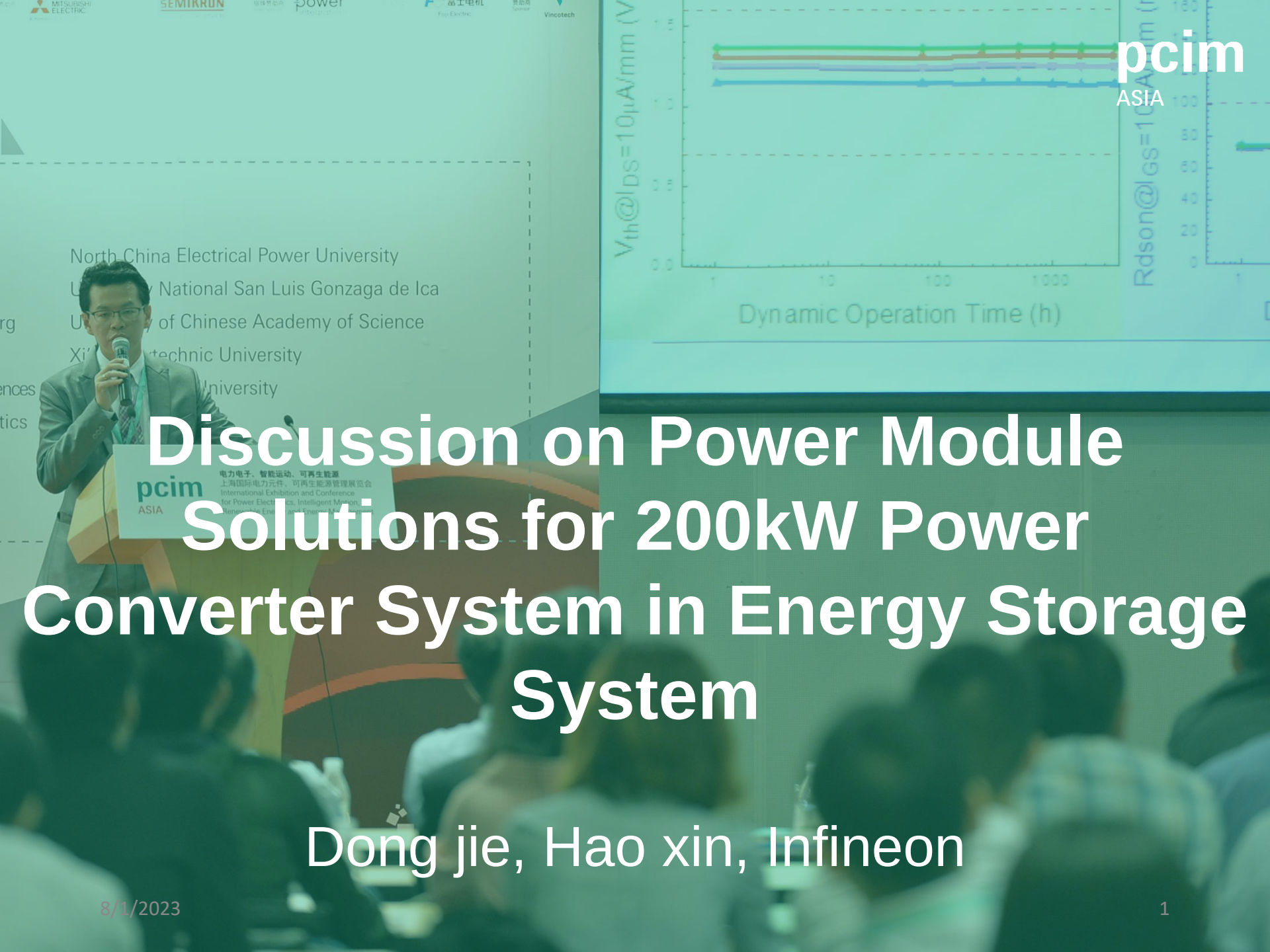

Discussion on Power Module Solutions for 200kW Power Converter System in Energy Storage System

Dong jie, Hao xin, Infineon

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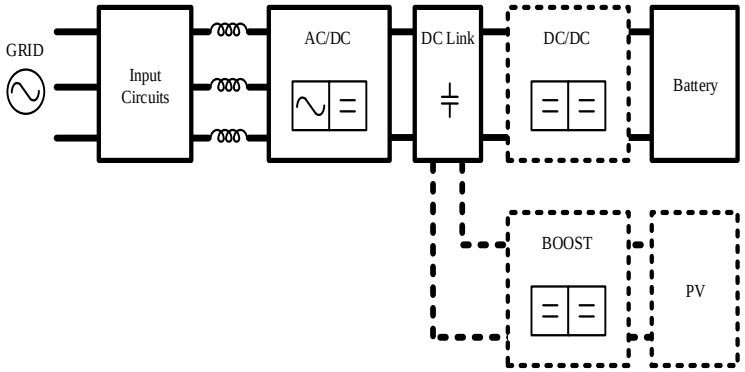
Energy Storage System (ESS)

