Triennial Review of VRR Curve Shape

Background

"Demand" in PJM's RPM auctions is described by the Variable Resource Requirement (VRR) curve, a segmented downward-sloping curve supporting the primary RPM objective of attracting and retaining sufficient capacity to meet resource adequacy objectives. A downward sloping demand curve for capacity should achieve the following objectives:

1. Provide an indication of the incremental reliability and economic value of capacity at different planning reserve levels, in contrast to a vertical demand curve in which the value of capacity is only defined at the installed reserve margin target
2. Avoid the extreme capacity price volatility that a vertical curve might produce by allowing capacity prices to change gradually with changes to supply and demand, and reflect the idea that capacity beyond the installed reserve margin target has value
3. Reduce the risk in capacity investment by mitigating price volatility and providing a consistent stream of revenue, encouraging investment when it is needed at a lower cost to the system
4. Mitigate the potential exercise of market power by moderating the change in price produced by a change in supply

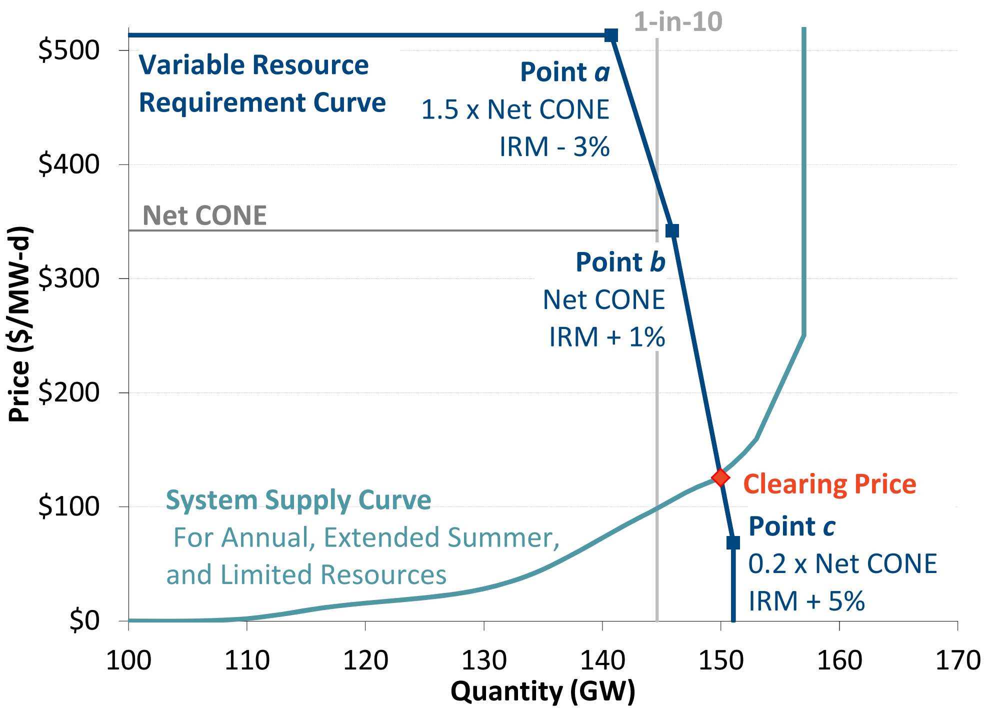
As part of the tariff-required periodic review of the VRR curve shape and parameters, The Brattle Group has conducted a comprehensive review of the shape of the VRR curve and has made numerous recommendations for changes to the curve shape to improve the overall performance of the VRR curve, including the primary RPM objective of procuring sufficient capacity to meet the 1 event in 10 years, or 1-in-10, loss of load expectation (LOLE) reliability standard, to which PJM is required to plan according to ReliabilityFirst (RFC) requirements.

This document focuses on those Brattle recommendations related to the VRR curve shape that PJM believes are critical for continuation of a well-functioning RPM capacity market.

Current VRR Curve

As shown in Figure 1, the current VRR curve is anchored at point "b" at a price of Net CONE and quantity at one percentage point above the installed reserve margin (IRM) needed to satisfy the system-wide Reliability Requirement. Net CONE is determined as the estimated nominal levelized fixed costs of new entry (Gross CONE) based on a 20 year asset life of a combustion turbine *net* of estimated energy and ancillary service (E&AS) margins (net revenues). The Reliability Requirement is the quantity needed to meet the 1 event in 10 years, or 1-in-10, loss of load event standard. The VRR curve yields a capacity price equal to Net CONE at point "b", at the target reserve margin plus 1 percentage point, or IRM + 1%. For lower supply levels to the left of point "b", capacity prices increase linearly until the quantity drops to IRM - 3% at point "a", where the capacity price is capped at the greater of: (1) 150% of Net CONE, or (2) 100% of Gross CONE. At higher reserve margins to the right of point "b", capacity prices decline linearly until IRM + 5% at point "c", where capacity price is equal to 20% of Net CONE. At even higher reserve margins, the capacity price drops to zero.

