Energy, Inc.

Integrating Storage and Renewable Energy Sources Into A DC Microgrid Using High Gain DC DC Boost Converters

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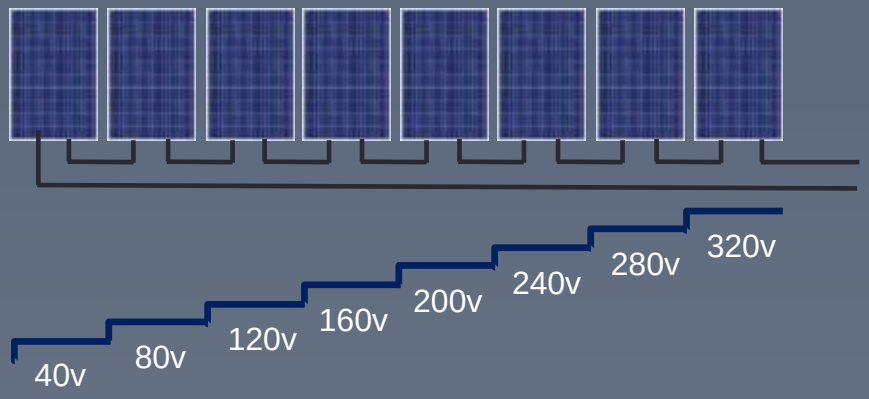
PV is not an Abstract Term

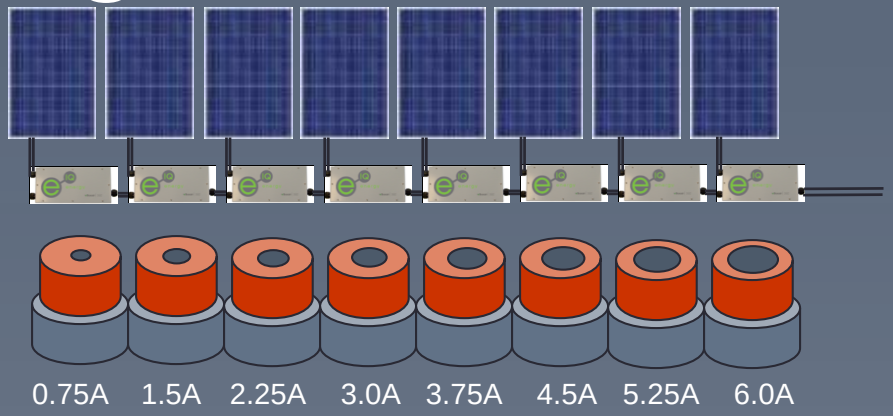
Easy-ish

Not so Easy
With Series String

The Parallel Advantage



Design limits:7 more panels
600V Limit 3,600W



Design limits: 32 more panels
30A Limit 9,600W

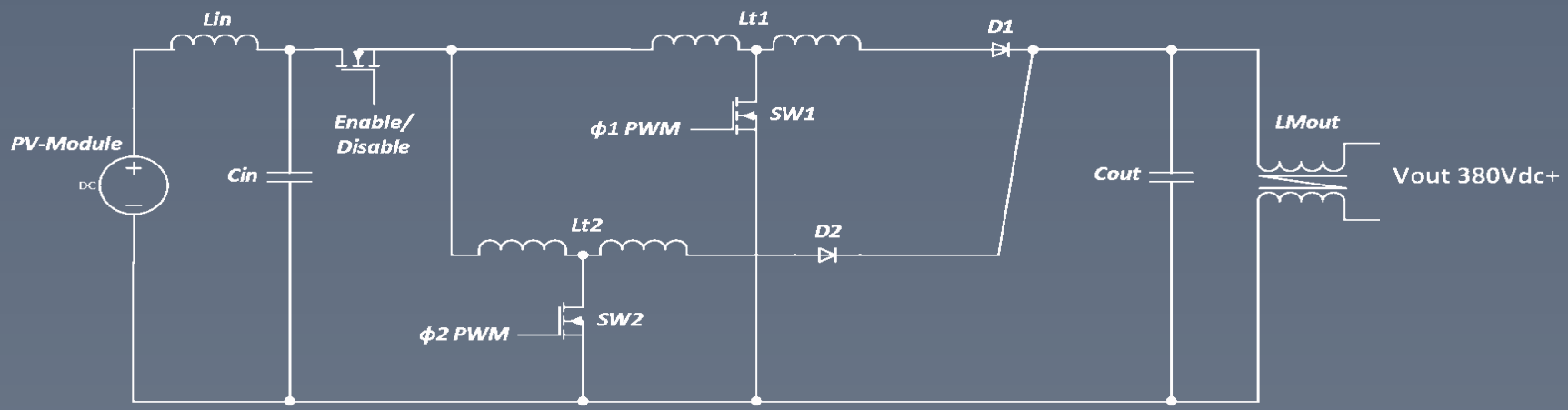
Conventional Series Strings	Parallel DC
Panels and strings must match	No matching or balancing required
Weakest panel sets performance	Each panel is independent
Panel voltage drives system design	Site conditions drive system design
Centrally set operating point	Each panel is optimized

