UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.	)	Docket Nos. EL19-58-000
	)	ER19-1486-000

AFFIDAVIT OF JAMES F. WILSON IN SUPPORT OF THE PROTEST OF THE CLEAN ENERGY ADVOCATES ("WILSON AFFIDAVIT – ORDC")

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("WILSON AFFIDAVIT – ORDC")

I. Introduction

1. My name is James F. Wilson. I am an economist and independent consultant doing business as Wilson Energy Economics. My business address is 4800 Hampden Lane Suite 200, Bethesda, MD 20814.

2. I have over thirty-five years of consulting experience in the electric power and natural gas industries. Many of my past assignments have focused on the economic and policy issues arising from the introduction of competition into these industries, including restructuring policies, market design, market analysis and market power. Other recent engagements have included resource adequacy and capacity markets, contract litigation and damages, forecasting and market evaluation, pipeline rate cases and evaluating allegations of market manipulation. I also spent five years in Russia in the early 1990s advising on the reform, restructuring, and development of the Russian electricity and natural gas industries for the World Bank and other clients. I have submitted affidavits and presented testimony in proceedings of the Federal Energy Regulatory Commission ("Commission"), state regulatory agencies, and U.S. district court. I hold a B.A. in Mathematics from Oberlin College and an M.S. in Engineering-Economic Systems from Stanford University. My curriculum vitae, summarizing my experience and listing past testimony, is Attachment JFW-1 attached hereto.

3. I have been involved in electricity restructuring and wholesale market design for over twenty years in PJM, New England, California, MISO, Russia, and other regions. With regard to the PJM system, I have also been involved in a broad range of other market design and planning issues over the past several years.

4. With regard to the reserve market pricing issues that are the subject of this proceeding, I have been involved in these issues in PJM, New England, California, and other regions. In 2010, I evaluated PJM's original shortage pricing proposal in an affidavit in support of a protest by the Pennsylvania Public Utilities Commission.[1] In 2018-2019 I actively participated in the PJM Energy Price Formation Senior Task Force ("EPFSTF") stakeholder process in which changes to PJM's energy and reserve pricing rules were considered.

5. On March 29, 2019, PJM filed, pursuant to section 206 of the Federal Power Act, proposed revisions to its operating reserves market rules, with a requested effective date of June 1, 2020 ("PJM Filing"). The PJM Filing was supported by affidavits by Drs. William W. Hogan and Susan L. Pope ("Hogan/Pope Affidavit"), Adam Keech ("Keech Affidavit"), Christopher Pilong ("Pilong Affidavit"), and Dr. Patricio Rocha Garrido ("Rocha Garrido Affidavit"), and a report by Drs. Hogan and Pope, *PJM Reserve Markets: Operating Reserve Demand Curve Enhancements* ("Hogan/Pope Report").

6. This affidavit was prepared at the request of the Clean Energy Advocates. My assignment was to:

1. Describe the fundamental principles that should guide the design of an Operating Reserve Demand Curve ("ORDC"); and
2. Comment on PJM's proposed ORDCs through the lens of these principles.[2]

[1] PJM Interconnection, L.L.C., FERC Docket No. ER09-1063-004 (PJM compliance filing on pricing during operating reserve shortages): Affidavit in Support of Comments and Protest of the Pennsylvania Public Utility Commission, July 30, 2010.

[2] A second affidavit estimates the extent to which consumers would be making duplicative payments for energy and ancillary services and for capacity under PJM's proposal, proposes transitional measures to mitigate the estimated double payment, and evaluates the need for a "circuit breaker" mechanism to have in place should PJM's proposal lead to extreme and unintended consequences, and propose the elements of such a mechanism ("Wilson Affidavit – Transition").

II. Summary

7. A fundamental guiding goal of market design efforts is to get the prices right – that is, to set prices that accurately reflect the balance of supply and demand, and the true incremental cost of supply and marginal value of consumption. This is especially important in PJM's energy and ancillary services ("E&AS") markets. Getting the prices right in E&AS markets results in high quality, granular price signals to guide operations and investment, and it also reduces the "missing money" that would have to be recovered through the administrative Reliability Pricing Model ("RPM") capacity construct.[3]

8. With regard to operating reserves, the system operators may take actions outside of the markets to create additional reserves at times, due to unusual circumstances, and this can suppress prices, because these additional reserves were not reflected in the pricing mechanism. PJM's proposed changes to its operating reserve products and pricing are largely intended to address this problem.