- Renewable energy source(PV & Wind): volatility and large-scale access

Energy Storage System

- Reduce power fluctuations
- Improve power quality
- Reduce the impact of renewable energy on grid



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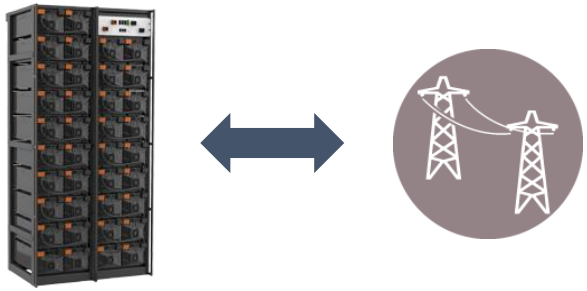
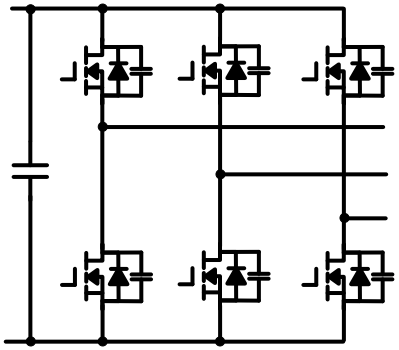
PCS topology: two level

Output power: P_{out}	200kW
Switching frequency: f_{sw}	16kHz
DC voltage: V_{DC}	1340V
AC voltage: V_{AC}	690V

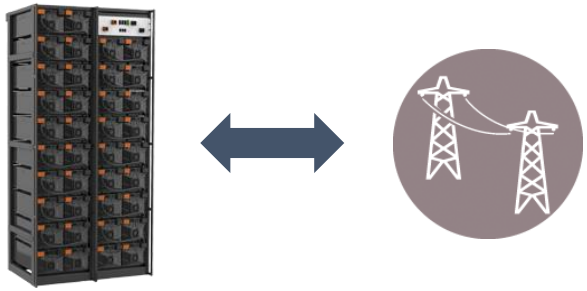


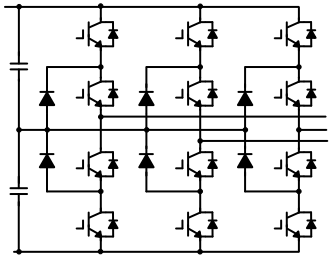


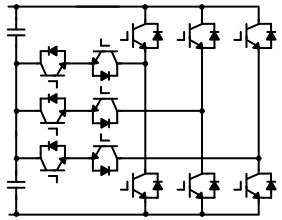
- Conventional topology
- Power device faces high voltage request

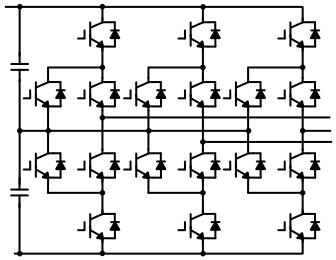
PCS topology: three level

Output power: P_{out}	200kW
Switching frequency: f_{sw}	16kHz
DC voltage: V_{DC}	1340V
AC voltage: V_{AC}	690V









- Operate with higher voltage
- Reduce the volume and cost of magnetic elements in higher frequency
- Harmonics can be optimized

PCS Topology

		Advantage	*Disadvantage*
Two level converters		*Simple control* *Less component*	*High voltage stress* *High harmonics*
Three level converters	NPC1 NPC2 ANPC	*Low voltage stress* *Low harmonics*	*Complex control* *More component*

NPC2

NPC1
ANPC

PCS Modulation Method

SPWM	SVPWM	DPWM
• Typical modulation method	• SVPWM can improve the DC voltage utilization	• Reduce the switching loss by decreasing the switching actions

modulation ratio M $$M = \frac{V_{AC} / \sqrt{3}}{V_{DC} / 2}$$

* V_{AC} is the AC line-voltage for three phase system and V_{DC} is the DC bus voltage