DC DC Converter

Objective: *Make each PV-module an independent power generator that can feed a grid tied inverter. Eliminate the "Christmas tree Light Effect" and minimize mismatch due to shading, soiling, temperature variation and breakage.*

- Challenges
  - PV-Module Output
    - Varies from 20Vdc to 130Vdc and 2A to 10A
    - Load (inverter) varies but ranges from 250Vdc to 550Vdc input
  - Efficiency greater than 95%
  - 99.9% Max Power Point Tracking/Response
  - Utilize Maximum Wire Ampacity – Maximum Power Transport
  - Reliable, 25 year operating life
  - Safety features
  - Easy to design-in and install

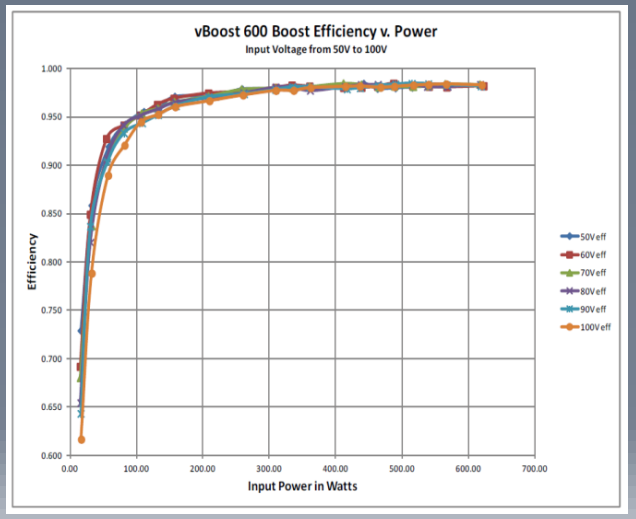
Boost Topology



- Tapped Inductor Boost Switcher
  - Opens up Duty Cycle for High Gain Boost
  - Performs PV-module MPPT
  - Impedance Matching for MPPT
  - Poly Phase For Flat Efficiency Curve across Power Range
  - 50 kHz Switching Frequency – 100kHz at Output Filters

