STORAGE IN HYBRID SYSTEMS

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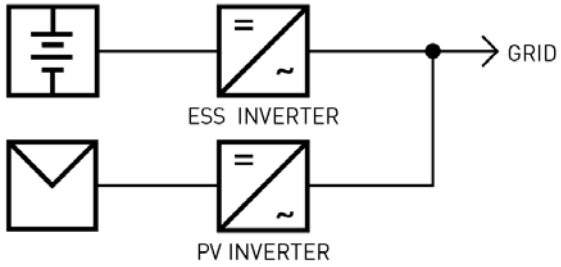
SOLAR PLUS STORAGE
TOPOLOGIES

AC-COUPLED

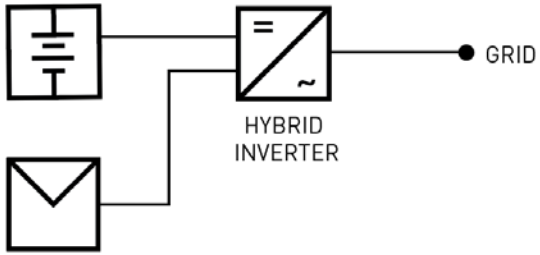
CPS



HAWAII

HYBRID SOLAR PLUS STORAGE

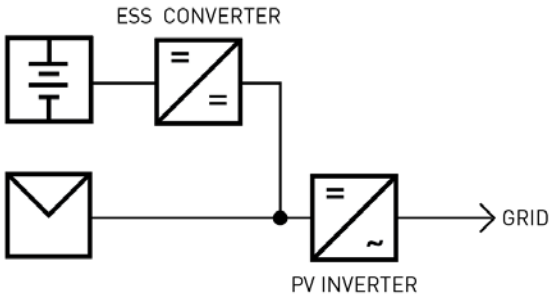
SPS



VERMONT

DC-COUPLED

DPS



FLORIDA

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SOLAR PLUS STORAGE
VALUE STREAMS

What we can do with any PVS topology

- **Capacity Firming**
- **Energy Time Shifting**
- **Ramp Rate Control**

What we can do additionally if we DC-couple our PVS

- **Lower Cost than AC-Coupled**
- **A Higher Efficiency than AC-Coupled Storage**
- **Increased Revenue Due to Clipping Recapture**
- **Ability to Retain Tax Incentives**
- **Low Voltage Harvest (LVH)**
- **Ramp Rate Control +**

