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The Advantage of SiC MOSFET for Three-phase Four Legs Converter in Off-grid Applications

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Abstract: Commercial and industrial (C&I) side energy storage system (ESS) is booming recently. Unbalanced load capability and output power quality are important indicators of PCS. 3P4L converter has the strongest ability to supply unbalanced loads but compared to the 3P3L topology, the cost increases and the output AC voltage harmonic distortion is higher. SiC MOSFETs can significantly increase the switching frequency compared with IGBTs due to their superior material characteristics. In this paper, the theoretical analysis combined with the simulation results show that SiC MOSFETs are more suitable for 3P4L converter, which is a cost performance solution.

The fourth leg is directly applied to the triple-frequency sinusoidal waveform for modulation, so that the triple-frequency component can be canceled out in the output of the phase voltage. This modulation method is easy to realize and widely used in engineering.

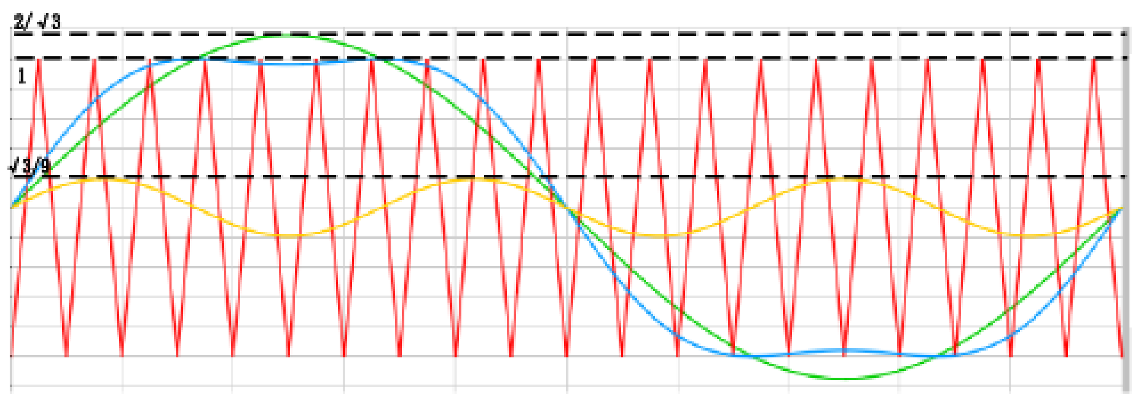

Fig. 6. 3P4L topology modulation waveform

$$M_a = \frac{2}{\sqrt{3}} m\sin(\omega t) + \frac{\sqrt{3}}{9} m(3\omega t)$$

$$M_b = \frac{2}{\sqrt{3}} m\sin(\omega t - 120^{\circ}) + \frac{\sqrt{3}}{9} m(3\omega t)$$

$$M_c = \frac{2}{\sqrt{3}} m\sin(\omega t + 120^{\circ}) + \frac{\sqrt{3}}{9} m(3\omega t)$$