600W Boost Converter

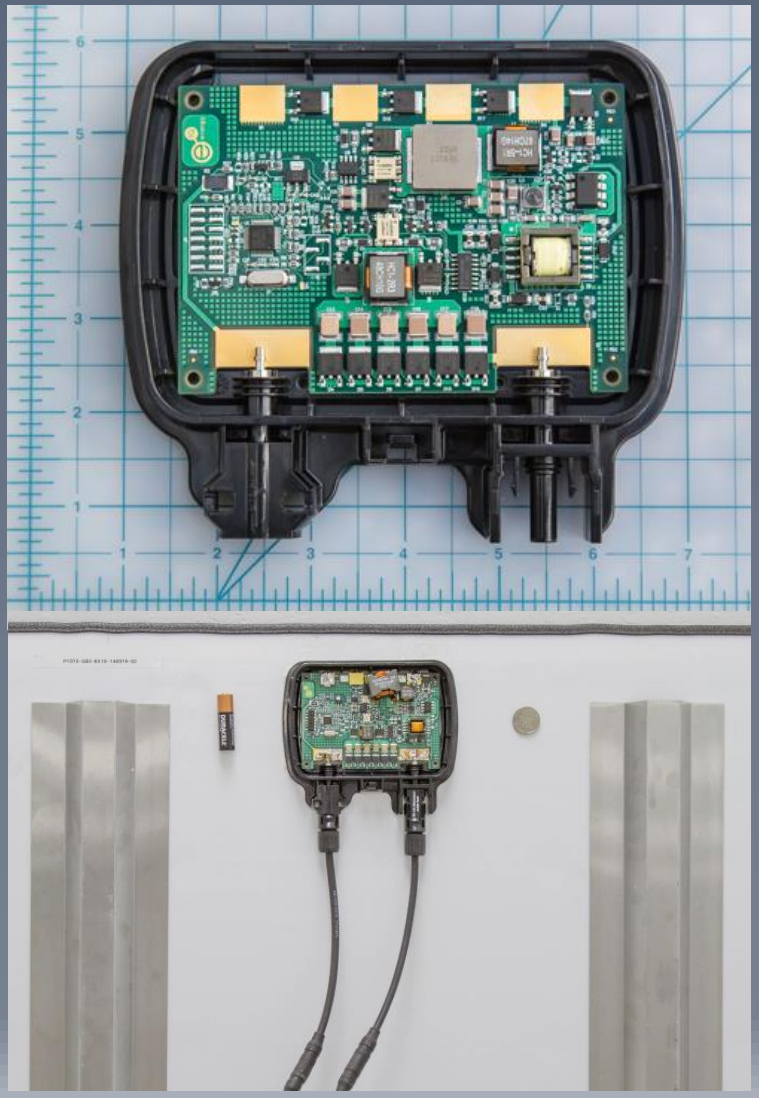
Parameter	Value	
Vin max	115V (Vmp)	125V (Voc)
Vin min	40V	
Iin max	10A	
Vout	320V min	400V max (420V Standby)
Iout	1.75A max	



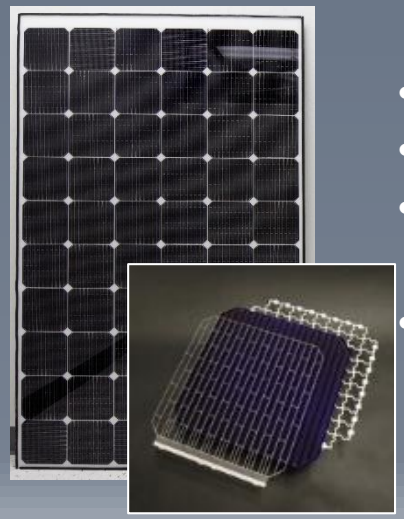
Peak Efficiency 98.3%

Integrated Boost

Powered by SunShot
U.S. Department of Energy



Parameter	Value	
Vin max	100V (Vmp)	115V (Voc)
Vin min	25V	
Iin max	10A	
Vout	320V min	400V max (420V Standby)
Iout	1A max	