9. The fundamental principles that guide ORDC design, described in the next section of this affidavit, are well-established and based upon the reliability value of reserves for consumers. However, PJM's proposed ORDCs are not based on these principles, but instead are "anchored" based on administrative parameters unrelated to the value of reserves to consumers. As a result, PJM's proposed ORDCs would set prices that are far above the marginal reliability value of reserves at nearly all reserve levels.

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[3] I further elaborated on this comparison of E&AS markets to capacity markets in *Post Technical Conference Comments, State Policies and Wholesale Markets Operated by ISO New England Inc., New York Independent System Operator, Inc., and PJM Interconnection, L.L.C.*, FERC Docket No. AD17-11, June 22, 2017; and *"Missing Money" Revisited: Evolution of PJM's RPM Capacity Construct*, report prepared for the American Public Power Association, September 2016, available at https://www.publicpower.org/system/files/documents/markets-rpm_missing_money_revisited_wilson.pdf.

III. Fundamental Principles of ORDC Design

10. The ORDC is an administrative construct that is supposed to establish the right operating reserve prices when reserves are short. The ORDC concept, and the principles for its design, have been well-established for many years now, and the ORDC concept's most eminent proponent, Prof. William Hogan of Harvard University, has explained these concepts in detail numerous times.[4]

11. The ORDC is needed because the demand side of the market is insufficiently engaged; the purpose of the ORDC is essentially to represent the prices at which various loads would choose to consume (and above which prices, they would choose not to consume), were they more engaged in the markets in real time. As Drs. Hogan and Pope put it, "An ORDC arises to proxy for the absence of demand bidding…"[5]

12. In principle, prices along an ORDC should rise, at the lowest reserve levels, to approach the value of service to consumers, because when reserves are depleted the system operator will have to call for firm load curtailment. The value of service is often called the Value of Lost Load, or "VOLL". Prices along the ORDC should actually approach not VOLL, but VOLL minus the marginal cost of the highest cost generation ("mc").[6] Drs. Hogan and Pope explain that the slope of the ORDC down from its highest level is based upon the probability, at each reserve

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[4] See, for instance Hogan, William H., *On An "Energy Only" Electricity Market Design for Resource Adequacy*, September 23, 2005, available at https://sites.hks.harvard.edu/fs/whogan/Hogan_Energy_Only_092305.pdf; Hogan, William H., *Scarcity Pricing and Locational Operating Reserve Demand Curves*, FERC Technical Conference on Unit Commitment Software, Docket No. AD10-12, June 2, 2010; Hogan, William H. and Pope, Susan L., *Priorities for the Evolution of an Energy-Only Electricity Market Design in ERCOT*, May 9, 2017 ("Hogan/Pope ERCOT Report") available at https://hepg.hks.harvard.edu/files/hepg/files/hogan_pope_ercot_050917.pdf.

[5] Hogan/Pope Report p. 14.

[6] Hogan/Pope Report p. 16 ("The VOLL-mc defines the marginal willingness to pay for an increment of operating reserves at the moment of load curtailment.")

level, that conditions will lead to firm load curtailment, if only that quantity of reserves is available (Loss of Load Probability, or "LOLP(r)"):[7]

> "Suppose that the ex post choices for the system operator are simply to meet the net change in load through use of the available operating reserves, or to involuntarily curtail load at the cost of the value of lost load (VOLL) net of the variable cost of generation at the margin (mc). Additionally, suppose the system operator has an estimated distribution of deviations from forecasted net load during actual system operations. With this information it can calculate the loss of load probability for any given level of reserves (Lolp(r)). By multiplying by the (VOLL-mc), this approach yields the expected cost of marginal load curtailment during actual operation corresponding to any given level of scheduled reserves."

13. Thus, the ORDC prices, in principle, equal (VOLL – mc) x LOLP(r), as shown in Figure 2 from the Hogan/Pope report, reproduced here.

14. Drs. Hogan and Pope also explain that the ORDC might begin its slope down from VOLL – mc at zero reserves, or at a higher "Security Minimum" level of reserves (sometimes called "X"):[8]

> "The loss of load probability calculation could reference zero reserves, or could require a minimum contingency level of reserves that provide the base level for the calculation."

