Transmission Constraint Penalty Factors - Education

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April 5, 2022

Background

- As highlighted in the Issue Charge, the use of transmission constraint penalty factors (TCPF) have the potential to impact the total LMP
- Currently, limited language exists to allow adjustments to the default TCPFs to ensure prices are consistent with system needs
- System conditions related to the Lanexa-Dunnsville-Northern Neck 230 KV circuit triggered the need to review guidelines where the default TCPF can be adjusted
  - FERC accepted PJM's filing to lower the default TCPF for constraints related to the outage (effective 2/1/22)

Transmission Constraint Penalty Factors

Transmission Constraint Penalty Factors
These are parameters used by the Security Constrained Economic Dispatch (SCED) applications to determine the maximum cost of the re-dispatch incurred to control a transmission constraint.

- The transmission constraint penalty factor parameter is defined in $/MWh terms
- The ultimate effect of the Transmission Constraint Penalty Factors is to limit the controlling actions that can be taken to resolve a constraint by respecting the cost limits that the system is willing to incur to control it

Transmission Constraint Penalty Factors

As a result of a 2018 stakeholder process initiative, the **Transmission Constraint Penalty Factor** is allowed to set the shadow price of a transmission constraint in the market-clearing software when the constraint cannot be adequately controlled in the market-clearing software.

- Effective on February 1, 2019
- Implementation was a result of a joint PJM/IMM package

Transmission Constraint Penalty Factor Defaults

- 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 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

Terminology

- **Penalty Factor ($/MWh):** Maximum value of the constraint shadow price, maximum cost willing to incur for relief
- **Initial Flow**: Current flow on the constraint (monitored facility)
- **Target Limit**: Constraint is being controlled to
- **Available Relief MW**: Amount of MW available to relieve congestion on constraint
- **Distribution Factor (DFAX)**: percentage of relief on a constraint, unique for each resource and constraint
  - Positive value = Lowering resource output to provide relief
  - Negative value = Raising resource output to provide relief
- **Shadow Price ($/MWh):** Solution derived, effective cost of controlling the constraint, amount willing to be paid for 1 MW of relief

Transmission 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 < TCPF	binding
> Target Limit	non-zero	= TCPF	Bind at the penalty factor

Violation Degree = amount by which the constraint flow exceed the target limit

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) = |(Offer - System Energy Price) / 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.

PJM Tariff Attachment K, Section 5.6.3

Example Overview

- Example 1
  - Single constraint
  - Sufficient relief available
  - Constraint binding at a shadow price below the TCPF
  - Calculation of LMP
- Example 2
  - Single constraint
  - No material relief available
  - Constraint binding at TCPF
  - Calculation of LMP

Example 1 – Constraint binding below TCPF

- Inputs
  - Default TCPF = $2,000/MWh
  - Initial Flow = 110
  - Target Limit = 100
  - Available relief MW = 10
- Outputs
  - Calculated flow on the constraint = 100
  - Violation Degree (MW) = 0
  - Shadow Price = non-zero
    - less than Default TCPF

- When sufficient relief MWs are available to control constraint, bind at effective cost of the controlling resource (shadow price)
- The flow on the constraint can be controlled with the available relief, constraint does not bind at the TCPF

Example 2 – Constraint Binding at TCPF

- Inputs:
  - Default TCPF = $2,000/MWh
  - Initial Flow = 110
  - Target Limit = 100
  - Available relief MW = 4
- Solution:
  - Calculated flow on the constraint = 106 MW
  - Violation Degree (MW) = 6
  - Shadow Price = $2,000/MWh

- The flow on the constraint **CANNOT** be controlled with the available relief, constraint binds at the TCPF

LMP (Locational Marginal Pricing) =

Congestion Component (CLMP)

- Represents price of congestion for binding constraints
- Uses the Shadow Price
- Will be zero in an Unconstrained System
- Varies by pnode (electrical “location”) if system is constrained
- Load pays Congestion Price, Generation is paid Congestion Price

Pnode LMP Calculations

- Inputs from **Example 1:**
  - Shadow Price = $325/MWh
  - DFAX = -0.998 (Raise Help)
  - Energy LMP = $40
  - Loss LMP = $1.50
- Solution

System Energy Price	$40
Loss LMP	$1.50
Congestion LMP	$324.35
Total LMP	**$365.85**