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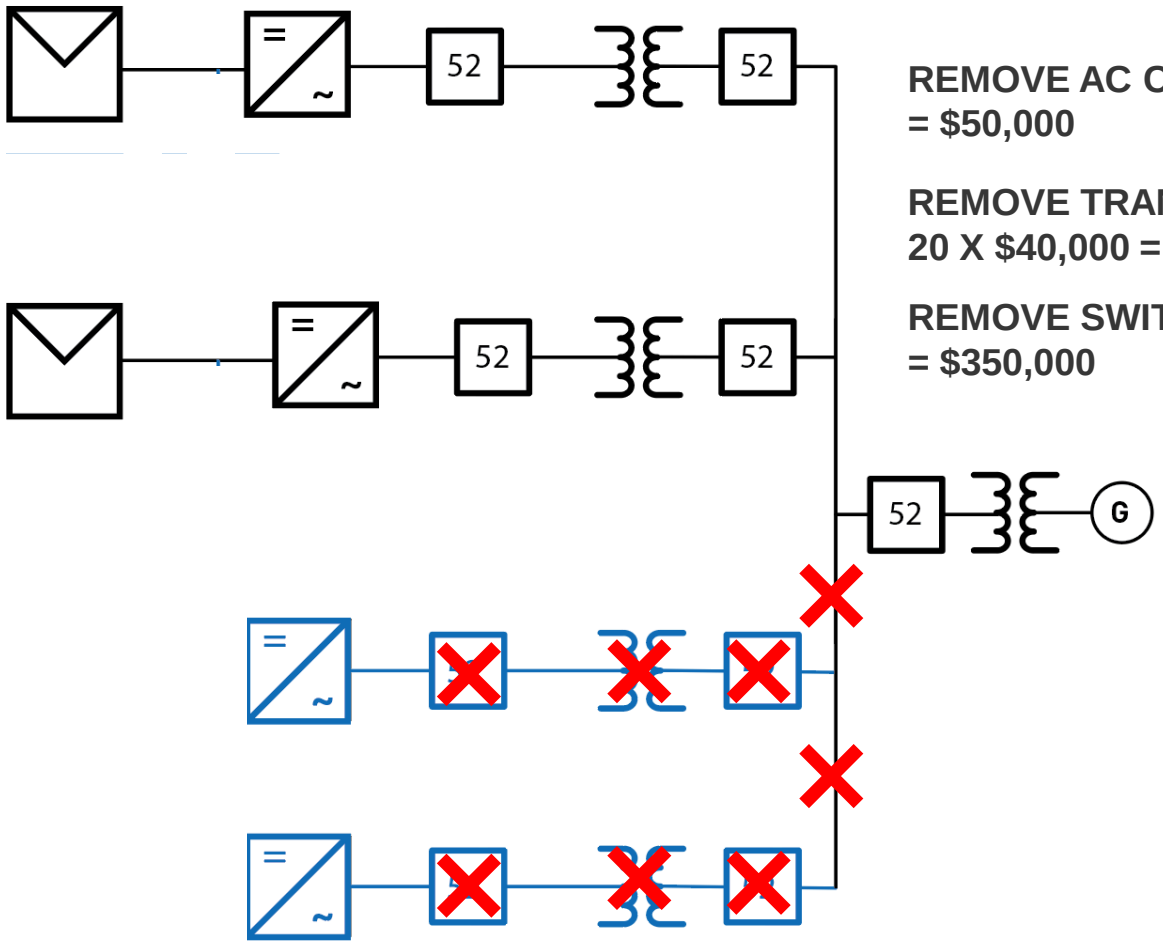
DC-DC COST REDUCTION

20MW CASE STUDY



REMOVE AC COLLECTION SYSTEMS
= $50,000

REMOVE TRANSFORMERS
20 X $40,000 = $800,000

REMOVE SWITCHGEAR
= $350,000

TOTAL SAVINGS: $1,200,000

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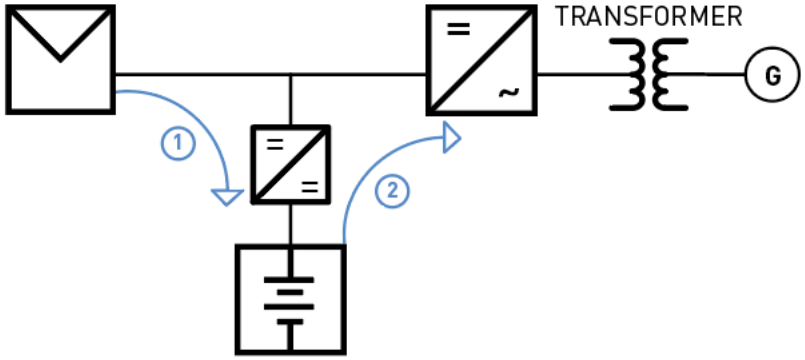
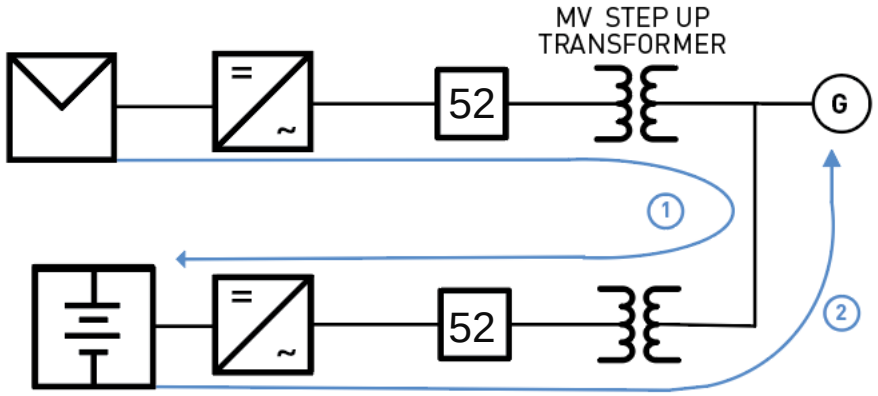
HIGHER EFFICIENCY





