Reactive Capability of Hybrid Resources

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Four types of solar-storage hybrids

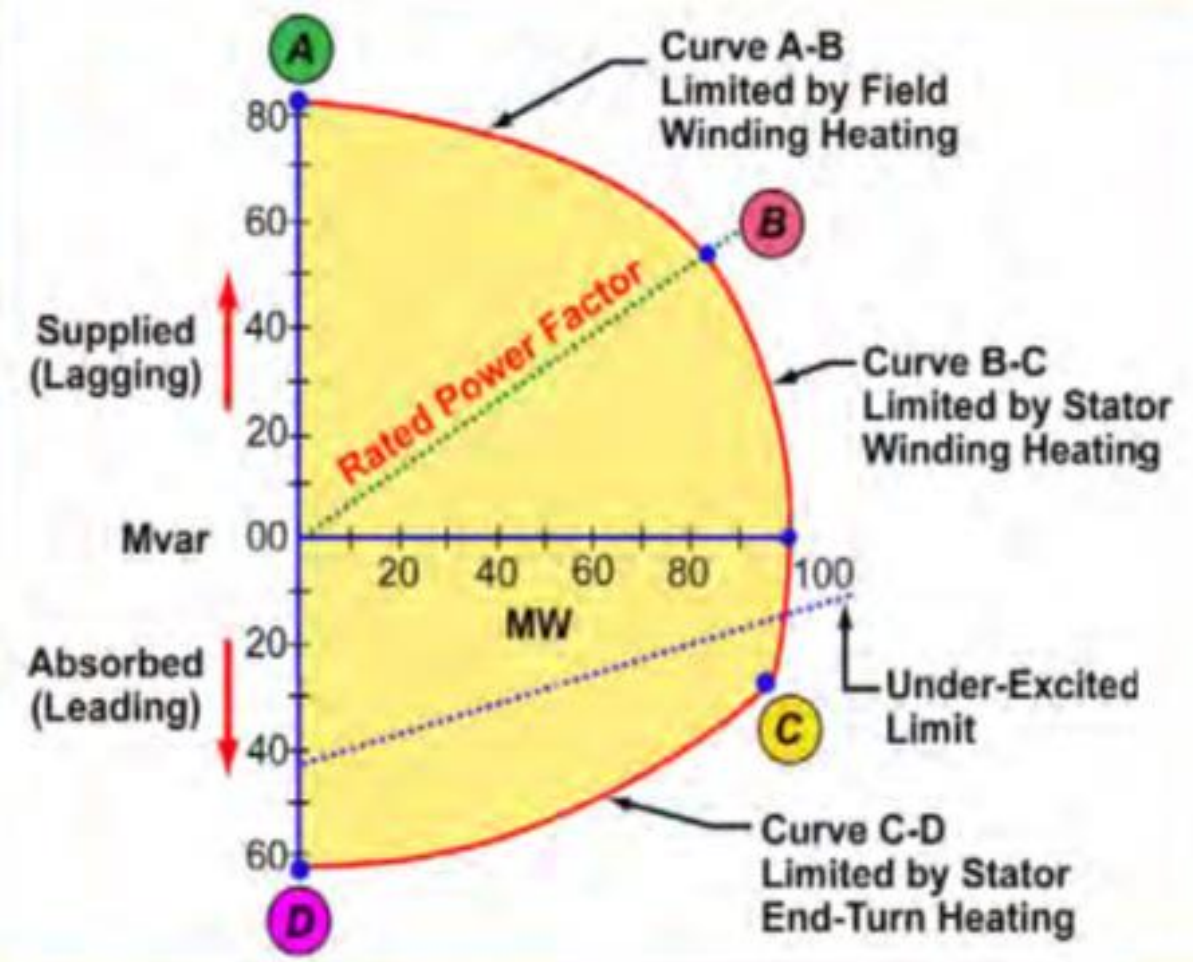
	Can charge from grid (open loop)	Cannot charge from grid (closed loop)
Shared Inverters (DC-coupled)	✓	✓
Separate Inverters (AC-coupled)	✓	✓