- Inputs from **Example 2:**
  - Shadow Price = $2,000/MWh
  - DFAX = -0.998 (Raise Help)
  - Energy LMP = $40
  - Loss LMP = $1.50
- Solution:

System Energy Price	$40
Loss LMP	$1.50
Congestion LMP	$1996
Total LMP	**$2,037.50**

Congestion LMP = SUM (ABS (∑ Dfax * constraint shadow price))

Example LMP Calculation – Multiple Constraints

	System Energy Price	X	* 1.0	=	System Energy Component
System Energy Component	$33.11	X	1.0	=	$33.11

	System Energy Price	X	Marginal Loss Sensitivity Factor	=	Marginal Loss Component
Loss Component	$33.11	X	-0.0315	=	($1.04)

Congestion Components	Constraint Shadow Price	X	DFAX	=	Congestion Component
Constraint A	-$9.96	X	-0.3151	=	$3.14
Constraint B	-$13.88	X	0.1225	=	($1.70)
Constraint C	-$26.06	X	-0.2151	=	$5.61
Constraint D	-$2000	X	-0.0200	=	$40.00
				LMP =	$79.12

Adjusting TCPF Examples

Why Adjust Default TCPF?

- Default TCPF can be raised or lowered per individual constraint to enable resources controlling a transmission constraint to set LMP
- The tariff defines scenarios for adjustments:
  - Increase: when sufficient congestion relief on the constraint cannot be provided by available resources at a cost below the default
  - Decrease: sufficient congestion relief on the constraint can be provided by available resources at a cost below the default TCPF in order to prevent a high cost resource that cannot provide material congestion relief on the constraint from inappropriately setting price for the constraint

PJM Tariff Attachment K, Section 5.6.3

Impact of Adjustments to Default TCPF

- Adjustments to the default TCPF are based on the effective cost ($/MW) of an impactful resource on a transmission constraint:
  - If the default TCPF is lowered, then cost of the controlling action is limited ($/MWh is lowered)
  - If the default TCPF is increased, then cost of the controlling action can go up to the raised value ($/MWh is increased)
- PJM incorporates a buffer typically of 25% above the effective resource's effective cost when adjusting the default TCPF:
  - This buffer accounts for any fluctuation in the system energy price that would increase a resource's $/MW cost

Increasing Default TCPF Example

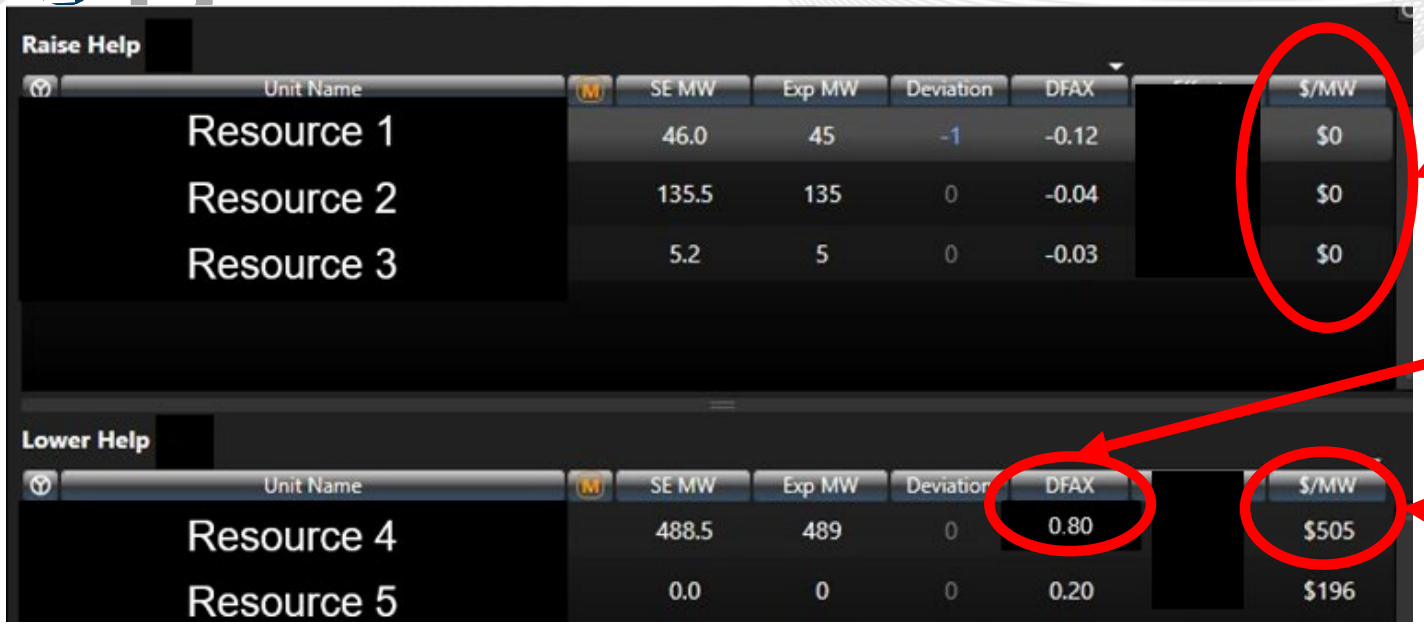
- Limited number of effective resources are available
- Constraint relief required from a resource with an effective cost above the $2,000 default TCPF
- Example:
  - Effective Cost = (Offer-System Energy Price) / dfax
  - ($250-$25) / 10% = $2,250
  - $2,250 x ~1.25% buffer, new default value is set to ~$2,800
    - The increased default TCPF allows the resource to be eligible to set LMP

