APPLICAION OF WIDE-BANDGAP POWER SEMICONDUCTOTR IN WIND ENERGY POWER CONVERTER

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INTRODUCTION

Wind power converter often takes the form of a 2-level topology, which relies on Silicon (Si-) Insulated Gate Bipolar Transistors (IGBT) to control current flows. These switching devices operate at medium frequency (e.g. 1 kHz) to achieve an acceptable trade-off between Pulse Width Modulated (PWM) waveform quality, filter size, and switching losses.

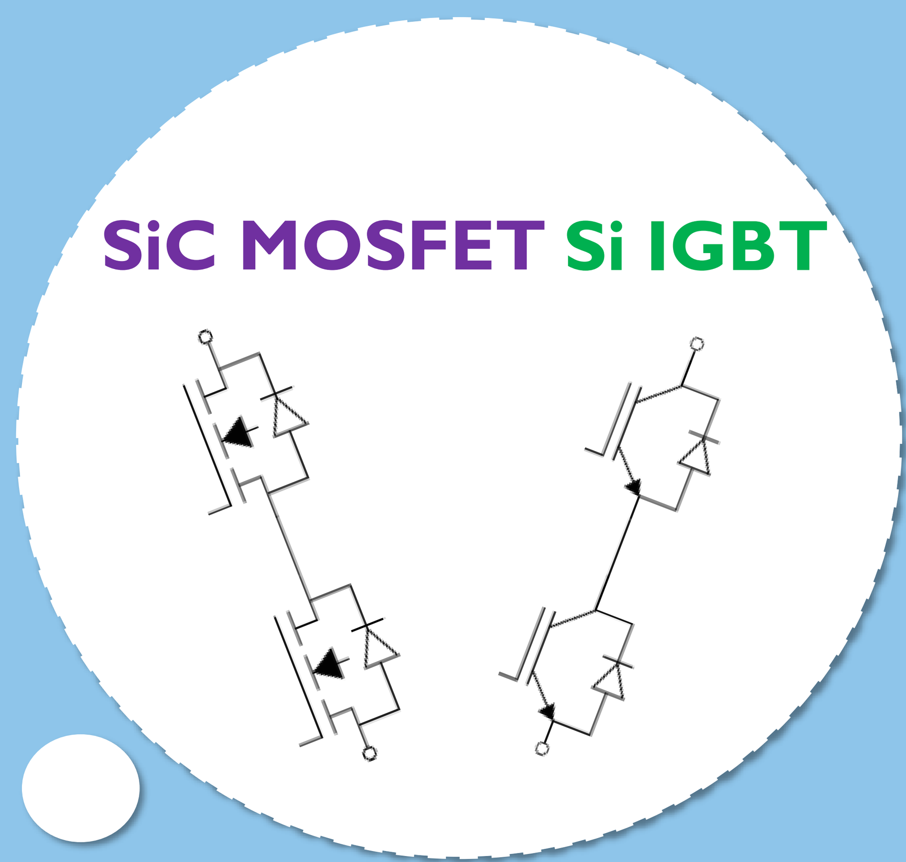
Wind turbines with increased power capability require a similar increase in current magnitude, further pushing the demand for more powerful electrical converters. This implies to scale the whole converter augmenting its size/weight. The number of semiconductors in parallel rises, the power efficiency and reliability tends to be more relevant

