Energy Storage (Order 841) Education

December 6, 2019

Agenda

1. Update on 841 filing status
2. Overview
3. Rule/manual changes
4. Opt-in process/timeline
5. Markets Gateway changes
6. Operating in the Energy Markets
7. Participating in Ancillary Services
8. Settlements

10/17/2019 Order on Compliance Filing

"In this order, we accept PJM's proposed revisions, to become effective December 3, 2019, ***subject to a further compliance filing,*** to become effective on a date to be established by PJM, as discussed below. We also institute an investigation pursuant to section 206 of the Federal Power Act (FPA) and establish ***paper hearing procedures*** regarding the justness and reasonableness of PJM's minimum run-time rules and procedures." - Issued October 17, 2019

https://www.ferc.gov/whats-new/comm-meet/2019/101719/E-2.pdf

Directives

New filing by December 16, 2019 in existing docket ER19-469:

1. Add additional definitions and items into the Tariff.
2. Add to the Model to account for additional parameters.
   - FERC allowing PJM to propose a later effective date in order to achieve full compliance with the Final Rule.

New filing by Dec 12, 2019 in new docket EL19-100 (including paper hearing):

3. Add provisions reflecting "minimum run-time"* rules and procedures applicable to all resources into the Tariff.
4. Brief on "minimum run-time" rules as applied to Capacity Storage Resources (10 hour rule).

"Minimum run-time" in Order 841 refers to the continuous output capability requirement in the Capacity market. This usage is not related to the PJM Tariff Term "Minimum Run Time".

Directive 1: Items to add to the Tariff

A. Add Minimum and Maximum Charge Limit; Minimum and Maximum Discharge Limit; and Charge and Discharge Ramp Rate bidding parameters into Tariff language.

B. Add descriptions of three modes (continuous, charge, discharge) into Tariff language.

C. Add which services constitute “dispatched to provide a service” in Dispatched Charging Energy definition into Tariff language.

D. Add a general description and references for metering and accounting practices into Tariff language.

E. Add provisions ensuring the separation and proper accounting of wholesale and retail uses into Tariff language.

F. Add statement that PJM will not charge a distribution-connected Energy Storage Resource for charging energy if the distribution utility is unwilling or unable to net out any energy purchases associated with the Energy Storage Resource’s wholesale charging activities from the host customer’s retail bill into Tariff language.

Directive 2: Add to the Model

G. Enhance the participation model to more appropriately account for an ESR's State of Charge, Maximum State of Charge, and Minimum State of Charge through bidding parameters or other means in both PJM's day-ahead and real-time market dispatch.

Conceptual Timeline for Energy Storage under Order 841

Initial Proposed PJM ESR Participation Model

Go Live Dec 3

ER19-469

More Definitions & Detail in Tariff

Dec 16

EL19-100

Continuous Output Requirement for RPM in Tariff

ER19-469

"Account for State of Charge" enhancement in PJM ESR Participation Model

Energy Storage Overview

841 Requirements

1. Can sell* energy, Capacity, and A/S (incl. Black Start etc.) the resource is technically capable of providing
2. Dispatched and sets price as seller and buyer
3. Bid parameters that account for ESR characteristics
4. Min market threshold is 100 kW
5. Stored MWh are billed at LMP as wholesale

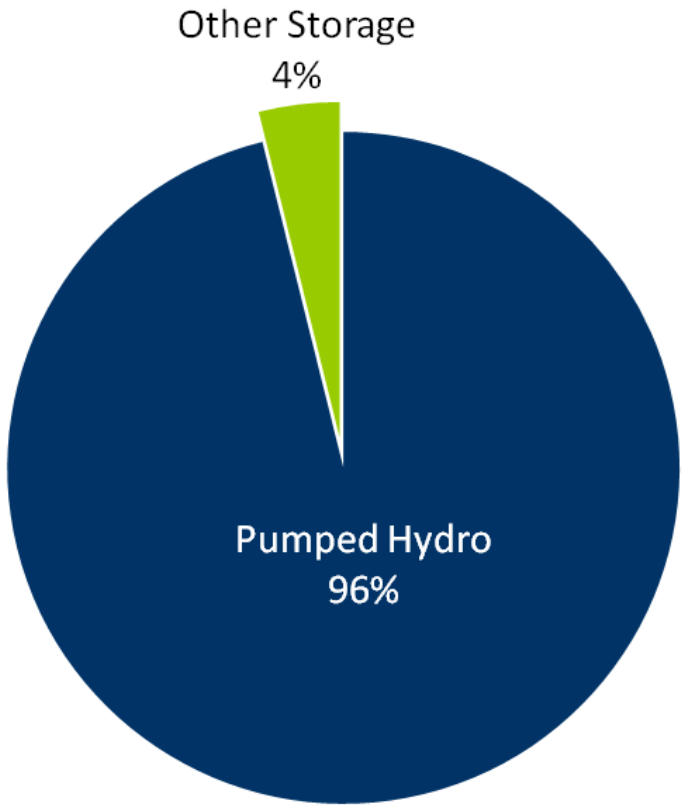
 = already in compliance

** "Eligible to provide…"*

Electric Storage Resource Definition

- Electric Storage Resource (**ESR**)= "a resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid."
- Connected at: transmission, distribution, or behind a customer meter.
  - PJM has ESR at both T and D today, none behind a meter **that inject**.
- Excludes demand response.
- Includes pumped hydro

Over 5,300 MW of Electric Storage Resources currently in PJM



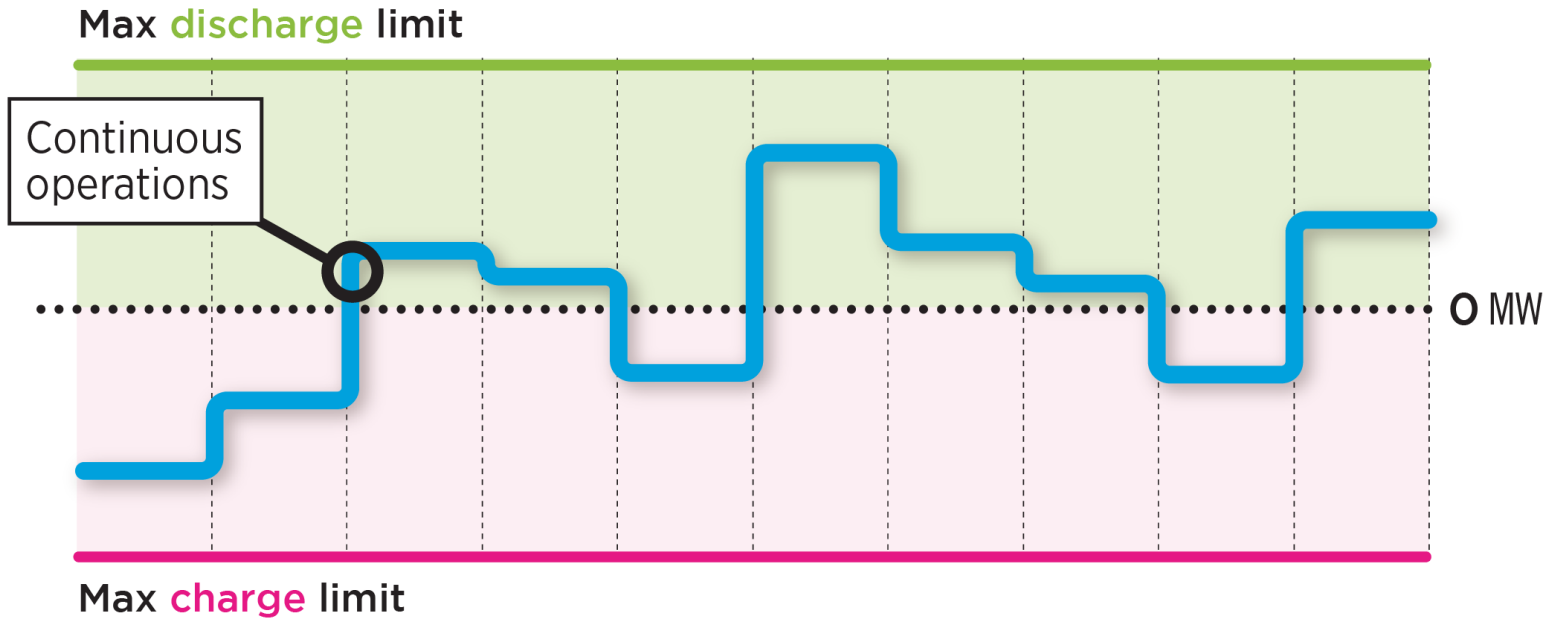
** Data taken from Generation Queue and EIA 860

ESR Participation Model Overview

- ESRs will be modeled as one continuous resource
- PJM will not make commitment decisions in the ESR model
    - Start-up and no load cost will not be considered
- PJM will not manage state of charge
    - Resource owners use mode of operation, offers, and parameters
- 3 modes of operation:
    - Continuous, Charge & Discharge
- Parameters
    - Max/Min charge/discharge, etc
    - Ramp rate considered infinite only in continuous mode

Continuous Operation Mode

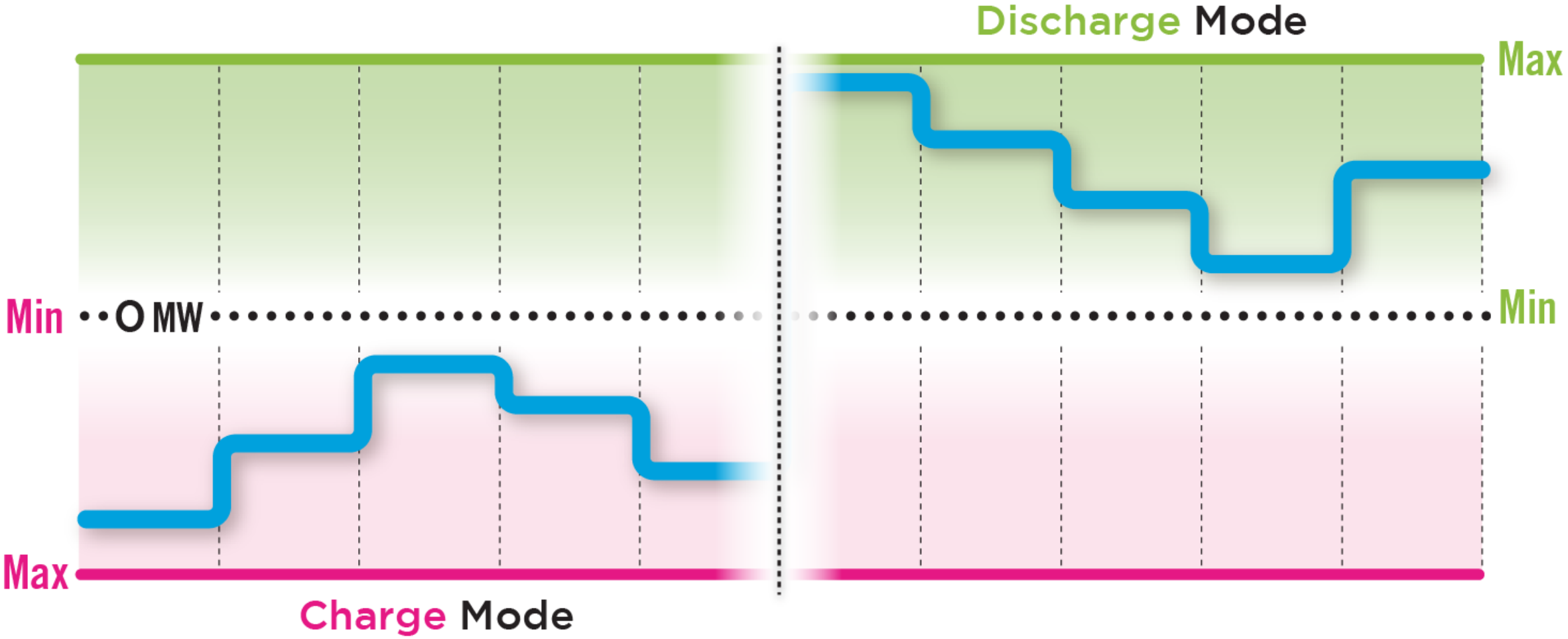
ESRs can update their max charge and discharge limits hourly in day-ahead, and more frequently in real-time.



