Hybrid Resource Market Model: Status Quo and Future Considerations

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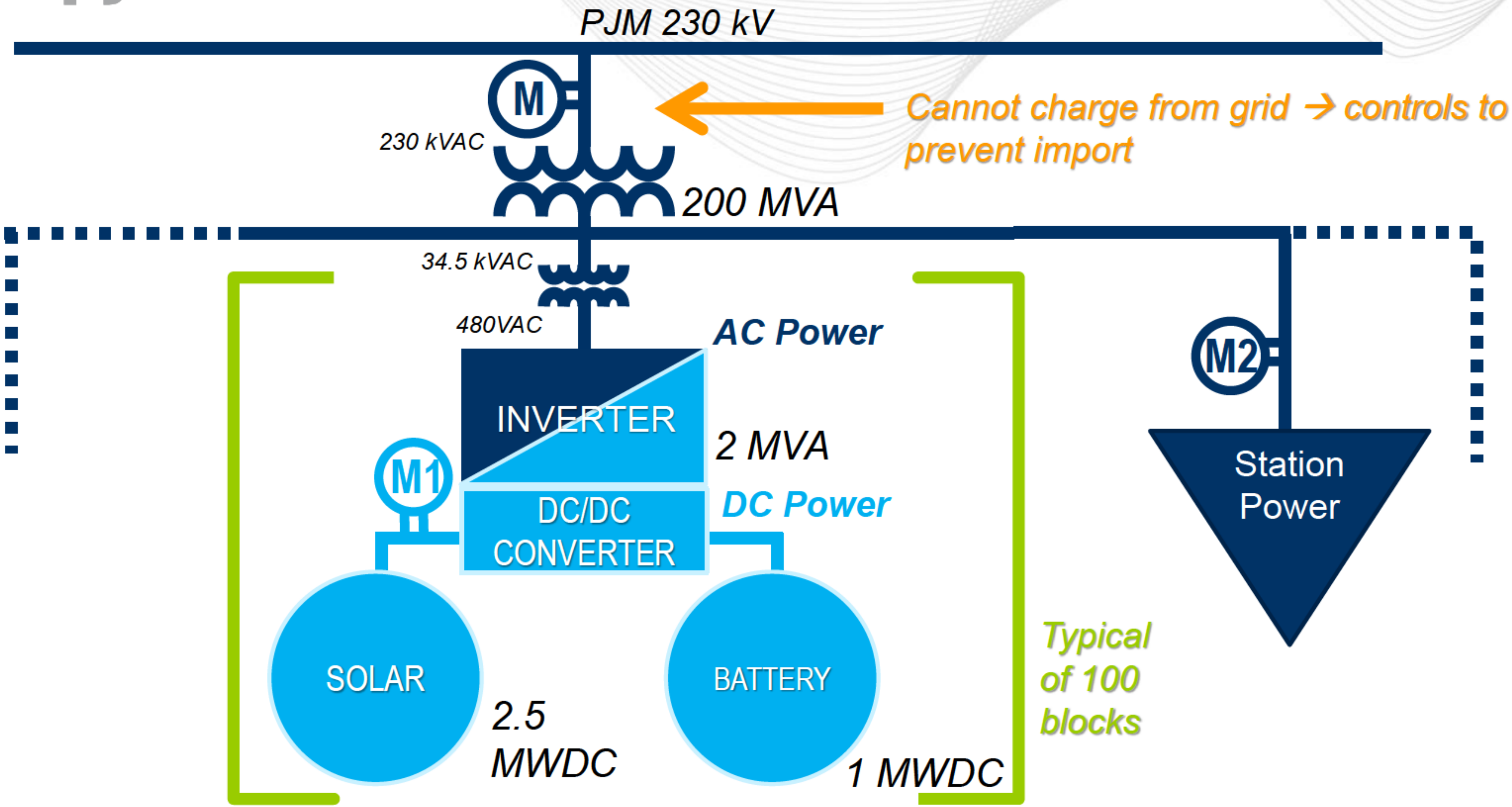
Initial scope of the stakeholder effort (Phase I)

