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2.3 kV SiC MOSFET with New High-Power Package HPnC for 1500 VDC Applications

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Introduction

- ✓ System voltage of renewable energy applications is increasing to improve energy transfer efficiency.
- ✓ 1500 VDC system voltage with 3-level topology was the mainstream in the market.
- ✓ 2300 V rated SiC MOSFET with HPnC (High Power next Core) package is newly developed for 1500 VDC system voltage with 2-level topology.

System Voltages and Power Device Ratings in Renewable Energy Applications

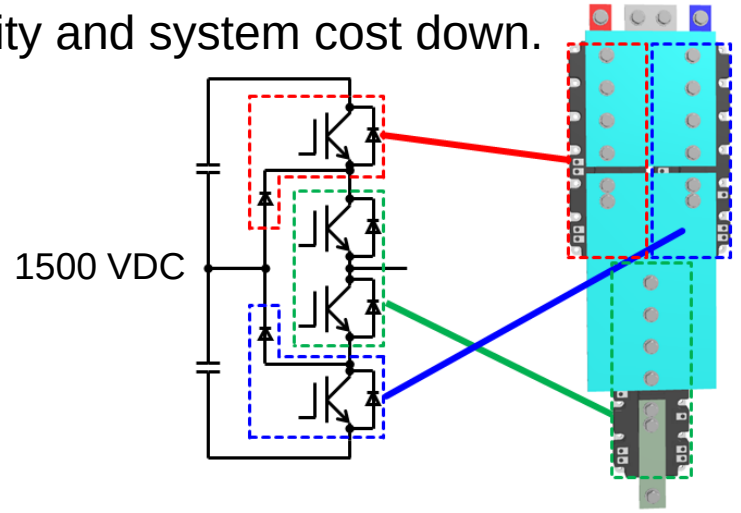
Applications	System Voltage		Power Device Rating	
	AC voltage	DC voltage	3-level	2-level
Solar (PV)	-	1000 V	-	1700 V
	-	**1500 V**	1200 V	**2300 V** NEW
Wind Power	690 V	1000 V	-	1700 V
	990 V	**1500 V**	1200 V	**2300 V** NEW
	1140 V (China)	1800 V	1700 V	-
	1800 V (China)	**2500 V**	**2300V** NEW	-

Introduction

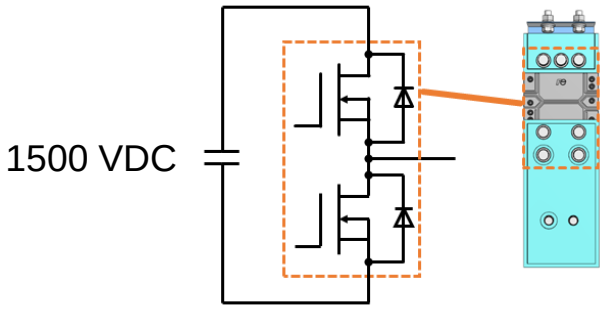
- ✓ 2-level topology with 2300 V rated SiC MOSFET shows several advantages for 1500 VDC applications.
- ✓ Comparing to 3-level topology with Si IGBT, 2-level topology with SiC MOSFET significantly reduces number of device and foot print and contributes enhancement of power density and system cost down.

Comparison between 3-level (Si) and 2-level (SiC) for 1500 VDC application

	3-level (Si)	2-level (SiC)
Number of devices	18 ☹ 2x1800 A/1200 V IGBTs x 3 x 3 phase	9 ☺ 3x1200 A / 2300 V MOSFETs x 3 phase
Footprint	100% ☹	33% ☺
Power losses	100% ☹	87% ☺