$$M_n = \frac{\sqrt{3}}{9} m(3\omega t)$$

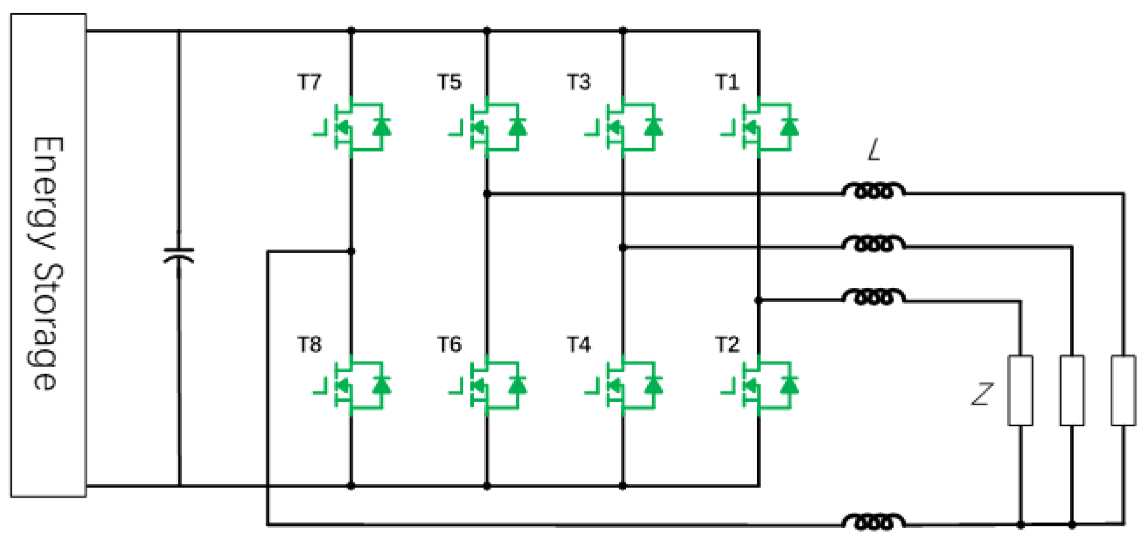

Fig. 11. SiC MOSFET in 2L 3P4L topology

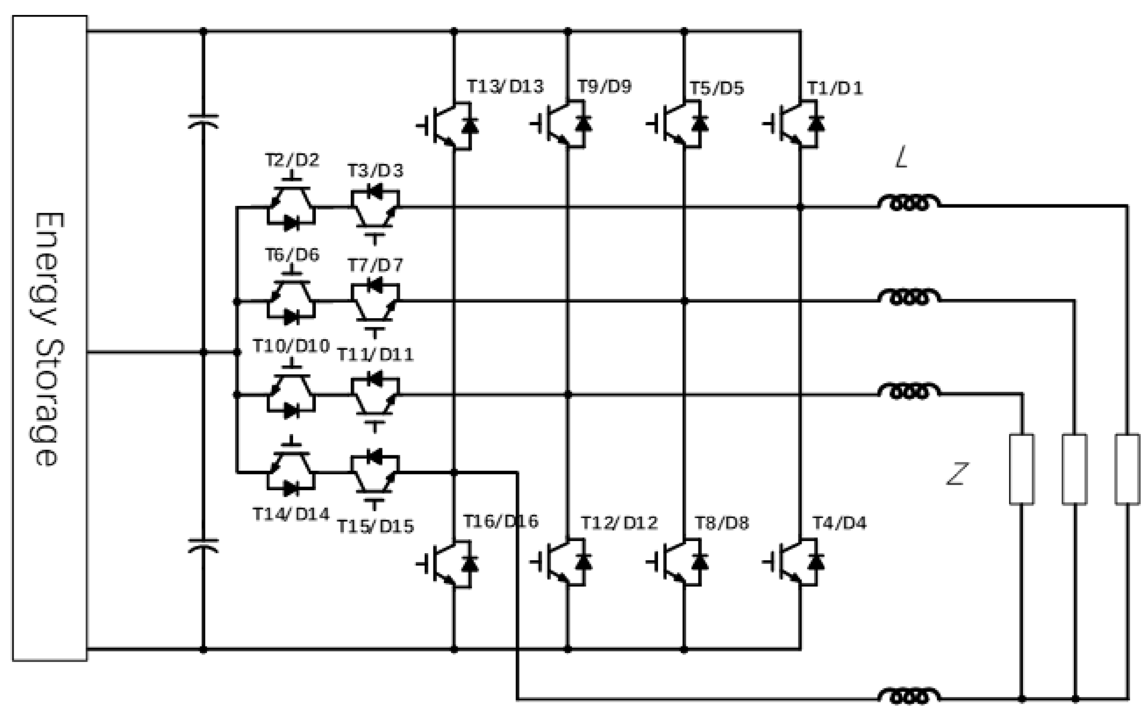

Fig. 12. Si IGBT in T-NPC 3P4L topology

SiC MOSFETs are believed to replace IGBTs for better performance in a variety of applications, such as energy storage system, where using SiC MOSFETs to improve efficiency can bring distinct economic benefits. The higher switching frequency of SiC MOSFET also improves the power quality of the inverter's grid-connected output.

