


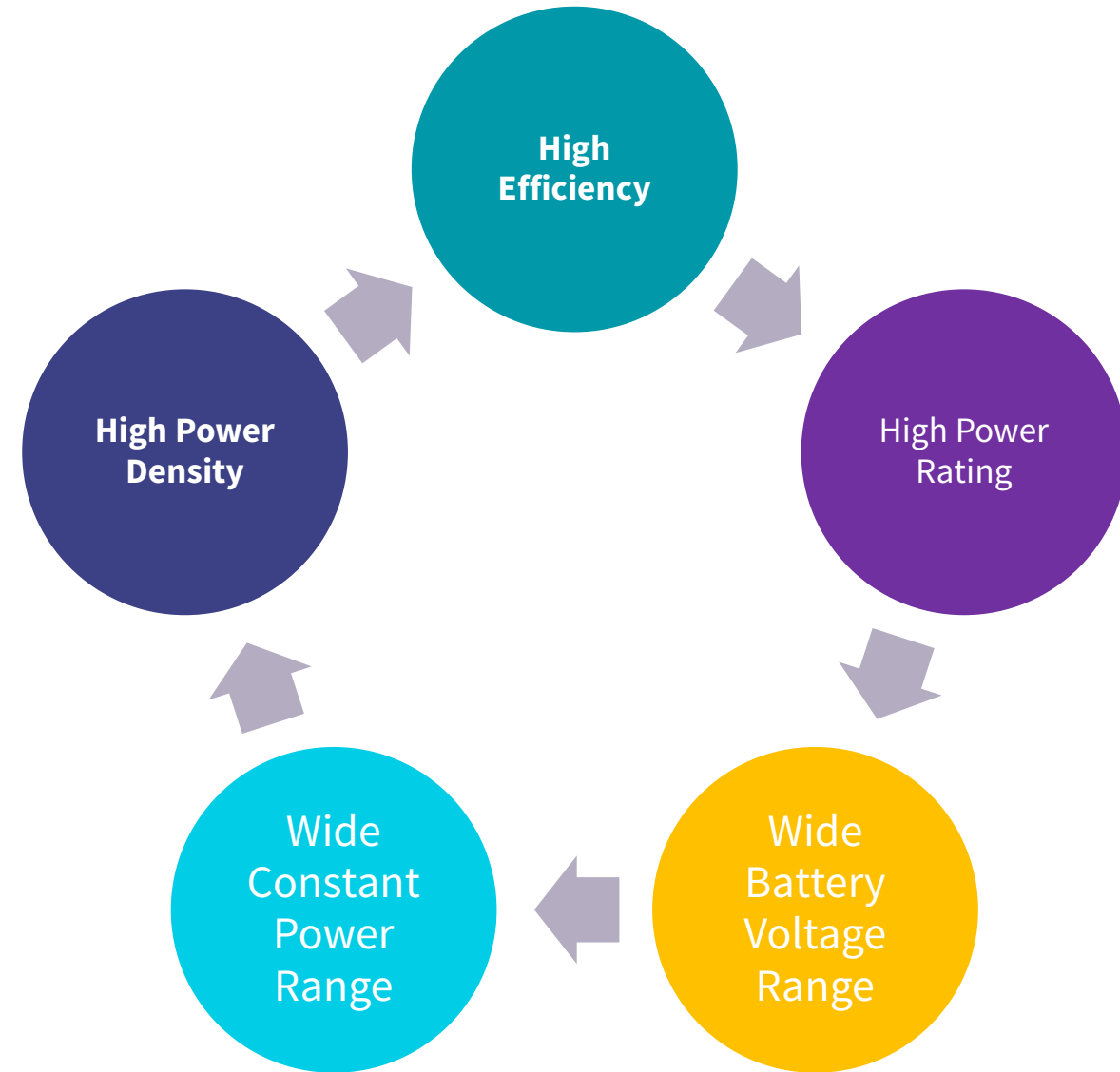


30kW Discrete Interleaved LLC DC-DC Converter

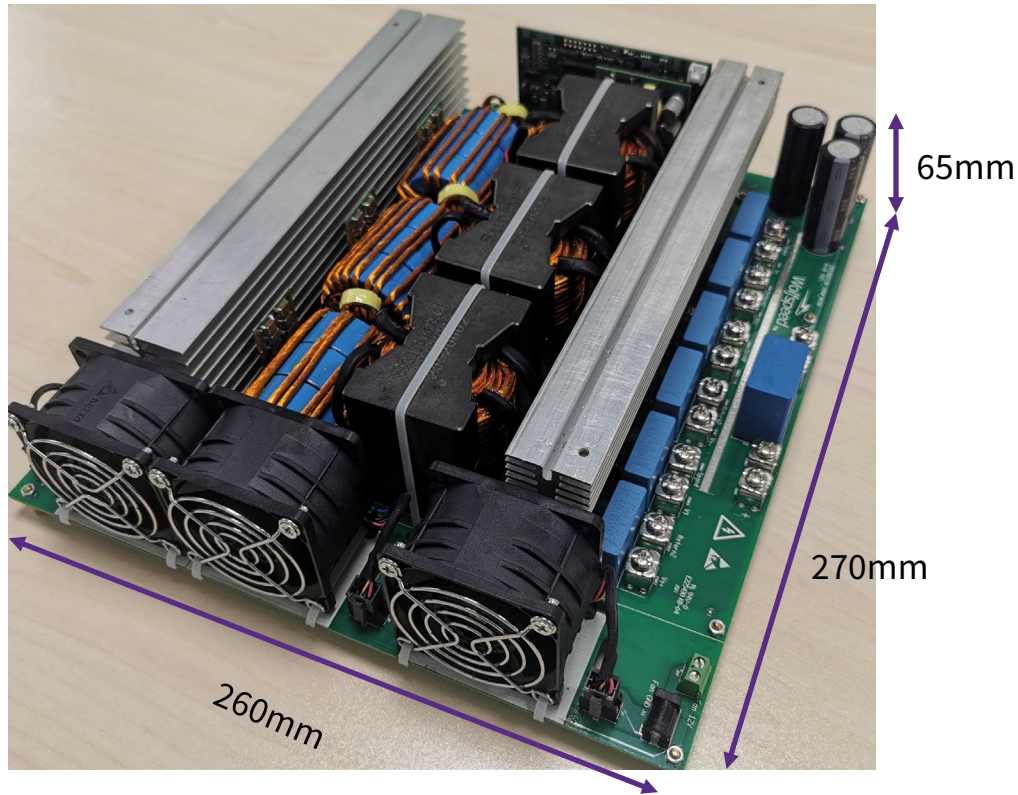


NEW TREND AND DESIGN CHALLENGES OF OFF BOARD CHARGING

| | DC FAST CHARGERS | | |
|----------------------|--|--|--|
| Power | 50kW~125kW | 150kW~350kW | 500kW~1MW |
| Location | Public area | Charging station, Highway corridor | Fleet charging, utility vehicle |
| Charging power block | 3Φ, 10~15kW | 3Φ, 20, 30, 40, 50kW, 60kW | 50kW,60kW 120kW module |
| Remark | All in one design | Converter cabinet + charging dispenser | Container solution |
| |  |  |  |