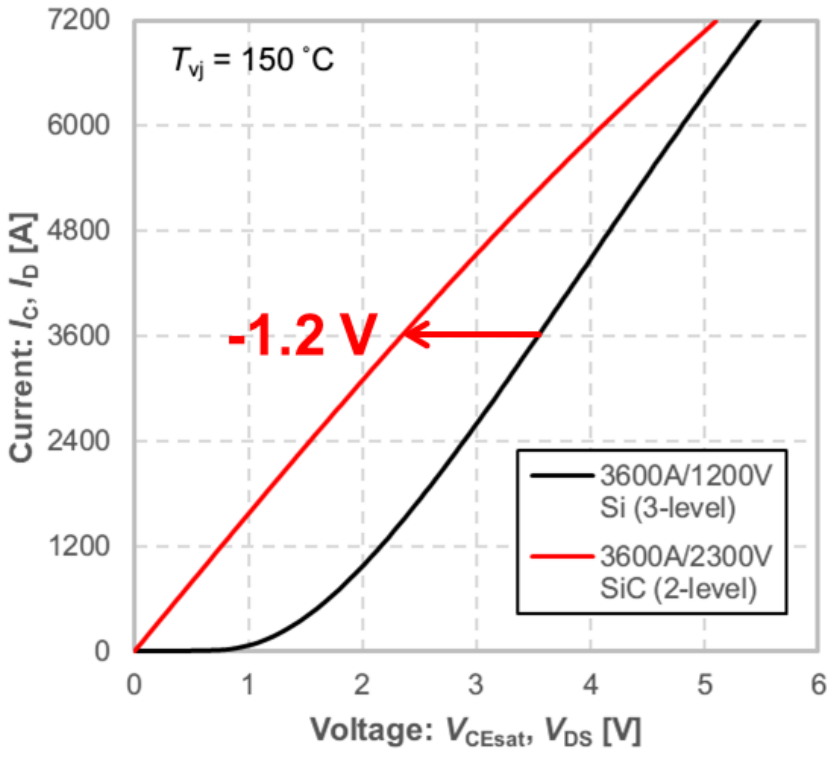
(a) 3-level with 1200 V rated 2in1 Si IGBTs



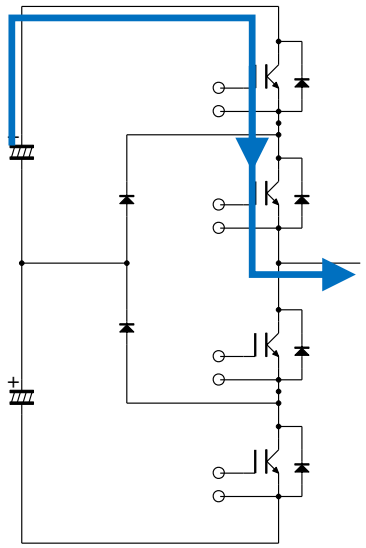
(b) 2-level with 2300 V rated 2in1 SiC MOSFETs

On-state Voltage Si IGBTs vs. SiC MOSFETs

- ✓ Comparing to 3-level topology with Si IGBTs, on-state voltage of 2-level topology with SiC MOSFETs is 1.2 V lower at the nominal current.

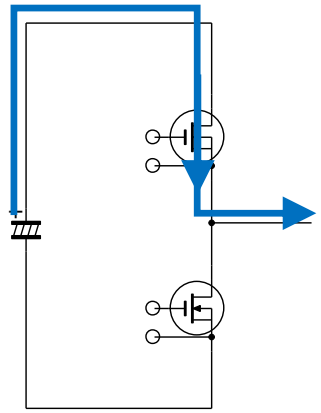


3-level (Si)



(a) 3-level with Si-IGBT
3600A / 1200V rating
(2 x 1800A/1200V rating)

2-level (SiC)



(b) 2-level with SiC MOSFET
3600A / 2300V rating
(3 x 1200A/2300V rating)

On-state Voltage Si FWDs vs. SiC MOSFETs

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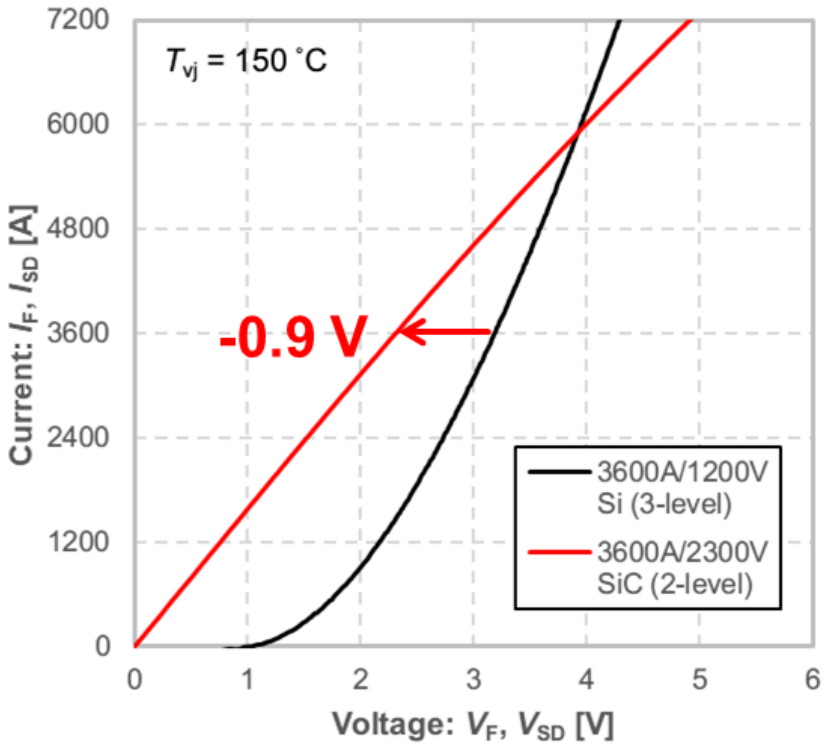
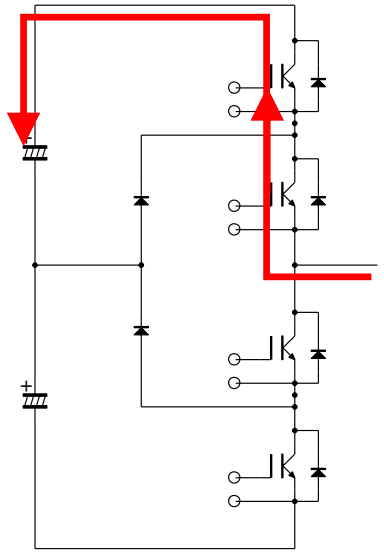
✓ Comparing to 3-level topology with Si FWDs, on-state voltage of 2-level topology with SiC MOSFETs (body diode) is 0.9 V lower at the nominal current.

