Enabling Versatility:

Allowing Hybrid Resources to Deliver Their Full Value to Customers

Rob Gramlich and Michael Goggin, Grid Strategies LLC

Jason Burwen, Energy Storage Association

September 2019

Summary

Hybrid resources are growing dramatically. Energy storage-paired generators offer enhanced capabilities and can respond to economic signals differently than traditional generator resources. Yet, many grid planning rules overstate the cost of interconnecting hybrid resources, and operating rules unduly limit the flexibility and other services that these resources can provide. Industry practices, market rules, and regulations need to be updated to remove barriers to entry and allow these resources to offer their full value to the power system, which will enhance market competition and ensure just and reasonable rates.

The Federal Energy Regulatory Commission (FERC) and regional grid operators must act quickly to ensure the development of these resources is not stunted or driven in inefficient directions. Some changes can be made in the near-term to better integrate these resources by treating hybrid resources as two separate units and harmonizing the participation models of those separate units.

However, for hybrid resources to deliver their full value, they may eventually need to be treated as fully integrated single machines, able to optimize what they provide and when they provide it. Neither current market rules nor those being actively considered by regional transmission organizations (RTOs) and independent system operators (ISOs) allow them this flexibility to optimize their output. A much broader discussion involving grid operators, regulators, and the industry can consider different ways of operating the bulk power system and electricity markets, where what happens behind the point of interconnection of a supply facility is treated as the responsibility of its owner and where grid operators focus on providing accurate market price signals to encourage efficient and reliable behavior of all participants.

Introduction: Hybrid resources are the next big thing in regional electricity markets

Among the biggest changes occurring in electricity markets today is the rush to develop hybrid resources. Hybrids now represent a large share of new proposed projects in all regions and are increasingly being selected as the most economic resources in competitive solicitations.

A hybrid resource is a co-located pairing of two different electric supply technologies.[1] Batteries are the core technology driving hybridization of resources since they are highly scalable and modular, and therefore can be installed in all parts of the electric grid—co-located at generation sites, directly integrated into transmission or distribution infrastructure, or located on customer premises, with the optimal site depending on localized conditions and needs. While solar photovoltaic generation paired with batteries are the most common hybrid resource, there are also wind-battery, gas-battery, and hydro-battery configurations in operation or being planned, as well as hybrids of wind-solar-storage and other paired generation configurations.

This paper assesses barriers to and proposes solutions for enabling storage-plus-generation hybrid resource deployment on the bulk power system, particularly in organized wholesale markets administered by RTOs and ISOs. We developed the following material and recommendations through interviews with developers of hybrid resources, grid operators, and transmission owners, as well as our own analysis. While there are related barriers to the deployment of hybrid resources on the distribution system or in behind-the-meter configurations, those considerations are beyond the scope of this paper. Similarly, while hybrid resources face barriers as qualifying facilities under PURPA rules,[2] those considerations are also beyond the scope of this paper. Many of the barriers here also reflect issues faced by stand-alone storage units; we include them to comprehensively catalogue the issues faced by hybrid resources. Finally, while many of the barriers to storage-generation hybrids discussed in this paper also apply to generation-generation hybrids, addressing generation-generation hybrid issues fully are beyond the scope of this paper.

The surge of market interest in hybrids is moving faster than the evolution of market rules, which are presently unclear at best and in many cases ill-suited to these projects. We strongly recommend RTOs/ISOs and FERC begin the process of reform now. Broad groups of market participants are

---

[1] Other definitions include: "Generating Facility with interconnection service that is less than the total Generating Facility Capacity and that has multiple energy production devices that have more than one Fuel Source."(John Fernandez, MISO Energy Storage Task Force (ESTF), https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf) . CAISO: "a combination of multiple technologies or fuel sources combined into a single resource with a single point of interconnection." California ISO, Hybrid Resources Issues Paper, July 2019, p.3. http://www.caiso.com/Documents/IssuePaper-HybridResources.pdf. EPRI: "A resource facility consisting of multiple co-located assets comprising of multiple technologies that can potentially inject and/or withdraw under a single (operation) control system and participates as a single resource" (Sangal, Ela, Abrantis, EPRI, "Alternative Market Designs for Hybrid Resources," Presentation to ESIG, June 2019)

[2] See for example testimony of Tyler Norris before the NCUC: https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=c4832d0d-187f-4840-8956-31d2da8427ed

requesting a clearer regulatory framework for hybrids.[3] The rationale underlying FERC Order 841, which was focused on removing wholesale market barriers for storage resources, justifies an effort to remove similar barriers for hybrid resources. We hope that this paper provides a useful starting point for the discussion of needed reforms.

Dramatic growth in hybrid resources is expected

Hybrid resource deployment is rising dramatically. Interconnection queues, where developers file generator interconnection applications with grid operators and transmission owners, are filling up with proposals for hybrid resources. PJM, ISO-New England (ISO-NE), and California ISO (CAISO) interconnection processes all allow specification of whether proposed resources will be co-located with a storage device, and MISO categorizes co-located interconnection requests as hybrids in their interconnection queue. Collectively, these four RTOs/ISOs have 56,547 MW of active hybrid projects in their interconnection queues.[4] In particular, California ISO reports that 41% of the projects in its interconnection queue are hybrid resources.[5]

Hybrids are also increasingly being selected as the most economic resources in competitive solicitations outside of RTO/ISO markets. Of the 430 proposed projects that Xcel Energy received in response to an all-source procurement request in 2017, 110 were hybrid projects featuring wind and solar connected to storage.[6] The Hawaiian Electric Company recently selected 262 MW worth of new solar-plus-storage contracts of solar and 1,048 MWh of storage capacity at contract prices 14% lower than those set in 2017 and 40% lower than 2016 prices.[7] In Oklahoma, Western Farmers Electric Cooperative recently signed a contract with NextEra Energy Resources for a hybrid 250 MW wind, 250 MW solar, and 200 MW/800 MWh battery project, while earlier this year Portland General Electric also signed a contract with NextEra for a hybrid 300 MW wind, 50 MW solar, and 30 MW/120 MWh battery project.[8] NV Energy in Nevada recently contracted for a portfolio of hybrid projects consisting of 1200 MW of solar and 590 MW of batteries, building on the prior year's procurement of 1,001 MW of solar and 100 MW of

---

[3] As stated by the MISO ESTF regarding many of the issues discussed herein, "The ESTF requests immediate attention." https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf p. 3.

[4] For interconnection queue data, see PJM (2019) New Services Queue, https://www.pjm.com/planning/services-requests/interconnection-queues.aspx ; ISO-NE (2019) Generator Interconnection Queue, https://irtt.iso-ne.com/reports/external; CAISO (2019) ISO Generator Interconnection Queue http://www.caiso.com/PublishedDocuments/PublicQueueReport.xlsx ; and MISO (2019),Generator Interconnection Queue,https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/.

[5] California ISO, Hybrid Resources Issues Paper, July 2019, p.3. http://www.caiso.com/Documents/IssuePaper-HybridResources.pdf.

[6] Hill, Marion (2019), "Viewpoint: Hybrid Projects Unlock New Revenue Streams," Wind Power Monthly, February 1, 2019, https://www.windpowermonthly.com/article/1523640/viewpoint-hybrid-projects-unlock-new-revenue-streams.

[7] Hill, Marion (2019).

[8] https://www.greentechmedia.com/articles/read/nextera-inks-even-bigger-windsolarstorage-deal-with-oklahoma-cooperative#gs.s9b85j

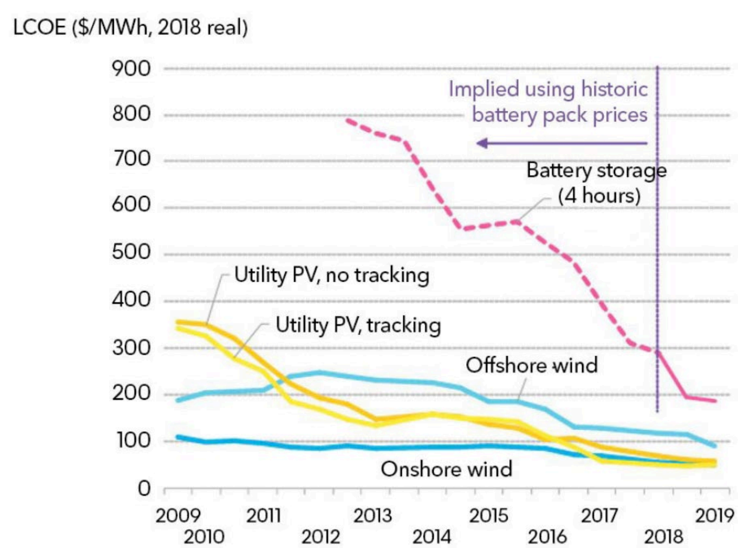
storage.[9] One of the first large-scale hybrid projects was a 100 MW solar and 30 MW battery hybrid contracted in 2017 and currently under construction for Tucson Electric Power.[10]

Market projections indicate rapid growth of hybrids. Analytical Research Cognizance estimated the global market for hybrid projects to reach $58 billion/year by 2023.[11] Major project developers are publicly reporting large increases in hybrid projects, with many announcing additions of storage to most or all of their renewable energy projects.[12]

In theory, there should be little reason to co-locate storage and generation resources that operate in wholesale electric markets. Since grid operating areas inherently aggregate all supply resources to meet demand, there is no need to co-locate a storage resource with a generator. In practice, however, technical, economic, and regulatory factors are increasingly driving wholesale market participants to co-locate storage with generation:

- *Cost reductions*. As illustrated in Figure 1, the costs of batteries, solar, and wind resources have fallen dramatically, making both stand-alone and hybrid resources with any combination of those resources far more competitive than just a few years ago. As shown in Figure 2 from NextEra, the cost of adding batteries to solar projects is expected to continue to decline.

