Proposal to Clarify Market Participation by Solar Battery Hybrids and Other Mixed Technology Facilities
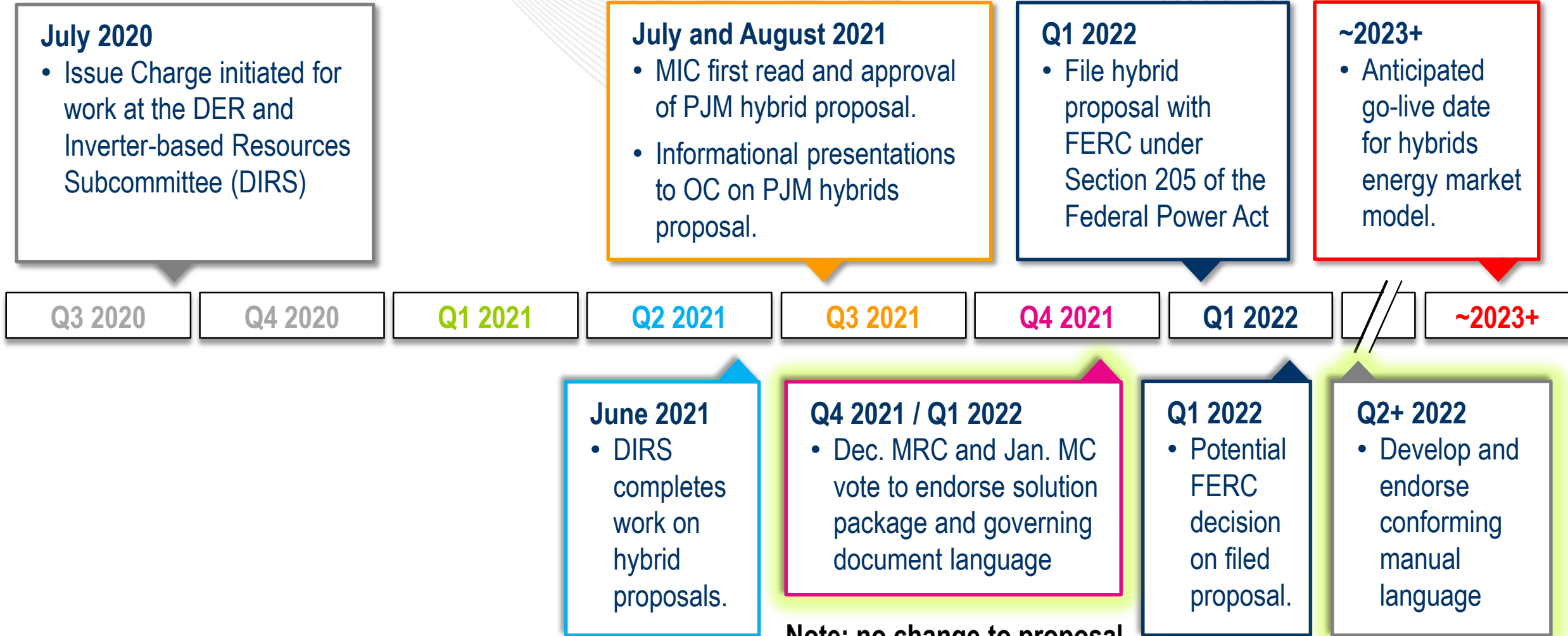
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PJM Members Committee Information Webinar

December 13, 2021

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.

Q1 2022
- File hybrid proposal with FERC under Section 205 of the Federal Power Act

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

Q3 2020	Q4 2020	Q1 2021	Q2 2021	Q3 2021	Q4 2021	Q1 2022		~2023+

June 2021
- DIRS completes work on hybrid proposals.

Q4 2021 / Q1 2022
- Dec. MRC and Jan. MC vote to endorse solution package and governing document language

Q1 2022
- Potential FERC decision on filed proposal.

Q2+ 2022
- Develop and endorse conforming manual language

Note: no change to proposal since Nov. MRC 2d first read.

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.

Existing definitions

Storage-type resources

Mixed Technology Facilities = various techs at same site

Co-Located Resource

Each component a separate resource using applicable standalone model

Only available when components can operate independently

Hybrid Resource

Gen+storage offering as 1 Integrated Unit

Closed-Loop Hybrid Resource Model
Available to solar hybrids that cannot charge from grid

Open-Loop Hybrid Resource Model
Available to solar hybrids that can charge from grid

Energy Storage Resources

Standalone storage

Energy Storage Resource Participation Model

- "**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 Resources and Hybrid Resources form all or part of Mixed Technology Facilities.

- "**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 an Energy Resource or a Generation Capacity 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. A Hybrid Resource forms all or part of a Mixed Technology Facility

- "**Closed-Loop Hybrid Resource**" shall mean a Hybrid Resource that is physically or contractually incapable of charging from the grid.