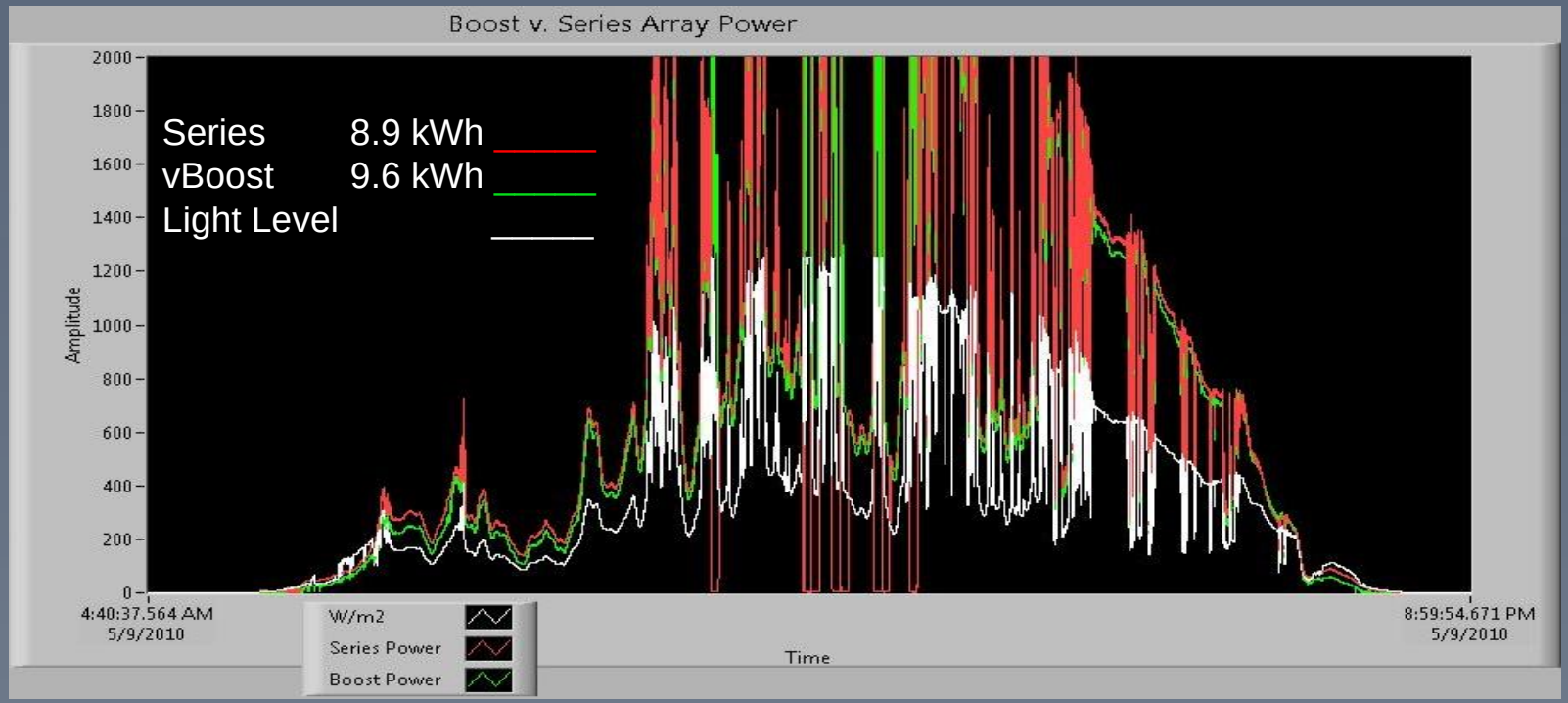


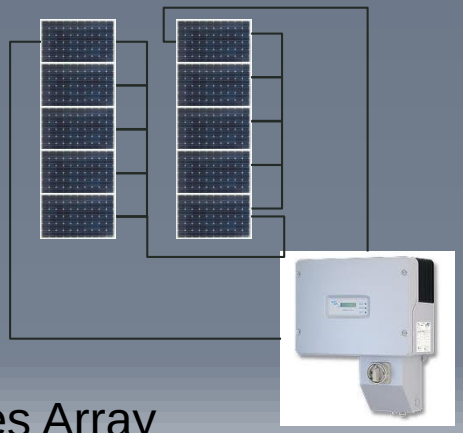
- Waaree PV-Module
- 250W x-Si
- Using GTAT Merlin Cell Interconnection
- 12 kg vs. 24 kg

Performance Advantages

Performance Challenge	Operating Advantage	Comment
Typical installation	6%	Typical operating conditions, minor shading
Multi-Facing Roof Installation	30%	Allows larger installations on varying roof orientations
Cloudy Climates	7.5%	DC:DC minimizes impacts of varying light conditions
Effects of aging, soiling, environmental conditions	14%	Optimization of each DC:DC boost system minimizes negative impact of module issues
Shaded Conditions	35%	Shade challenged sites show dramatically better performance with DC:DC

