Transmission Constraint Penalty Factors

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Transmission Constraint Penalty Factors

Constrained Optimization

- PJM's unit commitment, dispatch and pricing software are all constrained optimization problems
- Minimize system cost subject to limitations (objective function)
  - Unit limitations
    - Eco min/max emergency min/max, ramp rate, startup time, notification time, etc.
  - Transmission system limitations
    - MW flow limits on lines
  - System balance
    - Generation = Load + Losses

Optimization Limitations (Constraints)

- Limitations are expressed in mathematical terms as inequalities, equalities and integer constraints
  - x < 500
  - a + b + c = 10
  - Line Flow <= Line Limit
  - DispatchMW + Tier2MW <= EcoMax
  - Reserve MW >= Reserve Requirement

- These limitations/constraints confine the solution

Penalty Factors

- “Soft constraints” are those that can be violated in the optimization (if needed) in order to reach a solution
- Because it is desirable to find a solution that adheres to all constraints, **penalty factors** are assigned to discourage the optimization from violating a constraint
- The current **penalty factor** for not meeting a reserve requirement in PJM is $850/MWh

Penalty Factor Hierarchy

- Constraints that are the most desirable to adhere to typically have the highest penalty factors associated with them
  - Power Balance
  - Transmission facility limits

- Each time a constraint is violated, the objective function is penalized
  - Penalty Factor * MWh of violation

- Penalizing the objective function increases the cost of the solution and acts as a deterrent

Marginal Value Limits

- The IMM presented on Marginal Value Limits at the September MC Webinar
- **Penalty Factors** and **Marginal Value Limits (MVL)** are the same
  - Marginal Value Limit is the term used to describe a penalty factor associated with the violation of a transmission constraint
- A $2,000/MWh Marginal Value Limit means PJM will not dispatch beyond a cost of $2,000/MWh to control a constraint

Use of Penalty Factors

- Penalty factors are use in every application of constrained optimization
  - Transportation
  - Energy (PJM, MISO, NYISO, ISONE, CAISO)
  - Telecommunications
  - Airline

- They are necessary to produce feasible solutions when all constraints cannot be honored

Penalty Factors and Price-Setting

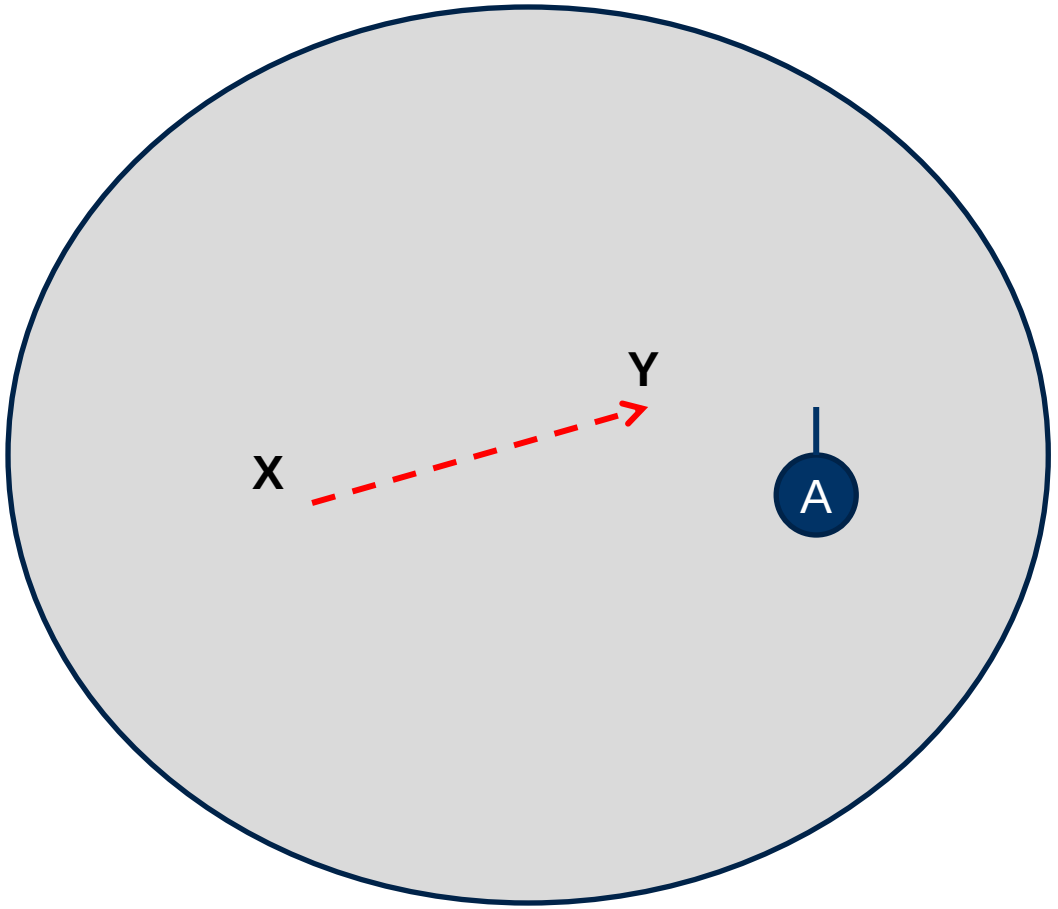
- Penalty Factors can be used to set market clearing prices or disallowed from setting market clearing prices
  - When we are short reserves and in shortage pricing, the penalty factor is setting the clearing price for reserves and used in the determination of the LMP
  - When we are short reserves and **NOT** in shortage pricing, the reserve constraint is relaxed so that the penalty factor cannot set the clearing price
- The same concepts apply to penalty factors for transmission constraints (or marginal value limits)