- "**Open-Loop Hybrid Resource**" shall mean a Hybrid Resource that is physically and contractually capable of charging its storage component from the grid. Open-Loop Hybrid Resources consisting of a solar component and a storage component shall be subject to the provisions that apply to Energy Storage Resources in the following sections: Tariff Part I, Tariff Attachment K-Appendix, Sections 1.4A, 1.7.2, 1.7.2B, 1.10, 3.2, and 7.4 (and the parallel provisions in Operating Agreement, Schedule 1), and Tariff, Attachment F-2.

GOVERNING DOCUMENT CHANGES

- Structure the term "Hybrid Resource" as a largely resource-neutral category in its own right (not related to the term "Energy Storage Resource").

  - Recognizing that, for now, certain provisions specific to solar-storage hybrids will be pursued before other hybrid types in step-wise fashion due to overwhelming presence of solar hybrids in PJM Queue.

- Definitions in Tariff and Operating Agreement (OA)

- Matching Tariff Attachment K Appendix and OA Schedule 1 sections:

  – Sections 1.4B – 1.4C

  – Section 1.7

  – Section 1.10

  – Section 3.2

  – Section 7.4

- Tariff Attachment DD Section 6.6A

- Tariff Attachment F-2 NITSA for Non-Dispatched Charging Energy

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

1. Definitions of parameters for Energy Storage Resource Participation Model broadened to apply also to solar-storage Open-Loop Hybrid Resources

   a) *Charge Economic Minimum* and *Maximum Megawatts* and *Discharge Economic Minimum* and *Maximum Megawatts*

   b) *Charge Ramp Rate* and *Discharge Ramp Rate*

   c) *Charge Mode, Discharge Mode,* and *Continuous Mode*

2. *Direct Charging Energy*, *Dispatched Charging Energy*, *Non-Dispatched Charging Energy*, and *Load Serving Charging Energy* broadened to include Open-Loop Hybrid Resources.

3. *State of Charge Management* broadened to include all Hybrid Resources.

4. *Energy Storage Resource* definition excludes Open-Loop Hybrid Resources.

5. Minor clarifications to terms *Hybrid Resource* and *Mixed-Technology Facility*.

6. Remove term *Standalone Energy Storage Resource.*

OATT Att. K Appendix (and OA Schedule 1) Sec 1.10.1A "Day-ahead Energy Market Scheduling" subsection (d)

Such offers shall be based on the ICAP equivalent of the Market Seller's cleared UCAP capacity commitment, provided, however, where the underlying resource is a Capacity Storage Resource, a ~~solar-storage Hybrid Resource,~~ Hybrid Resource consisting exclusively of components that in isolation would be Intermittent Resources or Capacity Storage Resources, or an Intermittent Resource, the Market Seller shall satisfy the must offer requirement by either self-scheduling or offering the unit as a dispatchable resource, in accordance with the PJM Manuals, where the hourly day-ahead self-scheduled values for such Capacity Storage Resources, ~~solar-storage Hybrid Resources,~~ Hybrid Resources consisting exclusively of components that in isolation would be Intermittent Resources or Capacity Storage Resources, and Intermittent Resources may vary hour to hour from the capacity commitment.

The following provisions for Energy Storage Resources related to charging energy broadened to apply also to Open-Loop Hybrid Resources:

- Tariff Attachment F-2 NITSA for Non-Dispatched Charging Energy

- Tariff AttK Appendix (and OA Schedule 1) Section 1.7.2 and 1.7.2B—permission to purchase Direct Charging Energy

- Tariff AttK Appendix (and OA Schedule 1) Section 7.4—ARR eligibility rules for storage

Tariff AttK Appendix (and OA Schedule 1) Section 1.4C on Participation Mixed Technology Facilities—added clarification around separate offers and settlements for Co-Located Resources.

## AttK Appendix Sec 3.2.3B Reactive Services subsection (c)

(c) A Market Seller providing Reactive Services from a steam-electric generating unit, an Energy Storage Resource Model Participant, **a** ~~closed-loop~~ **Hybrid Resource**, or a combined cycle unit operating in combined cycle mode, where such unit is pool-scheduled (or self-scheduled, if operating according to Tariff, Attachment K-Appendix, section 1.10.3(c) hereof), and where the real time LMP at the unit's bus is higher than the price offered by the Market Seller for energy from the unit at the level of output (or the level of Energy Storage Resource Model Participant charging withdrawals) requested by the Office of the Interconnection (as indicated either by the desired MWs of output from the unit determined by PJM's unit dispatch system or as directed by the PJM dispatcher through a manual override) shall be compensated for lost opportunity cost by receiving a credit for each Real-time Settlement Interval in an amount equal to…