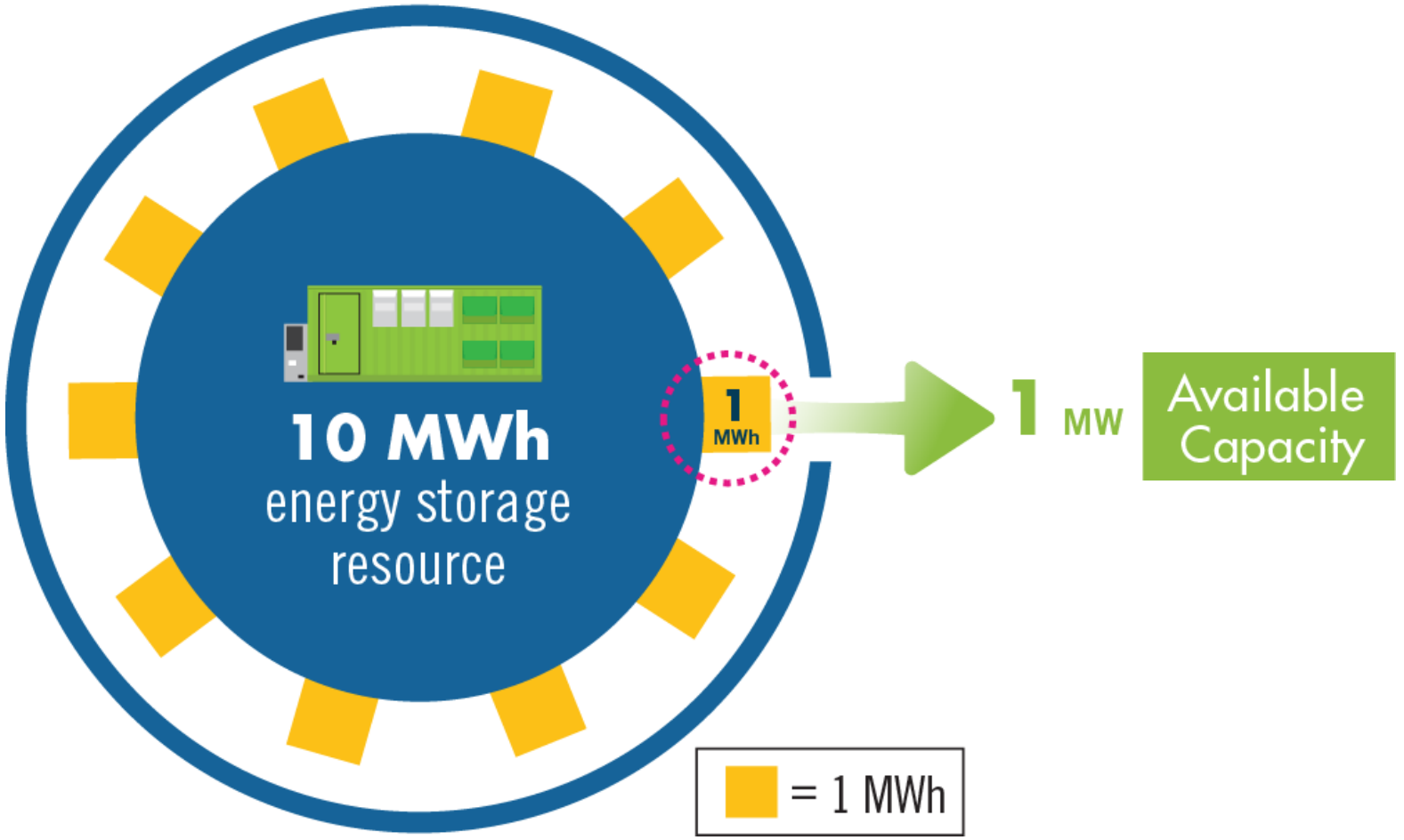
Price	MW
$ 10.00	20
$ 9.00	15
$ 8.00	10
$ 7.00	5
$ 6.00	0
$ 5.00	0
$ 4.00	0
$ 3.00	-5
$ 2.00	-10
$ 1.00	-15

** State of charge telemetry will be requested for telemetered resources

Charge and Discharge Modes



Capacity Market (RPM)



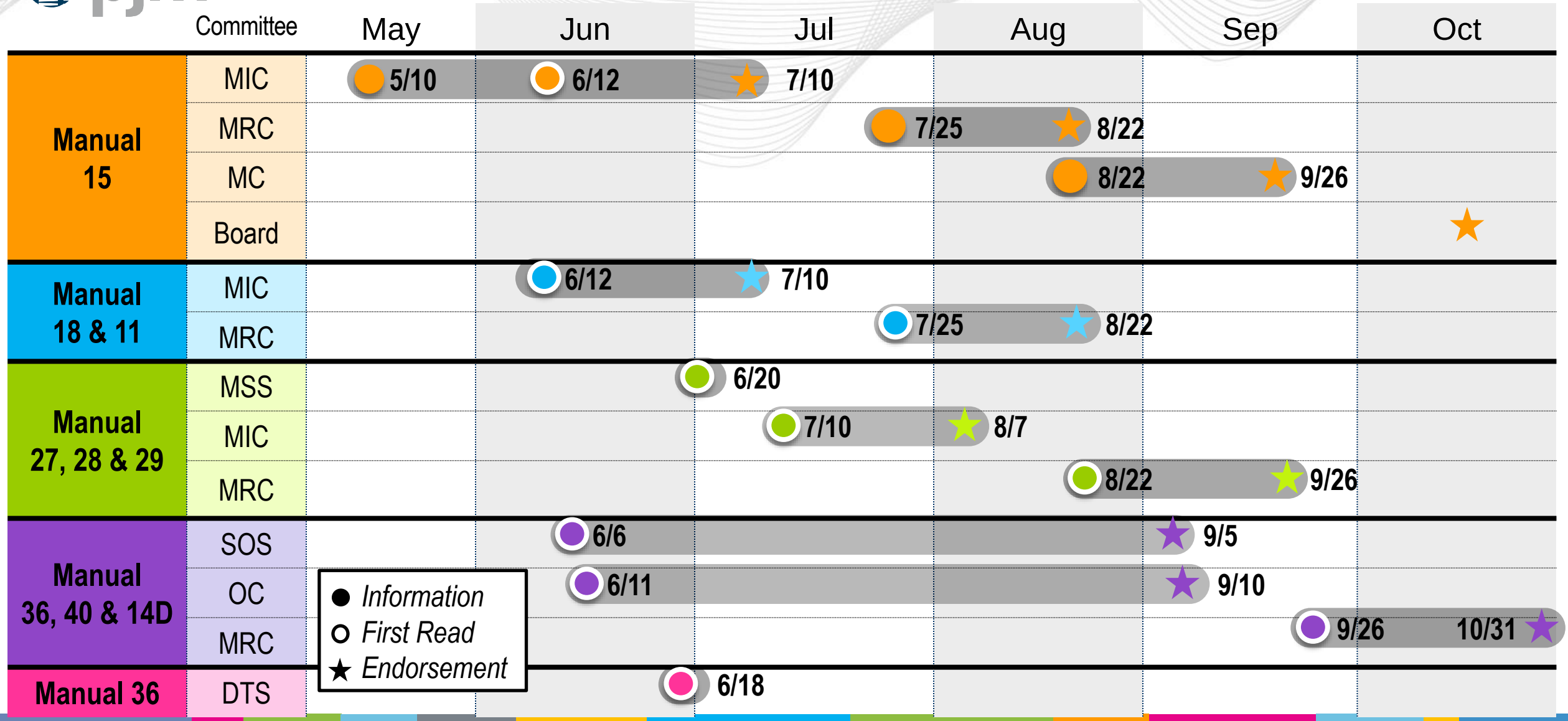
PJM maintaining the requirement, per manual 21, that capacity resources have a minimum 10 hour duration.

ESR capacity interconnection rights will be derated based on the total energy capability of the resource

- Total MWh/10h

Review of Manual Updates

2019 FERC 841 Manual Changes



Review Opt-in Process

Opt in Process

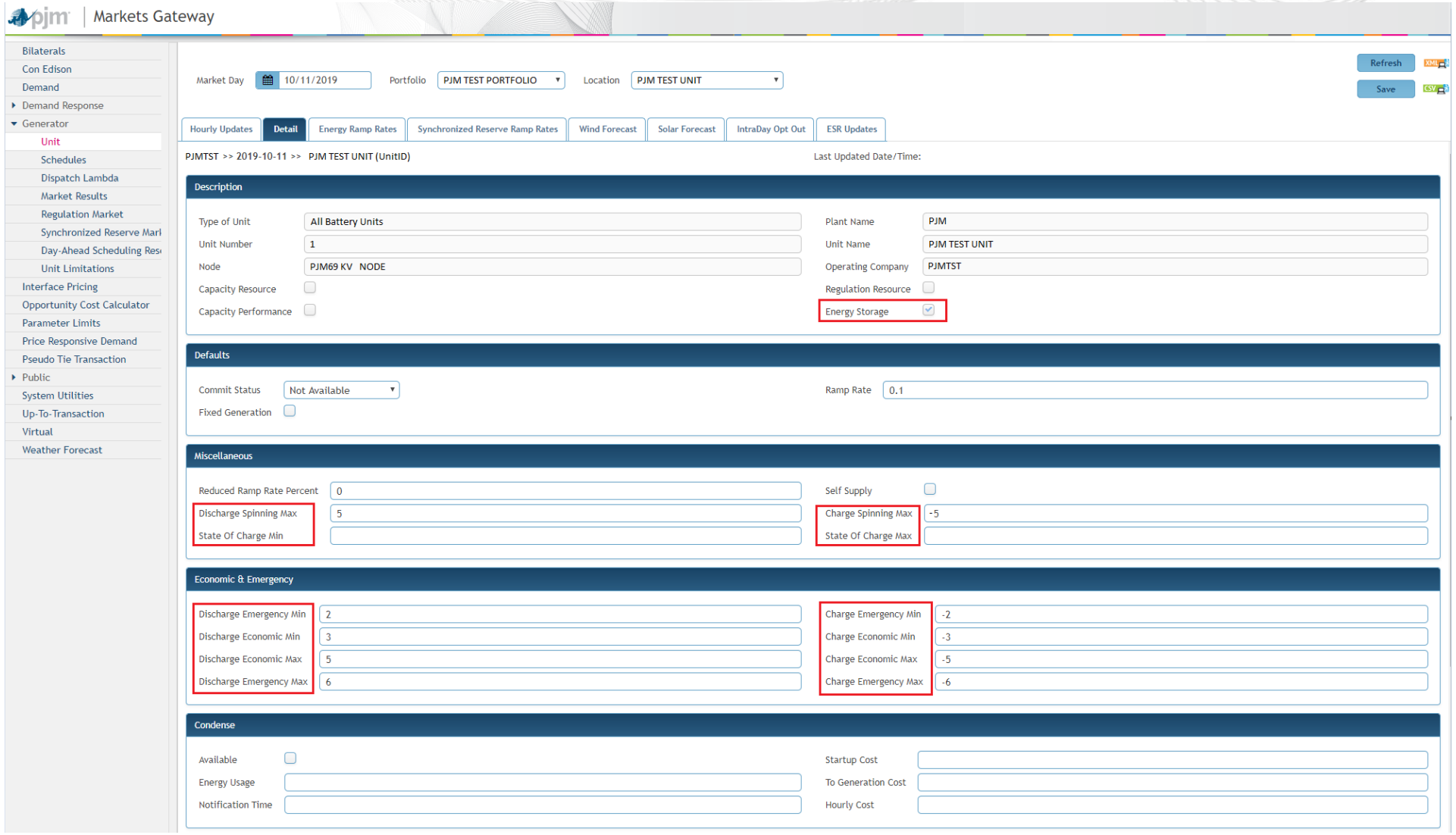
- Per Manual 11: ESR Participation Model Election (i.e. Opt In/Opt Out)
  - Existing resources must send opt-in requests no later than September 30 for the upcoming January 1 to December 31 participation months.
  - Resources within the new resource queue process must send an opt in request no later than three months in advance of their initial start in the energy markets.