Figure 1: Decreasing Global Costs of Battery Storage, Solar, and Wind[13]



Source: BloombergNEF, 2019

[9] https://www.greentechmedia.com/articles/read/nv-energy-signs-a-whopping-1-2-gigawatts-of-solar-and-590-megawatts-of-stor#gs.s9dtlv

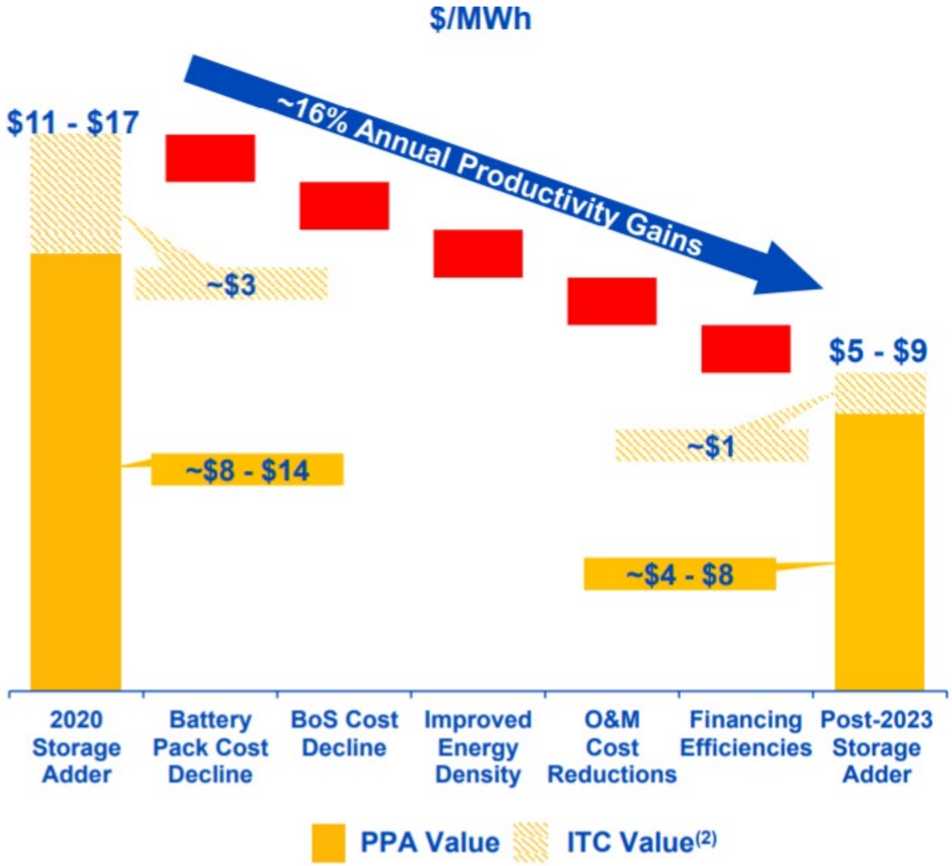
[10] https://www.tep.com/news/tep-to-power-21000-homes-with-new-solar-array-for-historically-low-price/

[11] https://www.reuters.com/brandfeatures/venture-capital/article?id=59087

[12] https://www.utilitydive.com/news/solar-wind-storage-developers-gearing-up-as-hybrid-projects-edge-to-m/556480/

[13] Henze, Veronika (2019), “Battery Power’s Latest Plunge in Costs Threatens Coal, Gas,” March, 26, 2019, https://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/#_ftn1.

Figure 2: Illustrative Estimate for Declining Cost of Adding Storage to Solar Projects[14]

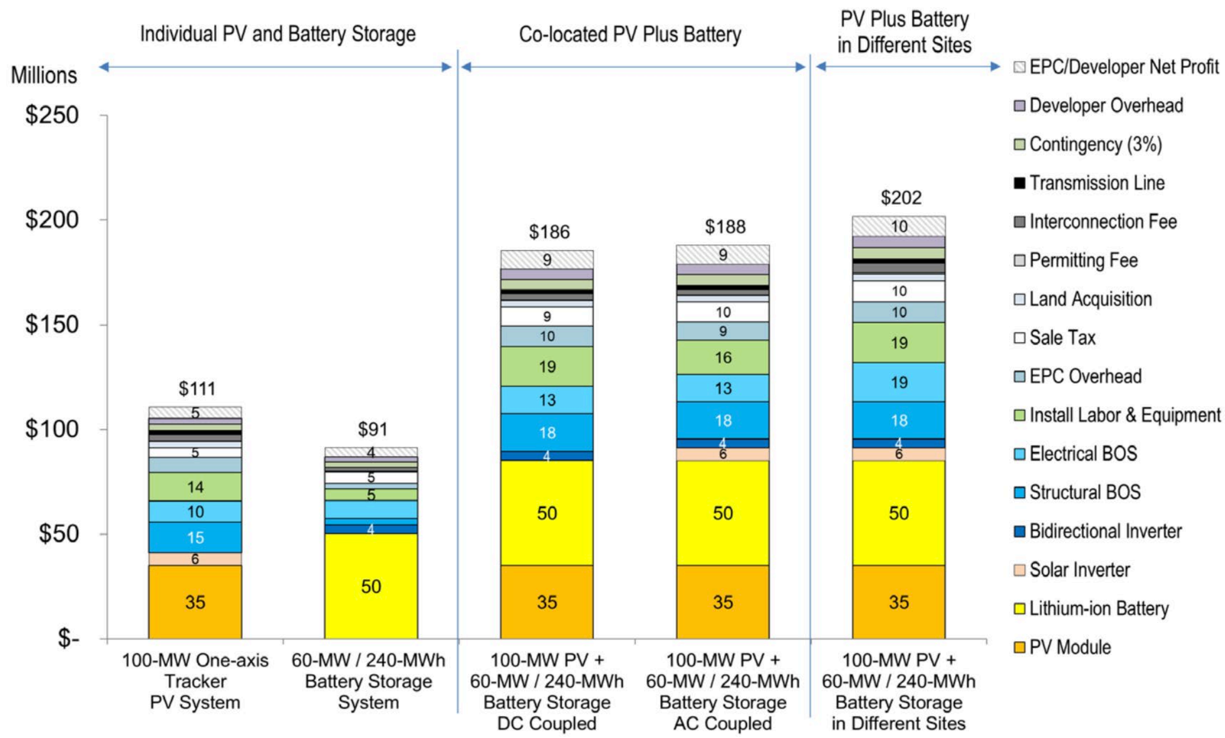


Source: NextEra Energy, 2019

- *Project cost savings.* The capital costs of co-located storage and solar projects are generally cheaper than two separate project installations, as shown in Figure 3. A recent study by the National Renewable Energy Laboratory (NREL) found that the cost of a co-located, DC-coupled storage-solar hybrid system is 8% lower than the cost of the system with storage and solar sited separately; similarly, the cost of a co-located, AC-coupled system is 7% lower. Project cost savings derive from the ability to share inverter and associated balance of system (BOS) electrical equipment, as well as the economies of scale from sharing relatively fixed design, interconnection, permitting, and construction costs.

[14] http://www.investor.nexteraenergy.com/~/media/Files/N/NEE-IR/news-and-events/events-and-presentations/2019/06-20-2019/june-2019-investor-presentation.pdf, page 133

Figure 3: Cost Savings from Co-locating Solar Power and Storage[15]



Source: NREL, 2018

- *Investment tax credit (ITC)*. Over the last several years the IRS has clarified rules around how the Section 48 and 25D investment tax credits (ITC) apply to storage integrated into solar power projects. The industry has become comfortable with the practice of applying the federal ITC to the battery portion of a renewable project which is eligible if 75 percent of the battery's charging comes from the renewable facility for the first five years of the project's operation. As the solar ITC phases down from 30% to 10%[16] over the next few years, this incentive creates pressure for utility off-takers and project developers to increasingly deploy these projects while this benefit is in effect. This tax credit advantage typically accrues to solar and not wind projects. Almost all land-based wind projects elect the Section 45 Production Tax Credit (PTC) and not the ITC option, as wind plants' high production relative to their investment cost makes the PTC more beneficial.[17] However, wind projects may elect an ITC in lieu of the PTC, which could potentially provide an incentive to integrate storage.

