# SiC Mosfet's Application

*Simon Kim, Infineon Technologies, Korea*

## Abstract

For most of application, total system cost is first priority to Engineer. Approach for making system cost down can be to reduce cooling cost by selecting low loss item or reducing filter cost by increasing frequency. SiC Mosfet (CoolSiC$^{TM}$) can approach both of case. This paper shows market-needs and reviews each application with SiC.

## Kilowatt power application needs SiC

Power electronics is applied in several of application: from megawatt Power transmission to some watt cell phone adaptor power. In general, megawatt application has low frequency and some watt application has high frequency (refer to Fig.1). Ralph Teichmann's paper showed that filter cost could be reduced in half for 100kW converter as example, when switching frequency is changed from 4[kHz] to 8[kHz] in 2 level,[2]. Kilowatt power application moves to increase switching frequency for reducing filter size. Especially PV (Solar), ESS(Energy Storage system) & EV Charger system needs low loss item at high frequency. SiC product can be one of solution in this Kilowatt power application.

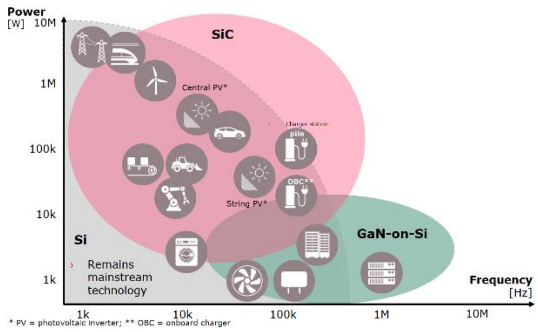


**Fig.1 different Applications from MW to W rate, [1]**

## Comparing power loss between Si & SiC

As example of Kilowatt application, 25kW 3 phase inverter can be considered. In this case, 1200V 100A Si IGBT and SiC Mosfet can be selected for this thermal simulation (Refer to Table 1 & 2).

| Power | P.F | Vdc | | Vout | Iout | Ta |
|---|---|---|---|---|---|---|
| [kW] | | [V] | | [V] | [A] | [℃] |
| 25 | 0.99 | 750 | | 380 | 38.37 | 50 |

**Table 1. Estimated 3 phase inverter spec. for simulation**

| Item | FF100R12RT4 | FF11MR12W1M1_B11 |
|---|---|---|
| Chip | Si IGBT 4 | CoolSiC$^{TM}$, SiC Mosfet |
| Current Cap. | 100A | 11mΩ (100A) |
| Width(mm) | 34 | 33.8 |
| Length(mm) | 94 | 62.8 |
| Figure |  |  |

**Table 2. Applied item for simulation**

For the same condition, heat-sink with poor cooling condition, Rth(h-a) = 1[k/w] was selected. In 25kW 3 phase inverter simulation result, Si IGBT's loss with Fs/w = 4[kHz] was similar with SiC Mosfet loss with Fs/w = 32[KHz] (Refer to Fig.2)

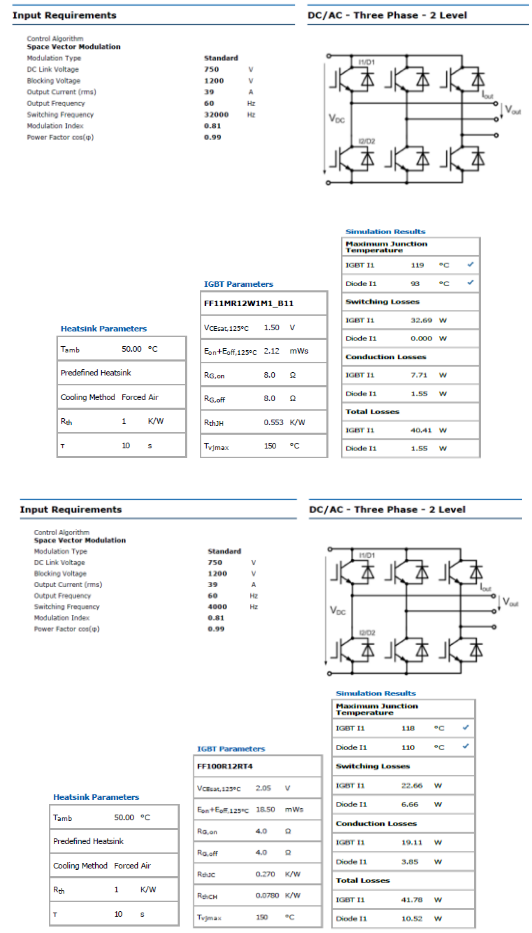


**Fig.2 Simulation result for Si IGBT(FF100R12RT4) & SiC Mosfet (FF11MR12W1M1_B11), [3]**

## Solar Inverter: DC-DC converter

In string solar inverter, there is needs for increasing switching frequency with purpose of inductor size reduction in DC-DC part.

