




PROS AND CONS OF AC AND DC COUPLED ENERGY STORAGE

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Presentation Overview

- 1. *PVEL's Energy Storage Testing***
- 2. *AC vs. DC Coupling: What's the Difference***
- 3. *AC vs. DC Coupling: Pros and Cons***
- 4. *Final Considerations***

PVEL is the Independent Lab for the Downstream Solar Market



Our mission is to support the worldwide PV buyer community by generating data that accelerates adoption of solar technology.

Global

300+ downstream partners worldwide with 30+GW of annual buying power

Comprehensive

Testing for every aspect of a PV project from procurement to O&M

Experienced

Pioneered bankability testing for PV products nearly a decade ago

Market-driven

Continuously refining test programs to meet partner needs

PVEL's Energy Storage Product Qualification Program (PQP)

Required Tests for Cell Manufacturers

Factory Witness

Characterization

C-Rate

Average resting state of charge

Ambient temperature

Differential depth of discharge

Energy throughput

Extended durability

C/2 extended testing

C/4 extended testing

Vocational testing

New tests

Factory Witness

All Bills of Materials submitted for testing are witnessed in production from opening of raw materials packages through every step of the production process to final packaging with tamper-proof tape.

Characterization tests

- 6-month test duration
- 36 individual cell tests
- Measures cell degradation due to various stressors
- Monthly capacity tests

Extended durability tests

- 24-month test duration
- Multiple cells per test leg for redundancy
- Monthly capacity tests

Required Tests for System Integrators

For Packs and Racks

Validation

Pack level cycling

Auxiliary load and standby loss verification

System capacity utilization

New Tests

Validation tests

- Measure performance
- Evaluate self-consumption
- Qualify rack design
- Characterize cell/module mismatch

For Residential Systems

Validation

Product derating

Inverter interactions

System-level functionality

Cycle fatigue and cell balancing

Cell operating temperature

BMS functionality

Validation tests

- 18 tests
- Maps system response across operational bounds
- Involve battery, inverter and battery management system
- Required for residential systems only

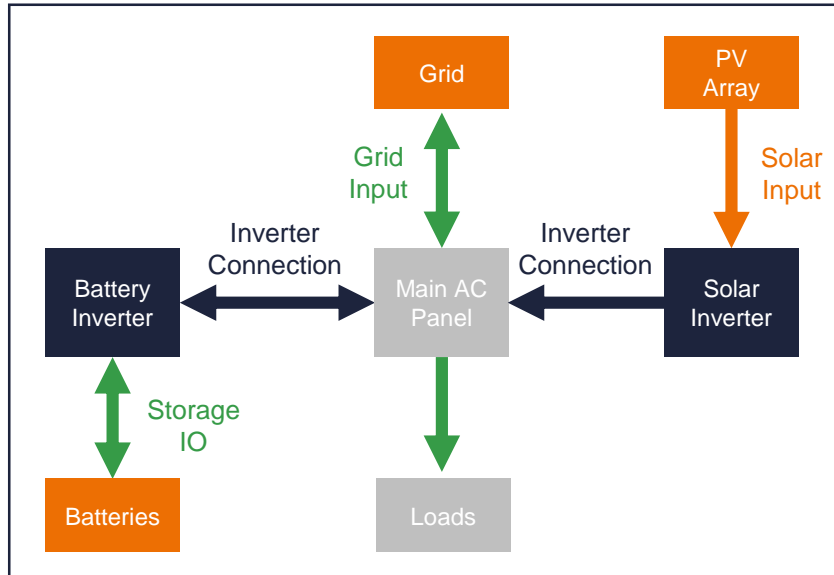


Beyond the PQP

We also provide Energy Storage Burn and Safety Testing, including UL 9540A / UL1973

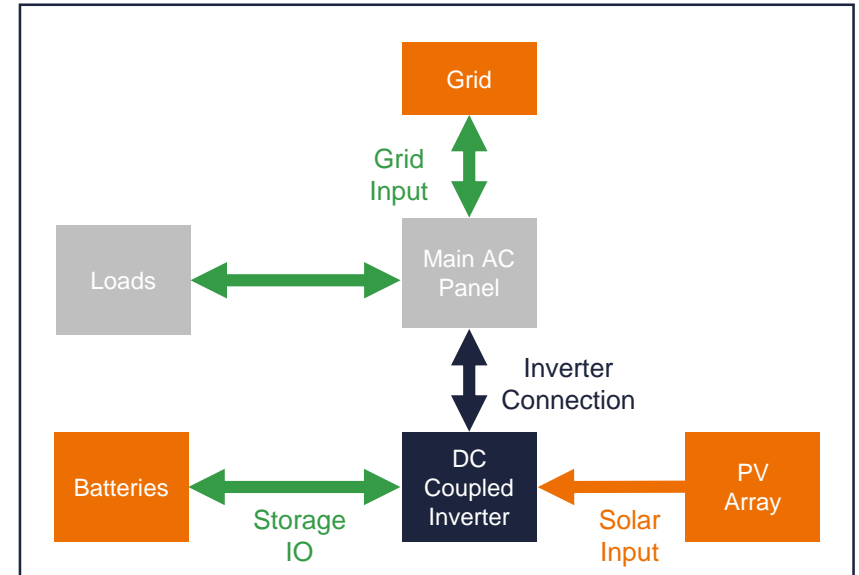
AC and DC Coupling for Grid-tied Solar + Storage Systems: What's the Difference?

- > AC Coupling requires two inverters:
solar & battery-based



AC Coupling

- > DC Coupling requires a single inverter with
both battery and PV interconnected on its input



DC Coupling

AC and DC Coupling: Pros and Cons

AC Coupling

Better for retrofits, C&I market and grid-service applications

VS.

DC Coupling

More economical, lower BoS costs, high DC loading ratios (shifting)



AC vs. DC Coupling: Final Considerations

> AC Coupled and DC Coupled

- Both approaches typically have multiple manufacturers involved in the final solution
- Both approaches have pros and cons depending on the end application

> Either Approach Requires Product Diligence

- Compatibility testing
- Performance and reliability testing
- Safety evaluations

> Together AC and DC Coupled Approaches Offer:

- Flexibility choices
- Cost considerations
- Design choices for end solutions



THANK YOU

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