UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

	)	
PJM Interconnection, L.L.C.	)	**Docket No. ER19-469-000**
FERC Order No. 841 Compliance Filing	)	
	)	

MOTION FOR LEAVE TO ANSWER AND ANSWER OF THE ENERGY STORAGE ASSOCIATION

Pursuant to Rules 212 and 213 of the Federal Energy Regulatory Commission's ("FERC" or the "Commission") Rules of Practice and Procedure,[1] the Energy Storage Association ("ESA") respectfully submits this Motion for Leave to Answer and Answer (the "Answer") to the response submitted by the PJM Interconnection, L.L.C., ("PJM") on March 5, 2019, in the above-captioned proceeding ("PJM Answer").[2] In its Answer, PJM incorrectly claims ESA argues for changes to PJM's existing capacity market requirements. However, as is detailed herein PJM is using Order 841 as a means of changing its existing rules and practices. Such changes, in addition to being inconsistent with the intent of Order 841, highlight that the terms and conditions of capacity market participation of electric storage resources are inappropriately susceptible to being changed unilaterally by PJM through its manuals, contrary to FERC's "rule of reason" policy that requires such terms and conditions to be filed in PJM's tariff and approved by FERC.

[1] 18 C.F.R. §§ 385.212, 213 (2019).

[2] This Answer is limited to those issues that PJM specifically directed to ESA. ESA takes no position on any issues not addressed herein.

Moreover, PJM incorrectly claims ESA is seeking a determination as to which storage resources are technically capable of providing capacity market services. Contrary to PJM's statement, ESA has demonstrated why PJM's duration requirement for capacity accreditation of storage is inconsistent with Order 841 and will result in unjust and unreasonable rates. ESA is filing this Answer presently to correct the mischaracterizations that PJM makes regarding ESA's argument.

I. MOTION FOR LEAVE TO ANSWER

Although responses to answers are not permitted pursuant to FERC rules as a course of normal business,[3] the Commission does allow answers when the answer provides useful and relevant information that will assist the Commission in its decision-making process,[4] corrects factual inaccuracies and clarifies the issues,[5] assures a complete record in the proceeding,[6] provides information helpful to the disposition of an issue,[7] or permits the issues to be narrowed.[8] As demonstrated herein, this Answer satisfies each of those criteria.

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[3] 18 C.F.R. § 385.213(a)(2).

[4] *See, e.g., Pioneer Transmission, LLC v. N. Ind. Pub. Serv. Co. and Midwest Indep. Transmission Sys. Operator, Inc.,* 140 FERC ¶ 61,057 at P 93 (2012); *Midwest Indep. Transmission Sys. Operator, Inc.,* 131 FERC ¶ 61,285 (2010); *Sw. Power Pool, Inc.*, 131 FERC ¶ 61,252 at P 19 (2010), *reh'g denied*, 137 FERC ¶ 61,075 (2011) (accepting answers that "provided information that assisted us in our decision-making process"); *Duke Energy Ky., Inc.*, 122 FERC ¶ 61,182 at P 25 (2008) (accepting answers in proceeding that "provided information that assisted us in our decision-making process"); *Tallgrass Transmission, LLC*, 125 FERC ¶ 61,248 at P 26 (2008); *PJM Interconnection, L.L.C.*, 120 FERC ¶ 61,083 at P 23 (2007) (answer to protests permitted when it provides information to assist the Commission in its decision-making process).

[5] *See, e.g., Entergy Servs. Inc.,* 123 FERC ¶ 61,227 (2009).

[6] *See e.g., Pac. Interstate Transmission Co.,* 85 FERC ¶ 61,378 at P 62,443 (1998), *reh'g denied,* 89 FERC ¶ 61,246 (1999); *Morgan Stanley Capital Group, Inc. v. N.Y. Indep. Sys. Operator, Inc.,* 93 FERC ¶ 61,017, 61,036 (2000) (accepting an answer that was "helpful in the development of the record…").

[7] *See, e.g., CNG Transmission Corp.,* 89 FERC ¶ 61,100, 61,287, n.11 (1999).

[8] *See, e.g., PJM Interconnection, L.L.C.,* 84 FERC ¶ 61,224, 62,078 (1998); *New England Ventures, Inc. v. S. Cal. Edison Co.,* 82 FERC ¶ 61,335, 62,323, n.1 (1998).

Accordingly, FERC is respectfully requested to grant ESA's Motion for Leave to Answer and to include its Limited Answer in the record of this proceeding.

II. ANSWER

A. Contrary to PJM's claims, ESA is not arguing for changes to PJM's existing capacity market requirements. Rather, PJM's ICAP proposal relies on what it claims are existing rules and practices but are in fact themselves changes in policy. PJM's use of its business manuals to modify FERC-approved tariff provisions violates the Commission's "rule of reason." As such, the ICAP proposal should be denied.

In its Answer, PJM claims that ESA is challenging its "ICAP Proposal" because its members cannot meet the technical requirements for participating in PJM's capacity market.[9] That is incorrect. It is PJM's decision to unilaterally develop rules that are designed to supersede a FERC-approved tariff and create additional barriers to storage providers that is the basis of ESA's Protest.

1. PJM claims that although the cited rules precede CSRs they should nonetheless apply to those resources. Yet, neither PJM nor FERC contemplated those rules during the initial establishment of the CSR asset type. Rather, in that proceeding PJM proposed--and FERC accepted--a standard for capacity market participation that supersedes the manuals that PJM now asserts as controlling.

Order 841 was never intended to be a vehicle for PJM to implement new tariff barriers to the participation of Capacity Storage Resources ("CSR") in the PJM market. Yet, as explained below, that is precisely what PJM seeks to accomplish in its proposed compliance filing. PJM now claims that it is applying its current rules to CSRs, citing the governing document RAA Schedule 9 and its Manual 21.

The tariff at RAA Schedule 9 explicitly applies to "Generation Capacity Resources." Manual 21 is designed to provide rules that complement PJM's tariff language. RAA Schedule 9

[9] PJM Answer at 4.

does not address CSRs explicitly, and Manual 21 is ambiguous on how CSRs will be treated. Despite these facts, PJM chooses to assert an interpretation of CSRs in Manual 21 that would effectively circumvent FERC's review of a new tariff provision. Contrary to PJM's argument, changes to Manual 21 subsequent to implementation of CSRs should not be interpreted to supersede PJM's tariff. It is PJM's decision to unilaterally develop rules that supersede a FERC-approved tariff that is the basis of ESA's Protest.

The CSR asset type was first established in PJM's Capacity Performance tariff filing in Docket No. ER15-623. As ESA has previously noted, CSR was repeatedly and exclusively discussed in all instances as part of a set of non-traditional resources ("Intermittent/Storage/DR/EE resources").[10] That grouping was intentional. PJM mentioned CSRs alongside these other resources for the purposes of explaining the opportunities that would be made available for such non-traditional resources in the proposed Capacity Performance market.[11]

For each of those similarly situated non-storage resources, a separate and explicit approach to installed capacity ("ICAP") determination had already been established. For DR and EE, RAA Schedule 6 was the governing document for ICAP determination. For intermittent generation, Appendix B of Manual 21 contained the description for ICAP determination. For CSRs, however, an explicit method was not described at the time in either Manual 21 or directly referenced in RAA Schedule 9. Indeed, Manual 21 was revised to include explicit mentions of

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[10] See Answer of PJM Interconnection, L.L.C., in Docket No. ER15-623-000 (February 13, 2015) at 20, where the first instance of "Intermittent/Storage/DR/EE" is noted and then used subsequently throughout the filing.

[11] See Answer of PJM Interconnection, L.L.C., in Docket No. ER15-623-000 (February 13, 2015) at 3: "While numerous issues are raised in this area, one over-arching theme, both in the initial definition of the products and in the transition, is the status and treatment of Demand Resources, Energy Efficiency Resources, Storage Capacity Resources, and intermittent generation."

CSRs subsequent to FERC approval of PJM's Capacity Performance tariff amendment.[12] Therefore, the tariff language approved by FERC in Docket No. ER15-623 expressly provided that capacity market participation would be based on average output during peak-hour periods. As the Commission stated:

> "100. We also find PJM's proposal, as clarified in its answer, to permit Demand Resources, Energy Efficiency Resources, Capacity Storage Resources, and Intermittent Resources offer as stand-alone Capacity Performance Resources to be just and reasonable. Therefore, we accept this aspect of PJM's proposal, subject to PJM submitting tariff revisions clarifying that, as PJM states in its answer, *Capacity Storage Resources*, Intermittent Resources, Energy Efficiency Resources, and Demand Resources *may submit stand-alone Capacity Performance sell offers in a MW quantity consistent with their average expected output during peak-hour periods*." [emphasis added]

PJM claims RAA Schedule 9 applies to CSRs; however, that governing document refers only to Generation Capacity Resources. Similarly, PJM's Capacity Performance tariff amendment also intentionally and repeatedly distinguishes Generation Capacity Resources from CSRs, indicating PJM's and FERC's understanding that CSRs were to be treated in a different manner from the Generation Capacity Resources discussed in RAA Schedule 9. For example, PJM's Open Access Transmission Tariff Attachment DD Section 5.5A on Capacity Resource Types explicitly separates these items:

> "…the following types of Capacity Resources are eligible to submit a Sell Offer as a Capacity Performance Resource: *internal or external Generation Capacity Resources*; Annual Demand Resources; *Capacity Storage Resources*; Annual Energy Efficiency Resources; and Qualifying Transmission Upgrades. To the extent the underlying Capacity Resource is an external Generation Capacity Resource, such resource must meet the criteria for obtaining an exception to the Capacity Import Limit as contained in section 1.7A of the Reliability Assurance Agreement." [emphasis added]

[12] See Manual 21, redline version indicating changes between Revision 11 (2014) and Revision 12 (2017). Available at https://www.pjm.com/forms/registration/Meeting Registration.aspx?ID=%7B28CCE14D-7109-456F-9EF9-497EB867D718%7D

Similarly, Attachment DD Section 5.6.1(a) does so as well:

> "A Sell Offer shall state quantities in increments of 0.1 megawatts and shall specify, as appropriate:
>
> (a) Identification of the *Generation Capacity Resource*, Demand Resource, *Capacity Storage Resource* or Energy Efficiency Resource on which such Sell Offer is based;"

Furthermore, Attachment DD Section 5.6.1 separately discusses the capacity sell offers of Generation Capacity Resources in subsections (b) and (c) from the capacity sell offers of Capacity Storage Resources in subsection (h).

Thus, while PJM argues that CSRs are dispatchable and therefore akin to Generation Capacity Resources,[13] there are numerous tariff provisions where PJM clearly distinguishes the treatment of CSRs from Generating Capacity Resources. It is immaterial that CSRs and generators are both dispatchable given the plain, unambiguous language in the tariff.

Moreover, there was never any indication in PJM's Capacity Performance filings or elsewhere in Docket No. ER15-623 that PJM's so-called "status quo" rules in RAA Schedule 9 and Manual 21 Section 2 on ICAP determination applied to storage. PJM omitted CSRs in RAA Schedule 9 and distinguished CSRs from Generation Capacity Resources in other tariff language and in other documents. By never highlighting this provision or Manual 21 Section 2 in the Capacity Performance filings, it is clear that PJM is relying on a post hoc rationale in its Order 841 compliance filing must be rejected.

[13] PJM Answer at 10. "The Markets and Operations Proposal, and specifically the ICAP Proposal, is consistent with this requirement by applying to CSRs the same technical standards for determining capacity value that is currently applied to all other dispatchable resources. As explained in the Affidavit of PJM's Manager of Capacity Market Operations, Mr. Jeffrey D. Bastian, supporting PJM's Markets and Operations Proposal, measuring the ICAP value for CSRs at the level of continuous output that can be sustained for ten hours ensures that PJM dispatchers can call upon such resources to manage loads on a summer peak day in a manner comparable to all other dispatchable resources."

2. PJM's reliance on manuals that not only conflict with the express intent of PJM's Capacity Performance tariff amendment, but also which significantly affect terms and conditions of service, is impermissible.