AttK Appendix Sec 3.2.3B Reactive Services subsection (f)

(f) A Market Seller providing Reactive Services from a steam-electric generating unit, an Energy Storage Resource Model Participant, **a** ~~closed-loop~~ **Hybrid Resource**, a combined cycle unit, or a combustion turbine unit, where such unit is pool scheduled (or self-scheduled, if operating according to Tariff, Attachment K-Appendix, section 1.10.3(c) hereof), and where the real time LMP at the unit's bus is lower than the price offered by the Market Seller for energy from the unit at the level of output requested by the Office of the Interconnection (as indicated either by the desired MWs of output from the unit determined by PJM's unit dispatch system or as directed by the PJM dispatcher through a manual override), shall receive a credit in an amount equal to…

Appendix: Additional Solution Details

PJM Transmission

POI

M1

M2

Battery
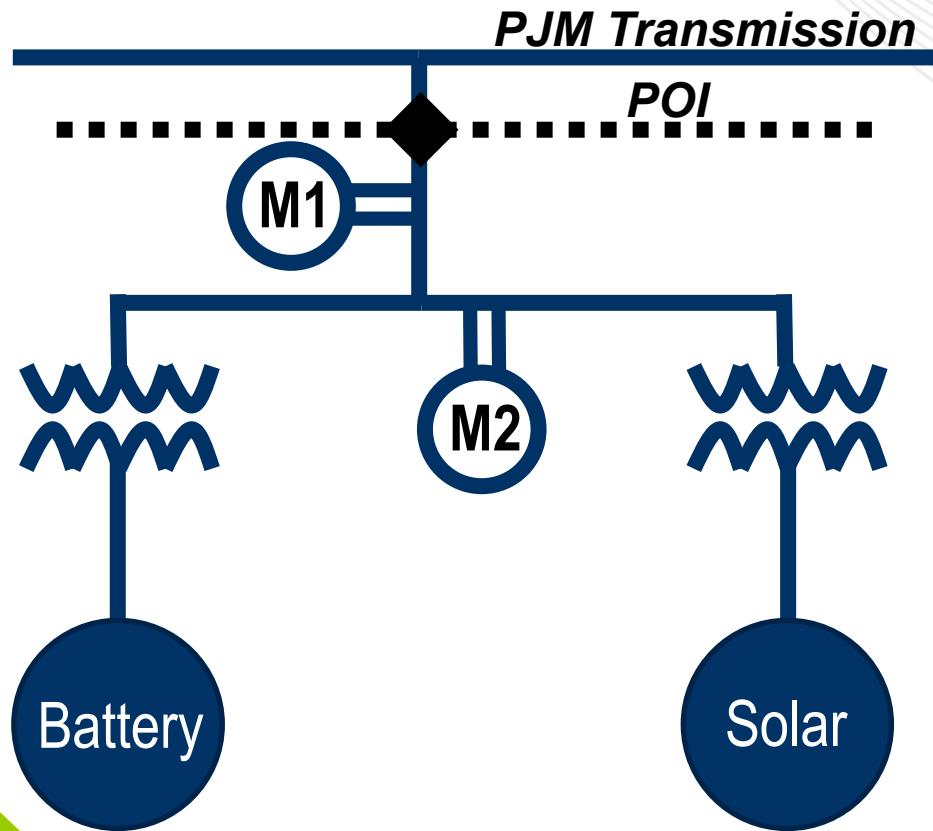
Solar

Co-Located Resources

- 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.

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, similar to ESR)
    3. Closed-Loop Solar-Battery Hybrid Resource Model (cannot charge from grid, unlike 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

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

- 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

- 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

- **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

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

- 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.