Decrease Default TCPF

- A thermal surrogate is used to set price for a resource called for voltage control and the resource's $/MW is lower than the default TCPF

- Prevent RTSCED from utilizing resources with high effective cost and small material relief for the constraint:
  - Avoid ACE deviations or system control issues
  - Send actionable price signals
  - Reduces uplift payments

Decrease Default TCPF Example (Pricing)



All raise help resources at economic maximum

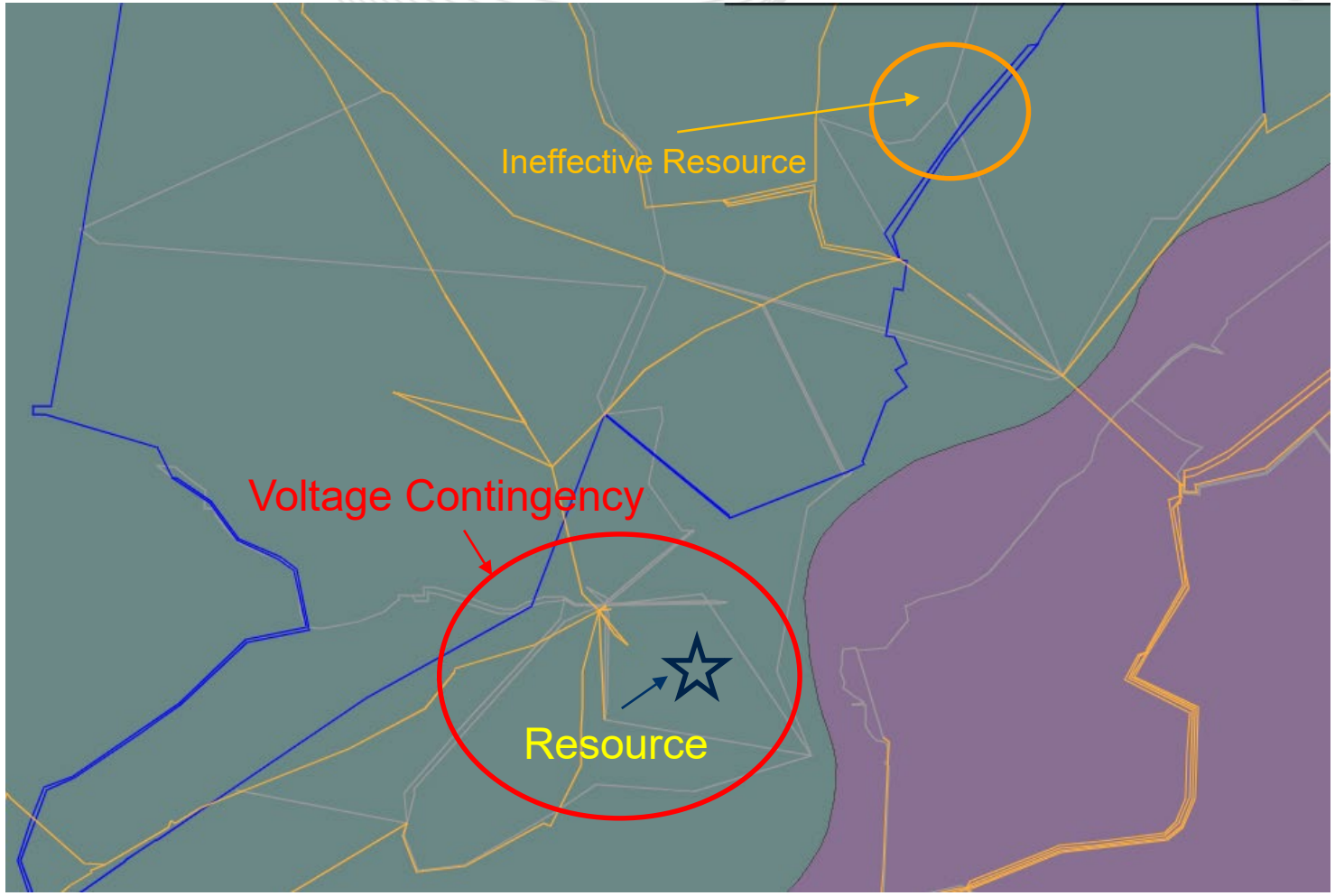
