Holistic Performance Index

for Effective Photovoltaic (PV) + Battery Storage Asset Management

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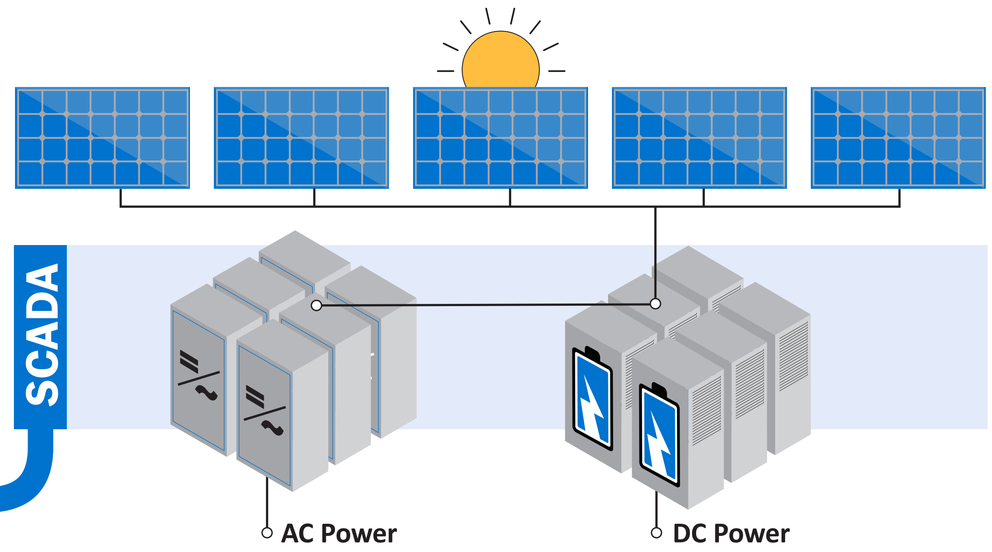
The Holistic Performance Index (HPI) is a comprehensive measure to assess PV array, PV inverters, Battery inverters, and Batteries **as a system**. The HPI captures overall performance of AC- and/or DC-coupled PV+Battery Energy Storage System (BESS) assets for one minute – up to the entire asset lifespan.



Data

HPI CALCULATION

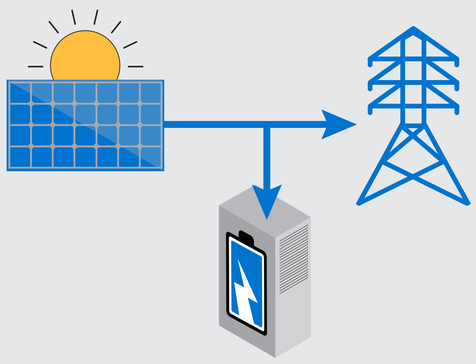
PV Parameters:
- Power Output
- Plane of Array Irradiance
- Back Panel Temperature
- Cell Temperature Coefficient

BESS Parameters:
- Charge Throughput
- Discharge Throughput
- State of Energy Delta
- Battery Efficiency

Other Parameters:
- Point of Dispatch Real Power
- Inverter Efficiency

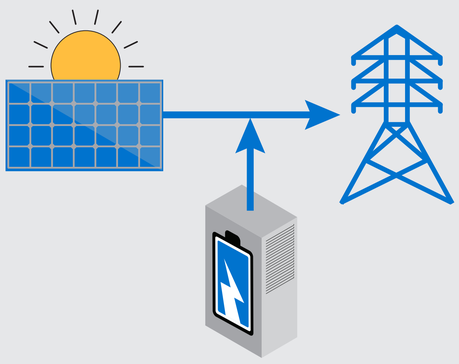
These source parameters are used to calculate efficiency for two BESS scenarios:

CHARGING



Site performance during charging depends on the efficiency of PV arrays, PV inverters, **charge throughput,** and change in state of energy.