---

[15] Fu, R., Remo, T., and Margolis, R. (2018), *2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark*, November 2018, https://www.nrel.gov/docs/fy19osti/71714.pdf, p. 17.

[16] The commercial solar ITC declines from 30% to 10% from 2019 - 2022, staying at 10% thereafter. The residential solar ITC declines from 30% to 22% from 2019 - 2021, and phases down to 0% thereafter.

[17] The PTC provides a disincentive for hybrid deployment because the cost of deploying the storage resource is not included in the tax credit value (unlike the ITC), and round-trip losses associated with using the storage resource reduce the production tax credits generated.

- *Efficient Use of Transmission Interconnection Capacity*. Generator interconnections have become a scarce and valuable commodity in most electric power markets. There are large queues of generation and long waits for projects to move through the process. FERC attempted to improve interconnection queues with its four-year process culminating in Order No. 845. While these reforms have helped, queue logjams remain. Long queues will likely continue as long as transmission planning processes fail to proactively develop transmission capacity to serve remote high-quality resource areas. Indeed, then-FERC Commissioner Cheryl Lafleur raised the question during the FERC interconnection process, "Where does the interconnection process leave off and the transmission planning process start?"[18] In many regions, the answer is that interconnecting generators carry a large share of the cost burden for network transmission upgrades. Scarce interconnections create an opportunity for hybrid resources since two resources together can utilize less interconnection capacity together than two separate interconnections. This is particularly true when storage resources can be charged by the co-located generator to limit injections onto the power system. Order No. 845 began to enable this efficiency, though as discussed below, barriers remain to developers' ability to capture this efficiency.

- *More efficient plant design*. Another efficiency aspect of hybrid resources is that components of the system, mainly the inverter and associated electrical equipment, can be shared. This is especially true for battery storage DC-coupled with a PV facility on the generation side of the inverter. Inverters and associated electrical equipment are expensive components of projects, so many solar developers significantly oversize the solar module's DC capacity relative to the rating of the inverter. This results in a DC solar module capacity rating that is higher than the AC capacity rating of the inverter, called the Inverter Loading Ratio (ILR). Average ILRs have increased from 1.2 in 2010 to 1.32 in 2017, and continue to increase as PV module costs decline faster than the cost of inverters and AC balance of plant equipment.[19] An additional reason driving high ILRs is that PV module output degrades somewhat over time, so a fully-sized inverter will not be fully used for much of its life. Higher ILRs also drive more energy production, higher capacity value, and less variable output, as the output from the oversized PV modules reaches the inverter rating in more hours. When the inverter capacity is less than the PV output, some of the output is "clipped," or "spilled," similar to when a hydroelectric dam cannot use all of the available water and must divert some to its spillway. High ILRs are economic because solar plants seldom reach maximum output, and the marginal value of midday production in solar-saturated markets is not high enough to justify the additional inverter expense. However, co-locating storage can "soak up" this excess production for later use, increasing utilization of the inverter and the output of the plant and often discharging this stored energy during more valuable hours in the evening or morning. In one analysis, the amount of clipping was reduced by 80 percent by co-locating a 3 MW/3 MWh battery with a 7.1 MW (AC) PV facility with a 1.4

---

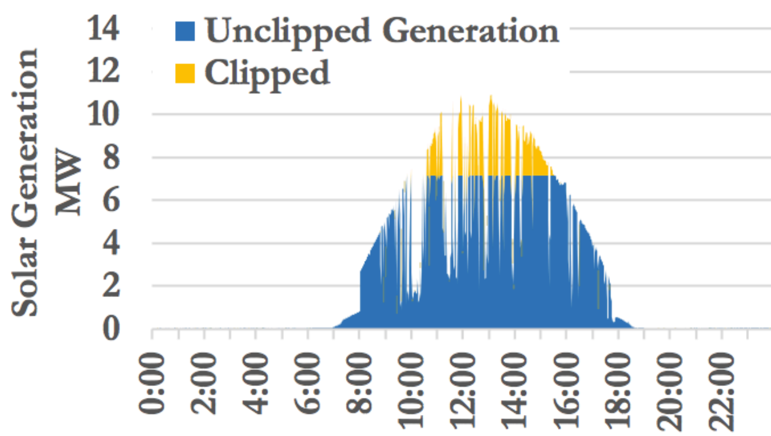
[18] https://www.ferc.gov/CalendarFiles/20160823100648-Transcript%20-%20Revised%20-%20051316FERCTechConf.pdf p. 47.

[19] Lawrence Berkeley National Laboratory. "Utility-Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States – 2018 Edition." 2018. Available at https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_report.pdf

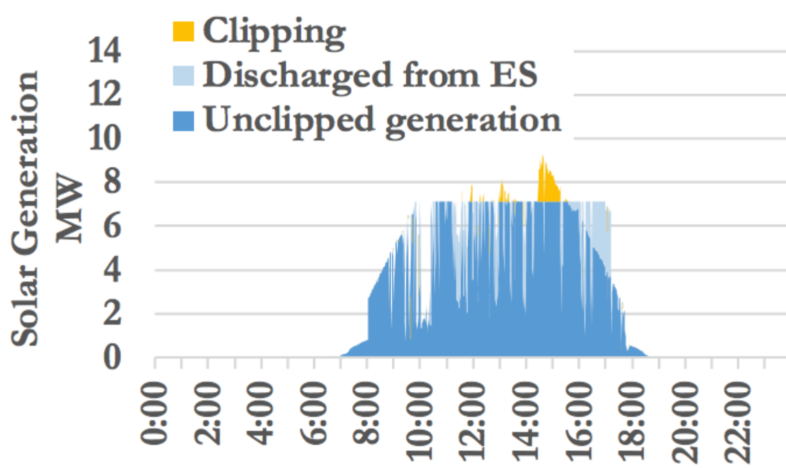
ILR.[20] Figure 4 shows the lower amount of clipping (in yellow) with a hybrid resource than with a solar resource alone.

Figure 4: Example of Solar PV Clipping With and Without Storage

Solar PV only



Hybrid Solar PV and Storage



- *Optimizing resources in inefficient markets*. In a perfectly efficient wholesale power market, each resource would sell its services into a market that would aggregate variable generation resources, more dispatchable resources like storage, and all other resources with no "firming" of individual resources would be necessary**.** However, many US power markets are a long way from such ideal efficiency. Outside of ISOs and RTOs, market participants rely on bilateral contracts that bundle multiple services together, and have limited liquid market opportunities to procure the range of services they need. Hybrid resources are therefore especially in demand in less efficient power systems. This is true internationally as well, where power markets are less

[20] NC State Energy Storage Team, Energy Storage Options for North Carolina, p. 131. https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf

developed than in US regions with RTOs.[21] Even in RTOs, inefficient scheduling and dispatch processes and penalties, capacity market crediting rules, rules setting duration requirements to provide ancillary services, and other requirements can limit the ability of resources, particularly variable wind and solar resources, to offer into markets. Until those requirements are updated, hybrid resources can ease participation of renewable resources in these markets.

- *Self-optimization opportunities*. Hybrid resources allow generation owners many more tools and strategies to optimize their resource in electric power markets compared to stand-alone generators. Many project owners have extremely sophisticated forecasting, marketing, and trading operations that they use to increase the value of the resources they own. Power markets are volatile, fast-moving, and complex. Very often small changes, such as shifting power output from one 5-minute period to another, can lead to much higher revenues. Efficient RTO markets strive to optimize dispatch for overall system efficiency, but plant owners possess superior knowledge about their resources and have a much greater incentive than anyone else to optimize their operations. This is particularly true for hybrids that incorporate energy-limited storage resources and stochastic wind and solar resources, as the optimal commitment and dispatch of those resources is best determined through probabilistic analysis that is not widely used by grid operators today. Providing the plant owner the option for self-control ensures they have the freedom to use their own forecasting and probabilistic analysis to optimize the commitment and dispatch of their own resources. This should result in more efficient commitment and dispatch of the entire system, with dispersed information aggregated and incentives coordinated through market prices. Indeed, a central tenet of markets is that de-centralized decision-making can increase efficiency by aggregating information and incentivizing individual market participants to maximize their value—one reason why power markets should consider allowing this versatility from individual project owners.

- *Congestion reduction*. Significant generation deployment is occurring in areas with limited transmission delivery capacity. Most high-quality renewable resource areas are remote from population centers with limited transmission access, and very limited transmission planning pro-actively taking place to access those resources. The result is low locational energy prices and occasional curtailment in the areas of the renewable energy development. This is occurring mainly for wind energy, but increasingly for solar as well. Storage can help a renewable project owner avoid some of the low prices and curtailment if it is placed on the generation side (as opposed to the load side) of these transmission constraints. The most efficient place on the generation side of the constraint may be on-site with the generator in order to capture the benefits described above. Congestion is expected to grow in coming years as renewable deployment, particularly the current flurry of activity driven by the phase down of the aforementioned tax credits, outpaces transmission expansion to renewable resource areas.