15. This Security Minimum is the point below which the system operator would call for involuntary load curtailment, because this level of reserves is required to manage the grid safely and minimize the risk of potentially catastrophic and widespread transmission system failures:[9]

> "The minimum quantity of reserves required for system security, represented by "X", is a limit that is the minimum allowable MW to meet the standards defined to avoid cascading system failures."

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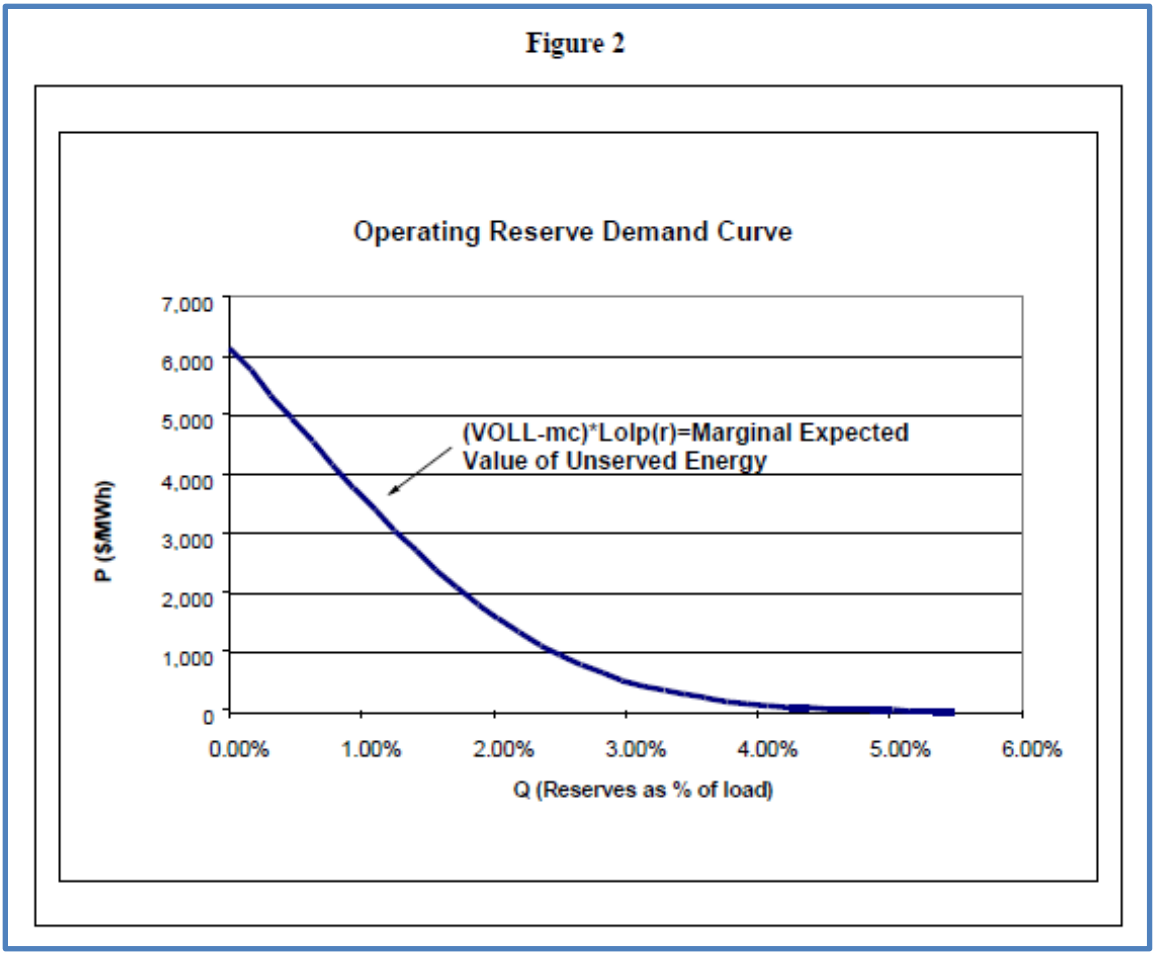
[7] Hogan/Pope Report p. 15.

[8] Hogan/Pope Report p. 34.

[9] Hogan/Pope ERCOT Report, p. 15.

