California ISO

Informational Posting: Constrained Optimization

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1. Constrained Optimization Mechanics

The ISO operates a market that relies on a constrained optimization problem, with nodal representation of generation and load, to arrive at an optimal solution. The solution includes a set of optimal dispatches and prices. This problem aims at matching energy supplied with demand in both the day-ahead and real-time markets. The constrained optimization includes an objective cost function that reflects costs of all generation available on the system with a goal of minimizing total costs. This objective function is subject to all resources and system constraints, including a constraint to enforce the power balance between supply and demand, constraints to limit flow from one node to another – representing transmission constraints, and constraints that represent various other limitations of the ISO grid operation.

Although all constraints are actively enforced in the markets, typically, many constraints do not reach their limit. When the constraint reaches its limit it is commonly said to 'bind' in the market optimization. For example, if the market optimization includes a constraint that represents a specific transmission limit, and modeled flow across that transmission line is below the limit, the constraint will not bind. Stated otherwise, the market solution would not be impacted by that specific constraint, and the market would have arrived at the same result, had that constraint been in place or not. However, if a constraint does bind it will have an impact on the market solution. If a binding constraint is removed from the constrained optimization problem, the optimization would likely arrive at a different solution.

Occasionally, when the market conditions are stressed, the optimization cannot arrive at a solution that complies with all of the modeled constraints. The optimization is formulated such that the achieved solution violates the imposed limit of the constraints. This condition is commonly called 'constraint relaxation.' When constraints are relaxed they are priced at a higher cost in the objective function than an economical solution. This cost is proportional to the degree to which a constraint is relaxed. For example, the additional cost associated with relaxing the power balance constraint by 1 MW (allowing supply to be 1 MW less than demand) is significantly less than allowing the constraint to be relaxed by 100 MW. The amount of additional cost the objective function incurs is also determined by the penalty parameter associated with the specific constraint that is relaxed. Different constraints may have different penalty prices based on the priority assigned to relax constraints. For example, in the real-time market the power balance constraint has a penalty parameter of $1,000, while transmission constraints typically have a $1,500 penalty parameter. This means that when the optimization cannot comply with the two constraints concurrently, the optimal solution will be determined by assessing the overall costs between relaxing the power balance constraint or relaxing a transmission limit. The lower the penalty price on a constraint, the lower its priority will be and the earlier it will be relaxed.

The penalty parameter for the power balance constraint is intentionally set above the bid cap, which limits how high participants can economically bid energy from resources into the market. This helps to ensure that the market optimization software will not relax the power balance constraint until all economical bids are exhausted.

2. Proposed Aggregate Capability Constraint

The ISO recently proposed new functionality for an existing constraint in the market. The proposal would allow for the use of multiple aggregate capability constraints at a single generating facility. This will more effectively optimize 'over-sized' co-located resources within their studied point of interconnection limits and will help support modeling efforts of multiple underlying contractual obligations for off-takers from the generating facility.

The ISO proposes a master aggregate capability constraint to model physical interconnection limits at the overall generating facility and subordinate aggregate capability constraints to model underlying contractual limits. The ISO also proposed to assign penalty parameters for subordinate aggregate capability constraints at a level just below the power balance constraint. Currently, the ISO applies a penalty parameter for master aggregate capability constraints that is higher than the power balance constraint.

Setting the master aggregate capability constraint at a level significantly higher than the power balance constraint means the market optimization will not relax the master constraint. Setting the subordinate aggregate capability constraint at a level just below the power balance constraint would allow the market to relax the constraint occasionally during stressed system conditions when reliability is threatened. However, similar to how the power balance constraint works today, the ISO would not relax a subordinate aggregate capability constraint for 'economic' tradeoffs. Said another way, the market optimization will not allow a resource to use capacity assigned to another aggregate capability constraint unless there are no remaining market bids to meet demand. Further, resources capable of generating will not be displaced from their share of capacity defined by the aggregate capability constraint, if those resources have the ability to generate.

As an example of this, if a scheduling coordinator for one off-taker bids energy from a resource at a very high price and a scheduling coordinator for another off-taker bids energy at a very low price, the market software will not relax the subordinate aggregate capability constraint to access more energy from the co-located resources with a low energy bid. Doing so would create additional costs in the market optimization from the penalty price associated with relaxing the subordinate aggregate capability constraint. The market optimization will relax the subordinate constraint only when it is on the verge of a supply demand imbalance and there is capacity at co-located resources behind one of subordinate aggregate capability constraints that is not available. This unavailability could occur because of outages or other operating limitations such as state of charge available from a storage resource. In this case, the market optimization may relax the subordinate constraint to reach supply from other co-located resources at the generating facility that is available to help balance demand. The following example illustrates this proposed rule.

Figure 1 illustrates a situation where the ISO may relax a subordinate aggregate capability constraint. In this illustration, there are four co-located resources at a single generating facility, subject to two subordinate aggregate capability constraints and one master aggregate capability constraints. In this particular case, assume that each solar resource is modeled as a 100 MW resource and each storage resource is modeled as a +/- 50 MW resource. Both subordinate aggregate capability constraints reflect a contractual limit of 100 MW. The forecast for both solar resources is 75 MW; one storage resource has a state of charge of 100 MWh; the other storage resource is completely depleted of state of charge. In this example, the market is not able to dispatch the second storage resource above 0 MW because it has no state of charge. If grid conditions were tight such that the market is trying to utilize any available energy before relaxing the power balance constraint, the market will relax the second aggregate capability constraint by up to 25 MW and issue a dispatch instruction to the first storage resource at up to 50 MW. This will result in 200 MW of flow on the master aggregate capability constraint, which will prevent the market from further dispatching any of the co-located resources, if more energy was available. Doing so would require a relaxation of the master ACC aggregate capability constraint that has a much higher penalty price.

In this example it was assumed that the second storage resource is unable to receive a dispatch to discharge energy. This could happen for a variety of reasons including lack of state of charge or an outage. If the second storage resource were able to receive positive dispatch instructions of up to 25 MW, the market software would not relax the subordinate aggregate capability constraint. The proposed subordinate aggregate capability constraint will ensure that the market optimization respects the contracted interconnection service capacity of 100MW dedicated to each off-taker. The market optimization will only relax the subordinate capability constraint if the off-taker cannot use the capacity for physical reasons.

Figure 1: Simple example where the sub-ACC may be relaxed