Transmission Constraint Penalty Factors

- Today, PJM does not use marginal value limits to set prices
- In the case that a constraint is violated, PJM relaxes the limit on the constraint (increases it) in order to arrive at a feasible solution
- Under this method, the most expensive resource at a price less than or equal to the marginal value limit will set the price

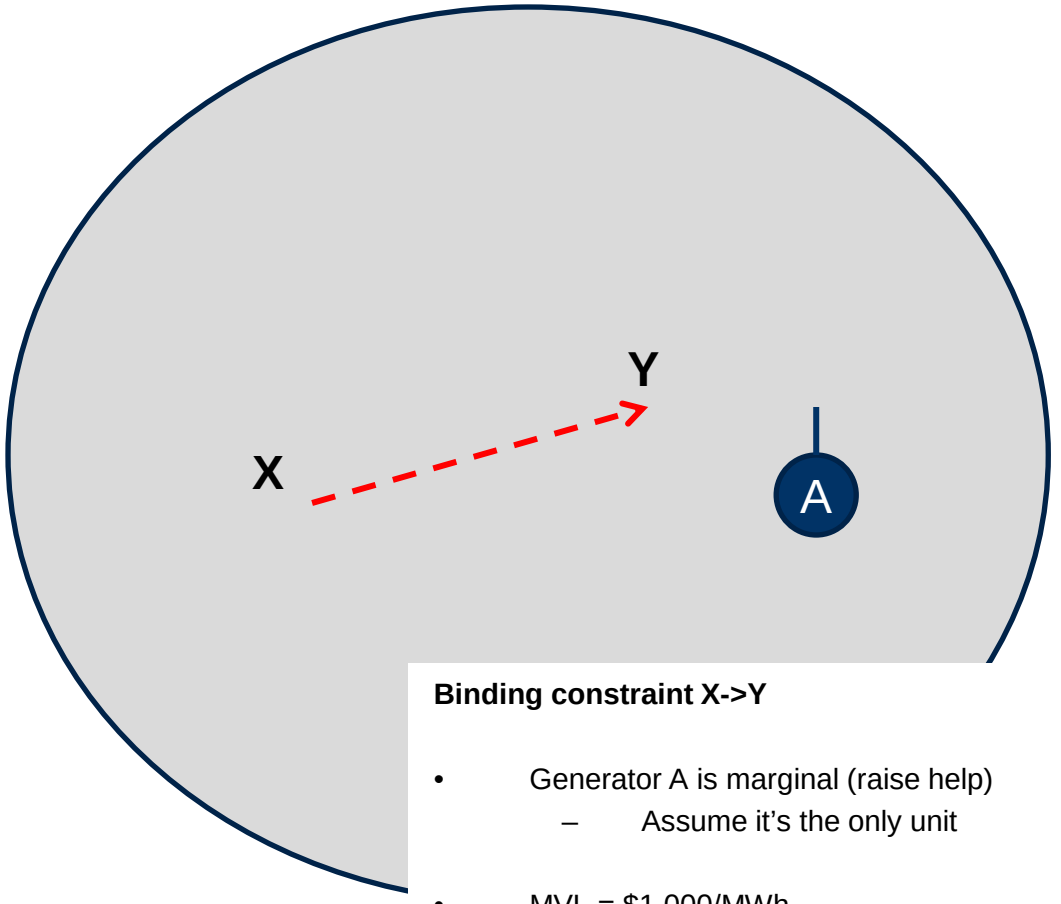
Binding constraint X->Y

- Generator A is marginal (raise help)
  - Assume it's the only unit
- MVL = $1,000/MWh
- XY Line Limit = 500 MW