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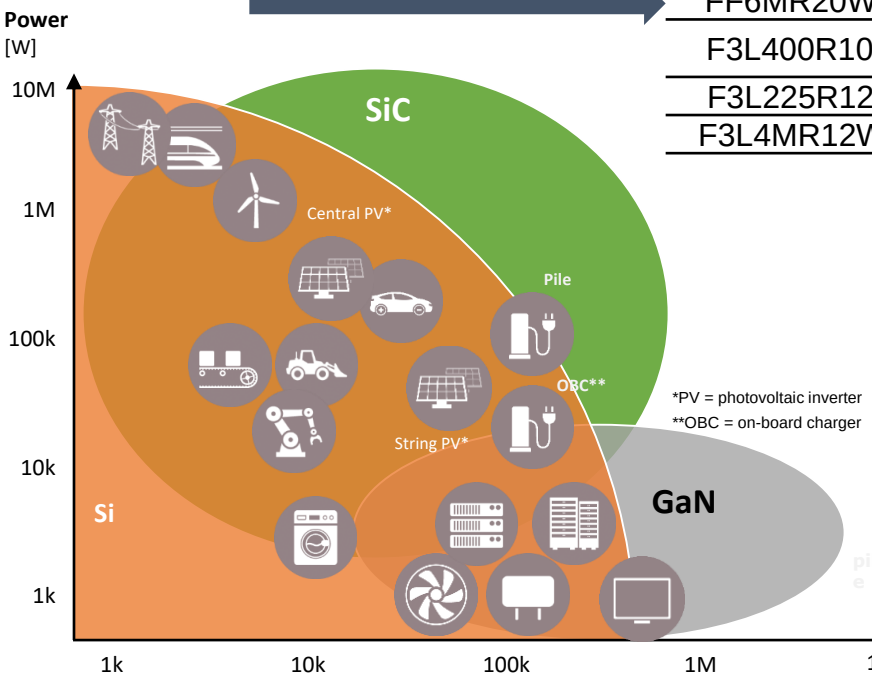
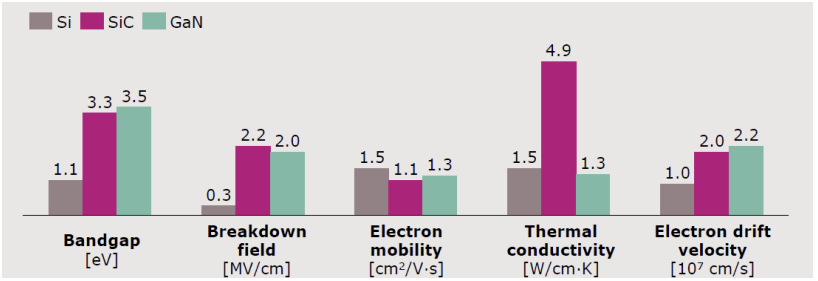
Module Solution and Comparison

– 2kV SiC MOSFET

	Topology	*Package*	*Parallel condition*
FF6MR20W2M1H_B70	*Half-bridge*	*Easy2B*	*2 in parallel*
F3L400R10W3S7_C25	*NPC1*	*Easy3B*	*No parallel*
F3L225R12W3H3_B11	*NPC1*	*Easy3B*	*2 in parallel*
F3L4MR12W3M1H_B11	*ANPC*	*Easy3B*	*2 in parallel*

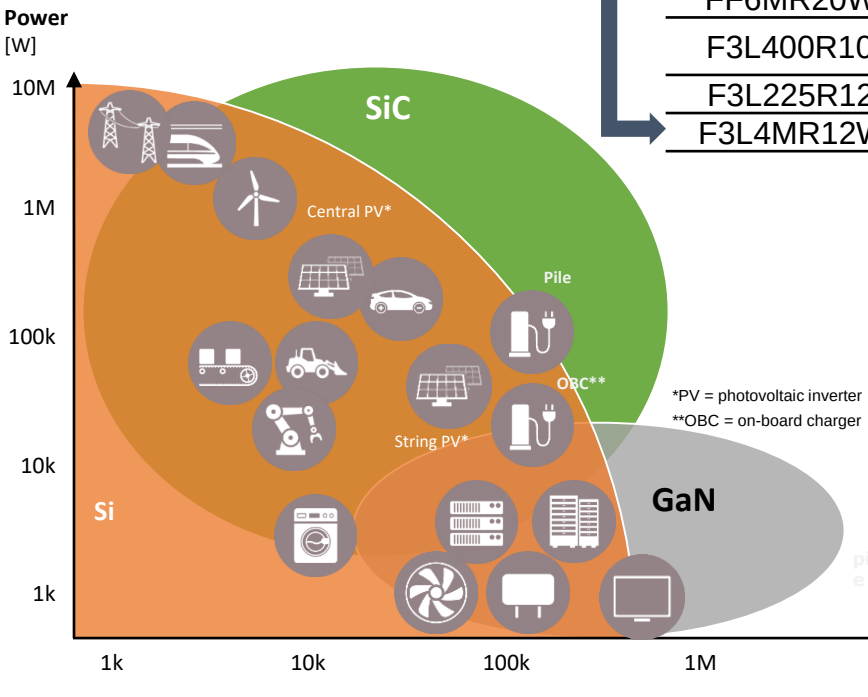


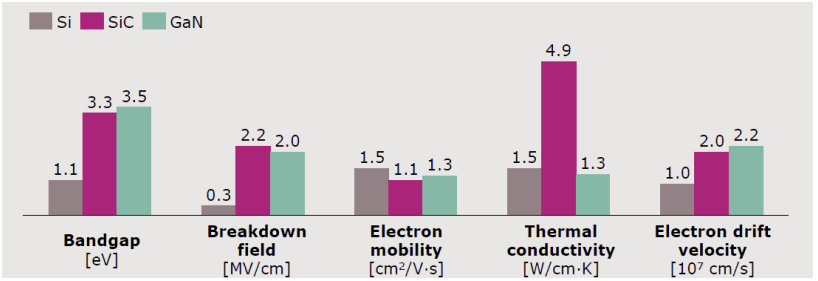


Module Solution and Comparison

– 1.2kV SiC MOSFET

	Topology	*Package*	*Parallel condition*
FF6MR20W2M1H_B70	*Half-bridge*	*Easy2B*	*2 in parallel*
F3L400R10W3S7_C25	*NPC1*	*Easy3B*	*No parallel*
F3L225R12W3H3_B11	*NPC1*	*Easy3B*	*2 in parallel*
F3L4MR12W3M1H_B11	*ANPC*	*Easy3B*	*2 in parallel*

