PJM Energy Storage Resource (ESR) Participation Model Education

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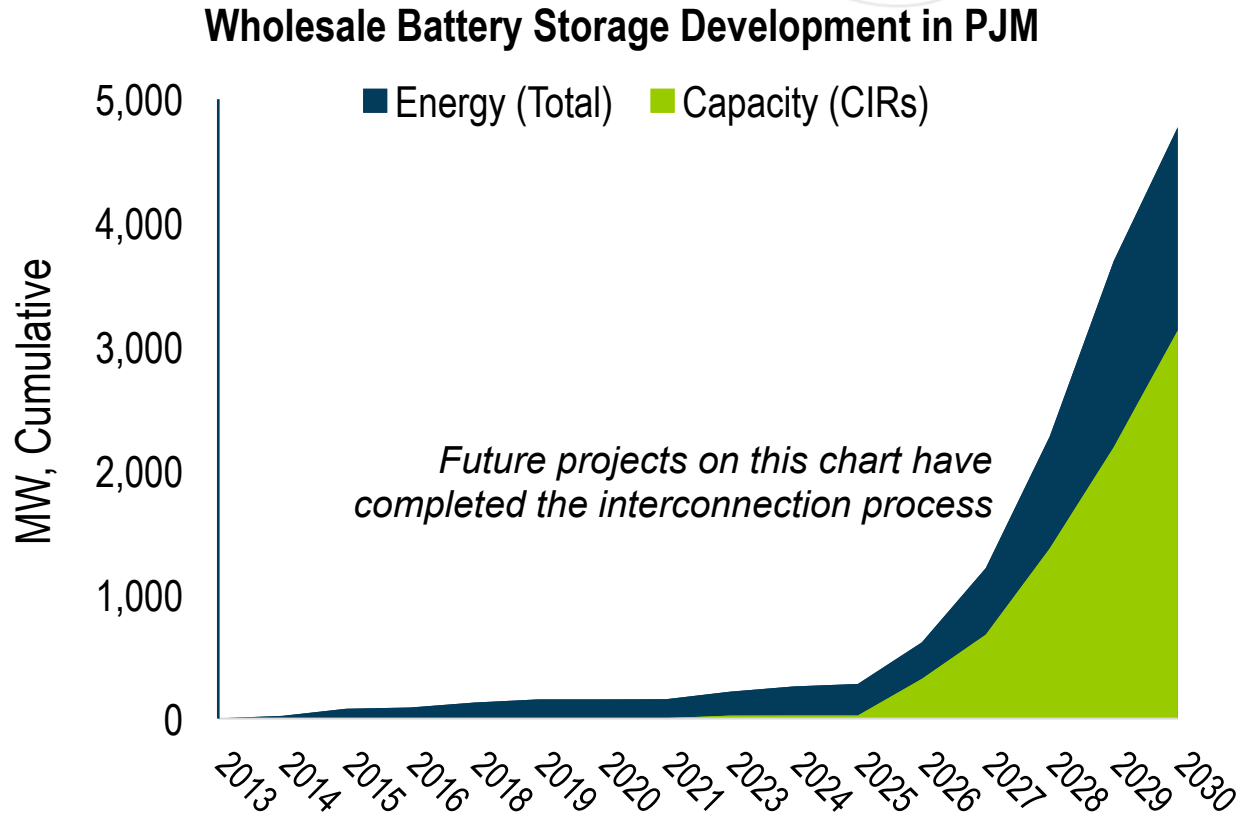
Purpose

- PJM published its position paper to support the stakeholder process on this issue charge.
- This presentation will provide education on the ESR Participation Model status quo.
- The issue areas identified in the paper, as well as the specific aspects of the ESR model design presented here, are items around which stakeholders have expressed considerable interest. They do not represent an exhaustive discussion of relevant topics.
- Additional items may be discussed within the stakeholder process, so long as they fall within the scope of the approved Issue Charge.

Why Revisit PJM's ESR Model Now?

PJM expects significantly more storage on the system by 2030, and beyond.
The ESR Model must support system reliability as the storage fleet grows.



4.5 GW
Under Construction

8.4 GW
Proceeding through Transition Cycle 2

66.5 GW
Proposed in Cycle 1

FERC Order 841 Background

PJM's Energy Storage Resource (ESR) Participation Model was developed pursuant to FERC Order 841 and implemented in 2020.

It is an opt-in model—a resource must proactively opt in to participate. Opt-in instructions are available in Manual 11.

All resources that comport with the Tariff definition of an "ESR" are eligible to opt in to the model.