- Energy / Ancillary Services market participation model for a solar + storage plant offering into the market as a single resource.
- "Combination of a generator and storage located at a single site"
- **Initial focus is on solar+storage**, which uniquely has over 13,000 MWE in the Queue. Also has unique inverter configuration possibilities.
- Four types of solar+storage (next slide)

Four types of solar-storage hybrids

	Can charge from grid (open loop)	Cannot charge from grid (closed loop)
Shared Inverters (DC-coupled)	✓	✓
Separate Inverters (AC-coupled)	✓	✓

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



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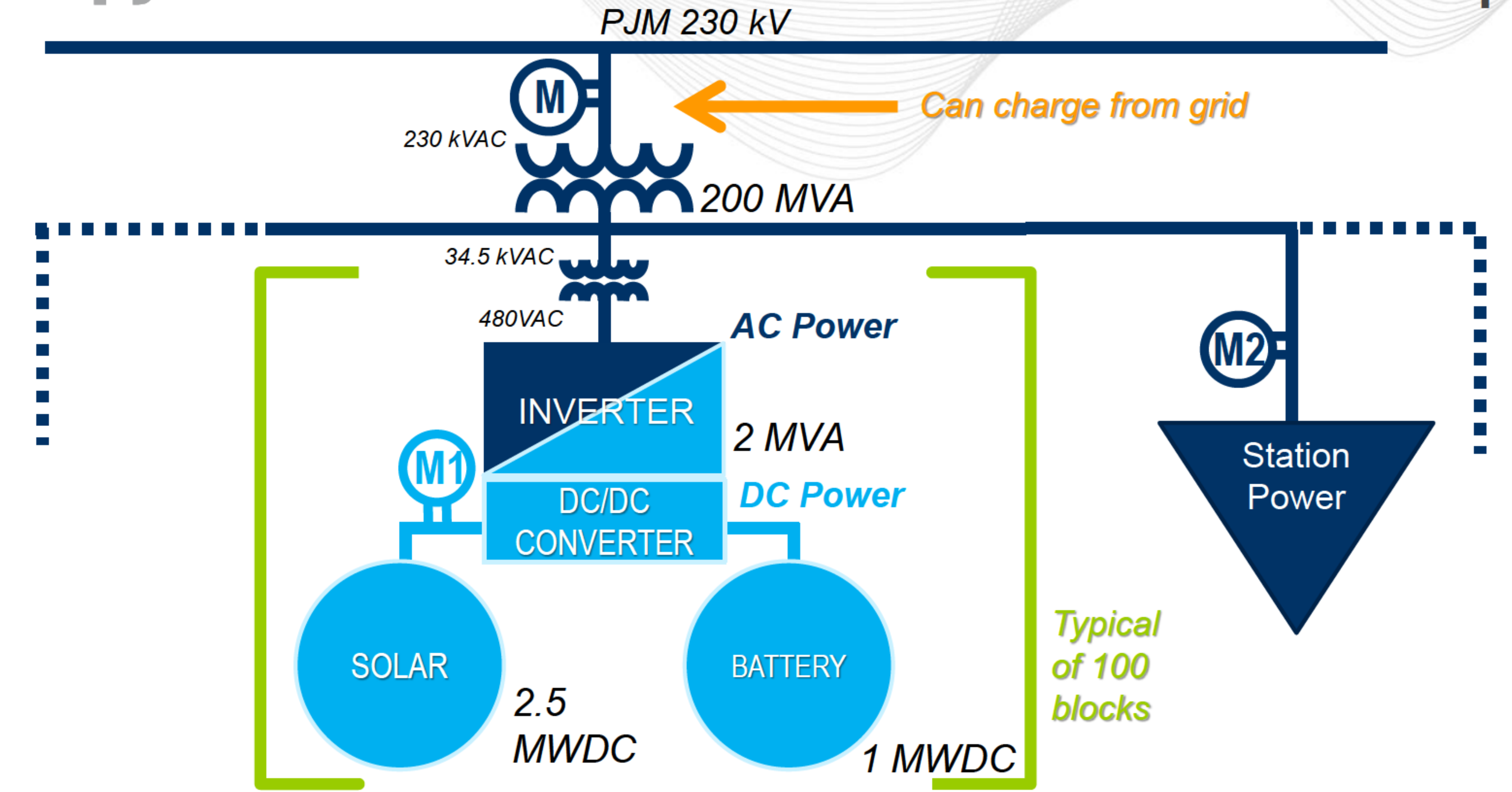
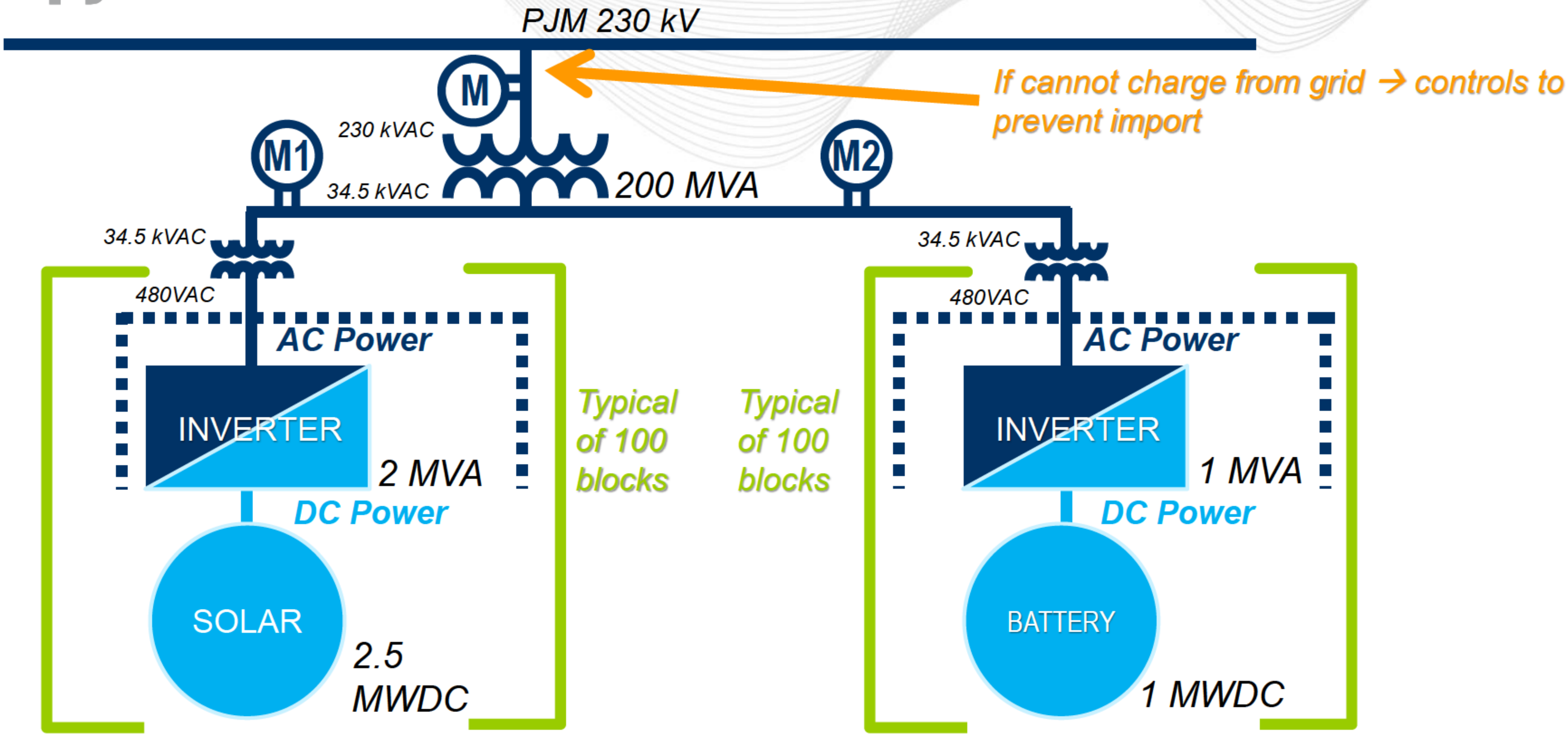


Ex.: Solar-Storage *Separate Inverters (AC-coupled)* Hybrid



Existing Terms in the Tariff Related to Hybrids

- "Intermittent Resource" shall mean a Generation Capacity Resource with output that can vary as a function of its energy source, such as wind, solar, run of river hydroelectric power and other renewable resources.