Traditional Generator MW/MVAR Pairing

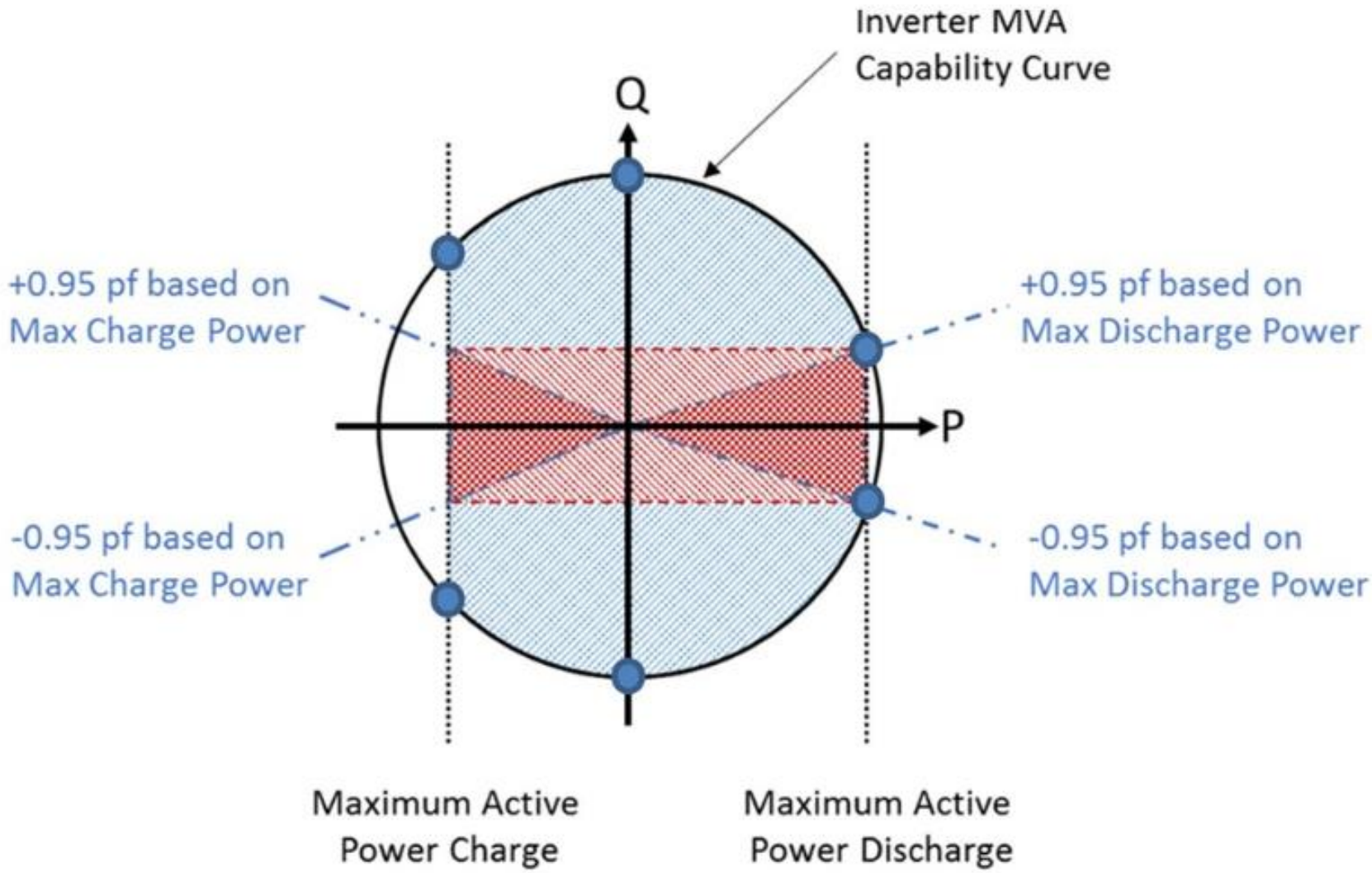
	MW	Minimum MVAR	Maximum MVAR
Point 1	0	-50	50
Point 2	15	-45	45
Point 3	30	-40	40
Point 4	45	-35	35
Point 5	60	-30	30
Point 6	75	-25	25
Point 7	90	-20	20
Point 8	100	-15	15

