Proposal to Clarify Market Participation by Solar-Battery Hybrids and Other Mixed Technology Facilities

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Outline

1. Hybrids proposal timeline
2. Purpose and highlights of proposed solutions
3. Summary of governing document changes
4. Appendix: complete details of proposed solutions

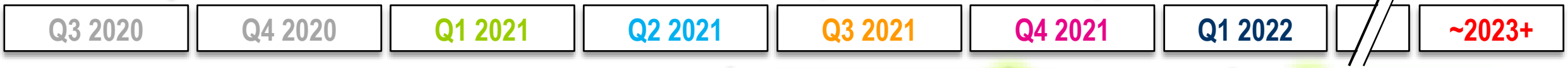
Hybrids Proposal Timeline

July 2020
- Issue Charge initiated for work at the DER and Inverter-based Resources Subcommittee (DIRS)

July and August 2021
- MIC first read and approval of PJM hybrid proposal.
- Informational presentations to OC on PJM hybrids proposal.

Q4 2021
- File hybrid proposal with FERC under Section 205 of the Federal Power Act

~2023+
- Anticipated go-live date for hybrids energy market model.



June 2021
- DIRS completes work on hybrid proposals.

Q4 2021
- Oct. MRC and Nov. MC vote to endorse solution package and governing document language

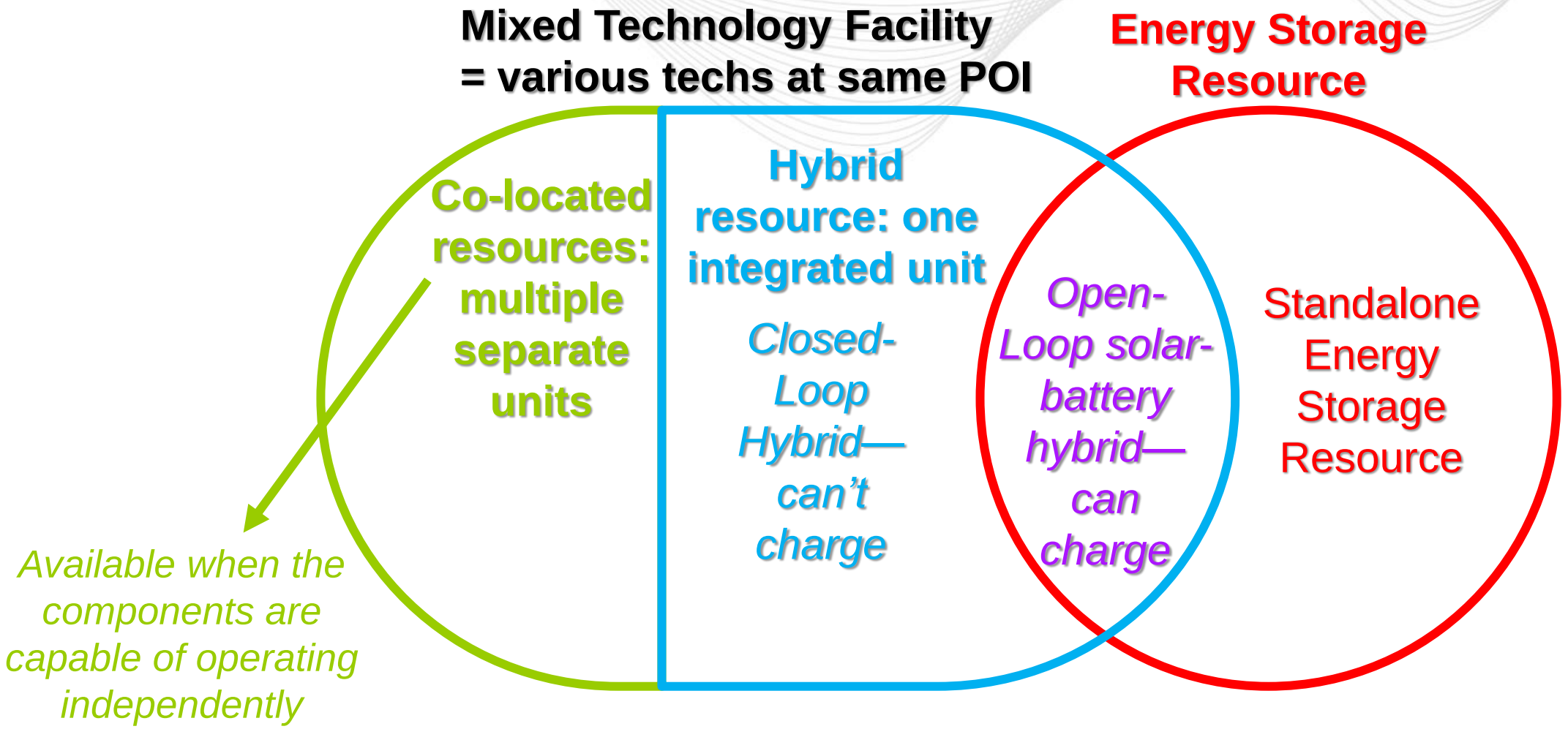
Q1 2022
- Potential FERC decision on filed proposal.

Q1+ 2022
- Develop and endorse conforming manual language

Purpose of Hybrids Proposal

1. Tens of gigawatts of solar-battery mixed technology facilities in the PJM Queue.
2. Potential for such resources to offer into 2023/24 BRA under ELCC.
3. Need to clarify energy and ancillary services market participation including metering and telemetry and basic operational requirements.
4. Intent is to clarify participation under the status quo.