- "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.

- "Energy Storage Resource Model Participant" shall mean an Energy Storage Resource utilizing the Energy Storage Resource Participation Model.

- "Energy Storage Resource Participation Model" shall mean the participation model accepted by the Commission in Docket No. ER19-469-000.

(Potential) Terms related to hybrid resources: To be defined and/or clarified during this stakeholder effort

- Hybrid resource
- Open-loop hybrid resource
- Closed-loop hybrid resource
- DC-coupled hybrid resource
- AC-coupled hybrid resource
- DC-bus power measurement device
- Storage component state of charge
- Others…?

Status Quo for Hybrid Market Participation

- Without significant interaction between the components: separate market modeling.
  - Several such plants in PJM today (mostly wind and battery storage)

- With significant interaction between the components (e.g., restrictive shared power constraint, can't charge from grid, DC-coupling): single market modeling.
  - Separate market modeling for such units presents several challenges today.

- Only Energy Storage Resources that opt in to the Order 841 model can schedule and be dispatched for negative energy (i.e., charging).

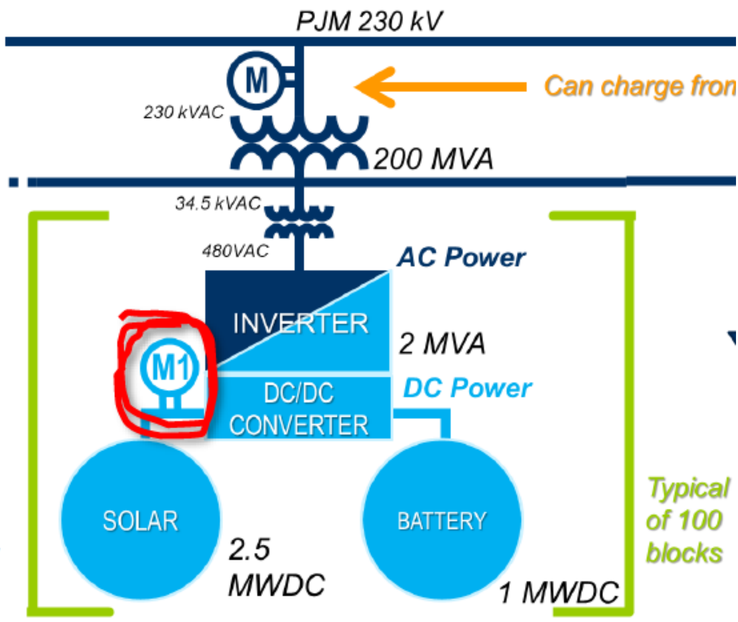
Status Quo for Hybrid Market Participation

- All resources scheduling energy with a dispatchable range in real time can be co-optimized for energy and ancillary services (i.e., Regulation and Synchronous Reserve).

- With single market modeling of hybrids, all settlements and ancillary service measurements are at the point of interconnection (POI).
  – Therefore, in order to avoid charges associated with deviation from economic dispatch, and in order to provide ancillary services, the plant controller would have to control the storage and the solar such that the sum (as measured at the point of interconnection) meets PJM's dispatch.

Status Quo for Telemetry

- Large resources, resources providing ancillary services, and Generation Capacity Resources all must provide telemetry on real and reactive power output.
  - For hybrids modeled as a single resource, this would be at the point of interconnection.
- Solar-storage hybrids also must provide directly measured telemetry of the solar output alone (M1 at right)*.
  - PJM uses this data to support development of a solar forecast for such sites, which is useful for situational awareness and operational planning.
  - This data is not used for energy settlements, and so the applicable accuracy and other technical requirements are those associated with forecast-related data, not those associated with settlements data. DIRS should discuss these requirements in the context of DC metering, esp. for DC-coupled hybrids.
  - This submeter data may also be used to support Effective Load Carrying Capability values, which is a further consideration regarding accuracy requirements.
- Meteorological data telemetry requirements: irradiance, back panel temperature, air temperature, wind speed, wind direction.
- State of charge telemetry is only required for Energy Storage Resources that have opted in to the Order 841 market participation model (not currently required for hybrids).