[21] Countries "leading the charge on hybrids have less technically advanced systems [and] want as much renewable energy as they can get to meet their growing demand, but need steadier delivery," Jean-Claude Robert, GE, as quoted in Utility Dive, https://www.utilitydive.com/news/solar-wind-storage-developers-gearing-up-as-hybrid-projects-edge-to-m/556480/

Regulations have not kept pace with technology and markets

Neither RTOs/ISOs nor the Federal Energy Regulatory Commission (FERC)--the government agency in charge of U.S. wholesale power market and transmission rules--have directly addressed hybrid resources. Grid operators have issued discussion papers (described in Appendix A) and held meetings on the topic, though many issues remain unresolved and proposed solutions at present take only modest incremental steps to clarify certain rules. The term “hybrid resource” does not appear in FERC’s recent rulemakings on storage (Order No. 841) or interconnection (Order No. 845). This is not surprising since the evidentiary records and testimony for these rules were submitted in the period of approximately 2015-2017, when there was little market interest in hybrids. In the current compliance stage of Order No. 841, grid operators have mentioned that hybrid resources are an issue for further work.[22] The omission of hybrids from these rulemakings reveals that the market is moving much faster than regulations, creating a regulatory gap.

However, FERC’s two major nation-wide rules lay the foundation for hybrid resources issues:

- Order No. 841 directs RTOs/ISOs to remove barriers to energy storage participation in their electricity markets; doing so enables fuller market competition that will ensure just and reasonable rates. RTOs/ISOs are presently establishing rules that are suited to the unique physical and operational characteristics of storage (as opposed to generators). Those rules do not specify how storage co-located with generation will be treated.
- Order No. 845 directs transmission owners and RTOs/ISOs to make a series of reforms to interconnection rules and processes, including establishment of a surplus interconnection service (service less than nameplate capacity) that expedites the co-location of storage with existing generation under certain conditions; doing so is necessary to increase the efficient utilization of the transmission system. Additionally, the term “generator” is now replaced with the term “facility” to account for generators, storage, and co-located resources alike. These rules do not specify how new interconnections of hybrid resources will be treated.

Between Orders 841 and 845, there is a compelling regulatory rationale that removing barriers to hybrid resource interconnection and market participation is necessary to ensure just and reasonable rates and enable efficient use of the transmission system. Moreover, FERC and RTOs/ISOs would be well served by planning for the increased pace of innovation around market software and operational controls that will require more flexible and parameterized approaches for market participation models.

Much of the challenge of hybrid resources is that present market rules will represent them as deviations from existing resource types, i.e., either as a variable generator that is also dispatchable, or as a storage resource that has onsite fuel. Each formulation brings its own challenges, either by inheriting the constraints from each resource type or removing salient accommodations for each. Ultimately, a

[22] For example, PJM says it “recognizes that there may be additional clarification and development of its rules required for hybrid resources. PJM intends to work in the stakeholder process in 2019 to develop additional business rules which address unique issues associated with hybrid resources.” PJM reply in 841 Compliance docket ER19-469 p. 8 https://www.pjm.com/-/media/documents/ferc/filings/2019/20190305-er19-469-000.ashx .

separate designation for hybrid resources will be more optimal for market operators and participants alike.

Devising a regulatory framework for hybrid resources

Electricity markets reduce costs to consumers through the more efficient allocation of resources achieved when individual market participants are given the power to make informed investment and operation decisions and the responsibility to live with the consequences. For markets to benefit customers, individual actors must be given that flexibility.

Electric power market designers and regulators have attempted to provide that flexibility to individual market participants, yet a legacy of centralized control remains in RTOs/ISOs that reduces market efficiencies. For electricity markets to overcome those inefficiencies:

- Individual market participants should be able to *make their own economic choices* about how and when to operate, as long as grid operators can ultimately step in to prevent violation of reliability constraints or the exercise of market power.
- Market participants should be allowed to *freely add capabilities to proposed and existing projects* as long as the changed electrical properties do not harm transmission system reliability.
- *Grid operators should appropriately value resources' contributions* in such a way that avoids systematically under-valuing (or over-valuing) certain configurations relative to others.

We compare current practice to these market features below, first identifying shortcomings and remedies for the near term. These changes mostly treat the storage and generation aspects of hybrid resources as separate units so that the grid operator can manage each one in a way that is familiar. We then consider the broader longer-term changes, for which discussions have not even begun, on how fully integrated hybrid resources should be treated when they operate as a single machine. Hybrid resources as single units lack precedent and will require significant analysis, testing, and discussion to develop optimal rules.

Interconnection Shortcomings and Remedies

Interconnection rules and processes determine how hybrid resources physically connect to the electric grid and specify constraints to unit operations. Market participants should be able to freely add capabilities as long as sufficient protections are in place to preserve reliability.

1) *Shortcoming: Adding storage to projects in interconnection queues can result in loss of valuable queue positions.* Despite FERC Order No. 845's reforms, RTOs/ISOs vary widely in how interconnection rules are applied by different ISOs and RTOs. This is a top priority because there are so many wind and solar projects already in interconnection queues, representing many years' worth of renewable development. Adding storage solely to shift the timing of energy output provides only reliability benefits, since the output is highly controllable, and therefore should not be the cause of a loss of queue positions. Allowing those projects that have already submitted interconnection requests the ability to add storage under their requested range of output would allow them to forego the significant added time and expense of dropping out of the queues and re-applying. Moreover, expiring federal tax credits provide some urgency to fixing this shortcoming.

- *Remedy: Tariffs and business practices should allow storage to be added without loss of queue positions*. Reliability can be preserved by limiting the injection rights to the same maximum level contained in the original interconnection request.
- *Remedy: FERC and RTO/ISOs could develop best practice guidelines for what constitutes a "material modification."* Transmission Providers are required under Order No. 845 only to have a policy for what constitutes a material modification, and provides wide discretion to the RTO/ISO and transmission owners (TOs) for compliance. FERC Order No. 845 states "the interconnection customer's technological advancement request must demonstrate that the proposed incorporation of the technological advancement would result in electrical performance that is equal to or better than the electrical performance expected prior to the technology change and not cause any reliability concerns (i.e., materially impact the transmission system with regard to short circuit capability limits, steady-state thermal and voltage limits, or dynamic system stability and response)."[23] RTO/ISOs should develop best practices for this technical determination. Such practices could clarify that controllable output should not be considered a material modification if the customer commits to keeping the output within the range of the interconnection request. Grid operators do need to review the electrical properties of any added storage resources. As they review new battery models, grid operators can help each other with these assessments, speeding up their review. Technical forums such as IEEE, Energy Systems Integration Group, or FERC technical conferences could be utilized to help RTO planning staff, project developers, and battery manufacturers better understand electrical impacts of different technologies for the purpose of determining material modification. Additionally, those best practices could also clarify that controllable output should not be considered a material modification if the customer commits to keeping the output within the range of the interconnection request.
- *Remedy: Project sponsors should be allowed to conduct certain re-studies for RTO/ISO planning staff review, in order to speed up the process and alleviate potential concerns.*
- *Remedy: Allow a resource to avoid a new study process if dispatch limiters or protection devices are used to avoid exceeding the existing interconnection limits.* For example, CAISO allows a hybrid resource to use an output limiter or tripping mechanism to ensure output does not exceed the interconnection agreement capacity rating.
- *Remedy: Allow multiple potential configurations of the project (based on different sizes of batteries, for example) to be proposed and studied, particularly in the early stages of interconnection studies*. This should reduce the need for projects to drop out of the queue and re-submit with slightly different configurations.
- *Remedy: Develop best practice processes to ensure that output does not exceed the level specified in the Interconnection Agreement*. One of the MISO Energy Storage Task Force (ESTF) Recommendations was: "Control systems to ensure output does not exceed interconnection service level; What processes can be used to ensure that net output does not exceed interconnection service?"[24] Controlling output within allowed boundaries is clearly physically possible as was recognized by FERC in Order No. 845 and by RTOs; the

[23] Order No. 845, Par 531.

[24] https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf table 1.

objective now is to develop the control, communications, and enforcement protocols to implement it.

- *Remedy: Allow for an expedited process in some circumstances.* For example, when resources are coupled on the DC side of an inverter, there should be no electrical impact on the AC side.

2) *Shortcoming: Shared Points of Interconnection (POI) are not allowed or are overly restrictive*. In some cases the generation and storage assets are treated as separate projects even if they are at the same physical point on the grid, sharing transmission interconnection capacity, land, and project components. Shared POIs are not allowed at all in SPP. MISO is working on defining when it should be allowed.[25] Significant extra time and expense is required to run separate studies and processes for separate resources compared to performing the studies and participating in the process as a combined project. Resource risks are being studied on different timelines.
    - *Remedy: FERC should require all RTOs and ISOs to provide the opportunity for hybrid resources to interconnect as a single interconnection customer with a single queue request and POI and obtain a single interconnection service*.

