatch as implemented by the IESO (2004), NYISO (2005), and CAISO (2009) also optimizes over time to account for known future ramp requirements, such as those associated with top of the hour changes in intertie schedules, a generation unit going on or off-line, or large expected changes in net load.

MULTI-INTERVAL OPTIMIZATION

A multi-interval optimization algorithm is responsible for determining the IESO's dispatch instructions in the real-time constrained schedule.

- SSM will need to ensure that the price formation rules align with the IESO's dispatch instructions.
- As a consequence, the multi-interval optimization algorithm will be used to calculate price.

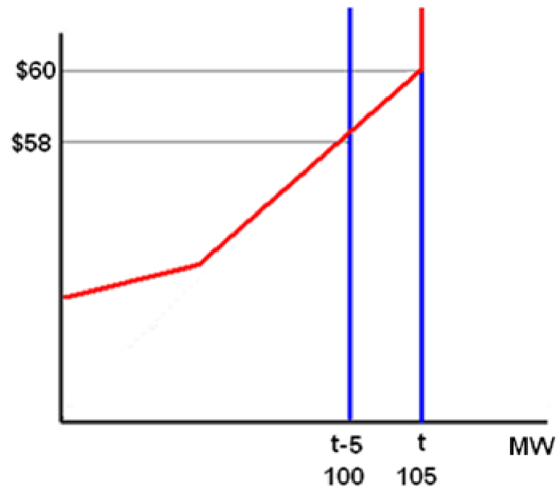
MULTI-INTERVAL OPTIMIZATION

How can multi-interval optimization create additional upward (or downward) ramp capability to meet a known ramp need in a future interval?

- Dispatching down (out-of-merit) resources whose available upward ramping capability is capacity limited creates additional upward ramping capability for the next interval or intervals.
- The output of the resources dispatched down can be replaced with the output of higher cost units whose available ramping capability is not capacity constrained.
- Additional downward ramp capability can be created by dispatching up out-of-merit resources whose downward ramping capability is limited by their minimum load point.

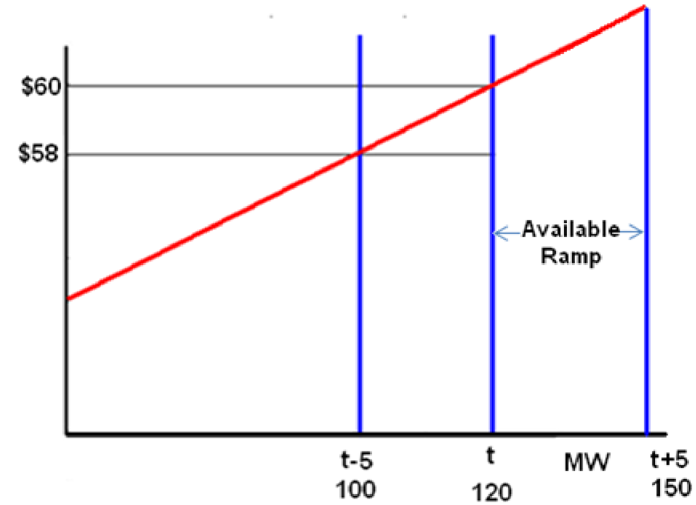
Conventional Dispatch: 30 Megawatts Upward Ramp Available t to t+5

Unit A
No Ramp Available at t
Capacity Limited Unit



105 megawatt capacity
5 megawatt ramp rate

Unit B
30 Megawatts Available at t
Ramp Limited Unit



200 megawatt capacity
30 megawatt ramp rate

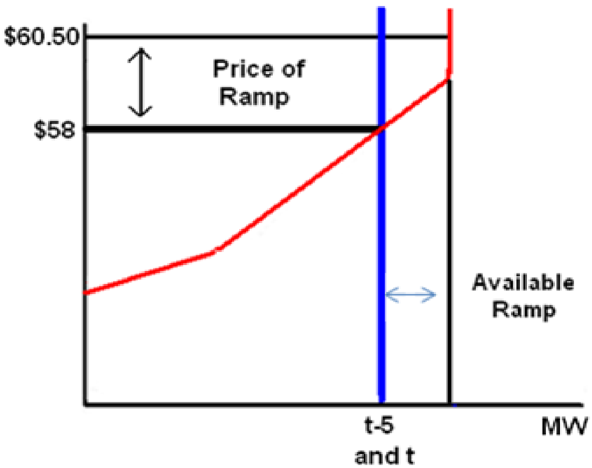
MULTI-INTERVAL OPTIMIZATION

In conventional economic dispatch, the system is dispatched to meet load at least cost while maintaining the target level of future load following capability and operating reserves.