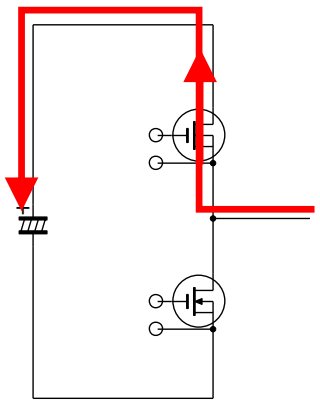


3-level (Si)



(a) 3-level with Si-FWD
3600A / 1200V rating
(2 x 1800A/1200V rating)

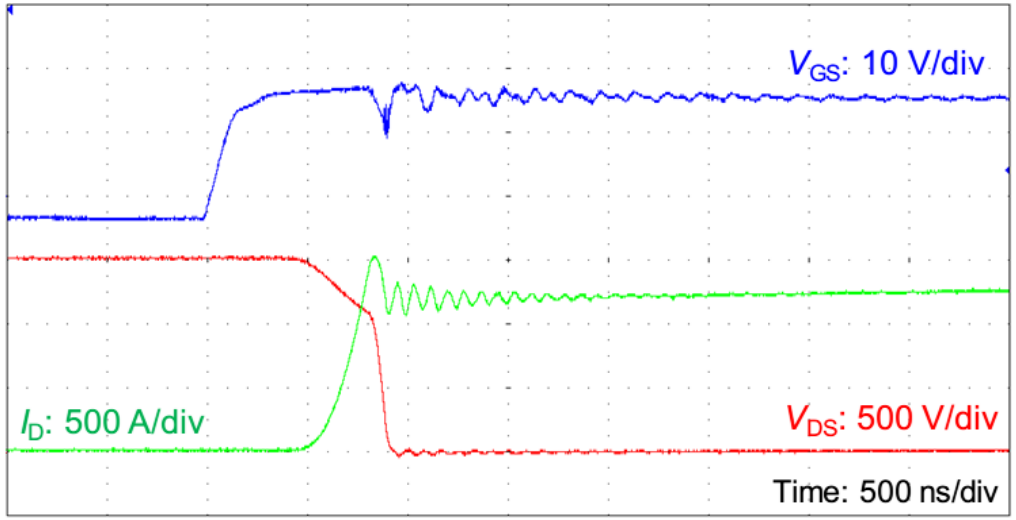
2-level (SiC)