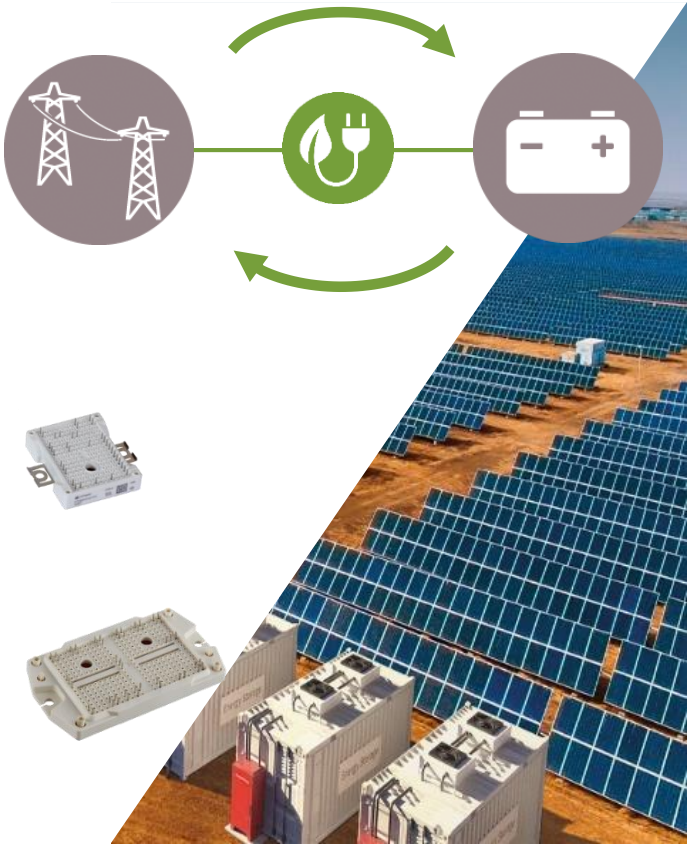




Module Solution and Comparison

	Topology	Package	Parallel condition
FF6MR20W2M1H_B70	Half-bridge	Easy2B	2 in parallel
F3L400R10W3S7_C25	NPC1	Easy3B	No parallel
F3L225R12W3H3_B11	NPC1	Easy3B	2 in parallel
F3L4MR12W3M1H_B11	ANPC	Easy3B	2 in parallel

	Chips
FF6MR20W2M1H_B70	2000V/6mohm SiC
F3L400R10W3S7_C25	T1/2/3/4: 950V/400A
	D1/2/3/4: 950V/300A
	D5/D6: 950V/200A
F3L225R12W3H3_B11	T1/2/3/4: 1200V/225A
	D1/4/5/6: 1200V/300A
	D2/3: 1200V/200A
F3L4MR12W3M1H_B11	T2/3:1200V/4mohm SiC
	T1/4/5/6: 1200V/150A
	D1/4/5/6: 1200V/150A