DC-COUPLED

- 3 power electronic conversions
- 1 battery charge and discharge
- 1 transformer conversion

Efficiency = 89.2%

= .95 * .982 * .982 * .984 * .99

AC-COUPLED

- 3 power electronic conversions
- 1 battery charge and discharge
- 3 transformer conversions

Efficiency = 86.2%

= .95 * .984 * .99 * .99 * .984 * .984 * .99

Assumed efficiencies: PV inverter = 98.4%, Battery inverter = 97.5%, DC-DC = 98.2%, transformer = 99%, batteries = 95% round trip

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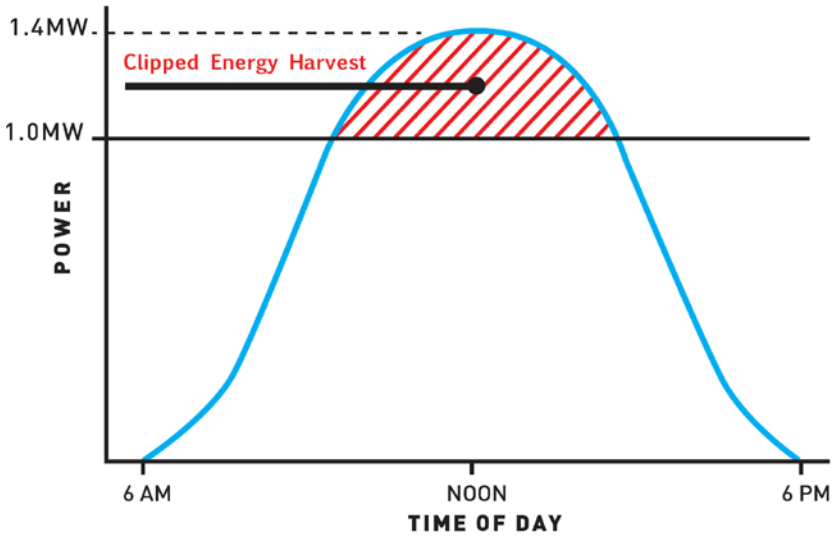
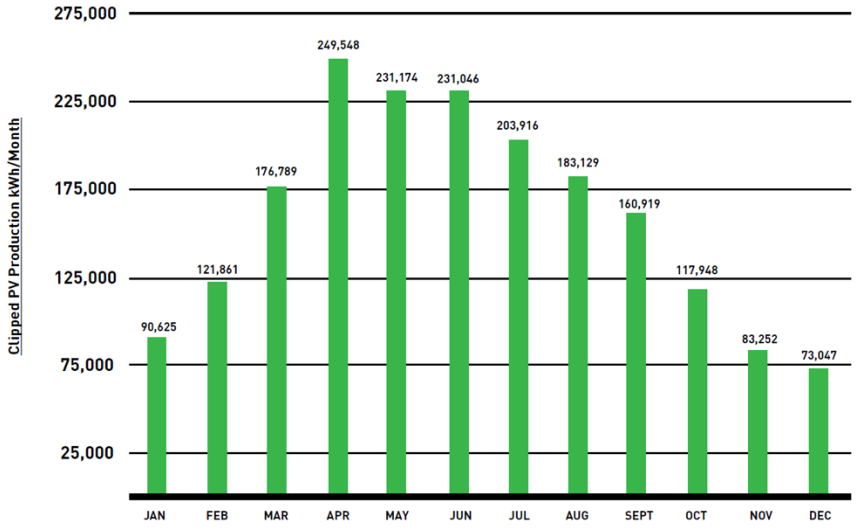
CLIPPING RECAPTURE

