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Intelligent SiC Power Module for 2- and 3-level high voltage applic ations

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Abstract

The paper introduces an intelligent high-power SiC module with optimized driver design and low stray inductance. The SiC-driver has integrated short circuit protection and is optimized for different SiC chip technologies . High-performance heat sink will help to increase the power density.

Also we will introduce a 3-level-design with intellligent high-power module with Si chips.

1. General market information

2- and 3-level-inverters are very common in China. 3-level-inverter is necessary if the DC voltage is above the standard blocking voltage of the IGBTs or SiC devices. Very common blocking voltage for IGBT/SiC devices are 1200V/1700V and 2000V.

2- and 3-level-inverter are very cost driven and standard power modules (Semix3p, EconoDual, ST20) are penetrating the market in multi-level applications. From the engineering point of view is this not a perfect solution because commutation inductance is very high. Mostly are 3 power modules involved in “long commutation” paths. Furthermore is the required area of 3-module very large and the modules cannot perform with 100% compared to 2-level applications because overvoltage limits must be considered.

SiC devices starting to penetrate the market. E-mobility is already using SiC devices in high quantities but mainly in 2-level application with battery voltages in the range of 400 – 850V. A suitable high intelligent power module with SiC for DC voltage above 1600V is not in the market yet.

2. Intelligent power module SKiiP SiC

In this paper we will introduce an intelligent high power SiC module with optimized driver design, baseplate less construction, no solder technology used and low stray inductance. The SiC-driver has an integrated short circuit protection and can protect the SiC chips in a very short time. (>2us) Solderfree DCB, latest pressure technology to optimize the thermal performance of the SiC chips and high performance heat sink will help to increase the power density and reliability.

This new intelligent SiC-power module is ready to use and allows the user to quickly enter the market. The intelligent SiC-driver can handle different SiC chip (Trench/Planar) and this is not anymore in the responsibility of the user.

This new intelligent power module is like a “lego” system. Modular configuration of the half-bridges is suitable for 2-level-application up to 1650V DC and in 3-level-application up to 2500V DC. (IGBT version

3. 2-level SKiiP SiC

3-level design are dominating in DC voltage applications above 1500V (ESS, solar, PCS) and 2300V (windmill)

Today 2kV SiC chips getting common, but the price is still high. In our paper we will concentrate on DC voltages up to 1650V. The enduser has to make a calculation which solution is more cost effective, is it a 2-level design with SiC chips or a common 3-level design with standard IGBT

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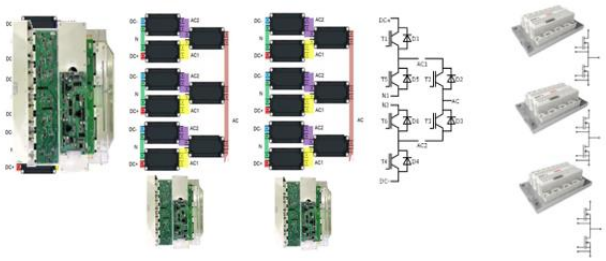
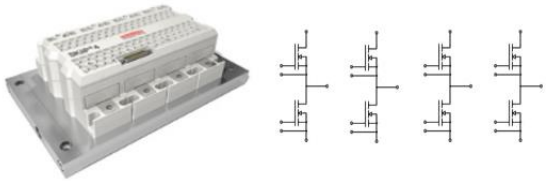
modules. Efficiency and mechanical dimension must be considered. Space saving by factor 3
Pic 1



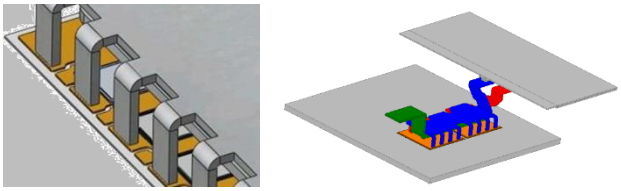
Pic 1:common 3-level design (left side) and alternative 2-level design with SKiiP SiC (right side)1.5MW converter