Figure 1
Capacity Supply and Demand in RPM
(Example: 2014/15 Base Residual Auction)



Performance Assessment of Current VRR Curve

The Brattle Group has conducted an extensive qualitative and quantitative analysis of the current VRR curve. The quantitative analysis included detailed probabilistic simulations of RPM auction outcomes using a Monte Carlo simulation model that estimates the distribution of capacity market price and procured quantity outcomes under a particular demand curve shape for 1,000 capacity market outcomes. This analysis supports, reinforces and quantifies their qualitative analysis of the current VRR curve and curve alternatives. Brattle's key findings from this thorough review of the performance of the current VRR curve are:

(1) The current VRR curve fails to meet the 1-in-10 LOLE reliability objective on a long-term average basis and shows procurement below the reliability requirement 35% of the time and procurement below a 1-in-5 LOLE (approximately IRM - 1%) 20% of the time. These results differ from RPM market experience to date because the probabilistic simulations are based on long-term equilibrium market conditions under which existing surplus resources and low-cost sources of new capacity are exhausted; whereas, RPM was initiated at a time of relative supply excess overall in the RTO and is only now approaching (but has not yet reached) long-run equilibrium reserve margins.

(2) Relative to a vertical demand curve, the downward-slope of the current VRR curve is consistent with its design objectives: prices above net CONE when the system is short resources (capacity less than IRM), prices below net CONE when the system is long (capacity greater than IRM), and working to mitigate price volatility and the potential exercise of market power. However, the concave shape of the current VRR curve is inconsistent with the incremental reliability value of capacity making it less effective at meeting certain design objectives than other shapes such as a straight line or convex shape. Figure 2 illustrates the impact of a 4% shift in reserve on LOLE and capacity market price using the current VRR Curve. Going from the IRM + 1% (16.7% or Point "b") to IRM + 5% (20.7% or Point "c") on the current curve reduces the LOLE from 0.06 to less than 0.01 events per year (better than 1 event in 100 years) and the change in capacity market price (or the marginal benefit in dollar terms) is <u>reduced by 80%</u> of Net CONE under the current VRR Curve. A 4% shift in reserve from IRM + 1 (16.7% or Point "b") to IRM – 3% (12.7% or Point "a") increases the LOLE from 0.06 to approximately 0.4 events per year (1 event in 2.5 years), but capacity market prices <u>only rise by 50%</u> of Net CONE. This result is counter-intuitive in that as the system becomes shorter, capacity market prices should rise more rapidly to signal the increasingly short resource position to encourage new entry rather than less rapidly as is the case with the current concave VRR Curve shape. Similarly, as the system becomes longer, capacity market prices should fall less rapidly, signaling that incremental capacity above the IRM has value, though the value is decreasing as the system becomes longer. In contrast the current concave VRR Curve looks increasingly like a vertical curve at higher reserve margins not reflecting the value of the incremental capacity.

Brattle Recommendations for Improvement of VRR Curve Performance

To improve RPM performance, Brattle recommended the following VRR curve revisions:

(1) **Right-shift point "a"** - shifting point "a" (highest quantity point at the price cap) to a quantity at 1-in-5 LOLE (at approximately IRM - 1%) would significantly improve reliability outcomes by providing stronger price signals when supplies become scarce. This change would also make the VRR Curve more consistent with the current backstop auction trigger at IRM - 1% such that PJM would procure all available resource in the BRA up the price cap before any such backstop auction would be triggered.

(2) **Stretch the VRR Curve into a convex shape** – A convex shaped VRR curve is steeper at lower reserve margins and flatter at higher reserve margins. It is more consistent with the shape of the reliability value of capacity at varying reserve margins with a more gradual decline at higher reserve margins helping to reduce price volatility under these conditions. This curve as shown was found to meet the 1-in-10 reliability standard on average under base modeling assumptions.

PJM Preliminary Recommendations for Improvement of VRR Curve Performance

PJM strongly believes that the input parameters to the RPM auctions must be structured such that RPM achieves its goal of procuring sufficient resources to maintain system reliability in the long term. PJM has reviewed the Brattle analysis and agrees that the recommended changes described above will provide a more effective curve for incentivizing capacity as the system goes short and provide price stability as the system goes long. However, while the VRR curve recommended in the Brattle report meets the 1-in-10 LOLE reliability requirement more often than the current PJM VRR curve, it still shows procurement below the reliability requirement 29% of the time and procurement below the IRM - 1% threshold 13% of the time. **PJM therefore recommends that the convex curve as defined by Brattle be adopted but further recommends that the entire curve be shifted to the right by 1%.** Relative to the Brattle-recommended convex curve, the frequency of procurement at levels below the reliability requirement are significantly reduced with PJM's recommended shifted curve. Simulation results of the shifted curve under base conditions show procurement below the reliability requirement 16% of the time and procurement below IRM - 1% threshold 7% of the time. The improvement in reliability associated with the shift is even greater under stressed conditions (see Table 15 of Brattle Report) allowing RPM to better handle year-to-year volatility in supply and demand conditions that are likely forthcoming given ever increasing RPS targets and the recently promulgated EPA Clean Power Plan under CAA 111(d) and increasing energy efficiency targets that will shift the earning of going forward, avoidable costs from the energy market more toward the capacity market. Consequently, PJM believes that this curve strikes the appropriate balance between reliability objectives and cost and will provide for a softer and more controlled "landing" as existing surplus resources are exhausted as many of the aforementioned policies take place and PJM approaches long-run equilibrium reserve margins with a very different mix of resources.

