Efficient and Reliable 2kV SiC Power Module for DC Infrastructure and Renewables

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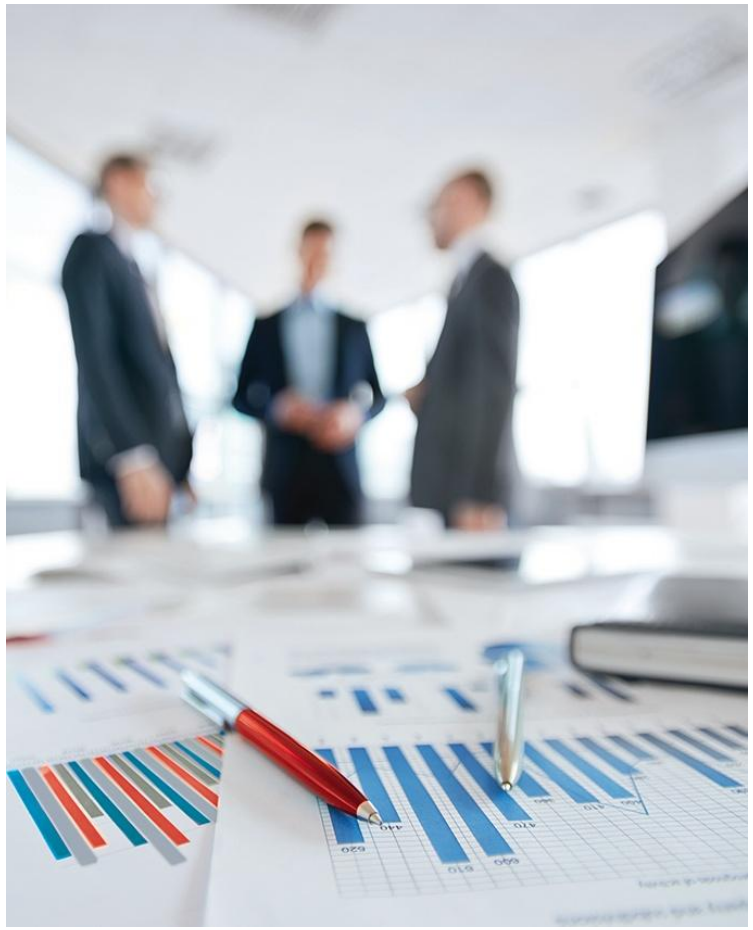
Bodo's
Wide Bandgap
Event 2025

Making WBG Designs Happen

SiC

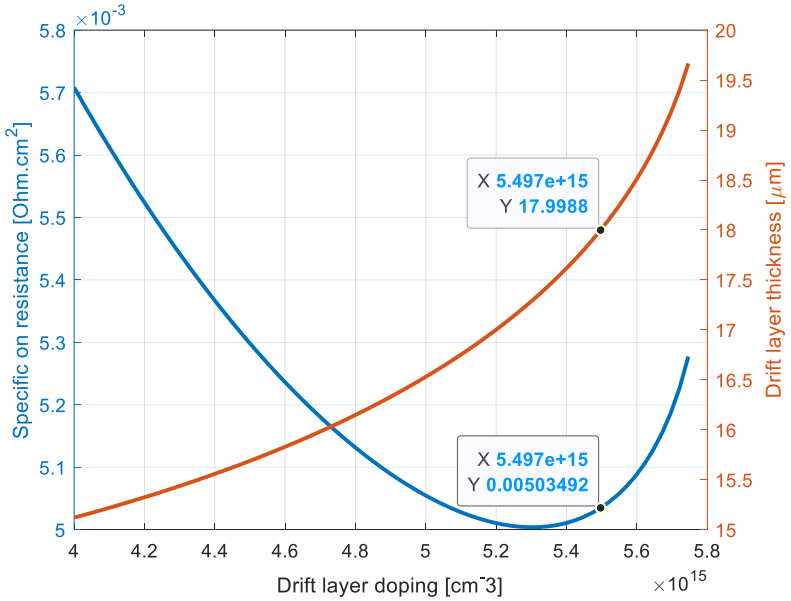
Agenda



1. The Impacts of SiC Voltage Class
2. Exemplary Solar and BESS Application
3. Operating Results
4. Additional Benefits
5. Conclusions

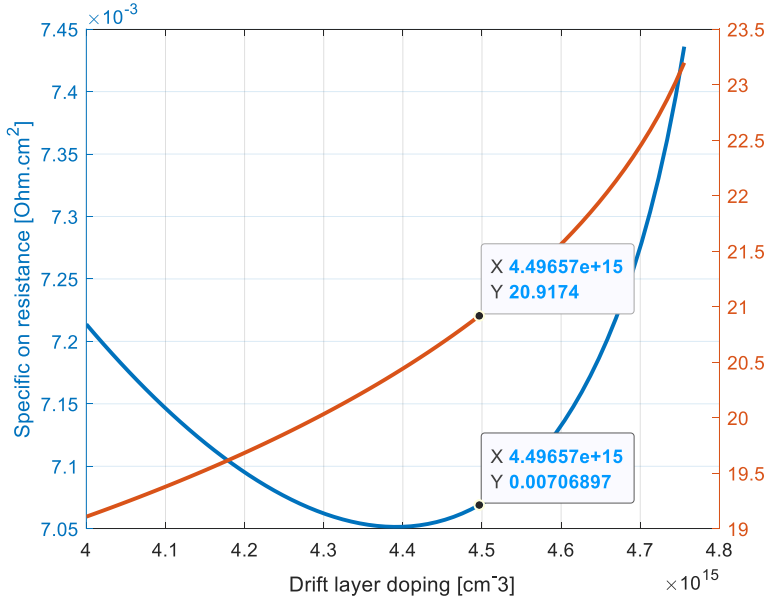
SiC Chip Design
Impact of Voltage Class on Fabrication