3) *Shortcoming: Interconnection studies make inappropriate assumptions about project operation*. Reliability assessments should be based on unavoidable impacts of a proposed project as opposed to impacts dependent on operator discretion. For example, the electrical properties of a facility are inherent and unaffected by a resource owner's economic choices in the market; those should be incorporated into interconnection studies. In contrast, electrical output during different time periods are choices the operator makes. If there is a reliability constraint such as overloading a transmission line, the project operator can avoid a problematic mode of operation either on its own or by agreement with the system operator. In fact, the market dispatch based on locational marginal prices used in all U.S. RTO/ISOs provides an inherent and strong incentive for resources to be dispatched in ways that do not create reliability problems. Because hybrid storage and generation resources are highly flexible and dispatchable, they can reduce their output in seconds or less in response to an LMP signal if a transmission constraint becomes binding. Interconnection studies should account for the fact that markets prevent unreliable dispatch and that agreements and controls can be put in place, rather than assume the most unreliable mode of operation will be performed. MISO is currently reviewing its study assumptions.[26]
    - *Remedy: Assumed output of battery and generator(s) at peak, off-peak, etc. should be provided by the developer and not the grid operator*. These are economic choices and the owner can commit to operational practices to avoid causing a reliability risk.

[25] https://cdn.misoenergy.org/20181113%20IPTF%20Item%2005%20Shared%20Point%20of%20Interconnection292766.pdf

[26] https://cdn.misoenergy.org/20190212%20PSC%20Item%2004b%20Hybrid%20Interconnection%20Study%20Practices317695.pdf , https://cdn.misoenergy.org/20190611%20PSC%20Item%2005b%20Draft%20BPM%20015%20Modeling%20of%20Hybrid%20Generating%20Facilities353122.docx

- *Remedy: Use different study assumptions for different coupling and charging configurations*. Projects with different configurations are operated differently. For example, those that charge the battery from the paired generator will tend to operate differently from those that mostly charge from the grid. These modes should be accounted for in interconnection studies.
- *Remedy: Studies should replace the common worst-case assumptions of nearly 100% coincident injection of the interconnecting resource with other supply resources on the system, particularly in studies of light load conditions*. As a default, the storage component of a resource should be modeled in charging mode during off-peak conditions, consistent with the modeling of pumped hydro storage.
- *Remedy: FERC and/or RTO stakeholder discussions should develop best practices on hybrid resource dispatch modeling*. MISO has held stakeholder discussions on what to assume about unit dispatch.[27]
- *Remedy: Aside from assessments for capacity value accreditation, RTO/ISOs should move away from including assessments of the deliverability of resources in interconnection studies*. Plant owners are better equipped than grid operators to weigh tradeoffs between the cost of interconnection upgrades and the weighted risk of congestion costs across all hours in a year and find solutions to those concerns. While studying resources at full nameplate capacity may have made sense for conventional resources that typically operate at or near their maximum capacity, most solar, wind, and renewable hybrid projects will spend the vast majority of their time at lower output levels, particularly during peak demand periods when the transmission system is likely to be most congested.

4) *Shortcoming: Data requirements are unclear and inconsistent.*
    - *Remedy: Develop and disseminate best practices.* RTOs/ISOs do need access to certain information, and since having access to more information than they strictly require can improve system operation, both voluntary and mandatory information standards for hybrid resources merit further development. MISO has been working on this,[28] and lessons from any RTO/ISO should be shared with others.

5) *Shortcoming: Unique Transmission Owner requirements on study assumptions and methodologies slow hybrid interconnection.* Interconnection is a three-way process between the customer (generator), RTO/ISO, and the transmission owner. If the owner of the specific transmission facility at the point of interconnection requires special information, it can slow the process down.
    - *Remedy: FERC and RTO/ISOs should make sure that hybrid resource study assumptions and methodologies are standardized at the RTO/ISO level, not the transmission owner level*. RTO/ISO assumptions and methodologies should be clearly stated in the relevant Business Practice Manuals with enough detail to allow the interconnection customer to conduct its

27 https://cdn.misoenergy.org/20190212%20PSC%20Item%2004b%20Hybrid%20Interconnection%20Study%20Practices317695.pdf

28 https://cdn.misoenergy.org/20181113%20IPTF%20Item%2006%20Appendix%20E%20of%20BPM15293073.pdf

own studies to determine what the calculated upgrade costs will be before entering the queue.

- *Remedy: Encourage early consultations on hybrid resource choices that can make interconnection more efficient.* Some transmission owners have encouraged early consultation with the transmission owner prior to interconnection in order to help the interconnection customer find an appropriate point on their system with which to interconnect. This could be a beneficial commercial practice. Developers will be reluctant to have those consultations when the Transmission Owner also owns generation, as they are a competitor, so this works better with more competitive markets in which utilities do not own generation.

6) *Shortcoming: An energy storage device charging from the grid may be required to file for interconnection as a load.* Charging is an economic choice, and control systems can be put in place to prevent violation of security constraints. CAISO requires resources that are not only charging from on-site generation to file for a load interconnection application (with some exceptions if the storage is being dispatched by CAISO. CAISO requires hybrid resources that have not been studied for charging from grid power to include a tripping mechanism if the hybrid resource provides negative generation. This could inadvertently trip a hybrid resource that is not charging from the grid, such as a wind or solar plant not producing real power but using grid power to provide reactive power support, or any type of generator using grid power to meet onsite parasitic loads.
   - *Remedy: Clarify interconnection rules and allow for a single interconnection application—i.e., without separate application as generation and as load resources--as long as reliability protections are in place*.
   - *Remedy: Allow limits to be imposed on the rate at which a storage resource charges from the grid during periods of congestion to reduce any assigned network upgrade costs.*
   - *Remedy: Reduce study burdens and requirements where grid power consumption will be low.* Eliminate the need for a load interconnection study if grid power consumption is expected to be low enough to be comparable to how most conventional generators have negative generation at some points in time. For example, when many conventional generators are starting up or shutting down, they have little to no power output and therefore use grid power to run plant ancillary equipment like water pumps, lighting and controls, fuel processing equipment, and pollution control equipment. Similarly, do not require hybrid resource tripping if grid power consumption is expected to be low enough to be comparable to the level of negative generation caused by parasitic loads at conventional generators.

Market Participation Shortcomings and Remedies

Market participation rules and processes determine how hybrid resources access markets, including bidding rules and how a resource is controlled and dispatched. While some of the issues debated regarding the control and dispatch of storage and hybrid resources are new, it has long been the case that other resources have specific considerations to accommodate their unique characteristics. For example, hydro plant owners have had recreational and flood control considerations, cogeneration owners have had industrial operations considerations, and gas plant owners have had gas market contracting and scheduling practices that influence their electricity market participation. Additionally, new types of demand side resources have many considerations governing their willingness and ability to participate.

System operators have low and decreasing visibility into many resources' operational considerations and limited ability to integrate large amounts of data, both of which reduce the ability to optimize the electric system through conventional control regimens.[29] A different grid architecture that relies more on price signals to drive voluntary action, rather than on grid operator physical controls, may be more effective as technological innovation and resource sophistication increases, such as with hybrid resources. Indeed, storage and hybrid resources have not only energy limitations to optimize but also extremely versatile control systems that provide asset managers with greater opportunities to optimize the value of their systems. The MISO ESTF noted, "market participants may have more ability to judge for themselves when to charge and discharge based on their own forecast of market dynamics."[30]

Electricity markets should allow individual market participants to make their own economic choices about how and when to operate, as long as grid operators can ultimately step in to prevent violation of security constraints. Organized markets can maximize the central optimization of the various resources on the system while also affording market participants wide latitude to self-determine their operation or surrendering control to the central optimization. We should expect to see both forms of operation, self-optimization and grid operator control, and combinations of them. For example, in a recent PPA with NV Energy, a storage project owner controls its own state of charge (SOC) during certain hours at one stated price, and the utility controls SOC during other hours at another stated price.

1) *Shortcoming: Market rules are unclear about hybrid resource participation.* FERC Order No. 841 generally required that storage be able to fully participate in RTO/ISO markets with many specific directives for reworking market rules. The order did not similarly clarify the rules for hybrid resources, which will only be able to enter markets by utilizing a pre-existing participation model. Hybrid resources are likely able to participate as a storage resource or as the other generation with which the storage is paired. However, the operations are not the same as either type, and may change from one to the other from one hour to the next.

---

[29] The U.S. Department of Energy and Pacific Northwest National Lab have seen this future coming and have been preparing the industry for it: "A problem with the pure control formulation for grid control with massive DER is that control systems have no means to obtain some of the information needed to support the optimization equation formulations, such as objectives and constraints of DER owners. In addition, the amount of data that can be needed to solve large scale control problems for high penetration of DER presents a communication network scalability problem." See JD Taft, Electric Market-Control Structure, 2017, PNNL, https://gridarchitecture.pnnl.gov/media/advanced/Market_Control_Structure_v0.2.pdf p. 5

[30] https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf

- *Remedy: FERC should undertake a proceeding to clarify how tariffs should treat hybrid resources on each of the dimensions addressed in Order No. 841*. ISO/RTOs should act on their own to initiate processes to do the same. Both CAISO and MISO have opened processes to consider these questions, though many of the questions remain unanswered.