PJM claims that Manual 21 specifies that ICAP for CSRs will be determined according to capability to sustain 10 hours of continuous output. PJM also claims that such limitation was in place at the time that CSRs were established and therefore represents the "status quo."[14] It is highly problematic for PJM to assert this rule, not only because it conflicts with its aforementioned Capacity Performance tariff amendment, but also because acceptance by FERC would allow PJM to materially modify the terms and conditions of the market participation of CSRs via its manuals and not as required, through its FERC-reviewed tariff.

While PJM has referenced studies to support its claim that a 10-hour duration is necessary for the ICAP determination of CSRs, ultimately PJM asserts that it does not rely on those studies to claim this requirement.[15] Consequently, ESA is deeply concerned that such an ICAP determination method is readily susceptible to specification. Under PJM's logic, if its manual language, which is not on file with the Commission, were to describe a 16-hour or 20-hour duration requirement for ICAP determination, such a requirement would not be subject to FERC review and would limit capacity sell offers of CSRs as specified in its tariff, regardless of how tenuously connected such a requirement would be to the actual capacity contributions of CSRs.[16]

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[14] PJM Answer at 16. "Taken together, these provisions make clear that PJM's status quo approach to determining ICAP value for CSRs to is to take the unit's MWh storage capability and divide it by ten hours." See also Bastian Affidavit at P 11.

[15] PJM Answer at 20.

[16] ESA notes that at the time of this filing PJM is proposing changes to Manual 21 language as concerns ICAP determination for CSRs; see "Manual 21 Revision 13 Redline," available at https://pjm.com/-/media/committees-groups/committees/pc/20190411/20190411-item-05c-m21-rev13-redline.ashx. Specifically, PJM has proposed to insert new language that states "Battery storage units must have their ICAP determined by adjusting for state of charge (SOC) under summer conditions." Were PJM to also propose changes to Manual 21 language on the duration

Decisions regarding whether an item should be placed in a tariff or in a business practice manual are guided by the Commission's "rule of reason" policy,[17] under which provisions that "significantly affect rates, terms, and conditions" of service, are readily susceptible of specification, and are not generally understood in a contractual agreement must be included in the tariff, while items better classified as implementation details may be included only in a business practice manual.[18] Indeed, FERC has previously found technical details of PJM's Regulation market to merit filing in its tariff rather than specification in its manuals on similar grounds.[19]

PJM's characterization of a 10-hour duration to determine the ICAP of CSRs is not a mere implementation detail, but instead significantly impacts CSRs' participation in the capacity market and, ultimately, capacity market clearing. Under this manual language, capacity sell offers of CSRs cannot actually be based on average output over peak hours, as PJM's Capacity Performance tariff provisions specify. Moreover, PJM explicitly designed the Capacity Performance tariff provisions to enable storage resources to exceed expectation of delivery;[20] by

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requirement for ICAP determination of CSRs, at the present juncture and under PJM's logic FERC would still have no ability to review such changes that materially affect the terms and conditions of capacity market participation.

[17] *See, e.g., Midcontinent Indep. Sys. Operator, Inc.*, 158 FERC ¶ 61,003, at P 69 (2017) (citing *PacifiCorp*, 127 FERC ¶ 61,144, at P 11 (2009); *City of Cleveland v. FERC*, 773 F.2d 1368, 1376 (D.C. Cir. 1985) (finding that utilities must file "only those practices that affect rates and service *significantly*, that are reasonably *susceptible* of specification, and that are not so generally understood in any contractual arrangement as to render recitation superfluous"); *Public Serv. Comm'n of N.Y. v. FERC*, 813 F.2d 448, 454 (D.C. Cir. 1987) (holding that the Commission properly excused utilities from filing policies or practices that dealt with only matters of "practical insignificance" to serving customers)); *see also Midwest Indep. Trans. Sys. Operator, Inc.*, 98 FERC ¶ 61,137, at 61,401 (2002), *clarification granted*, 100 FERC ¶ 61,262 (2002) ("It appears that the proposed Operating Protocols could significantly affect certain rates and services and as such are required to be filed pursuant to Section 205.").

[18] *See, e.g., Cal. Indep. Sys. Operator Corp.*, 122 FERC ¶ 61,271, at P 16 (2008).

[19] See *Energy Storage Association v. PJM Interconnection, L.L.C.*, 162 FERC ¶ 61,296 (2018) at P 105 and P 107.

[20] See Answer of PJM Interconnection, L.L.C., in Docket No. ER15-623-000 (February 13, 2015) at 4: "…demand-side resources, storage, and intermittent generation have considerable flexibility to determine the capacity level at which they offer and clear their resources in the RPM Auctions. Because the "second settlement" of Capacity Performance pays resources that *exceed expectations*, the seller's ability to *set expectations*, by selecting its capacity commitment level, opens considerable revenue opportunities for these very resources. As PJM illustrates in later

proposing to limit storage to an ICAP reflecting output over 10 hours, PJM in fact prohibits CSRs from ever making sell offers that exceed expectations of deliveries per its stated intent in its tariff filing, and materially restricts a "seller's ability to set expectations."

PJM's ICAP proposal significantly affects the rates, terms, and conditions of capacity market service and is reasonably susceptible to specification. Accordingly, the Commission cannot rely on the manual to justify PJM's proposed actions here.

3. Contrary to PJM's claims that its 10-hour duration ICAP requirement already applies to pumped hydro storage ("PHS") resources, publicly available data show PHS resources with ICAP reflecting a shorter duration of continuous output. PJM has not adequately explained this contradiction, and application of a 10-hour qualification requirement to CSRs may thus also be discriminatory.

As discussed by Public Interest Organizations,[21] publicly available data show that some PHS resources have an ICAP that reflects continuous output of less than 10 hours at rated capacity. PJM fails to explain why its proposal contradicts publicly available information. Instead, PJM suggests that complainants misunderstand the way that PHS units are treated versus a whole PHS facility.[22] If PJM is to be believed, then the 10-hour duration requirement determines ICAP for individual units and not for the whole PHS facility. As such, those units have even lower rated capacity than the full facility, meaning that the ICAP cannot possibly be based on a 10-hour duration for a given unit if the entire facility operating in concert cannot meet that duration requirement. To the extent that PJM intends to apply a different standard to non-

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sections of this answer, market participants that embrace these opportunities can realize significant increases in their compensation from the PJM capacity market."

[21] Protest and Comment of the Public Interest Organizations in Docket ER19-469-000 (February 7, 2019) at 12-15.

[22] PJM Answer at 9 in footnote 28. "…their claim appears to be based on the premise that the minimum run time is based on evaluation of duration on a facility-wide basis, when in fact, currently under PJM Manual 21, duration is determined on a unit basis."

hydro CSRs than to PHS, it is unclear how PJM can claim that its ICAP proposal is based on existing rules or is being applied in a non-discriminatory manner.

Not only is it uncertain that the 10-hour requirement has been applied to PHS projects for many years, but the time period such a requirement has been the status quo assumed for all storage resources is likewise uncertain. ESA notes that as recently as 2013, PJM Manual 21 Section 2 referred to a 12-hour duration[23]—which diverges from the 10-hour duration PJM cites as being the status quo at or before the 2010 Demand Response study.[24] This discussion of Manual 21's history is notably absent from PJM's assertions of the lengthy precedent of the 10-hour requirement.

B. Contrary to PJM's claims, ESA is not seeking a determination of which storage resources are technically capable of providing capacity market services. Rather, PJM's duration requirement for capacity accreditation of storage not only is inconsistent with Order 841, but also results in unjust and unreasonable rates.

PJM claims that ESA seeks to "devise a set of relaxed rules" for storage resources contrary to the directives of Order 841.[25] Setting aside that the PJM tariff already provides for different treatment of CSRs from other Generation Storage Resources, ESA is not asking for special treatment of storage. Rather, ESA seeks an accurate measure of the capacity contribution of CSRs. Capacity market qualification rules are a heuristic to approximate the reliability contribution of various resources. To the extent that there is variation from nominally 'equal' treatment of diverse resources in those rules, it is justified when necessary to ensure "reliability-

[24] Bastian Affidavit at P 11. "PJM has long used the output level that can be sustained for at least ten hours to determine the maximum capacity level provided by pumped-storage hydro projects." See also PJM Transmittal Letter at 22. "Manual 21 has for many years stated that the 'number of hours of continuous operation [that is] commensurate with PJM load requirements [is] specified as 10 hours.'"

[25] PJM Answer at 3.

agnostic" accuracy in calculating contributions to resource adequacy.[26] As discussed in the attached affidavit from Kevin Carden of Astrape Consulting ("Carden Affidavit"), different capacity resources have heterogenous constraints that affect how they contribute to system reliability.[27]

Therefore, it is crucial that the capacity contribution of storage resources in PJM's capacity market be accurately described to achieve just and reasonable rates. PJM's customers should only pay for the capacity that is demonstrably needed to meet resource adequacy of the balancing area. PJM's ICAP proposal limits the capacity sell offers that CSRs can make according to its tariff, regardless of whether a 10-hour duration corresponds to the actual capacity value that CSRs contribute to resource adequacy. To the extent that CSRs can provide full capacity value at less than 10 hours' duration under significant penetrations in the market, PJM's ICAP proposal violates Order 841's directive that storage be allowed to provide all services for which it is technically capable.

Accordingly, it is critical that FERC consider the evidentiary basis underlying PJM's 10-hour requirement to assess whether such a standard violates Order 841 as an effective barrier to capacity market participation. PJM states in its Answer that protestors "have not offered alternatives that are anchored in any analysis specific to PJM's load shape during peak periods or other analyses that their alternatives would better meet the PJM system's reliability needs."[28] As described in the Carden Affidavit, ESA here presents such analysis.

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[26] See *City of Frankfort, IN v FERC,* 678 F 2nd 699 (7th Cir. 1982) at 37 and *BP Energy Co. v. Fed. Energy Regulatory Comm'n*, 828 F.3d 959, 967 (D.C. Cir. 2016). Where different treatment is "based on relevant, significant facts which are explained," such treatment is not arbitrary and capricious.

[27] See Affidavit of Kevin Carden on Behalf of the Energy Storage Association at 7. ("Carden Affidavit").

[28] PJM Answer at 14.

An accurate analysis of PJM's reliability need and various resources' contributions to meeting that need requires a different method than PJM's cited study.[29] Specifically, the standard for reliability analysis is developing supply portfolios that do not exceed a 1-day-in-10-years loss-of-load probability, which is the prevailing industry convention by which PJM abides. The Carden Affidavit discusses the method employed to conduct such a resource adequacy analysis of the PJM system, examining the capacity contribution of storage resources of varying durations (e.g., 4 hours, 6 hours, etc.) under varying penetrations (e.g., 1000 MW, 4000 MW, etc.) and simulating loads, outages, imports and exports, and other relevant system conditions based on historical inputs.[30]

The Carden Affidavit's resource adequacy study finds that, even at significant penetrations, storage with less than 10 hours of continuous output at nameplate rating would provide full capacity value on par with other resources. Specifically, an incremental addition of 4,000 MW of 4-hour storage and an incremental addition of over 10,000 MW of 6-hour storage would provide capacity value on par with generation capacity resources today.[31] Indeed, this finding is consistent with the IEEE Study cited by PJM in its Answer, which also finds over 4,000 MW of 4-hour storage and 10,000 MW of 6-hour duration of storage could reliably serve peak conditions.[32] The latter value represents over 40% of all storage resources (e.g., PSH and

[29] As set forth in the Carden Affidavit at P 11-13, the 2010 study of demand response resources referenced in the PJM's filings and in the Bastian Affidavit makes several assumptions that are inappropriate for assessing the reliability contribution of storage resources and biases toward underestimating capacity value of storage.

[30] Carden Affidavit at 10 and 15.

[31] Carden Affidavit at 16.

[32] See PJM Transmittal Letter at footnote 51 and PJM Answer at footnote 72. Aramazd Muzhikyan, Laura Walter, Scott Benner, and Anthony Giacomoni. "Limited Energy Capability Resource Duration Requirement for Participation in PJM Capacity Market." 2019. Available at https://www.pjm.com/-/media/library/reports-notices/special-reports/2019/esr-duration.ashx?la=en

battery storage) installed on the U.S. electric grid today—a level of deployment unlikely to be achieved in PJM's footprint for many years to come.