- In contrast, multi-interval optimization algorithms schedule generation to provide additional ramp capability for future intervals to avoid ramp constraints in those future intervals that are anticipated based on expected future conditions.
- This multi-interval dispatch will at times raise the cost of meeting load in the current dispatch interval in order to reduce the cost of meeting load in future intervals.
- In the example above, no ramp up would be available on resource A in the dispatch interval beginning at t because resource A would already be at its upper limit.

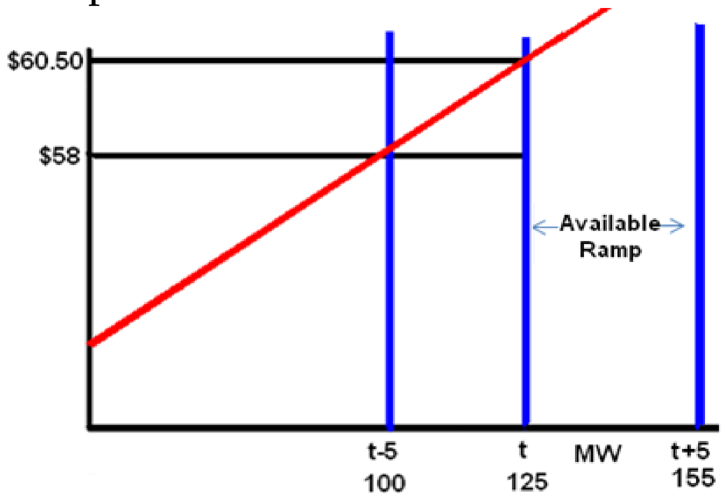
Look-ahead Dispatch to Increase Upward Ramp: 35 Megawatts of Upward Ramp Available t to t+5

Unit A
5 Megawatts Ramp Available at t
Capacity Limited Unit



105 Megawatt Capacity

Unit B
30 Megawatts Available at t
Ramp Limited Unit



200 Megawatt Capacity

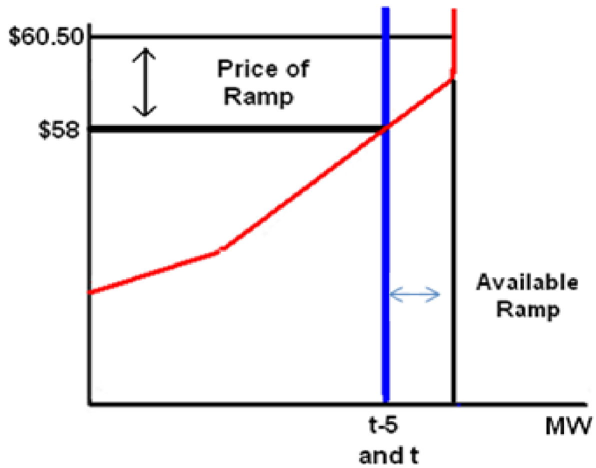
MULTI-INTERVAL OPTIMIZATION

More upward ramp capacity would be available at time t if resource A were dispatched down below its upper limit in the dispatch interval beginning at t-5.

- Resource B would be dispatched higher to replace the output of resource A.
- This re-dispatch increases the amount of ramp available in future periods because resource B is ramp rate constrained in the amount of ramp it can provide while resource A is capacity constrained.
- As relatively lower cost generation is dispatched down out of merit to create more upward ramp to meet known ramp needs in future intervals, the incremental cost of ramp rises (the change in the cost of meeting load associated with an increase in the ramp available in the future interval).