30KW INTERLEAVED LLC DC-DC SPECIFICATIONS



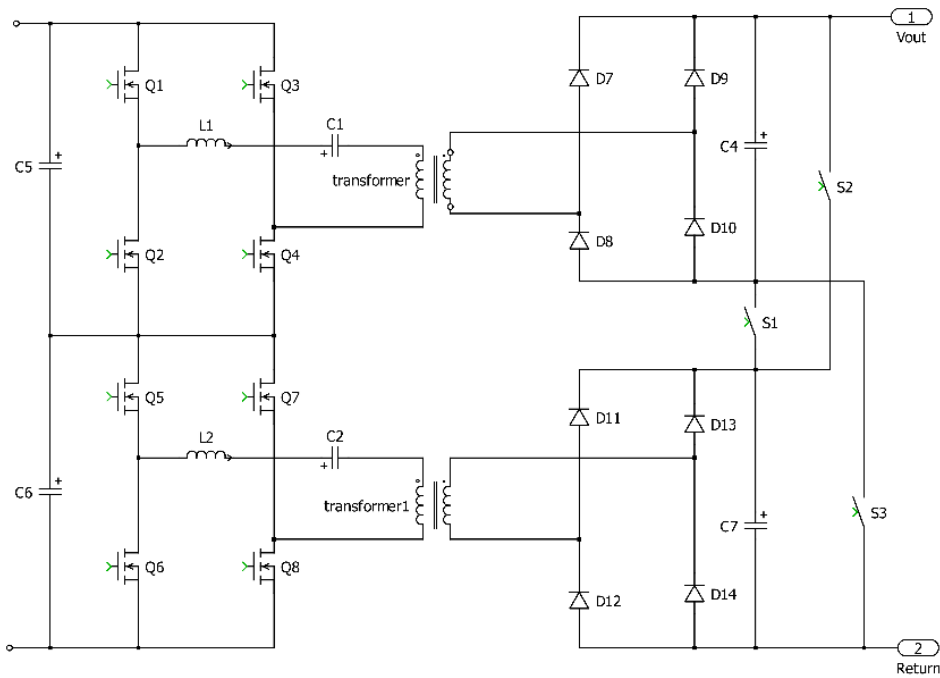
Peak Eff >98% Power Density 6.5kW/L

| Description | Requirement |
|----------------------|---|
| DC Input Voltage | 650Vdc - 850Vdc |
| DC output | 200V-1000V; CP 30kW when $V_o \geq 300V$ |
| Switching Frequency | 130kHz-250kHz; $f_s=180kHz$ |
| PCBA size | 270mm*260mm*65mm (6.5kW/L) |
| Efficiency LLC | >98%(peak), >97%(full load)@ $V_{out}=300V$ |
| Heatsink Temperature | Max 85°C |

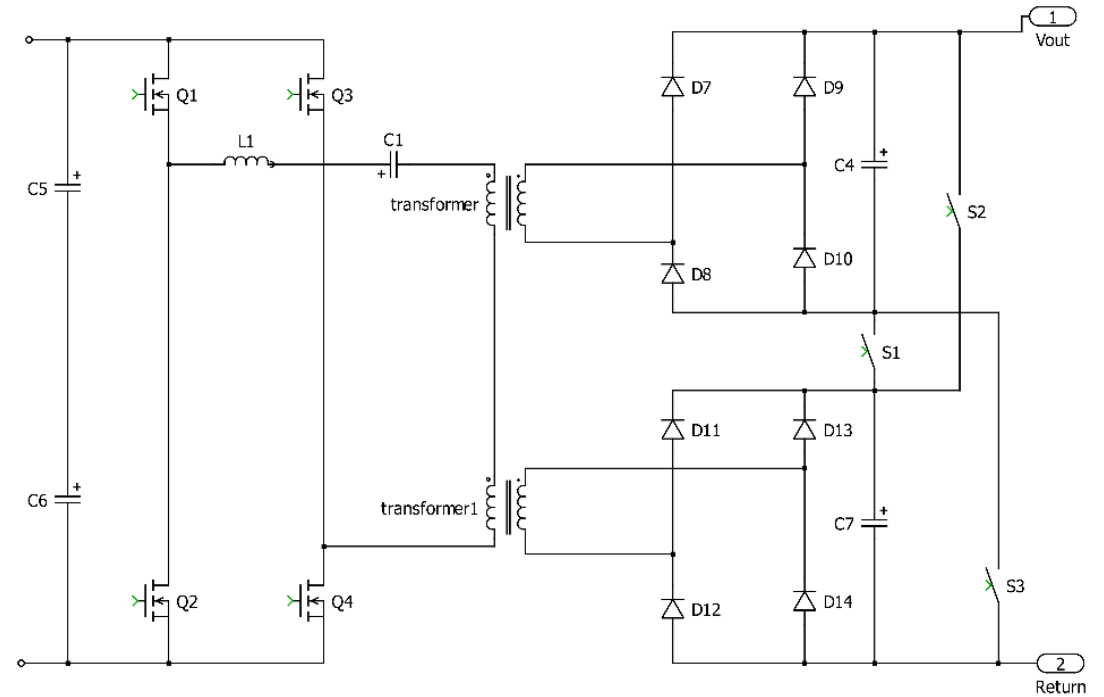
Application target is DC fast charging stations

TOPOLOGY EVOLUTION: FROM SI TO SILICON CARBIDE (15KW-20KW MODULE)