ONLY WITH DC-COUPLED



SAMPLE 20 MW PV INSTALLATION

INVERTER RATIO: 1.45



ANNUAL LOST PRODUCTION:

1,923,256 **kWh**

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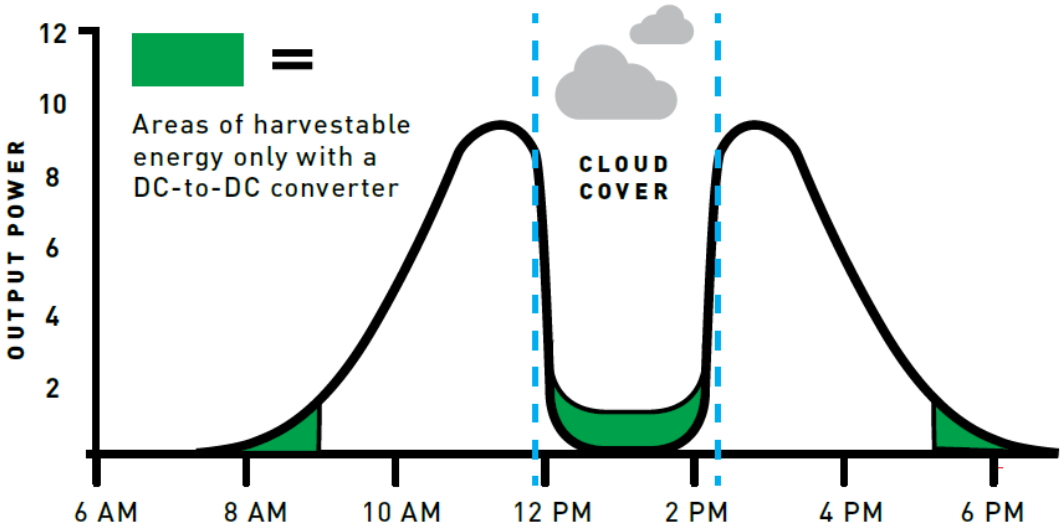
LOW VOLTAGE HARVEST (LVH)

ONLY WITH DC-COUPLED



PV inverters harvest DC input when the array or string voltage is above a certain threshold. *This impacts generation at beginning of day, end of day and in heavy cloud cover.*

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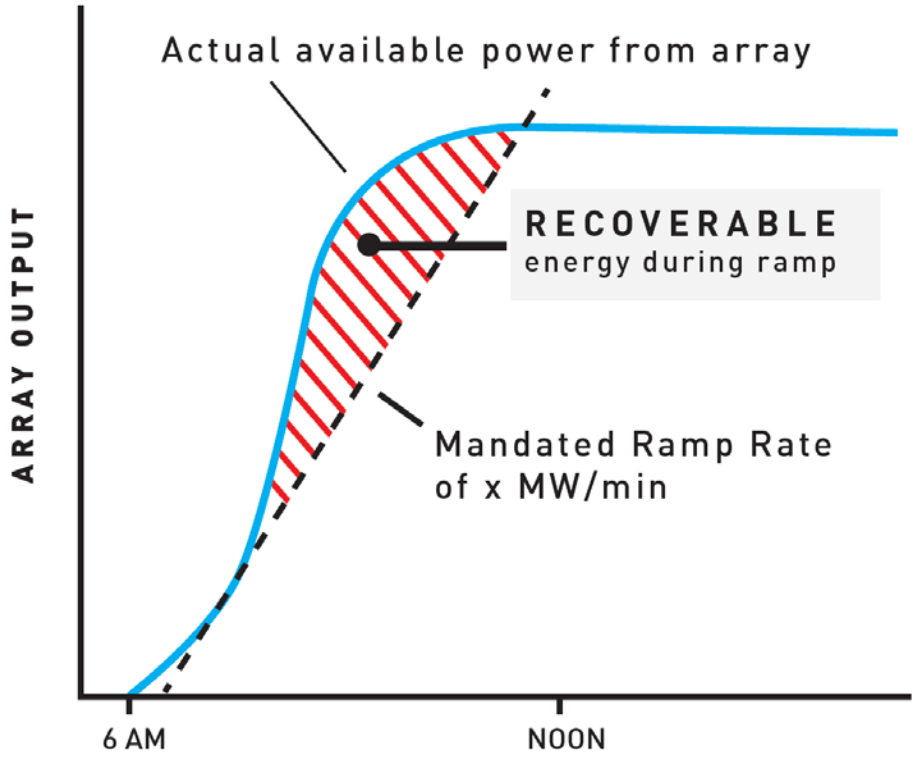
RAMP RATE CONTROL+
ONLY WITH DC-COUPLED

