Transmission Constraint Control Logic in Market Clearing Engines

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April 12, 2017

Background

- The objective of the document is to describe how transmission constraint control logic, including constraint relaxation, is performed in PJM's market clearing engines (MCE).
- While there are multiple MCEs that clear the various PJM markets, the method used to control transmission constraints is done uniformly across all applications.

What are Transmission Constraint Penalty Factors?

- Transmission constraint penalty factors are parameters used by the MCE to determine the maximum cost willing to be incurred to control a transmission constraint.
- The transmission constraint penalty factor parameter itself is defined in $/MWh terms
- The ultimate effect of the penalty factor is that it limits the controlling actions the MCE can take to resolve a constraint by limiting the cost that is willing to be incurred to control it.

What Are Transmission Constraint Penalty Factors?

- The transmission constraint penalty factor does not directly impact the shadow price of a constraint as long as the constraint can be solved by resources whose effective costs are lower than the value of the penalty factor.

Unit Effective Cost

- The cost of using a resource to control a constraint, or its effective cost, can be calculated using the equation below.
  - Effective Cost ($/MWh) = |(Energy Price – Incremental Cost) / Dfax|
- Holding the denominator constant, the effective cost will increase as the difference between the energy price and a resource's marginal cost grows larger.
- Holding the numerator constant, the effective cost will increase as the resource's dfax on the constraint gets smaller.

Penalty Factor Defaults and Exceptions

- PJM internal constraints, regardless of voltage level, are defaulted to a $2,000/MWh transmission constraint penalty factor
  - Selected as the default value because historically most constraints can be effectively controlled at a cost below $2,000/MWh
- The default value can be overridden on an individual constraint basis
  - Dependent on system conditions and the amount of generation able to be re-dispatched to control the constraint

- Input Variables to the MCE
  - **Constraint Limit.** The constraint limit is typically the long-term thermal rating of the facility (usually a 4-hour rating). It is passed to the MCE from the EMS for each active constraint.
  - **Limit Control.** The limit control is the percentage of the constraint limit to which the operator controls the constraint.
  - **Target Limit.** The target limit is the product of the constraint limit and the limit control and is ultimately the limit to which the MCE attempts to control the constraint.
    - Target Limit = Constraint Limit * Limit Control
  - Transmission Constraint Penalty factor
  - Resource Dfax
  - Resource specific information (offer curve, economic limits, ramp rate etc.)

Constraint Control Outcomes

- The objective of the constraint control logic is to dispatch the least cost set of resources to meet the target limit of the constraint at a marginal cost at or below the transmission constraint penalty factor.

Constraint Flow	Violation Degree (MW)	Shadow Price ($/MWh)	Constraint Outcome
< Target Limit	0	0	non-binding
= Target Limit	0	non-zero < penalty factor	binding
> Target Limit	non-zero	= penalty factor	binding & violated; constraint relaxation applied

Violation Degree = amount by which the solution flows exceed the target limit

Constraint Relaxation

- PJM does not allow the transmission constraint penalty factor to set the shadow price of a constraint.
  - The longstanding business practice is to have the price set by a resource that is providing constraint control in the dispatch solution
- In the MCE, constraints that are violated must be relaxed to prevent the penalty factor of a violated constraint from setting the clearing price (referred to as Constraint Relaxation).
- For a constraint which initially solves with a non-zero violation degree, the constraint relaxation logic adds the violation degree back to the target limit of the constraint and re-solves.

Constraint Control Examples

Example 1: Binding Constraint, Zero Violation Degree (adequate control)

- Inputs:
  - Penalty Factor = $2,000/MWh
  - Constraint Limit = 100 MW
  - Limit Control = 95%
  - Target Limit = 95 MW
- Final Constraint Solve:
  - MCE calculated flow on the constraint = 95 MW
  - Violation Degree = 0 MW
  - Shadow Price of the constraint = $500/MWh

Example 2 - Constraint Is Violated and Constraint Relaxation Logic Is Applied

- Inputs:
  - Penalty Factor = $2,000/MWh
  - Constraint Limit = 100 MW
  - Limit Control = 90%
  - Target limit = 90 MW
  - Target Limit = ~~90~~ **95** MW

Initial Constraint Solve Results
Calculated Flow = 95 MW
Violation Degree = 5 MW
Shadow Price = $2,000/MWh
Constraint Violated ➡ Apply Constraint Relaxation!

Constraint Relaxation Solve Results
Calculated Flow = 95 MW
Violation Degree = 0 MW
Shadow Price = $1,200/MWh