Resource Dfax

Resource 4 is target resource, no additional resources available up to TCPF

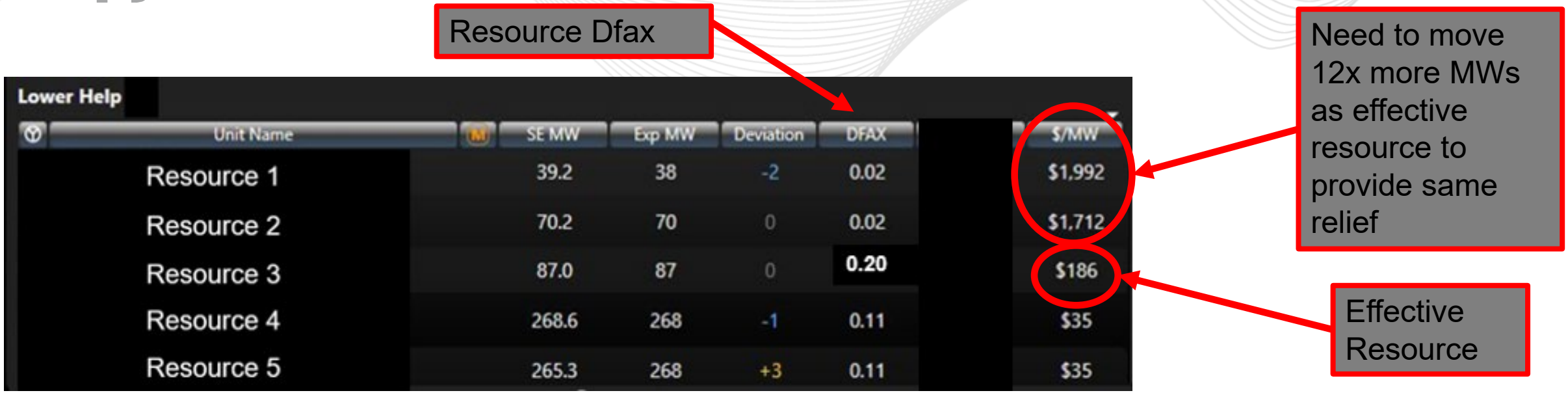
- Used for thermal surrogates and local constraints
  - Resource 4 is a target resource
  - No additional material relief available

- Decrease Default TCPF
  - Effective Cost = (Offer-System Energy Price) / dfax
  - ($419-$15) / 80% = $505/MWh
  - 25% Energy Price buffer
  - Lower default TCPF to ~$632/MWh

Decrease Default TCPF Example Illustration (Pricing)