| Power | | Vin | Iin | Vdc | Idc | Ta |
|---|---|---|---|---|---|---|
| [kW] | | [V] | [A] | [V] | [A] | [°C] |
| 20 | | 400 | 50.0 | 600 | 33.3 | 50 |

**Table 3. PV estimated DC-DC spec. for simulation**

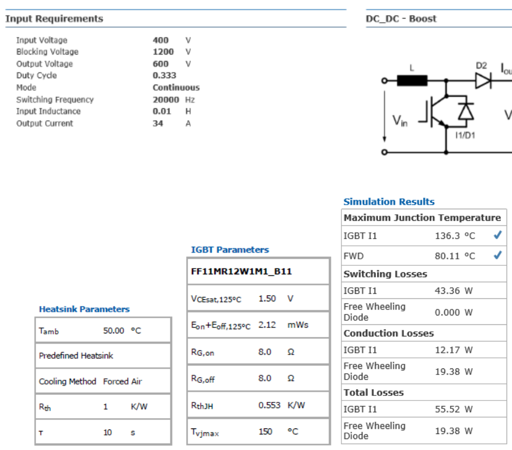


**Fig.3 Simulation result for SiC Mosfet (FF11MR12W1M1_B11) in DC-DC part, PV string Inverter**

For 20kW DC-DC part with Voltage boost from 400Vdc to 600Vdc, SiC Mosfet can have switching frequency around 20[kHz] with Rth(h-a) = 1[k/w]. If Si IGBT would be applied, its switching frequency was 3[kHz] in simulation with similar thermal result, Tj = 138[°C].

## ESS (Energy storage system)

ESS' Power circuit configuration is similar with solar inverter. One difference is that energy flows is in bi-direction (refer to Fig.4). As simulation example, converter mode with 25kW 3 phase Inverter circuit can be done in simulation. In this case, P.F is negative value. In this thermal simulation, hottest point is not Si IGBT, but Diode in Fig.5. Also, SiC Mosfet can be applied. In converter mode operation, customer can reduce power loss with synchronous rectification method. At this operation, Power loss is occurred in SiC mosfet by "turning on" in 3rd quadrant, not in body diode (refer to Fig.6).

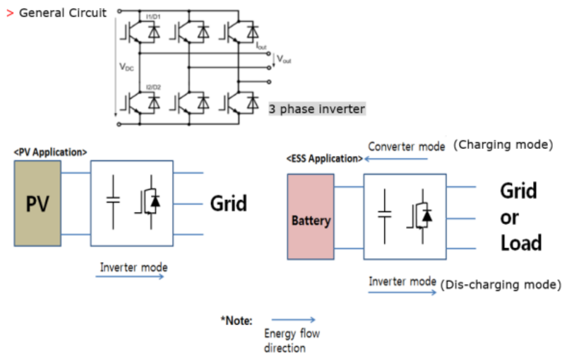


**Fig.4 Energy flow direction in both PV (Solar) & ESS**

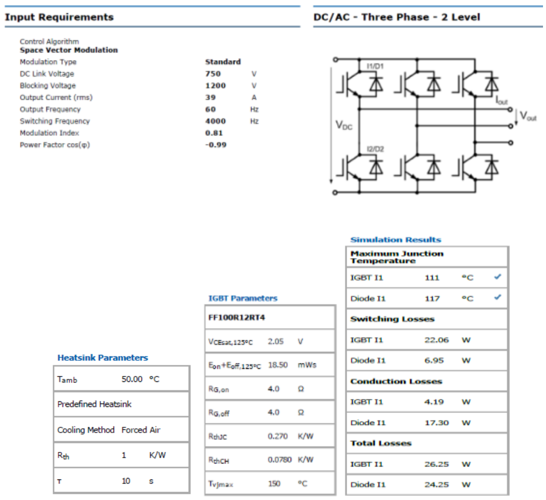


**Fig.5 Simulation result for Si IGBT (FF100R12RT4) in Con. Mode: Diode chip's temperature is hotter than IGBT chip's.**

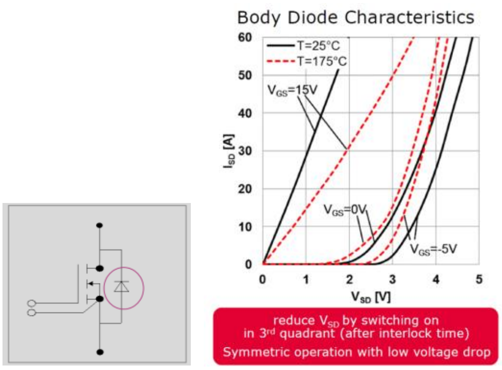


**Fig.6 Body diode characteristics example in SiC mosfet**

## EV Charger station

Recently, EV charger station is booming application. Charger Inverter was developed with Si IGBT. Some maker have used Si mosfet for high frequency.