- Analysis uses the MW output of the resource to determine where the MVAR output
- This is very straightforward for traditional resources or even shared inverters
- A singular Min/Max MVAR pair for each MW output

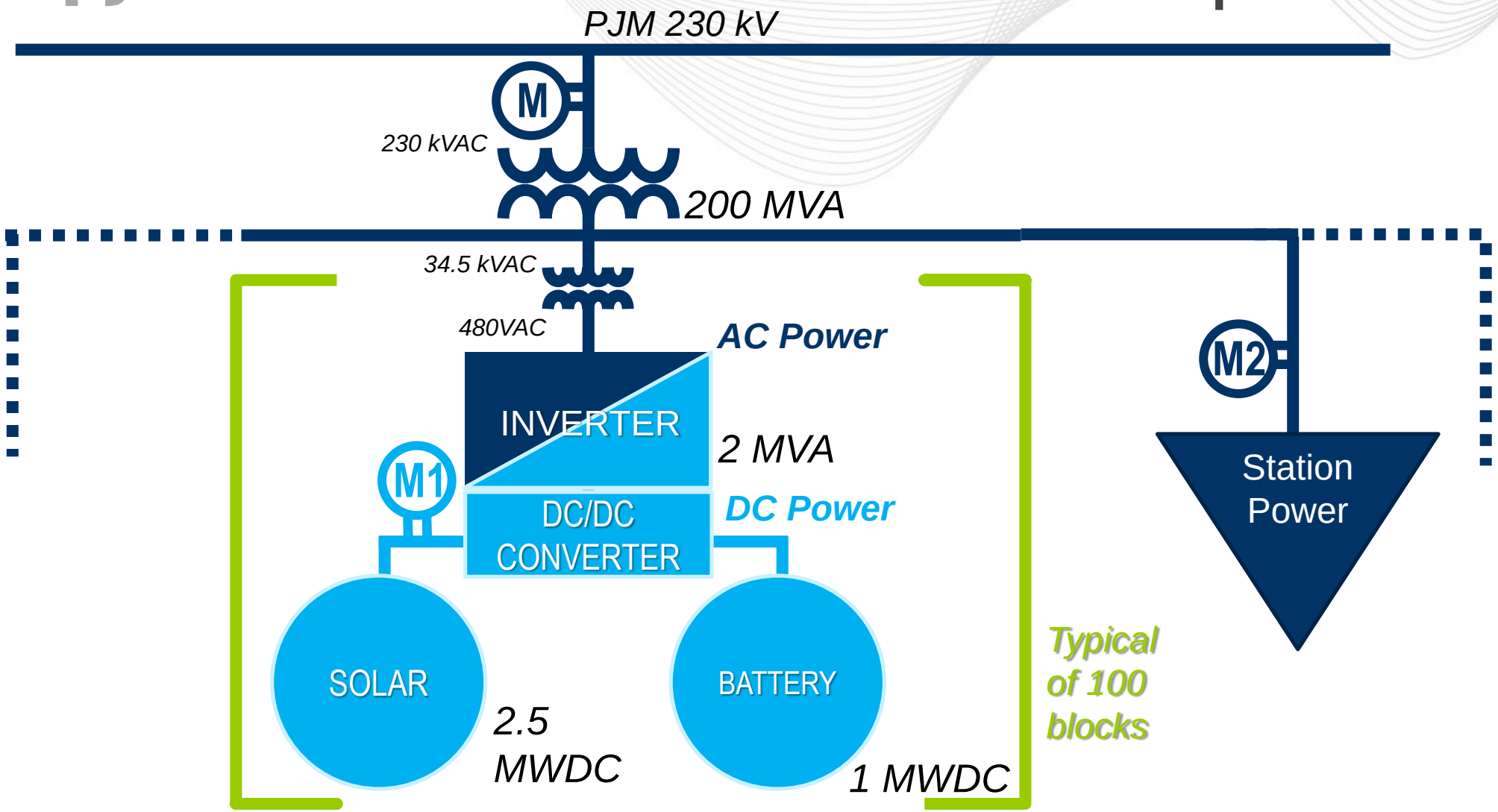
Traditional D-Curve



Inverter-Based Reactive Curve



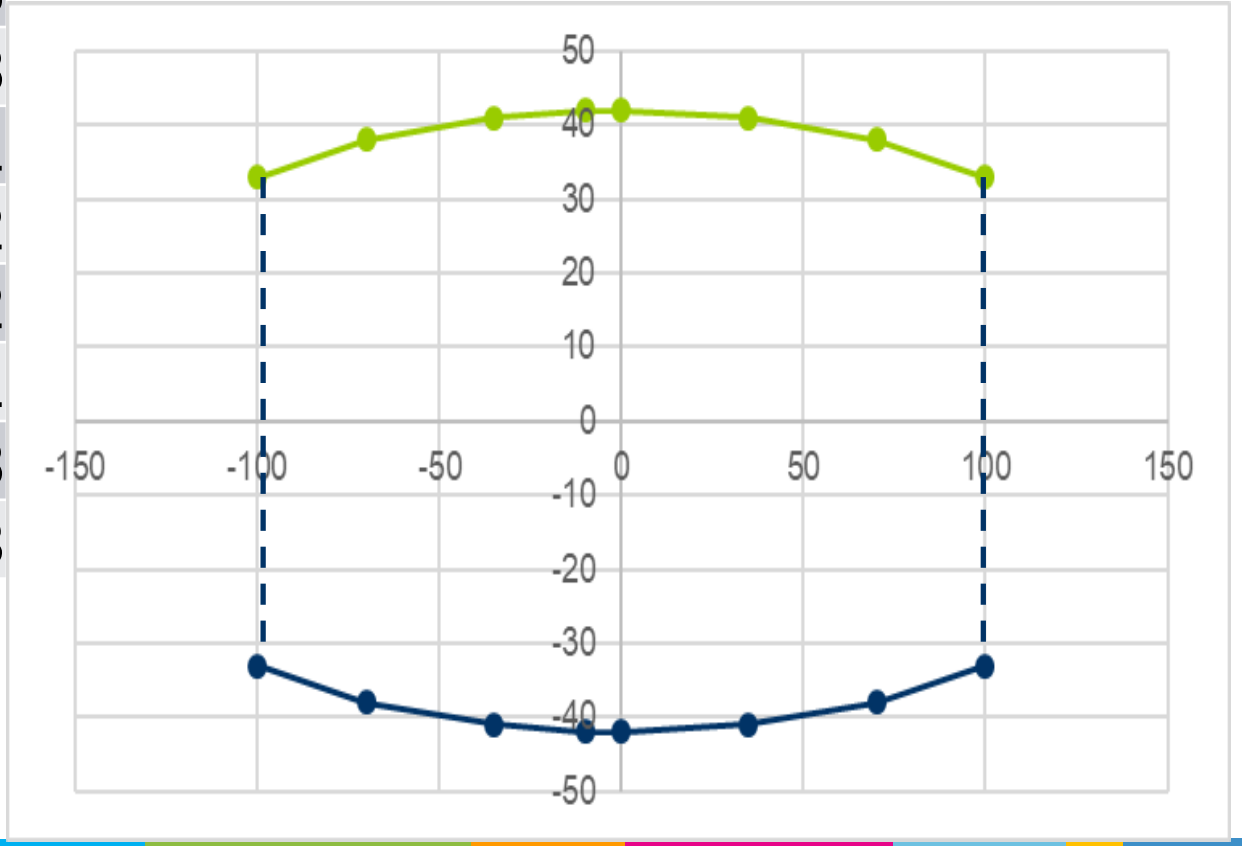
Ex: Solar-Storage *Shared Inverter (DC-coupled)* Hybrid, **Open or Closed Loop**