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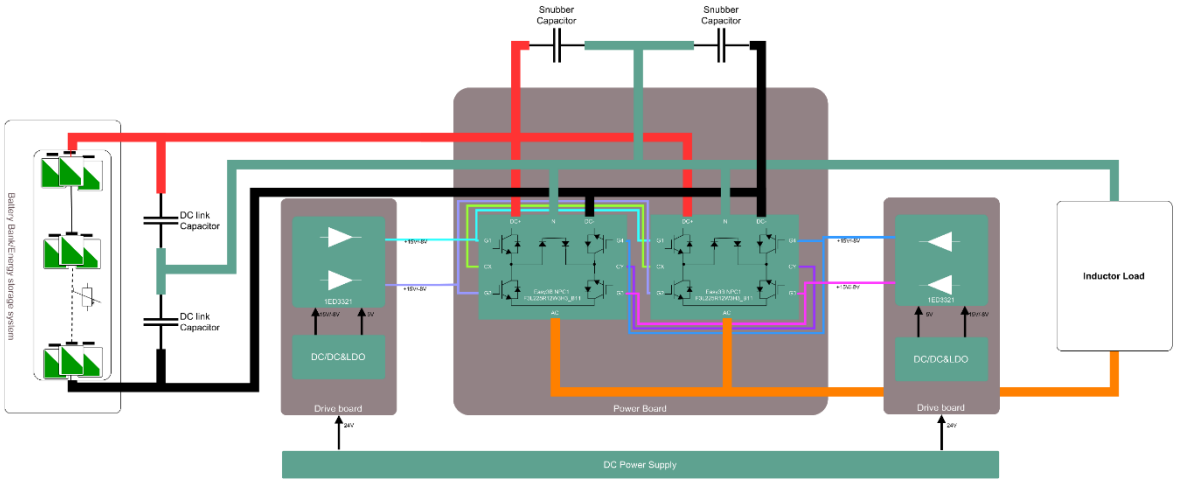
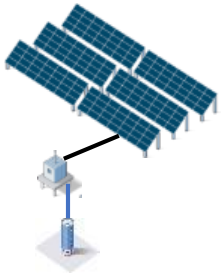
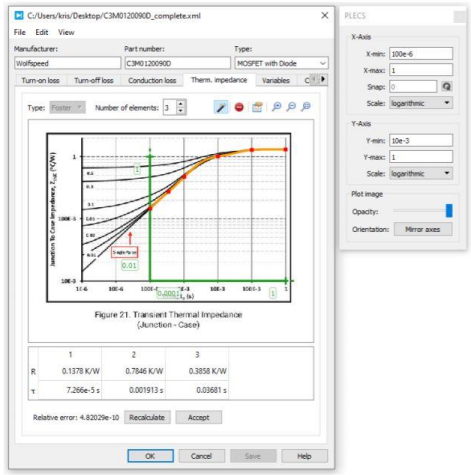
F3L225R12W3H3_B11 Double Pulse Test



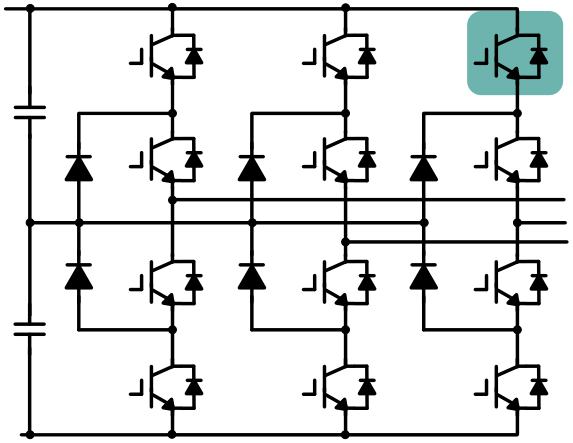


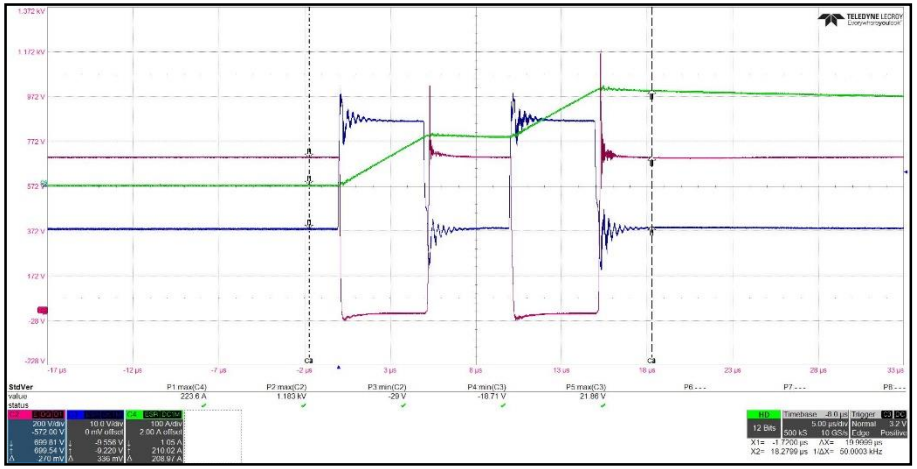
200kW module simulation model

- The model includes conduction loss, switching loss, thermal chain and etc.