PJM Transmission

POI

MW/ MVAR

MW

Battery

Solar

Hybrids

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

- Metering at POI required.
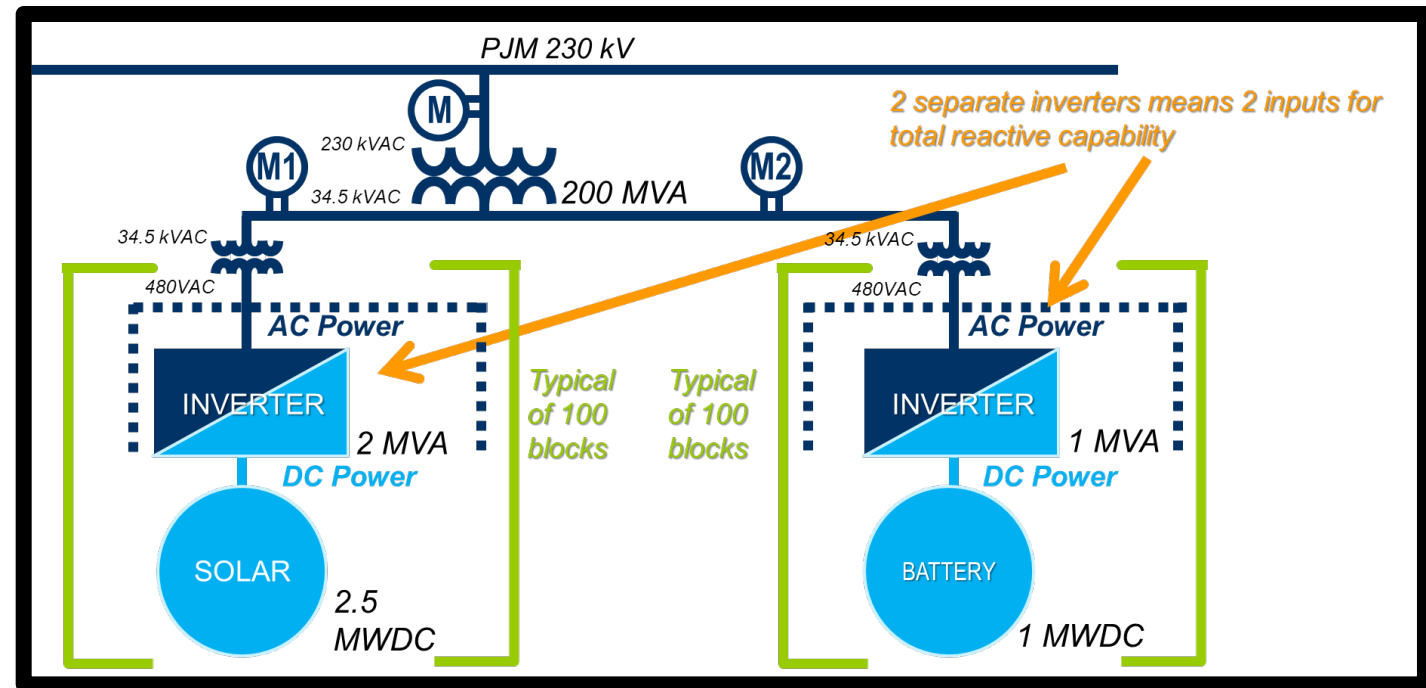