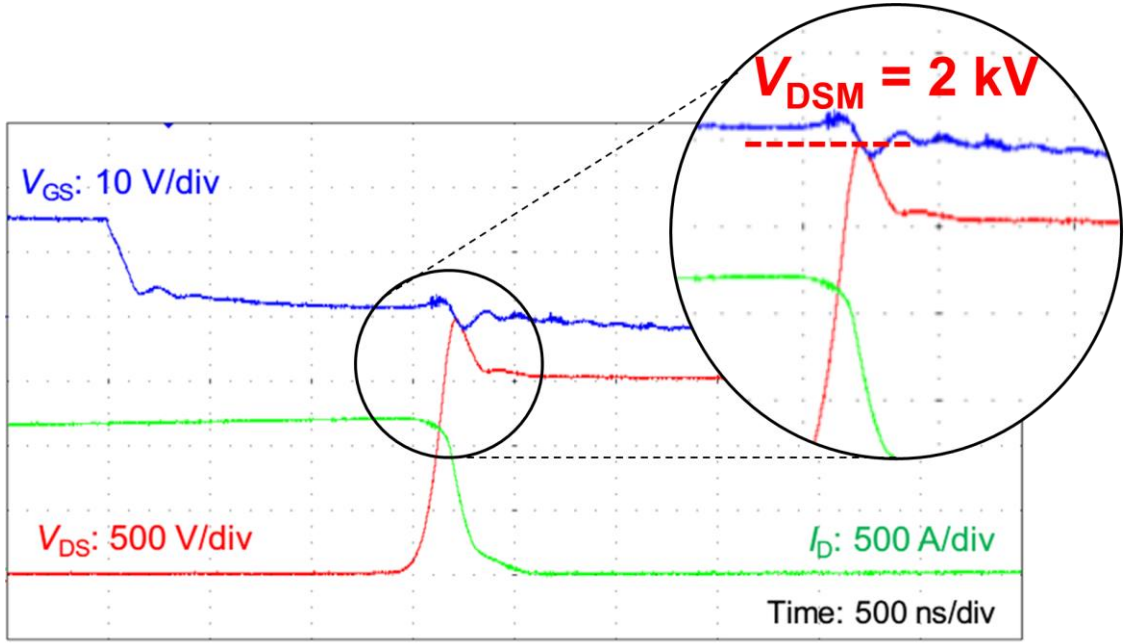
(b) 2-level with SiC MOSFET
3600A / 2300V rating
(3 x 1200A/2300V rating)

Switching Waveforms (R.T.)

- ✓ 2300V SiC MOSFET shows fast and stable switching waveform.
- ✓ Turn-off spike voltage is around 2 kV at 1500 VDC link voltage without snubber capacitors.



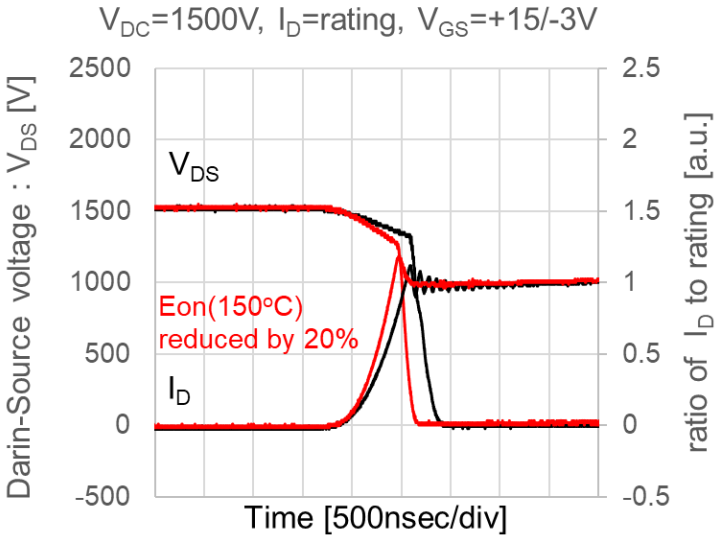
(a) Turn-on waveform



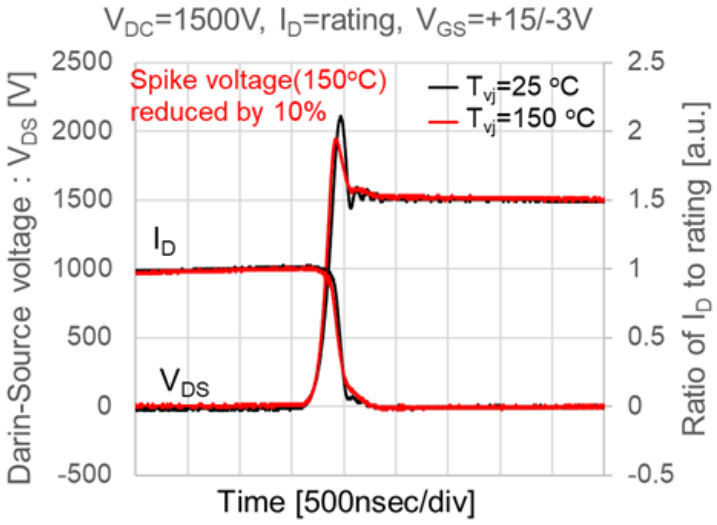
(b) Turn-off waveform

Switching Waveforms (R.T. vs. 150 ˚C)

