pcim ASIA

Intelligent SiC Power Module (SKiiP) for 2- and 3-level high voltage applications

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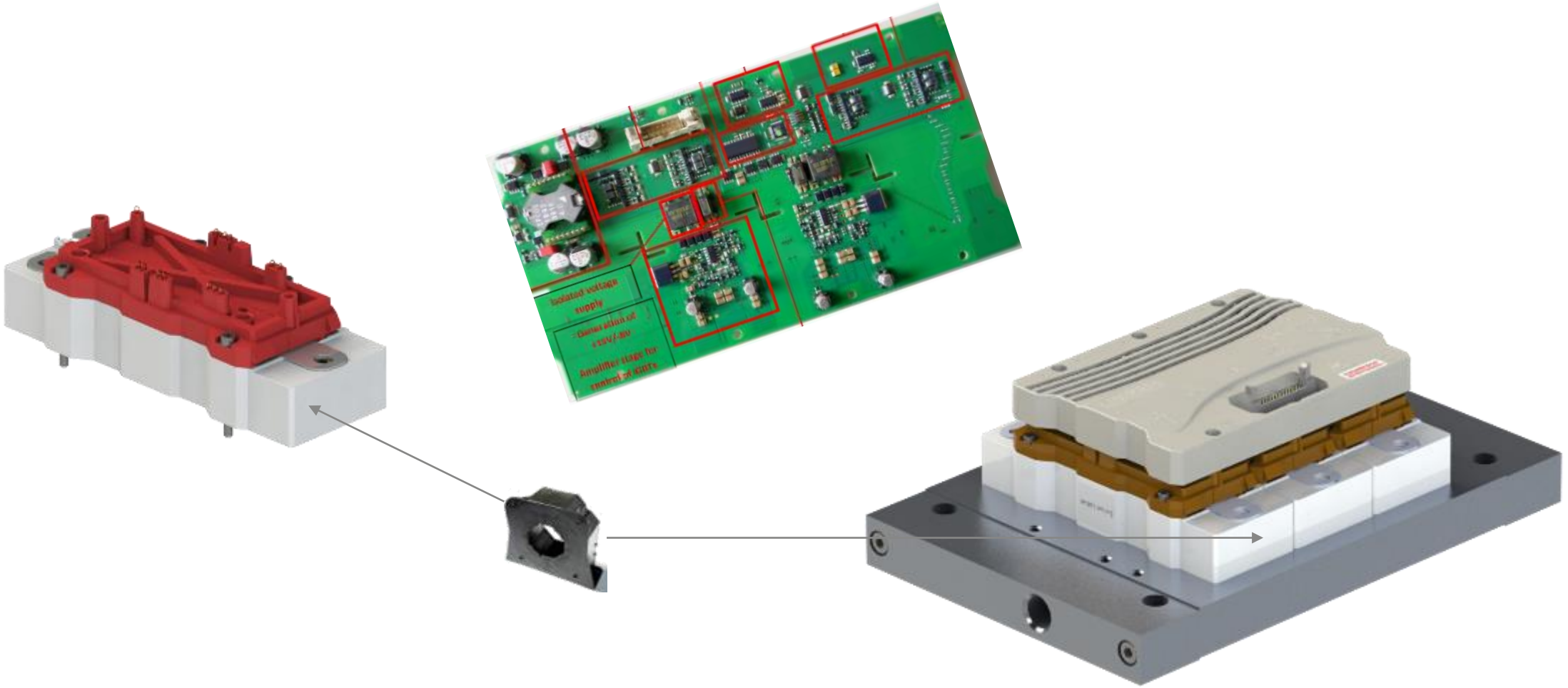
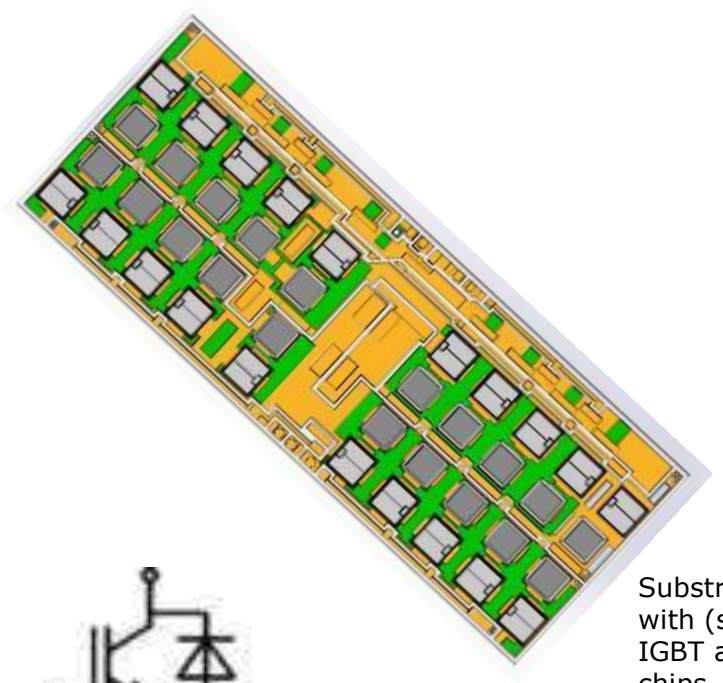
What is an intelligent high power module „SKiiP“?

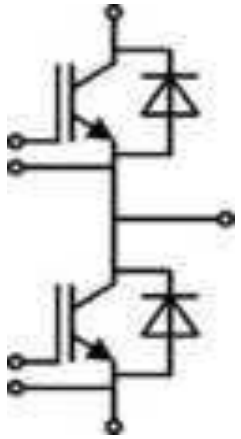
SKiiP is:
power module & driver & current sensor & HP-heatsink

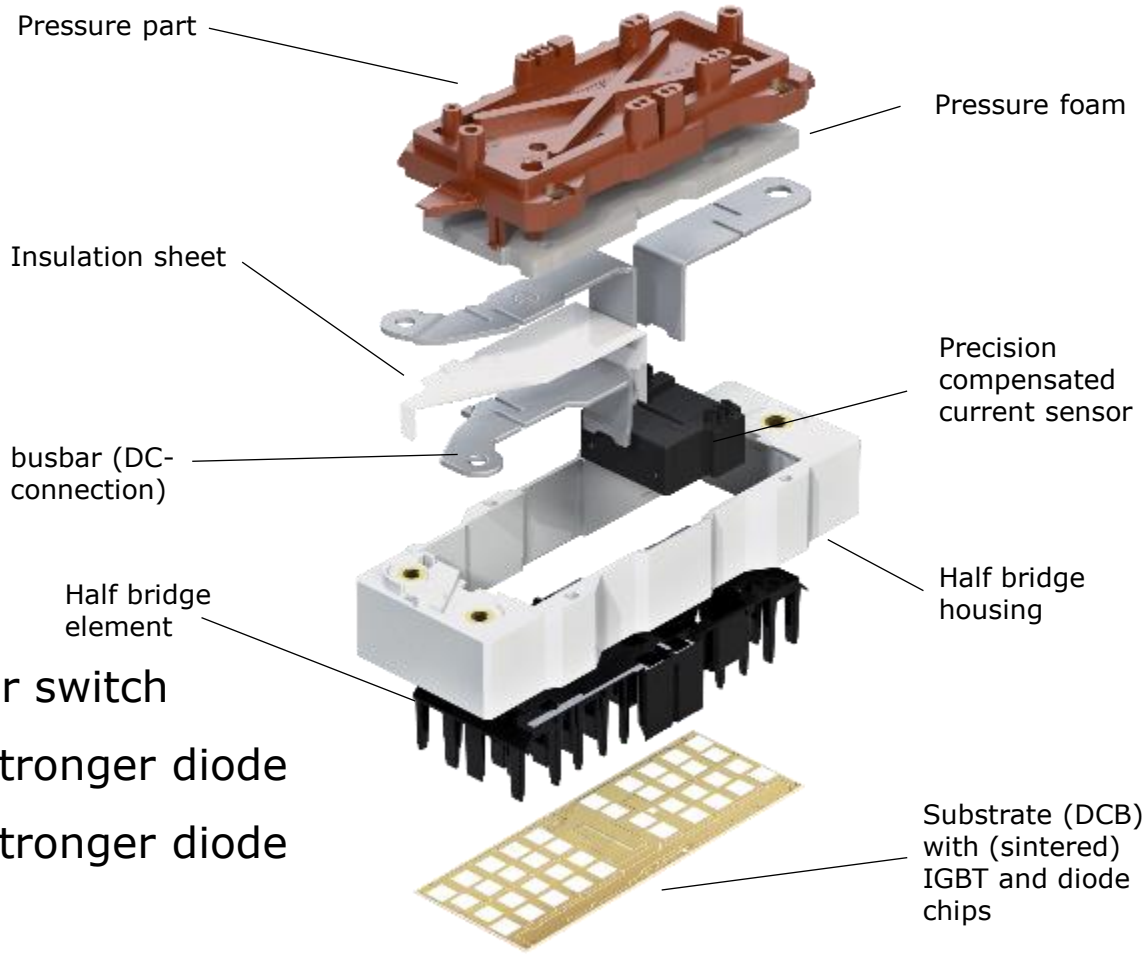


Construction of SKiiP



Substrate (DCB) with (sintered) IGBT and diode chips



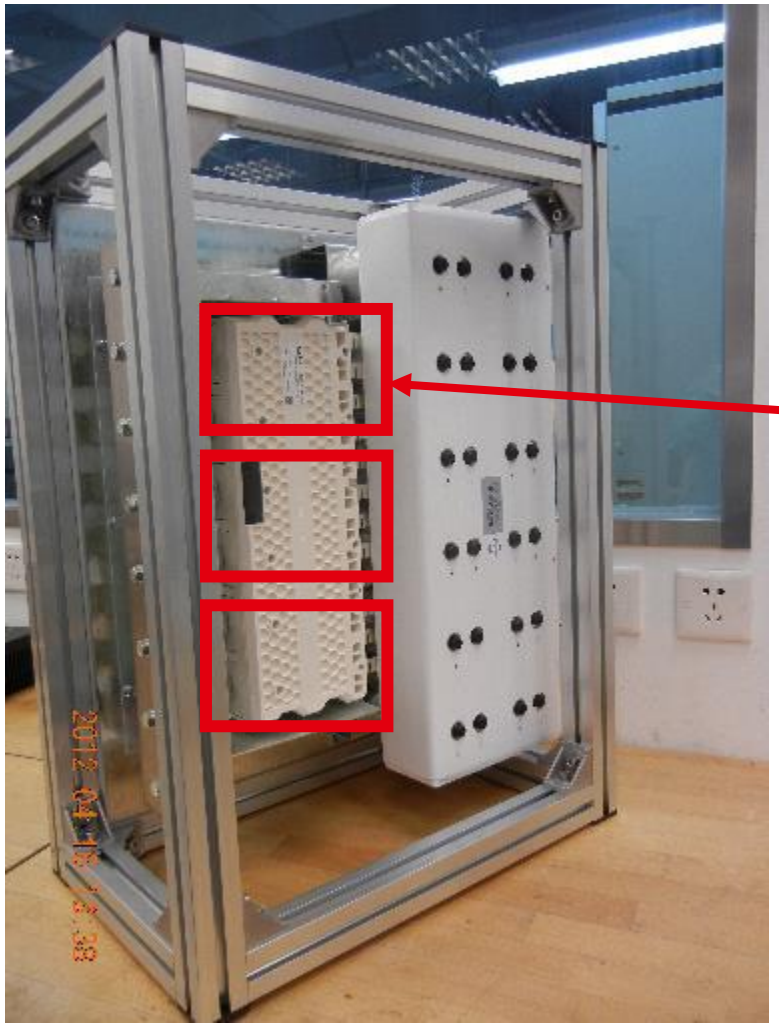


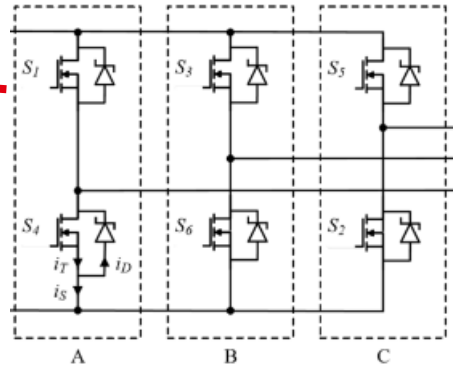
- Voltage class
  - 1200V - Si
  - 1700V - Si
  - 2.xV - SiC
- Current class per switch
  - 600A – Si-stronger diode
  - 750A – Si-stronger diode
  - 300A – SiC
  - 600A - SiC