Ramp Rate Control Mode

- System can be sized to provide ramp rate control to a defined spec: X MW/minute.

- Required in island scenarios (Hawai'i, Puerto Rico, Caymans) or may be required for PV on weak feeders



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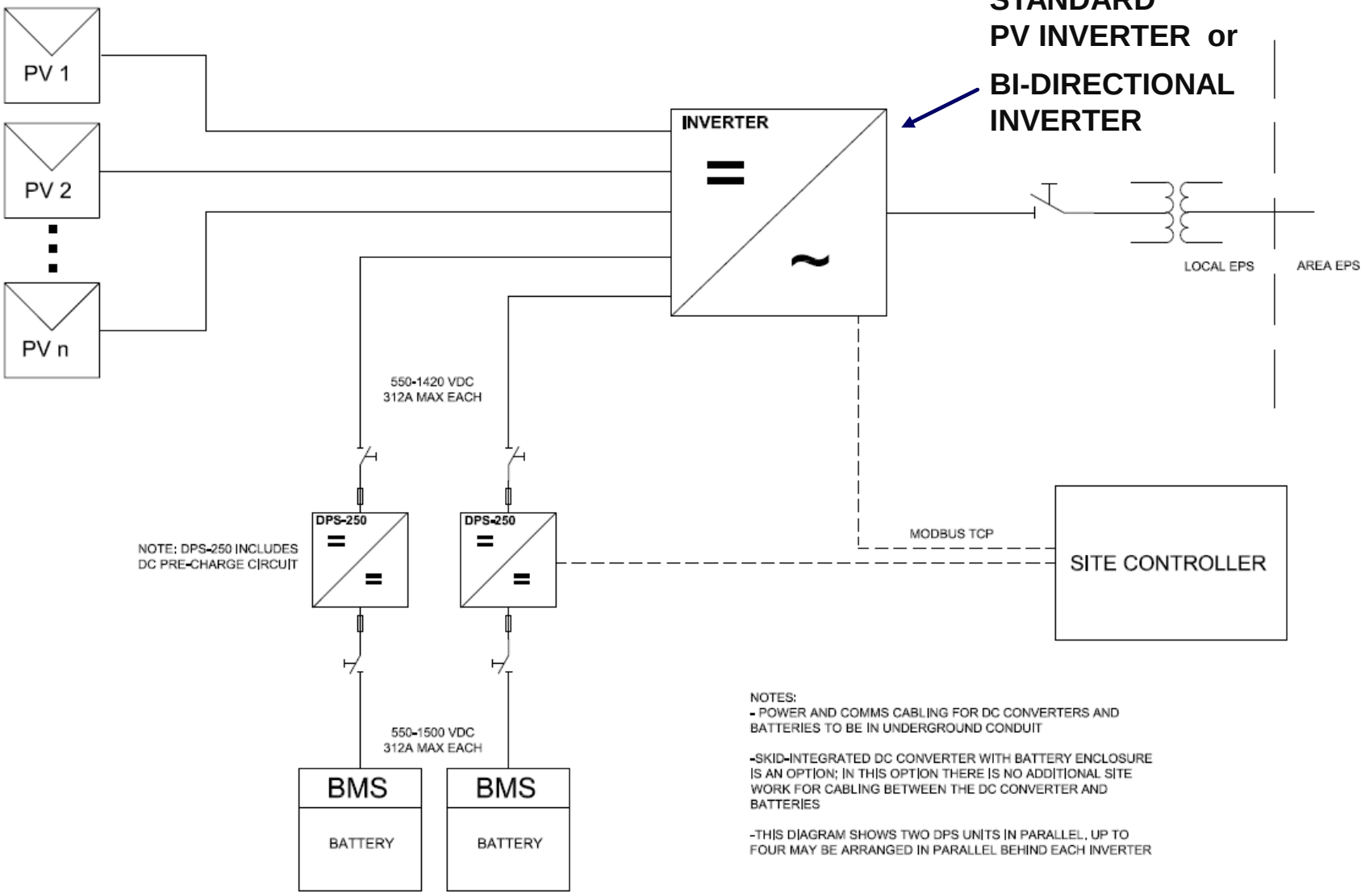
TYPICAL CONFIGURATION