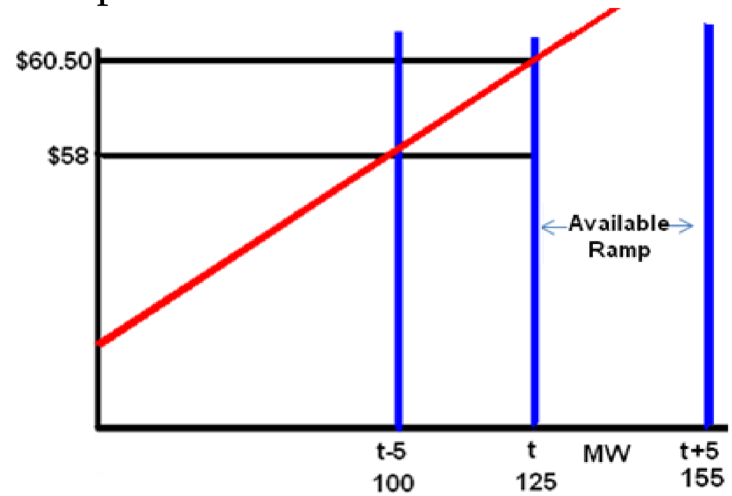
Look-ahead Dispatch to Increase Upward Ramp: 35 Megawatts of Upward Ramp Available t to t+5

Unit A
5 Megawatts Ramp Available at t
Capacity Limited Unit



105 Megawatt Capacity

Unit B
30 Megawatts Available at t
Ramp Limited Unit



200 Megawatt Capacity

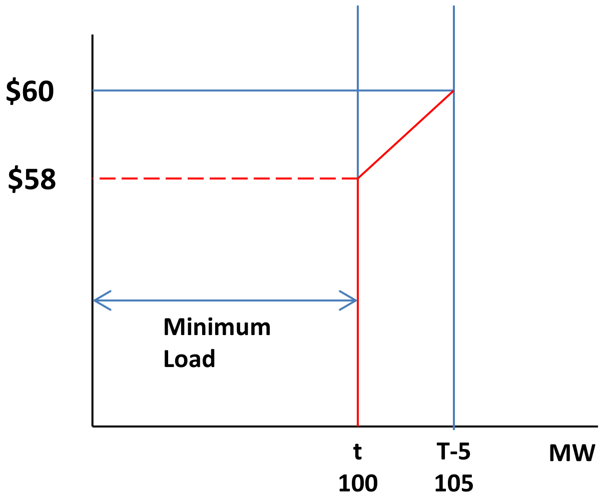
MULTI-INTERVAL OPTIMIZATION

The incremental cost of meeting load would be determined by the offer price of resource B, so the LMP price in the interval t-5 would be increased by the dispatch to create more upward ramp in future intervals.

- This dispatch would be economic if the availability of more upward ramp reduced the cost of meeting load in future intervals by avoiding the need to dispatch very high cost generation or of avoiding power balance violations.

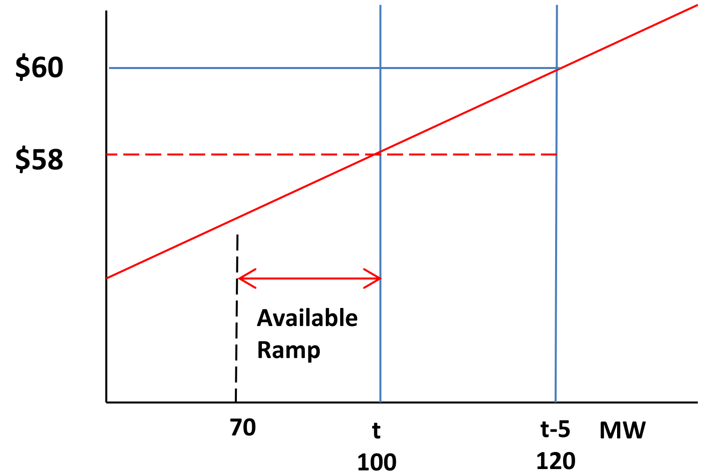
Conventional Dispatch: 30 Megawatts Downward Ramp Available t to t+5

Unit A
No Ramp Down Available at t



100 megawatt minimum load
5 megawatt ramp rate

Unit B
30 Megawatts Ramp Down
Available at t Ramp Limited Unit



200 megawatt capacity
30 megawatt ramp rate

MULTI-INTERVAL OPTIMIZATION

Multi-interval optimization can also dispatch resources to make more ramp down available in future intervals.

- In the example above, resource A cannot provide any ramp down in interval t because it would already have been dispatched down to its lower operating limit.