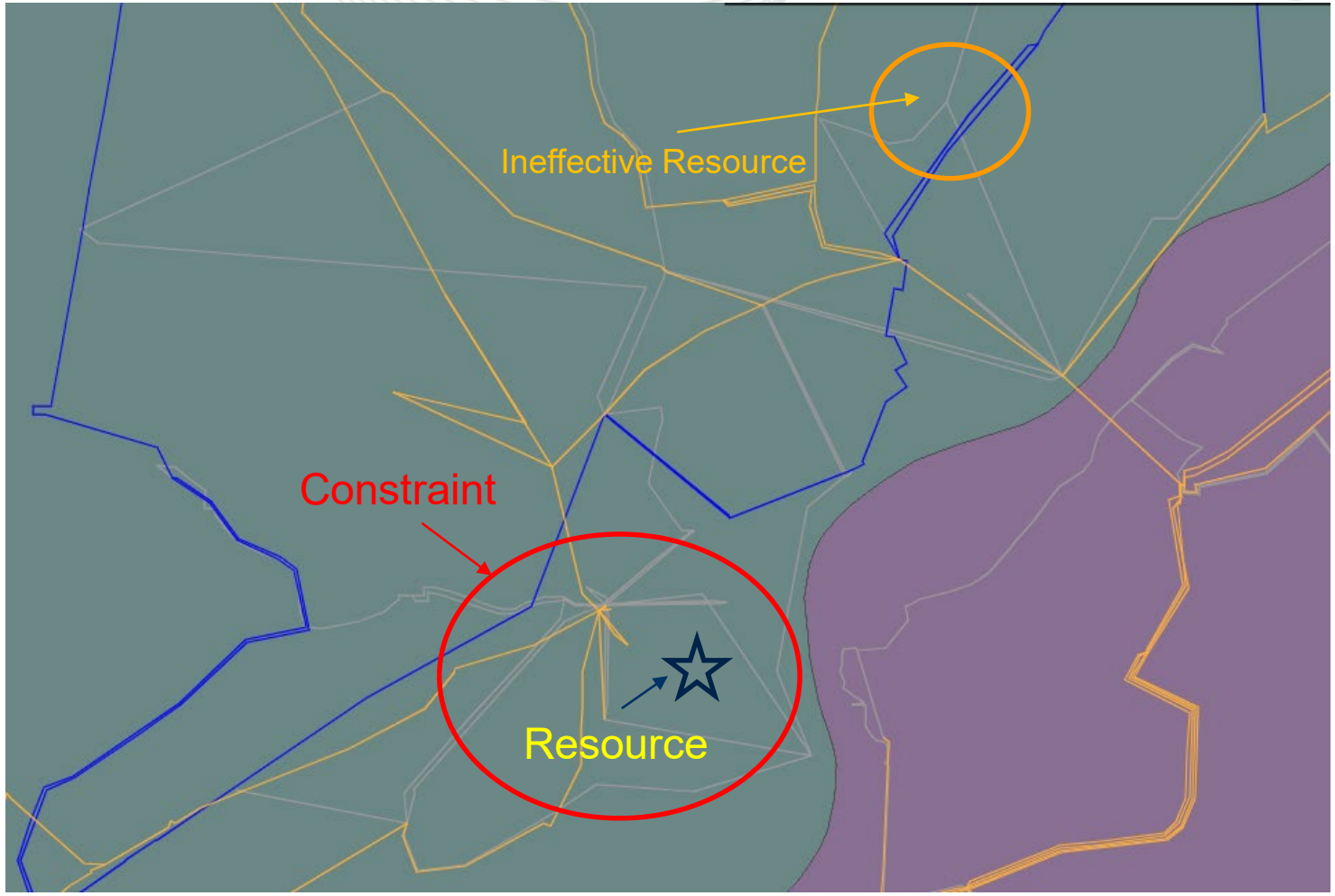
Decrease Default TCPF Example (ACE Control)



- Significant amount of MW needed from resource 1 and 2 to provide any material relief
  - Could lead to ACE Control Issues
- Resource 3 able to provide 20% relief

- Decrease Default TCPF
  - Effective Cost = (Offer-System Energy Price) / dfax
  - ($52.20-$15) / 20% = $186/MWh
  - Additional 25% Energy Price buffer
  - Lower default TCPF to ~ $233/MWh

Decrease Default TCPF Example Illustration



Transparency

- PJM posts all constraints where the default TCPF of $2,000/MWh is adjusted for Real-Time
  - https://dataminer2.pjm.com/feed/rt_default_mv_override

- PJM posts the Real-Time binding constraints and the TCPF value used
  - https://dataminer2.pjm.com/feed/rt_marginal_value

Additional Reference Material

- PJM Tariff Attachment K, Section 5.6.3
- PJM Manual 11, Section 2.17: Applying Transmission Constraint Penalty Factors in the Market Clearing Engine
- White Paper – Marginal Value Limit Adjustments – 6/27/2018

Contact

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