



Three Pivotal Supplier Test: Theory and Application

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- Overall approach to market design
 - Market design should not require market power for sustainability
 - Market power mitigation in the context of non-competitive market structure
 - Overall efficiency of the market has to also include sustainability:
 - RPM, Ancillary services, real time and day ahead markets
 - Scarcity rules
 - Market power mitigation



- On November 16, 2005, PJM filed a “Settlement Agreement” resolving all issues regarding PJM's market power mitigation rules:
 - the three pivotal supplier test
 - provisions for scarcity pricing
 - offer caps for frequently mitigated units
 - PJM’s internal interfaces.



- 3 pivotal supplier test
 - More precise market mitigation
 - Market structure test
 - Behavior test
 - Impact test
- Modification of Frequently Mitigated Units rules
 - Provides an adder to unit cost offers if the unit qualifies

- **Scarcity Pricing Rules**

- Triggers: emergency energy request events; maximum emergency generation events; manual load dump events; and voltage reduction events.
- Based on the implementation of one or more of these emergency actions over a predetermined scarcity pricing zone.
 - an area consisting of two or more contiguous zones with 5 percent or greater positive distribution factor (“dfax”) relative to concurrently binding 500 kV or greater transmission constraints.
- Effect: Price goes to the highest offer of a unit running for PJM within the zone.



- The Commission adopted market power screens and tests in the AEP Order.
 - 107 FERC ¶ 61,018 (2004) (AEP Order)
 - defined two indicative screens and the dispositive delivered price test.

- **Delivered price test**
 - Defines the relevant market as all suppliers who offer at or below the clearing price times 1.05 and applies:
 - pivotal supplier analysis – fail if pivotal
 - market share analysis – fail is 20% or more mkt share
 - market concentration analysis—fail if $HHI > 2500$

- The three pivotal supplier test is a reasonable application of the Commission's delivered price test
 - HHI and Market share can vary
 - Tests for whether excess supply is adequate to offset other structural features of the market (pivotal and market share results) and result in an adequately competitive market structure.
 - The greater the supply relative to demand, the less likely that three suppliers will be jointly pivotal, all else equal.

- The goal of the three pivotal supplier test, proposed by PJM, was not to weaken the local market power rules but to make them more flexible by adding an explicit market structure test.
 - Goal is to lift mitigation in constrained markets where the market structure is reasonably competitive
 - Does not guarantee competitive results
 - Subject to annual review by the MMU

- The three pivotal supplier test is a
 - **structure test**
 - a participant **behavior test**
 - a market **impact test**.

- The three pivotal supplier test measures the degree to which the supply from three generation suppliers is required in order to meet the demand to relieve a constraint.
 - Test of the market that is relevant to the relief of the constraint

- Two key variables in the analysis are the demand and the supply.
 - Demand consists of the incremental, effective MW required to relieve the constraint.
 - Total supply consists of all effective MW of supply incrementally available to relieve the constraint at a distribution factor (DFAX) greater than or equal to the DFAX used by PJM in operations

- Incrementally available effective MW of supply from a unit is dependent on:
 - DFAX of the unit relative to the constraint
 - Within hour incrementally available capacity over current load levels.
 - Effective, incrementally available MW from an unloaded 100 MW 15-minute start combustion turbine (CT) with a DFAX of .05 to a constraint would be 5 MW relative to the constraint in question.
 - Effective, incrementally available MW from a 200 MW steam unit, with 100 MW loaded, a 50 MW ramp rate and a DFAX of .5 to the constraint would be 25 MW.

- Incrementally available effective MW of supply from a participant is dependent on:
 - Incrementally effective MW from units attributed to that participant on the basis of their control of the assets in question.
 - Generation capacity controlled directly or indirectly through affiliates or contracts with third parties are attributed to a single supplier.
 - Tests the portfolio of a participant, not individual units, for pivotal status in the defined market

- **Relevant Effective Supply (S)**
 - Incremental, effective MW of supply that are available at a price less than, or equal to, 1.5 times the clearing price (P_c) that would result from the intersection of demand (constraint relief required) and the incremental supply available to resolve the constraint.

- In every case, incrementally available supply (S_i) is measured as incremental effective MW of supply, as shown in the following equation:

$$S_i = MW(P_{ie}) \cdot DFAX_i \quad \text{Where:}$$

Price of the clearing offer

$$P_c = \frac{\text{Offer}_c - \text{SMP}}{DFAX_c}$$

$$P_{ie} = \frac{\text{Offer}_i}{DFAX_i} \leq 1.5 \cdot P_c$$

- **Total relevant, effective supply**
- Where, S_i is the relevant effective supply (relevant, incremental and effective supply) of supplier i , total relevant effective supply (total relevant, incremental and effective supply) for suppliers $i=1$ to n :

$$S = \sum_{i=1}^n S_i$$

- Each effective supplier, from 1 to n , is ranked, from largest to smallest relevant effective supply, relative to the constraint for which it is being tested.
- In the first iteration of the test, the two largest suppliers are combined with the third largest supplier, and this combined supply is subtracted from total relevant effective supply, described above.
- The resulting amount of net relevant effective supply is divided by the total relief required (D).