PJM has failed to demonstrate a relationship between its proposed 10-hour ICAP requirement and the capacity value of storage of durations less than 10 hours. By proposing a 10-hour duration requirement, which does not appear to have been applied to pumped hydro storage resources, despite what PJM asserts in its filings, PJM effectively prohibits storage from providing capacity service it is technically capable of, which is a violation of Order 841.

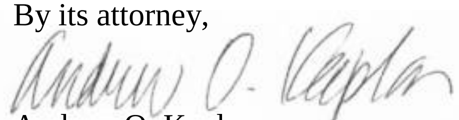
III. CONCLUSION

PJM's proposal to assign storage an ICAP based on 10-hours' duration is not only a contradiction of its own tariff, but also highlights a susceptibility to specification that merits formal tariff review under FERC's "rule of reason." At heart, these are also violations of Order 841 to the extent that PJM's proposal constrains electric storage resources from providing capacity service it is technically capable of. ESA respectfully requests that FERC reject PJM's Order 841 compliance filing with respect to its 10-hour requirement and direct PJM to enable storage to offer capacity equal to average output over peak hours, as defined in PJM's tariff, until such a time as PJM brings its ICAP Proposal to FERC for formal review as a part of a 205 filing.

Respectfully submitted,

ENERGY STORAGE ASSOCIATION

By its attorney,



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Dated: April 12, 2019

CERTIFICATE OF SERVICE

I, Anne O'Hanlon, hereby certify that the foregoing Motion for Leave to Answer and Answer of The Energy Storage Association were served via electronic mail to the service list.

Dated in Boston, MA this 12th day of April, 2019.

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DOCKET NO. ER19-469-000

AFFIDAVIT OF KEVIN CARDEN

ON BEHALF OF

THE ENERGY STORAGE ASSOCIATION

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.	)))	**Docket No. ER19-469-000**

AFFIDAVIT OF KEVIN CARDEN
ON BEHALF OF
THE ENERGY STORAGE ASSOCIATION

1. My name is Kevin Carden. I currently serve as the Director of Astrapé Consulting, LLC ("Astrapé"). My business address is 1935 Hoover Court, Suite 200 Hoover AL, 35226.

2. As the Director of Astrapé Consulting, I primarily manage the Strategic Energy and Risk Valuation Model ("SERVM") software for Astrapé and perform reliability studies, capacity valuation studies, and renewable integration studies using SERVM for clients across North America and internationally. In addition to providing resource adequacy analysis for many of the largest utilities in the nation, Astrapé has performed resource adequacy analysis for many of the structured markets in North America including MISO, SPP, ERCOT, PJM, and AESO. Most of these entities rely on SERVM simulations for their resource adequacy assessments. I have also performed studies for FERC and DOE on implications of market structure and reliability.

3. Prior to starting Astrapé in 2005, I was employed by Southern Company as a reliability engineer where I performed resource adequacy studies for Alabama Power, Georgia Power, Mississippi Power, and Gulf Power. I hold a Bachelor of Science Degree in Industrial Engineering from the University of Alabama. I am an active participant in several industry groups concerned with resource adequacy and reliability including the NERC Probabilistic Assessment Working Group and IEEE Loss of Load Expectation Working Group.

4. As an expert in resource adequacy and resource planning, I have been involved in regulatory proceedings in many jurisdictions, including Alabama, California, Florida, Georgia, Kentucky, Louisiana, New Mexico North Carolina, Oregon and South Carolina.

5. In this proceeding, I have been retained by the Energy Storage Association to evaluate PJM Interconnection, L.L.C's ("PJM") rationale and analysis for implementing a 10-hour duration requirement for Capacity Storage Resources to reliably provide capacity, as part of its Order 841 compliance filing. I have also been engaged to perform an independent analysis using SERVM on the need for duration in PJM to reliably provide capacity.

6. The analysis offered by Astrapé follows the processes used in resource adequacy analyses by MISO, SPP, ERCOT, AESO, CPUC, Southern Company, Duke Energy, and TVA,

which all use SERVM with similar input development methods to plan for reliability. The representation of loads is based on a robust neural network model using recent historical load patterns to develop more than 150 synthetic profiles to reflect a wide range of possible weather and economic growth conditions. The representation of the generation fleet is based on unit-level data publicly available from PJM and its neighbors. All existing pumped storage hydro and conventional hydro resources are modeled consistent with their physical capabilities and typical dispatch patterns. The existing and projected demand response portfolio is modeled consistent with how it would be expected to be utilized in actual operations. Non-dispatchable renewable resources are modeled based on recent historical profiles. Generator outage uncertainty is based on class average forced outage rate data provided in PJM resource adequacy documentation. The SERVM model has been vetted in public processes over several decades in many states. While PJM uses a different resource adequacy software platform, in many respects the approach employed by Astrapé is very similar and the capacity value results are similar when the future system being modeled is realistic in terms of expected loads, resource mix, and dispatch order. From this perspective, rather than comprehensively challenging the PJM resource adequacy modeling approach, the majority of this affidavit attempts to counter PJM's unrealistic system composition and resource fungibility expectation which identified a 10-hour duration threshold.

7. In their answer, PJM implies that the principle of resource agnosticism with respect to capacity qualification requires having a standard set of technical requirements that apply to all resources.[1] As recognized by the treatment of renewable resources for capacity qualification,[2] the real measure of capacity value is performance during reliability critical hours. In order to perform during critical hours, some technology-specific requirements are appropriate. However, having performed resource adequacy studies around the world for nearly two decades, it is an empirically verifiable fact that maintaining a reliable system is possible with a set of capacity resources with heterogeneous constraints. Many classes of resources which provide capacity have various characteristics or limitations which affect how they contribute to system reliability. Conventional CTs may have environmental-related run limits or may not have firm gas supply. Hydro resources frequently have daily minimum and maximum flow requirements. Pumped storage resources have energy constraints. Wind and solar resources are largely non-dispatchable. Demand response resources can have seasonal, weekly, or daily availability limitations based on their underlying load. Other conventional resources have a wide range of forced outage rates. The solution to maintaining a reliable system in light of these characteristics is to recognize the attributes and interactions of the various classes of resources in resource adequacy planning rather than attempt to artificially enforce conformity and perhaps make the system resource mix inefficient. This does not entail relaxing the requirements for provision of capacity as suggested by PJM,[3] but rather setting minimum threshold requirements which recognize each resource class' unique set of attributes. This approach is consistent with the repeated directive in Order 841 to take into account the physical and operational characteristics of ESRs.

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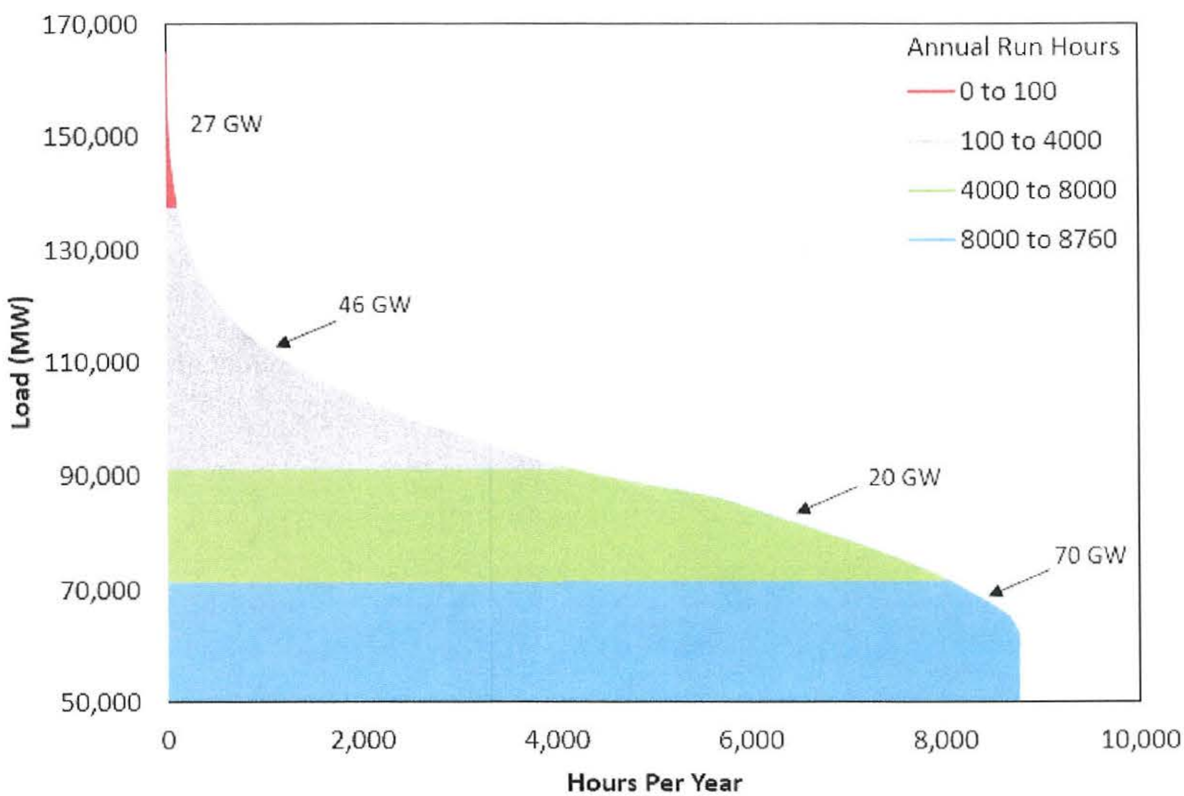
[1] See Answer of PJM Interconnection, L.L.C. To Protests and Comments, Docket No. ER19-469-000 (February 15, 2019) at 4 ("Answer of PJM Interconnection, L.L.C. To Protests and Comments").

[2] "Intermittent Resource Participation in RPM for 2020/21 and beyond". 2018. ("Intermittent Resource Participation in RPM for 2020/21 and beyond").

[3] Answer of PJM Interconnection, L.L.C. To Protests and Comments, at 5.

8. The 10-hour requirement specified by PJM is intended to cover peak load hours, but in the context of capacity planning, PJM's approach and specification of the peak is essentially arbitrary. Ultimately, a full range of resource durations, from highly-responsive resources with only a few hours of duration up to resources with the ability to run for 24 hours a day are needed. Reliability events tend to occur during the day, but lights need to stay on at night too. The minimum annual load in PJM is approximately 60 GW, so at least that much capacity plus reserves should be available 24 hours a day year-round. But not all resources are needed around-the-clock. An illustration of the PJM load duration curve, shown in Figure 1, gives indicative portfolio sizes for various tranches of annual run hours.

Figure 1: PJM Load Duration Curve[4]



Approximately 27 GW of capacity resources are only needed less than 100 hours a year. Given this information it does not make sense to impose a requirement on all capacity resources that they be able to operate thousands of hours per year, or that they be able to run for extended periods when they are deployed. In some jurisdictions, such a requirement would disqualify many combustion turbines which have environmental run hour constraints. Capacity qualification then must recognize the expected utilization and reliability contribution of each respective class of resource, given its physical and operational characteristics.

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[4] Composite load duration curve for entire PJM system developed by Astrapé from modeled load profiles.

9. The calculation of continuous operation hour requirements is more complex than that for annual run hour requirements, but the principle is the same. If energy storage resources can maintain system reliability just as well as a nuclear unit while being operated very differently, it should be awarded the same capacity value, just as peaking gas turbines are valued identically to nuclear resources for purposes of establishing credit toward meeting the resource adequacy reliability target. The market structure in PJM already provides the appropriate distinction; the capacity market compensates for providing resource adequacy and the energy and ancillary service markets compensate for differences in efficiency and utilization. As PJM has implicitly recognized, duration requirements are not generally necessary for conventional resources. Nuclear and other baseload resources are not built to only be available 12 hours a day. Conceptually, capacity market design could be modified to allow resources to bid both duration and price and the clearing mechanism would efficiently select resources that ensure reliability. But as we will show in a rigorous assessment of the reliability implications of duration-limited resources, this is not necessary in PJM. The existing and projected resource mix in PJM has the ability to incorporate significant energy limited resources ("ELRs") that supply full capacity value with only modest duration requirements.