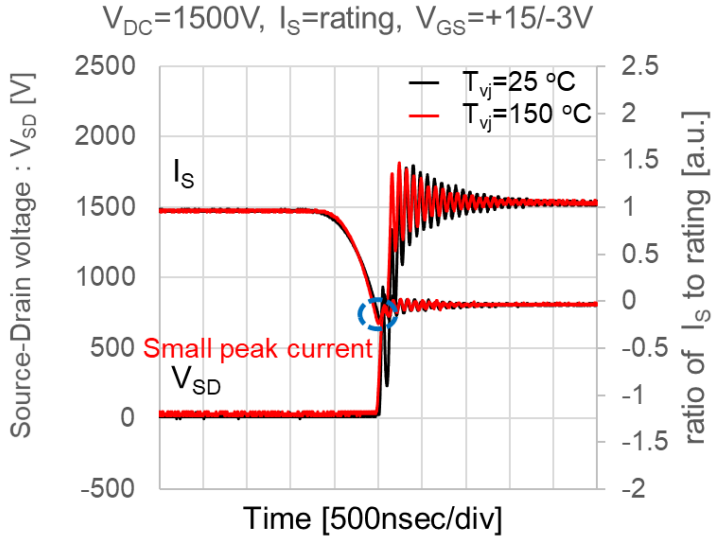
- ✓ Turn-on energy at 150 ˚C is 20 % lower than at 25 ˚C.
- ✓ Turn-off spike voltage at 150 ˚C is 10 % lower than at 25 ˚C.
- ✓ Extremely small peak current at reverse recovery.



(a) Turn-on waveform



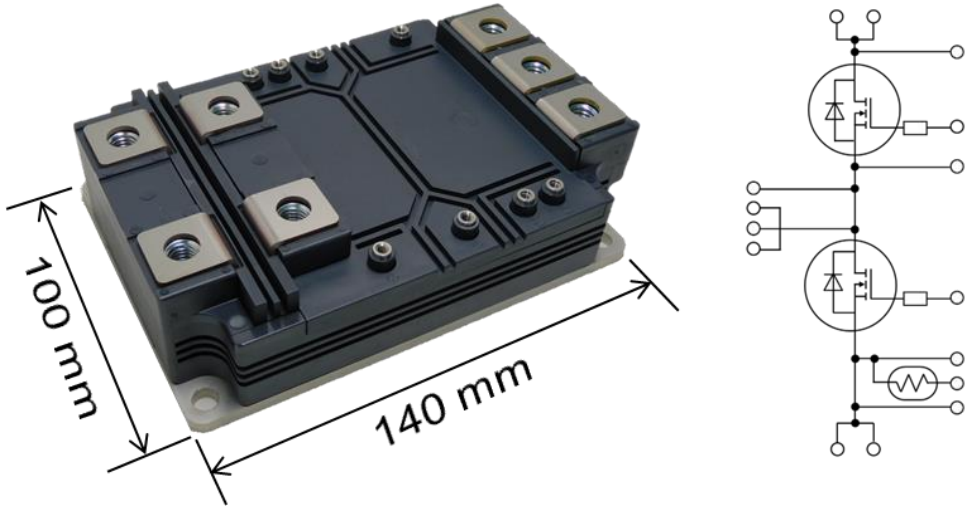
(b) Turn-off waveform



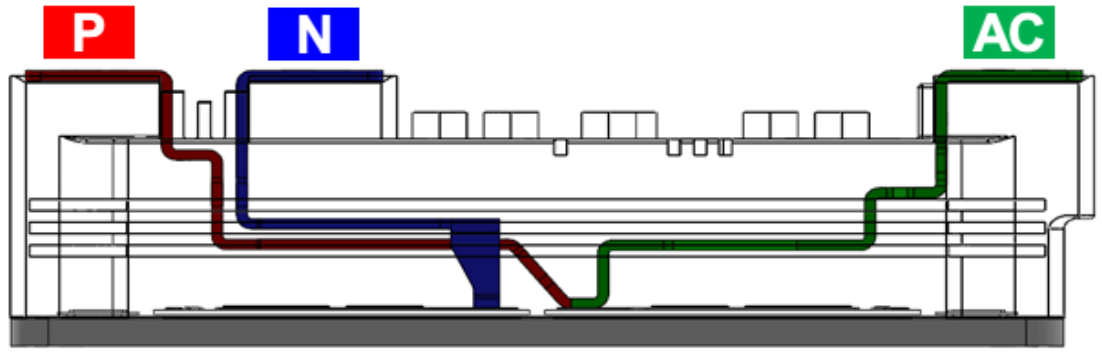
(c) Reverse recovery waveform

HPnC Package Features

- ✓ New market standard outline (100 x 140 mm) for high power applications.
- ✓ Compact and suitable package for paralleling of power modules (= more output current).
- ✓ Approximately 10 nH parasitic inductance by paralleled P-N terminals.
- ✓ High CTI (> 600) plastic resin case.