"Energy Storage Resource" shall mean a resource capable of receiving electric energy from the grid and storing it for later injection to the grid that participates in the PJM Energy, Capacity and/or Ancillary Services markets as a Market Participant. Open-Loop Hybrid Resources are not Energy Storage Resources.

Energy & Ancillary Services Market Model

Model Overview:

- PJM's ESR Participation Model is a self-schedule model, meaning PJM will not make commitment decisions for model participants.
- ESRs* can be economically dispatched within their specified operating limits.
- ESRs are modeled as one continuous resource, with an offer curve that may comprise both positive and negative MW values.

Available parameters in Markets Gateway:

- Mode of Operation (described on subsequent slides)
- Min and Max Charge and Discharge Limits, representing Eco Min/ Max, depending on operating mode
- Charge/Discharge Ramp Rate
- State of Charge (optional hourly parameter, used for awareness only)

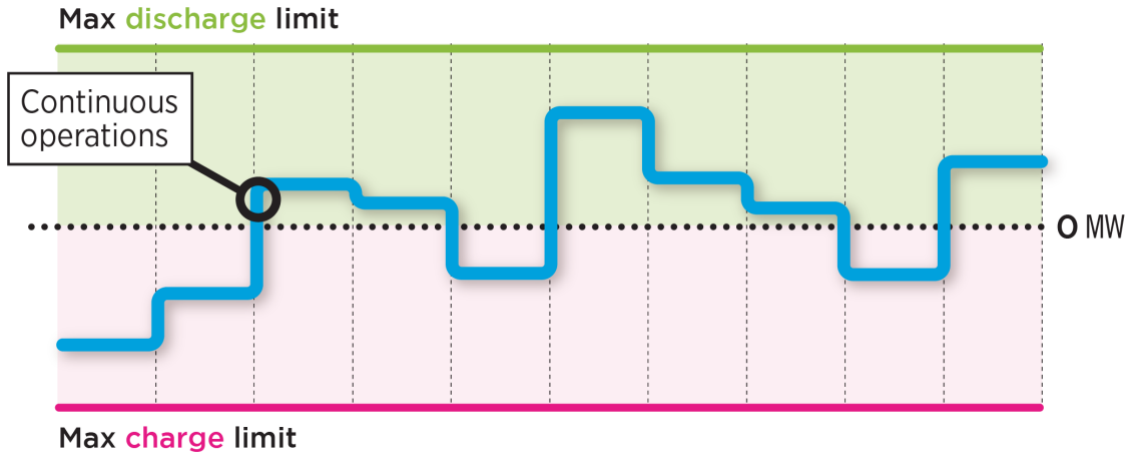
* "ESR" is used as shorthand for "ESR Model Participant" throughout this presentation.

Existing and Potential Market Parameters for ESR

Parameter	Description	Model
Charge Eco Min	The greatest magnitude of MW power consumption available for charging in economic dispatch for an ESR in Charge or Continuous mode	Legacy/nGEM basic
Charge Eco Max	The smallest magnitude of MW power consumption available for charging in economic dispatch for an ESR in Charge Mode	Legacy/nGEM basic
Discharge Eco Min	The minimum MW power output available for discharge in economic dispatch for an ESR in Discharge or Continuous mode	Legacy/nGEM basic
Discharge Eco Max	The maximum MW power output available for discharge in economic dispatch for an ESR in Discharge or Continuous Mode	Legacy/nGEM basic
Charge Ramp Rate	The Ramping Capability of an ESR in Charge Mode	Legacy/nGEM basic
Discharge Ramp Rate	The Ramping Capability of an ESR in Discharge Mode	Legacy/nGEM basic
Mode of Operation	Charge, Discharge, Continuous	Legacy/nGEM basic
Roundtrip Efficiency	The ratio of the SOC energy increase divided by the energy the ESR consumes in the charging process	nGEM ESR Model
Min SOC	The minimum quantity of physical energy stored in an ESR that should not be violated, measured in MWh	nGEM ESR Model
Max SOC	The maximum quantity of physical energy stored in an ESR that should not be exceeded, measured in MWh	nGEM ESR Model
Day Ahead SOC	The prospective SOC at the beginning of the first interval as offered into the DA Market	nGEM ESR Model
Real Time SOC	The current SOC of an ESR, measured in MWh	nGEM ESR Model