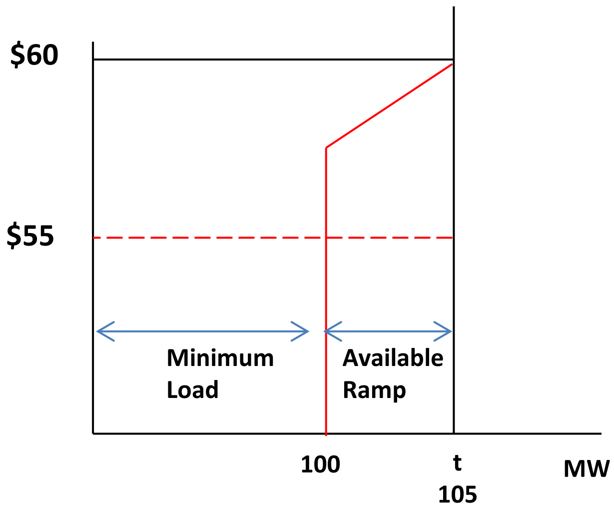
Look-ahead Dispatch to Increase Downward Ramp: 35 Megawatts of Downward Ramp Available t to t+5

Unit A

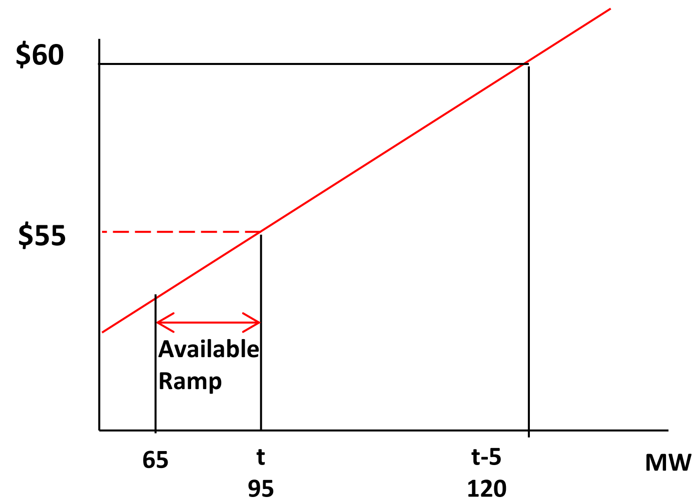
5 Megawatts Ramp Down Available at t

Unit B

30 Megawatts Ramp Down Available at t Ramp Limited Unit



105 Megawatt Capacity



200 Megawatt Capacity

MULTI-INTERVAL OPTIMIZATION

More ramp down could be made available at time t if resource A were dispatched up above its lower operating limit in the dispatch interval beginning at t-5.

- Resource B would be dispatched lower to offset the increased output of resource A.
- This re-dispatch would increase the amount of down ramp available in the next interval because resource B is ramp constrained in the amount of down ramp it can provide while resource A is capacity constrained.
- In single schedule markets with multi-interval optimization, the incremental cost of meeting load is set by resource B. The multi-interval optimization would decrease the price in the current interval while raising the price in one or more future intervals by avoiding downward power balance violations.

The IESO's multi-interval optimization design looks forward over the next 55 minutes and targets 4 critical intervals designated by the operators in addition to the current interval.

- The 11 intervals are assigned weights that decline from 1 for the current interval to 0.5 for the 11th interval.
- The critical intervals are assigned their own weight and ½ the weight of the non-critical intervals that precede or follow it.
- The constrained schedule produces binding dispatch instructions for the current interval and advisory dispatch instructions for the 4 future intervals.
- The constrained schedule calculates prices at generator nodes, but these prices are not used for settlements.

Other ISOs with multi-interval optimization use slightly different designs. The New York ISO's Real-Time Dispatch (RTD) program looks forward 50 minutes to an hour in five intervals composed of a mixture of 5 minute, 10 minute and 15 minute increments.[1]

- This design implicitly assigns more weight to the immediate 5 minute interval than to the future 10 or 15 minute intervals, but all of the future 10 and 15 minute intervals have the same weight.
- The design in which the program may be looking out over 10 and 15 minute long dispatch intervals reduces the ability of the program to see ramp constraints, which are less likely to bind over longer time periods.