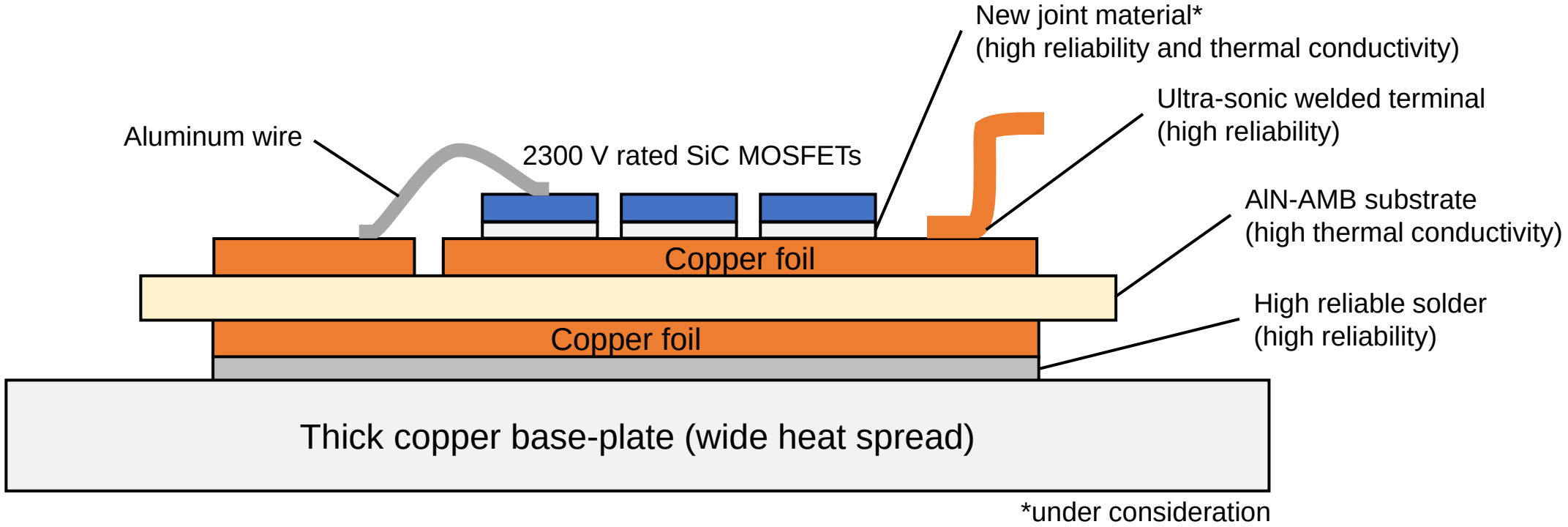
(a) HPnC package outline and equivalent circuit



(b) HPnC internal terminal structures (cross-section)

HPnC Package Technologies

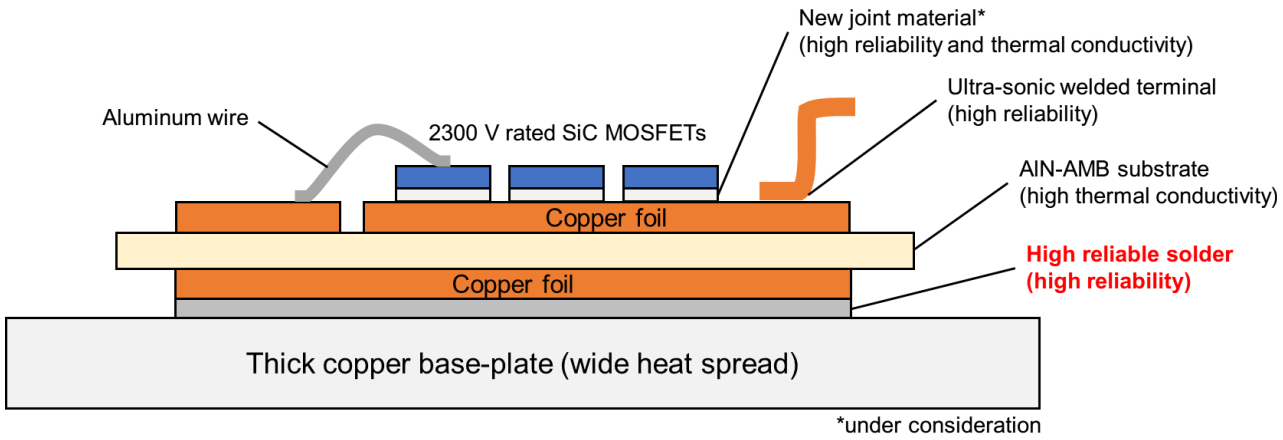
- ✓ Several technologies are applied to ensure higher reliability and better heat dissipation.
- ✓ Ultra-sonic welded terminals for high reliability.
- ✓ High thermal conductivity Aluminum Nitride (AlN) substrate.
- ✓ Thick copper base-plate enables wide heat spread.