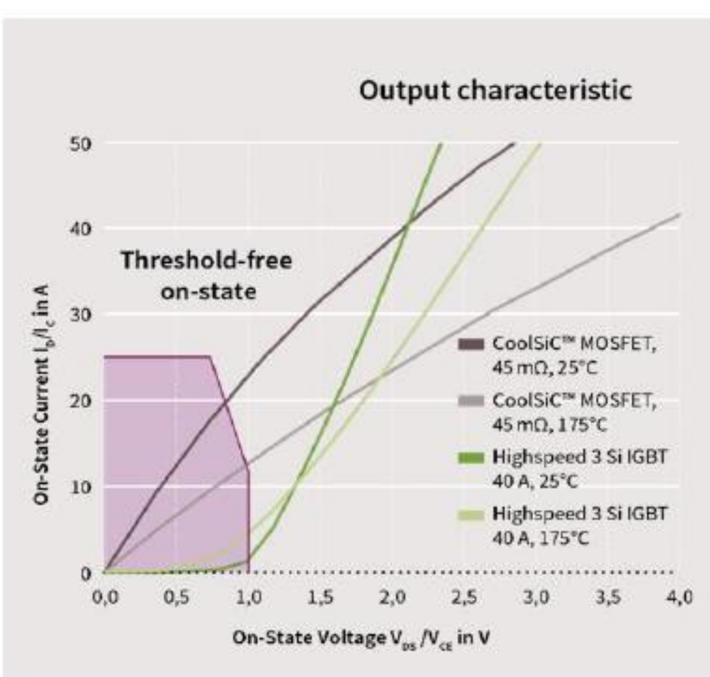

Fig. 8. Conduction characteristic comparison between SiC MOSFET and IGBT

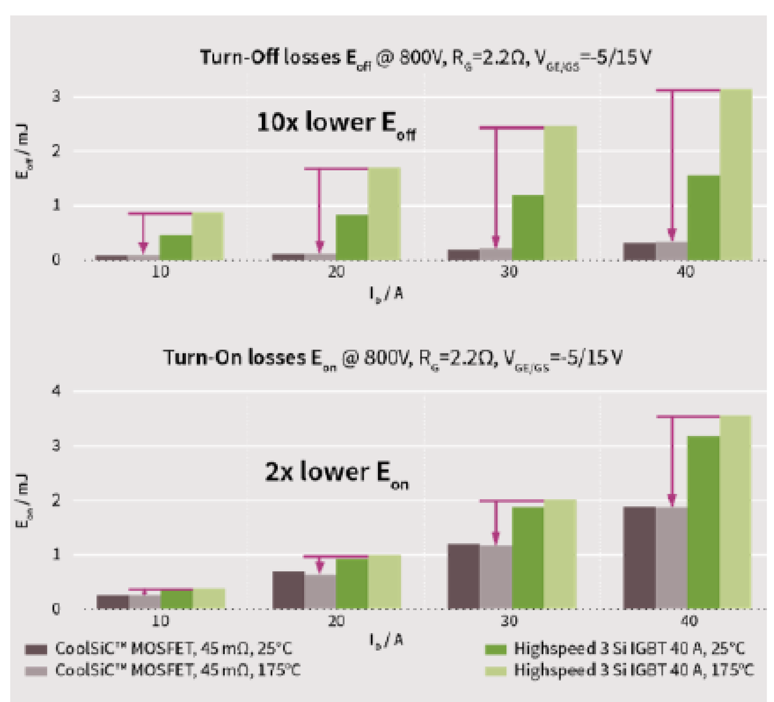

Fig. 9. Switching losses of SiC MOSFET compared with Si IGBT at different temperature

Table.1 the typical operating conditions for the 125kW C&I PCS

Parameter	Value
V_{DC}	900Vdc
U_{out}	400Vac
f_{sw}	20kHz(IGBT) 32kHz(SiC)
PF	1
$Rg_{on/off}$	1Ω/5Ω (SiC) 10Ω/10Ω (IGBT)
$T_{heatsink}$	80℃
Overload	110% long-term

Under the three-phase load-balanced condition, for the 3P4L converter, employing the 2L-SiC solution can simplify the circuit topology, reduce the number of power devices by 50%, reduce the inductance value by 36%, and improve the efficiency by about 0.5% under the same output phase-current THD. Under 100% unbalanced operating conditions, the maximum junction temperature difference of the two solutions is very small.