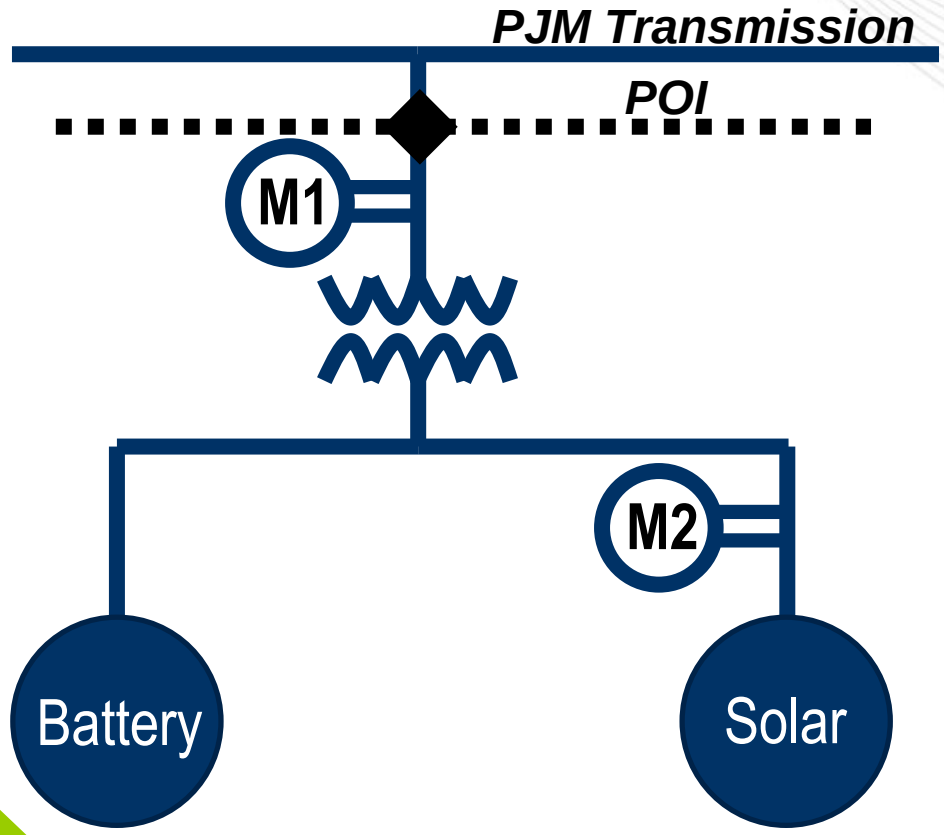
New Definitions and Categories



Proposed Tariff Text of New Definitions

- **"Mixed Technology Facility"** shall mean a facility composed of distinct generation and/or electric storage technology types behind the same Point of Interconnection.
- **"Co-Located Resource"** shall mean a component of a Mixed Technology Facility that operates in the capacity, energy, and/or ancillary services market(s) as a separate resource from the other components of such facility.
- **"Hybrid Resource"** shall mean a resource composed of one generation component and one energy storage resource component behind the same point of interconnection operating in the capacity, energy, and/or ancillary services market(s) as a single integrated resource.
- **"Open-Loop Hybrid Resource"** shall mean a Hybrid Resource that is physically and contractually capable of charging its storage component from the grid. An Open-Loop Hybrid Resource consisting of a solar component and a storage component is an Energy Storage Resource.
- "**Closed-Loop Hybrid Resource**" shall mean a Hybrid Resource that is physically or contractually incapable of charging from the grid.
- "**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. An Open-Loop Hybrid Resource consisting of a solar component and a storage component is an Energy Storage Resource.
- **"Standalone Energy Storage Resource"** shall mean an Energy Storage Resource that is not a Hybrid Resource.
- *OATT Attachment K Appendix Section 1.4E*: "A Mixed Technology Facility with components that are physically incapable of operating independently are modeled and participate in capacity and energy markets as a single Hybrid Resource."

Co-Located Resources and MWh Metering



- Each Co-Located Resource at a facility has separate metering, offers, schedules, dispatch, settlement, etc.
- Each resource follows the respective rules of the corresponding standalone resource: e.g., rules for solar, rules for storage, etc.
- Metering at POI required.
- PJM requires direct metering of at least one component (with correction for losses to the POI).
- Metering scheme requires consultation with applicable Fully-Metered EDC via Queue process.

Co-Located Resources

Solar-Battery Hybrid Resources: Energy Market Model

- New “family” of models for resource with batteries, to include three types:
  1. Existing standalone Energy Storage Resource (ESR) Participation Model
  2. Open-Loop Solar-Battery Hybrid Resource Model (can charge from grid, type of ESR)
  3. Closed-Loop Solar-Battery Hybrid Resource Model (cannot charge from grid, not a type of ESR)
- Participation models for solar-battery hybrids will be similar to existing ESR Participation Model, except: add “solar-only mode”, delete non-energy Regulation & reserves modes, closed-loop model lacks negative MW functions.
- **Hybrid Resources submit a single offer, receive a single dispatch point, have a single measurement point and single settlement value.**
  - Cost Offers up to $0 are acceptable; other methods follow rules in Manual 15.
  - Energy Market Must Offer rules for hybrids match those currently used for ESR and solar.