PJM Transmission
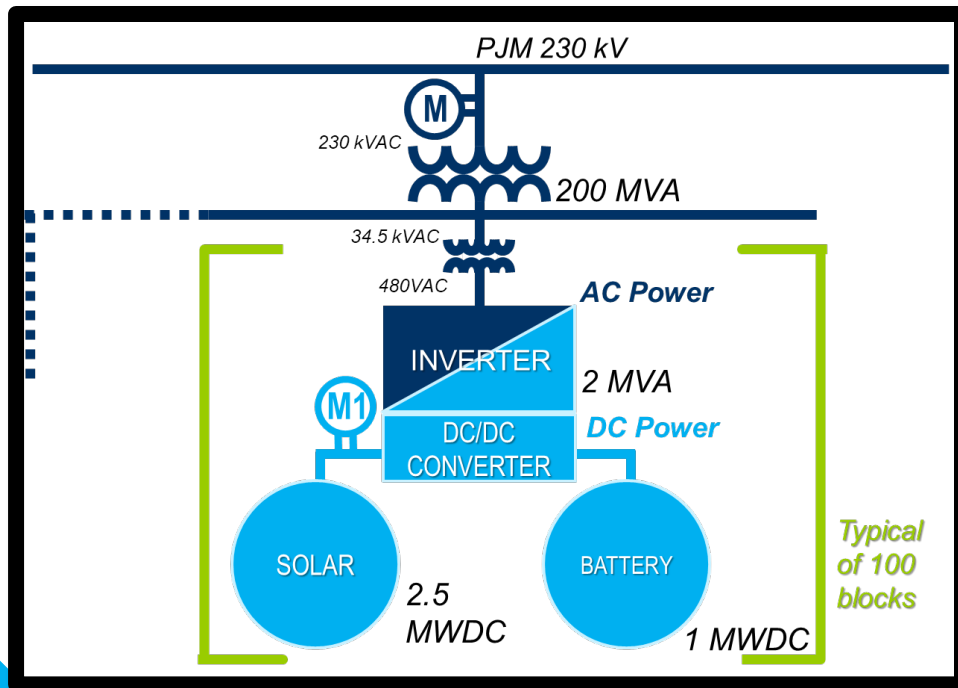
POI

M1
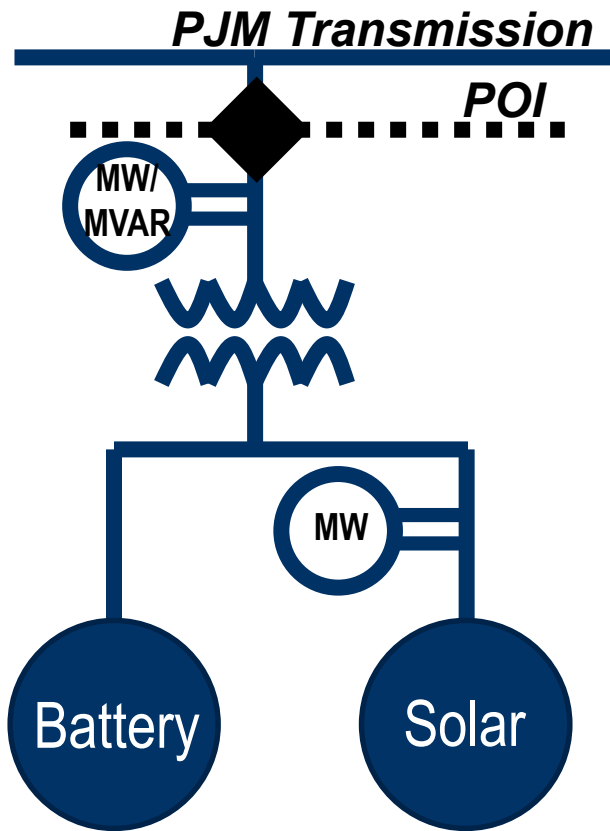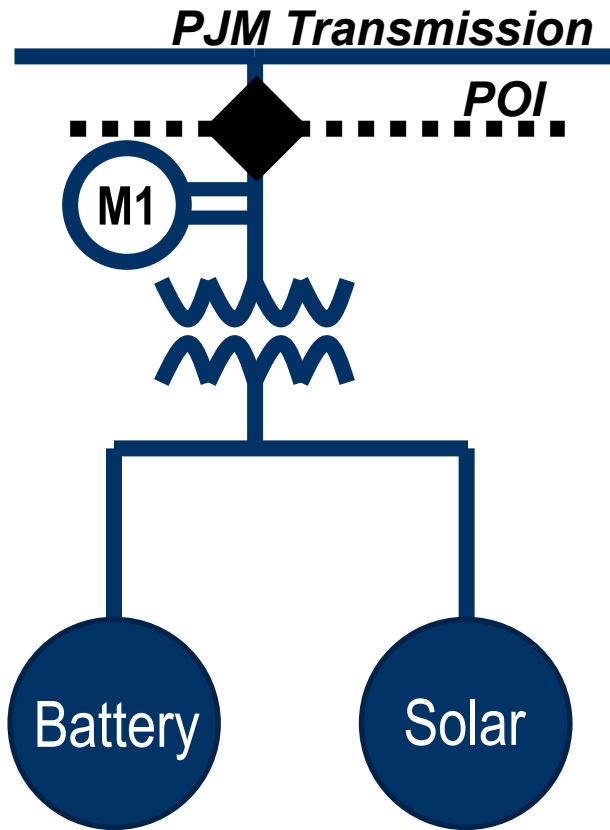
Battery