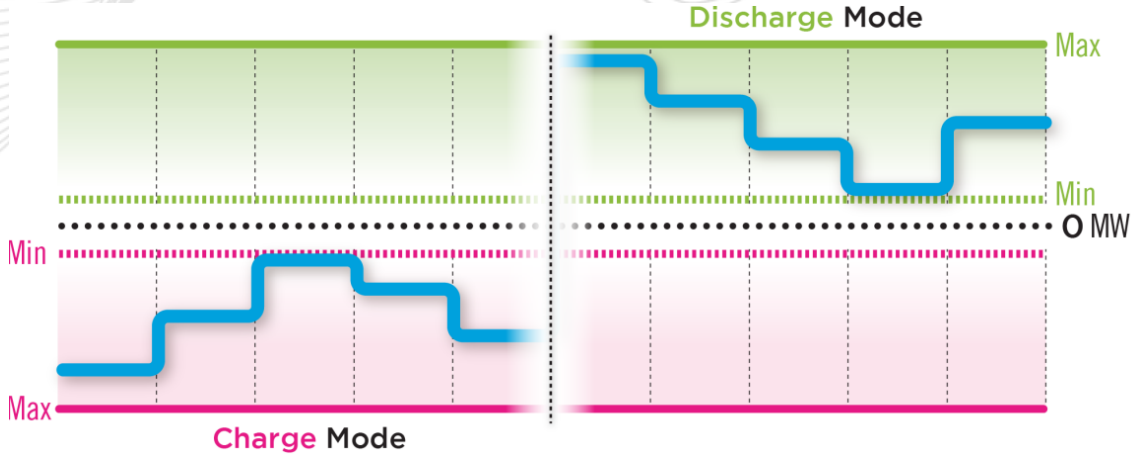
Energy & Ancillary Services Market Model

- ***Continuous Mode*** allows an ESR to be dispatched across its full operating range. This mode represents the ability to immediately transition from withdrawing to injecting energy and includes both negative and positive MW quantities.
- This mode requires the ESR's Max Discharge Limit to be greater than or equal to zero and Max Charge Limit to be less than or equal to zero.



Energy & Ancillary Services Market Model

- ***Charge Mode*** allows offers with a negative megawatt dispatchable range only, representing withdrawals.
- This mode requires the ESR to have a Min and Max Charge less than or equal to zero, and a defined ramp rate.
- ***Discharge Mode*** allows offers with a positive megawatt dispatchable range only, representing injections into the grid.
- This mode requires the ESR to have a Min and Max Discharge Limit greater than or equal to zero, and a defined ramp rate.



Modes of operation may be used in both the Day-ahead and Real-time Markets. They are submitted by the Market Participant on an hourly basis through Markets Gateway by 11:00 the day before the Operating Day for Day-ahead and 65 minutes before the operating hour for Real-time.

Energy & Ancillary Services Market Model

- ESRs are dispatched in accordance with their mode of operation for the applicable hour.
  - Economic limits for the operational mode are honored.
  - Ramp rate is considered infinite in continuous mode only.
- Dispatchable ESRs will have the ability to set price in all operating modes.
- State of Charge:
  - SOC is not tracked or accounted for today in market dispatch today.
  - SOC telemetry must be provided in real-time. Today, these values are only used in settlement calculations to determine uplift payments if the resource receives a manual dispatch to address a system constraint.

ESR Participation in Ancillary Services

- ESRs are eligible to provide Synchronized and Secondary Reserves.
  - ESRs are always considered online if available and are therefore not eligible to provide Non-Synchronized Reserves.
- ESRs are not considered available by default; PJM does not calculate their available reserve quantity.
  - The Market Participant must submit a separate reserves offer to be considered.
- ESRs can provide Ancillary Services only (i.e., they can provide regulation or reserves, but not energy).
  - Market participant must select Ancillary Only = 'Yes' in Markets Gateway for any hour in which the ESR is providing AS only.
- An ESR committed for capacity has a reserves must offer requirement.

Cost Offer Development Guidelines

- Cost offer development guidelines for batteries are enumerated in Manual 15, Section 11.
- The cost offer may include the Fuel Cost (Charging Cost) and Variable Operation and Maintenance Adders, if justified
  - Charing Cost ($/MWh) = average charge cost ($/MWh) / efficiency factor
    - The specific methodology used to calculate charging cost must be specified in the resource's Fuel Cost Policy.
  - Variable operating and maintenance costs must be specified in the Fuel Cost Policy.
- Start up and no-load costs are not permitted.