Blocking Voltage:**2000V**



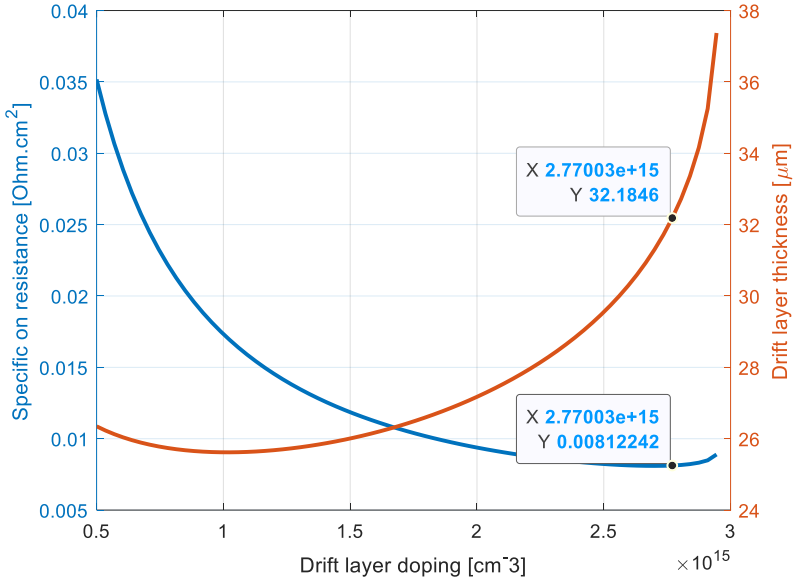
18 µm epitaxial layer needed

Blocking Voltage:**2300V**



21 µm epitaxial layer needed

Blocking Voltage:**3300V**

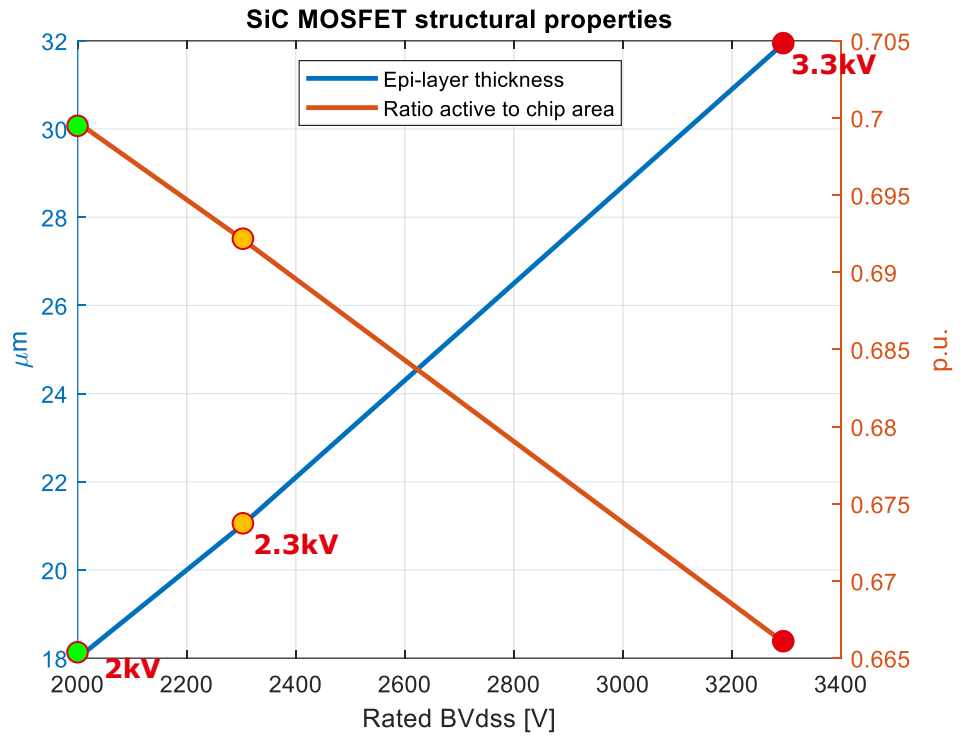


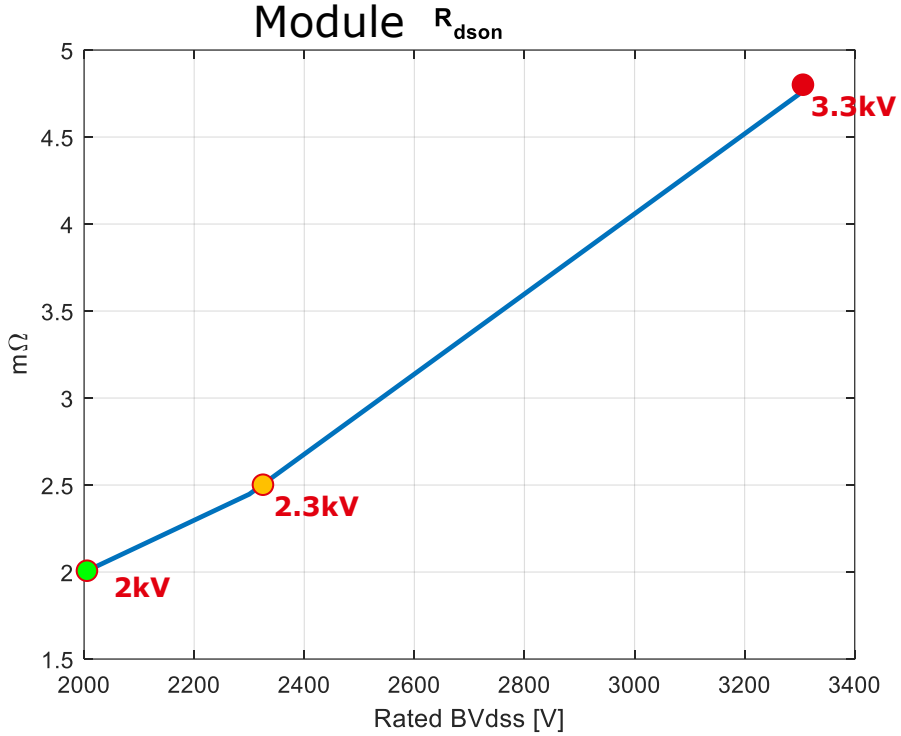
32 µm epitaxial layer needed

Voltage Class	Drift Layer Thickness	Typical Growth Rate	Estimated Growth Time	Cost Impact
1200V				Moderate
2000V	~20–30 µm	10–20 µm/hr	~1–3 hrs	High
3300V	~30–50 µm	10–20 µm/hr	~2–5 hrs	Very High

SiC Chip Design
Impact of Voltage Class on Structure/Module

Assumption: same number of chips and same brute (total) chip area for all voltage classes