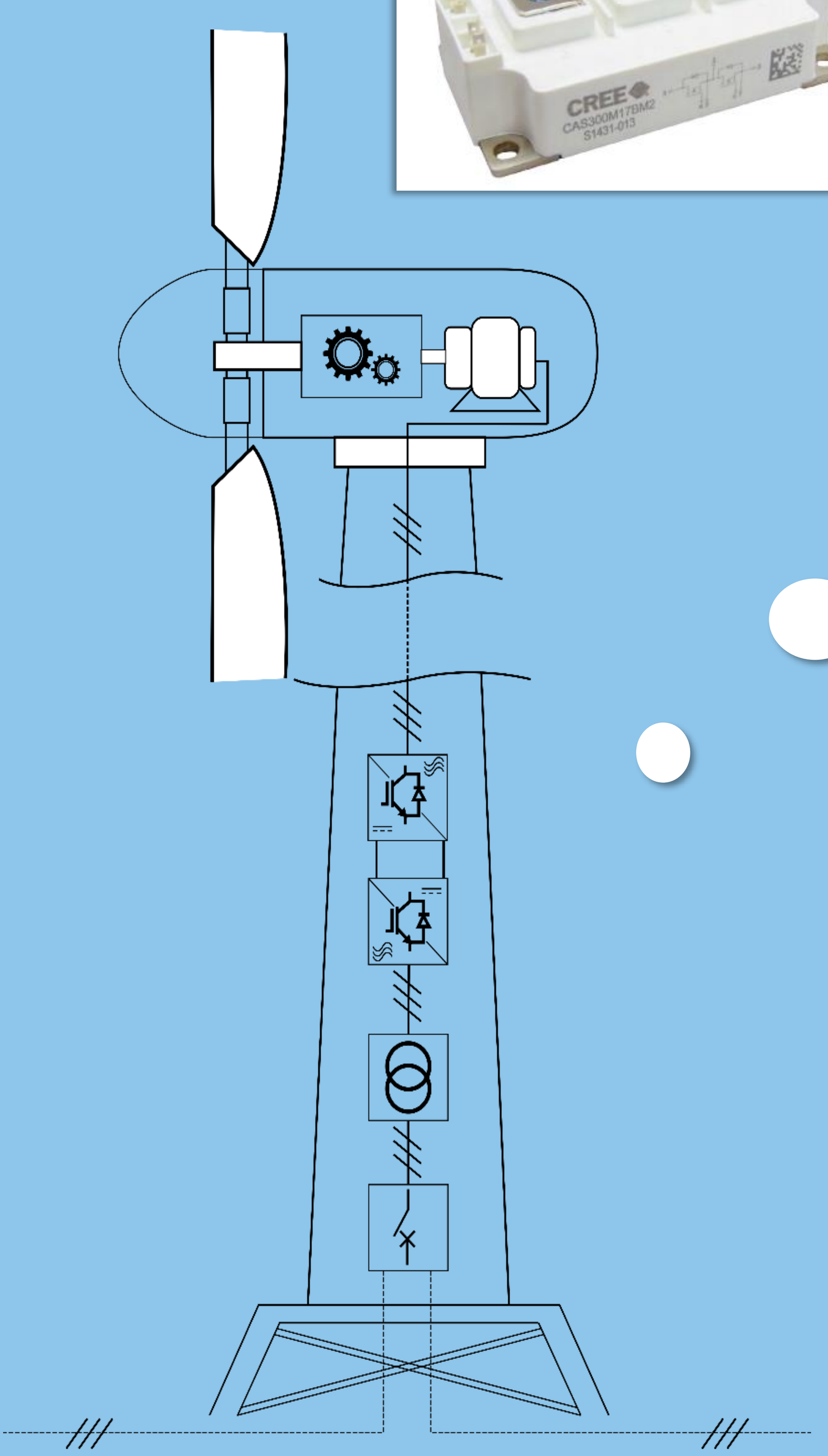
Silicon Carbide (SiC) MOSFETs are an emerging class of commercially-available power semiconductor devices, with their voltage and current ratings now sufficient for MW-scale wind turbine systems. SiC MOSFETs exhibit:

- ✓ Significantly lower switching losses
- ✓ Improved part-loading efficiency
- ✓ Higher voltage blocking capability

These advantages over Si-IGBT come however at a price: higher cost, higher EMI emissions, lower current rating, and unproved reliability track records.

The main objective of this poster is to make a comparison between the two semiconductors at similar current and voltage rating. See its reliability and the current available ratings module in the market.





SiC vs Si TECHNOLOGY

1. SWITCHING LOSSES.

Two similarly-rated modules, 1700 kV, at different temperatures.[1]

SiC MOSFET | Si IGBT

Operating Conditions	1000 V, 230 A, 25°C	1000 V, 230 A, 75°C	1000 V, 230 A, 125°C
$E_{ON}(mJ)$	12 | 68	9 | 89	8 | -
$E_{OFF}(mJ)$	28 | 86	26 | 99	27| -

SiC MOSFET exhibits significantly lower switching losses and only little influence from temperature compared to Si IGBT (which cannot sustain 125°C).

2. CAPABILITY CURRENT RATING

- ✓ 1.7kV, **1500A**/ Infineon IGBT module - FF1500R17IP5
- ✓ 1.7kV, **300A**/ Cree SiC MOSFET - CAS300M17BM2

To be able to supply the same power rate, there is a need to have a greater number of SiC dies connected in parallel than Si. However, working at higher frequency SiC currents could replace up to three times Si currents [2].

3. RELIABILITY

SiC modules switch much faster, e.g. 72 ns for SiC instead of 300 ns for Si. This also renders the current sharing between parallel dies challenging at turn-on and turn-off since the dies switching might not be perfectly synchronised at this speed [3]. This effect impacts the reliability of SiC module in addition to the lack of data on their lifetime behaviour given their relative novelty on the market.

4. EXPENSES

High substrate prices and much lower yields have been identified as some of the principal reasons for SiC higher cost. Besides having a dead time of around 52 weeks for power modules adds risk to the supply chain.
By comparison, SiC modules rated at 1.7 kV, 300 A presently cost around £1,200 while similarly voltage rated Si modules cost around £390.

CONCLUSION

SiC MOSFET modules offer lower switching losses, enabling converters to operate at higher switching frequencies and reduce required filter sizes. However, the limited current capability of SiC modules combined with challenging paralleling operation of dies impact negatively the converter cost and reliability.

REFERENCES:
1. M. Nawaz and K. Ilves, "On the comparative assessment of 1.7 kV, 300 a full SiC-MOSFET and Si-IGBT power modules," in 2016 IEEE Applied Power Electronics Conference and Exposition (APEC), Mar. 2016, pp. 276–282
2. "SiC MOSFET Module Replaces up to 3x Higher Current Si IGBT Modules in Voltage Source Inverter Application," p. 3
3. H. Li, S. Munk-Nielsen, S. Beczkowski, and X. Wang, "A novel DBC layout for current imbalance mitigation in SiC MOSFET multichip power modules," in 2016 IEEE Applied Power Electronics Conference and Exposition (APEC), Mar. 2016, pp. 704–708.

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