SiC Switches in Booster Power Modules for Highly Efficient, High-frequency Operation in Solar Inverters

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What Drives the Great Demand for SiC?

Outstanding physical properties

- High breakdown field strength (tenfold that of Si)
- A wide band gap (threelfold that of Si)
- High thermal conductivity (threelfold that of Si)

⇒ These properties are conducive to applications that demand greater efficiency, a smaller footprint and operate at higher frequencies and temperatures.
SiC Components Today

Schottky diodes
- Practically no reverse recovery charge

→ The solution of choice for many of today's applications

Active switches: SiC MOSFET
- Low tail current
- Very low specific on-resistance ($R_{DS(on)}$)

→ These days the main focus of research & development
Steps to Improve a Boost Converter’s Efficiency

1: Use SiC Schottky diode as an FWD
2: Add a SiC-MOSFET for the switch
   ➔ Full SiC boost converter
The Simulation Environment

- Calculations made with Vincotech ISE simulation software
- Measurements obtained during modules' characterization to enable fast, accurate comparisons of heat losses and temperature at various operating points
- A photovoltaic system’s typical operating point with 350 V input and 700 V output voltages taken into account for benchmarking
Measured/Simulated Modules

- IGBT switches and Si diodes ➜ Starter module
  
  **flowBOOST 0** (part no. V23990-P629-F72-PM) with a 40 A/1200 V Ultra Fast IGBT and a 30A/1200V STEALTHTH diode. Labeled Si_ in the following graphs

- IGBT switches and SiC diodes ➜ 1st step to improve efficiency
  
  **flowBOOST 0** (part no. V23990-P629-F62-PM) with a 40 A/1200 V Ultra Fast IGBT and 3x5 A/1200 V SiC diodes. Labeled SiC_ in the following graphs

- SiC MOSFET switch and SiC diodes ➜ 2nd step to improve efficiency
  
  **flowBOOST 0 SiC** (part no. 10-PZ12B2A045MR-M330L18Y) with a 45 mΩ/1200 V SiC MOSFET and 4x10 A/1200 V SiC diodes. Labeled SiC-MOSFET_ in the following graphs
Efficiency increases and losses decrease with the SiC diode even at switching frequencies > 4 kHz. Losses can be halved from 1.6% to 0.8% at 16 kHz and 5A output current
Losses may be reduced by another 37% to 0.5% at the same output power and switching frequency by using an SiC-MOSFET in place of an IGBT. Given the same output current and a switching frequency of 64kHz, efficiency increases and losses are reduced by just under 35%.
Given the same losses - for example, 50W total dynamic and static losses - and a 16kHz switching frequency, output power can be increased as much as 85% by using SiC diodes in place of Si diodes. Given the same switching frequency, output power can be increased up to 50% by using a SiC MOSFET in place of an Si IGBT.
Switching frequency can be increased from 16kHz to > 48kHz with switching losses remaining the same. The SiC diode/SiC-MOSFET combination's switching frequency may even be increased to over 100kHz.
Challenges in Using SiC Components

Fast facts and obvious **technical** challenges:

- SiC components increase efficiency and switching frequencies while reducing losses.
- Engineers can reduce device size and overall system cost with passive components such as inductors and transformers. ➔ However, components with inductances for high-frequency switching applications beyond 50 kHz have yet to be mass manufactured.

- Assembly and bonding techniques have to be adapted to SiC components' higher performance capabilities. Devices with SiC components can operate at relatively high current densities with the heat-sink temperature remaining the same. ➔ Sintering, pressure sintering with silver powder, optimized bonding compounds, copper braiding or large-area foil contacts could counter such effects.
Challenges in Using SiC Components

Fast facts and obvious cost challenges:

- Cost is the greatest barrier to SiC semiconductors' mass rollout.
- That barrier is gradually eroding as unit volumes rise, generations progress and R&D expenditure decreases.
- The price of 600 V SiC diodes dropped some 35% to 45% from 2011 to today. It is expected to come down another 10% or so in the next three years.
- The price of SiC MOSFETs is predicted to fall by more than 50% in the next three to four years, for example, for the 1200 V/80 mΩ type.

→ We see this price development as the door-opener for widespread use of SiC components, and SiC switches especially, in the years ahead.
We are ready to Drive Your Development with our standard products and custom solutions.

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*under preparation
Speed and Flexibility

Thank you