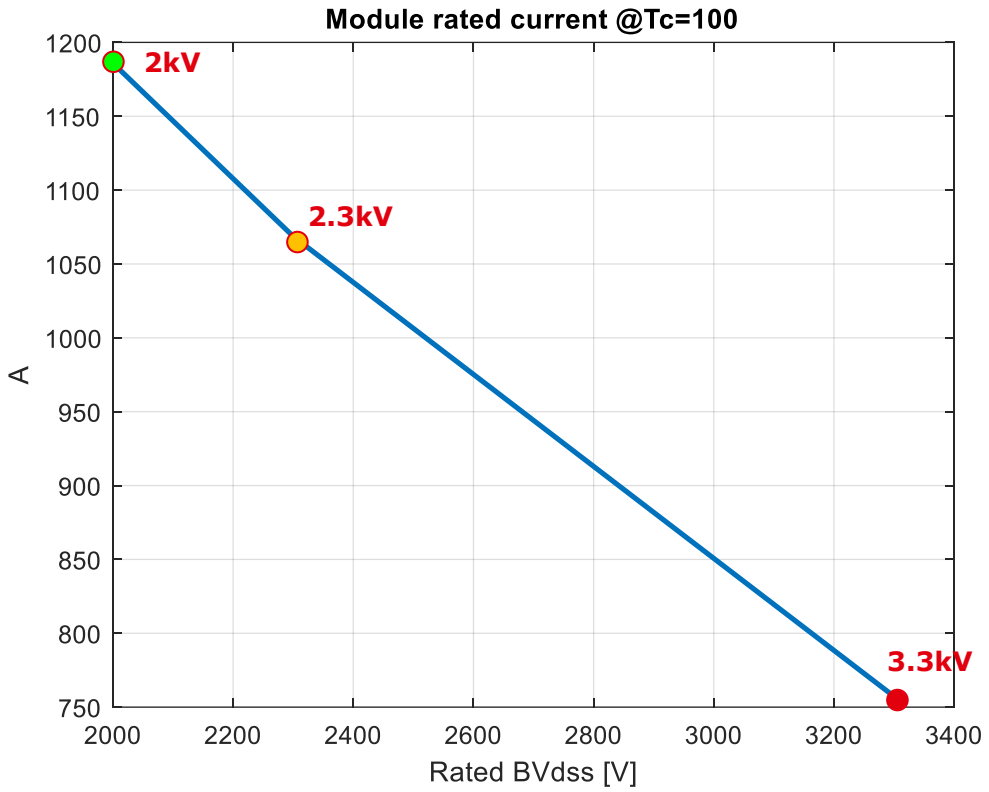


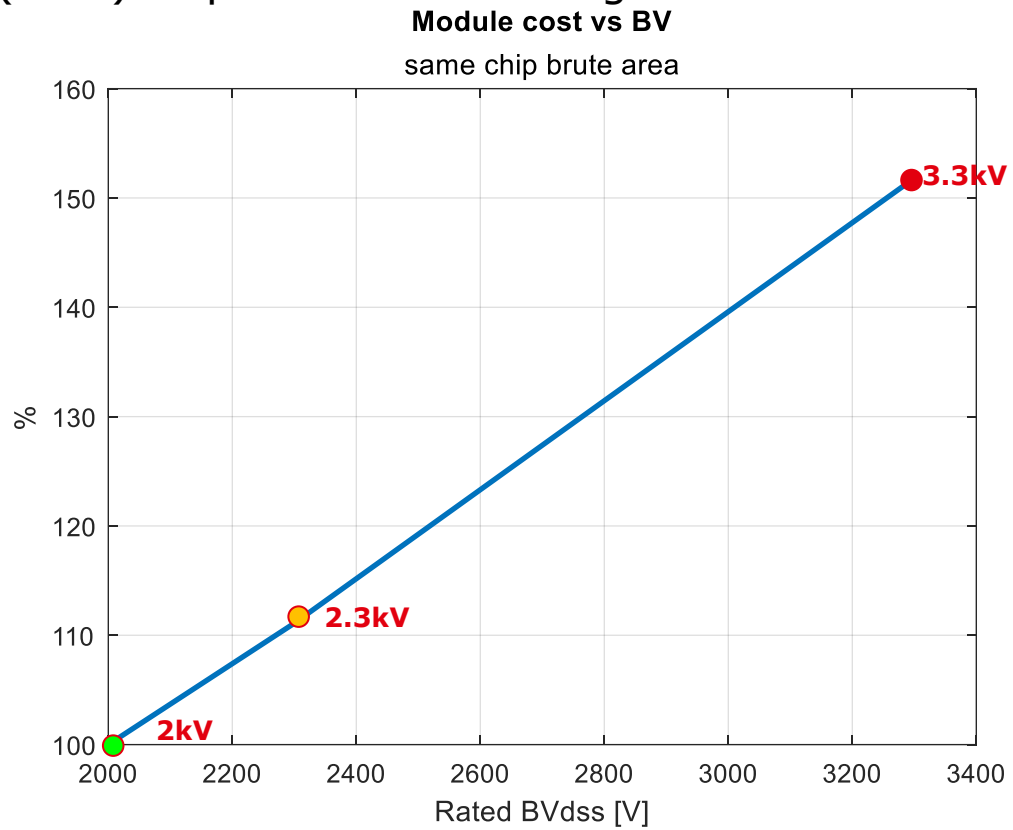
- Edge termination grows with voltage class
- Increase number of floating field rings

- Resulting $R_{DSon\_150°C}$ with same MOSFET head at all voltage classes only *active area* and *epi-layer* changes