4. SKiiP SiC design in solder-free and pressure technology

The new SKiiP SiC (Pic2) is designed with an optimized DCB design to guarantee a homogenous switching behaviour of all paralleled SiC chips. The mechanical connection from the DCB to the power terminals is designed with a low stray-inductance construction. Pic 3

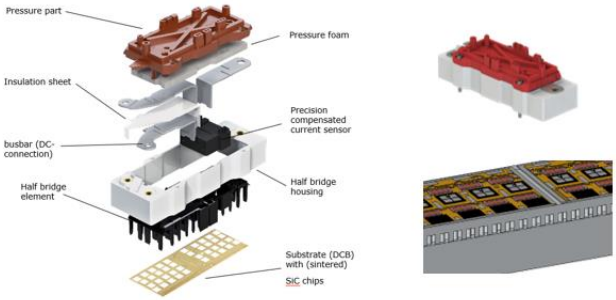


Pic 2: SKiiP SiC with 4-SiC halfbridges in parallel



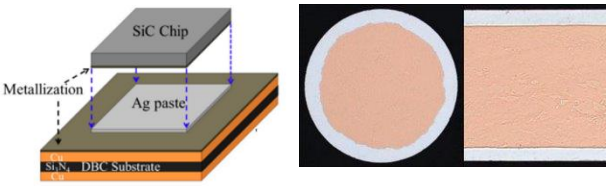
Pic 3：low commutation inductance and symmetrical high current distribution design for SiC chip

SKiiP SiC is designed in pressure technology. The DCB with sintered SiC chips is pressed to the high performance heatsink. No solder or welding technologies are used to guarantee a long life time. Pic 4



Pic 4: SKiiP SiC in pressure technology and "one half-bridge" on HP heatsink (right side)

The SiC chips are sintered on the DCB. Alu/copper bondire are used and in this combination an extended power cycyle capability can be guaranteed. Pic 5



Pic 5: Sintered SiC chip with Aluminum Clad Copper bond-wire

5. SKiiP SiC driver

On top of these half-bridge is the SiC driver which is capabile to charge up to 16 SiC chips per switch. (max 32 chips on one HB-DCB) A special ASIC make the driver reliable and intelligent. Gate voltage adjustments to controll SiC chips from different supplier is possible (-2V/-4V/-8V). This is unique by today. An electrically isolated interface for controll and error messages. The CAN bus interface for communication can be used. Pic 6

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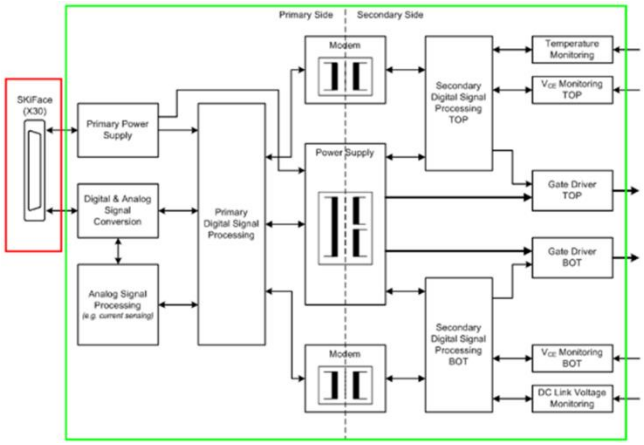
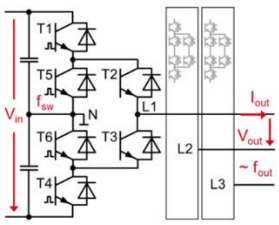


Pic 6: Block diagram of SKiiP SiC driver

6. Loss comparison of 3-level Si technology and 2-level SiC technology

If we make a loss and efficiency comparison between 3-level-IGBT version and 2-level-SiC version, the SiC version has better performance than the 3-level-IGBT version. Pic 7 (3-level-IGBT) Pic 8 (2-level SiC)