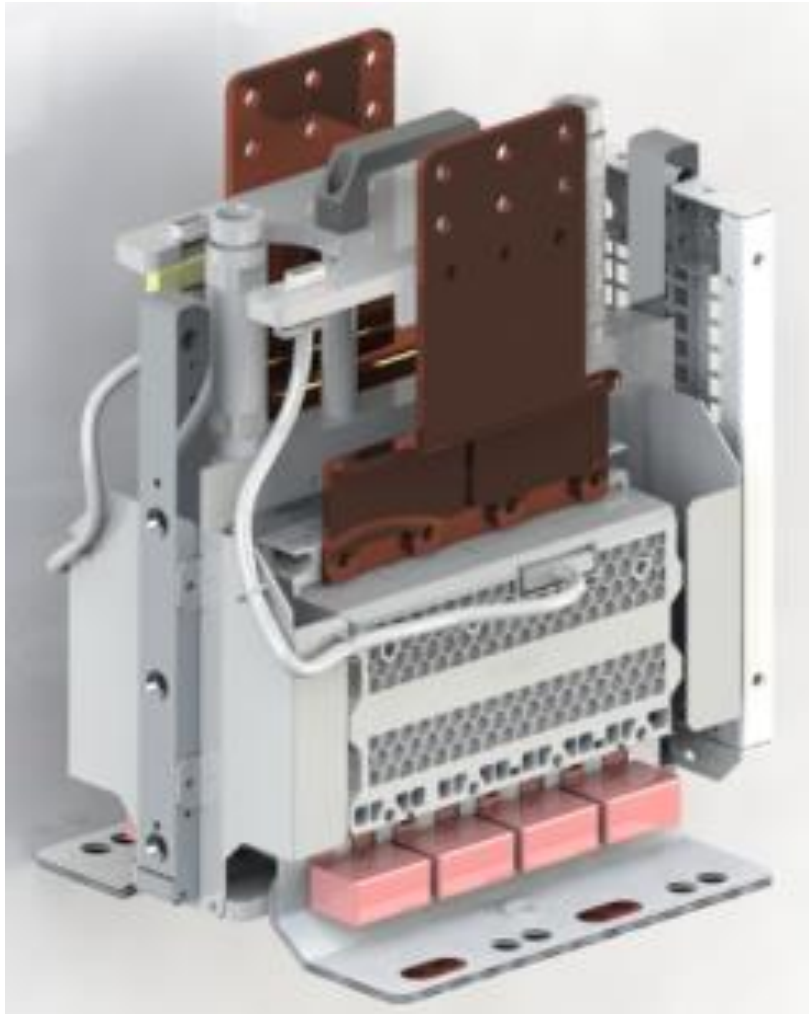
SKiiP is available as (air cooled/water cooled) :

2 – level IGBT-IPM up to 3600A/1700V
2 – level SiC-IPM up to 2400A/2.xkV
3 – level IGBT-IPM up to 2400A/2550V

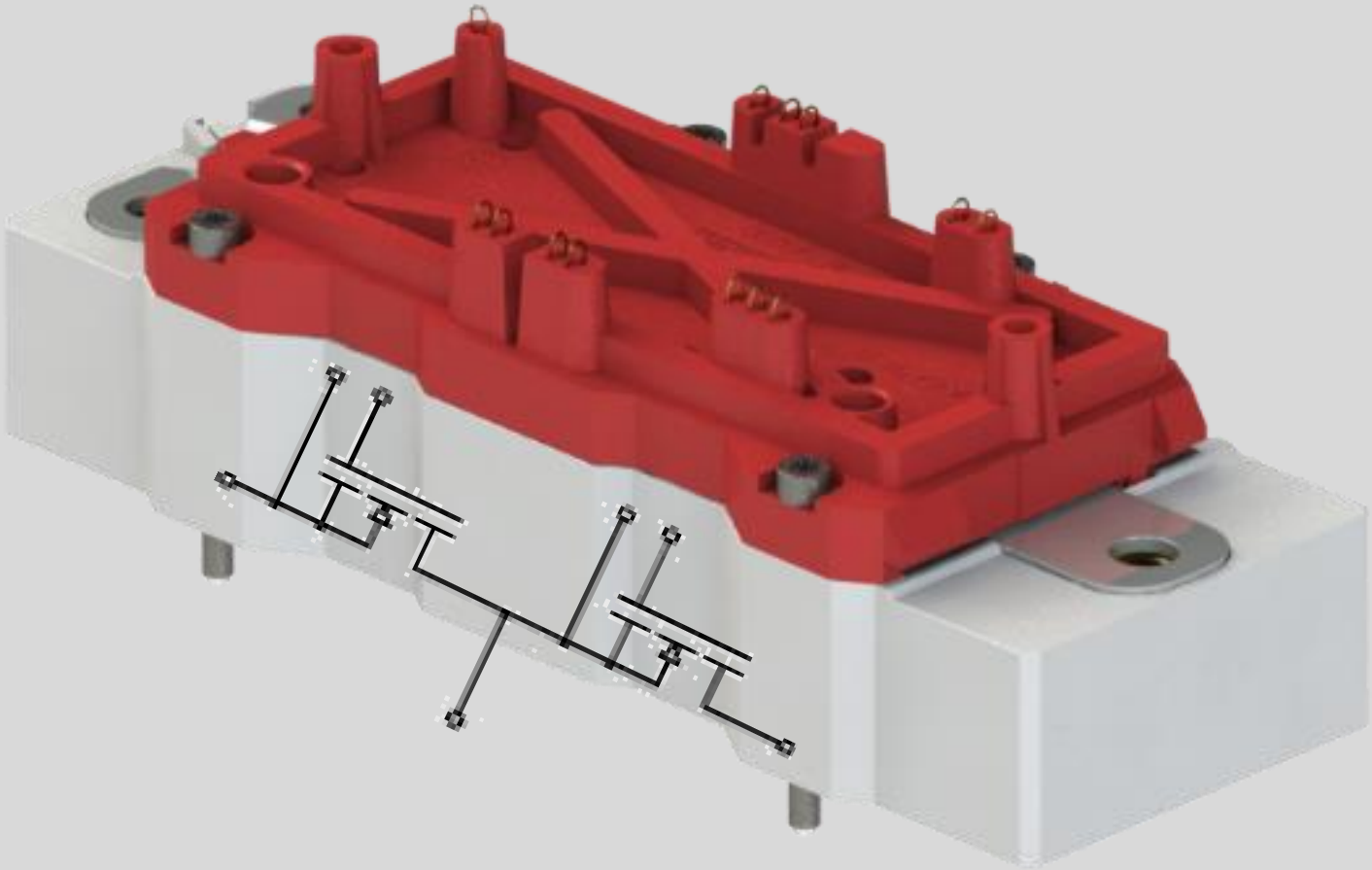
SKiiP 4 – 6-fold stack – 3 phase SiC inverter with 1MW (1600V DC)
SKiiP 4 – one phase line side & generator side IGBT converter 1.5MW







SKiiP SiC 2.xkV



Why an intelligent higher power module with SiC?

Challenge:
New SiC technology is quite different from Si IGBT technology, therefore SiC design know-how is necessary.

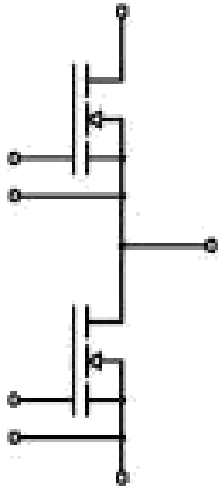
Qualification efforts: definition of test and qualification itself

Solution:

With an IPM, the customer gets a well designed and 100% qualified product

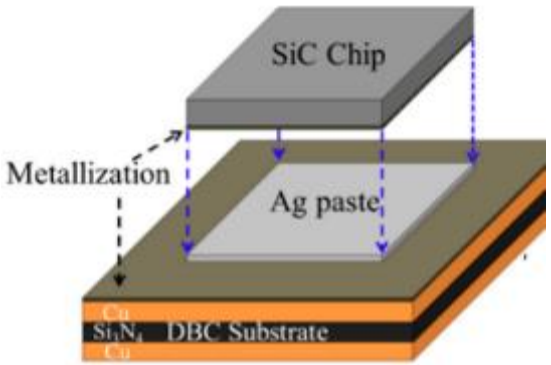
Time to market:

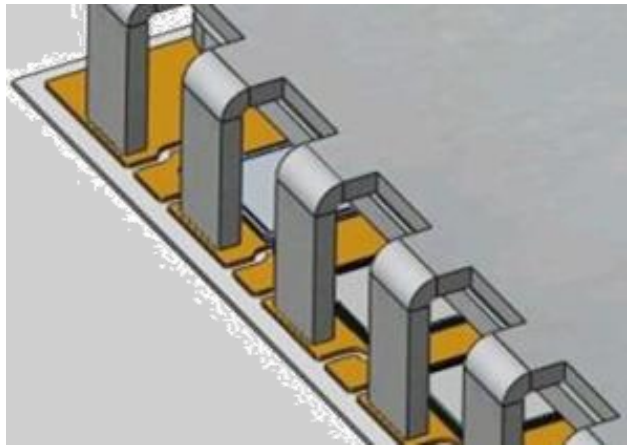
Time to market is very fast and special in our fast changing time

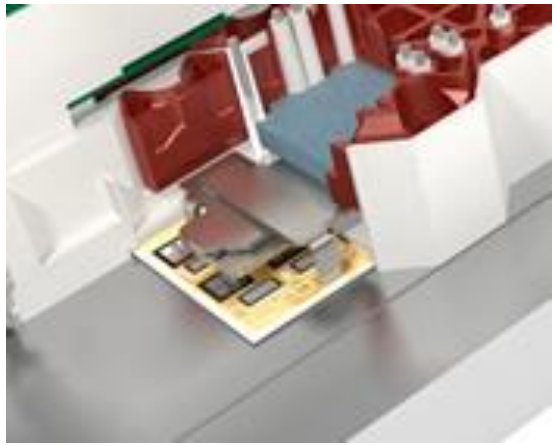


Design and Technology benefit

SKiiP Technology Benefits: Reliability investigations shows best lifetime for Sinter+AlCu[1].
Combination with busbar and baseplate-less design optimized for SiC technology







Chip Attachment

Exceptional reliability and inverter lifetime due to **sintered interfaces**

Chip Top Contact

Several chip top connections are possible

- Aluminum bondwires
- **Aluminum Clad Copper bonding** for higher power cycling capabilities.

Terminal Connection

Solderless and bond wire-less terminal connections for exceptional reliability under passive and active temperature cycles

Thermal Performance

Baseplate-less design provides exceptional thermal performance esp. with water cooler

High Performance Cooler (HPC) further improves SKiiP performance compared to base plate modules.