Figure 2



16. Drs. Hogan and Pope further explain that the appropriate value of VOLL for this purpose would reflect the average value of service to those customers that would most likely be curtailed when the system operators call for a rotating outage, not a higher value representing customers that would not be curtailed:[10]

> "… in the case of involuntary load curtailment, the VOLL represents the appropriate concept to guide the decision. However, empirical studies will provide only a little guidance as to which value is appropriate across a range of estimates. The choice will depend in part on the actual curtailment policy applied by the system operator. For example, a rolling blackout will have priorities to exclude certain loads, such as for hospitals or other emergency facilities. For those who are curtailed, the relevant value for ORDC construction would be the average value of

[10] Hogan/Pope Report p. 21.

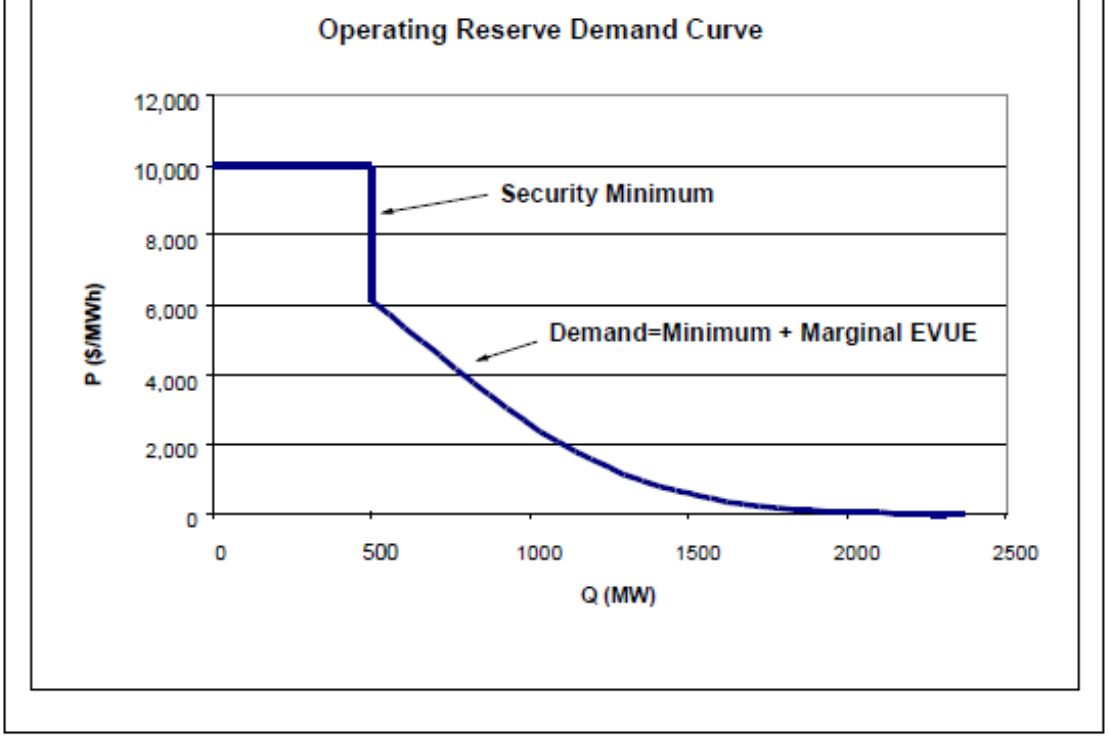
lost load for all those included, not the implied higher VOLL for those that would not be curtailed."

17. Thus, the ORDC in principle is constructed based on VOLL-mc, LOLP(r), and the Security Minimum, as shown in Figure 5 from the Hogan/Pope Report, reproduced here.

18. Drs. Hogan and Pope also describe that prices along the ORDC could also be set at somewhat lower levels, reflecting the costs of other, lower-cost actions (other than curtailing firm load) that the system operators might be able to take:

"The basic model for valuing operating reserves illustrated in Figure 2 illustrates the logic and the connection to only one action, which is to the curtailment of load… The extension to include a sequence of increasingly costly emergency actions

Figure 5



would replace the single estimate of the VOLL with a series of emergency actions."[11]

19. Thus, the ORDC represents the marginal reliability value to consumers of incremental reserves at each point along the curve (based on VOLL as representing reliability value, and LOLP(r) as the risk of curtailment), unless other, lower-cost operator actions are available at some points along the curve.

20. Drs. Hogan and Pope also recommend co-optimization of energy and reserve markets,[12] which is PJM's current practice, and this means that operating reserve prices set by an ORDC will generally be reflected in energy prices, since the potential profit from providing reserves is an opportunity cost for many resources providing energy.