Markets Gateway Changes

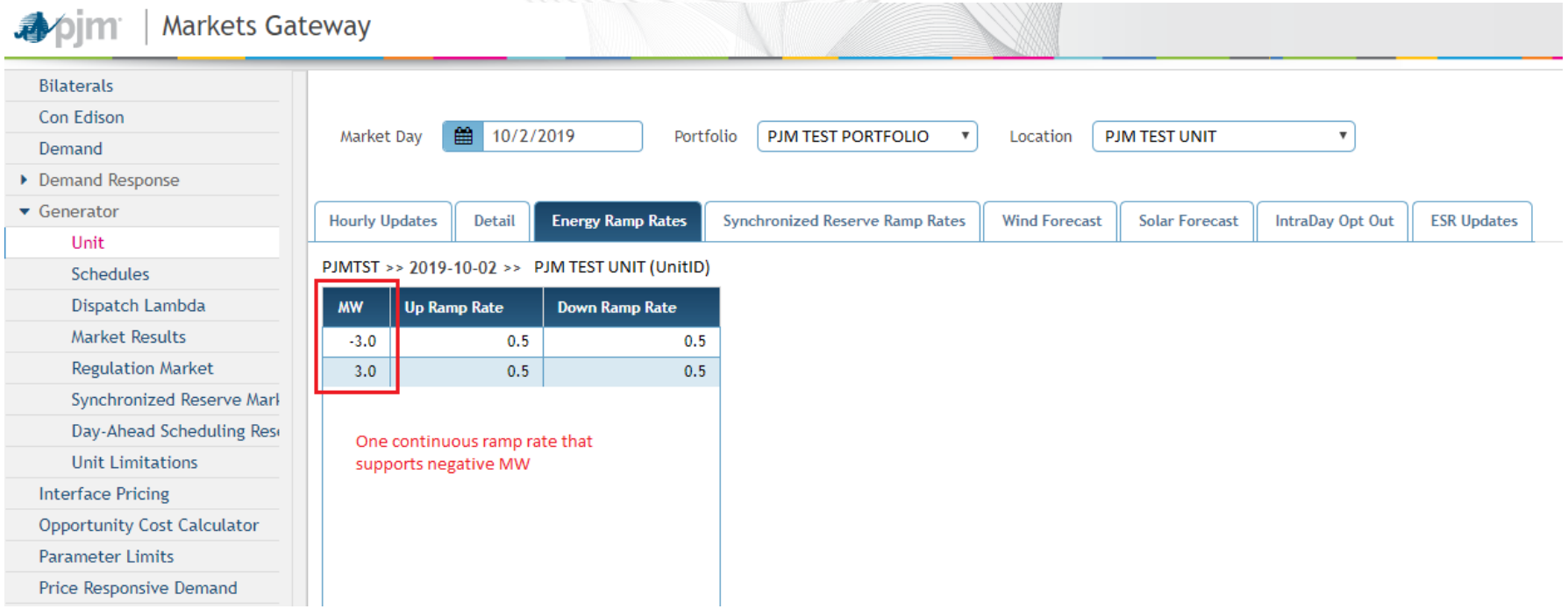
Generator > Unit > Hourly Updates

Hour	Discharge Emer. Min. (Default)	Discharge Emer. Min. (MW)	Discharge Econ. Min. (Default)	Discharge Econ. Min. (MW)	CIR	Discharge Econ. Max. (Default)	Discharge Econ. Max. (MW)	Discharge Emer. Max. (Default)	Discharge Emer. Max. (MW)	Charge Emer. Min. (Default)	Charge Emer. Min. (MW)	Charge Econ. Min. (Default)	Charge Econ. Min. (MW)	Charge Econ. Max. (Default)	Charge Econ. Max. (MW)	Charge Emer. Max. (Default)	Charge Emer. Max. (MW)	Commit Status	Fixed Gen.?	Ancillary Only?
1	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
2	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
3	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
4	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
5	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
6	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
7	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Charge	No	No
8	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Discharge	No	No
9	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Continuous	No	No
10	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
11	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
12	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
13	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
14	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
15	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
16	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
17	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
18	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
19	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
20	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
21	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
22	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
23	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No
24	2.0		3.0			5.0		6.0		-2.0		-3.0		-5.0		-6.0		Unavailable	No	No