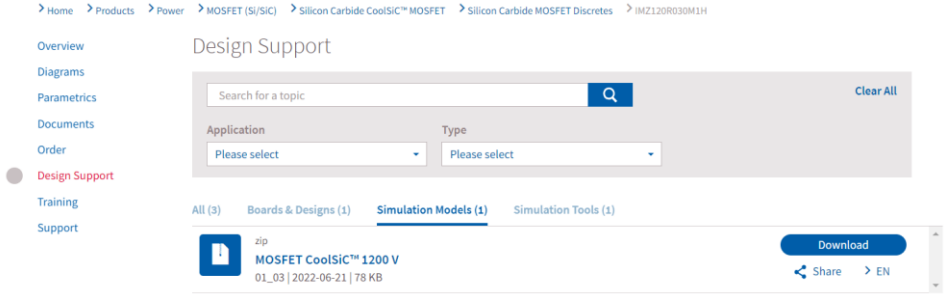
F3L225R12W3H3_B11 Double Pulse Test





The red line is V_{CE} curve, green line is I_{CE} curve and blue lin

V_{BUS}	700V
I_{CE}	115A
R_{gon}	7.5Ω
R_{goff}	5Ω



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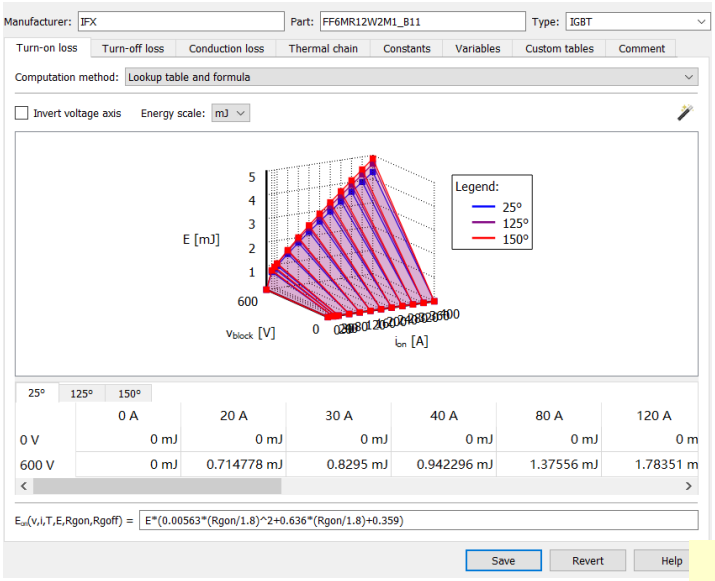
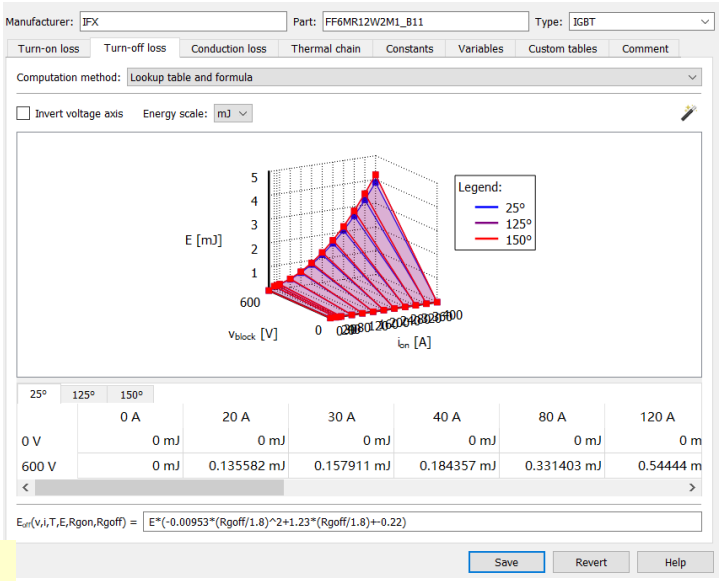
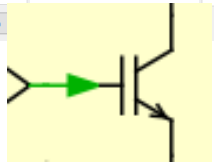
PLECS model