DISCHARGING



Site performance during discharging depends on efficiency of PV arrays, PV inverters, **discharge throughput,** and change in state of energy.

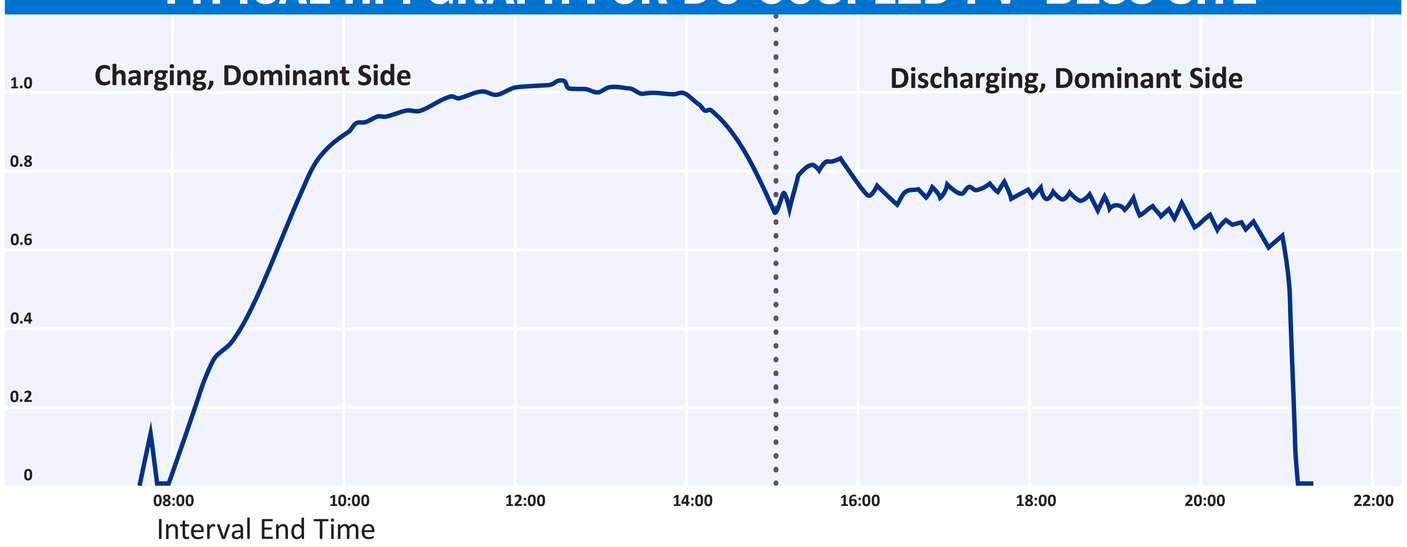
LIMITATIONS OF PV KPI FOR PV+BESS SITES

- Performance measures based on common PV parameters (e.g. irradiance, backpanel temperature) do not provide a comprehensive measure of PV+BESS plants.
- PV measures do not account for bi-directional power flow and battery inefficiencies.

SCENARIO CALCULATIONS

PV Expected Production	=	Expected energy output of PV side based on irradiance; adjusted for temperature.
PV Direct Expected Energy	=	Energy expected to be delivered from PV directly to grid. This is calculated by deducting Charge throughput from PV Expected Energy.
Battery Expected Output	=	Energy expected to be delivered from battery to the grid. This is calculated based on change in state of energy, charge throughput energy, and battery efficiency.
Total Expected Energy	=	Sum of PV Direct Expected Energy and Battery Expected Output.
Holistic Performance Index	=	Ratio of Point-of-Dispatch Real Power Output to Total Expected Energy.

TYPICAL HPI GRAPH FOR DC-COUPLED PV+BESS SITE



ADVANTAGES OF THE HPI

- Investigate PV+BESS performance objectively based on a single index point.
- Set an alarm to indicate underperformance for any desired timeframe.
- Effectively identify underperforming or defective equipment.