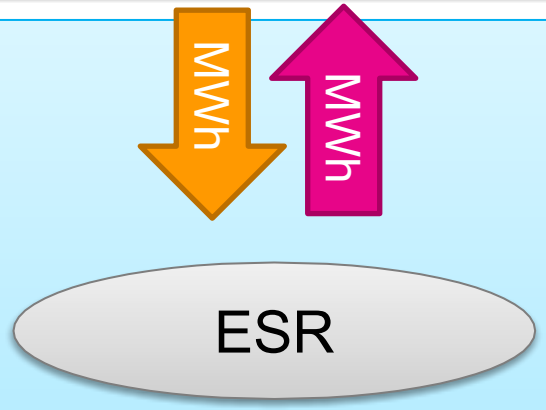
Opportunity Cost in Cost-Based Offers

- Per the OA, Schedule 2, a unit may include opportunity costs in cost offer if:
  - It is subject to operational limitations due to energy or environmental limitations imposed by Applicable Laws and Regulations
  - It is subject to operational limitations resulting from the physical equipment limitations of the unit, for up to one year, due to original equipment manufacturer recommendations or insurance carrier restrictions
  - It is subject to a fuel supply limitation, for up to one year, resulting from an event of Catastrophic Force Majeure
- Forward Energy-Limited Opportunity Cost, or foregone revenue associated with being run in one interval when it could have been more profitable to run in a higher-valued interval, is not included in M15.
  - As such, there is very limited ability for an ESR to reflect forward opportunity cost in cost-based offers today.*

* A Market Seller may seek an exemption, exception or change to any time frame, process, methodology, calculation or policy set forth in M15, or the approval of any cost or methodology that is not specifically permitted by submitting a request to PJM and MMU.

Settlements for Charging Energy

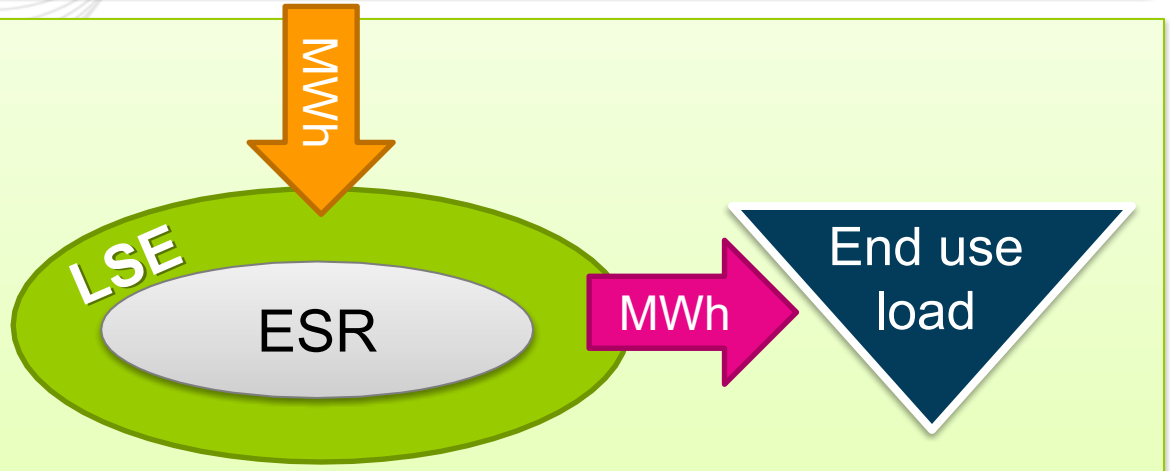
PJM Energy Market



Direct Charging Energy

Energy stored for later wholesale sale

- Dispatched Charging Energy
- Non-Dispatched Charging Energy



Load Serving Charging Energy

Energy stored for later end use

- Must be an LSE
- Settled as load rather than as negative generation

Settlements for Charging Energy

Dispatched Charging Energy

- Dispatched for a service:
  - Economically dispatched by PJM in real-time
  - Assigned Regulation, Sync Reserves or Reactive Service
  - Manually dispatched for system reliability

Non-Dispatched Charging Energy

- Operating outside of PJM instructions
- Pays applicable transmission service charges as a Network Service User

ESR Participation in the Capacity Market

- ESRs offer into the Capacity Market following all the applicable rules of the RPM.
- ESRs are considered a Limited Duration Resource and accredited using the class ELCC for the relevant duration (e.g., 4, 6, 8, and 10 hours).
  - An ESR with a duration of less than 4 hours may derate its hourly capability to match the desired ELCC class. For example: a 2-hour 40 MW battery can be accredited as a 4-hour 20 MW battery.
- An ESR committed for capacity has an energy must offer requirement.
  - ESR Model Participants with a capacity commitment must self-schedule the unit into the DA Market (i.e., make the unit available to the Day-Ahead Market) with an hourly megawatt quantity that may vary hour to hour from the capacity commitment. –*Tariff, Att K-Appx, Sec 1.10*

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