1. See New York ISO Service Tariff, Section 17.1.2.1.1 Attachment B.

MULTI-INTERVAL OPTIMIZATION NYISO

- The New York ISO's Real-Time Dispatch (RTD) both dispatches energy and optimizes ancillary services (regulation and reserves) over both the current interval and future periods.

MULTI-INTERVAL OPTIMIZATION CAISO

The California ISO's RTD program looks out an hour in 5 minute increments.

- All of the 5 minute intervals have equal weights.
- RTD only dispatches energy, however; it takes ancillary service schedules as fixed, so cannot shift regulation or reserves across resources in response to ramp constraints in a particular region.
- Since December 1, 2016 RTD schedules both energy and flexi-ramp (additional ramp capability that is maintained to improve the California ISO's ability to balance large unexpected variations in net load).

MULTI-INTERVAL OPTIMIZATION

While the IESO's multi-interval optimization in the constrained schedule minimizes the cost of meeting load over the dispatch horizon and calculates LMP prices for each dispatch interval, the prices are not used for settlements.

- It is possible that a slow ramping resource would be dispatched up out of merit in the current interval because this would allow the resource to achieve a higher output in a future interval in which the cost of meeting load, and prices, are projected to be higher.
- In this situation, the slow ramping resource may recover its costs through increased output in future intervals when prices exceed costs.
- However, this may not happen if the IESO load forecast for the future intervals turns out to be wrong.

MULTI-INTERVAL OPTIMIZATION

It is conversely possible that a resource that would otherwise be at its upper limit would be dispatched down in order to create additional upward ramp capacity to meet projected large changes in net load in a future interval.

- Future energy market revenues may not cover the resource's opportunity cost of being dispatched down (because of the optimization) even if the IESO's load forecast is correct.

MULTI-INTERVAL OPTIMIZATION

The trade off involved with multi-interval optimization is the longer solution time required for the software to optimize over the multiple intervals.

- The greater solution time for multi-interval optimization requires that the program initialize further in advance of the period covered by the dispatch instructions.
- This means that the dispatch instructions will be based on data (demand forecast, resource loading points, and wind/solar forecasts) calculated further in advance of the period covered by the dispatch instructions.
- The increased solution time can therefore lead to larger differences between actual and projected net load, requiring more use of regulation to balance load and generation.

EX ANTE AND EX POST PRICING

Some ISOs have used a design in which the prices used for settlement are calculated after the dispatch interval (ex-post) while the dispatch instruction is calculated prior to the dispatch interval (ex-ante).

- This design originated in PJM in 1998. PJM at that point in time could only send out a single electronic dispatch signal to each of the 8 transmission owner zones and used telephone instructions to adjust the output of individual units.
- The prices calculated in the ex-ante electronic dispatch were therefore not consistent with the actual dispatch at all locations.
- The ex-post pricing design calculated settlement prices that were most consistent with the combination of electronic and operator dispatch instructions.

EX ANTE AND EX POST PRICING

The original ex-post design evolved over a few years into a design in which settlement prices were calculated after the fact based on which resources were following their dispatch instructions.

- PJM continues to use this pricing design.
- MISO abandoned ex-post pricing in 2009 and ISO New England abandoned it in 2015.
- There were two types of concerns with ex-post pricing:
  - A variety of implementation complexities tended to create overstated prices and anomalous congestion patterns.
  - The design can result in substantially understated prices during high load and reserve shortage conditions.

Hence, most ISOs have migrated to ex-ante pricing in which both the dispatch and settlement prices are calculated before the dispatch interval.

The IESO unconstrained pricing model executes ex-post to the dispatch interval.

PRICING PASSES

A number of North American ISOs use multiple passes in order to calculate the physical dispatch and to calculate settlement prices.

- NYISO and MISO use a separate pricing pass in which some fixed block resources are treated as dispatchable to implement hybrid pricing in NYISO and Extended-LMP in MISO.
- CAISO uses a separate scheduling pass with extremely high penalty prices to enforce and potentially curtail historical rights to the use of the transmission system. The results of the scheduling pass are then used in the pricing pass to calculate locational marginal prices.
- More recently the California ISO has used the pricing pass to apply a “load bias limiter” which reduces prices that would otherwise be set by load balance violation penalty prices in a variety of situations.