Hybrids

Summary of Governing Document Changes

- Definitions in Tariff and Operating Agreement (OA)
- Matching Tariff Attachment K Appendix and OA Schedule 1 sections:
  - Section 1.10
  - Sections 1.4A – 1.4E
  - Section 3.2
- Tariff Attachment DD Section 6.6A

(Note: only redlined Tariff language has been posted, not matching OA language.)

Appendix: Complete Solution Details

Proposed Classification Process for Mixed Technology Facilities

Some Mixed Technology Facilities can be classified either as a Hybrid Resource or as multiple Co-located Resources. In such cases:

- Energy Market modeling must match Capacity Market modeling for the same Delivery Year.
- The Effective Load Carrying Capability proposal holds that resources that can choose co-located vs. hybrid modeling must retain the choice for 5 years.
- Energy-only Mixed Technology Facilities that have a choice of hybrid vs. co-located modeling can change classifications once per year with notice to PJM by no later than May 30 for the upcoming January 1 to December 31 participation months. Once a status is chosen, it remains until an another request is received. For an Energy-only Mixed Technology Facility within the new resource queue process, the modeling choice must be made to no later than 6 months in advance of their initial start in the energy markets.

Co-Located Resources

Co-Located Resources: Telemetry

- MW telemetry required for each component. One of the components is calculated as POI minus the other components.
- MVAR from each component.
- Battery state of charge in MWh.
- Solar met data:
  - Irradiance (required)
  - Back panel temperature (required)
  - Ambient air temperature, wind speed, and wind direction are optional.

Co-Located Resources

Solar-Battery Hybrid Resources

Hybrids

“Solar-Only Mode” for Solar-Battery Hybrids

- Due to variability in solar resource availability, PJM would expect different behavior from dispatchable batteries relative to dispatchable solar.
- PJM therefore proposes that operators of solar-battery hybrids must indicate to PJM which of two modes the resource is operating in at any given time:
  - “Hybrid mode”, a dispatchable mode in which the battery is providing power to keep total hybrid plant output consistent with dispatch.
  - “Solar-only mode”, a dispatchable mode in which the battery is ***not*** providing power to keep total hybrid plant output consistent with dispatch, but the plant is nonetheless dispatchable downward relative to solar availability.
- Deviations penalties and uplift eligibility are the same in hybrid mode and solar-only mode.

Hybrids

Solar-Battery Hybrid Resources: Regulation

- **Hybrid Resources submit a single energy market and regulation market offer, receive a single dispatch point, have a single settlement value.**
  - The dispatch basepoint is a function of offer prices and Economic Minimum and Economic Maximum values.
  - Offer prices potentially eligible to be updated hourly (65 minutes before the hour).
  - Economic limits can be updated in real time.
- Regulation is scheduled and dispatched the same as it is today for Energy Storage Resource Model Participants:
  - Co-optimization option
  - Self-schedule option
  - *Remove the "Non-Energy" Regulation and reserves option*

Hybrids

Solar-Battery Hybrid Resources: Reserves

Reserves scheduling and dispatch for hybrids will match the approach under the "reserves price formation filing" for Energy Storage Resources:

- Recall the reserves price formation filing include Day-Ahead and Real-Time equivalents of 10 minute and 30 minute online reserves and 10 minute offline reserves.
- The proposed energy market models, like the ESR model, are not capable of committing offline resources and cannot assign offline reserves.
- *Remove the "Non-Energy" Regulation and reserves option.*

- Hybrid Resources by default **may offer** all such reserves they are capable of providing, and (like storage) are responsible for determining the quantity of such reserves that they are physically capable of reliably providing.
- Hybrid Resources **must offer** such reserves consistent with the rules for all resources.

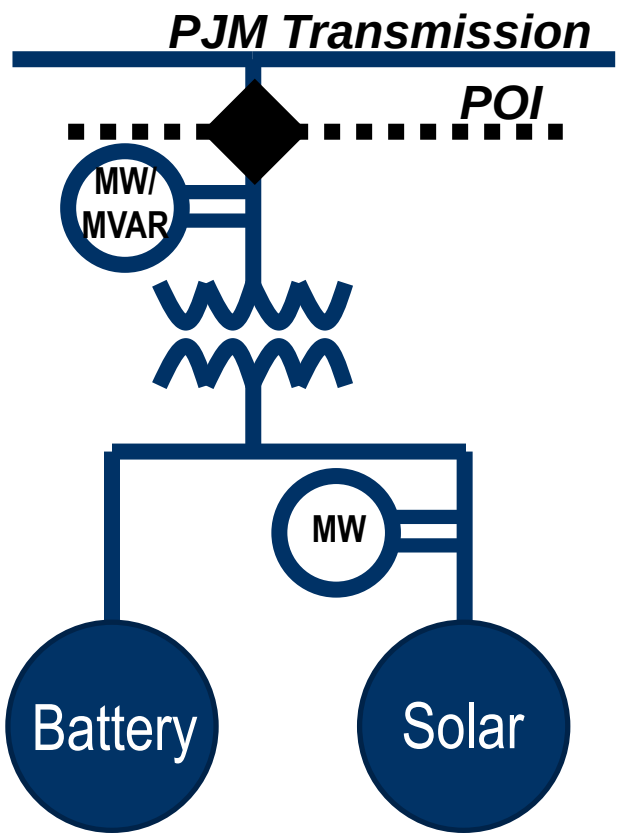
Hybrids

Solar-Battery Hybrid Resources: Capacity Market

- Effective Load Carrying Capability (ELCC) to set the UCAP value that hybrids may offer starting with Delivery Year 2023/24.
- FERC approved the PJM ELCC proposal, therefore Mixed Technology Facilities may now make Queue requests for CIRs up to the lesser of the Maximum Facility Output or the sum of the solar CIR eligibility plus the "X-hour rule" storage CIR eligibility, regardless of closed-loop or open loop.
  - *The X-hour rule for a battery in the 4-hour class would be the power level the unit can run at for 4 continuous hours.*
- Hybrid Resources are proposed to be exempt from the Capacity Market Must Offer rule if all of the components are so exempt.