21. Drs. Hogan and Pope also discuss market designs with multiple reserve products.[13] Drs. Hogan and Pope also generalize the ORDC model to circumstances with multiple zones, applying a "probability tree" approach that reflects the particular topology.[14] The extension of the fundamental ORDC concepts described above to multiple products and zones is complex; in particular, the detailed analysis does not suggest that prices are simply additive across products and zones.

22. While the ORDC is a critical element of the real-time market, Drs. Hogan and Pope explain that if an ORDC is implemented in a forward market, most likely the day-ahead market, consistent principles should be applied to its construction:[15]

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[11] Hogan/Pope Report p. 20.

[12] Hogan/Pope Report p. 7.

[13] Hogan/Pope Report pp. 18-20 and pp. 38-47.

[14] Hogan/Pope Report pp. 22-25 and pp. 47-63.

[15] Hogan/Pope Report p. 26.

> "Consistency requires that the day-ahead representation of the ORDC reflects the uncertainty regarding the net load deviations from the forecast dispatch."

23. In particular, the day-ahead LOLP(r) function will be different from the real-time LOLP function,[16] and reflect the uncertainty between the day-ahead scheduling and real-time dispatch.[17]

24. To summarize, the ORDC as described by Drs. Hogan and Pope, shown in their Figure 5 (reproduced above), is based on the value of lost load (VOLL), the Security Minimum (X), and the probability of having to curtail firm load at each reserve level (LOLP(r)).

IV. PJM's ORDC Proposal

25. PJM's proposed ORDC deviates from the model described by Drs. Hogan and Pope, and does not employ any of these three fundamental elements (Security Minimum, VOLL, LOLP(r)). The deviations are explained in the Keech Affidavit (pp. 2-11). The main difference, as Drs. Hogan and Pope acknowledge, is that while PJM's proposed ORDC slopes based on a probabilistic calculation, it is not anchored according to the fundamental principles: [18]

> "PJM's formulation of its ORDCs is consistent with the theory presented here about how the value of incremental reserves will vary with the probability of loss of load during actual operation, but is anchored around PJM-specific assumptions about the actions that will be taken as the level of reserves declines below the MRR."

26. In particular, PJM's proposed ORDC is anchored on a price/quantity point that, as I will explain, is distant from the point that would be set based on the fundamental concepts described by Drs. Hogan and Pope.

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[16] Hogan/Pope Report p. 26.

[17] Hogan/Pope Report p. 72.

[18] Hogan/Pope Report p. 17.

27. First, PJM's ORDC does not employ the concept of the Security Minimum. Instead, the horizontal segment of PJM's curve extends to a point PJM calls the Minimum Reserve Requirement ("MRR").[19] Recall that the Security Minimum is the quantity of reserves that must be maintained to avoid potentially cascading system failures; the system operators will call for curtailment of firm load to keep reserves from falling below the Security Minimum. The MRR is not a Security Minimum; it is a totally different concept, and a much larger quantity. The MRR is the same target operating reserve quantity PJM uses today in its operating reserve markets and current ORDC, based on NERC standards.[20] According to PJM's current ORDC, additional synchronized reserves above the MRR level (plus a small additional step, added recently) are not acquired, even if available at a very low price.[21]

28. Second, PJM's ORDC prices are not related to an estimate of VOLL, or of (VOLL – mc). PJM's filing has no estimate of VOLL, in fact there was no discussion of VOLL within the EPFSTF stakeholder process.[22] Instead, PJM's proposed curve is anchored by associating a "penalty factor" with the MRR quantity, as under the current ORDC. PJM proposes $2,000/MWh as the penalty factor.[23] This leads to the ORDC as illustrated in stylized form in the Keech Affidavit, reproduced below.

29. Under PJM's current market rules and ORDC, PJM will generally not acquire any reserves above the MRR plus the small additional step; the ORDC sets a price of zero for reserves

[19] Keech Affidavit p. 7.