10. Duration has historically been a concern for demand response resources. PJM previously implemented a cap on eligibility for demand response capacity with limited duration capabilities. This cap, along with the associated minimum duration requirement, was eliminated in the Capacity Performance Rehearing Order. The Commission determination stated that "the rehearing requesters are in effect asking for special treatment for certain resources, permitting them to provide a lesser quality of service for the same price. We cannot find unreasonable PJM's conclusion that non-year-round resources do not provide equivalent service as year-round resources."[5] The concerns stated by the Commission in the rehearing order are not applicable to energy storage resources which provide at least 6 hours of continuous operation and are available year-round because the reliability service they provide would be equivalent to that supplied by conventional resources as demonstrated by our subsequent analysis.

11. Identifying the technical requirements for provision of capacity must be based on rigorous Loss of Load Expectation ("LOLE") analysis. LOLE analysis simulates the full set of generation in a system against system loads in a resource adequacy model to assess the likelihood of shedding firm load. The full resource mix of a system must be considered since the capacity value of any class of resource cannot be calculated in isolation or solely against the system load shape. The industry standard for resource adequacy is 0.1 LOLE which represents one day of expected load loss due to resource inadequacy in a 10 year period. PJM uses this standard in all of its resource adequacy analysis, and although they use different tools than those employed by Astrapé, the approaches to assessing resource adequacy are generally similar.

12. PJM has referenced multiple resource adequacy analyses which assess the implications of duration in its system. The first was a 2010 study of demand response resources by PJM.[6] While the framework of the analysis was generally reasonable, there were a number of deficiencies which unfairly penalize the capacity value of ELRs. First, the analysis

[5] Order on Rehearing and Compliance, 155 FERC ¶ 61,157.

[6] Affidavit of Thomas A. Falin on Behalf of PJM Interconnection, L.L.C 2012. Docket No. ER11-000. ("Falin Affidavit").

assumed that energy-limited resources are scheduled to dispatch simultaneously. In other words, in this study, in the first hour of need, the entire portfolio of energy limited resources is dispatched. This is not how ELRs would operate. Only the most economic resources needed to meet the need would be selected for dispatch. Further, ELRs are often used to provide operating reserves which allows for their energy to be preserved during high load periods. This more efficient dispatch optimizes the reliability contribution of ELRs, reducing the need for duration. While PJM in its Answer did not challenge the representation that efficient dispatch raises the reliability contribution of ELRs, they stated that assuming efficient dispatch would place an unwarranted operational burden on PJM.[7] However, this conflicts with PJM's own stated value proposition. They represent that "PJM's regional grid and market operations produce annual savings of $2.8 billion to $3.1 billion in ensuring reliability, providing the needed generating capacity and reserves, managing the output of generation resources to meet demand and procuring specialized services that protect grid stability." They also state that "PJM reacts to changes in demand in real time, adjusting generation to be in balance with demand and maintain the transmission system at safe operating levels."[8] Given these statements, efficient dispatch of energy limited resources is not an onerous expectation of PJM. To some extent, market forces will naturally lead to diversity of dispatch among ELRs, but oversight of energy storage dispatch during critical hours to ensure reliability is not burdensome.

13. A second limitation of the 2010 study of demand response by PJM is that it only considers the duration of high load periods in assessing the need for duration from generators. The need for duration, however, is not only driven by load uncertainty but also affected by generator outage uncertainty. The length of time that a specific magnitude of generation is unavailable can affect the need for duration. PJM's approach uses a capacity outage table which does not consider duration of outages and instead assumes generator outages persist over the entire time period of analysis.[9] This overstates duration needs since generators frequently fail and are returned to service over short intervals. Duration needs are driven by the confluence of generator outages and high loads, rather than by simply looking at the duration of high loads. Given the in-house resource adequacy simulation tools available to PJM with the embedded capability of modeling the chronology of generator outages, it is not clear why this simplified approach was used.

14. A final observation from the 2010 demand response study by PJM is that they stated that some slight degradation to reliability is acceptable when incorporating ELRs: "Based on the information in Figure 2, engineering judgment must be applied to choose a DR penetration level at which PJM is comfortable that the probability of needing more than ten interruptions is not too large. A reasonable DR limit might be 8.5%, which is the point at which there is only a 10% chance that more than ten interruptions are needed (or, as indicated in Figure 2, a 90% chance of needing ten or fewer interruptions)."[10] While we are neither advocating for special treatment for ELRs, nor did we assume that ELRs would be held to a lesser standard than other resources in our simulations, we believe it is important to recognize the probabilistic nature of reliability studies reflected in PJM's use

[7] Answer of PJM Interconnection, L.L.C. To Protests and Comments at Page 23.

[8] "PJM Value Proposition". 2019. https://www.pjm.com/about-pjm/value-proposition.aspx

[9] Falin Affidavit, at Page 4. "The PJMRTO cumulative capacity probability table from the 2009 IRM Study is used. The cumulative capacity probability table represents the distribution of available capacity each week."

[10] Falin Affidavit, at 8.

of "engineering judgment." Reliability contributions are not binary, and analysis does not produce unequivocal, clearly demarcated thresholds. A resource with energy limitations versus one with a higher forced outage rate versus a renewable resource with limited dispatchability will have different reliability contribution profiles, and it is more appropriate to calculate relative capacity values than to hold all resources to an arbitrary binary threshold. In all of Astrapé's work in calculating capacity value of resources with various constraints, capacity value is calculated in relative terms. Recent work in the New York Control Area demonstrates this approach.[11] In fact, PJM applies a similar approach when calculating the capacity contribution of renewable resources.[12] Calculating a relative capacity value does not reflect preferential treatment, but rather simply recognizes the probabilistic nature of resource adequacy contribution.

15. More recent analysis performed by PJM analysts takes a more realistic approach to dispatching ELRs.[13] Rather than assume all available ELRs are dispatched simultaneously, PJM models ELRs that are dispatched efficiently to meet load obligations. This substantially increases the volume of duration-limited resources which can reliably serve load. This study cited by PJM identifies a threshold of 20% penetration of ELRs before a 10-hour duration requirement would be binding.[14] A 20% penetration in PJM would be nearly 30 GW of energy-limited capacity. As mentioned in our original affidavit, this penetration is not realistic in the planning window[15]. Given that duration requirements should be based on the current and projected system, it would not be appropriate to set duration requirements based on an unrealistic hypothetical future. While the need for duration varies by region, other similar analyses in other jurisdictions[16] attempt to model realistic energy storage deployment levels.

16. For the analysis performed by Astrapé, PJM and its neighbors were modeled in SERVM using publicly available load and resource data.[17] Reliability for all zones was calibrated to 0.1 LOLE by removing conventional capacity. To identify whether the system met the 0.1 LOLE standard, thousands of SERVM simulations representing a wide range of weather-related load uncertainty, economic forecast uncertainty, and generator outage uncertainty were performed. After calibrating to 0.1 LOLE, energy-limited resource capacity was added to the system which improved reliability. Finally, perfect capacity was removed from the system until reliability returned to 0.1 LOLE. For each of these incremental steps, thousands of simulations representing the same distributions of uncertainty were also performed. These steps were replicated for various combinations of energy-limited resource duration and penetration. The capacity value of energy-limited resources is

[11] "Load Shape Development and Energy Limited Resource Capacity Valuation". NY-BEST. 2019. ("NY-BEST NYISO Study").

[12] Order on Rehearing and Compliance, 155 FERC ¶ 61,157, at 47.

[13] Aramazd Muzhikyan, Laura Walter, Scott Benner, and Anthony Giacomoni. "Limited Energy Capability Resource Duration Requirement for Participation in PJM Capacity Market". 2019. https://www.pjm.com/-/media/library/reports-notices/special-reports/2019/csr-duration.ashx?la=en. ("A. Muzhikyan, L. Walter, S. Benner, and A. Giacomoni").

[14] "An analysis based on historical load profiles from 2008–2017 and BTM solar ICAP projections for 2028 shows that for 20% LECR penetration, the eligible resources should meet a 10- hour equivalent duration requirement". A. Muzhikyan, L. Walter, S. Benner, and A. Giacomoni, at 7.

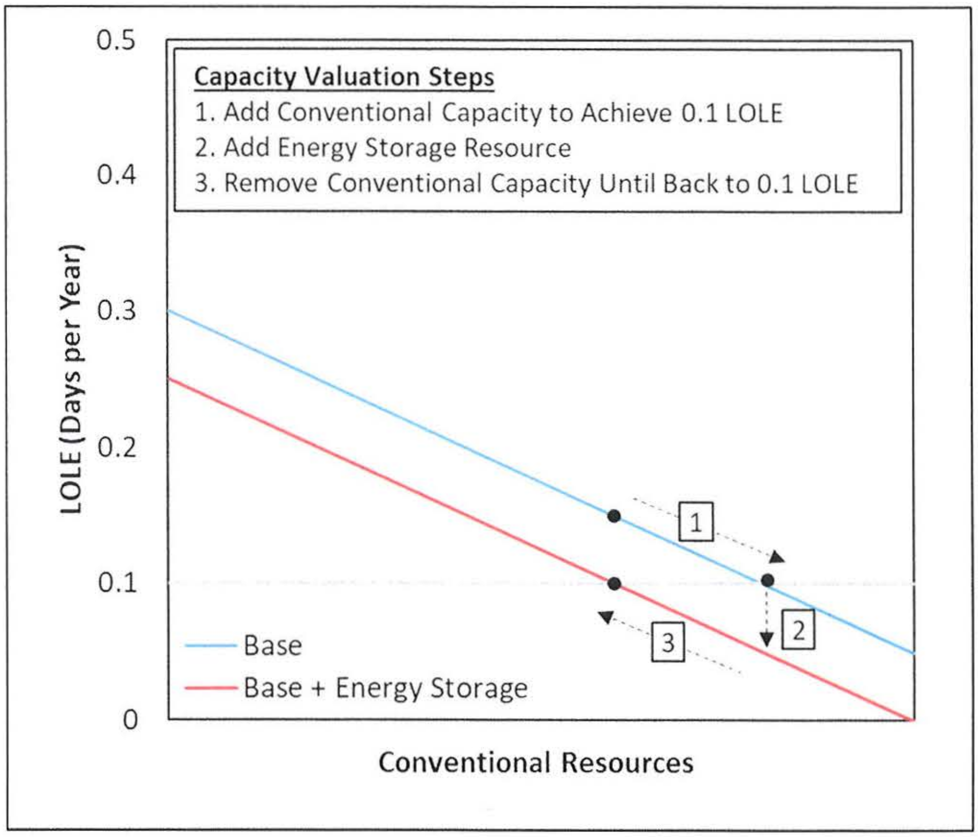
[15] The planning window as used in this report refers to a period of 10 years which is used to reflect ample opportunity to monitor load and technology trends and update resource requirements to protect reliability.

[16] "*Valuing Capacity for Resources with Energy Limitations*". GE Energy Consulting, 2019.

[17] Input assumptions documented in appendix.

calculated as the ratio of perfect capacity removed to energy-limited capacity added. If 0.1 LOLE was achieved when 1000 MW of energy storage resources were added and 1000 MW of capacity with perfect availability were removed, the energy storage would provide 100% capacity value. The reason capacity with perfect availability is utilized in this process is to isolate the effect of duration, so that differences in forced outage rates do not distort the comparison. The analysis is intended to identify what duration is required for energy storage to provide identical capacity value to that provided by conventional dispatchable resources before the impact of forced outage rates is considered. This process is illustrated in Figure 2.

Figure 2: SERVM Capacity Value Approach



17. The results of our simulations are clear and consistent: energy limited resources with continuous operation capability of 4 to 6 hours provide capacity equivalent to conventional resources with the current and projected PJM resource mixes.[18] Adding energy storage resources and simultaneously removing the same volume of conventional resources while maintaining resource adequacy at the 0.1 LOLE standard is an explicit demonstration of equivalent capacity value. While capacity value of energy-limited resources would decline with increases in penetration in a system with an otherwise static resource mix, this should

[18] Astrapé utilized a conservative approach to estimating projected PJM resource mixes out to 2030. The penetration of conventional thermal generation was held constant even though renewable resources are expected to increase in penetration, and short-duration ELR capacity was deployed up to 12,000 MW.

not be a concern for the 10-year planning window. First, our findings show that declines in capacity value do not become material until very high penetrations. Our simulations demonstrate that 4,000 MW of incremental 4-hour ELRs can be incorporated and provide full capacity value with the current resource mix.[19] Over 10,000 MW of 6-hour ELRs could be incorporated at effectively full capacity value.[20] Second, the resource mix of the system is not static. Renewable resources, which steepen the net load peak and reduce the need for duration, are expected to increase in penetration. Simulations with higher renewable penetrations were not simulated since even with the current resource mix ELRs with 6 hours or less of duration provide full capacity value, but our work in other jurisdictions[21] demonstrates that such changes expand the amount of ELR with 6 hours or less of duration that can provide very high levels of capacity to existing systems.