2) *Shortcoming: Market rules limit hybrid resources' ability to fully control their output.* Resource owners often have sophisticated optimization strategies, implemented through software algorithms. Order No. 841 states, "each RTO/ISO must permit electric storage resources to manage their state of charge because it allows these resources to optimize their operations to provide all of the wholesale services that they are technically capable of providing, similar to the operational flexibility that traditional generation resources have to manage the wholesale services that they offer."[31] This principle is clear enough, but it is not clear where the line is drawn between that principle and grid operators' need and desire to control resources for reliability. PJM's compliance filing states, "Energy Storage Resource Model Participants shall be responsible for their own State of Charge Management, *provided that they must comply with PJM operational orders regardless of the incidental impact on State of Charge*."[32] (emphasis added). The details of where this boundary lies between self-dispatch and grid operator override are in dispute both in practice and in certain ISO/RTO tariff filings. [33] Moreover, state of charge specification for stand-alone storage may not apply well to hybrid resources. The MISO ESTF noted, "Determining the Unit State may require a new type of state to be defined. This topic requires more discussion and education of hybrid capabilities vs current determination of intermittent resources."[34] Only NYISO and CAISO allow both options of self-control and system operator control.
    - *Remedy: In the near term, RTO/ISOs should clarify their tariffs to allow hybrid unit owners to control their SOC, and clearly identify the instances in which the grid operator can override those operational choices*.
    - *Remedy: In the longer term, RTO/ISOs should either create a new hybrid participation model or a more open, flexible generic participation model*. As there is no standard configuration of a hybrid plant, a "Universal Participation Model" (UPM) will likely be necessary.[35] In a UPM, resources offer all relevant capabilities and constraints to the grid operator for the grid operator to be able to optimize, if the owner opts for central optimization.

---

[31] Order 841 P 251 (errata version)

[32] PJM response to FERC data request in Order 841 compliance proceeding, Docket ER19-469, p. 16. https://pjm.com/directory/etariff/FercDockets/4084/20190501-er19-469-001.pdf

[33] See, for example, ESA Protest to NYISO 841 Compliance filing, p. 5. NYISO proposes to require storage resources that participate in the capacity market to be controlled by NYISO. http://energystorage.org/system/files/attachments/2019.2.7_ferc_er19-467_esa_response_to_nyiso_order_841_compliance_filing.pdf

[34] https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf

[35] Mark Ahlstrom, The Universal Participation Model, https://www.esig.energy/blog-the-universal-market-participation-model/
.

3) *Shortcoming: RTO/ISOs are not providing central optimization opportunities to storage as they do for other resources.* A great deal of work has been done by system operators and their market software vendors to optimize fossil generation commitment and dispatch with their non-convexities. The MISO ESTF recommended, "MISO [should] continue to evaluate the potential inclusion of a hybrid model in the Enhanced Combined Cycle project," reflecting the significant work going into RTO/ISO software attempting to better optimize conventional resources. MISO, ISO-NE, and SPP also offer RTO/ISO state of charge management but not if scheduling would cause an infeasible state of charge. CAISO generally controls dispatch of storage, though some hybrid projects can charge from their own generation outside of the CAISO's control. In MISO, according to the Energy Storage Task Force, "MISO does not explicitly capture the optimization of the dispatch of a single hybrid resource when the capability of that resource is in part driven by a forecasted value." Hybrids with wind and solar plants have forecasted output, so these plants may not be allowed to be optimized by MISO. Because RTO/ISO tools may not optimize hybrid resources, which increases the importance of providing hybrid plant owner/operators with the option of optimizing their own resources, they may be able to perform better than the RTO/ISO.
    - *Remedy: RTOs and ISOs should provide the voluntary option for central optimization and control of hybrid resources, based on submitted capabilities and constraints.* Resource owners should have the option of an efficient central optimization, as has been the practice for RTOs/ISOs attempting to optimize total efficiency while taking account of fossil unit non-convexities. System operations methods will need to improve significantly to make this option attractive, as present methods would be deleterious to hybrids. Resource owners should retain the option to self-optimize.

4) *Shortcoming: Market power mitigation rules are poorly designed.* Market power mitigation rules were developed to apply to resources that are not energy limited. The standard competitive bid for a fuel-based generator is calculated as the product of the unit's heat rate and its estimated fuel cost, as that is its marginal opportunity cost. The marginal opportunity cost of energy-limited resources is different—it is the value of the foregone opportunity to sell the limited charge in another hour. In dynamic electricity markets, that opportunity cost value can change rapidly, and one owner's calculation of it may not be the same as what a market monitor assumes.
    - *Remedy: Hybrid resource owners should be allowed to bid using their own calculation of opportunity cost*. To mitigate any market power, it may be necessary to rely solely on structural measures rather than comparisons with competitive reference bids. A structural measure is a metric such as "pivotal supplier" conditions where a resource owner supplies a significant share of the market compared to the amount of the market supplied by others such that they have the power to directly influence the market price.[36] A massive amount of storage penetration by an extremely concentrated set of owners would be necessary for there to be structure market power for storage resources in the next few years, and a

[36] Robert Gramlich, "The Role of Energy Regulation in Addressing Generation Market Power," Environmental and Energy Law and Policy Journal, Vol 1. No. 1, 2005. https://www.law.uh.edu/eelpj/publications/1-1/04Gramlich.pdf

reassessment of mitigation methods can be made down the road after experience is evaluated by FERC and market monitors.

5) *Shortcoming: Bidding flexibility is limited.* Hybrid resource owners, as with stand-alone storage and renewable resource owners, know much more about their output closer to real time. More efficient outcomes result when they are allowed to adjust their bids close to real time. Ideally, system optimization should occur as close to real time as the system software can handle, though the limits of current computing power often force longer lead times on bidding than resources actually need, potentially limiting the benefits of more flexible storage and hybrid resources.
    - *Remedy: Market protocols should allow bids to be submitted or changed closer to real time.* Improvements in computing power could contribute to this RTO/ISO capability.
    - *Remedy: System operator software can be simplified over time, allowing for faster dispatch optimization and closer-to-real-time operation*. A tremendous amount of computing complexity is caused by fossil unit non-convexities. As the resource mix changes, less attention and accommodation will need to be made for fossil unit characteristics.

6) *Shortcoming: Must-offer obligations are unclear.* Must-offer obligations are often part of RTO/ISO market power mitigation policies and are usually required of units that sell capacity into capacity markets. While RTO/ISO compliance with Order 841 is addressing rules on must-offer obligations for storage, it remains to be seen how such rules will apply in practice; moreover, presently there is not clear guidance on how must-offer obligations apply to hybrid resources. Must-offer obligations are a poor fit for energy-limited resources because there is a risk of requiring the resource to fully discharge in one hour when it may be more needed in another hour. For hybrid resources there is little clarity as to whether the obligation applies to both resources or the project as a whole. The MISO ESTF recognized the problems with must offer requirements: "Must offer requirements …must be amended to allow the stand alone energy storage and/or the hybrid to set the available hours for the must offer (with review) based upon the design and capabilities of the hybrid and/or storage resource. The current must offer in the tariff is not achievable. The capability of the hybrid is a component of the capacity it should be awarded."[37]
    - *Remedy: FERC and RTO/ISOs should clarify whether and how must offer obligations should apply to hybrid and storage resources.*
    - *Remedy: Eliminate must-offer obligations for energy-limited resources unless they can be clearly specified in a way that is efficient and reliable*.

7) *Shortcoming: RTO analyses of generation resilience and fuel security are ignoring hybrid resources.* None of the studies of electric system resilience by ISO-NE or PJM studies thus far mention hybrid resources or give much weight to either renewables or storage in providing energy over the 1-2 week cold snap periods that they are concerned about.