SiC Chip Design
Impact of Voltage Class on Module Ampacity and Cost

Assumption: same number of chips and same brute (total) chip area for all voltage classes



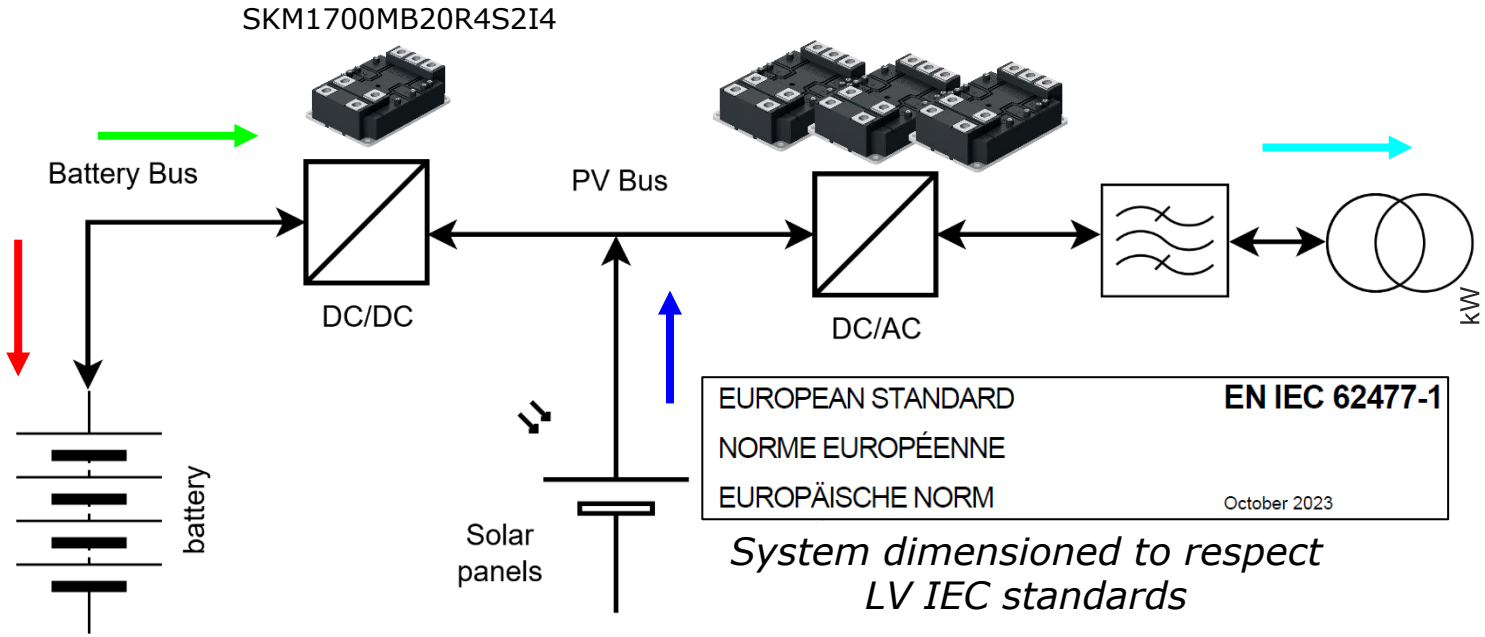


- DC current rating for modules
- *Active area* reduces with BV while ceramic thickness increases