[1]Results from power cycling tests of 3,3kV SiC MOSFETs with different bonding and joining technology, Roman Boldyrev-Mast, TU Chemnitz

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Stray inductance comparison

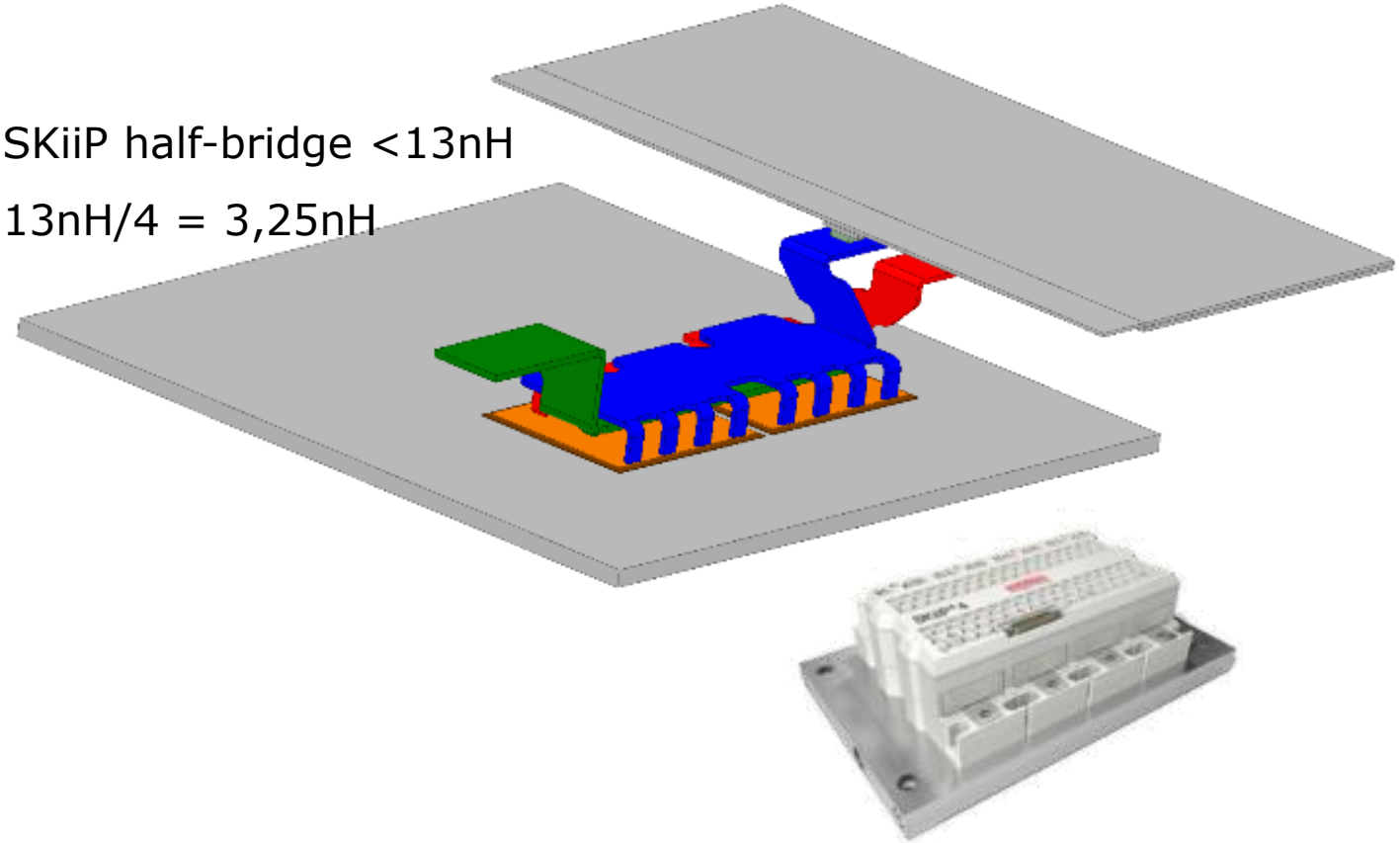
ED – half-bridge 3-level configuration < 160nH – 240nH

160nH/4 = 40nH-SC

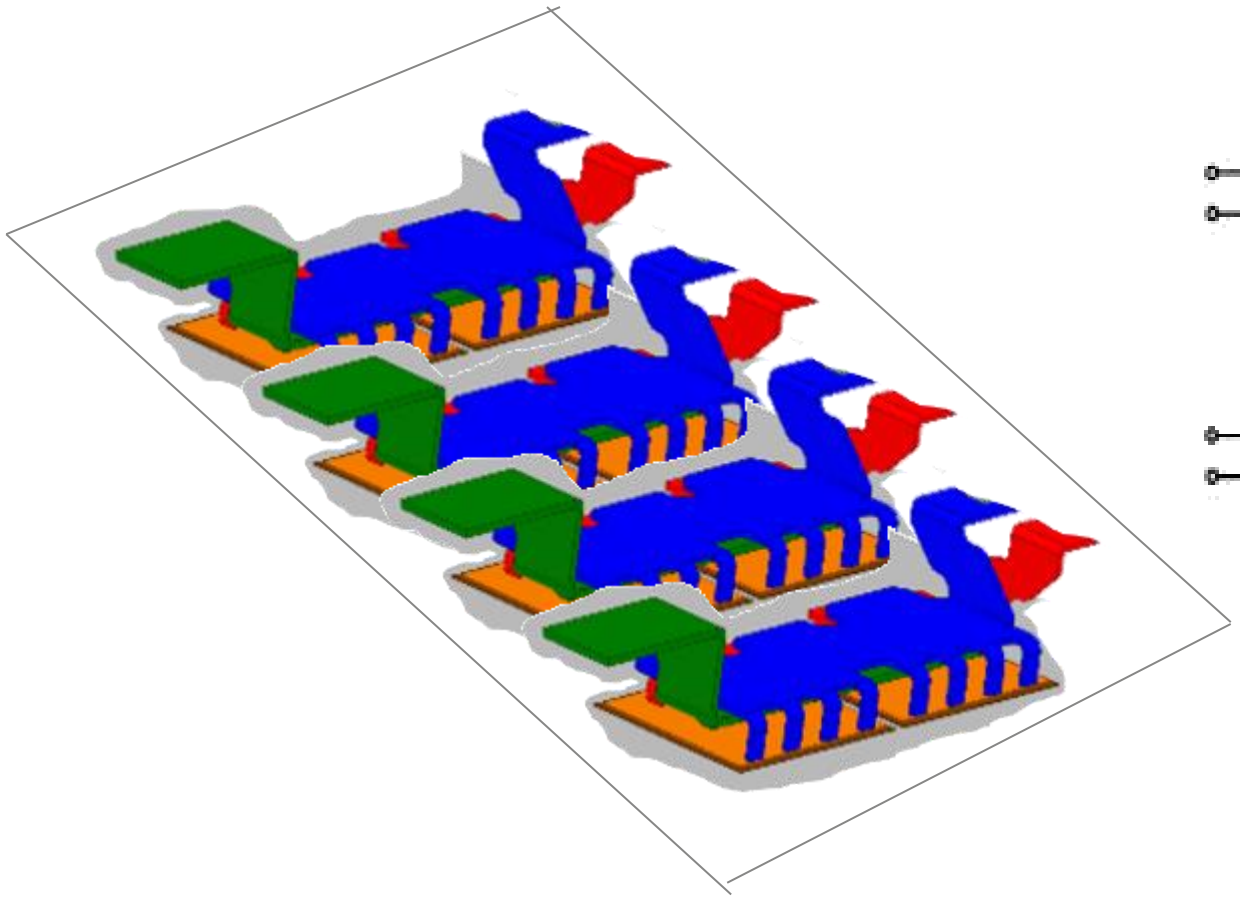
240nH/4 = 60nH-LC

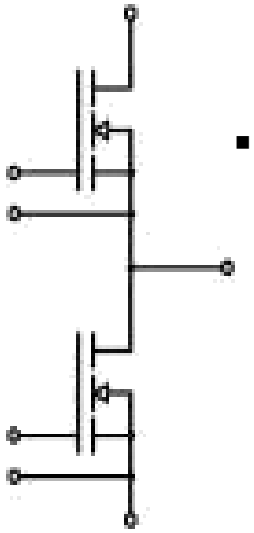
SKiiP half-bridge <13nH

13nH/4 = 3,25nH



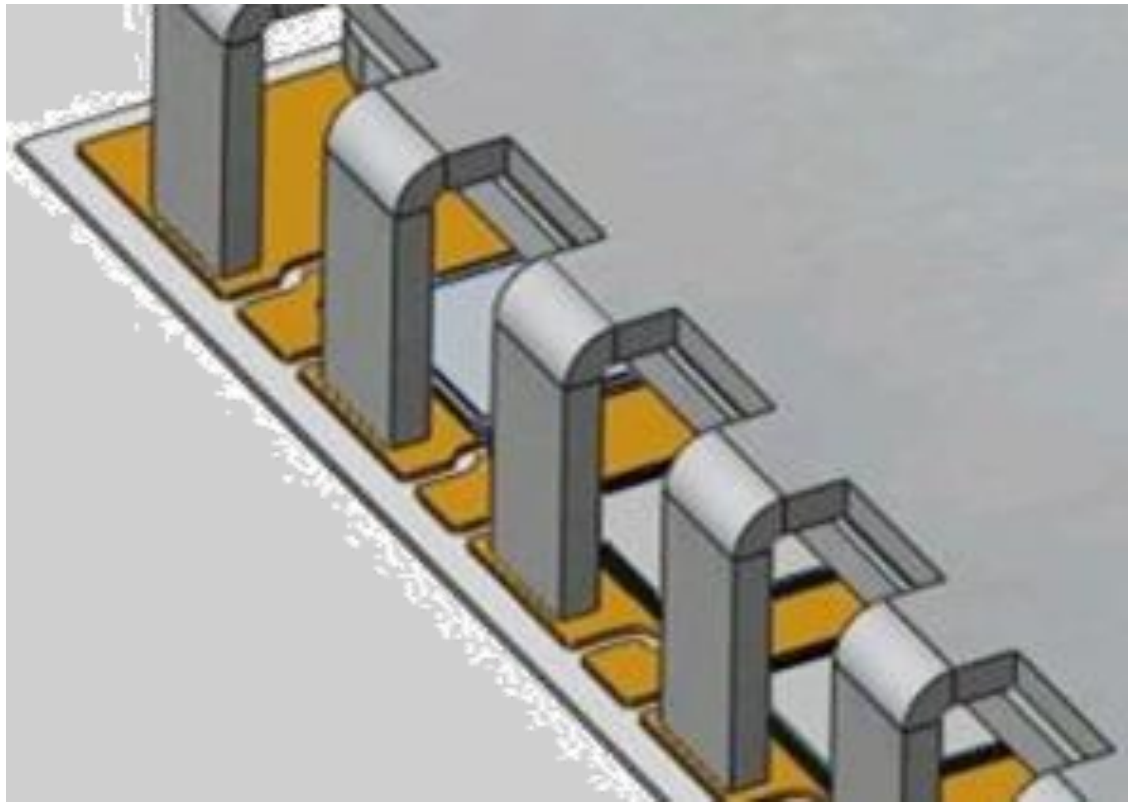
SKiiP - SiC stray inductance (< 4nH) -

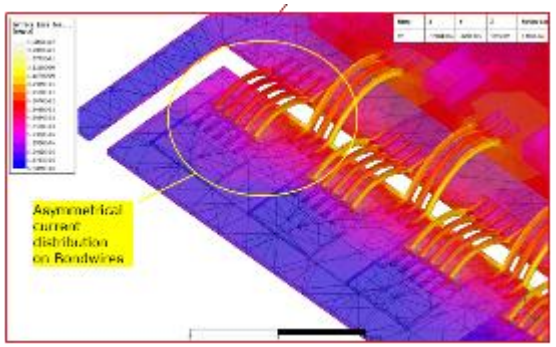


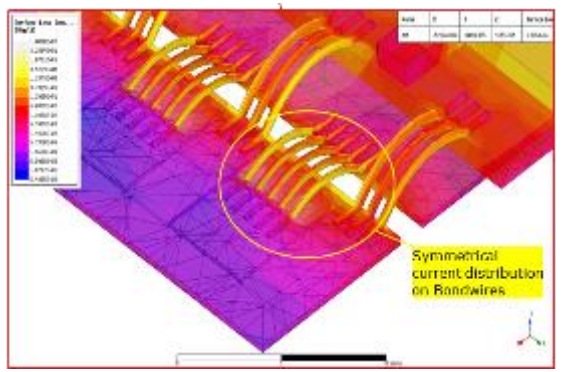


- 2 Version are available
  - 8 chips per switch (1200A/2.xkV)
  - 16 chips per switch (2400A/2.xkV)