FComp: Frequency Response

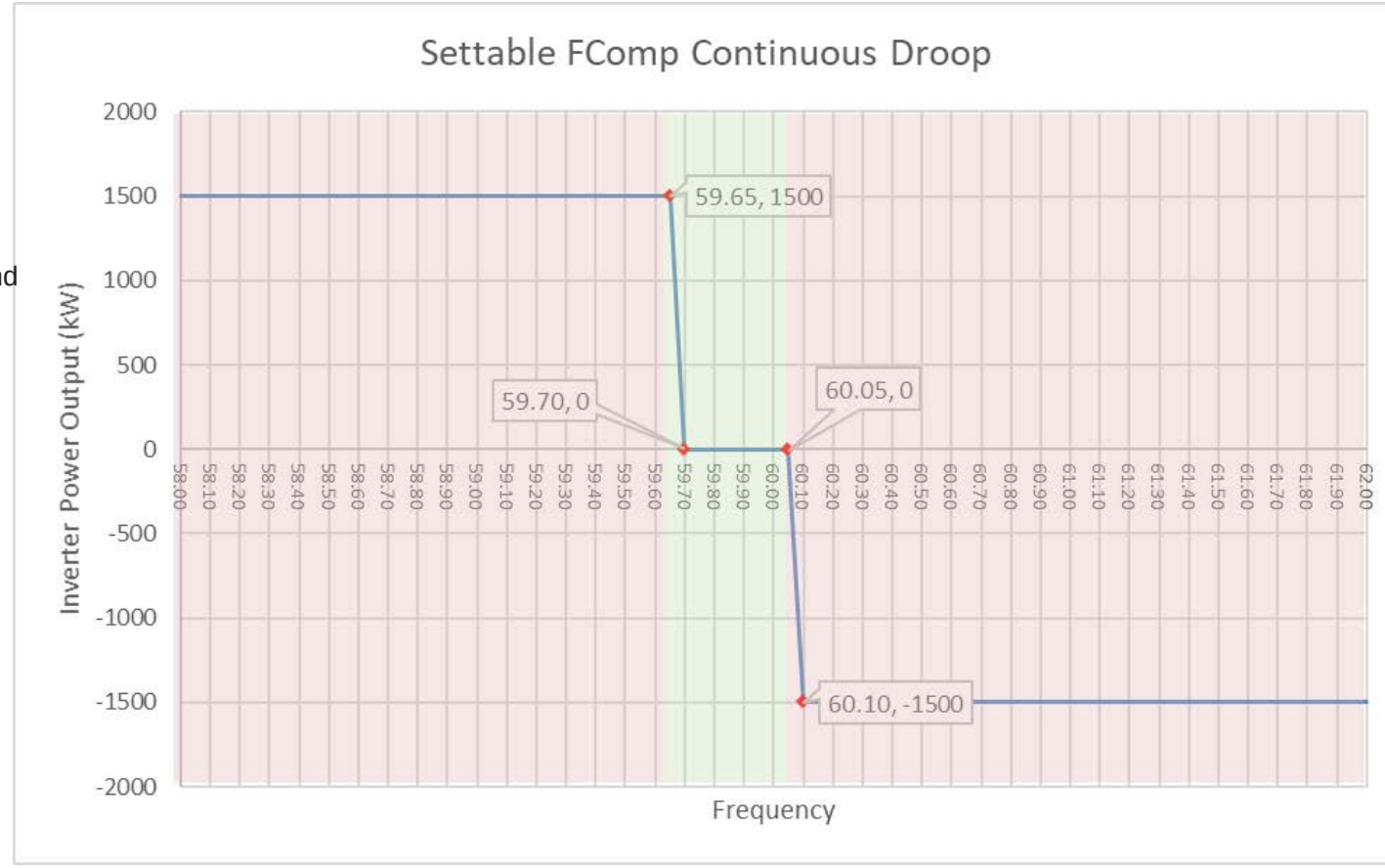
Fcomp

Frequency Response

Autonomous, settable frequency support. Sub-cycle response when local frequency deviates from set deadbands. Operates in background but can be given priority.

Note this function can meet requirements for rate of change of frequency.