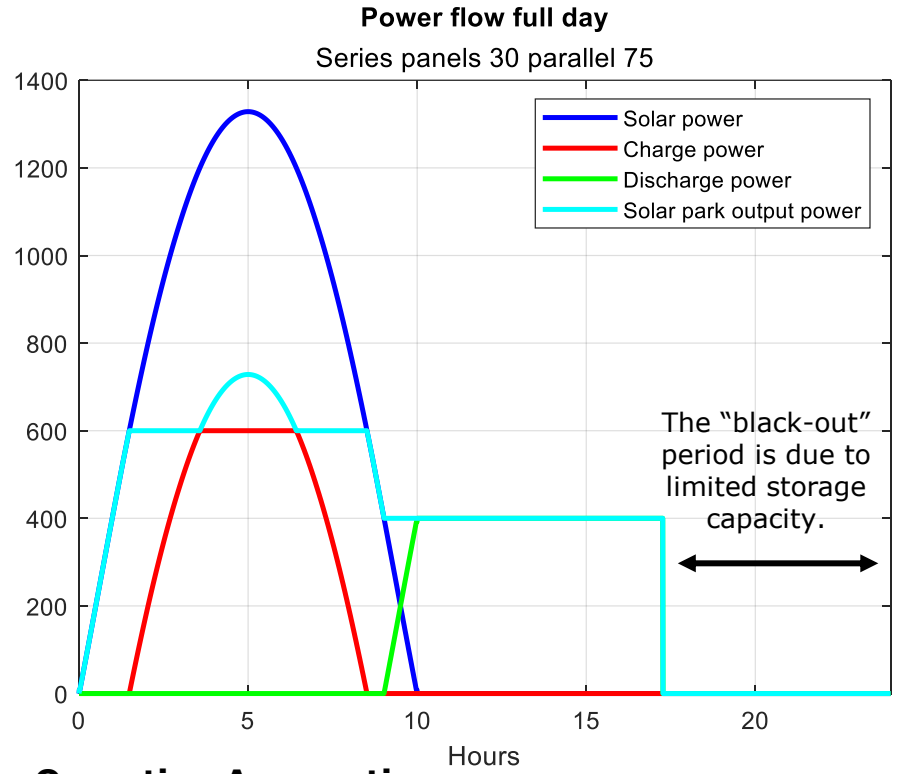
Compared to a 2kV module

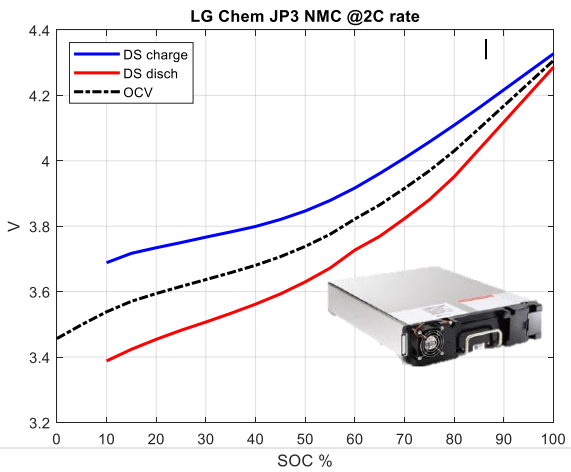
- 2.3 kV costs 10% more
- 3.3 kV costs 50% more

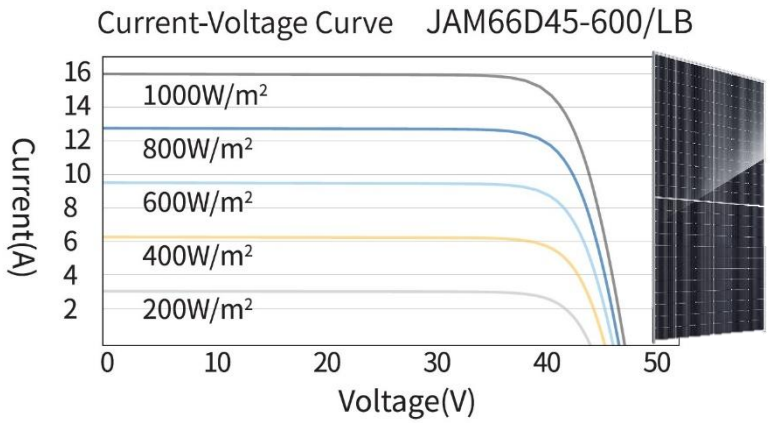
Example
Utility PV Installation with BESS