Homogeneous current distribution by optimized DCB design







Parasitic Minimization

- **Homogeneous** power and gate loop inductance is key for chip paralleling
- **Inductive coupling** power to gate loop affects switching behaviour
- **Rg** necessary to damp resonant series Oscillation

Why SiC IPM? Chip independency

Integrated driver with **Gate voltage adjustment:**

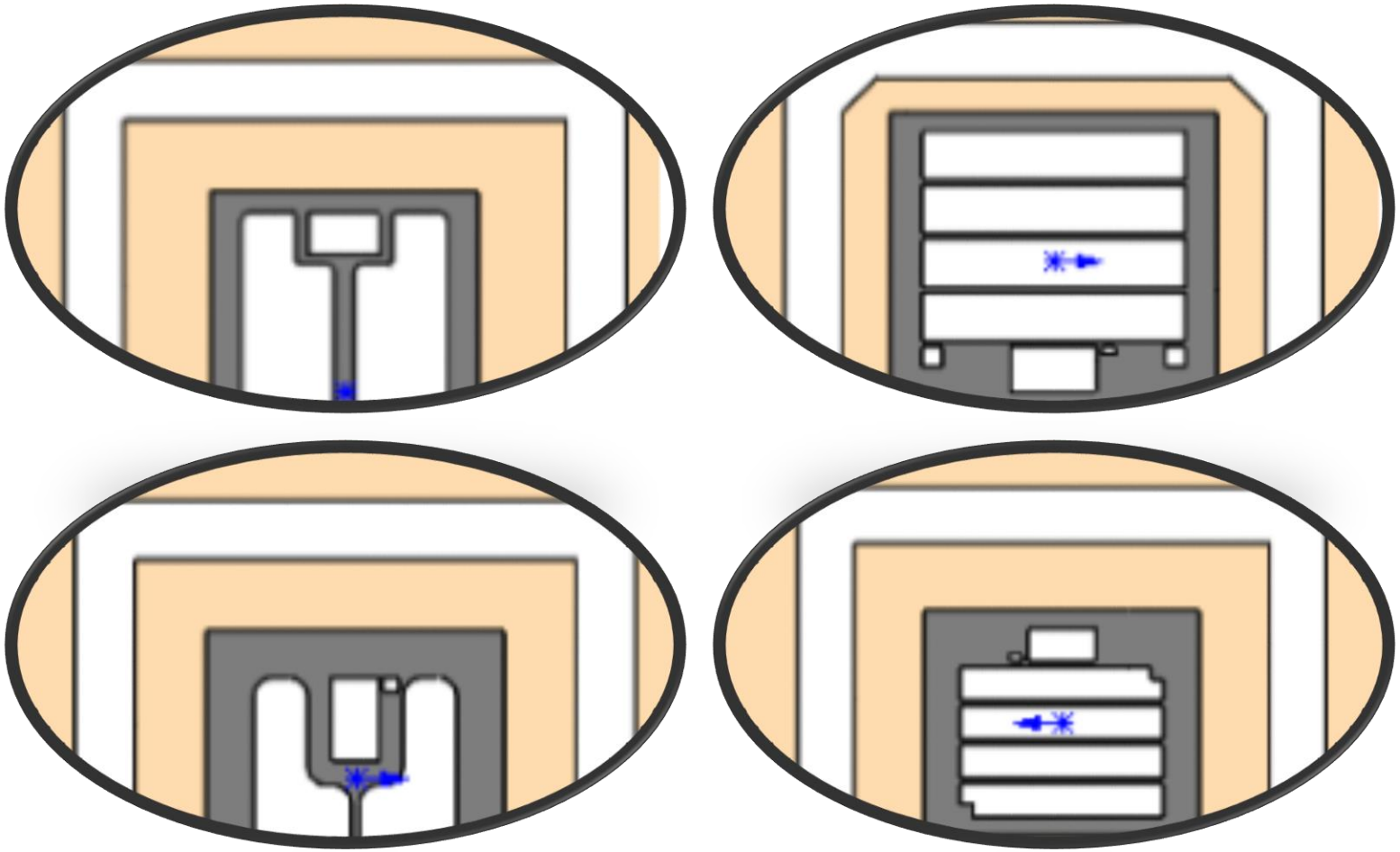
Usage of SiC chips of **multiple suppliers** possible

Trench SiC

Planar SiC

Adaptation of driver/testing/production/design/ qualification is the task of Semikron-Danfoss

Customer gets assembled and 100% tested IPM



Why IPM? Integrated driver

Gate voltage adjustment possible to control SiC chips of different supplier

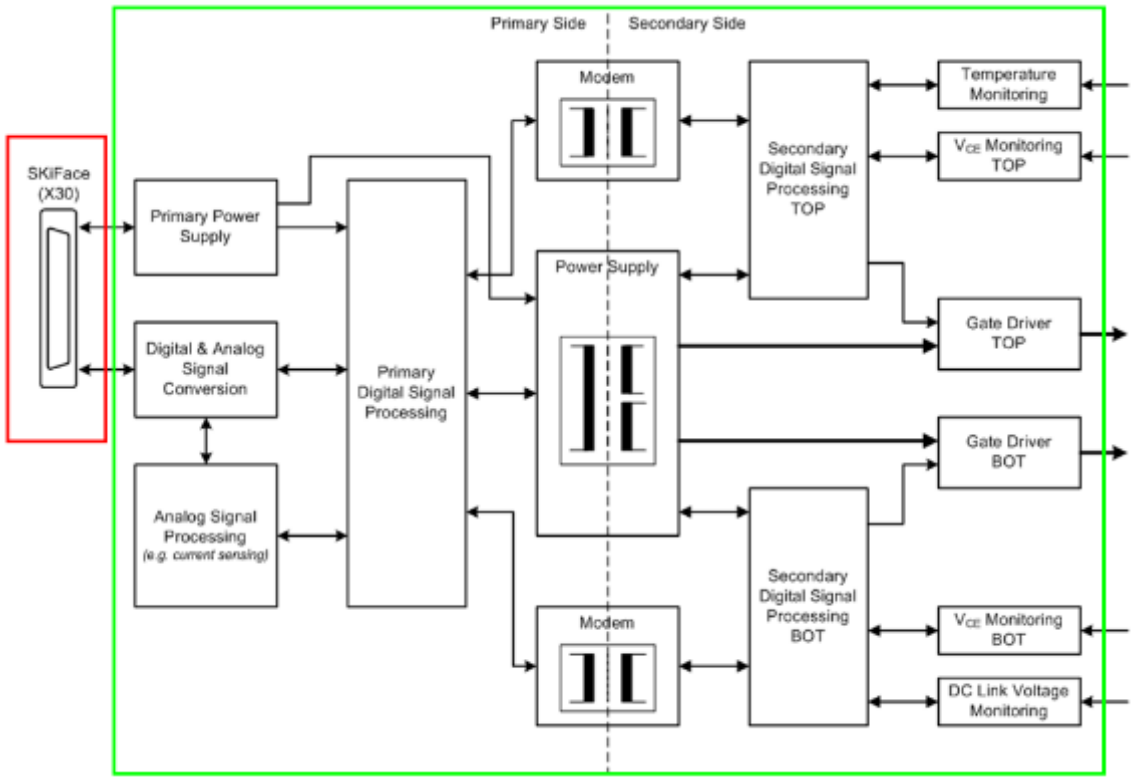
Gate charge for up to 16 SiC chips per switch

Semikron-Danfoss **ASIC**s make it reliable and intelligent

Electrically isolated interface for control and error messages

CAN bus connection with further enhanced functionality (see Technical Explanation)

Optional **fiber optical** interface converter

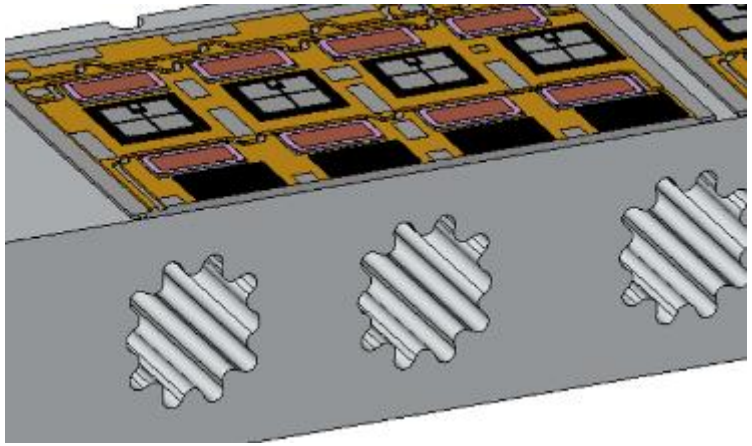


New High Performance Cooler (HPC)

Standard water cooled heat sink:

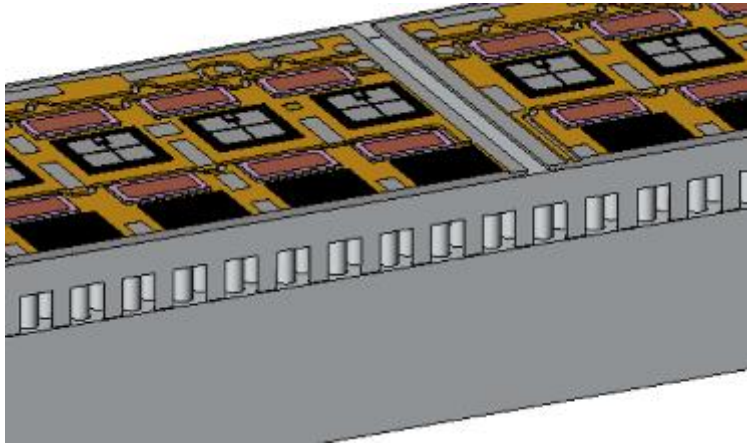
Advantage:
pressure system controlled contact of DCB to heatsink through High Performance Thermal Paste (HPTP)

Disadvantage:
Comparatively large Rth(Al)

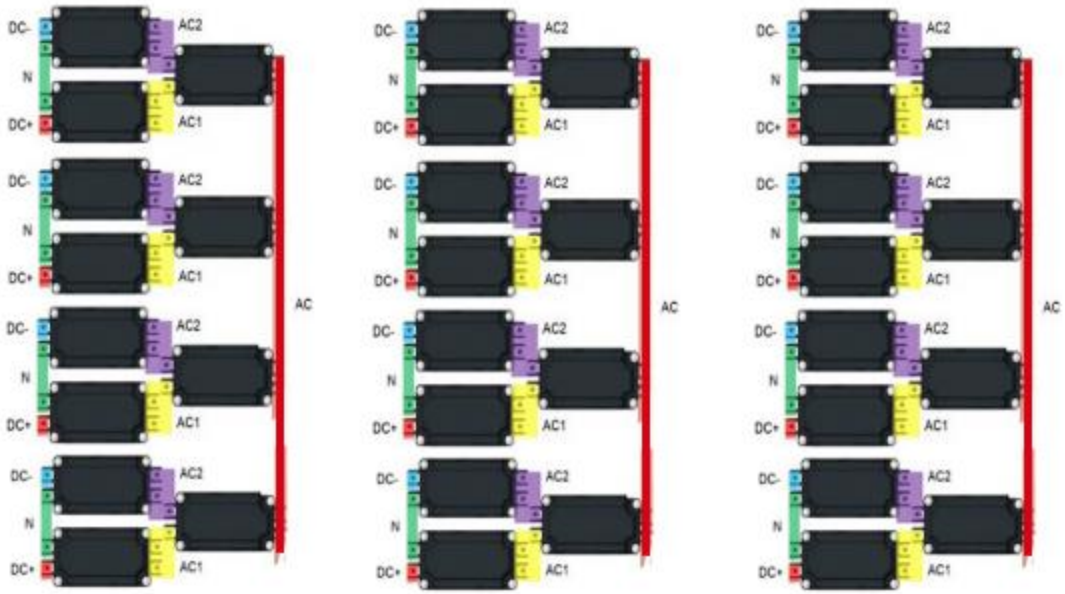


New high performance heat sink:

Advantage:
- pressure system controlled contact of DCB to heatsink through High Performance Thermal Paste (HPTP)
- comparatively small Rth(Al)
- large surface to cooling fluid



3-level solution (600A/1200V) compared with 2-level solution 2kV-SiC 2.5MW/1500 DC



03 EconoDUAL™3 connection diagram

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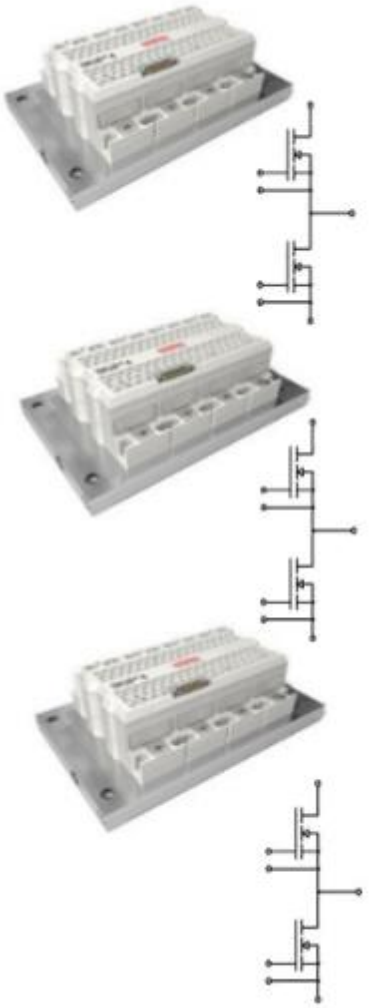

- More compact
- Higher efficiency
- Save space in the cabinet
- Reasonable price

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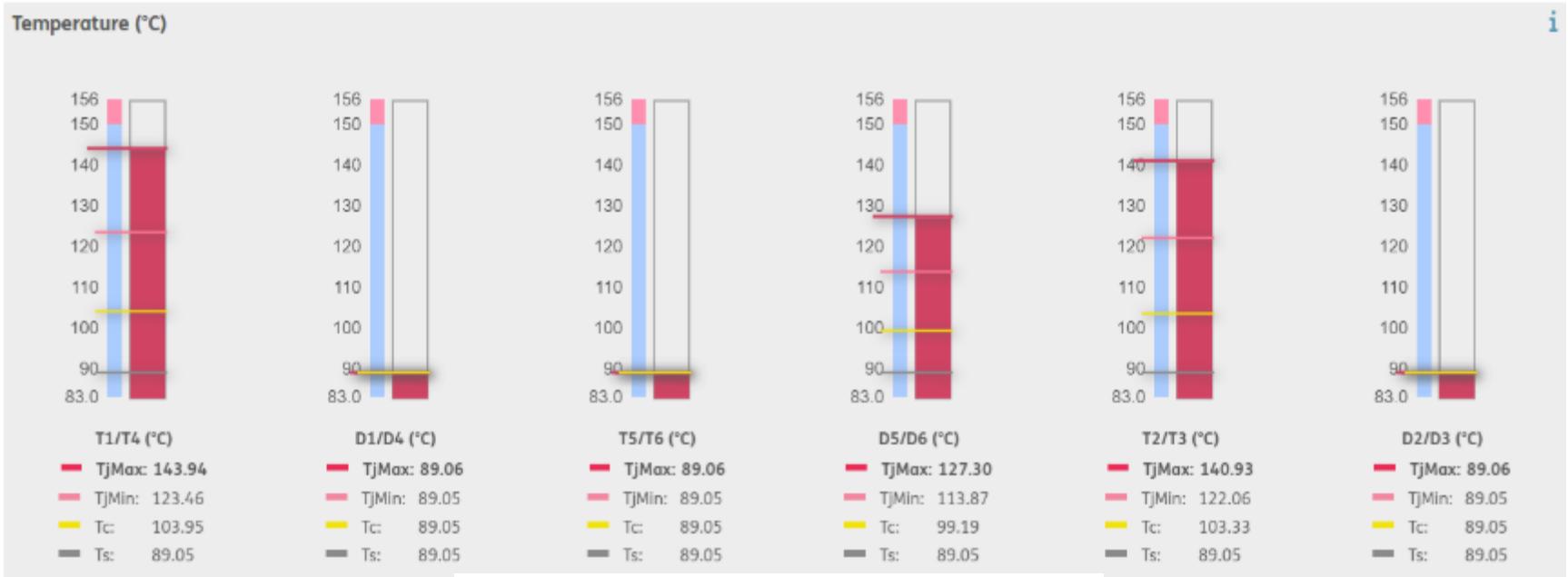
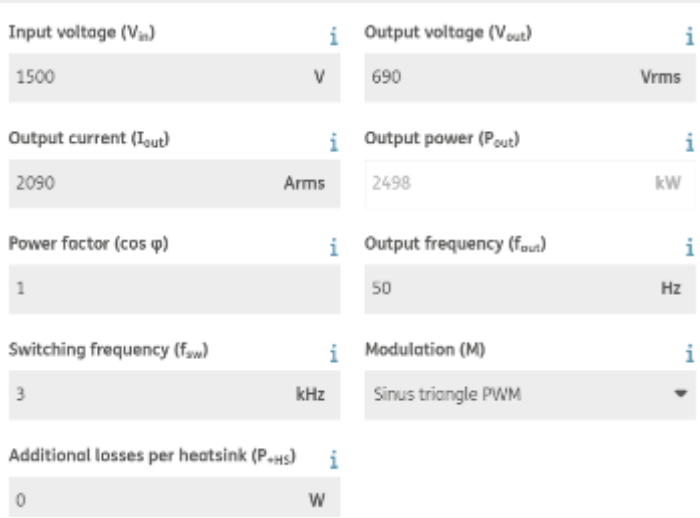
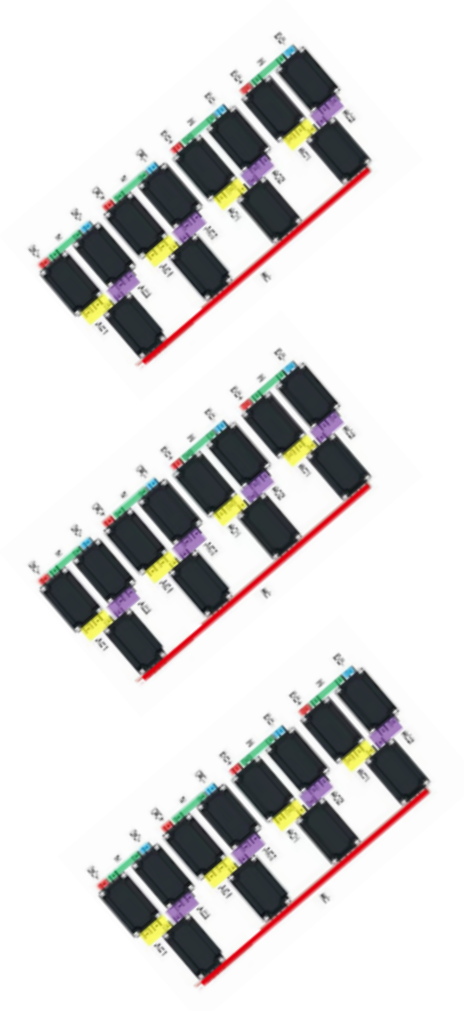
2.5 MW with Semix3p (ED) in 3-level topology (fs/2 compared to 2-level topology)







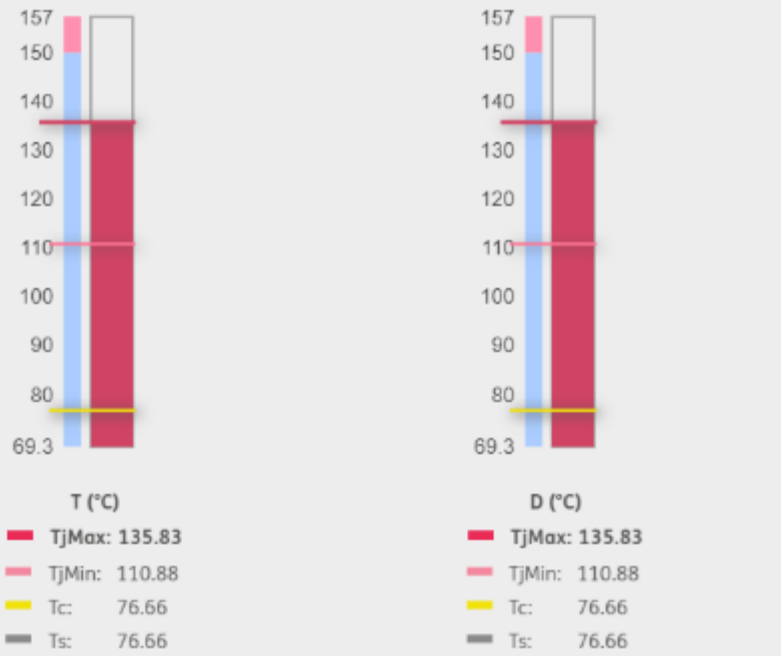
2.5 MW with SiC SKiiP in 2-level topology (double fs compared to 3-level topology)

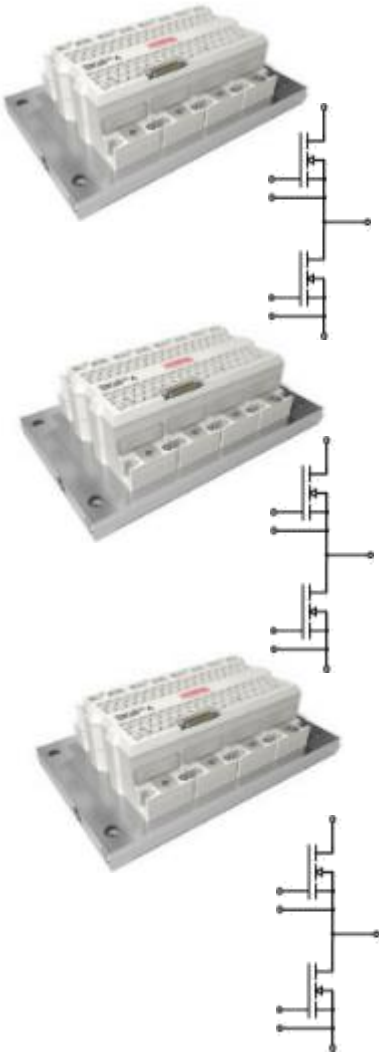
Topology & circuit

Nominal load

Input voltage (V_{in})	1500 V	Output voltage (V_{out})	690 Vrms
Output current (I_{out})	2090 Arms	Output power (P_{out})	2498 kW
Power factor (cos φ)	1	Output frequency (f_{out})	50 Hz
Switching frequency (f_{sw})	6 kHz	Modulation (M)	SVPWM
Additional losses per heatsink (P_{+HS})	0 W		

Temperature (°C)





Compact design - - - Cabinet size cost “money”