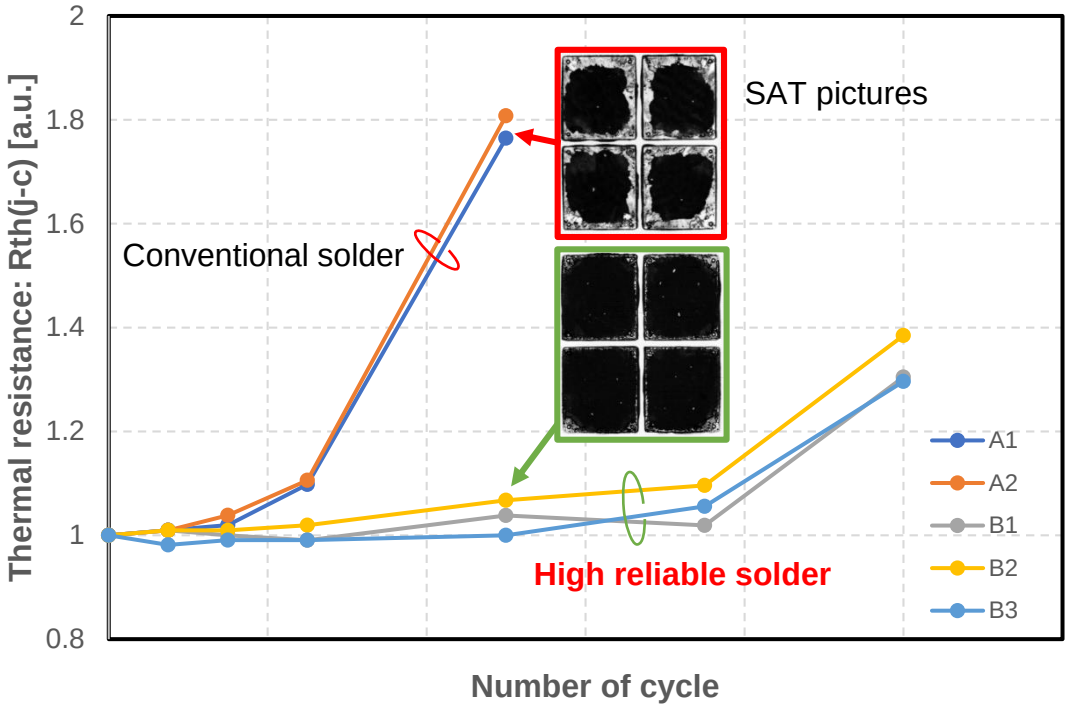
HPnC package technologies (cross-section)

HPnC Package Technologies

- ✓ High reliable solder is applied to HPnC for under substrate.
- ✓ Solder composition is optimized and mechanical strength is improved.
- ✓ ΔT_c power cycling capability is more than 2 times longer than conventional solder.



HPnC package technologies (cross-section)