Hybrids

Solar-Battery Hybrid Resources: PJM Telemetry Requirements



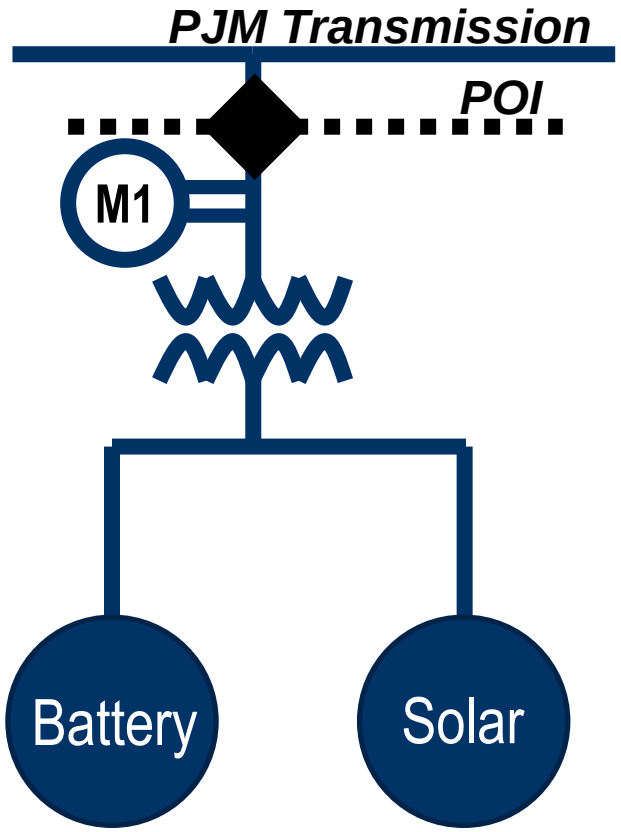
Real-time telemetered values required for:

- MW and MVAR at the POI
  - Accuracy must meet existing requirements in Manual 01 Section 5.2.3
- MW output of each component, where one component is directly measured and compensated for losses to the POI, and the other is calculated vs. POI.
  - Accuracy must meet existing requirements in Manual 01 Section 5.2.6
- Battery state of charge, in MWh
- Solar met data:
  - Irradiance (required)
  - Back panel temperature (required)
  - Ambient air temperature, wind speed, and wind direction are optional

Hybrids

Solar-Battery Hybrid Resources: MWh Settlements Metering

- Metering at POI required.



Hybrids

Solar-Battery Hybrid Resources: Operational Requirements

- A solar-battery hybrid's Economic Minimum shall not exceed the level of its CIR
- A solar-battery hybrid's Emergency Minimum should be set to 0
- The output of a solar-battery hybrid should achieve its dispatch point within 5 minutes or consistent with the resource's ramp rate bid.
- PJM should be notified if the response time is expected to exceed 5 minutes.
- The operator of a solar-battery hybrid that is dispatchable must indicate to PJM the hours for which the plant is operating in “solar-only” mode, during which time the battery is *not* providing power for the purpose of maintaining hybrid output consistent with PJM dispatch.
- Dispatchable solar-battery hybrids must follow dispatch in both "solar-only" mode and "hybrid mode".

Hybrids

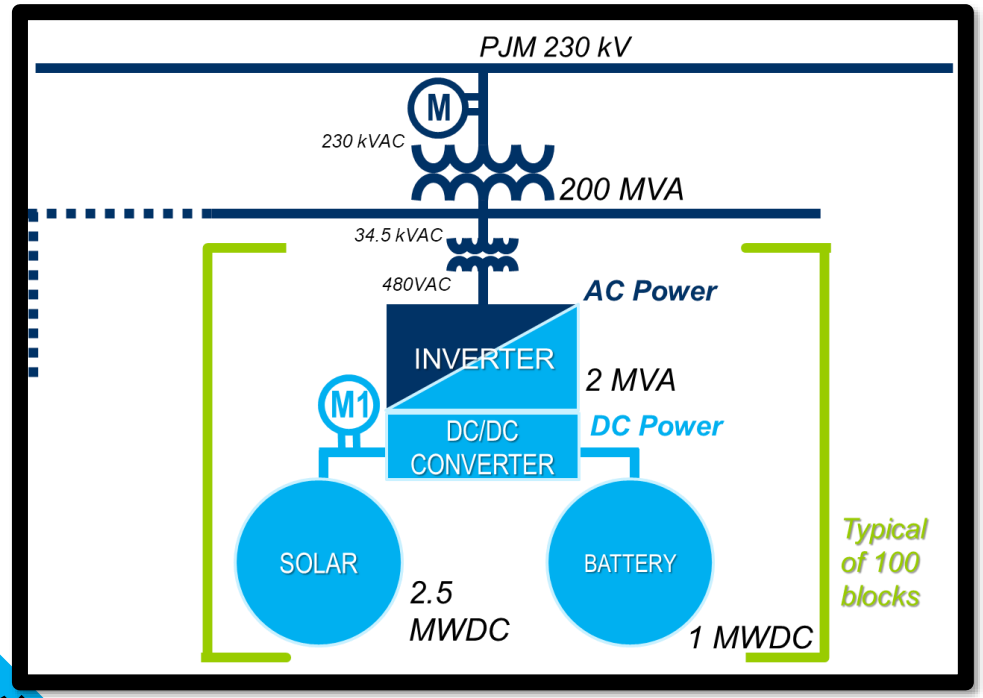
Solar-Battery Hybrid Resources: Outage Reporting