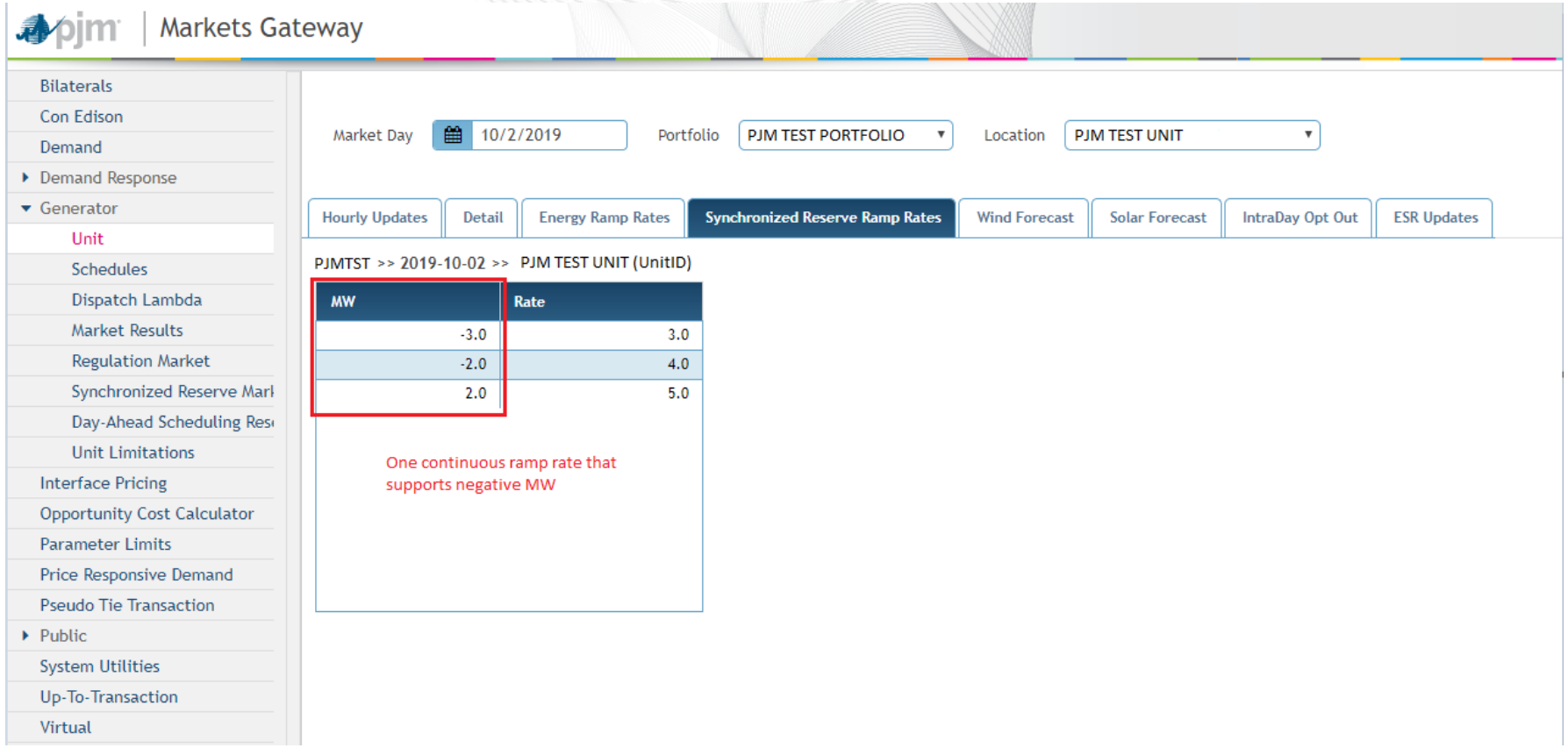
Generator > Unit > Detail



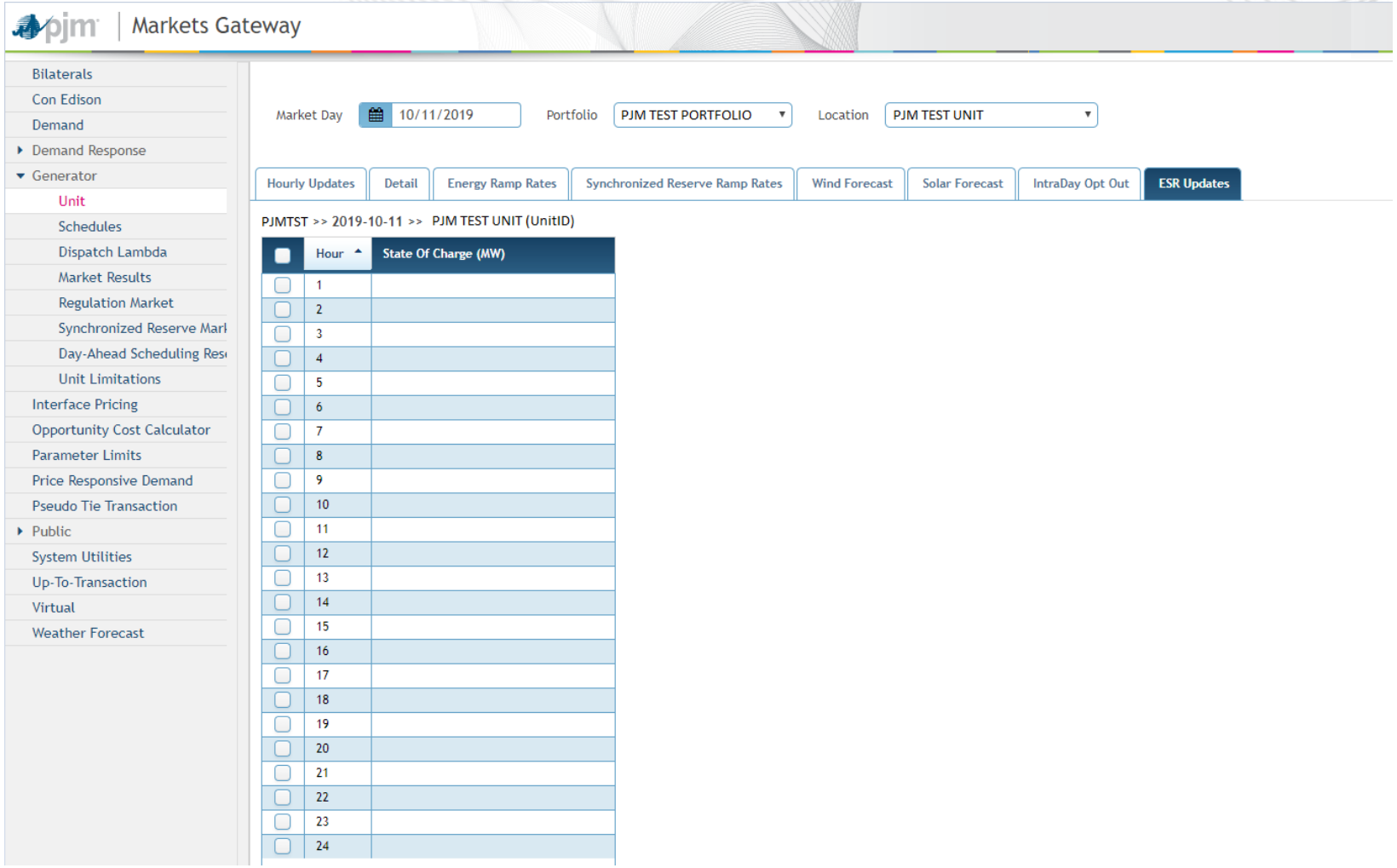
Generator > Unit > Energy Ramp Rates



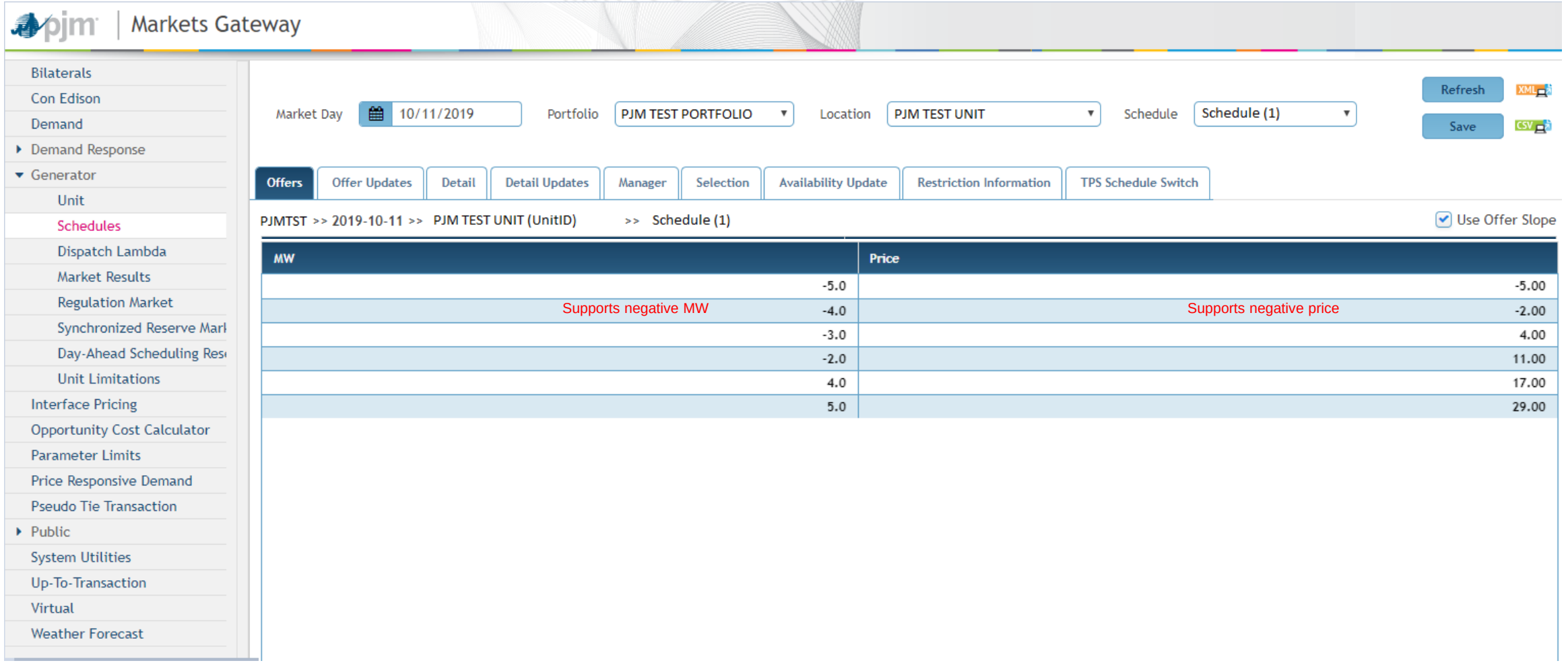
Generator > Unit > Synchronized Reserve Ramp Rates



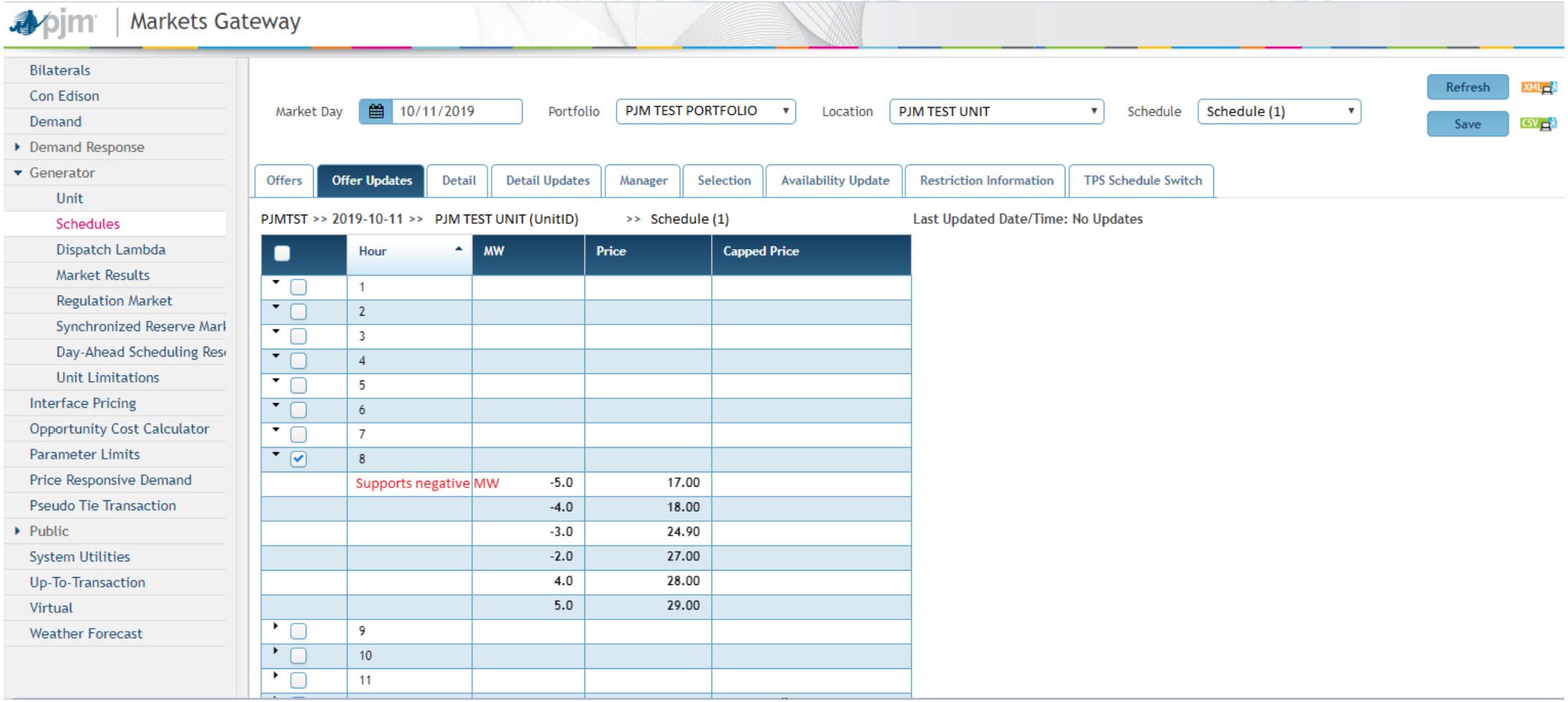
Generator > Unit > ESR Updates (information only)