7.5%+ More Energy on Cloudy Day

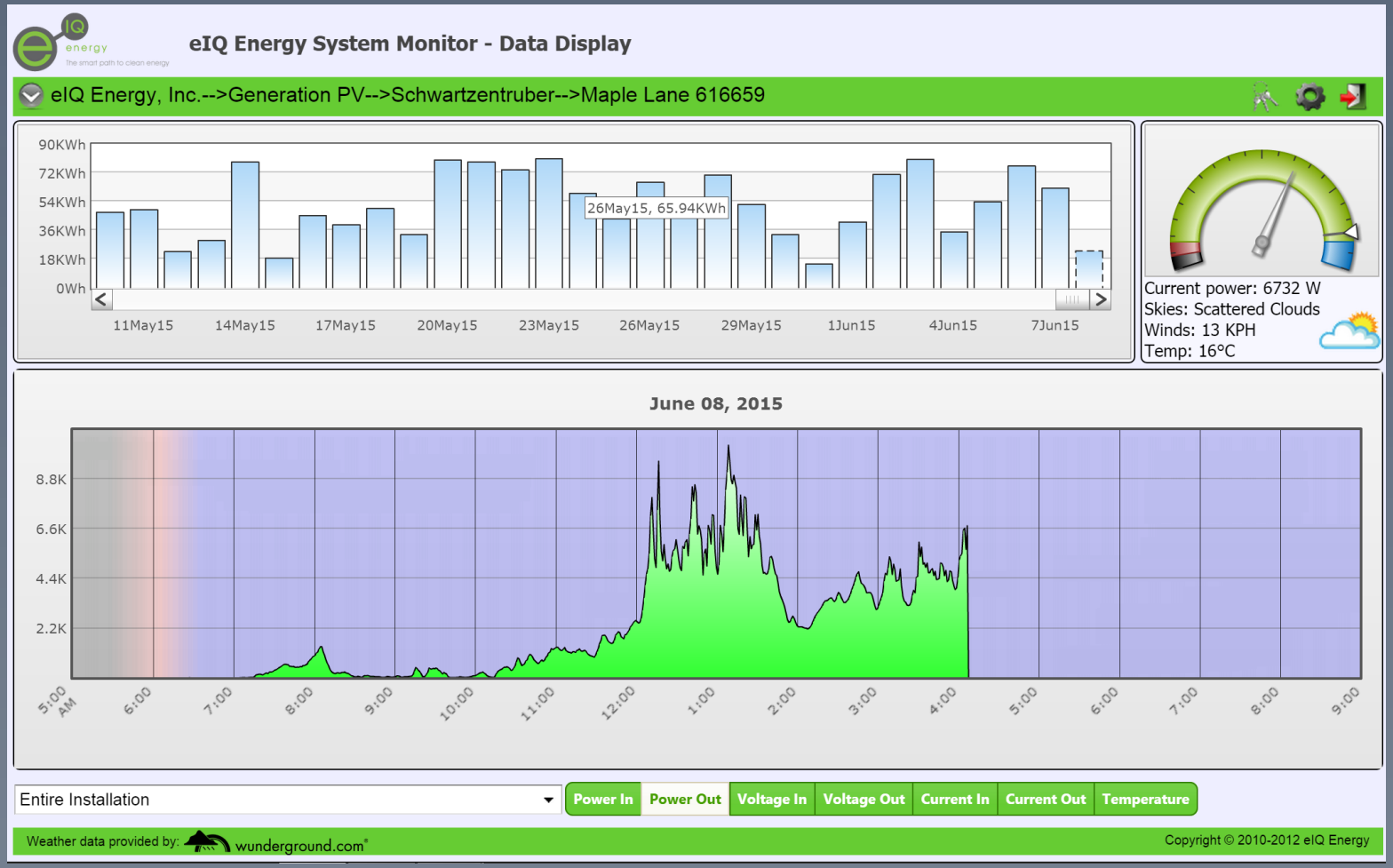




Series Array

vBoost Array

PV-Module Level Monitoring



Power Line Communications: 120kHz over HVDC, CANBUS Protocol

Cost Advantages

- PV-Modules with vBoost Technology
  - $1.20/W MSRP
  - HVDC Bus Wiring Included
- Savings
  - More Watts per 10AWG wire
    - 5,500W max with 600V series string
    - ~10,000W with parallel vBoost
  - In-line Fuses can replace combiner boxes
  - Lower Design Costs
    - Faster Designs
    - Flexibility: PV-modules at optimum pricing at installation time