18. The conclusions from the Astrapé analysis are actually very similar to the capacity values shown by PJM for duration limited resources at current and projected system resource mixes. The recent study by PJM analysts shows that 3% or 4.5 GW of ELRs with four hours of continuous operation capability could be integrated and provide full capacity value.[22] Our analysis shows 4 GW of similar 4-hour ELRs provide full capacity value. PJM analyzed portfolios up to 30 GW before the need for 10-hour duration would be binding.[23] While our analysis did not cover such high penetrations as they are not realistic in the 10-year planning window and the composition of the remainder of the fleet is also evolving, we did show that 6-hours of duration would supply full capacity value up to at least 12 GW. As penetration of ELRs changes over time the capacity value could be revisited.

19. This concludes my affidavit.

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[19] Raw results from SERVM simulations show 99.9% capacity value for 4-hour duration resources at 4,000 MW.

[20] Raw results from SERVM simulations show 97.9% capacity value for 6-hour duration resources at 10,000 MW.

[21] NY-BEST NYISO Study, at Page 6.

[22] A. Muzhikyan, L. Walter, S. Benner, and A. Giacomoni, at Page 6.

[23] A. Muzhikyan, L. Walter, S. Benner, and A. Giacomoni, at Page 6.

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.) **Docket No. ER19-469-000**

VERIFICATION OF KEVIN CARDEN

I, Kevin D Carden, being first duly sworn, deposes and states that I am the Kevin Carden referred to in the foregoing document entitled "Affidavit of Kevin Carden. I have read the same and attest that the foregoing document was prepared by me or under my direct supervision. I am familiar with the contents thereof, and that the facts set forth therein are true and correct to the best of my knowledge, information, and belief.

Kevin D. Carden

Kevin D. Carden

4/12/19

Date

Subscribed and sworn to before me, this 12th day of April, 2019.

Signature of Notary Public

Thomas Harrison

Print Name

My Commission expires on: 2/20/2023

Seal

THOMAS HARRISON NOTARY My Comm. Expires Feb. 20, 2023 PUBLIC ALABAMA STATE AT LARGE

{W7220914.1}

Attachment 1

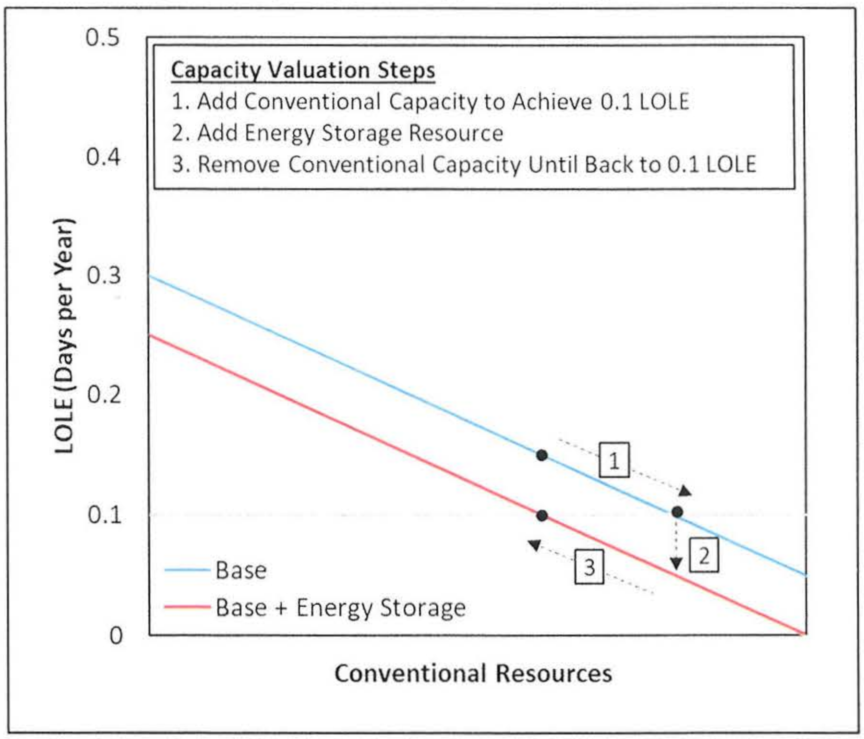
Astrapé March 2019 PJM Capacity Value Analysis

Summary

Astrapé Consulting performed a capacity valuation of energy-limited resources (ELRs) using the Strategic Energy and Risk Valuation Model (SERVM) for the PJM Interconnection, L.L.C. (PJM). The intent of this analysis was to determine the duration requirements for ELRs based on their ability to provide the same reliability benefits as conventional fully-dispatchable resources. This analysis was performed using the projected and potential resource mix in PJM over the planning horizon[1] which included aggressive energy storage deployments. Since reliability considerations are unique to the composition of the fleet in each electric system, it was critical that our analysis use an accurate representation of the current and projected PJM system.

The calculation of ELR capacity value in SERVM included several steps, as shown in Figure 1. First, reliability was calibrated in PJM and its neighbors to 0.1 Loss of Load Expectation (LOLE). This threshold is the generally accepted reliability criterion employed in the United States and represents a single day of firm load shed in a 10 year period. Next, ELR capacity was added to the system, improving reliability. Finally, perfectly available and fully dispatchable capacity was removed until reliability returned to 0.1 LOLE. The ratio of perfect capacity removed to ELR capacity added defines the ELR capacity value.

Figure 1. Capacity Value Approach Using SERVM



The results of our analysis demonstrate that with energy storage deployments up to 4,000 MW, 4 hours of duration allows those resources to provide full capacity value relative to a resource without duration limits. With energy storage deployments up to 12,000 MW, 6 hours of duration allows those resources to provide full capacity value.

The binding limit on providing reliability is generally either a capacity constraint or an energy constraint. This varies by system. In most of the United States, reliability is primarily constrained by capacity. In these systems, reliability events occur when peak loads exceed the capacity of available resources. However, in the Pacific Northwest which serves a majority of its load with hydro resources, energy is the binding constraint. In these systems, the installed capacity is significantly higher than the most extreme peak

[1] The planning horizon as used in this report refers to a period of 10 years which is used to reflect ample opportunity to monitor load and technology trends and update resource requirements to protect reliability.

demand, but limits on the availability of hydro energy can result in reliability events that can occur for extended durations over both peak and non-peak load hours. PJM is currently capacity constrained. In addition to assessing the capacity value of marginal additions of energy-limited resources, this study analyzed whether a shift to energy constrained reliability was possible in the PJM system with the incorporation of potential ELR deployments. With high enough penetrations of energy-limited resources, reliability events occur in shoulder load hours when ELRs exhaust their energy supply. However, the level of ELR deployments of typical durations between 4 and 6 hours that was required to shift PJM to energy-constrained reliability was unrealistic in the 10-year planning window.

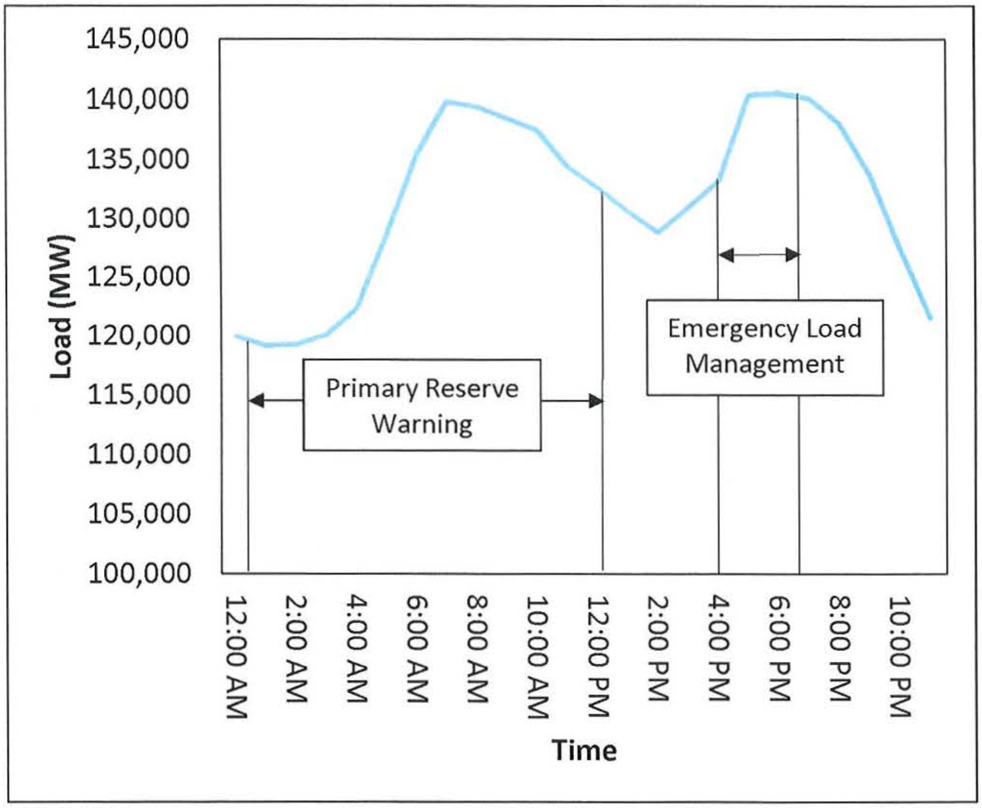
As part of this analysis, Astrapé also provided a qualitative review of the duration of historical reliability events. While our bottom-up analysis using SERVM demonstrates the value of 4-6 hour duration ELRs, a review of historical events can provide some level of calibration. In PJM, performance assessment periods are recorded when the confluence of generator availability and load conditions are such that reliability is of concern. Generally during these periods demand response resources are dispatched. In the period from June 2011 through the end of 2014, PJM recorded 9 system-wide performance assessment periods. These events ranged from less than one hour to 11.3 hours in duration, with almost all being 6 hours or less. The only event significantly longer than 6 hours was an event that declared in anticipation of tight conditions and was not due to energy constraints. The implications of this event will be discussed in more detail. Having performed reliability studies for nearly two decades, our experience demonstrates that reliability is actually improved by resource diversity even if resources being added have constraints. The survey of historical reliability-constrained periods is shown in Table 1. Of note, there have been no performance assessment periods in PJM since 2014.

Table 1. PJM System-Wide Performance Assessment Periods Since 2011

Date	Emergency Procedure	Start Time (EPT)	Stop Time (EPT)	Duration of Event (Hours)
March 4, 2014	Emergency Load Management	5:30 AM	8:30 AM	3.00
January 30, 2014	Voltage Reduction Warning	6:50 AM	7:35 AM	0.75
January 8, 2014	Emergency Load Management	6:00 AM	7:00 AM	1.00
January 7, 2014	Emergency Load Management	4:00 PM	6:16 PM	2.27
January 7, 2014	Primary Reserve Warning	12:55 AM	12:14 PM	11.32
January 6, 2014	Voltage Reduction Warning	7:27 PM	9:23 PM	1.93
July 18, 2013	Emergency Load Management	2:40 PM	6:00 PM	3.33
July 17, 2012	Emergency Load Management	3:08 PM	7:05 PM	3.95
July 22, 2011	Emergency Load Management	1:30 PM	7:37 PM	6.12

The only performance assessment period with a duration significantly longer than 6 hours was on January 7, 2014 during the Polar Vortex. The load pattern on this day, as shown in Figure 2, was not suggestive of the need for long duration resources. Reliability was of concern for a long period this day because of correlated outages. Between a lack of access to firm fuel, cold weather related availability issues, and other forced outages, over 40 GW were unavailable[2]. The correlated issues that resulted in conventional generator outages generally would not apply to batteries. A system with more homogeneous resources is more susceptible to these coincident issues than one which contains more heterogeneous resources with different categories of constraints.