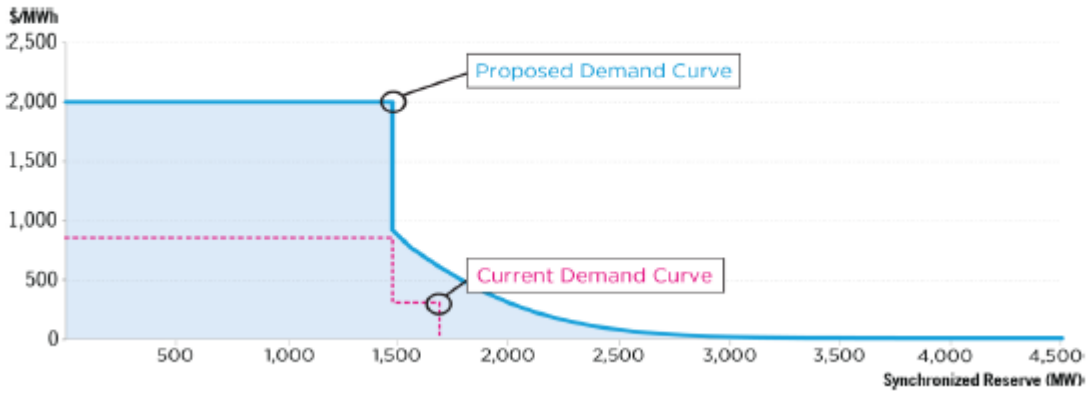
[20] Keech Affidavit p. 7; Pilong Affidavit p. 6, referencing NERC standard BAL-002.

[21] In 2017, a small additional step was added to the ORDC, priced at $300. See PJM Filing pp. 24-25.

[22] PJM has more recently acknowledged that it has no estimate of VOLL. See PJM, *Response to the 2018 State of the Market Report*, May 6, 2019, p. 6 ("In the PJM market, no estimate has been made of the value of lost load."), available at https://www.pjm.com/~/media/library/reports-notices/state-of-the-market/20190506-pjms-response-to-the-2018-state-of-the-market-report.ashx.

[23] Keech Affidavit p. 3.

Figure 1. Stylized Depiction of PJM-Proposed ORDC.



beyond this level. The fact that PJM's current ORDC has been in place for many years with only minor changes suggests that PJM's system operators have generally been comfortable with this program for acquiring reserves (noting that in a subset of intervals there have been out-of-market procurements or schedule "biasing."[24]) That suggests that at or near the MRR, the risk of a situation requiring firm load curtailment must generally be very low (that is, at this reserve level the LOLP(r) is very low). A Security Minimum quantity (a non-zero level of reserves at which PJM system operators would immediately call for firm load curtailment[25]) would be far lower than the MRR.

30. Because LOLP(r) at the MRR point is very low, the appropriate price for reserves at this point on the ORDC, based on the fundamental principles described above, would be very low. A rough and very conservative estimate (i.e., one that overstates the price), could use

[24] Apparently the PJM dispatchers occasionally fudge or "bias" the inputs to the scheduling software in order to commit additional resources. See PJM Filing, p. 34.

[25] In the EPFSTF stakeholder process it was suggested that there was no minimum reserve level at which the system operators would immediately order firm curtailment, that there were generally other actions the system operators could take to maintain reliability. EPFSTF meeting June 8, 2018 Item 3A: *Minimum Reserve Requirements and Operational Capacity Emergencies.*

LOLP(MRR) = 0.001 (it is probably much lower, since the system operators have generally been comfortable with the MRR), VOLL = $10,000/MWh (this is a high estimate[26]), and mc = 0 (it is always higher than this), resulting in 0.001 x ($10,000 – 0) = $10/MWh. That is, the marginal reliability value of incremental operating reserves to consumers at the MRR point, based on ORDC first principles, is on the order of $10/MWh. While the marginal reliability value may rise sharply when reserves fall below this point, the marginal reliability value at the MRR is very low.

31. PJM states that it assigns the much higher penalty factor to the MRR point because NERC "requires" it to acquire this level of reserves.[27] Further, PJM interprets the NERC standard as requiring it to be willing to pay any allowable price without limit to acquire incremental reserves at or below this point. The PJM Filing characterizes any circumstance in which a quantity of reserve is available but is not acquired because it is priced above the ORDC as an "economic shortage," and takes the position that the ORDC should be defined such that this never occurs at any quantity up to the MRR.[28] However, as explained above, the marginal reliability value of reserves at the MRR point is very low, on the order of $10/MWh, under normal circumstances. The ORDC is supposed to serve as a proxy for demand bids, and to represent consumers' value and willingness to pay for incremental reserves, in light of the risk of firm curtailments; but PJM's proposed ORDC sets a price at the MRR point that is roughly two orders of magnitude higher than the marginal reliability value. This is the fundamental flaw in PJM's proposed ORDC – at the

[26] As "bookends" for a reasonable VOLL value for use in shortage pricing, the Commission has approved $3,500/MWh in the past for the Midcontinent Independent System Operator's shortage pricing mechanism, and the Electric Reliability Council of Texas (which lacks a capacity market and, therefore, sets deliberately high values for its energy market parameters) uses $9,000/MWh.