Solar

Hybrids

- 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".
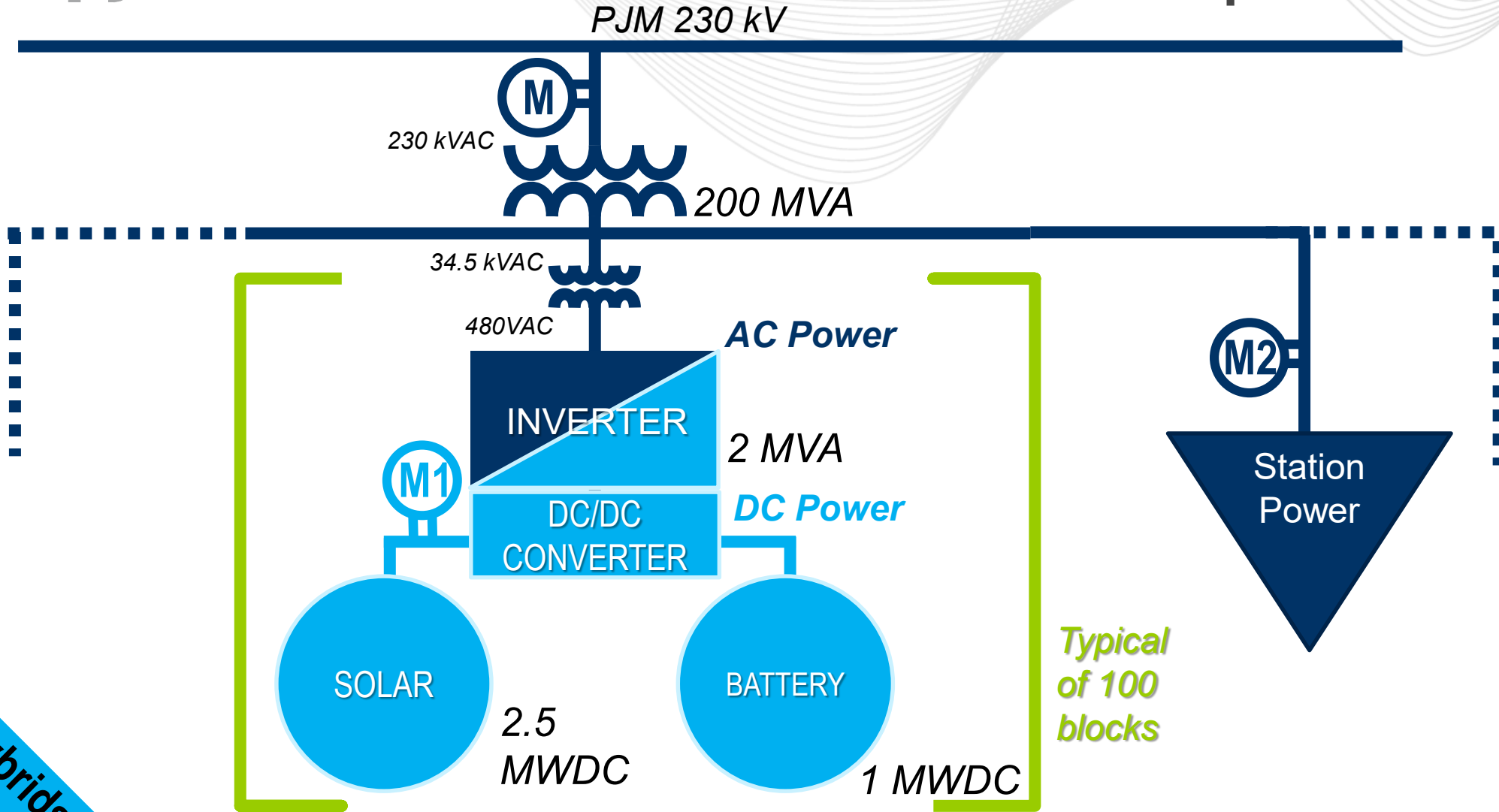
Hybrids

- 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

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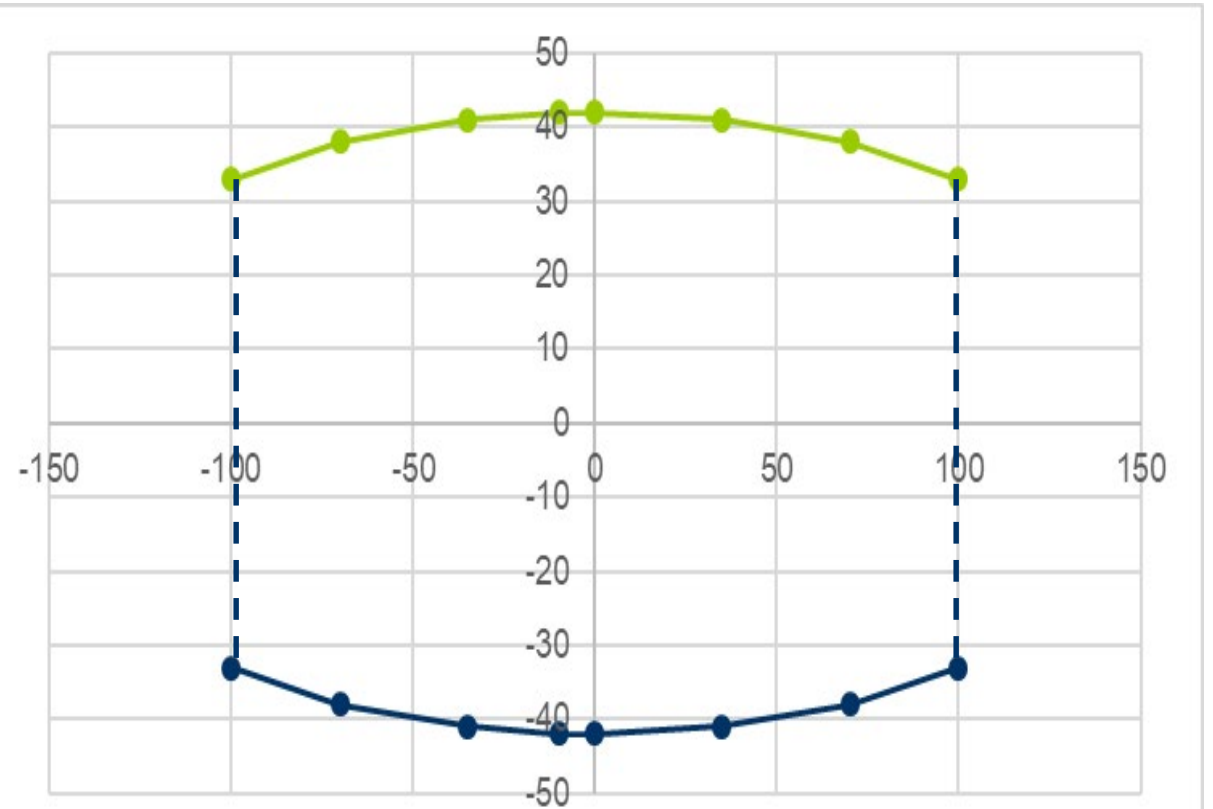