[37] https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf

- *Remedy: Incorporate the valuable capabilities of storage and hybrids to provide energy that saves fuel over that period into the next study iterations.*

8) *Shortcoming: Adding storage to a variable renewable resource may make the renewable resource ineligible for dispatch provisions that facilitate the integration of variable resources*. Several RTO/ISOs have created rules for variable renewable resources to facilitate their incorporation into dispatch by creating new requirements for those resources in exchange for waiving some others. For example, in CAISO, an Eligible/Participating Intermittent Resource (EIR/PIR) that adds storage under a single resource ID can no longer participate as an EIR/PIR resource, losing the advantage of being able to submit a resource forecast in lieu of an output bid and avoid imbalance penalties. The resource's imbalances would be settled at the real-time price and it would be allocated a share of the flexible ramping costs. CAISO notes "one forecasting issue is the inability for the CAISO to be aware of the charging behavior of storage generation components. The charging behavior can cause the potential forecast error to increase."[38] The basis for not charging imbalance penalties to Variable Energy Resources was their limited ability to forecast output. To avoid the concerns raised by CAISO, the hybrid resource must either register under two resource IDs, one for the storage and one for the generator, or lose its scheduling and imbalance privileges. It is unclear how the addition of storage to a MISO Dispatchable Intermittent Resource or an SPP Dispatchable Variable Energy Resource would affect its participation in those resource categories. The MISO ESTF raised the question: "If a hybrid resource is participating as a DIR, how will the storage output be incorporated into MISO's 5 minute forecast?" [39] CAISO notes a conundrum: if the resource is no longer participating in the forecast, then the operator loses valuable information which may harm reliability. Its white paper poses the question: "CAISO seeks feedback on the need for additional requirements for forecasting for the variable energy generation components of single resource ID hybrid resources."[40]
    - *Remedy: The all-or-nothing status of dispatchable intermittent resources may need to be amended*. There is likely some level of forecasting that is still meaningful and some level of imbalance charges that can be dropped on the basis of these forecasts. It may be beneficial for RTOs and ISOs to have some visibility into real-time resource capability and state of charge even for fully integrated hybrid resources with a single resource ID.

9) *Shortcoming: Barriers to ancillary service market participation*. Renewable energy, storage, and hybrid resources often do not fit the standards of resources providing continency reserves, frequency regulation, and other services necessary for short term grid operations procured by system operators. Duration requirements are sometimes unnecessarily strict. New resources should be able to provide any and all services of which they are capable.
    - *Remedy: RTOs and ISOs should review product definitions to ensure they are truly technology neutral.*

---

[38] CAISO White Paper, p. 13.

[39] https://cdn.misoenergy.org/20190124%20ESTF%20Item%2004%20Hybrid%20Interconnection311836.pdf

[40] CAISO White Paper, p. 14.

- *Remedy: Hybrid and storage resources should be allowed to freely switch among providing energy and ancillary services, and to have their highest and best use optimized by the grid operator*.
- *Remedy: Hybrid resources should be better enabled to address frequency deviations.* As suggested by the MISO ESTF , RTOs/ISOs could "allow hybrid projects to briefly increase their output above their injection limits and transmission system thermal limits (but not stability limits) to provide primary frequency response and other short-duration upward ancillary services." The quantity and duration of additional energy provided by resources for regulation service does not impose on security limits so this is a way to increase market efficiency without harming reliability. These minimal and temporary excursions above the limits in their agreement are not considered material enough to harm reliability or transmission system assets.

10) *Shortcoming: Capacity value for hybrid projects is unduly restricted*. Because energy storage does not fit well into traditional capacity value calculation methods, the developer should have more freedom to determine their capacity credit/obligation based on economic tradeoffs including non-performance penalties. There is no additional capacity value for the storage component of DC-coupled hybrids in PJM.[41] Duration requirements, which are an issue for stand-alone storage are also an issue for hybrid resources. PJM's proposed rules qualify capacity contribution of storage based on what can be continuously provided for 10 hours, while other systems use two- or four- hour duration requirements. The need for duration is a function of how long peak conditions last. In any system where solar energy is increasing (which is every system), system peaks are shortening because the typical summer peak of 3 p.m. through 7 p.m. on hot summer afternoons is served by solar for the first half, leaving only a shorter window of 2-3 hours that needs to be covered. Four-hour batteries are sufficient to cover those peaks.
    - *Remedy: Shorten or eliminate unreasonably long duration requirements for storage and hybrid projects*. In particular, onerous requirements like PJM's 10 hour rule should be avoided.
    - *Remedy: Allow both separate and combined accreditation as recommended by the MISO ESTF*.[42] In particular, RTOs/ISOs should ensure that capacity value does not significantly bias market participants toward or against hybridization of resources.
    - *Remedy: Capacity valuation should account for changing supply mix and system peaks expected in the future*. As the supply mix evolves, capacity value of storage and hybrids may also change, particularly in systems with higher shares of renewables. Rules on capacity qualification should reflect those expectations, rather than simply retrospective analysis.
    - *Remedy: Provide more freedom to the resource owner to indicate (and receive capacity market revenue for) its expected capacity value contribution in the planning timeframe*. Storage's capacity value is heavily determined by how it is dispatched. Capacity payments can be subject to economic penalties and rewards in real-time dispatch for meeting or

---

[41] https://www.pjm.com/-/media/committees-groups/committees/mic/20190206/20190206-item-07c-faq-for-order-841-and-hybrids.ashx p. 14.

[42] MISO ESTF recommendation #1. https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf

exceeding the credited level of capacity. By moving more of the performance incentive to the operating timeframe, this ensures resource owners have the freedom to use their own forecasting and probabilistic analysis to optimize the commitment and dispatch of their own resources, which results in more efficient commitment and dispatch of the entire system and is coordinated through market prices. Given that most grid operators have lagged in implementing probabilistic commitment and dispatch decisions and advanced forecasting methods, it is critical that resource owners have the opportunity to use those methods if they believe they can more efficiently dispatch their resources to meet peak demand needs.

- *Remedy: Clarify must-offer obligations that are required for hybrid resources providing capacity*. As discussed above under market power mitigation, must offer obligations are more complicated in the case of energy limited resources because of the chance of forcing a resource to produce when its energy is less needed. The MISO ESTF noted complicating factors when storage and other resources share interconnection via net zero interconnection: "Displacement agreements between an energy and capacity resource will be part of a Net Zero condition complicating compliance with must -offer obligations."[43]
- *Remedy: Encourage use of reasonable methodology such as Effective Load Carrying Capability (ELCC)*, probabilistically accounting for expected state of charge of batteries and dispatch patterns going into a peak demand event based on historical net load forecasts and dispatch patterns. As the resource mix changes, ELCC may itself need revision to better assess the capacity value of all resources.

11) *Shortcoming: As with stand-alone storage, rules are unclear and inconsistent as to whether transmission service is needed by the resource owner when charging from the grid*. Grid operators such as PJM and CAISO are not requiring contracts for transmission service when charging energy is recycled from the grid rather than paired generation, although some RTOs/ISOs do. Order No. 841 gives the RTO/ISO discretion. PJM and CAISO do not charge. PJM stated, "Network Transmission Service and Point-to-Point Transmission Service are not required for purchases of Dispatched Charging Energy." [44]
    - *Remedy: At a minimum, a battery and other resource should be allowed to take a combined transmission service rather than having to separately procure the service*.

[43] An Energy Displacement Agreement is "an agreement between an Interconnection Customer with an existing generating facility on the Transmission Provider's Transmission System and an Interconnection Customer with a proposed Generating Facility seeking to interconnect with Net Zero Interconnection Service. The Energy Displacement Agreement specifies the term of operation, the Generating Facility Interconnection Service limit, and the mode of operation for energy production (common or singular operation)." MISO Tariff Attachment X p. 5
https://www.misoenergy.org/api/documents/getbyname/Attachment%20X.pdf .

[44] PJM response to FERC data request in Order 841 compliance proceeding, Docket ER19-469, p. 15.
https://pjm.com/directory/etariff/FercDockets/4084/20190501-er19-469-001.pdf

Gas-Storage and Other Hybrids

Hybrids of energy storage paired with natural gas-fired power plants face many of the same issues as hybrids of storage paired with wind and solar discussed in this paper. Market reform efforts for hybrids generally will thus capture a number of concerns for gas-storage hybrids.

However, since gas-storage hybrids utilize a fuel source and are thus not considered energy-limited, different considerations may be warranted than for wind-storage and solar-storage. For example, market mitigation approaches to gas-storage hybrids are likely to be more critical since physical withholding is a key concern with fuel-based resources. As a corollary, the use of fuel may make market optimization of gas-storage resources more achievable in the near term.

In many ways, combined cycle gas turbines represent the first hybrid resource – i.e., a gas combustion turbine and a steam turbine with integrated control architecture – and there are a number of projects underway in RTOs/ISOs to optimize the use of combined cycle gas turbines.[45] Not only would these market enhancement projects benefit from incorporating gas-storage configurations into their considerations, but also they demonstrate that work on hybrid resources has already been underway for some time under a different name. Without similar work to enable other hybrid resource types, market rules run the risk of becoming discriminatory.

Moreover, there has been work on hybrid hydropower and battery storage units,[46] and work is underway on pairing nuclear plants with certain forms of energy storage.[47] While progress on a framework for hybrids is best focused on projects in interconnection queues, technology innovation in hybrids will continue to require updates to any framework.

Near-term reform priorities by region

Reforms needed in all regions are similar because of a widespread lack of clarity about hybrid resources in the interconnection process and market participation. A major priority reform across all RTO/ISOs is to allow storage to be added to existing resources and projects in the interconnection queue without going through the full lengthy interconnection process. A simpler test of electrical properties can be performed, and the battery generally adds reliability capabilities to the system. With so many projects already in interconnection queues, it is critical that the process for allowing additions to projects already in the queues be made more efficient rather than having to start anew.