This is different from Frequency Regulation in which the inverter is passive and is receiving an outside dispatch command.

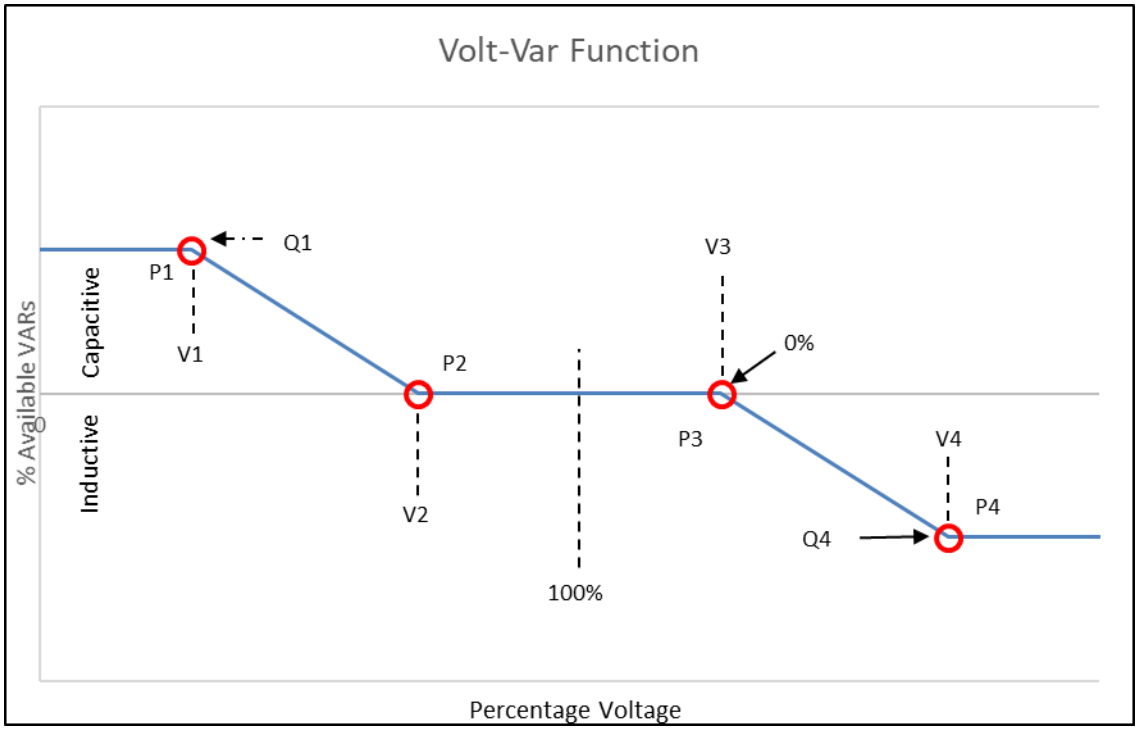


EComp: Volt-VAR

EComp

“Volt-VAR support”

Autonomous, settable voltage support. Sub-cycle response when local voltage deviates from set deadbands. Operates in background but can be given priority.