*Manual 14D Section 12: Solar Park Requirements: "If a solar park is collocated with an energy storage facility such as a battery, then separate metering is required for each component in order to preserve solar forecast accuracy."

PJM Proposal for Capacity Capability Value of Hybrids*

Calculate ELCC reliability value of entire hybrid class → Use a heuristic to allocate those MW among hybrid units (big vs small ESR) incl. performance adjuster → Unit ELCC capacity capability value

ELCC = Effective Load Carrying Capability

**capacity capability proposals are currently under discussion at the Capacity Capability Senior Task Force.*

ELCC Model Example: Solar + 6hr ESR Open Loop

Solar+6 hour battery total ELCCMW = 2,640 MW
3,000 MW nameplate solar
1,600 MW nameplate ESR

1,500 MW of hybrid ELCCMW allocated according to solar component: 3,000 MW nameplate solar would be **1,500 MW** at 50% class ELCC% for solar

Residual hybrid ELCCMW allocated according to ESR component: 2,640 – 1,500 = **1,140 MW**

Unit ELCCMW of each solar+6 hour ESR hybrid unit is the sum of:

- Pro rata share of yellow portion based on UnitSolarMW*PerformanceAdjuster
- Pro rata share of blue portion based on UnitESRMW*(1-EFORd)

ELCC Model for Hybrids

- Each class of hybrid resources to be modeled separately. Each will have a separate hybrid class total ELCCMW calculated. There would be a total of 12 classes:
  - Open loop (i.e., capable of charging from grid)-- Solar+4 hour ESR, Solar+6 hour ESR, solar+10 hour ESR, other Gen+4 hour ESR, other Gen+6 hour ESR, other Gen+10 hour ESR
  - Closed loop (i.e., incapable of charging from grid)-- Solar+4 hour ESR, Solar+6 hour ESR, solar+10 hour ESR, other Gen+4 hour ESR, other Gen+6 hour ESR, other Gen+10 hour ESR
- Total ELCCMW per class would be allocated to each unit in the class via 2 metrics for each unit:
  1. [Solar/other gen nameplate MW]*PerformanceAdjuster
  2. [ESR nameplate]*(1-EFORd)
- The share of the hybrid class total ELCCMW that is allocated by each of the two above metrics is based on:
  A. Share of the hybrid class total ELCCMW corresponding to the solar/other gen ELCC. I.e.: [total nameplate solar/other gen]*[Class ELCC% of the solar/other gen class]
  B. Share of the hybrid class total ELCCMW corresponding to the ESR is the residual ELCCMW after subtracting the solar/other gen ELCC MW identified in step A above.

ELCC: Hybrid Class and Unit Example

- ELCC model shows 2,640 MW total ELCCMW value for class of solar+6 hour storage.
- This class has 3,000 MW total nameplate of solar components and 1,600 MW total nameplate of ESR components.
- The ELCC% for the solar-alone class is 50%.
- The 2,640 MW hybrid class ELCCMW is divided into:
  - 3,000 MW * 50% = 1,500 MW related to the solar components
  - 2,640 MW – 1,500 MW = 1,140 MW related to the ESR components
- A given hybrid unit will have ELCC credit based on the sum of:
  - [1,500 MW/3,000 MW]*[Unit solar nameplate MW]*[PerformanceAdjuster] plus
  - [1,140 MW/1,600 MW]*[Unit ESR nameplate MW]*[1-EFORd]
- A hybrid with 100 MW solar and 25 MW storage, 110% solar Performance Adjuster, and 10% EFORd, would therefore have an ELCCMW of:
  - 0.5*100*110% = 55 MW, plus
  - 0.7*25*(100% - 10%) = 15.8 MW

70.8 MW

Hybrid Deployment Scenarios for ELCC model

- Developed from Queue numbers
- Subtracted from solar, storage, and other relevant deployment assumptions via vendor forecast

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