Topology & circuit

Nominal load

Input voltage (V_{in})	1500 V	Output voltage (V_{out})	690 Vrms
Output current (I_{out})	2090 Arms	Output power (P_{out})	2498 kW
Power factor (cos φ)	1	Output frequency (f_{out})	50 Hz
Switching frequency (f_{sw})	6 kHz	Modulation (M)	SVPWM
Additional losses per heatsink (P_{+HS})	0 W		

>330mm

>580mm

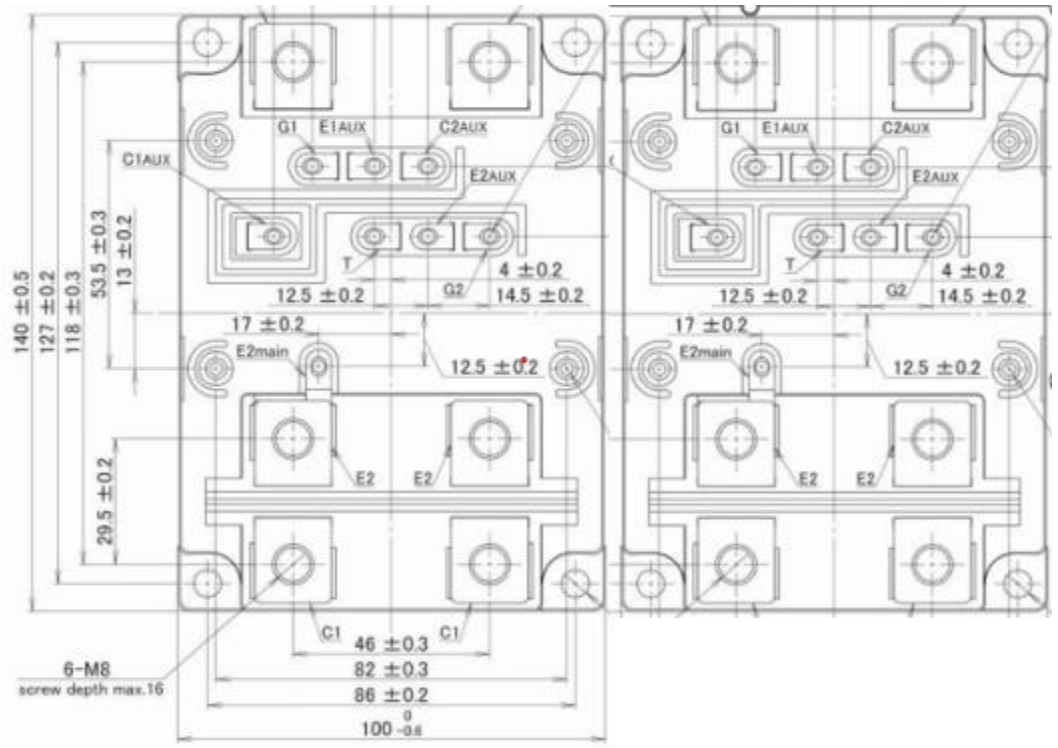
3-level design
2400A/1200V
4 x HF/LF in
Parallel (ED)

>215mm

>360mm

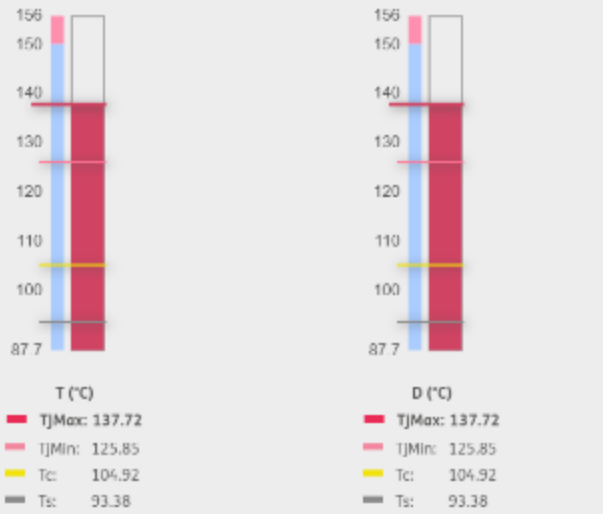
2-level design
2400A
/1200V

Alternative SiC power modules to SKiiP-SiC



Input voltage (V_{in})	1500 V	Output voltage (V_{out})	690 Vrms
Output current (I_{out})	1750 Arms	Output power (P_{out})	2091 kW
Power factor (cos φ)	1	Output frequency (f_{out})	50 Hz
Switching frequency (f_{sw})	6 kHz	Modulation (M)	Sinus triangle PWM
Additional losses per heatsink (P_{+HS})	0 W		

Temperature (°C)



2.5MW

25%
More power

First summary

SKiiP SiC solution has less losses

total losses 3-level-26 kW for 2.5MW converter
total losses 2-level-18 kW for 2.5MW converter

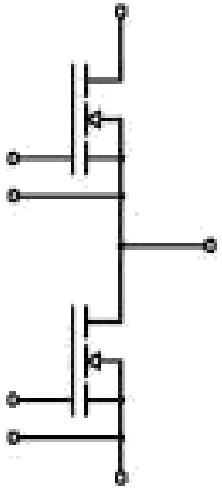
SKiip SiC solution is more compact

factor 2.5 smaller cabinet necessary

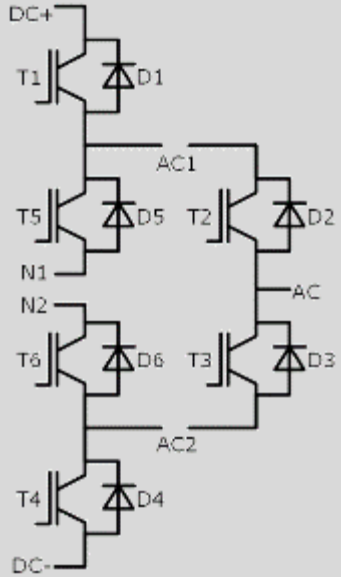
Time to market:

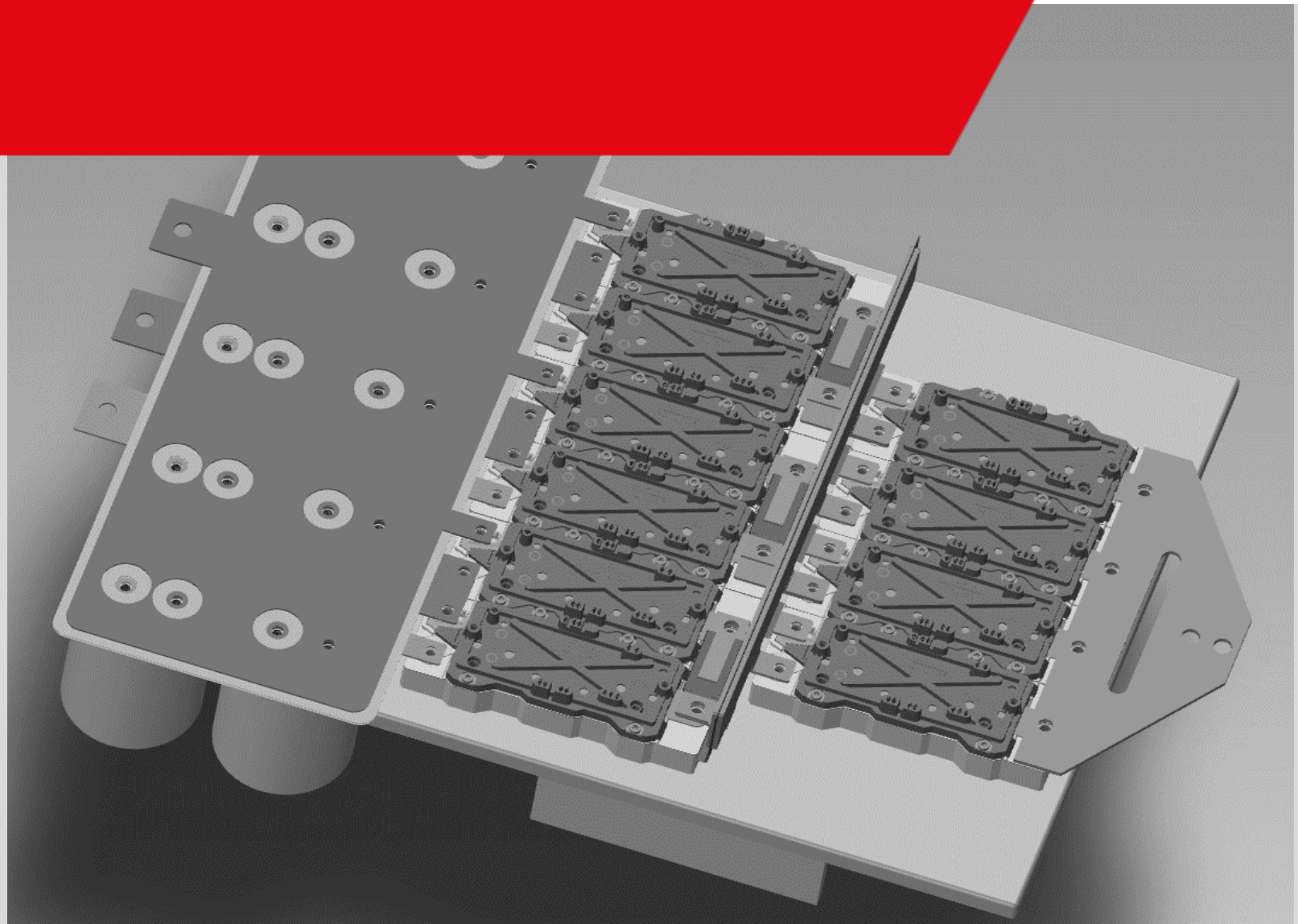
SKiiP SiC is tested and ready to use (burn in tested)