  Higher Production
    - 5-15%

Reliability

- Less than 0.5% Field Failures (Population~10k)
- MTBF (vB|350/600) >1,000 Years
- No Electrolytic Capacitors
- NEMA 6 (IP67) Enclosure
- Device Specifications less than 50% Stress
- Thermal Output Power Fold-back
- Heat Spreaders to case
- Soft Start, OVP and OCP

Safety

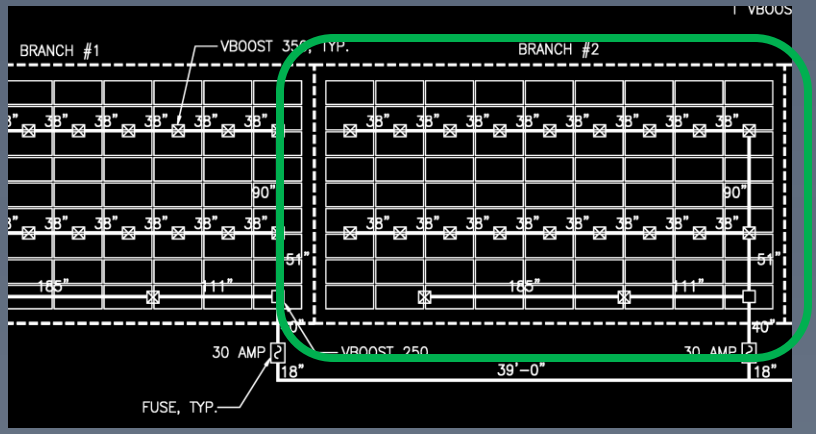
- Plug & Play, MC4 Type Polarity Keyed Connectors
- 50Vdc Output Until Commissioned
- Commissioned and Tested After Install
- Remote Shut-Down via PLC
- OVP and OCP with Rapid Shutdown

LV / EMC Directives

UL1741	EN60950
IEEE 1547.1	EN61000
FCC Part 15, Class B	NEMA Type 4 / IP66

PV Module Connector: NEC2008 MC3/MC4
vBoost Bus Connector: NEC 2008 40A

Rapid Design and Deployment

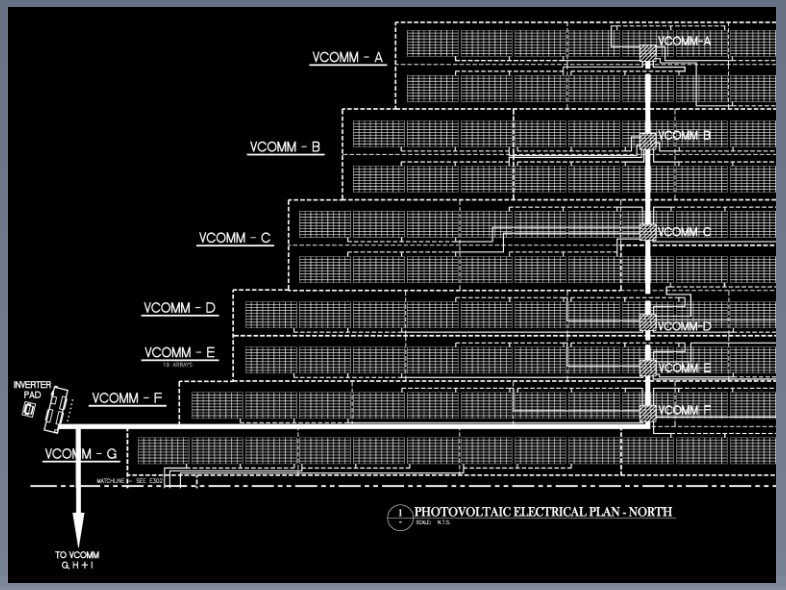


From a Single Block…..