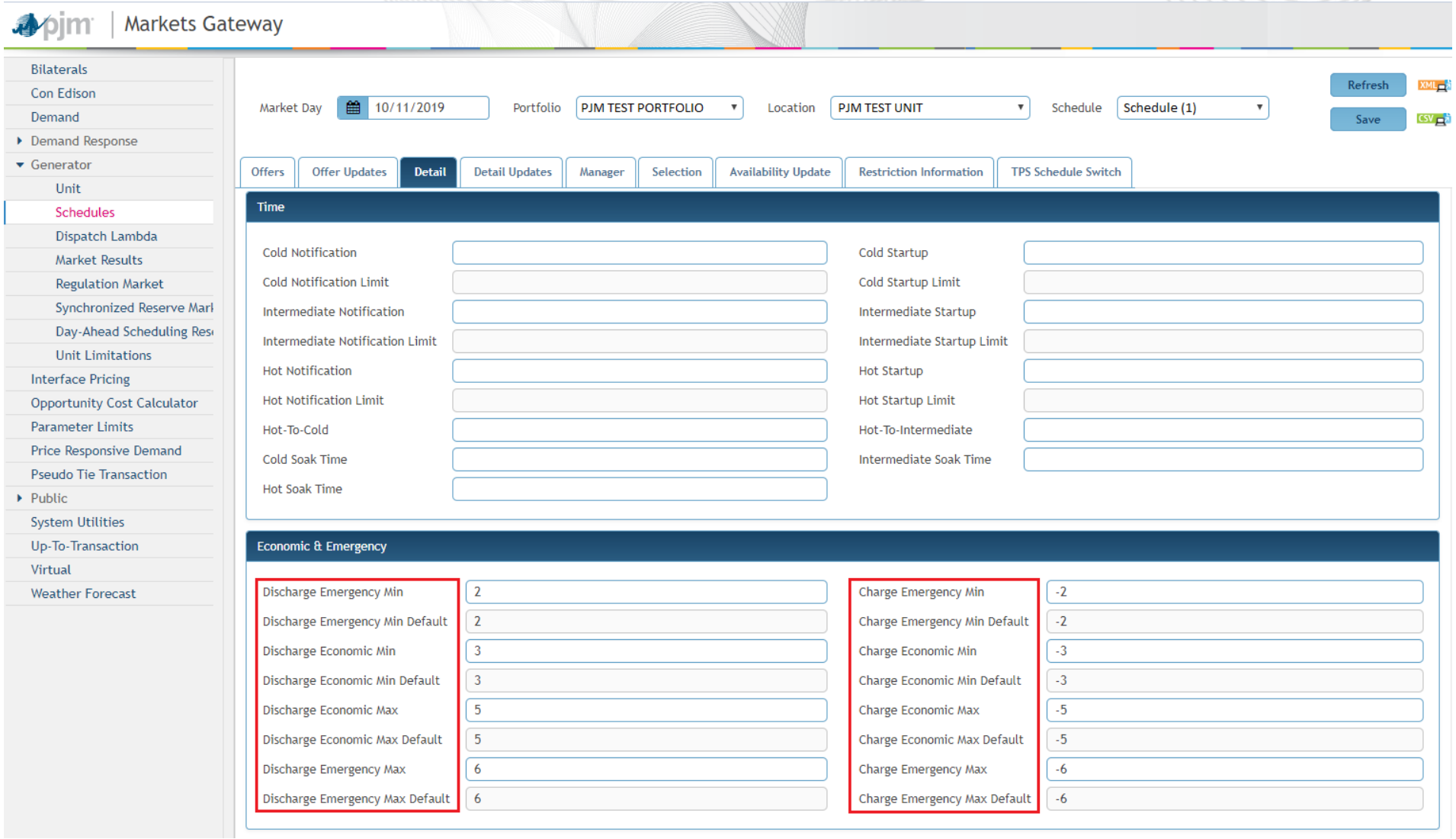
Generator > Schedules > Offers



Generator > Schedules > Offer Updates



Generator > Schedules > Detail



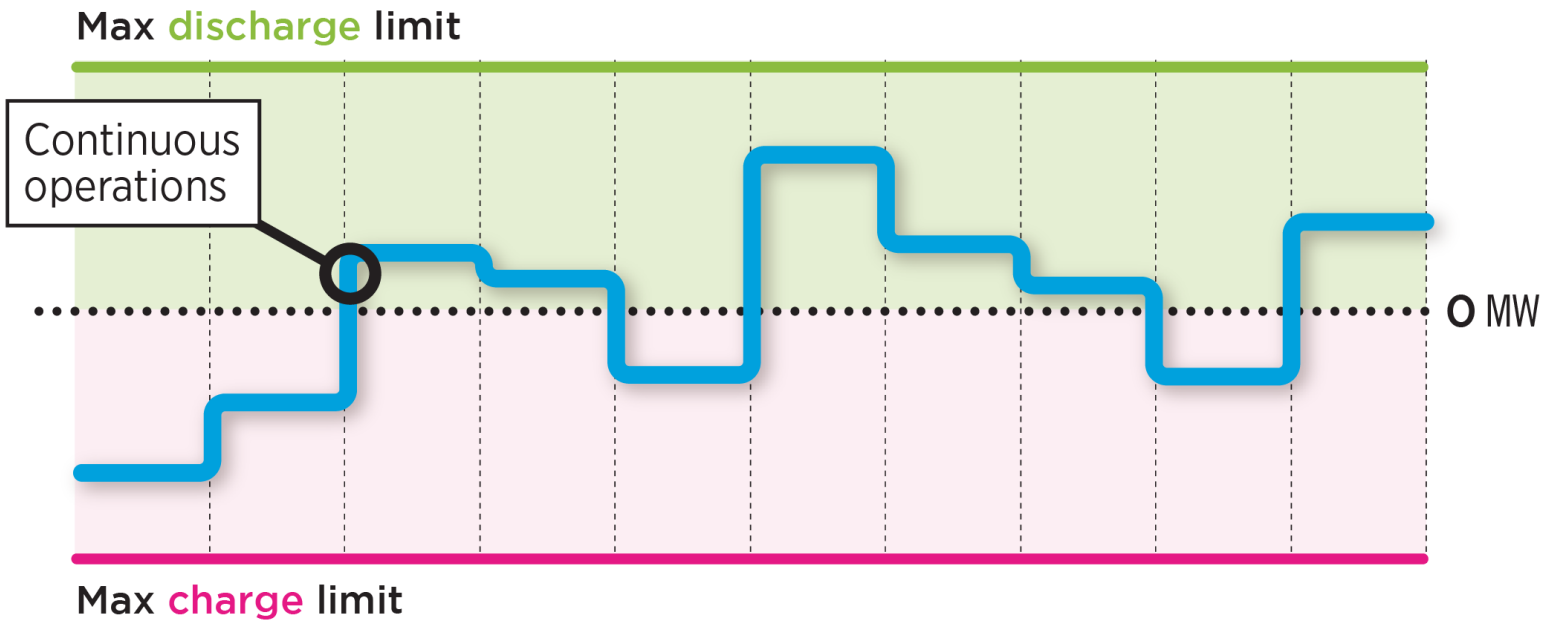
Operating in the Energy Markets (DA & RT)

ESR Participation Model Overview

- ESRs will be modeled as one continuous resource
- PJM will not make commitment decisions in the ESR model
    - Start-up and no load cost will not be considered
- PJM will not manage state of charge
    - Resource owners use mode of operation, offers, and parameters
- 3 modes of operation:
    - Continuous, Charge & Discharge
- Parameters
    - Max/Min charge/discharge, etc
    - Ramp rate considered infinite only in continuous mode

Continuous Operation Mode

ESRs can update their max charge and discharge limits hourly in day-ahead, and more frequently in real-time.



Price	MW
$ 10.00	20
$ 9.00	15
$ 8.00	10
$ 7.00	5
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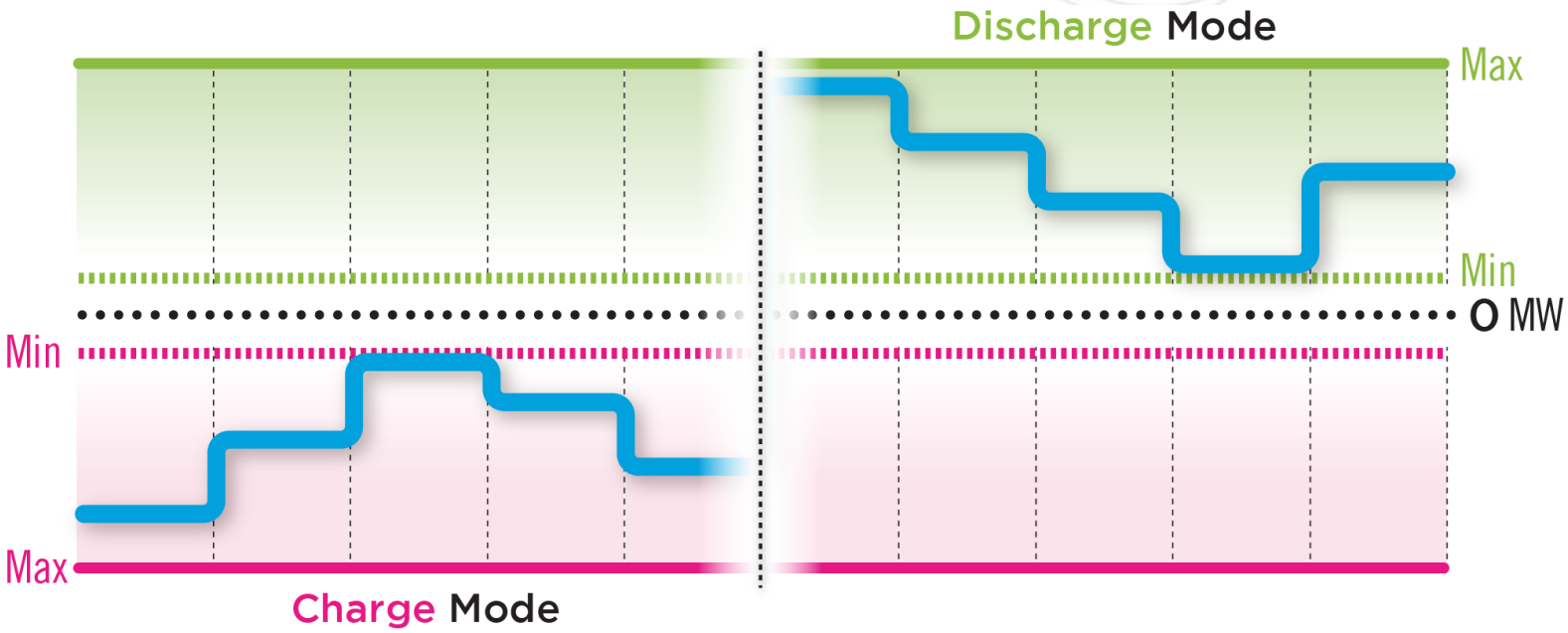
$ 5.00	0
$ 4.00	0
$ 3.00	-5
$ 2.00	-10
$ 1.00	-15

** State of charge telemetry will be requested for telemetered resources

Charge and Discharge Modes



Charge & Discharge mode will be available to ESR resources in Day Ahead and Real Time.

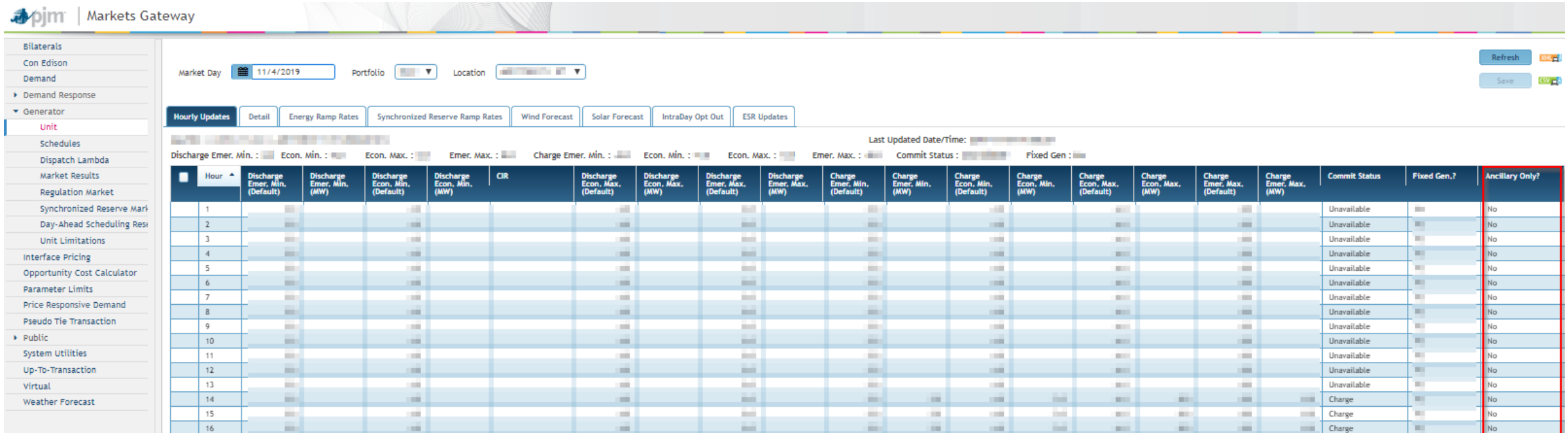
Summary - Dispatch of ESRs

- ESRs will be dispatched following the operational mode for the applicable hour.
  - Economic limits for the operational mode will be honored.
  - Ramp considered infinite only in continuous mode.
  - State of charge managed by the market participant.
- Dispatchable ESRs will have the ability to set price.
  - Applies to all three operational modes.
- Regulation assignments for ESR will be honored in the real time dispatch.
  - No change from current logic.