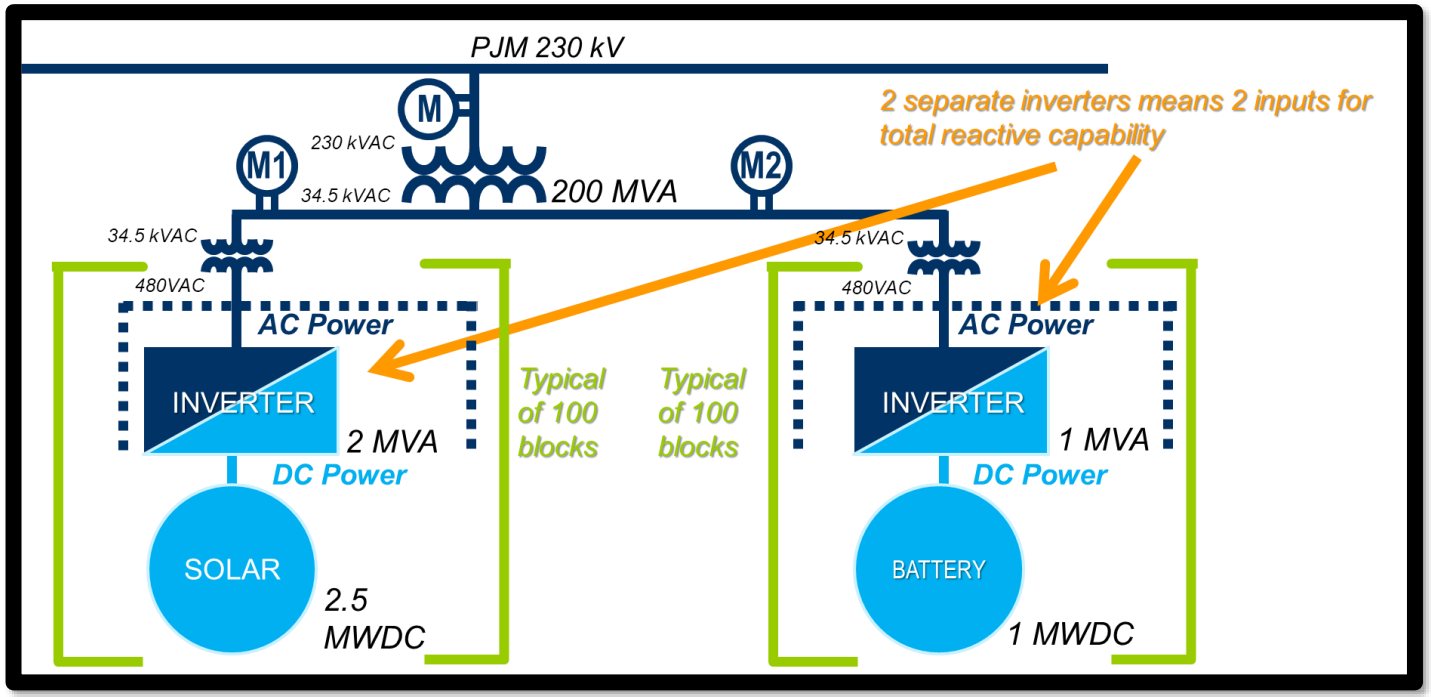
- For solar-battery hybrid Generating Facilities, eDART and GADS outages shall be reported separately for the solar component and storage component whenever unavailable or derated. No eDART ticket is required for lack of solar irradiance, charging, nor lack of charge.