Comparison of VRR Curve Performance

Figure 2 shows the current PJM VRR curve, the Brattle-recommended VRR curve and the PJM-recommended VRR curve. The demand curves used by NYISO and ISO-NE are also shown.

For comparison purposes and to better under the impact of demand curve shape on reliability, price and cost outcomes, Brattle conducted analysis using the Monte Carlo simulations of each of the shown demand curves as well as a vertical demand curve under base modeling conditions. The reliability and price performance of each curve is shown in Table 1.

Figure 2
Current and Recommended VRR Curves

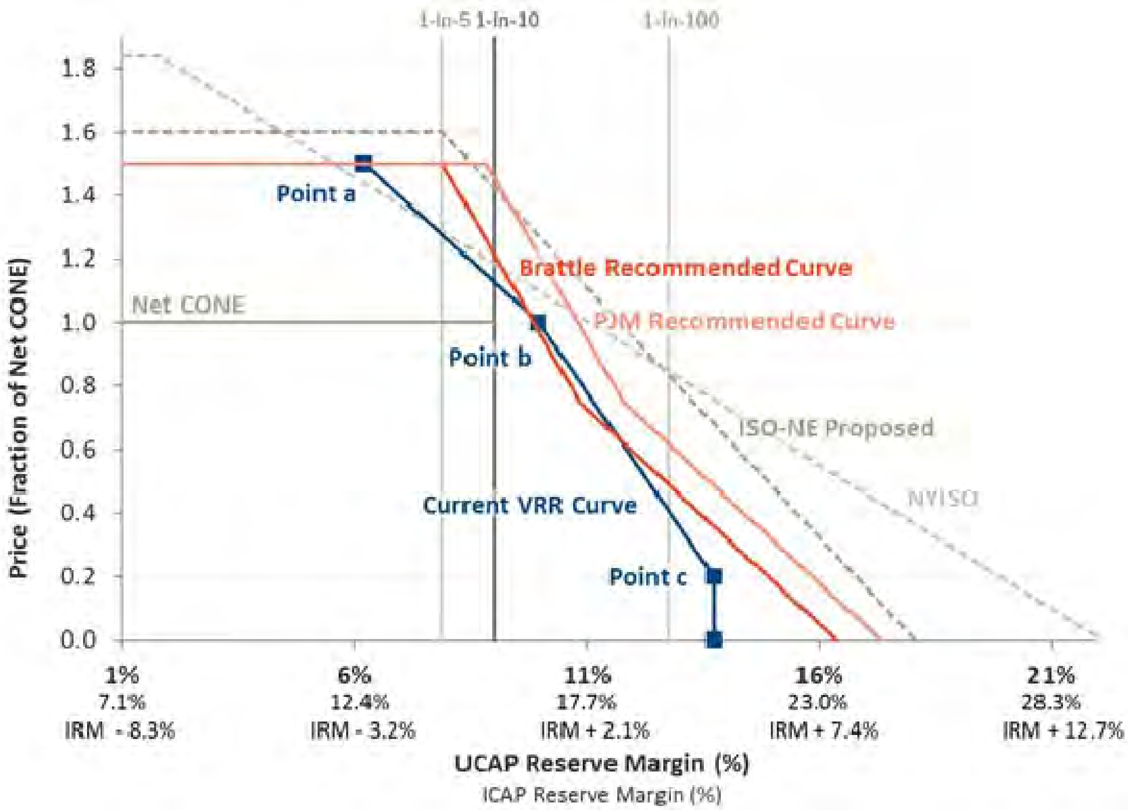


Table 1
Current and Recommended VRR Curves Simulation Results

	Price			Reliability					Procurement Costs		
	Average	Standard Deviation	Freq. at Cap	Average LOLE	Average Excess (Deficit)	Reserve Margin St. Dev.	Freq. Below Rel. Req.	Freq. Below 1-in-5	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(Ev/Yr)*	*(IRM + X%)*	*(% ICAP)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Base Modeling Assumptions											
Vertical Curve	$331	$147	69%	0.175	-0.8%	1.4%	36%	24%	$19,980	$8,030	$31,531
Current VRR Curve	$331	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,167	$12,672	$28,094
ISO-NE Proposed Curve	$331	$96	3%	0.039	2.7%	2.1%	10%	3%	$20,554	$13,327	$29,310
NYISO Curve	$331	$69	0%	0.065	2.0%	2.4%	20%	9%	$20,456	$15,394	$26,490
PJM Recommended Curve	$331	$107	13%	0.060	1.7%	1.9%	16%	7%	$20,383	$12,461	$29,859
Brattle Recommended Curve	$331	$107	13%	0.100	0.7%	1.9%	29%	13%	$20,210	$12,379	$29,631