Nonetheless, RTOs/ISOs vary in their current rules on hybrids. To that end, a useful starting point to enable hybrids in each region is as follows:

[45] For example, see MISO's Enhanced Modeling of Combined Cycle Generators project, https://www.misoenergy.org/stakeholder-engagement/issue-tracking/enhanced-modeling-of-combined-cycle-generators/

[46] https://www.wartsila.com/media/news/20-10-2017-greensmith-and-aep-launch-hybrid-hydro-energy-storage-project-in-usa

[47] https://www.powermag.com/exelon-is-exploring-nuclear-power-plant-hydrogen-production/

- PJM: Loss of queue position from adding or changing storage is a major risk in PJM. PJM network upgrade cost assignments due to inappropriate modeling of hybrid resources is also significant. Capacity credits and allowing for owner-managed control also require attention.

- NYISO: Capacity credits, interconnection rules, and state of charge management are the priority areas in New York.

- ISO-NE: The need to allow storage to be added without losing a queue position is particularly acute in New England. Requirements for capacity credit and interconnection rules should also be a major focus. A single application for interconnection service is needed.

- MISO: Interconnection, and not interfering with commitment and dispatch rules for variable energy resources, are important in MISO.

- CAISO: Interconnection, and not interfering with commitment and dispatch rules for variable energy resources, are also important in CAISO.

- SPP: A shared point of interconnect is needed in SPP. A single application for interconnection service is needed.

- ERCOT: A single application for interconnection service is needed.

Fully integrated hybrid operation requires much broader changes

Many of the changes described above can be made in the near term by treating the storage and generation parts of the hybrid resource separately. For example, renewable resource output can be forecast by the grid operator for incorporation into dispatch algorithms, and the storage part can participate and interconnect according to the rules and principles of FERC Orders No. 841 and 845. Capacity value of hybrids can be treated as the sum of the capacity values of the separate units. Must-offer obligations can apply separately. Interconnection studies can model the solar or wind generation per the standard approaches for those resources, and the batteries as batteries.

However, designing and operating hybrid units as two separate but co-located units can sub-optimally utilize the hybrid resource. Market participants are developing increasingly integrated single machines that contain both storage and generation capabilities connected on the DC side of an inverter, with sophisticated electronic control algorithms. In lieu of central market operation improvements that better optimize the power system to take these capabilities into account, project developers can act now to optimize their units, allowing for multiple charge/discharge cycles in a day and switching from providing one service to another.

Current systems are very far from allowing this self-optimized single machine mode of operation. CAISO stated it cannot allow fully integrated units (those with a single “resource ID”) to participate under the "intermittent resource" rules (in which resources are exempt from imbalance charges and output is centrally forecast) because it would not be able to predict output of an owner-controlled machine. At the same time, CAISO stated it is concerned that if these resources do not participate in the "intermittent resource" program, they will lose good information about resource output.

Fully integrated hybrids do not operate like conventional resources, yet the rules force them to do so. CAISO notes that when a hybrid operates as a single resource (single resource ID), it loses its status as an intermittent resource and must operate as a conventional generator. Conventional generator schedules can only be updated once an hour at 75 minutes before the operating hour.[48] Forcing such inflexible operation from extremely fast-responding flexible resources robs consumers of a great deal of value.

Grid operators are accustomed to controlling slow-moving generation to meet predictable load according to the well-understood and predictable behavior of nuclear, coal, gas combined cycle, and gas combustion turbine units. Hybrid resources are far more nimble, versatile, and controllable. Forcing them to operate either as conventional units or as separate generation and storage units leaves the value of their fully integrated operation unrealized. There is no industry consensus on how hybrid resources operating as fully integrated single machines should operate with power markets. Discussions have barely begun; most of the discussions at ISOs and RTOs has been about clarifying how current rules apply to hybrids, and some incremental reforms. A much broader discussion is required that considers how to enable flexible hybrid resources to participate and provide their full value.

The interconnection process also does not allow fully integrated machines to operate optimally. Interconnection planning processes generally assume resource output will occur at the worst possible times, such as high wind output at low load conditions, causing transmission system overloads. That generally does not reflect how a rational hybrid resource owner would operate, as they would use the storage resource to control output in response to energy market price signals that reflect transmission congestion and reflect the real-time value of injecting energy at that location. A fundamental change is needed in the approach to evaluating hybrid resources for interconnection purposes, ideally allowing the interconnecting resource to make economic decisions about the tradeoff between paying for grid upgrades versus the cost of transmission congestion.

Conclusion: Continuing progress toward wider market competition

As power sector technology innovation continues to evolve rapidly in electricity markets, there are significant opportunities to improve electricity market rules, remove barriers to entry, and evolve industry practices to better enable RTO/ISOs to serve customers with reliable and low-cost energy. Hybrid resources present another significant new technology advancement, potentially comparable to the recent growth of wind, solar, and stand-alone storage. In the near-term, co-locating storage and generation can provide efficiencies with plant design and interconnection, as well as allow customers to gain the benefit of tax credits that cover the storage portion as well as the renewable portion of the

[48] CAISO Hybrid Resources Issues Paper, p. 15. http://www.caiso.com/Documents/IssuePaper-HybridResources.pdf

plants. FERC and each RTO and ISO have major roles to play in this endeavor. A few of the RTOs and ISOs have begun the complicated and important stakeholder discussions and analysis needed to clarify rules for hybrid resources and allow for some incremental improvements. FERC can extend the leadership it showed recently with Order No. 841 for energy storage and Order No. 845 for generator interconnection to address hybrid resources, which were not addressed in either rulemaking. There is some urgency to this initiative, since so many market participants are making business decisions without the clarity of market rules and regulatory policy they need.

Longer term, there are more fundamental issues of how to allow hybrids to participate in markets as fully-integrated single machines, which may require broader reforms in the level of control maintained by grid operators over individual plants on the system. With hybrid resources comprising a large share of newly interconnecting generation and with most of the new plants capable of operating as fully integrated machines, there is little time to wait for this analysis of broader reforms.

Appendix A: Grid operator discussion papers on hybrid resources

Three grid operators, PJM, MISO, and CAISO have held meetings and issued discussion papers on hybrid resources.

CAISO Hybrid Issues White Paper:[49]

Citing an increase in interest in hybrid resources by stakeholders, as well as an increase in hybrid interconnection requests and actual deployment, CAISO released a white paper in July of 2019 that seeks to address solutions that can more easily integrate these resources into the market. This paper touches on topics that explore issues related to interconnections, markets and operations, ancillary services, deliverability, and resource adequacy, as well as metering telemetry, and settlements. CAISO offers this paper as part of the preliminary stage of a stakeholder engagement plan, which ultimately aims to produce a proposal for enhanced or potentially new market rules and business processes that can more efficiently accommodate hybrid resources.

PJM's FAQ:[50]

Following the release of the original PJM electric storage resource participation model FAQ document in September of 2018,[51] the ISO later revised the FAQ to include a section on hybrid resources in February of 2019. The document includes links that summarize FERC Order 841 and lay out its directives, as well as describe the current state of the market as it relates to storage resources and how PJM plans to comply with the Order. With regard to hybrid storage in particular, the FAQ document topics range from the different types of hybrid resources that PJM considers to how they might participate in the capacity market, among other specifics.

MISO ESTF:[52]

In May of 2019, the MISO ESTF submitted an issue form concerning a market participation model for generating facilities with multiple fuel sources. The ESTF notes that while FERC Orders 845 and 845-A allow for the interconnection of hybrid interconnection facilities, they find there to be issues and requirements that necessitate an evaluation of solutions that can increase market efficiency as the number of hybrid resources on the grid increases in the future. Specifically, the task force identifies

---

[49] CAISO (2019), *Hybrid Resources Issue Paper*, (July 18, 2019), (http://www.caiso.com/Documents/IssuePaper-HybridResources.pdf).

[50] PJM (2019), "Electric Storage Resource Participation Model (Additional Hybrid Resource Questions Addressed," (February 6, 2019), (https://www.pjm.com/-/media/committees-groups/committees/mic/20190206/20190206-item-07c-faq-for-order-841-and-hybrids.ashx).

[51] PJM (2018), "Electric Storage Resource Participation Model," (September 10, 2018), (https://www.pjm.com/-/media/committees-groups/committees/mic/20180914-special/20180914-item-06b-faq-for-order-841.ashx).

[52] MISO (2019), "Issue Submission Form," Submitted by Energy Storage Task Force, (May 2019), (https://cdn.misoenergy.org/20190523%20ESTF%20Hybrid%20Storage%20Issue%20List%20-%20Submission%20Form341397.pdf).

issues related to reliability, planning and cost allocation, resource adequacy, and markets, and considers the issue surrounding hybrids to be a candidate for the MISO "Integrated Roadmap."[53]

[53] "An Integrated roadmap candidate is a problem or issue that enhances market participation or market outcomes See MISO (2019).