Participating in Ancillary Services

ESR Participation in Ancillary Services

- Resources cannot be both in the ESR model and also a non-energy resource
- However, ESRs can select Ancillary Only = ‘Yes’ for any hours they wish to provide Regulation or Reserves and not provide Energy

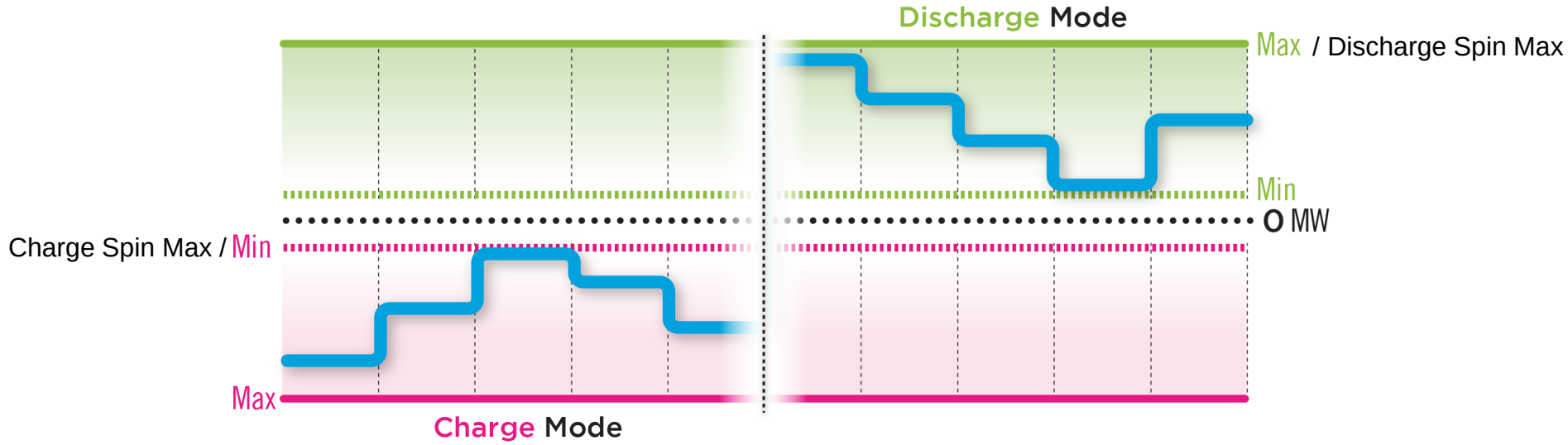


ESR Participation in Reserves

- ESRs can provide Synchronized Reserve in charge, discharge, or continuous modes
- An ESR that is providing both Energy and Reserves will be considered flexible Tier 2 SR
- For ESRs that choose Ancillary Only:
  - Pumped storage hydro will need to offer as Spin as Condenser = Yes and will be considered inflexible Tier 2 SR
  - All other Ancillary Only ESRs can set their flexibility by the Flexible parameter under Unit > Synchronized Reserve Market > Offers (Daily) or Updates (Hourly)
- By default, ESRs are not included in the Tier 1 Synchronized Reserve calculation, but can follow the current process to request an exception
- Available ESRs are always considered online, therefore they are not eligible to be considered for Non-Synchronized Reserve

New Ancillary Parameters in Markets Gateway

New Parameters	Location
Charge Spin Max	Unit > Detail (Default) Synchronized Reserve Market > Updates (Hourly)
Flexible	Synchronized Reserve Market > Offers (Daily) & Updates (Hourly)
Ancillary Only	Unit > Hourly Updates

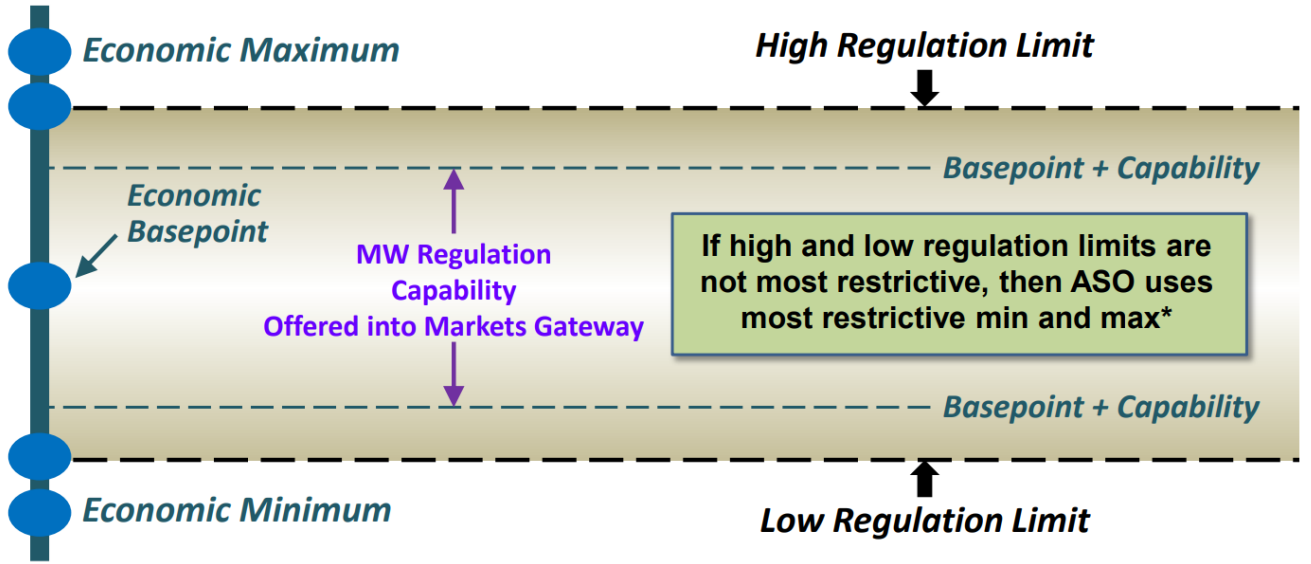


ESR Participation in Regulation

- ESRs can provide Regulation in charge, discharge, or continuous modes

The Regulation MWs available to clear are bounded by the following limits:

$$RegMW \leq Min[\frac{Abs[RegHigh - RegLow]}{2}, Reg\ Offer]$$



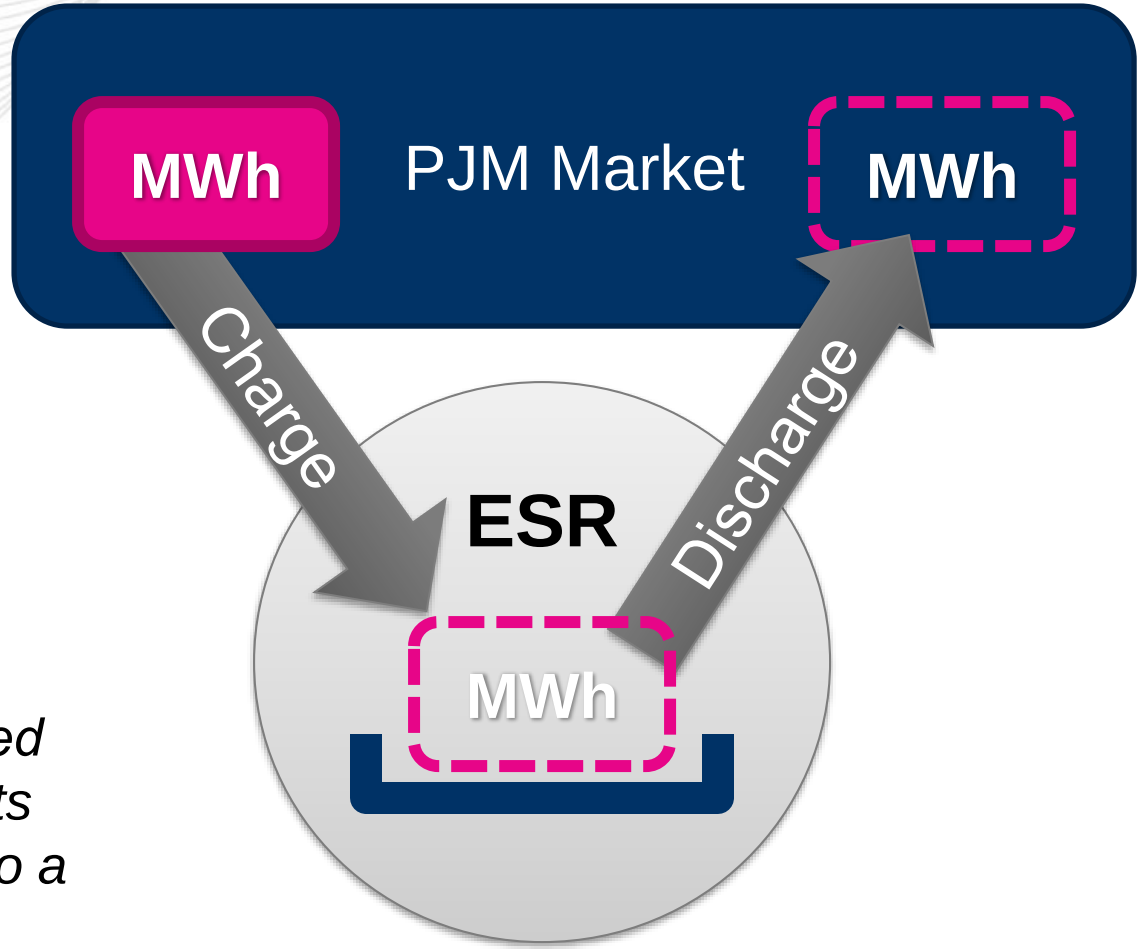
	Charge Mode	Discharge Mode	Continuous Mode
RegHigh =	Min(RegMax, ChargeMin)	Min(RegMax, DischargeMax)	Min(RegMax, DischargeMax)
RegLow =	Max(RegMin, ChargeMax)	Max(RegMin, DischargeMin)	Max(RegMin, ChargeMax)

Settlements

Definition of Energy Storage Resource and Charging

PJM Order 841 Compliance filing
ER19-462 and current Tariff:
"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.

M28 draft*:*
"An Energy Storage Resource shall be considered charging when the Revenue Data for Settlements for a Real Time Settlement Interval corresponds to a withdrawal."



Non-Dispatched Charging Energy

- New sections 22.1 and 22.2 of Manual 28 and matching new sections 8.1 and 8.2 of Manual 27
- Manual 28 new section 8.4

Dispatch Implications for Charging Energy

- Dispatched Charging Energy
  - Dispatched for a service
    - Economically dispatched by PJM in real-time
    - Assigned Regulation, Tier 2 Sync Reserves or Reactive Service
    - Manually dispatched for system reliability
- Non-Dispatched Charging Energy
  - Pays applicable transmission service charges as a Network Service User

Section 22.2: Charges for Non-Dispatched Charging Energy

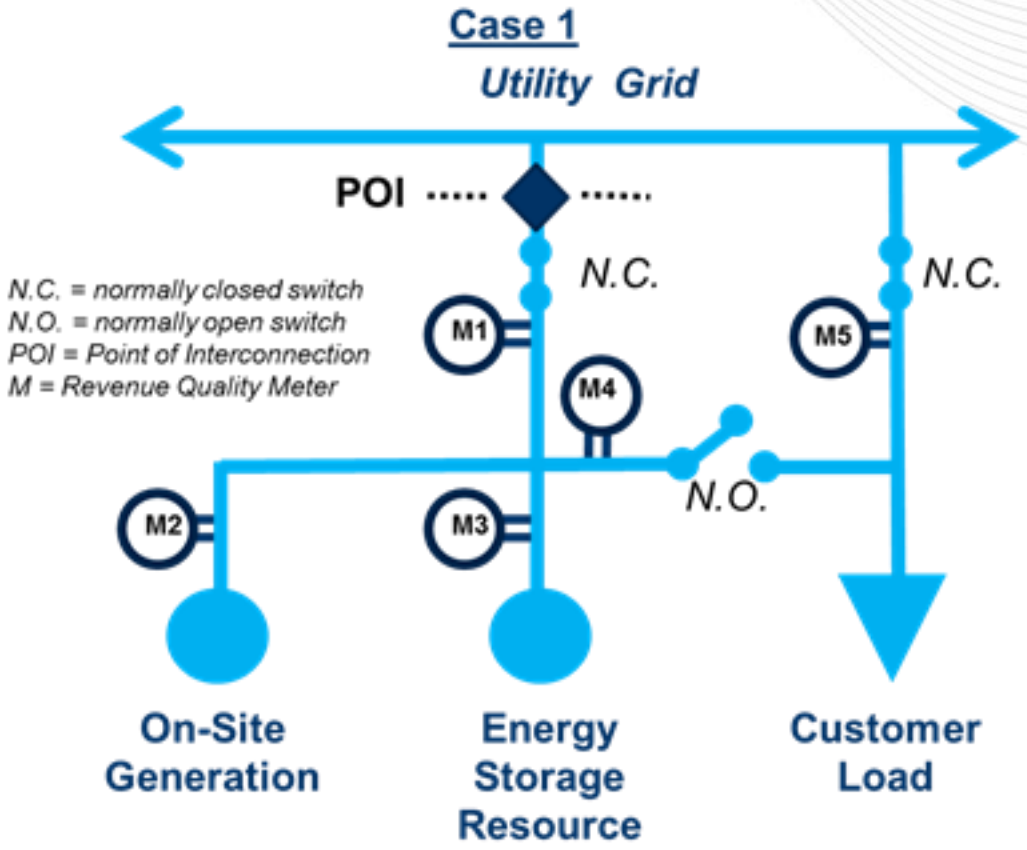
"Therefore, Non-Dispatched Charging Energy is eligible for allocation of the following non-LMP charges and credits:"