Hybrids

Solar-Battery Hybrid Resources: Reactive Testing

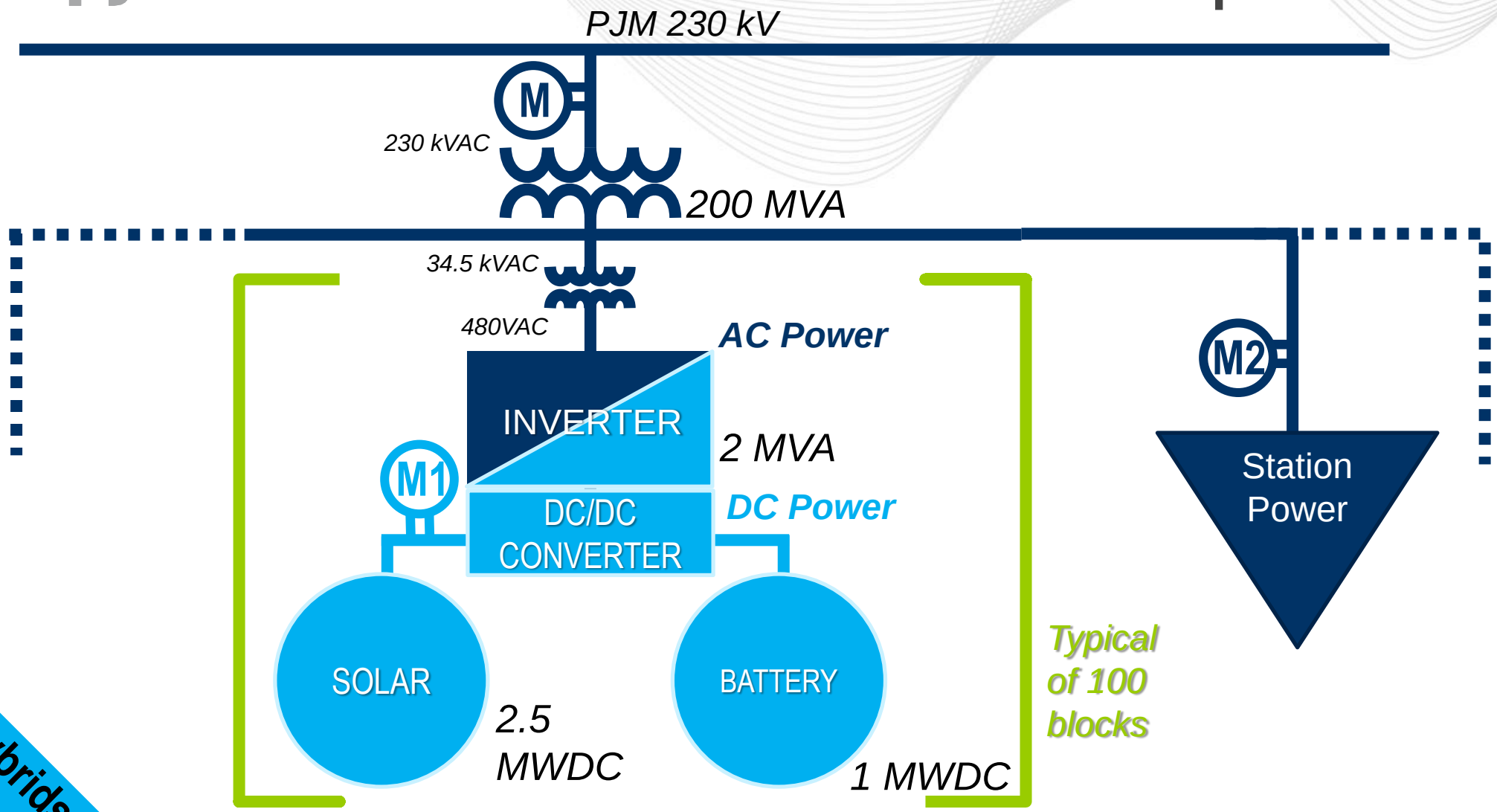
Hybrid Resources do reactive testing as a single resource.
Expectations depend on AC-coupled vs DC-coupled.