Hybrids

PJM 230 kV

230 kVAC

200 MVA

34.5 kVAC

480VAC

AC Power

INVERTER

2 MVA

DC Power

DC/DC CONVERTER

SOLAR

2.5 MWDC

BATTERY

1 MWDC

M2

Station Power

Typical of 100 blocks

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

PJM 230 kV

M

230 kVAC

M1   M2

34.5 kVAC   200 MVA

2 separate inverters means 2 inputs for total reactive capability

34.5 kVAC   34.5 kVAC

480VAC   480VAC

AC Power   *AC Power*

INVERTER   2 MVA   *Typical of 100 blocks*   *Typical of 100 blocks*   INVERTER   1 MVA

DC Power   *DC Power*

SOLAR   2.5 MWDC   BATTERY   1 MWDC
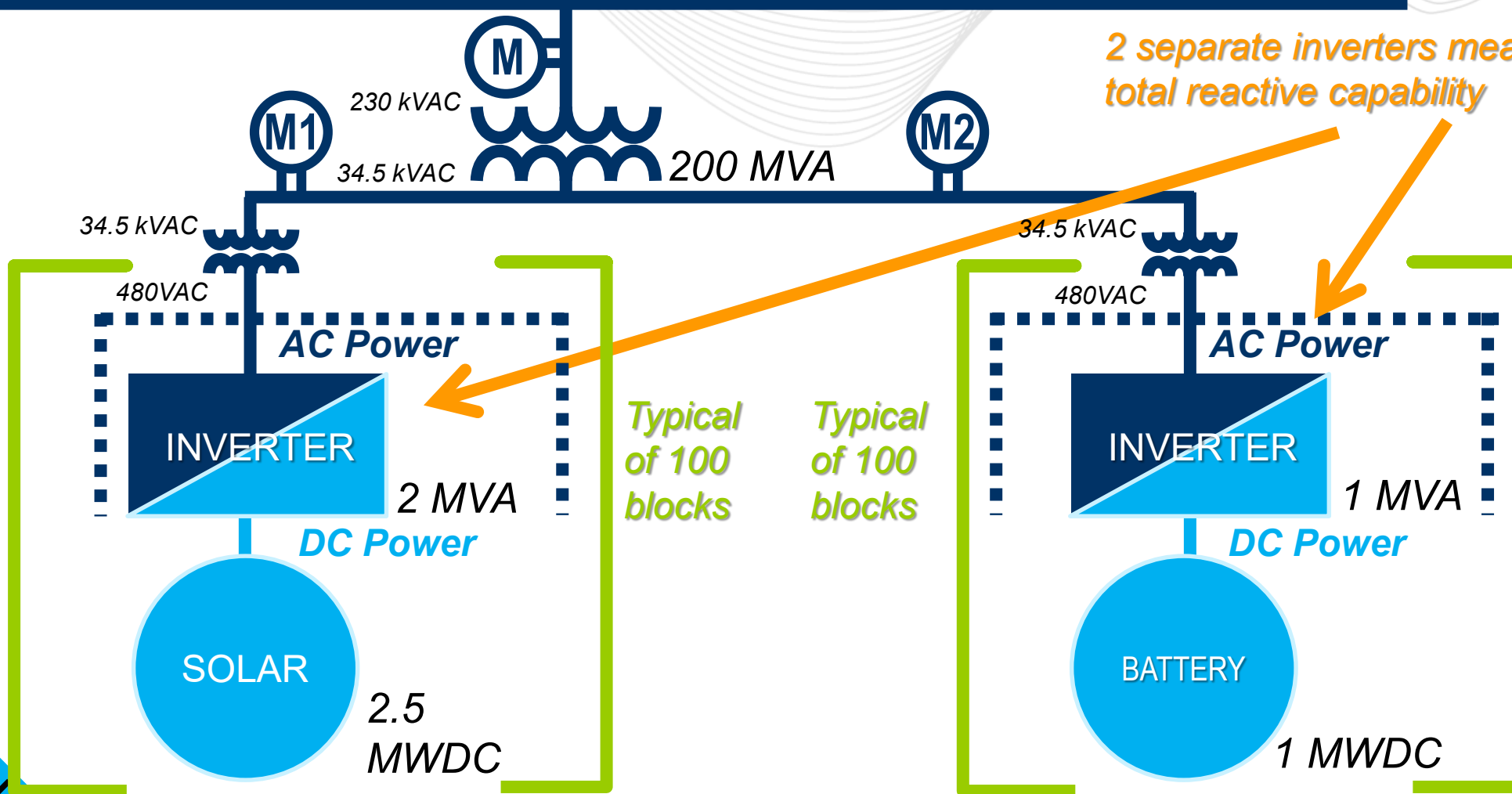
Hybrids