- Where j defines the supplier being tested in combination with the two largest suppliers (initially the third largest supplier with $j=3$), Equation 0-6 shows the formula for the three pivotal supplier metric, the three pivotal residual supplier index (RSI3).

$$RSI3_j = \frac{\sum_{i=1}^n (S_i) - \sum_{i=1}^2 (S_i) - S_j}{D}$$

- Where this ratio (RSI3) is less than or equal to one, the three participant portfolios of effective and relevant supply tested fail the test

- Where $j=3$, if RSI_{3j} is less than, or equal to, 1.0, the three largest suppliers in the market for the relief of the constraint fail the three pivotal supplier test.
 - That is, the three largest suppliers are jointly pivotal for the local market created by the need to relieve the constraint using local, out of merit units.
- If RSI_{3j} is greater than 1.0, the three largest potential suppliers of relief MW pass the test and the remaining suppliers ($j=4..n$) pass the test.
- In the event of a failure of the three largest suppliers, further iterations of the test are needed, with each subsequent iteration testing a subsequently smaller supplier ($j=4..n$) in combination with the two largest suppliers.

- In each iteration, when RSI_{3j} is less than 1.0, it indicates that the tested supplier, in combination with the two largest suppliers, has failed the test.
- Iterations of the test continue until the combination of the two largest suppliers and a supplier j achieve a result of RSI_{3j} greater than 1.0. When the result of this process is that RSI_{3j} is greater than 1.0, the remaining suppliers will pass the test.

- If a supplier fails the test for a constraint, units that are part of a supplier's relevant effective supply with respect to a constraint can have their offers capped at cost + 10%, or cost plus relevant adders for frequently mitigated units and associated units.
- However, capping only occurs to the extent that the units of this supplier's relevant, effective supply are offered at greater than cost + 10% and are actually dispatched to contribute to the relief of the constraint in question.



Basic theoretical concepts (Structure, Conduct and Impact)

- 3 pivot results vs. relevant market
 - Example of portfolio distribution in included supply
 - HHI vs. 3 pivot result
 - Ability to exercise market power

THIS SLIDE IS A PLACEHOLDER for new analysis section

- Basic test as applied to RT
 - Determination of demand
 - Determination of supply
 - Available effective supply
 - DFAX Online units with room to move, $\text{Min}(\text{RAMP}, \text{MW remaining}) \times \text{DFAX}$
 - Offline units with relevant start times (less than 1 hour) $\text{Min}(\text{RAMP}, \text{MW available}) \times \text{DFAX}$
 - Supply curve effective cost based on Cost offers (unless exempt) of offline units units and DFAX

- Determination of supply (Cont.)
 - Available and relevant supply (subset of available and effective supply)
 - Available and effective supply with effective costs $<$ or equal to 1.5 times the shadow price of the constraint based on Cost offers (unless exempt) of units

- DA and RT implementation differ
 - Tested intervals
 - Supply and demand components
 - Ramp limit enforcement
 - Solution optimization
 - Offer mitigation

- DA market is solved hourly, therefore TPS tests are performed based on the structure of each hour's market solution
- Each hour in DA constitutes a unique market structure
- RT calculations are on 5 minute intervals, therefore multiple tests may be executed within an hour
- Each interval in RT constitutes a unique market structure

- DA implementation includes virtual bids
 - INC offers are treated as supply
 - DEC bids are part of system load and affect flows on transmission elements
 - INC offers are part of a participant's portfolio of supply for purposes of the TPS test
 - Virtual bids have no cost basis and are therefore not subject to mitigation due to a failing TPS test score

- DA ramp limits are not enforced in the same manner as in RT
- DA optimization process allows starting of units ahead of constraint
- RT implementation must respect ramp ability of units based on current state and physical capability of specific resources

- RT solution optimized based on actual operating conditions and unit start/notification times and ramp limits
- DA solution optimizes resource selection based on entire operating day
- DA solution may “go back in time” and start a unit so that it will be available when needed

- Both DA and RT mitigated units may be operated on their price based schedule
- RT mitigation selects the lesser of a resource's price or cost offer
- DA mitigation optimizes schedule selection based on offer price and other bid parameters
- DA mitigation will select the offer schedule which results in the lowest system production cost over the operating day

- MMU currently reviewing implementation of TPS in DA and RT markets
- MMU will recommend improvement opportunities as identified

- Ensure non-exempt constraints are consistently tested in DA implementation
- Creation of reliable and complete record of DA testing inputs, results and related operator actions
- Link specific test results in DA and RT to system operator mitigation decisions
- Ensure DA implementation is consistent with physical resource capabilities and operational practices



Units Eligible for Mitigation - Results

Constraint	Period	Average Number Units	Average Number of Units Eligible for Mitigation	Average Percent of Units Eligible for Mitigation
5004/5005 Interface	Peak	412.5	2.6	1.1%
	Off Peak	354.2	1.5	0.4%
Bedington - Black Oak	Peak	253.6	1.8	0.8%
	Off Peak	227.3	1.2	0.5%
AP South	Peak	372.0	5.5	1.8%
	Off Peak	330.6	3.9	1.1%
Western	Peak	426.7	0.3	0.1%
	Off Peak	392.4	0.7	0.1%
Central	Peak	448.7	0.7	0.3%
	Off Peak	434.1	0.0	0.0%
Eastern	Peak	257.8	10.6	6.5%
	Off Peak	292.0	42.0	14.4%

- The results indicate that a very small proportion of the units failing TPS are eligible for mitigation.
- Units actually mitigated are a subset of the units that both fail the TPS and are eligible for mitigation.
- Units that fail the TPS are mitigated only when they are the least cost solution to the constraint and they are brought on to relieve the constraint

- The small number of tests which may result in mitigation does not support PJM's assertion that TPS may result in "over mitigation" or "false positive" outcomes.
- PJM does not link specific test results to dispatcher mitigation decisions.
- When the data is available, the MMU will include such analysis in its quarterly reports.