System dimensioned to respect LV IEC standards



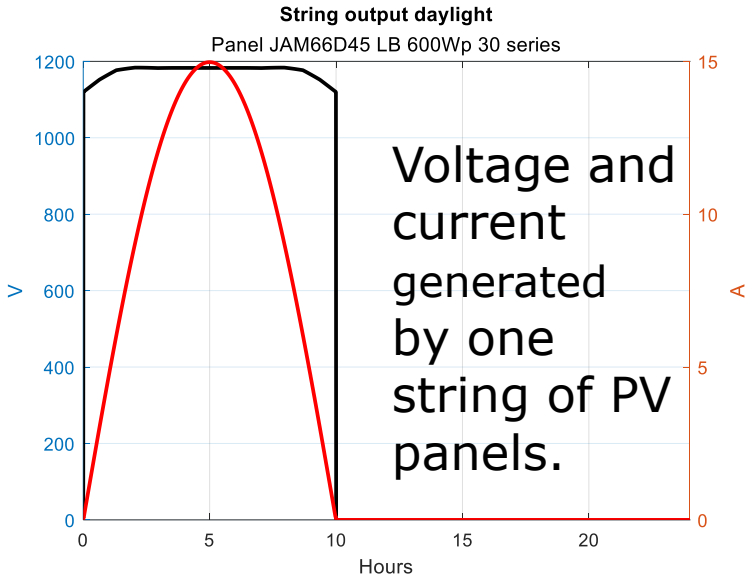




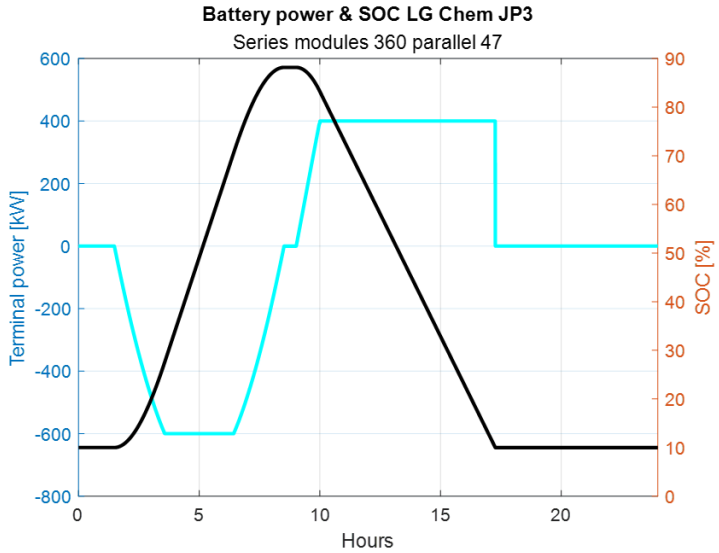
Operating Assumptions

- Sell power when sun shines
- Recharge battery when irradiation >8kW/string
- Charge power at DC/DC limited to 600kW
- Battery system dimensioned to:
  - 1500V max when full charge
  - 10 to 90% SOC swing once per day
  - 3.97MWh storage with NMC LG cells

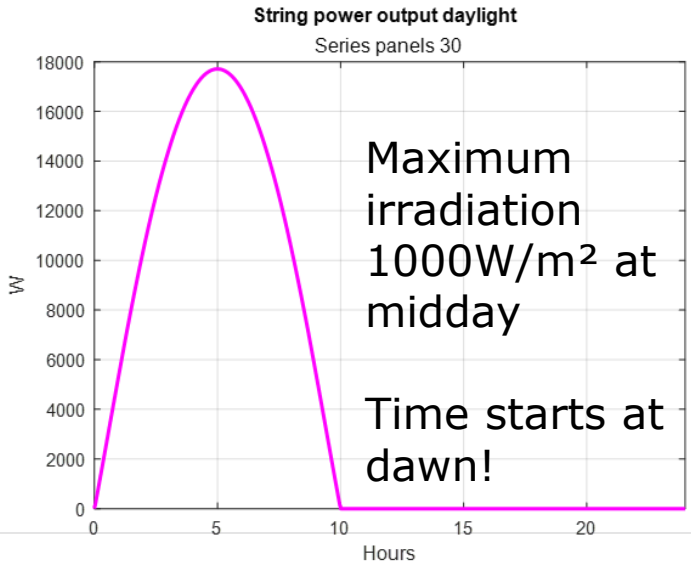
System variables
PV panels and battery in operation



Voltage and current generated by one string of PV panels.

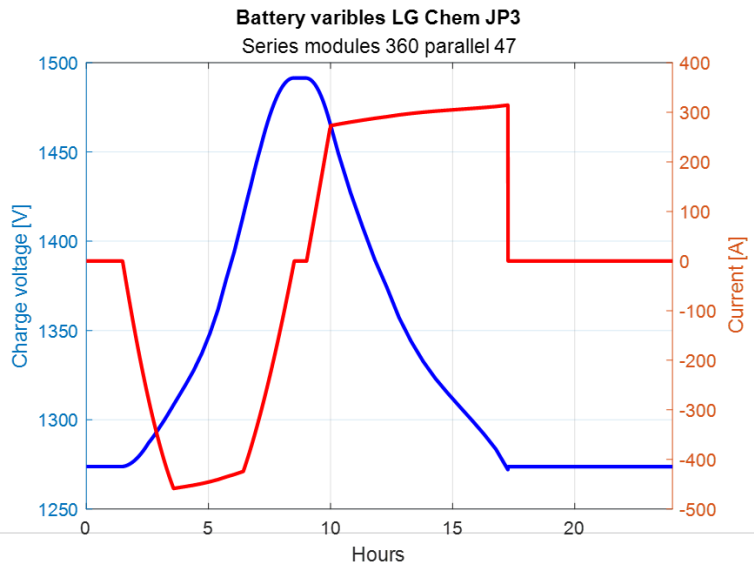


Cyclic operation 10% to 90% SOC and back
Charge rate up to 600kW
Discharge rate limited to 400kW (operation driven, not converter)



Maximum irradiation 1000W/m² at midday

Time starts at dawn!