[27] PJM Filing p. 25.

[28] PJM Filing pp. 28-30.

critical MRR point, it sets a price that is normally orders of magnitude above marginal reliability value, but would nevertheless be reflected in the market-clearing prices paid to all sellers of energy and ancillary services.[29] When prices are paid that are orders of magnitude above the marginal reliability value to consumers for the incremental reserves, the rationale for reflecting such payments in market-clearing prices for reserves and, through co-optimization, also for energy, does not exist; this is clearly inconsistent with the goal of "getting the prices right."

32. Ideally, the ORDCs would represent the marginal reliability value of reserves at all times, the resulting reserve procurements would always accord with the system operators' judgments of the capacity needed by the system, and, as a result, the system operators would never feel a need to pursue out-of-market procurements. This ideal is not achievable due to the variability of the circumstances that can occur; even if the system operators have substantial authority to shift the ORDC quantities higher at times, there likely would still be situations leading to out-of-market procurements. The system operators should have the authority to acquire reserves out of market, even at very high prices, when in their judgment that is important to preserve reliability (or required by regulatory rules). However, in principle, the ORDC should represent the marginal reliability value to consumers and the "right prices," and any acquisitions at higher prices should be paid on an out-of-market basis.

33. PJM's proposed ORDCs slope from this anchor point (the $2,000 penalty factor, at the MRR), starting with prices that are over $1,000/MWh for summer and winter peak periods,

[29] The fact that the LOLP and marginal reliability value are very low at the MRR point was pointed out multiple times during the course of the EPFSTF stakeholder process, beginning in spring of 2018, and neither PJM nor any stakeholder made any attempt to argue otherwise.

and in the $600/MWh to $1,200/MWh range during all seasons and time blocks.[30] This suggests that the ORDC prices along the beginning of the sloped section of the curve are also well above the marginal reliability value for operating reserves at these higher reserve levels. PJM's proposed probabilistic function represents the probability of reserves falling to or below MRR ("PBMRR"), not a Security Minimum, however this difference in principle only shifts the function.[31] The PBMRR is conservative (that is, rather flat), as it is based on uncertainties over a 30 minute interval,[32] so prices all along the sloped section of the ORDC will be well above marginal reliability value.

34. On the other hand, at extremely low reserve levels (near zero), the maximum price on the ORDC – $2,000/MWh – is likely too low and below marginal reliability value. However, at what point marginal reliability value reaches $2,000/MWh has not been estimated.

35. PJM's proposal also calls for separate ORDCs for three reserve products and two zones, and proposes that the prices across "nested" products and zones simply be added together.[33] This can of course lead to prices that are even further from marginal reliability value, and even more inconsistent with the goal of "getting the prices right." To see this, consider a situation where the system is a few MW below the target (MRR) reserve level for each of the three products. While marginal reliability value is still very low (each of the three reserve quantities is very close to its target level), the three penalty factors would sum to $6,000/MWh.

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[30] The PJM Filing does not include illustrations of the various ORDCs for different seasons and time blocks, but such details were provided in the stakeholder process. See, for instance, *ORDC Regulation Requirement Shift Update*, EPFSTF Item 3A on January 23, 2019, available at https://www.pjm.com/-/media/committees-groups/task-forces/epfstf/20190123/20190123-pjm-ordcs-hourly-regulation-requirement-shift.ashx.

[31] Rocha Garrido Affidavit p.8.

[32] Rocha Garrido Affidavit p.7.

[33] PJM Filing p. 11.

36. Finally, PJM's proposal calls for ORDCs in the day-ahead markets that are the same as those used in the real-time markets.[34] This too deviates from the fundamental principles, under which the same concepts would be applied, and the LOLP(r) function would be very different day-ahead, among other possible differences.

37. This concludes my affidavit.

[34] PJM Filing p. 14.