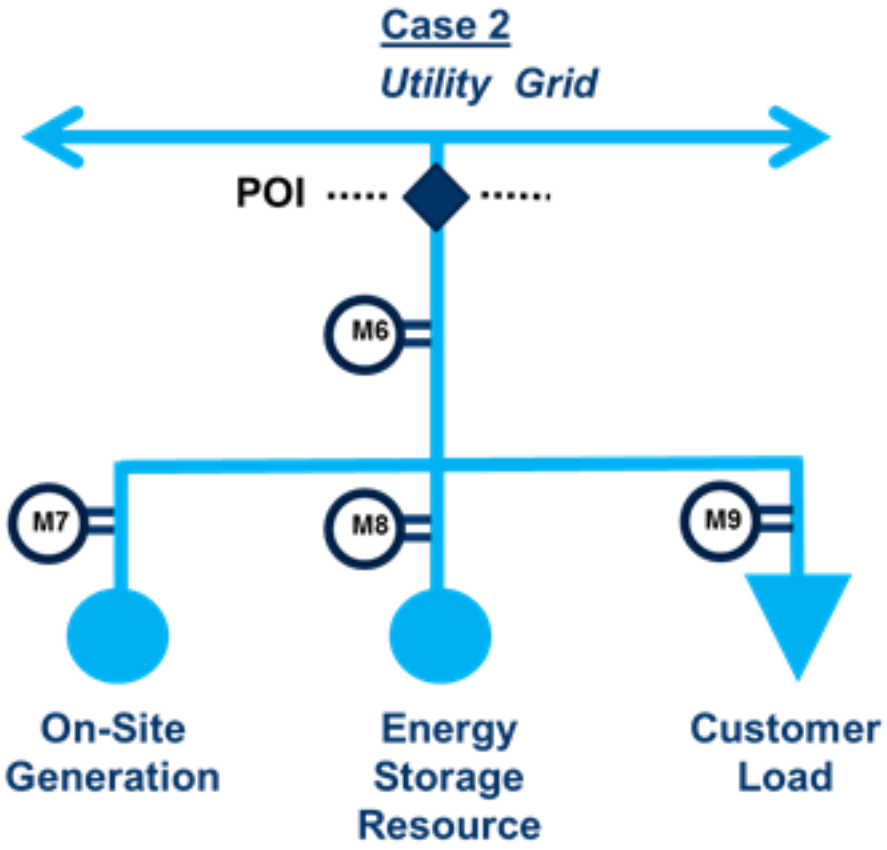
- *Schedule 1A Transmission Owner Scheduling, System Control and Dispatch Service*
- *Schedule 9-3, 9-FERC, 9-OPSI, 9-CAPS, 9-FINCON, 9-MMU, and 9-PJM Settlement*
- *Schedule 10-NERC and 10-RFC*
- *Network Integration Transmission Service*
- *Network Transmission Service Offset*
- *Network Integration Transmission Service (ATSI Low Voltage)*
- *MTEP Project Cost Recovery*
- *Transmission Enhancement*
- *Other Supporting Facilities*
- *Non-Firm Point-to-Point Transmission Service*
- *RTO Start-up Cost Recovery*
- *Black Start Service*
- *Unscheduled Transmission Service*
- *Reactive Supply and Voltage Control from Generation and Other Sources Service"*

Load Serving Charging Energy

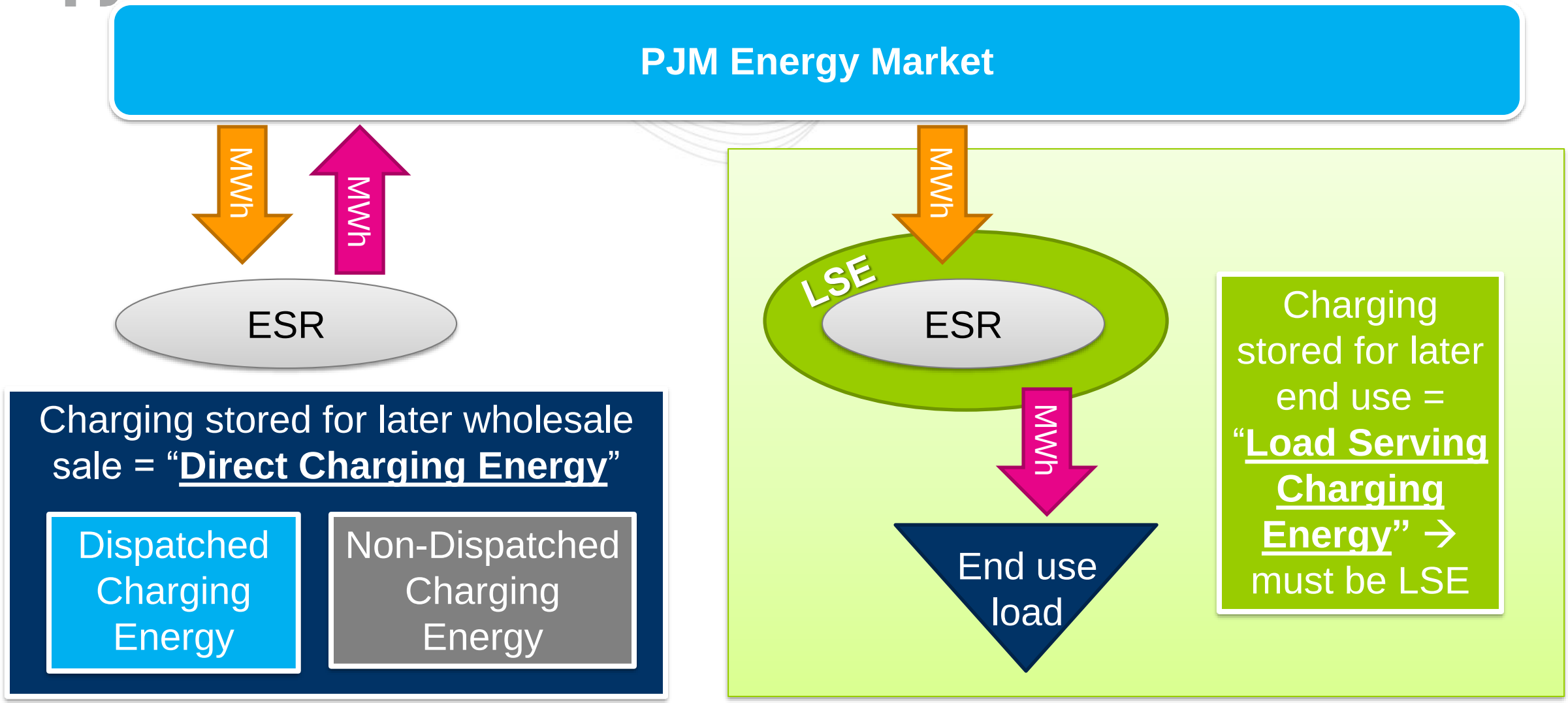
- New section 22.1 of Manual 28 and matching new section 8.1 of Manual 27
- Manual 27 new section 8.3
- Manual 28 new sections 22.3, 22.4, and 22.5

Possible Load Serving Energy Storage Resources





Order 841 Compliance: categories of charging energy

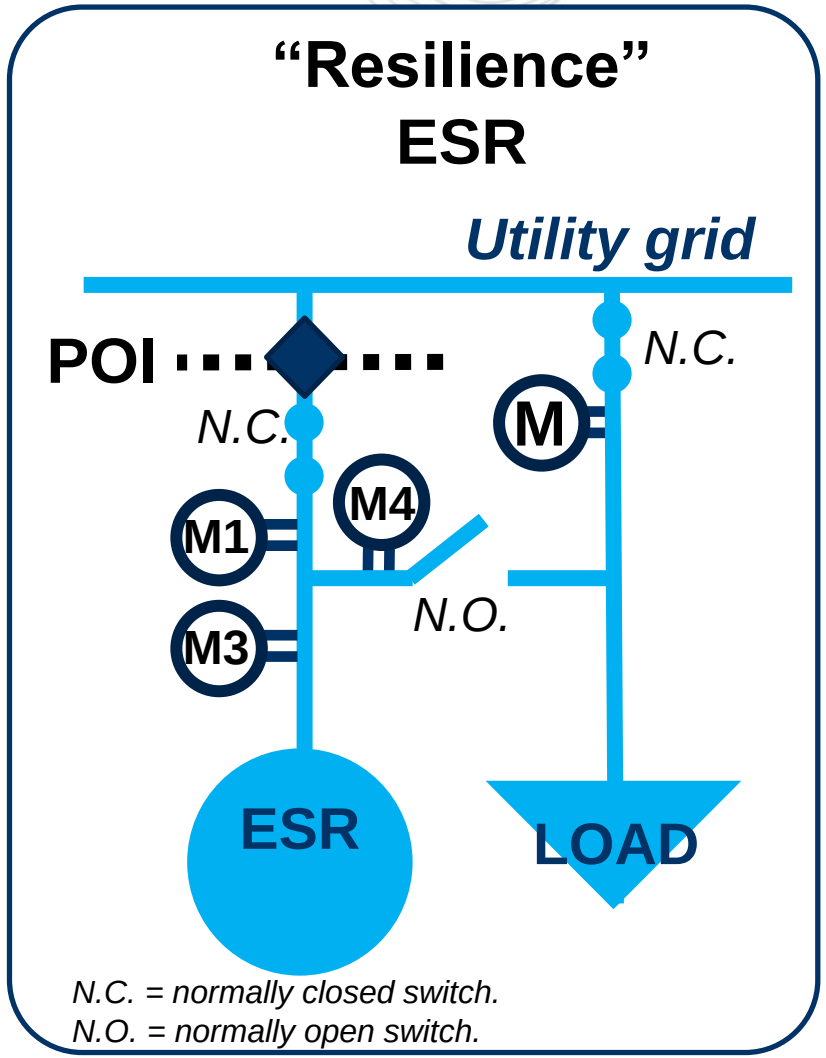


Settling Charging Energy for Load Serving ESR

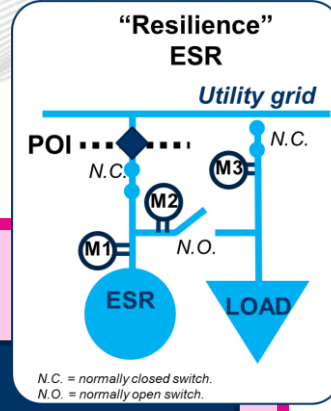
- Load Serving Energy Storage Resources are capable of directly serving end use load.
- Metering and methods are defined to distinguish:
  1. Charging energy that is later returned to PJM (“Direct Charging Energy”) from
  2. Charging energy that is later provided to end use load (“Load Serving Charging Energy”)
- PJM to provide Electric Distribution Company with processes to appropriately account for Direct Charging Energy (as negative generation) vs. Load Serving Charging Energy (as load).