(81 Panels connected with 20 vB|350 and 1 vB|250)

….To a 1.2MW Layout

Click and Repeat

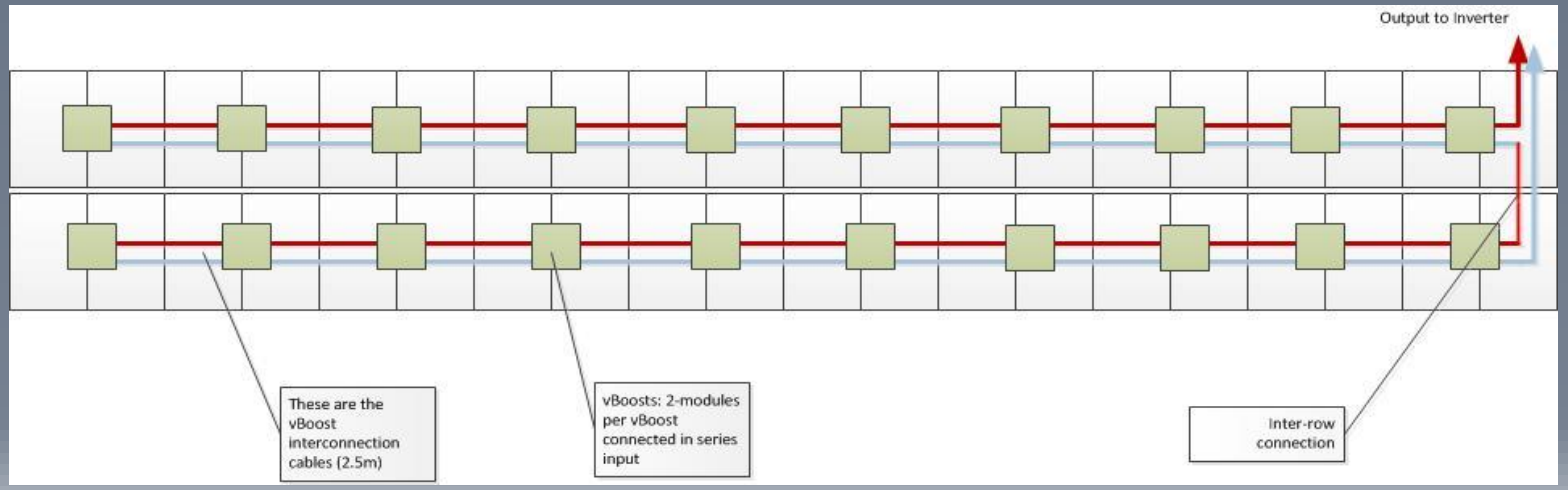


1,000Vdc Applications

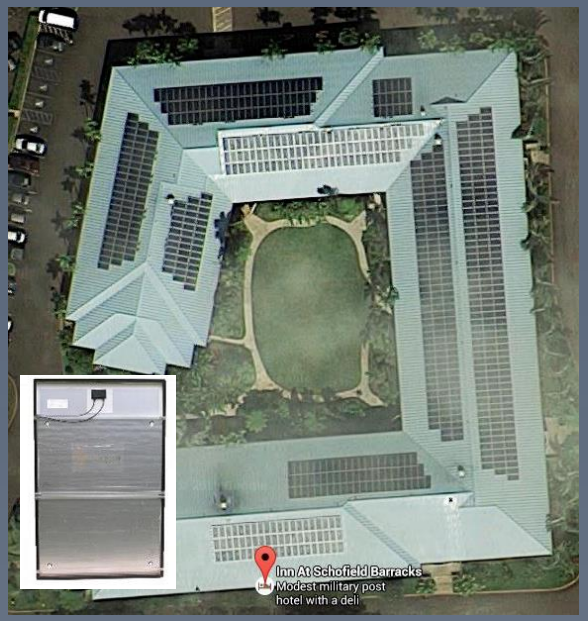
For Retrofit application in Hungary where the line voltage is 1000V.