Figure 2. Load on January 7, 2014



While caution is warranted in using historical data to justify duration requirements since the system will be evolving, the primary takeaway is that the duration of reliability concern does not necessarily match the shape of the load. PJM frequently refers to the load shape as being very high for 10 hours in a day to support the need for 10 hours of duration for capacity resources. However, this need is not borne out in the historical data. So, the anecdotal historical review can provide some support for the findings from the SERVM-based simulations that demonstrate that 4-6 hour duration energy limited resources can provide full capacity value compared to conventional resources, even with a system with a load shape that is relatively flat during high load days. The following sections detail the input development for the SERVM simulations.

Model Development

The development of this capacity value analysis for PJM was a time-intensive process. All the generators and loads in PJM plus one tier away required construction from publicly available datasets.

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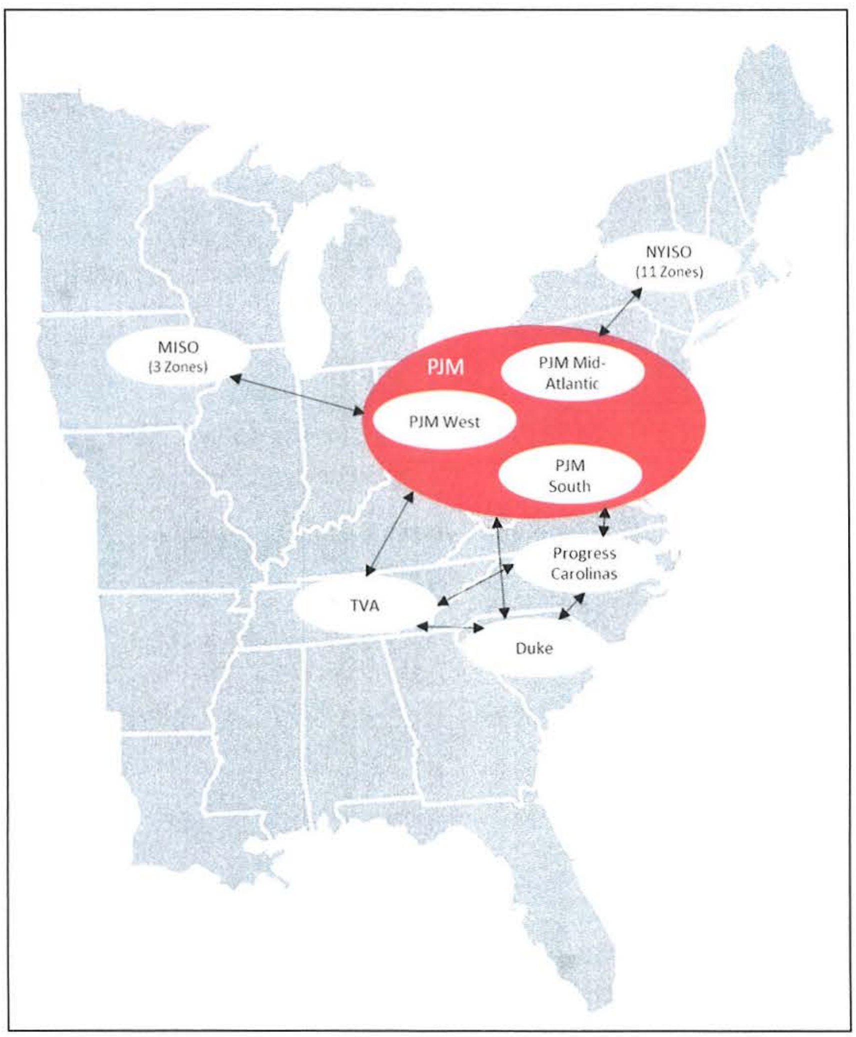
[2] https://www.pjm.com/~/media/library/reports-notices/weather-related/20140509-analysis-of-operational-events-and-market-impacts-during-the-jan-2014-cold-weather-events.ashx

Study Topology

Figure 3 shows the study topology that was used for the study. SERVM models the regions in Figure 1 with a pipe and bubble representation, allowing for regions to share capacity based on economics and subject to physical transmission constraints. The following is a list of regions included in the study:

- PJM MidAtlantic
- PJM West
- PJM South
- NYISO (Zones A-K)
- Wisconsin-Michigan (MISO)
- Indiana (MISO)
- Illinois (MISO)
- TVA
- Progress Carolinas
- Duke

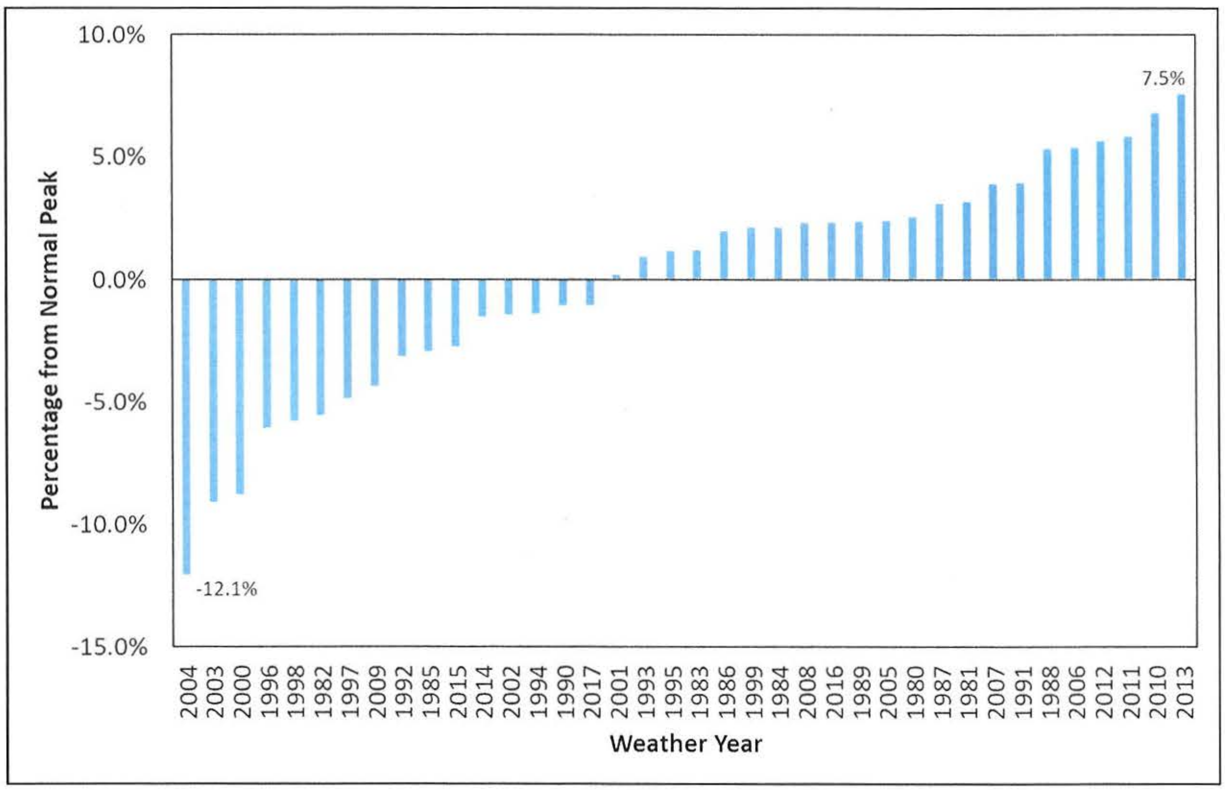
Figure 3. Study Topology



Load Modeling

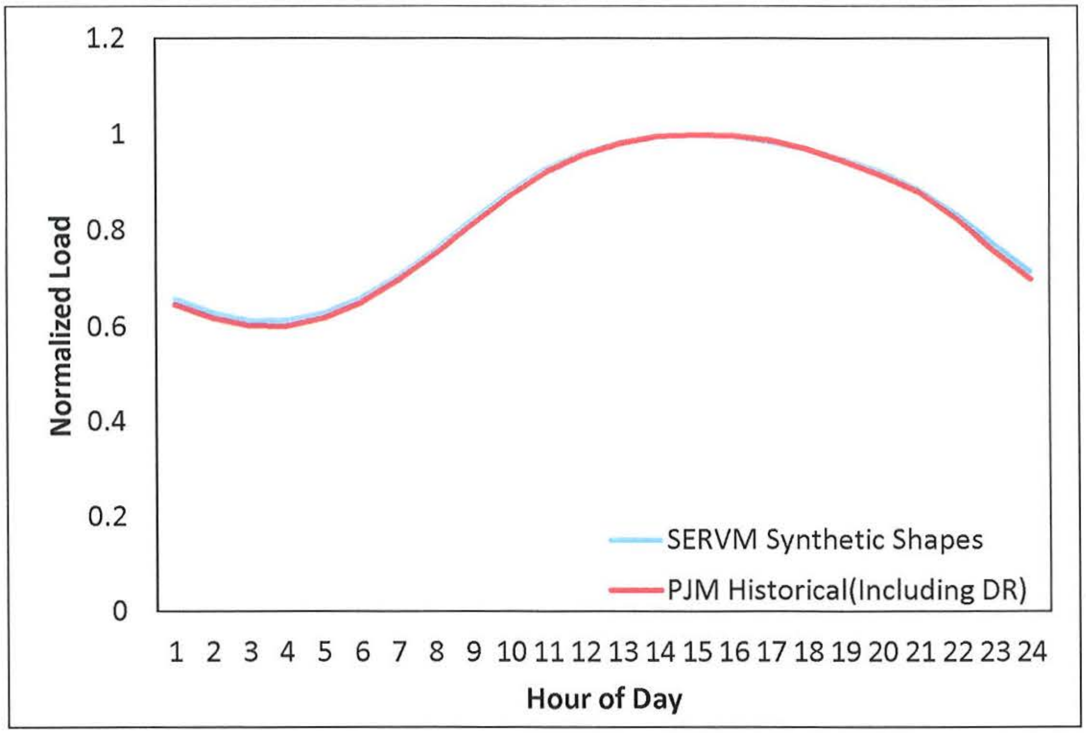
To model the effects of weather uncertainty, 38 weather years were developed to reflect the impact of weather on load. Based on the 2011 to 2018 historical weather and load, a neural network program was used to develop relationships between weather observations and load. Different relationships were built for each season and for each zone to ensure that proper weather diversity was captured. These relationships were then applied to the last 38 years of temperature profiles to develop 38 load shapes for 2019. Equal probabilities were given to each of the 38 load shapes in the simulations. Figure 4 ranks all weather years by summer peak load and shows variance from normal weather. In the most severe weather conditions, the peak can be as much as 7.5% higher than under normal weather conditions.

Figure 4. 2019 PJM Peak Loads by Weather Year



Since this study was designed to measure the need for duration, an important step in the calibration was ensuring the daily load shape matched historical profiles. Figure 5 shows a comparison of the average daily shape during the top 10 load days in the synthetic shapes versus the top 10 load days from recent history confirming that our modeled shapes are consistent with the load patterns expected in PJM.

Figure 5. Comparison of Average Daily Shape of the Top 10 Load Days



Loads for each external region (Duke, MISO, PJM, Progress Carolinas, and TVA) were developed in a similar manner as the PJM loads. A relationship between hourly weather and publicly available hourly loads was developed based on recent history, and then this relationship was applied to 38 years of temperature data to develop 38 load shapes.

Table 2 summarizes the peak load for the PJM system and the load diversity relative to the interconnected regions.