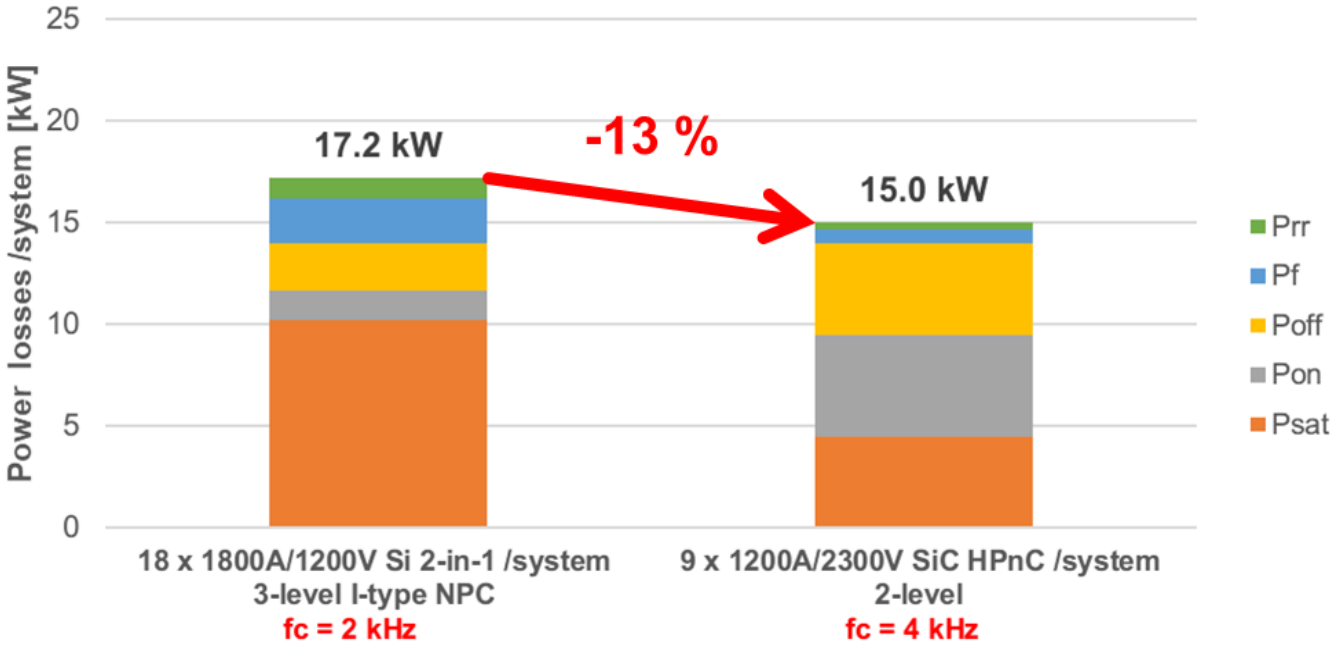


ΔT_c power cycling test results (thermal resistance vs. cycles)

ΔT_c = 80 K, T_{cstart} = 70 ˚C

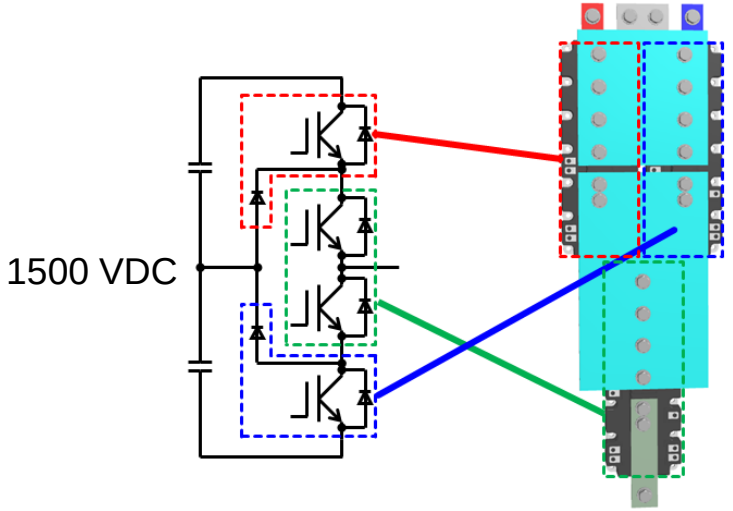
Power Losses (3-level Si vs. 2-level SiC)

- ✓ Comparing to 3-level Si IGBT, 13 % of power losses are reduced even though the switching frequency of 2-level SiC MOSFET is 2 times higher.
- ✓ Further output power is available with 2-level SiC MOSFET.

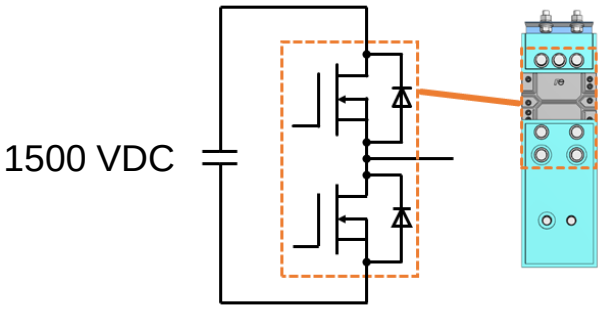


Comparisons of power losses (left: Si 3-level, right: SiC 2-level)

I_o = 1800 Arms, V_{DC} = 1500 V, pf = 0.9, λ = 0.9, f_o = 50 Hz, f_c = 2 kHz (3-level), 4 kHz (2-level)



(a) 3-level with 1200 V rated 2in1 Si IGBTs



(b) 2-level with 2300 V rated 2in1 SiC MOSFETs

Conclusion

- ✓ 2300V / 1200A rated SiC-MOSFET HPnC is newly developed.
- ✓ The new product enables replacement from 3-level ANPC topology to 2-level topology for 1500 VDC applications represented by photovoltaic (PV) power generation and wind power generation.
- ✓ 2-level topology can reduce number of power devices and contributes downsizing of power conversion systems.
- ✓ It can lead to system cost down and accelerate growing speed of renewable energy market.