Hybrids

Ex: Solar-Storage *Shared Inverter (DC-coupled)* Hybrid, **Open or Closed Loop**

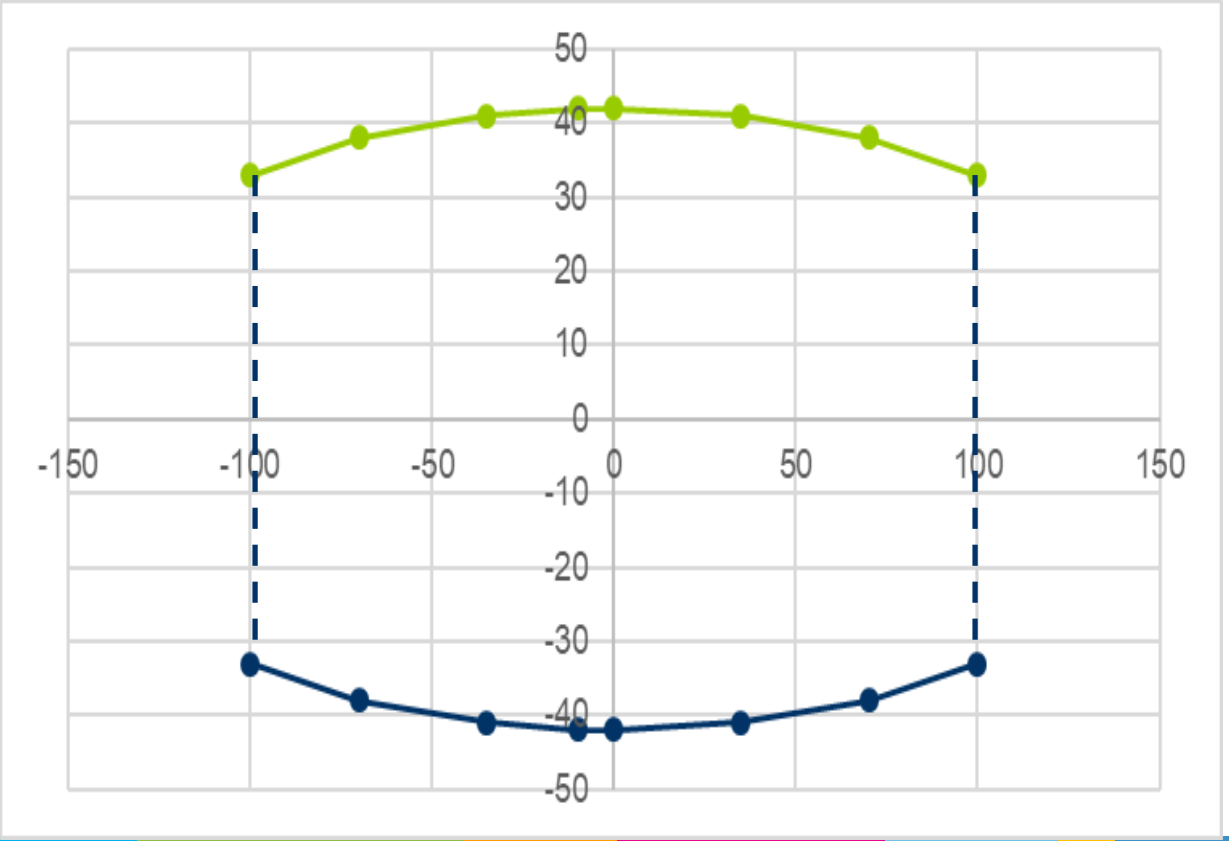


Hybrids

DC-Coupled (Shared Inverter) Hybrid Capability Curve

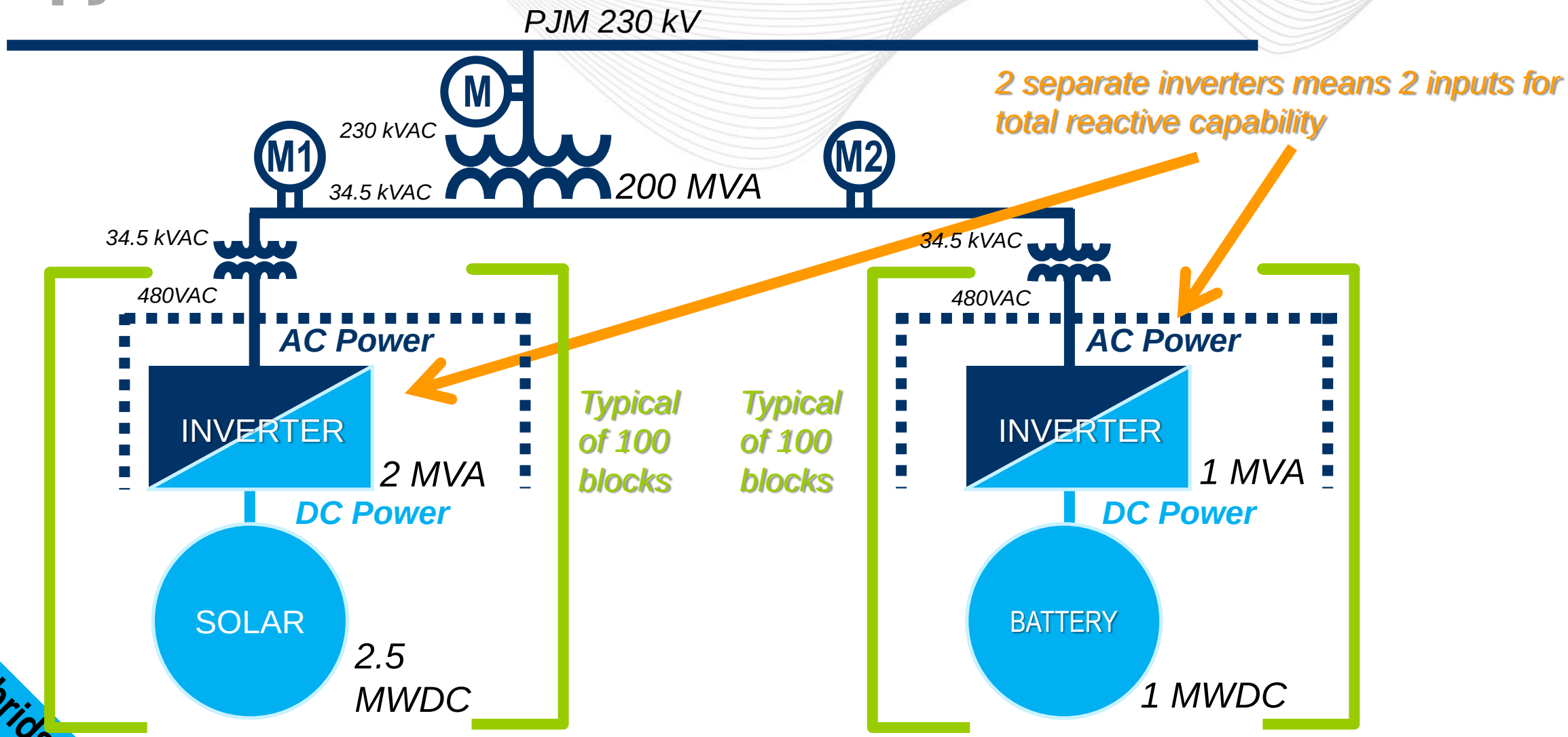
	MW	Min MVAR	Max MVAR
Point 1	-100	-33	33
Point 2	-70	-38	38
Point 3	-35	-41	41
Point 4	-10	-42	42
Point 5	0	-42	42
Point 6	35	-41	41
Point 7	70	-38	38
Point 8	100	-33	33