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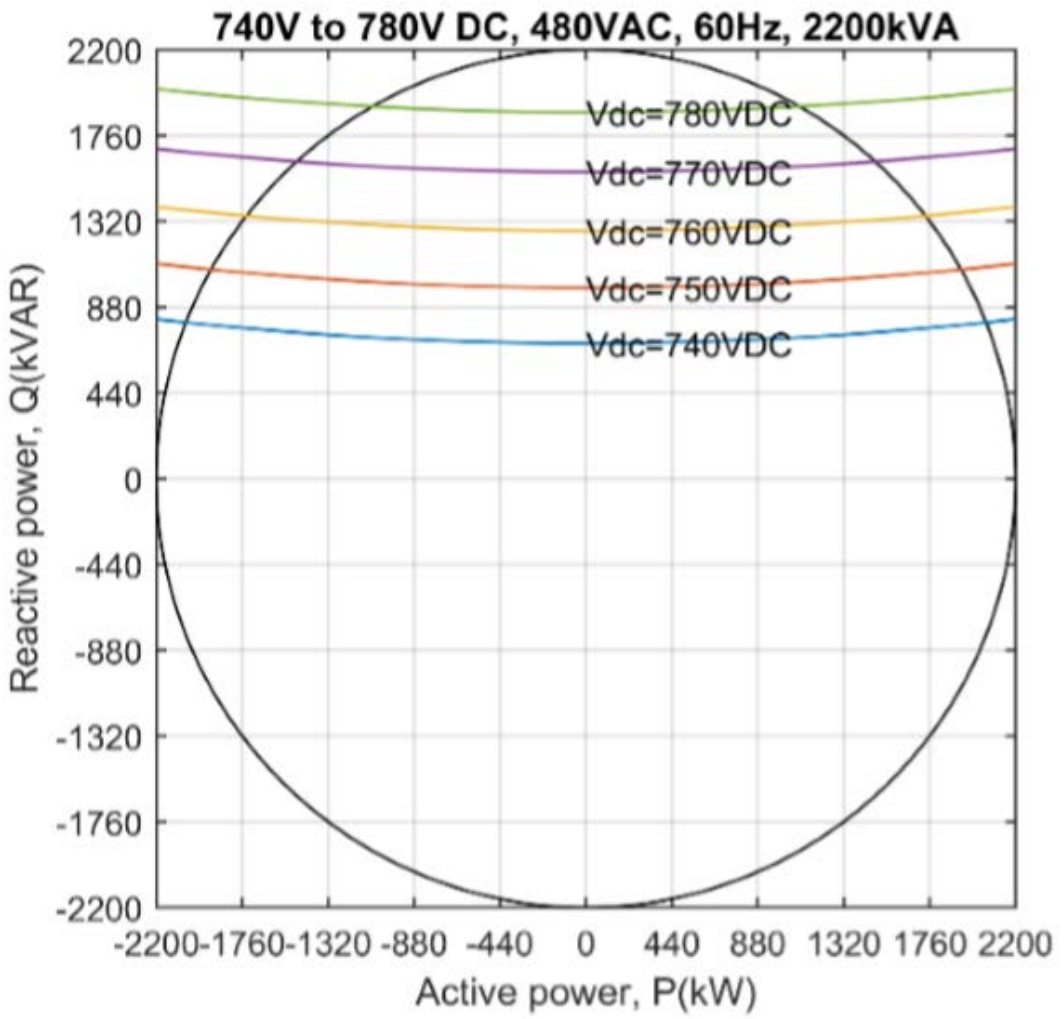
REACTIVE POWER CAPABILITIES

S-Plane curve

Reactive Power capability

Example inverter reactive power capabilities. The outer circle represents available output points in normal operation. The colored cut lines illustrate reduced reactive power (positive) capabilities when the battery input voltage is reduced.



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CONTACT

THANK YOU

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