Turn-on Loss



Turn-off Loss

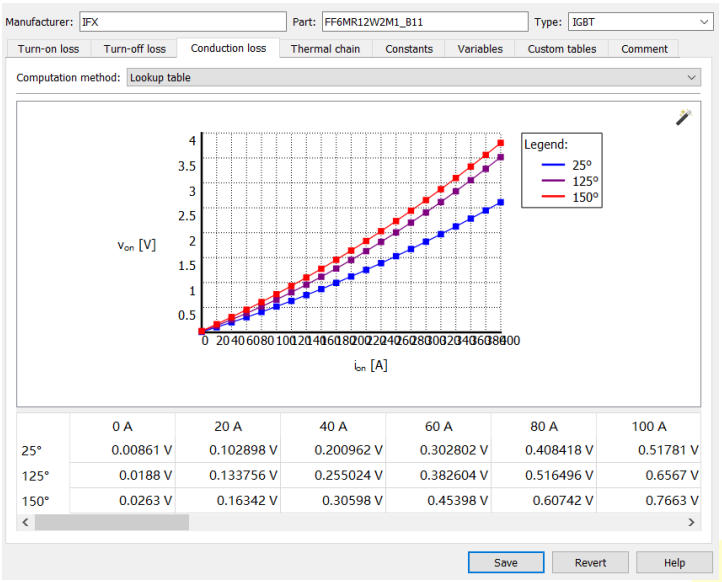




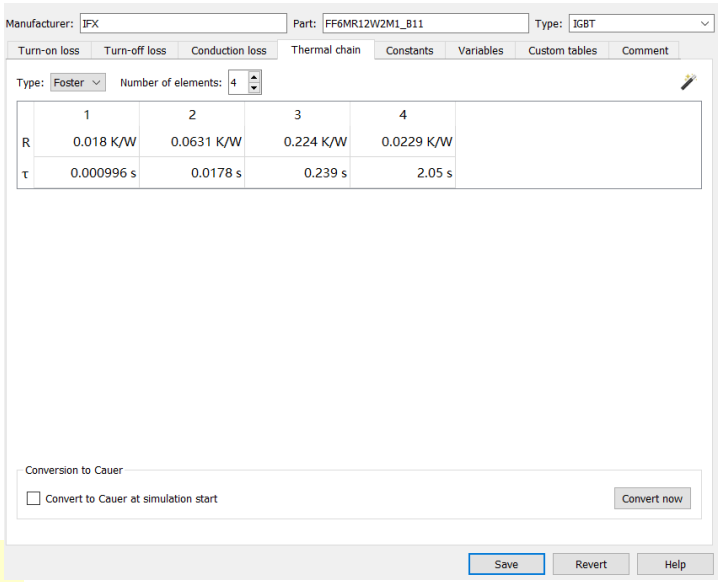
$$E_{off} = E_{off\_measure} - \varphi \times E_{oss}$$