Table 2. Regional Load Diversity

	Peak Load (MW)	Load Diversity (% below non-coincident 50/50 peak)	
	Non-Coincident Peak Load	**At System Coincident Peak**	**At PJM Coincident Peak**
Duke	18,137	-5.6%	-7.4%
MISO	57,665	-5.2%	-7.7%
NYISO	33,254	-5.8%	-6.6%
PJM	153,379	-0.6%	0.0%
Progress	14,011	-10.5%	-11.6%
TVA	32,283	-12.4%	-13.5%
System	**295,435**	**0.0%**	**-0.8%**

Economic Load Forecast Error

The two uncertainties that are modeled in SERVM are uncertainties due to weather and uncertainties due to economic growth. These non-weather drivers of load forecast errors differ from weather-related forecast errors because they increase with the forward planning period, while weather uncertainties remain relatively constant and can be independent of the forward period.

The non-weather load forecast error multipliers were developed by reviewing the Congressional budget Office (CBO) GDP forecasts 3 years ahead and comparing those forecasts to actual data. A standard deviation was calculated, and a normal distribution was developed for economic load forecast error. Because electric load grows at a slower rate than GDP, a 40% multiplier was applied to the raw CBO forecast error.

Table 3 shows the economic load forecast multipliers and associated probabilities used in this study. The table shows that 6.1% of the time, it is expected that the load will be under-forecasted by 4% 3 years out. The load forecast multipliers were applied to all regions.

Table 3. Economic Load Forecast Multipliers Used in Modeling

Load Forecast Error Multiplier	Probability (%)
0.96	6.1
0.98	24.2
1.00	39.4
1.02	24.2
1.04	6.1

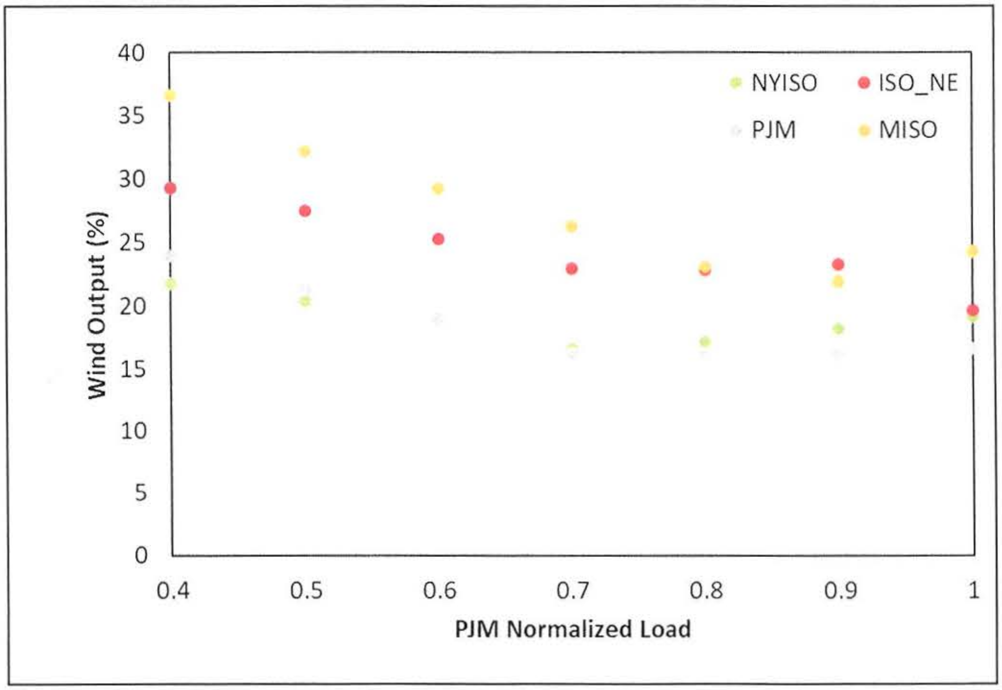
The SERVM Model utilized each of the 38 weather years and applied each of these 5 load forecast error points to create 190 different load scenarios. Each weather year was given equal probability of occurring.

Renewable Profiles

Wind Profiles

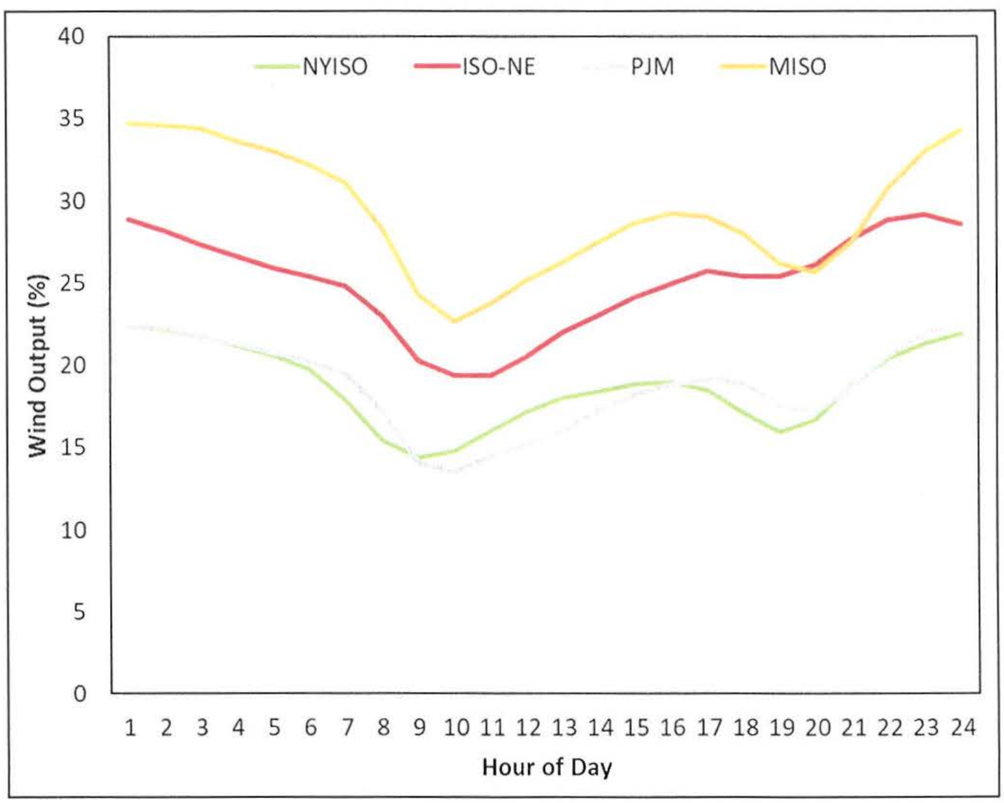
Wind profiles were constructed based on hourly historical data for 2016 to 2018 for PJM, NYISO, MISO, and SPP. The raw data was found on the entities' respective websites. To construct wind shapes back to 1980, random days were selected from the 2016 to 2018 dataset based on the aggregate PJM load. To maintain correlation, as shown in Figure 6, between load and wind and between the wind output in different regions, the same day was used for each region being captured.

Figure 6. Average Wind Output as a Function of PJM Load



To smooth the transition between days (since days selected were not consecutive), the modeled output in hours 23 to 2 was averaged (hour 23 was the average of the profile in hour 22, 23, and 24; hour 24 was the average of hours 23, 24, and 1, etc.). The average final summer wind shapes are shown in Figure 7.

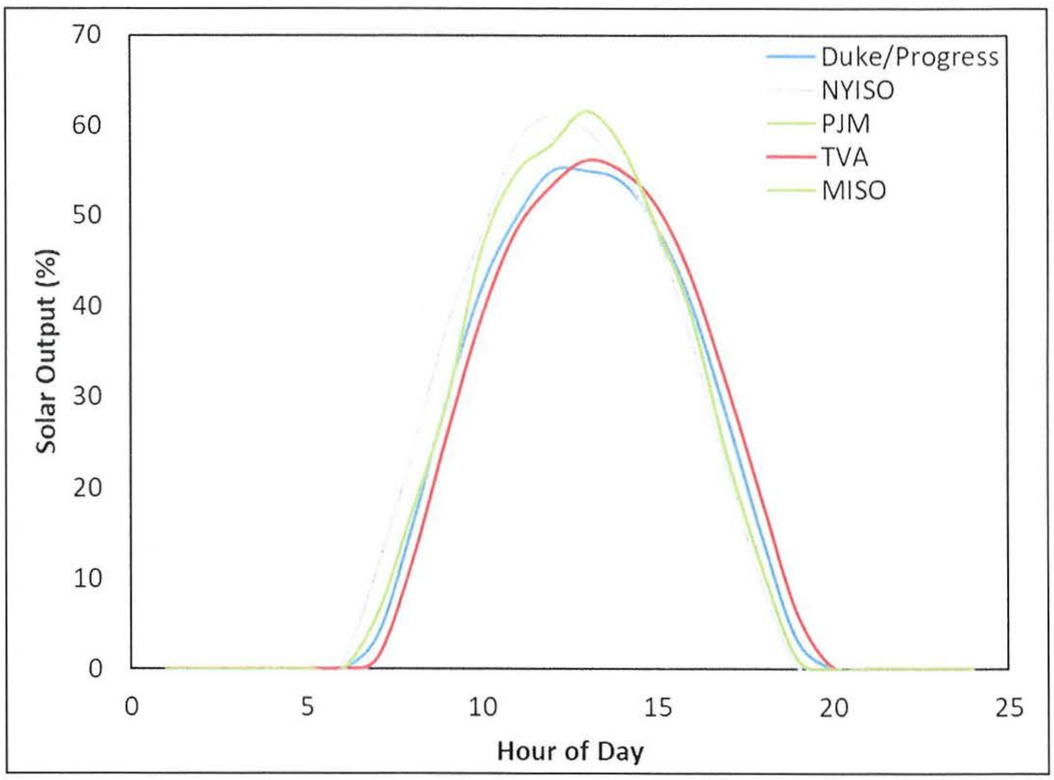
Figure 7. Final Average Summer Wind Shapes



Solar Profiles

Four solar profiles (one for each of PJM, NYISO, Duke, and TVA) were developed from data downloaded from the NREL National Solar Radiation Database (NSRDB) Data Viewer[3]. Data was downloaded for the 4 different locations for the available years, 1998 to 2017. Historical solar data from the NREL NSRDB Data Viewer included variables such as temperature, cloud cover, humidity, dew point, and global solar irradiance. The data obtained from the NSRDB Data Viewer was input into NREL's System Advisory Model (SAM)[4] for each year and location to generate the hourly solar profiles based on the solar weather data for a fixed solar PV plant. Inputs in SAM included the DC to AC ratio of the inverter module and the tilt and azimuth angle of the PV array. Data was normalized by dividing each point by the input array size. Solar profiles for 1980 to 1997 were selected by using the daily solar profiles from the day that most closely matched the peak load out of all the days +/- 2 days of the source day for the 1998 to 2017 interval. The profiles for the remaining years 1998 to 2017 came directly from the normalized raw data. The previous steps for selecting a profile were completed for each of the 4 locations. Figure 8 shows the August average daily solar profiles for 1980 to 2017.