Binding constraint X->Y

- In this scenario PJM can only use Gen A to control the constraint
- PJM will dispatch Gen A to a cost of $1,000/MWh to maintain the 500 MW limit on line XY
- If that is not adequate, the line limit will be violated



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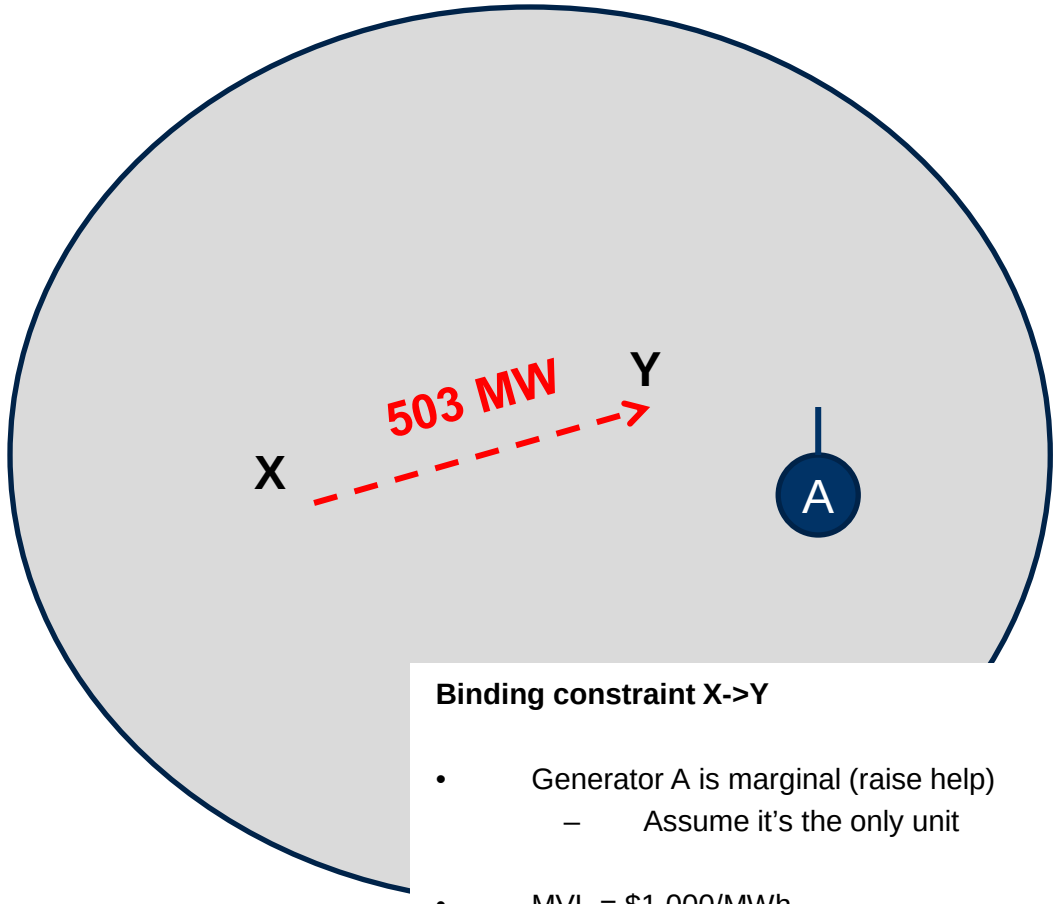
Example: Constraint Relaxation

Binding constraint X->Y

- Suppose the constraint cannot be controlled and the flow is 503 MW
- PJM will relax the constraint to ensure the $1,000/MWh MVL does not set the price
- This is done by increasing the constraint limit to just above 503 MW and resolving the optimization



Binding constraint X->Y

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Pricing Outcomes

- The pricing outcome of this relaxation is that Gen A's offer sets the price at the level PJM dispatches it based on the $1,000/MWh MVL limit
- This could result in a marginal value (or shadow price) for constraint XY that…
  1. is equal to the MVL if the cost to dispatch Gen A out-of-merit is $1,000/MWh, or,
  2. is lower than the MVL is the cost to dispatch Gen A out-of-merit to its full capability is less than the MVL.

Actions

- If the constraint is violated (Flow > Limit) and Gen A's relief capability is limited by the MVL the MVL could be increased to fully control the constraint.
- PJM system operators have the ability to adjust the MVL based on system conditions and available controlling actions.
- The default marginal value limit for PJM constraints is $1,000/MWh.