	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
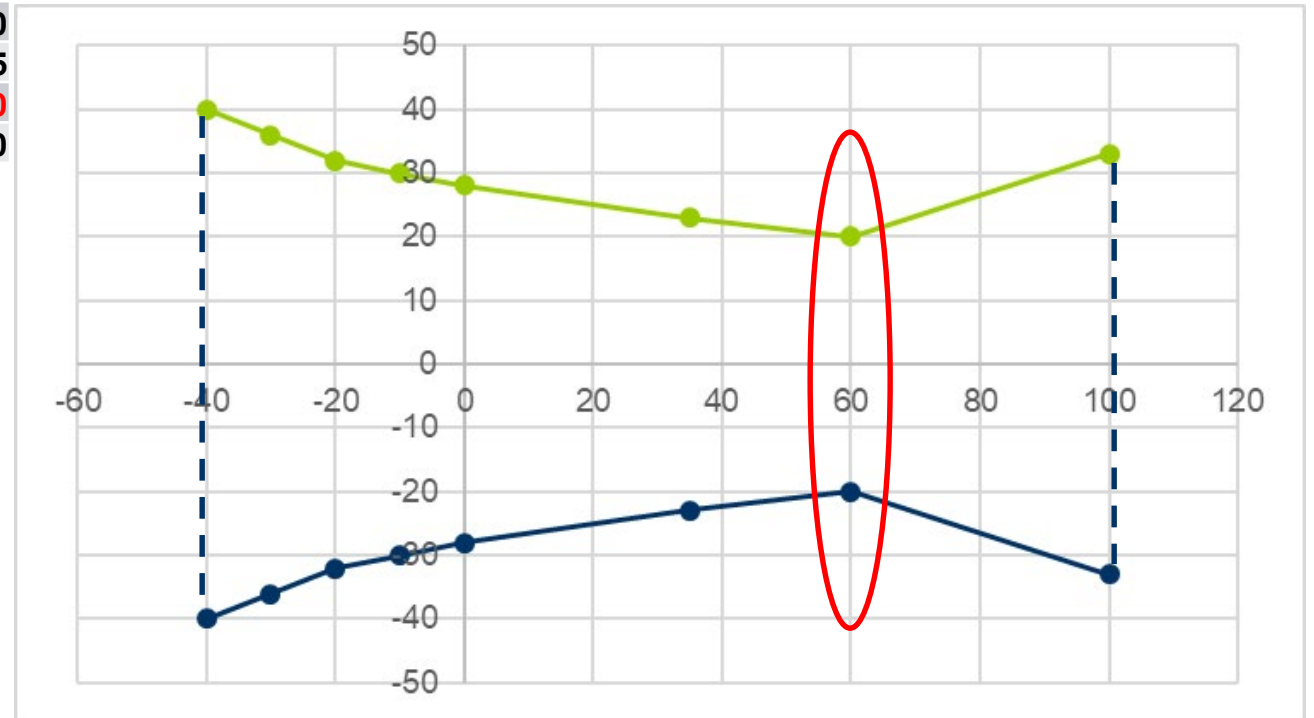
Hybrids

Unit Type	MW Output	MVAR Output	Test Duration
DC-COUPLED SOLAR-BATTERY HYBRIDS	MAX	MAX LAG	WHEN LIMIT REACHED
	MAX	MAX LEAD	WHEN LIMIT REACHED
Max MW Output = fully discharging	ZERO	MAX LAG	WHEN LIMIT REACHED
	ZERO	MAX LEAD	WHEN LIMIT REACHED
Min MW Output = fully charging	MIN	MAX LAG	WHEN LIMIT REACHED
	MIN	MAX LEAD	WHEN LIMIT REACHED
AC-COUPLED SOLAR-BATTERY HYBRIDS	MAX	MAX LAG	WHEN LIMIT REACHED
	MAX	MAX LEAD	WHEN LIMIT REACHED
Max MW Output = fully discharging	MAX INVERTER OPERATING NET MW POINT	MAX LAG	WHEN LIMIT REACHED
Min MW Output = fully charging	MAX INVERTER OPERATING NET MW POINT	MAX LEAD	WHEN LIMIT REACHED
Max inverter operating point = solar at full output and battery at full charging	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

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