Example: Resilience ESR Alone

- 100% of withdrawals initially settled as negative generation (i.e., Direct Charging Energy)
- ESR can only charge from grid.
- **Monthly M4 appropriately captures stored grid energy that is sent to end user→ monthly "Load Serving Charging Energy".**
- The sum of M4 over a month is the monthly quantity that should be ex-post adjusted from "Direct Charging Energy" into "Load Serving Charging Energy".



Section 22.5: Adjusting ESR Charging Energy



Initial Settlement

PJM Settlements

Debit

100% of Charging

ESR

LSE

Final Settlement

PJM Settlements

EDC

Meter Correction

Credit

90% of Charging

10%

ESR

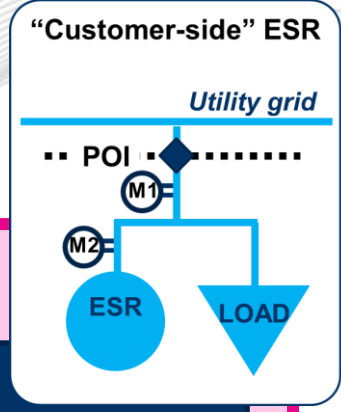
Load reconciliation

Debit

10%

LSE

Section 22.5: Adjusting ESR Charging Energy



Initial Settlement

PJM Settlements

Debit

ESR

100% of Charging

LSE

Final Settlement

PJM Settlements

EDC

Meter Correction

Debit

10%

ESR

Load reconciliation

Credit

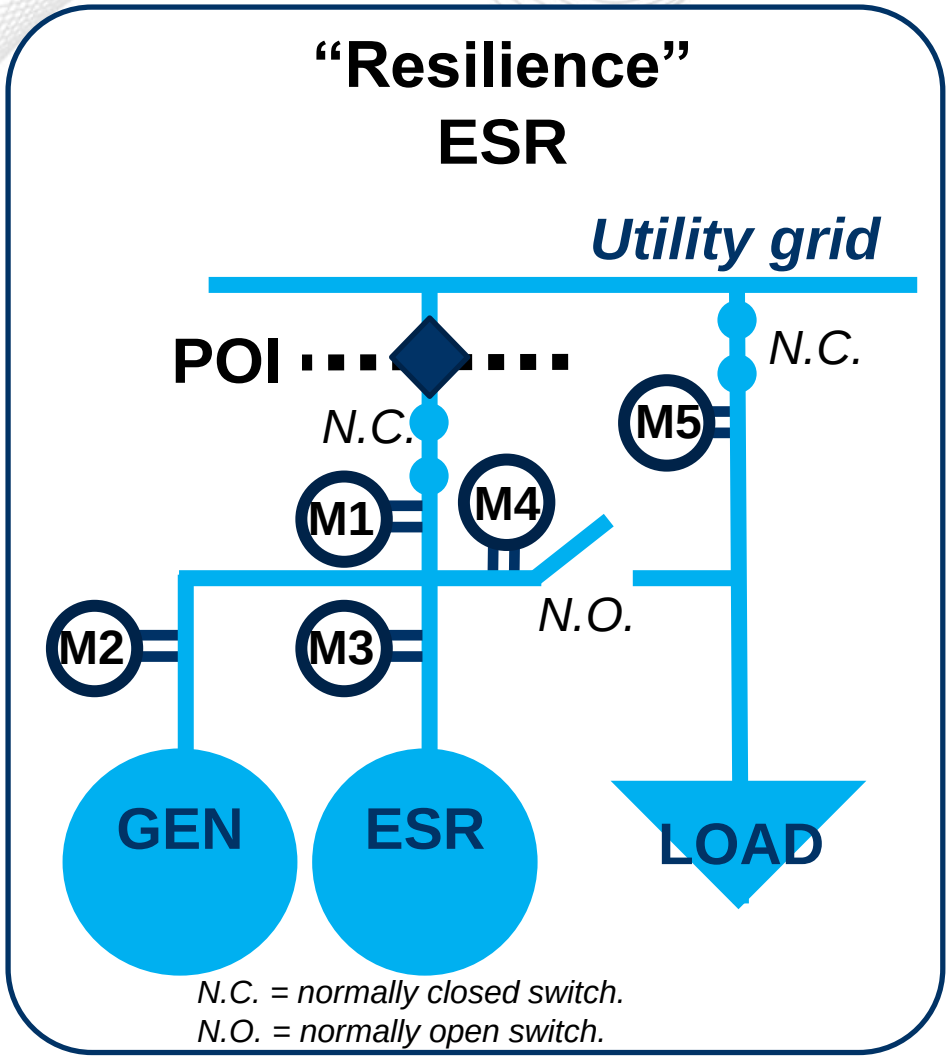
90% of Charging

10%

LSE

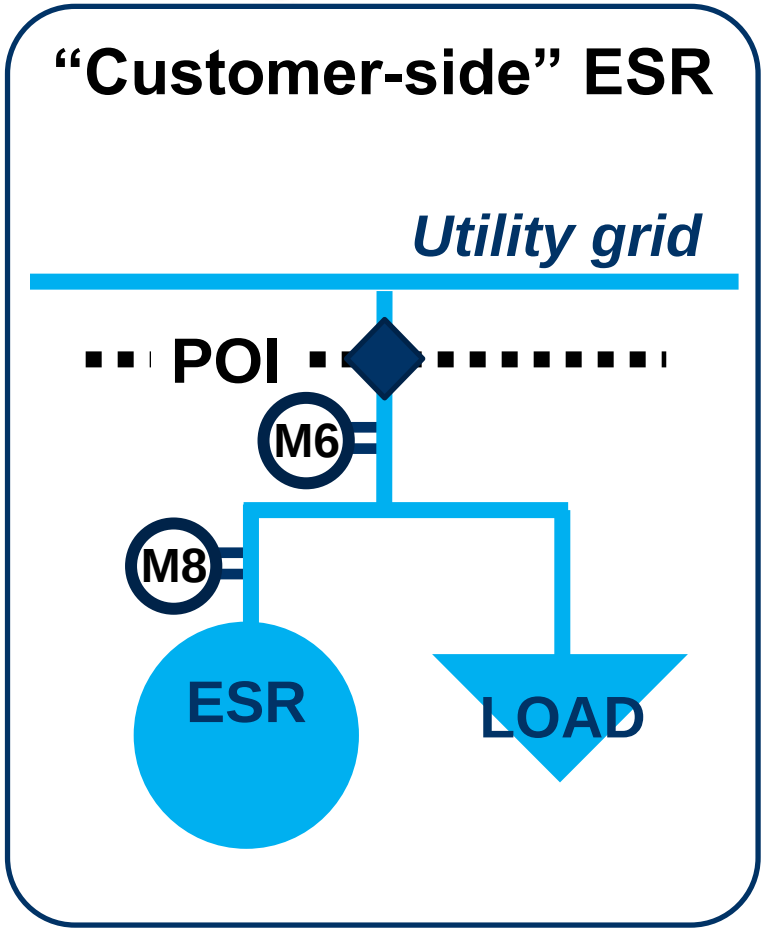
Resilience ESR + On-site Generation

- 100% of withdrawals initially settled as negative generation (i.e., Direct Charging Energy)
- ESR can charge from grid or on-site gen.
- EDC to determine how much of the ESR inventory that was discharged to the end user consisted of energy charges from the grid → "Load Serving Charging Energy"
- **An appropriate billing convention: if monthly M2 > monthly M4, then all end-use energy came from stored or directly-provided on-site gen, and no Load Serving Charging Energy was consumed.**



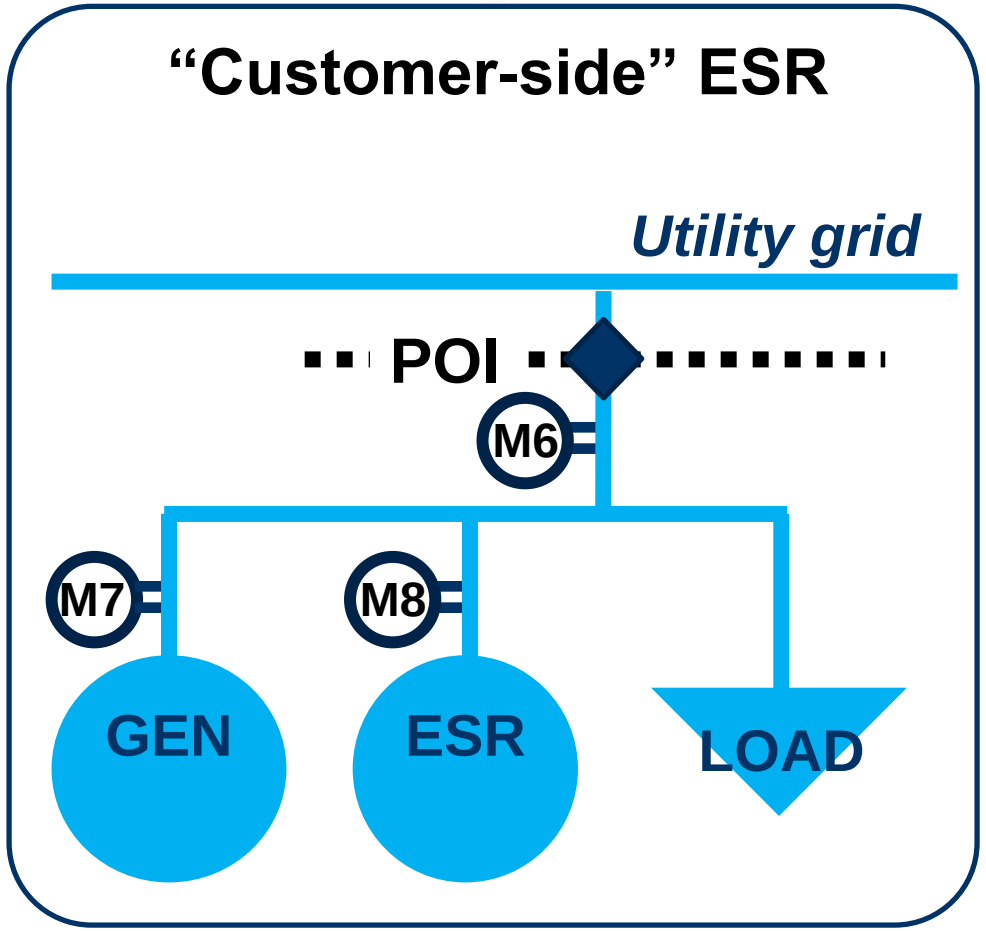
Customer-side ESR Alone

- 100% of withdrawals initially settled as load (i.e., load and/or Load Serving Charging Energy)
- Net injections measured at M6 consist of previously-stored Direct Charging Energy.
  - Corresponding losses are also Direct Charging Energy. ESR can report losses to EDC through PJM, or EDC can work directly with ESR to quantify losses.
  - **Monthly Direct Charging Energy is the sum of monthly injections at meter "M6" plus associated losses.**
  - EDC calculates monthly quantity for ex-post adjustment from Load Serving Charging Energy into Direct Charging Energy.
- M8 is required to identify which intervals the ESR was charging to use in ex-post adjustment.



Customer-side ESR + On-site Generation

- Net injections measured at M6 could consist of Direct Charging Energy, self-supplied charging energy, and/or on-site Generation.
  - The inventory in the ESR could also consist of a mix of grid energy and self supplied energy.
  - Losses corresponding to stored grid energy that is resold to PJM is also Direct Charging Energy.
- **EDC calculates monthly Direct Charging Energy for ex-post adjustment.**
- M8 is required to identify which intervals the ESR was charging for ex-post adjustment.



Questions?