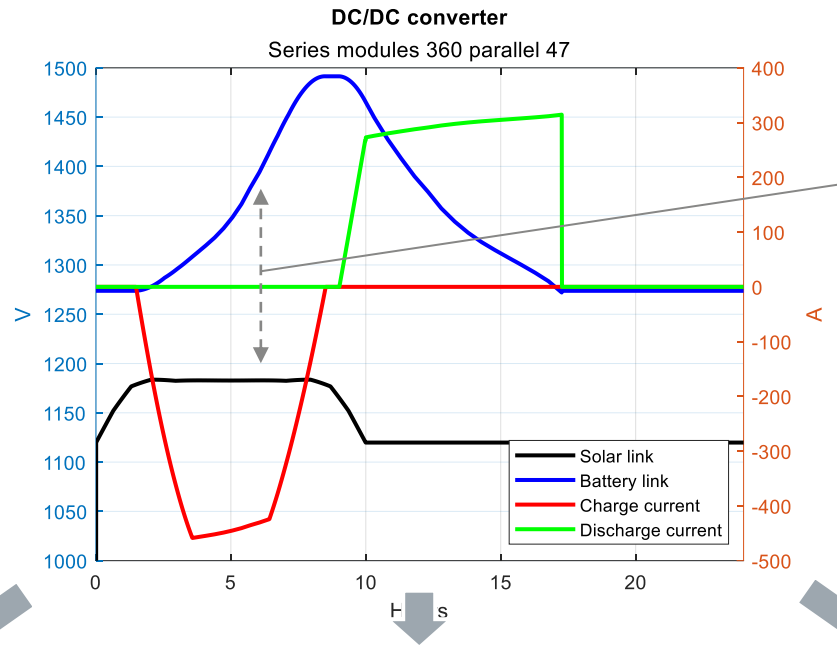


Voltage reaches ~1450V when 90% charged
Drops down to 1275 V when 10% at discharge
47 strings in parallel of the chosen JP3 cell 235Wh

Operating Results
DC/DC Converter

Assumptions for each voltage class:

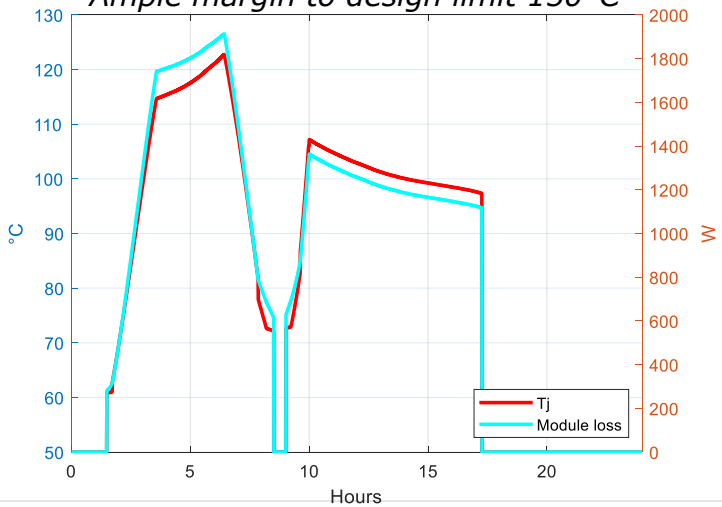
- Same module type (“SEMITRANS 20”)
- Equal number of chips
- Equal total chip area
- 12kHz switching frequency
- in boost / buck converter
- Water cooled, 5 l/min
- T_{inlet} = 50°C
- $R_{th(module)}$ = 22K/kW



This gap enables buck or boost operation and justifies the number of PV panels in series.

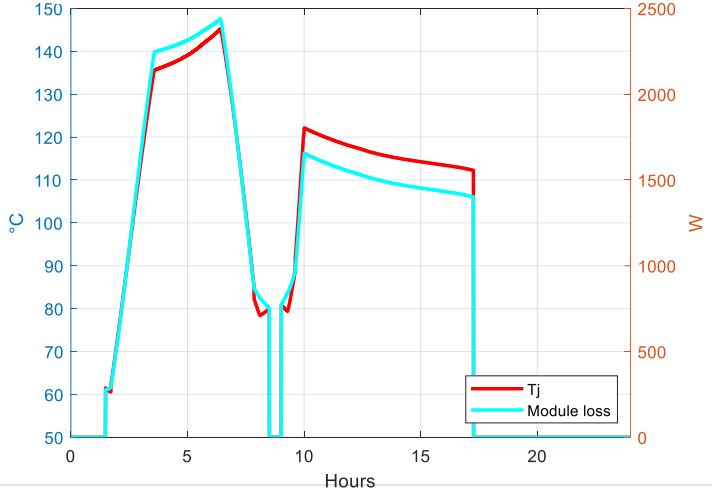
2kV device:

Ample margin to design limit 150°C



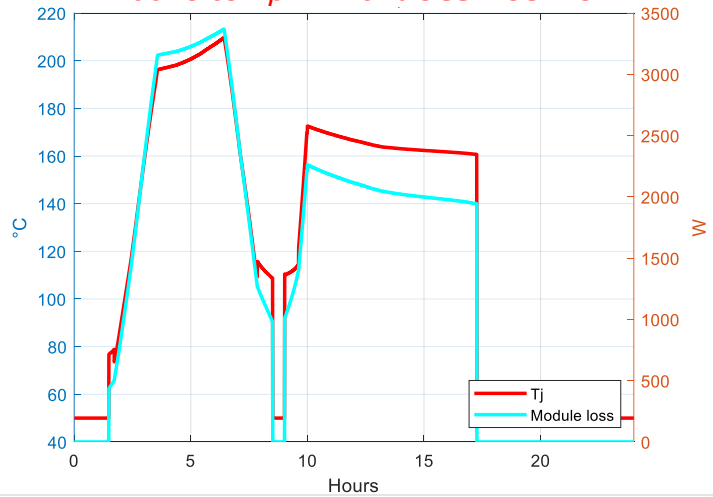
2.2kV device:

20°C hotter than the 2kV device

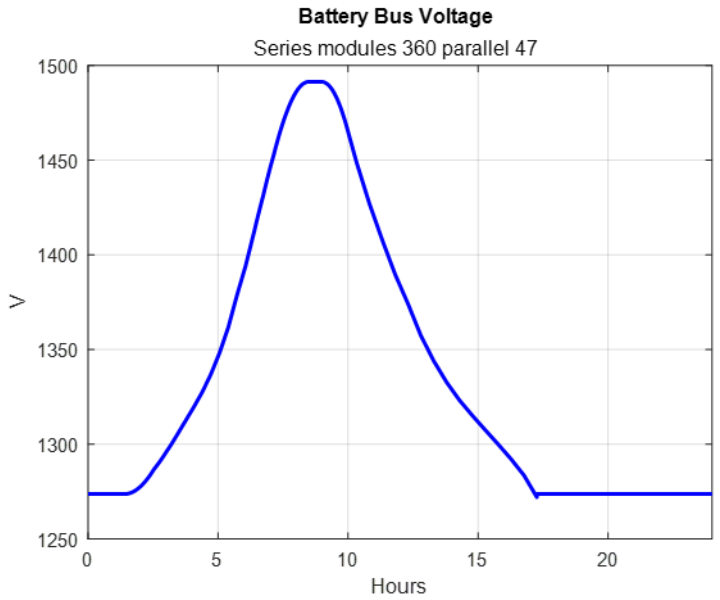


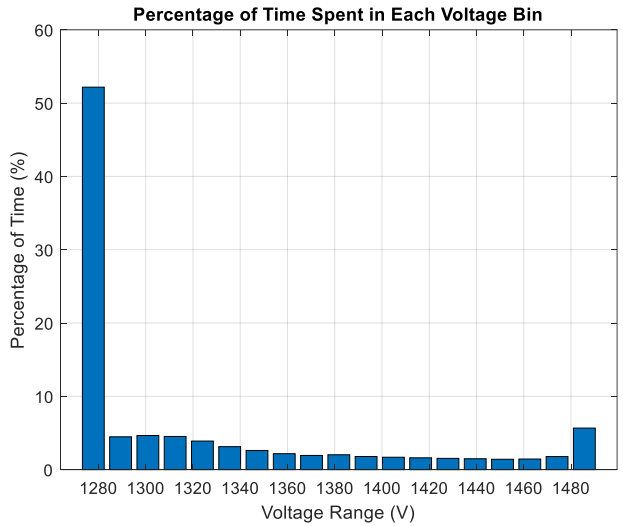
3.3kV device:

Above temp. limit: ***does not work!***



Terrestrial cosmic radiation





Cosmic Ray Endurance

- Left: Battery voltage operation daily
- Right: Battery voltage operation histogram

Altitude	0m	3000m
MTBF, 2kV device	14.5k yrs	**1821 yrs**

Based on neutron-lab measurements

No problem for 2kV devices!

EU & US Export Control Regulations

European Commission

Trade and Economic Security

U.S. DEPARTMENT OF STATE
Directorate of Defense Trade Controls

3A228 Switching devices, as follows:

c. Modules or assemblies with a fast switching function, other than those specified in 3A001.g. or 3A001.h., having all of the following characteristics:

1. Anode peak voltage rating greater than 2 kV;
2. Anode peak current rating of 500 A or more; and
3. Turn-on time of 1 µs or less.

Export Controls

- High-current (>500A), high-voltage (>2kV) power semiconductor modules are export controlled by the EU and USA
- 2.3kV/3.3kV modules above 500A are affected
- Additional logistics/legal/service costs

No problem for 2kV devices!

Conclusions

Blocking voltage	2000V	2300V	3300V
R_{DSon} 150°C	2 mΩ	+25%	+135%
DC rating	1150A	1050A	750A
Cost	100%	+10%	+50%
Buck 600kW 12kHz	120°C	145°C	210°C
MBTF TCR 1475/1200V	1821 years	n.a.	n.a.
Dual use EU/USA	No	Yes	Yes

All modules same brute chip area

Contact us

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