Example of inverter-based DC-coupled solar-storage hybrid



Hybrids

Ex.: Solar-Storage *Separate Inverters (AC-coupled)* Hybrid

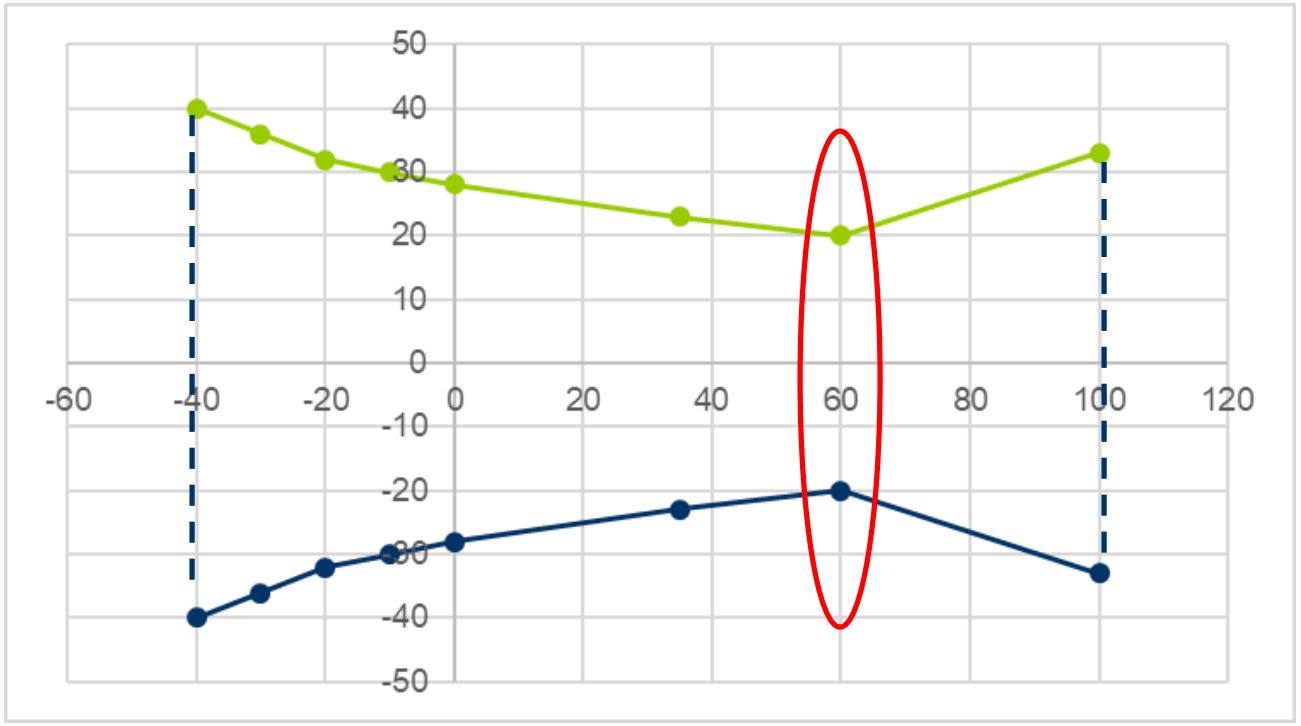


Hybrids

AC-Coupled Hybrid Conservative Reactive Capability

	MW	Min MVAR	Max MVAR	Example of output at battery terminals	Example of output at solar terminals
Point 1	-40	-40	40	-40	0
Point 2	-30	-36	36	-40	10
Point 3	-20	-32	32	-40	20
Point 4	-10	-30	30	-40	30
Point 5	0	-28	28	-40	40
Point 6	35	-23	23	-40	75
Point 7	60	-20	20	-40	100
Point 8	100	-33	33	0	100

Example of inverter-based AC-coupled solar-storage hybrid with 100 MW solar and 40 MW battery operated as a single combined unit



Hybrids

Proposed Testing Summary

Unit Type	MW Output	MVAR Output	Test Duration
DC-COUPLED SOLAR-BATTERY HYBRIDS *Max MW Output = fully discharging* *Min MW Output = fully charging*	MAX	MAX LAG	WHEN LIMIT REACHED
	MAX	MAX LEAD	WHEN LIMIT REACHED
	ZERO	MAX LAG	WHEN LIMIT REACHED
	ZERO	MAX LEAD	WHEN LIMIT REACHED
	MIN	MAX LAG	WHEN LIMIT REACHED
	MIN	MAX LEAD	WHEN LIMIT REACHED
AC-COUPLED SOLAR-BATTERY HYBRIDS *Max MW Output = fully discharging* *Min MW Output = fully charging* *Max inverter operating point = solar at full output and battery at full charging*	MAX	MAX LAG	WHEN LIMIT REACHED
	MAX	MAX LEAD	WHEN LIMIT REACHED
	MAX INVERTER OPERATING NET MW POINT	MAX LAG	WHEN LIMIT REACHED
	MAX INVERTER OPERATING NET MW POINT	MAX LEAD	WHEN LIMIT REACHED
	ZERO	MAX LAG	WHEN LIMIT REACHED
	ZERO	MAX LEAD	WHEN LIMIT REACHED
	MIN	MAX LAG	WHEN LIMIT REACHED
***Additional test points may be required if these do not capture the most restrictive capability scenarios.**	MIN	MAX LEAD	WHEN LIMIT REACHED

Hybrids

Contact

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PJM Proposal to Clarify Market Participation by Solar-Battery Hybrids and Other Mixed Technology Facilities

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