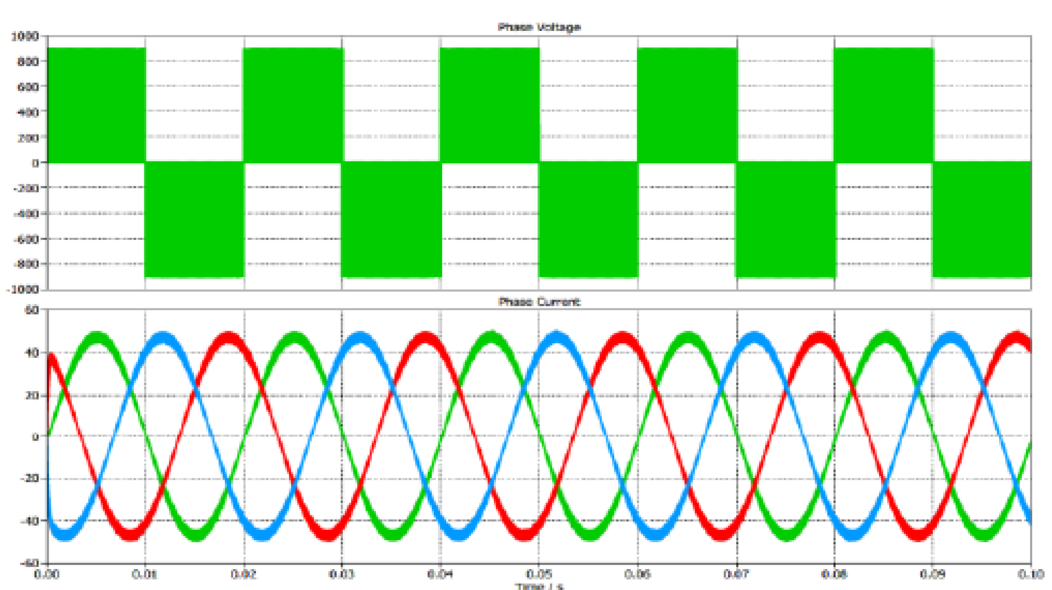

Fig. 13. Phase voltage and current of 2L-SiC, current THD=3.15%

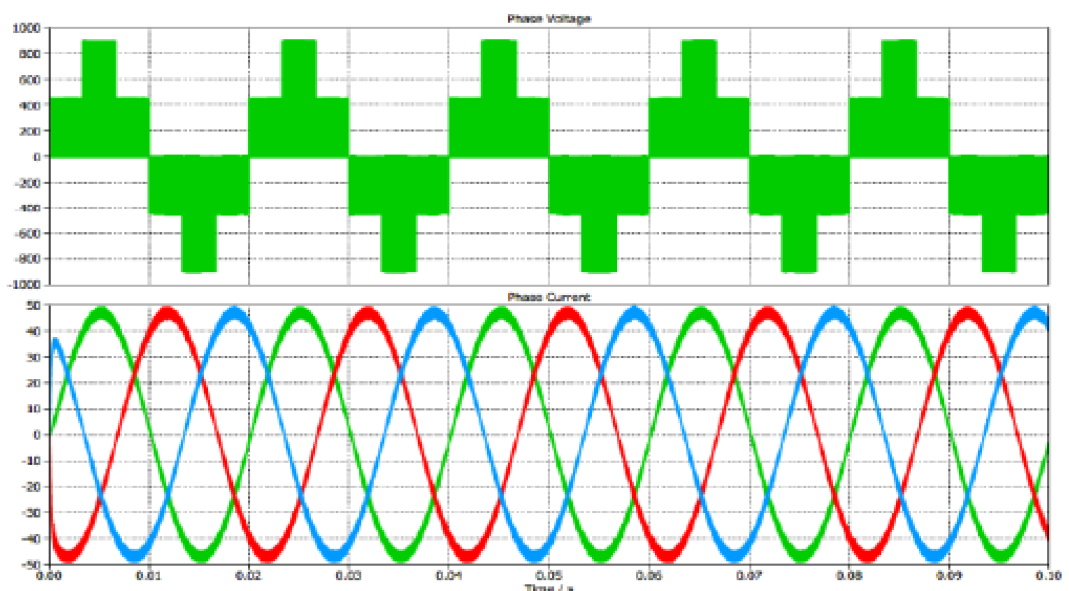

Fig. 14. Phase voltage and current of T-NPC, current THD=3.14%

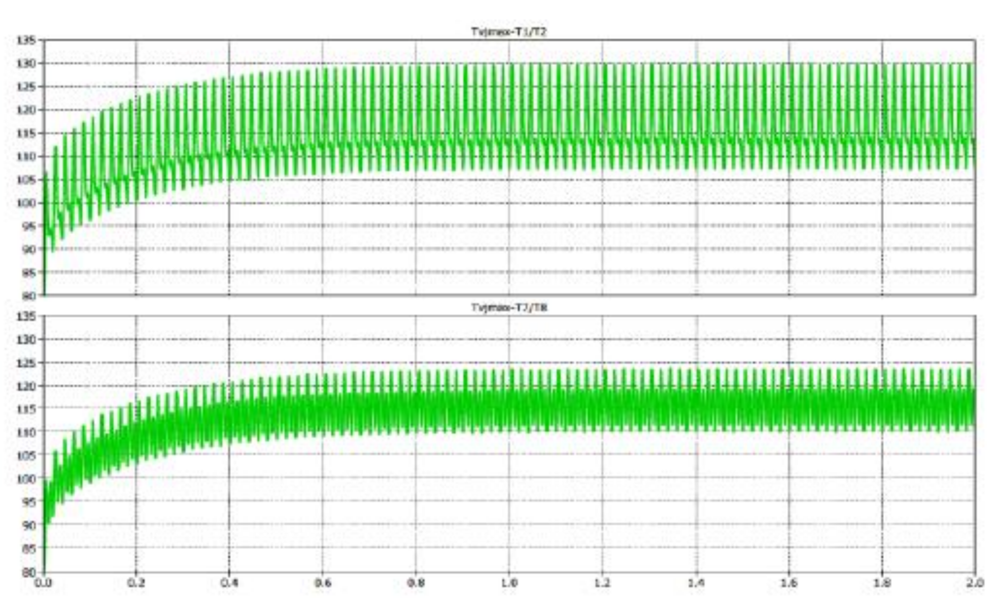

Fig. 15. Different junction temperature fluctuations between T1/T2 and T7/T8.