Figure 8. August Daily Fixed Solar Profile



[3] https://nsrdb.nrel.gov/nsrdb-viewer
[4] https://sam.nrel.gov/

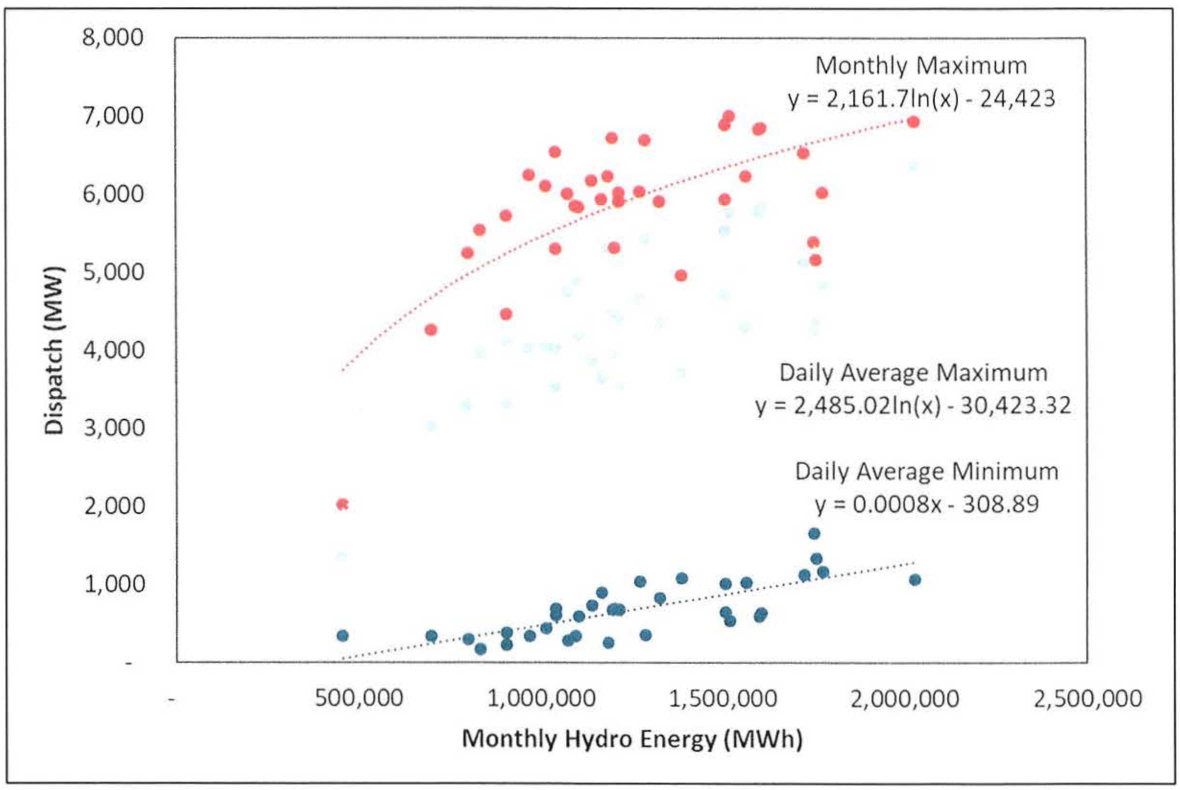
Hydro Profiles

Available hydro data from 1980 to 2017 was collected from the U.S. Energy Information Administration Form 923. The projects in all of the zones modelled were assigned to their appropriate regions for all 38 weather years. Using the aggregate actual hourly data provided by PJM from 2016 to 2018, inputs were developed to be used by the proportional load following algorithm for the proper PJM zones.

The average daily minimum and maximum dispatch levels, the total monthly energy, as well as the monthly maximum dispatch levels were identified from the historical hourly data for PJM. Minimum and maximum daily dispatch levels and monthly maximum dispatch levels were defined as a function of monthly total energy as shown in Figure 9.

PJM did not supply hourly hydro data by resource type, so all projects are modeled together, including pumped storage hydro. The low minimum daily flows then reflect some pumping during low load periods. In the model, the entire hydro fleet was modeled as a single unit but dispatched consistent with the patterns described below.

Figure 9. PJM Hydro Dispatch Levels



The curve fit equations were then used to apply to historical energy from the monthly energies calculated in the EIA form. SERVM optimally schedules the hourly hydro energy while respecting these constraints. The daily maximum and minimum dispatch and monthly maximum dispatch in conjunction with the total monthly energy are parameters that go into the determination of the hourly hydro schedule. The daily minimum hydro dispatch is scheduled at the minimum load hour of the day, and the daily maximum hydro is scheduled at the maximum load hour of the day. The monthly maximum hydro is scheduled at the max load hour of the month.

The above process was repeated for neighboring regions with hydro capacity. For regions where hourly generation was unavailable, the PJM hourly hydro generation was scaled by capacity and then applied to the monthly generation from the EIA form.

Scheduled hydro units are modeled with maximum capacity, total energy, daily average energy, and the schedule flow range. The total energy is the total amount of hydro that will be produced in a given month. This value cannot be greater than the total maximum hydro capacity multiplied by the number of hours in the month. The simulation logic will not allow the unit to simply run at the maximum hydro capacity for all hours because the monthly hydro energy constraint will be violated. After the minimum weekly flows are taken into account, the remainder of the month's energy is scheduled as peak shaving.

Conventional Resources

The conventional resources included in the 2019 study are the same resources listed on the PJM website as being included in their 2019-2020 RPM Resource Model[5]. To accurately reflect the flexibility of the PJM system, each resource was modeled with detailed unit variables and all constraints were respected by SERVM in the simulations. While fuel prices and other economic variables were not available publicly, Astrapé developed inputs that allowed for a reasonable commitment and dispatch schedule of the entire fleet; base load resources were modeled to operate at availability while peaking resources dispatched less than 1,000 hours per year. Conventional resources were selectively retired in the analysis in order to achieve 0.1 LOLE for the base case.

The neighboring region resources were also modeled with publicly available unit data found in IRPs and on their respective websites.

Unit Outage Data

Unlike typical production cost models, SERVM does not use an Equivalent Forced Outage Rate (EFOR) for each unit as an input. Instead, historical events are entered in for each unit, and SERVM randomly draws from these events to simulate the unit outages. The events are entered using the following variables:

Full Outage Modeling
Time-to-Repair Hours
Time-to-Fail Hours

Partial Outage Modeling
Partial Outage Time-to-Repair Hours
Partial Outage Derate Percentage
Partial Outage Time-to-Fail Hours

Planned Outages
Planned outage rates are entered for each unit. SERVM schedules each planned outage event during shoulder seasons to minimize reliability impact for each zone.

Astrapé inserted generic outage distributions and scaled the data so the system average forced outage rate would be comparable to typical averages seen in that region. PJM publishes forced outage rate data used in their resource adequacy studies, but their data is based on must-run dispatch, so it is not directly

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[5] https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2019-2020-rpm-resource-model.ashx?la=en

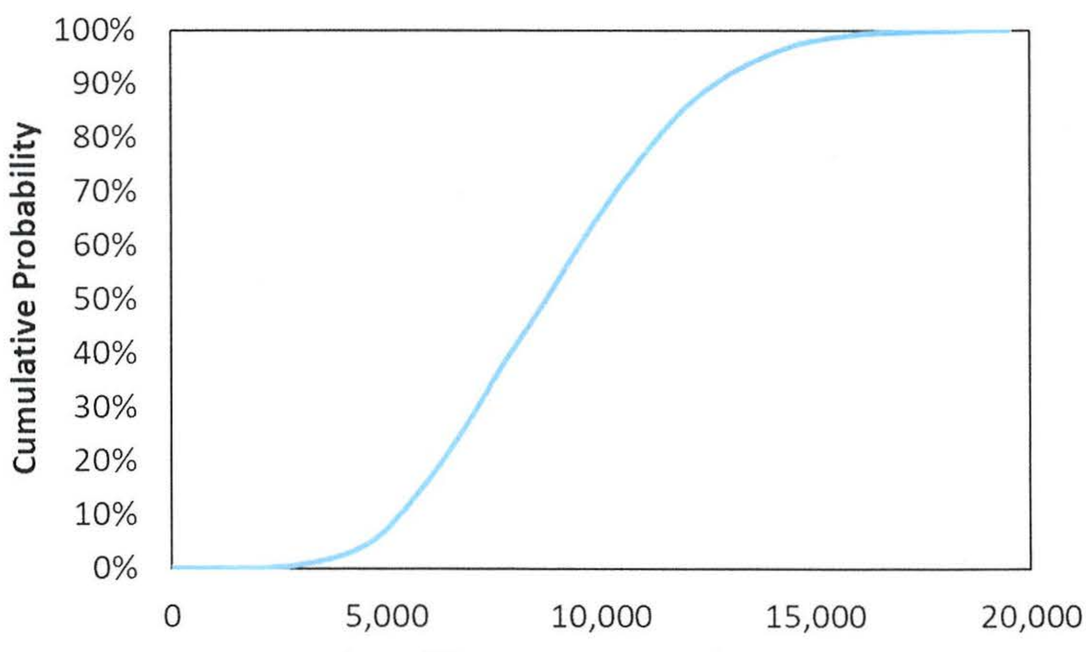
comparable to the values shown here. Table 4 shows the average EFOR values from all the distributions imported into SERVM for each PJM unit category.

Table 4. PJM EFOR Values by Unit Category

Unit Category	EFOR (%)
Nuclear	5.47
Combined Cycle	5.89
Gas Turbine	12.10

An important aspect of unit performance modeling is the cumulative MW offline distribution. Most service reliability problems are due to significant coincident outages. Figure11 shows the distribution of outages for the PJM Balancing Area based on historical modeled outages. The figure demonstrates that in any given hour, the system can have between 0 and 20,000 MW of its generators offline due to forced outages. Each point on the curve demonstrates the probability that a specific MW quantity of capacity or less is forced offline. The figure shows that in approximately 90% of all hours throughout the year, the balancing area has less than 12,700 MW in a non-planned outage condition. The corollary is that in 10% of all hours in the year, more than 12,700 MW are in a forced outage state.

Figure 10. Cumulative Probability of Conventional Resources on Forced Outage



It is important to note that generator outages also have a shape. Outages do not remain static over a long period of time as generators are frequently failing or returning to service. The approach employed in prior

PJM analysis[6] essentially assumes a static shape to generator outages which will tend to overstate the need for duration as compared to the SERVM approach which as an hourly chronological model reflects variability in generator outages over time.

Dispatch Order and Emergency Operating Procedures

The order in which energy storage resources are dispatched has an impact on their capacity value. To be consistent with a methodology that protects reliability, energy limited resources are dispatched after demand response resources which do not have duration limitations. Also, energy storage resources are modeled with the ability to supply operating reserves which allows their energy to be preserved to a large degree during high load periods. Dispatching these resources late in the dispatch stack or using them to serve ancillary service obligations does not reflect preferential treatment however, but rather simply reflects efficient dispatch. Other emergency operating procedures such as voltage reduction are not modeled prior to firm load shed to be consistent with approaches employed by PJM in prior resource adequacy analysis.

Energy Storage Resource Configurations

To identify potential thresholds of duration and penetration of energy storage resources that could affect reliability goals, the following matrix of energy storage portfolios was constructed.

Table 5. Energy Storage Portfolios Modeled in SERVM

		Storage Duration (HR)	
		4	**6**
Penetration (MW)	**1,000**	X	X
	2,000	X	X
	4,000	X	X
	8,000	X	X
	10,000		X
	12,000		X

While our results reflect the probabilistic nature of capacity valuations with capacity values that range significantly depending on the configuration, we do identify portfolio sizes of various duration energy storage portfolios that provide full capacity value.

Simulation Results

For each portfolio analyzed, the full complement of synthetic weather years and load forecast error scenarios was simulated for a range of perfect generation being removed until a value of 0.1 LOLE was achieved. As an example, when the 1,000 MW energy storage portfolio with 4 hours of duration was simulated, a range from 800 – 1,000 MW of conventional perfect capacity was removed. The LOLE in the

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6 "Demand Resource Saturation Analysis". Page 4. Affidavit of Thomas A. Falin on Behalf of PJM Interconnection, L.L.C 2012. Docket No. ER11-000.

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800 MW removed scenario was lower than 0.1 and in the 1,000 MW scenario was equal to 0.1, demonstrating a 100% capacity value. The simulated results are shown in Table 6.

Table 6. Capacity Value Results for Simulated Studies

Duration (Hours)	Penetration (MW)	Capacity Value (%)
4	1,000	100.00
4	2,000	100.00
4	4,000	99.90
4	8,000	95.60
6	1,000	100.00
6	2,000	100.00
6	4,000	100.00
6	8,000	100.00
6	10,000	97.89
6	12,000	93.33

Conclusion

Provision of capacity is not a binary function. Almost all classes of resources have some category of constraint which results in a different reliability contribution than that from a perfect generation resource. Renewable resources are largely non-dispatchable and their reliability contribution varies by technology and season. Conventional base-load resources have widely varying forced outage rates which affect their capacity value. Peaking gas units may not have firm gas supply or have environmental run limits. Demand response capacity value is affected by its underlying load which may have seasonal, weekly, or daily availability concerns. However, each of these resources play an integral and often complementary role in ensuring resource adequacy. Recognizing the unique characteristics of each resource type does not entail giving preferential treatment, but rather making efficient use of the resources that are available.

Simulating the entire PJM electric system plus those of its direct neighbors demonstrates that energy storage systems with duration capability of 4-6 hours can provide equivalent capacity value to that supplied by conventional resources and there is no justification for setting higher duration requirements for the foreseeable future.