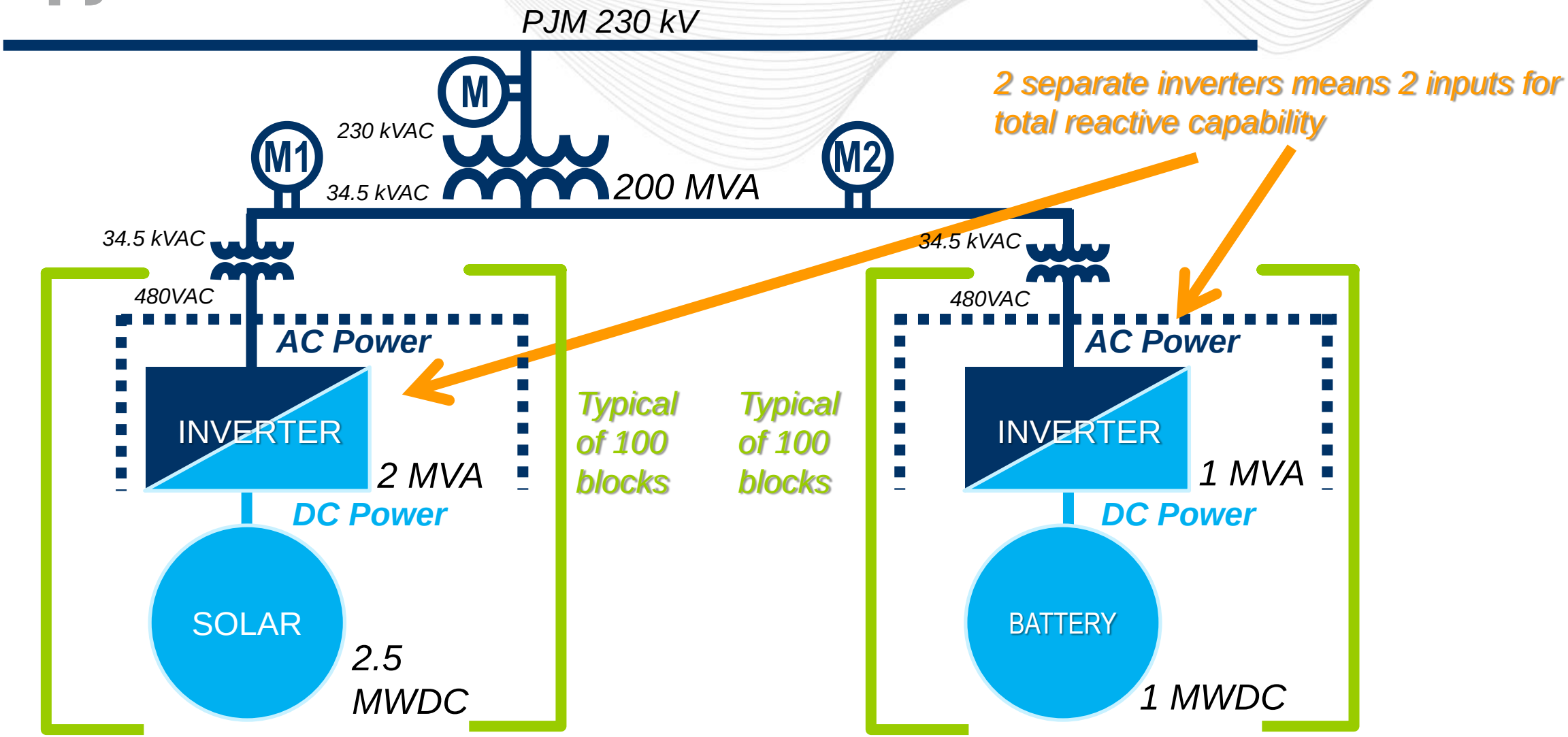
Shared Inverter Capability Curve

	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



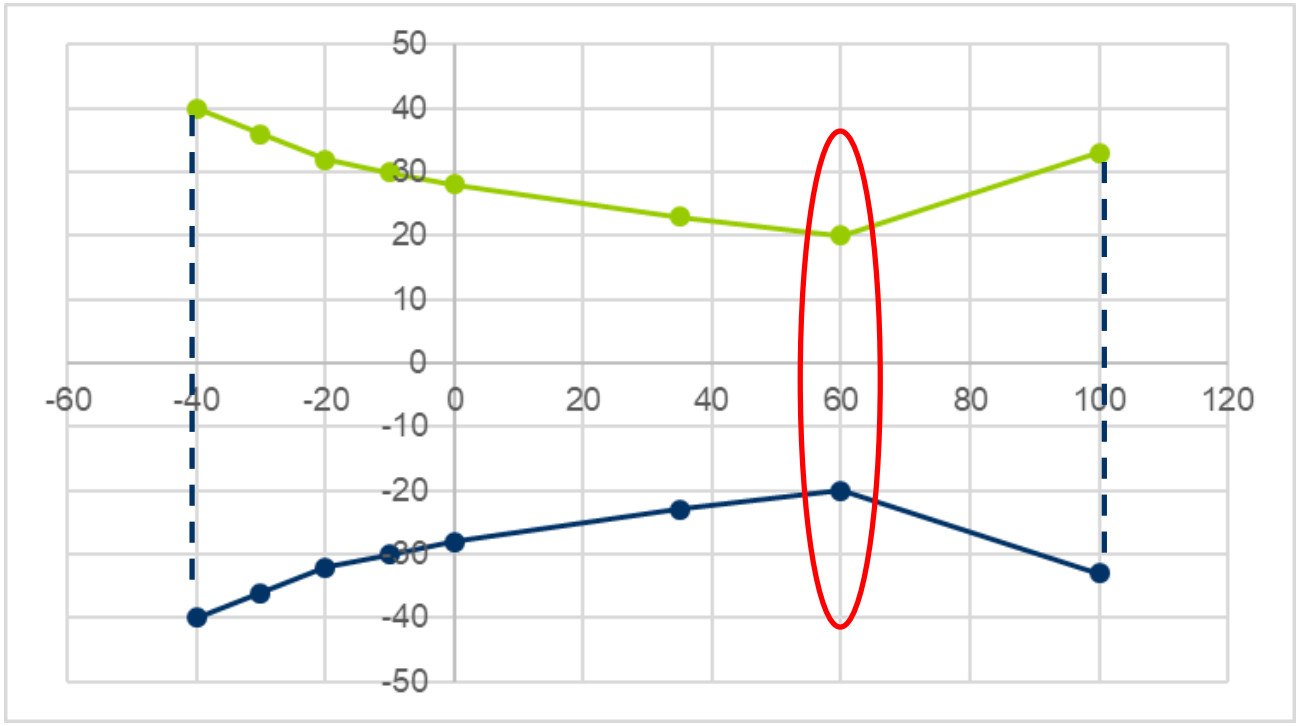
Ex.: Solar-Storage *Separate Inverters (AC-coupled)* Hybrid



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



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* ***Additional test points may be required if these do not capture the most restrictive capability scenarios.**	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
	MIN	MAX LEAD	WHEN LIMIT REACHED

Benefits of Simplified Conservative Approach

No additional telemetry required of resources

Less computational stress and complexity for EMS analysis

Allows plant controller to do the work

- Controller is already coordinating resource outputs to prevent any GSU or inverter overloads

Contact

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