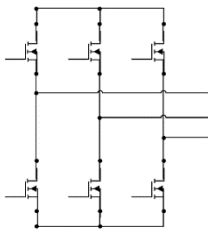
Input voltage (V_{in}) 1500 V	Output voltage (V_{out}) 690 Vrms
Output current (I_{out}) 1250 Arms	Output power (P_{out}) 1494 kW
Power factor (cos φ) 1	Output frequency (f_{out}) 50 Hz
Switching frequency (f_{sw}) 4 kHz	Modulation (M) Sinus triangle PWM
Additional losses per heatsink (P_{+HS}) 0 W	

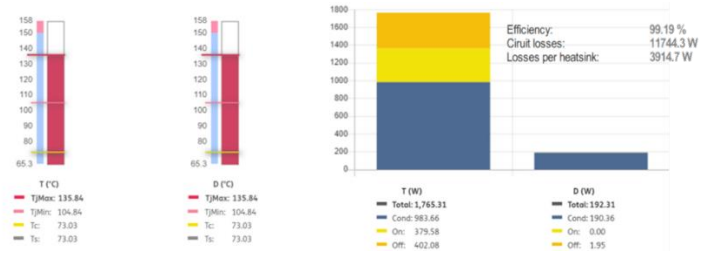


Efficiency: 99.01 %
Circuit losses: 14929.61 W
Total losses per heatsink: 4976.52 W

Pic 7: 3-level-IGBT version (Tj max < 175 degree)

Input voltage (V_{in}) 1500 V	Output voltage (V_{out}) 690 Vrms
Output current (I_{out}) 1250 Arms	Output power (P_{out}) 1494 kW
Power factor (cos φ) 1	Output frequency (f_{out}) 50 Hz
Switching frequency (f_{sw}) 8 kHz	Modulation (M) Sinus triangle PWM
Additional losses per heatsink (P_{+HS}) 0 W	

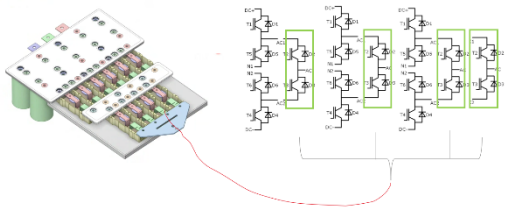




Pic 8: 2-level SKiiP SiC version (Tj max < 200 degree) we considered double fs to 3-level (8kHz)

7. 3-level-SKiiP(IGBT/SiC)

A new approach for 3-level application is possible with SKiiP modules as well. SKiiP half-bridges with 1200V/1700V can be used in 3-level design. Pic 9



Pic 9：3-level-converter design with high-power IPM

The intelligent power module is also available in IGBT technology. A 3-level design in HF/LF configuration and optimized stray inductance guarantee a fast time to market. Creepage and clearance are considered and according to standards.

The SKiiP 3-level is a modular design and flexible in power rating. The SKiiP 3-level is available in air-cooled and water-cooled technologies.

Optimized DC bus connection and low commutation inductance design for HF/LF

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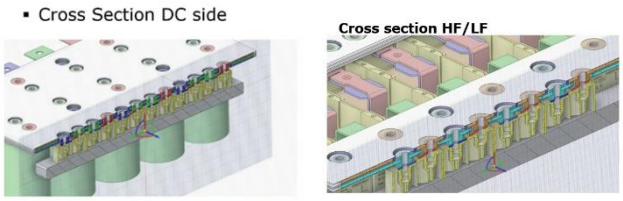
connection avoiding high overvoltage during commutation Pic 10



Pic 10 cross section for DC bus capacitors and connec tion between HF and LF paths

Driving factor to use SKiiP is the cost performance. 2 % lower cost by same performance, time to market, burn in tested system, high-performance heatsink and less R&D cost.

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