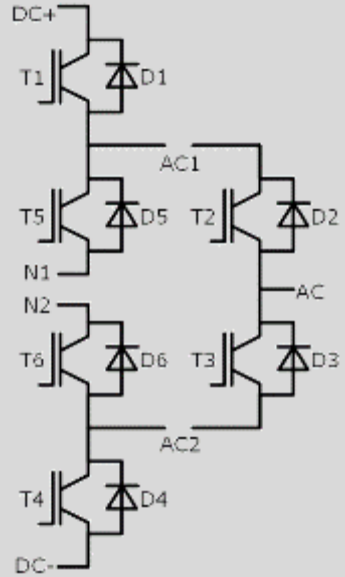
many features already inside



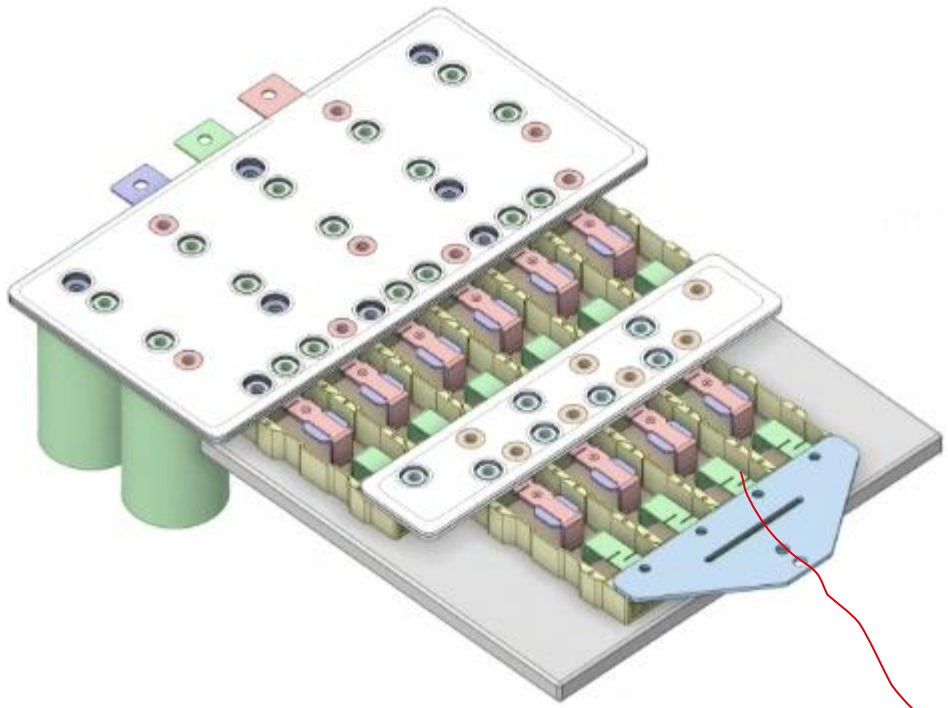
SKiiP 3-level converter

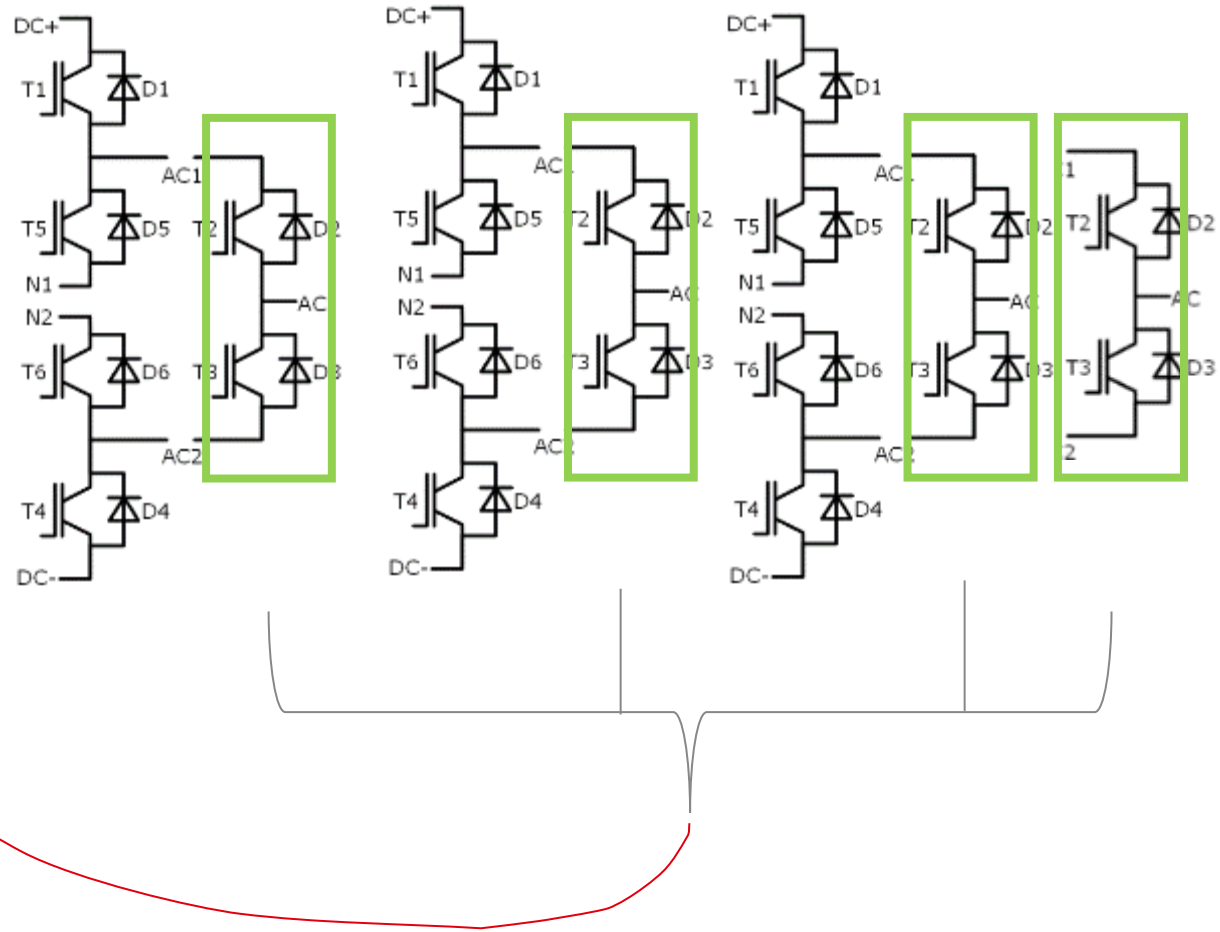




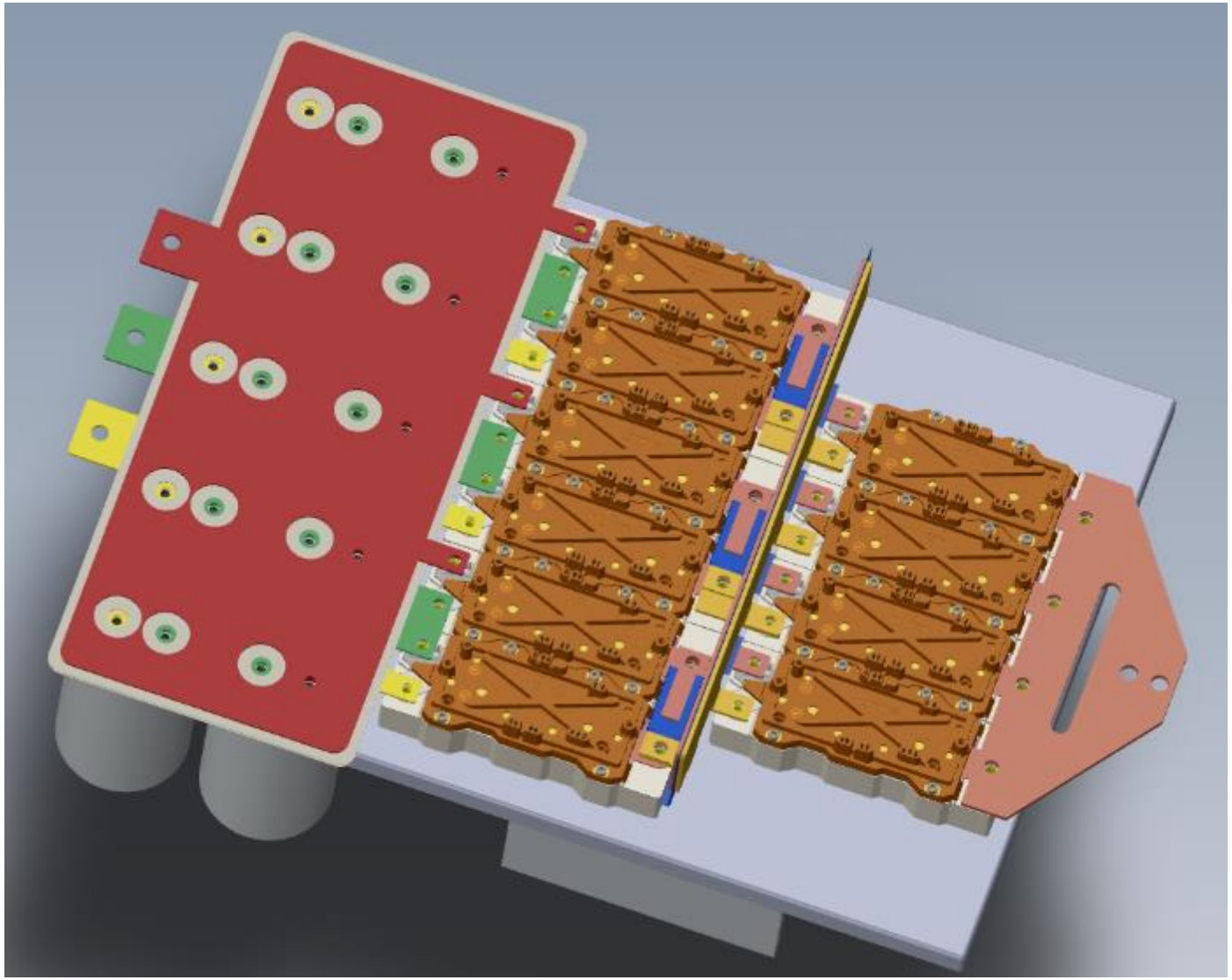


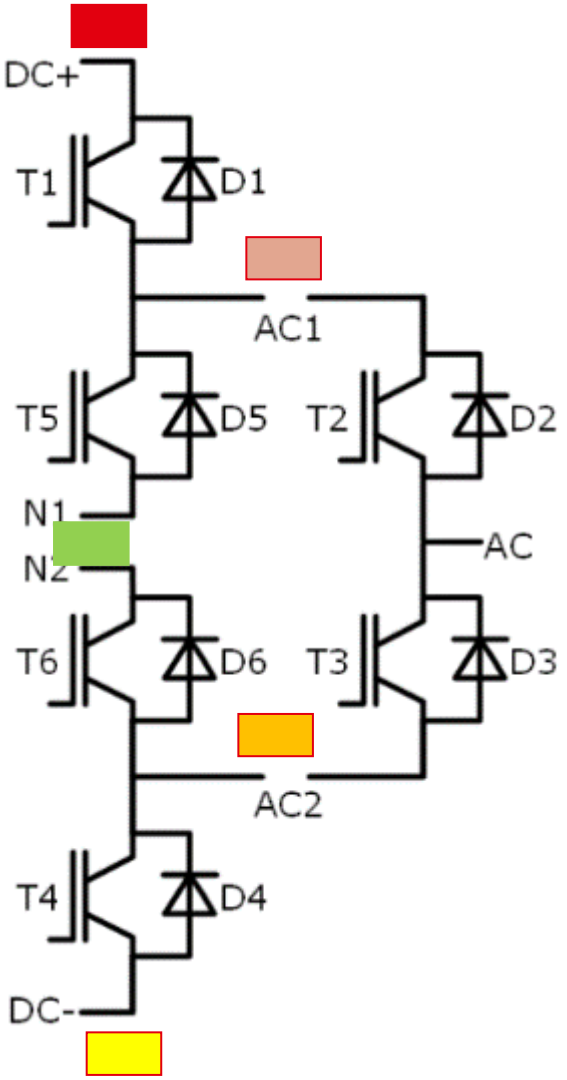
3-level SKiiP power unit based on no baseplate modules