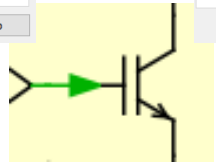
PLECS model

Conduction Loss

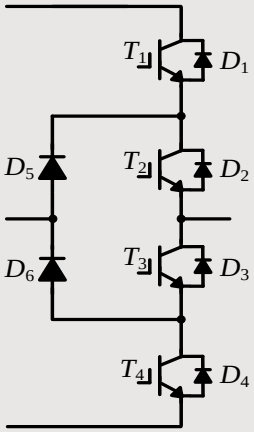


Thermal Chain



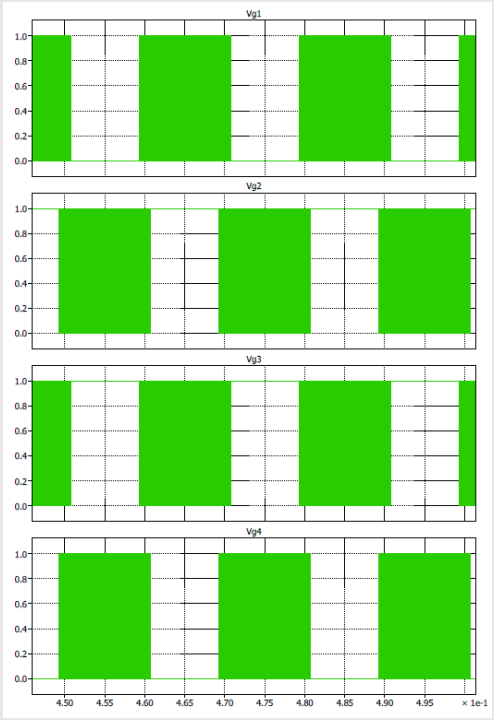


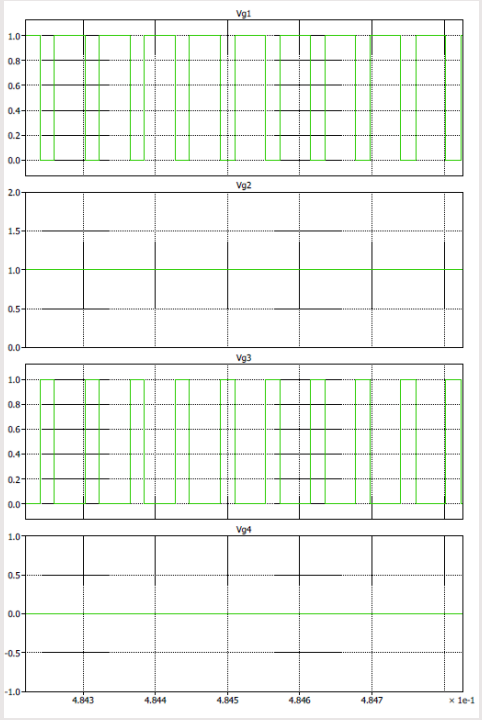
PLECS Simulation Example



Single phase circuit NPC1

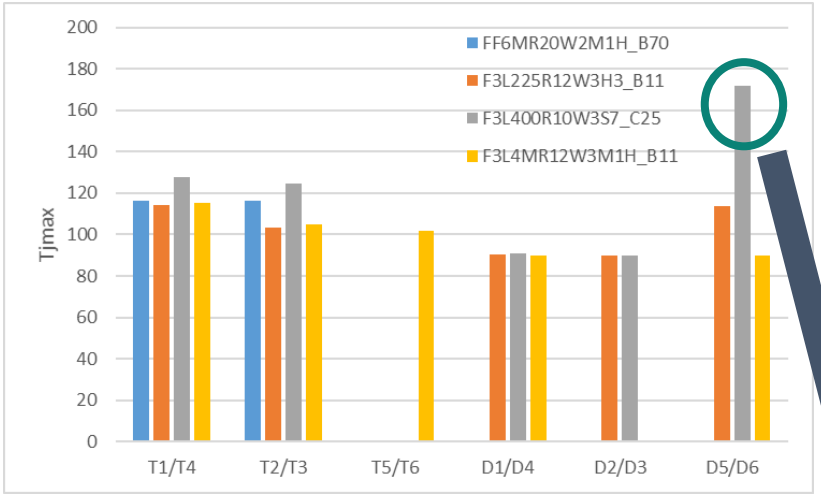
SVPWM modulation



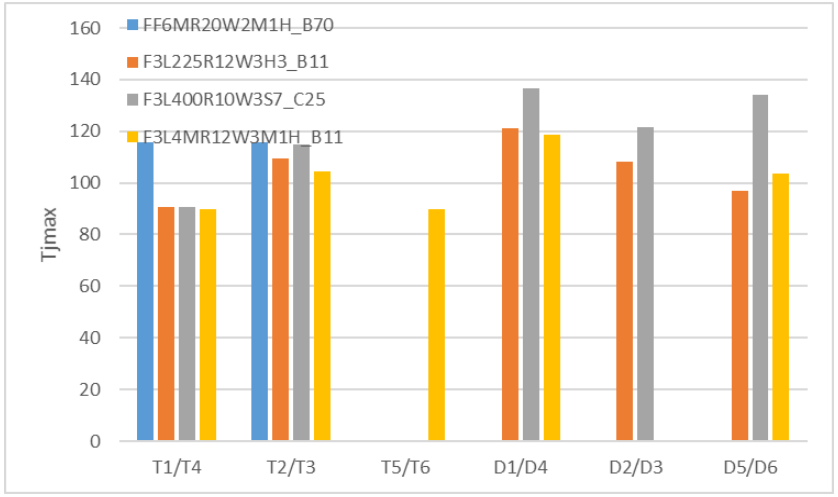


PLECS Simulation Results

PF=1



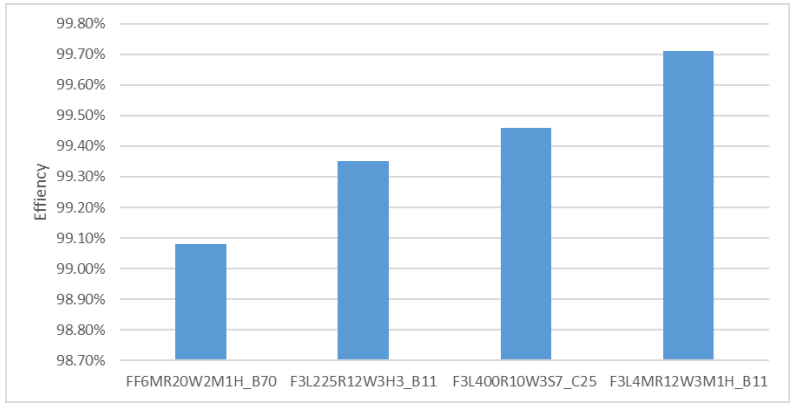
PF=-1



– If the V_{DC} can be reduced to 1200V, then the temperature can be limited under 140℃

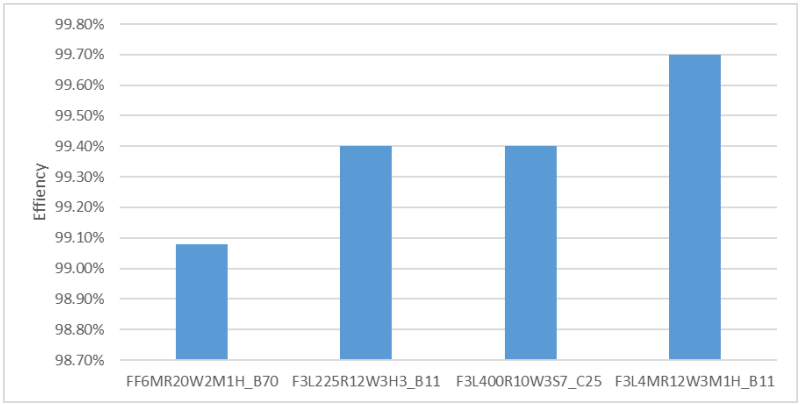
PLECS Simulation Results

PF=1



- Highest efficiency, can save the operation cost.

PF=-1



- Smallest module size
- The number of control signals and driver circuits are reduced to simplify the system structure

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The Advantage and Disadvantage of 200kW PCS solution

	Advantages	*Disadvantages*
FF6MR20W2M1H_B70	*Small module size; High power factor; Less support circuit*	*Low efficiency; High harmonics*
F3L400R10W3S7_C25	*Single module; High power factor*	*Limited condition*
F3L225R12W3H3_B11	*Cost-effective*	*Easy3B in parallel*
F3L4MR12W3M1H_B11	*High efficiency*	*Complex control method; in parallel*

- FF6MR20W2M1H_B70 can achieved simplest circuit and control method.
- F3L400R10W3S7_C25 can achieve 200kW in single module,
- F3L4MR12W3M1H_B11 which is SiC MOSFET hybrid module can provide the highest efficiency.
- F3L225R12W3H3_B11 is designed for 200kW PCS, which is the most cost-effective for this application


Infineon