After recently battery voltage range was increased into 750Vdc, circuit using Si mosfet was complexed with Vienna PFC, dual H-Bridge & dual Transformer. But, with 1200V SiC Mosfet and 1200V SiC diode, EV charger station's circuit can be simplified (refer to Fig.7)

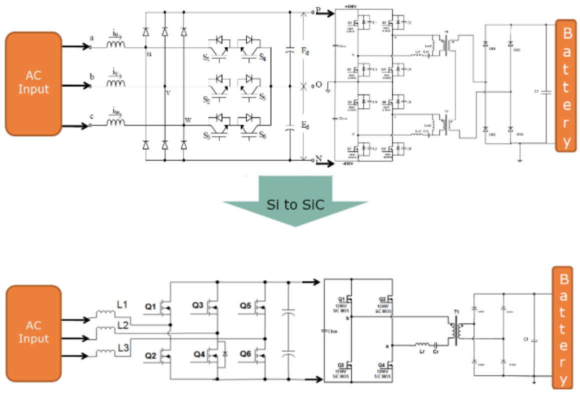


**Fig.7 EV Charger system simplified with CoolSiC$^{TM}$**

## Unipolar Voltage bias for gate driver

Some customer wants to use unipolar voltage bias(+15V/0V) due to simple Aux power supply, instead of bipolar voltage bias(+15V/-5V). In this case, by double pulse input, customer must check "turn on" and "turn off" waveform.

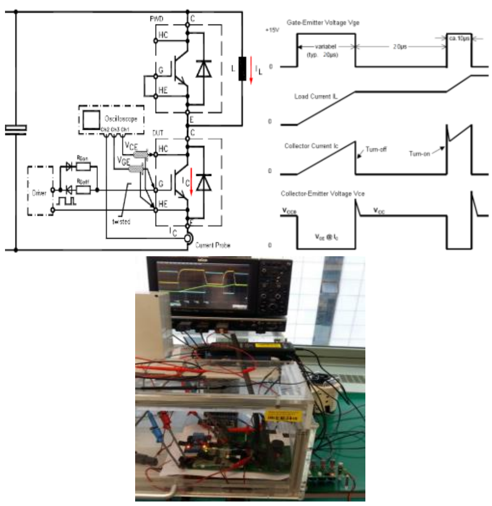


**Fig. 8 Double pulse test circuit(left) and test with Unipolar Voltage bias in SiC (right)**

## Conclusion

This paper showed some application needs high frequency for system cost reduction by filter size. Simulation for both Si IGBT and SiC Mosfet were done with the same cooling condition. 100A SiC Mosfet can be applied in 20~30kW PV & ESS application with switching frequency from 20 to 32[kHz]. If heatsink with lower thermal resistance is applied, power capability or switching frequency capability can be higher. Also, in Charger system, 1200V SiC Mosfet & Diode can make system circuit simple. Infineon supplies 11mΩ (100A) ~ 45mΩ (25A) SiC mosfet(refer to Fig. 9) and Customer can select proper power rating with using IPOSIM [3].

Lead products

| Schematic | Type | $R_{DSON}$ | $V_{DS}$ | Package |
|---|---|---|---|---|
| Single switch | IMW120R045M1 | 45 mOhm | 1200 V | TO247-3pin |
| Single switch | IMZ120R045M1 | 45 mOhm | 1200 V | TO247-4pin |
| Half bridge with NTC | FF11mR12W1M1_B11 | 11 mOhm | 1200 V | Easy1B PressFIT |
| | FF23mR12W1M1_B11 | 23 mOhm | 1200 V | |
| Booster with NTC | DF11mR12W1M1_B11 | 11 mOhm | 1200 V | |
| | DF23mR12W1M1_B11 | 23 mOhm | 1200 V | |

**Fig.9 SiC mosfet Product, CoolSiC$^{TM}$**

## [Reference]

[1] M. Buschkühle, Dr. F. Björk, Dr. P. Friedrichs, "CoolSiC$^{TM}$ Mosfet revolution to relay on, ion file" presentation file, May 2017

[2] Ralph Teichmann, Mariusz Malinowski and Steffen Bernet, "Evaluation of Three-level Rectifiers for Low-voltage Utility application", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS VOL.52, NO.2 , April 2005"

[3] Web Infineon module Simulator (IPOSIM): https://infineon.transim.com/iposim/Pages/topology.aspx