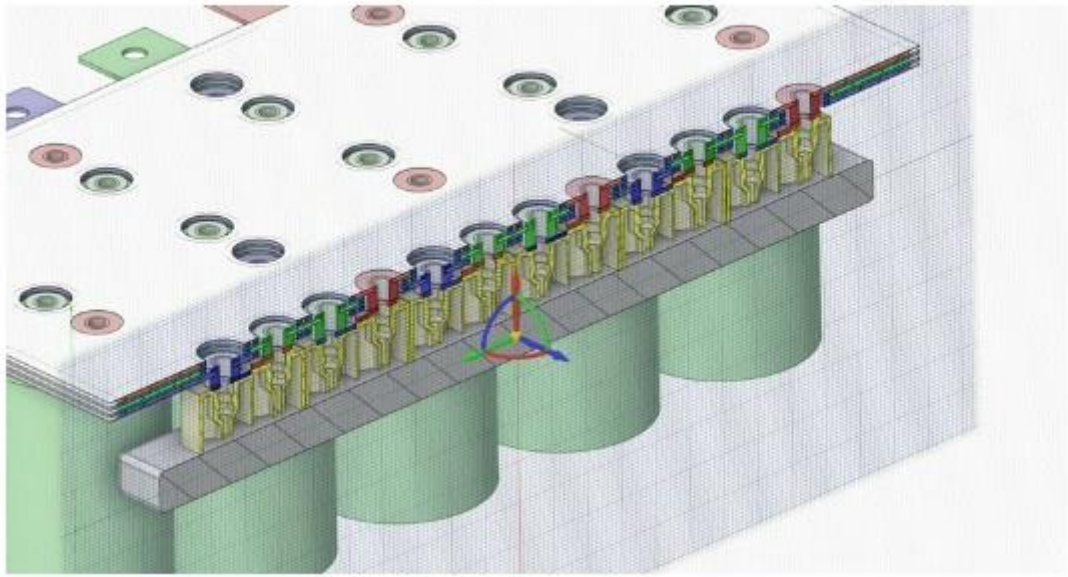
SKiiP 3-level design up to 3MW/1380V AC

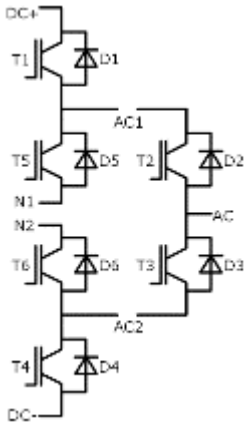




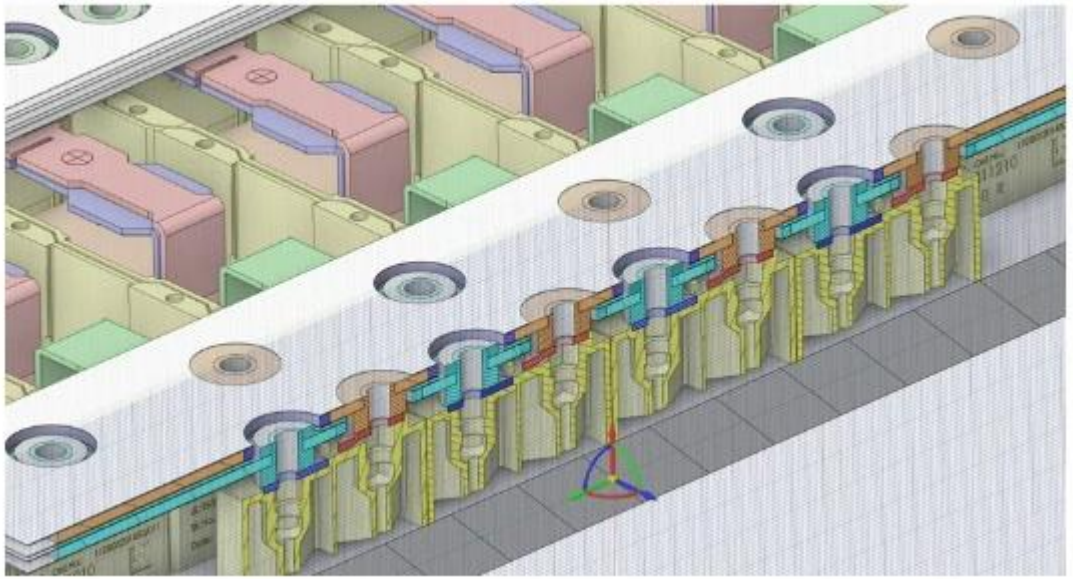
SKiiP 3-level-busbar design to get low stray inductance

- Cross Section DC side

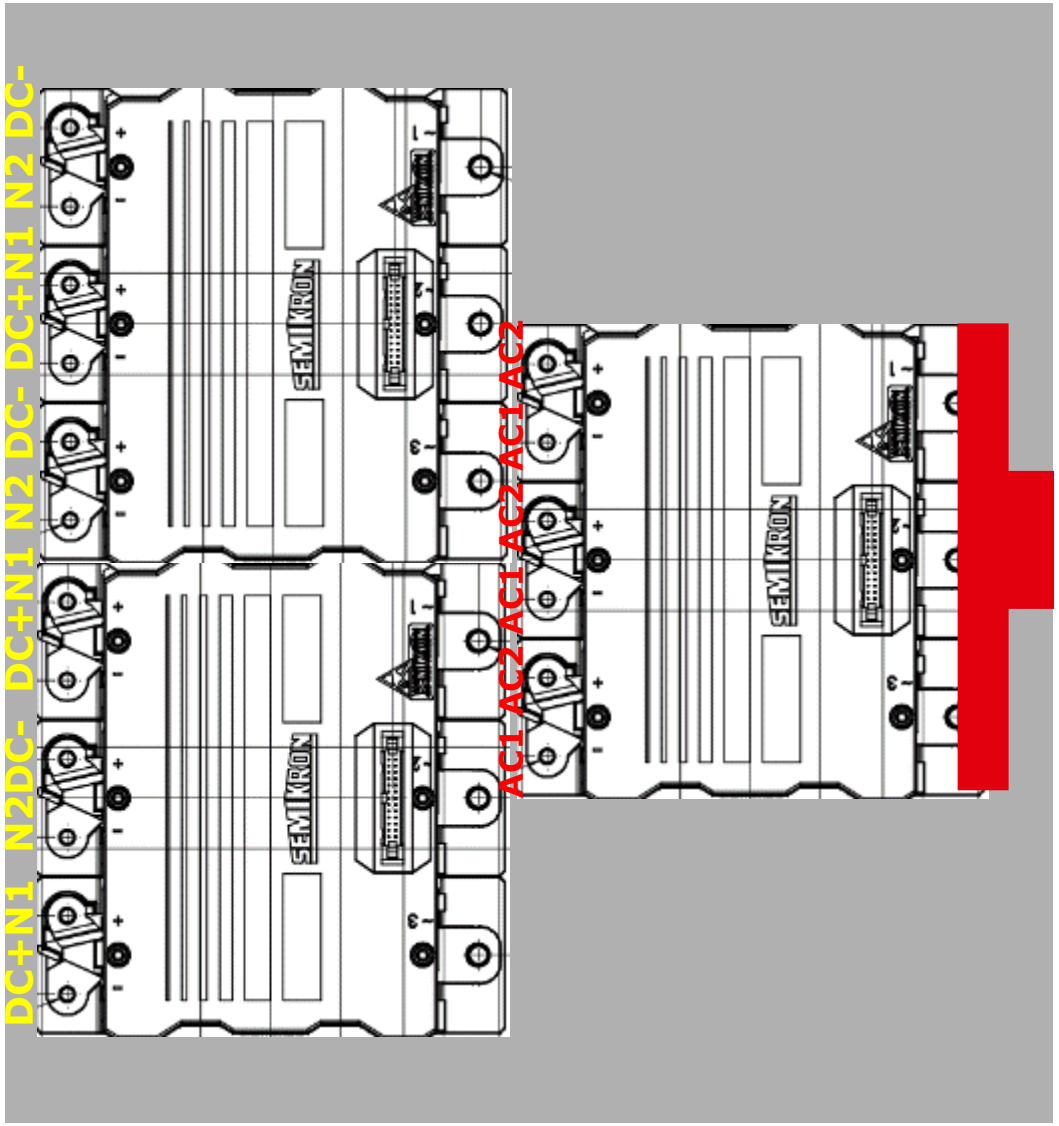


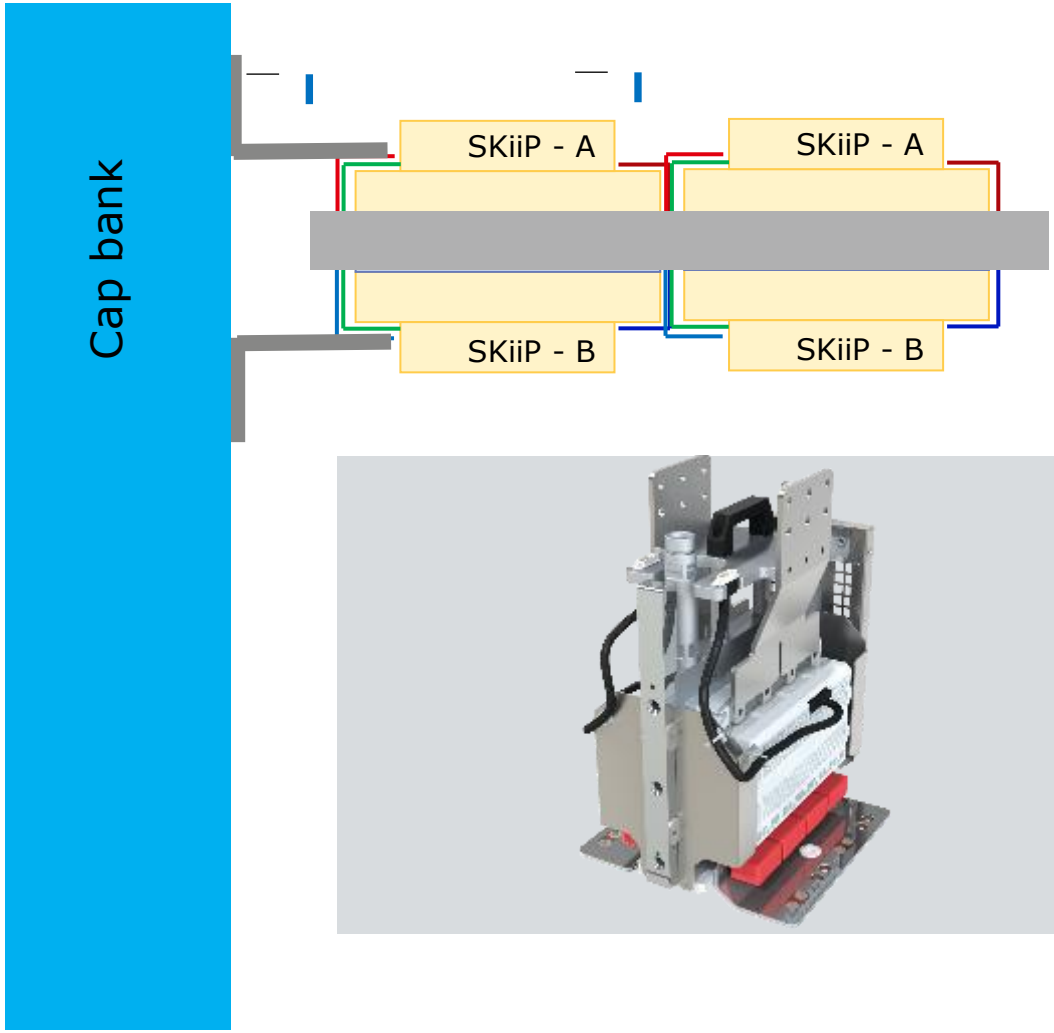


- Cross Section AC side



SKiiP – 3-level configuration – 6 MW/1140V AC -study





Final summery

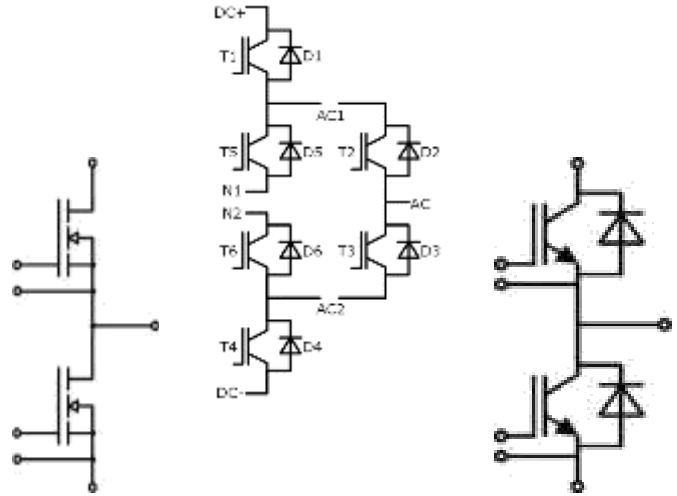
SKiiP SiC solution is perfect for 1500V DC solution and open the door for new application

2.xkV SiC chips from different suppliers are tested and available (planar/Trench – driver is optimized)

2.2 kV/2.3kV in testing procedure

SKiiP 3-level as sample available and extend our IPM –SKiiP product folio

SKiiP 3
SKiiP 4
SKiiP 7



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