Rows of vBoosts were connected serially to add their output voltages to produce 760Vdc

Increase in production compared to standard string was ~13%



CdTe, a-Si & x-Si
1-HVDC Bus (330Vdc)



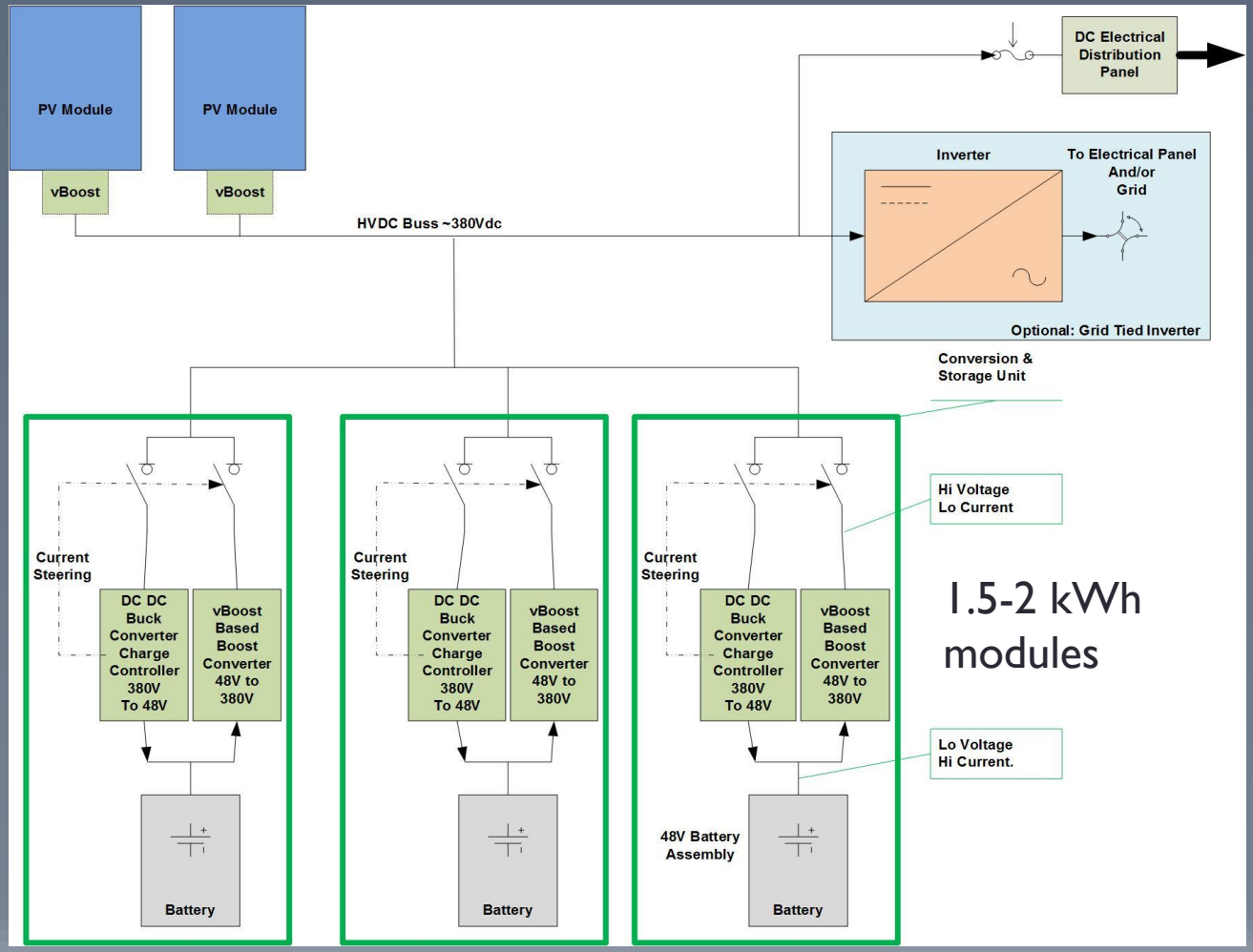
N, S, E & W Orientation
Plus Water Heating Back

Architectural PV Glass
Plus Rooftop PV

81-Module Block Design using CIS Thin Film Modules

Residential Multiple Orientations

Battery Integration – A Work In Progress



Thank You

Comments, Questions, Discussions:

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