Cascode 650 V Si Solution



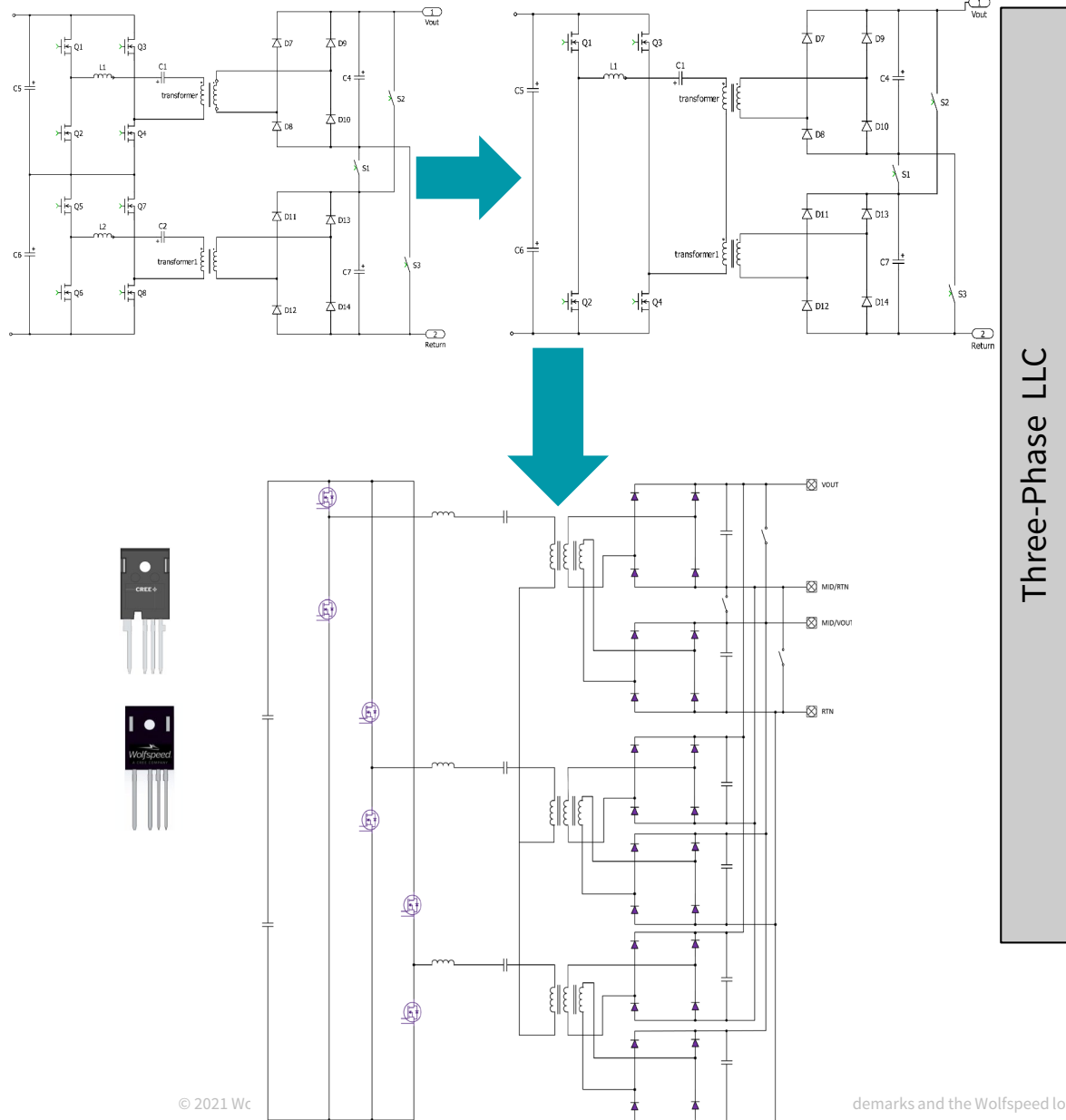
2 level 1200 V Silicon Carbide Solution



With 1200 V Silicon Carbide, 2 level LLC simplify the topology

- Higher efficiency
- Higher power density
- Lower system cost

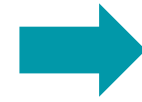
TOPOLOGY SELECTION : DC-DC UNIDIRECTIONAL



Three-Phase LLC

30kW design (Done)

- 6x 1200V 40mOhm SiC or
- 6x 1200V 32mOhm SiC



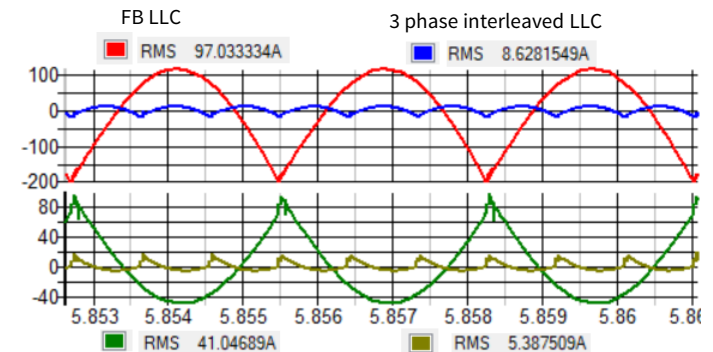
60kW design (two MOSFETs in parallel)

- 12x 1200V 40mOhm SiC or
- 12x 1200V 32mOhm SiC

| BENEFITS | CHALLENGES |
|---|--|
| <ul style="list-style-type: none"> • Low input current ripple • Low output ripple Smaller output Capacitor • Automatic current sharing • Lower current stress on primary MOSFETs compared with FB LLC • Scalable to lower phases (shedding) to handle 40kW | <ul style="list-style-type: none"> • Tolerance of resonant C,L and magnetizing Lm can cause unbalanced currents • Complex vector control although three phase analysis applies |

Output ripple current @300V/200A

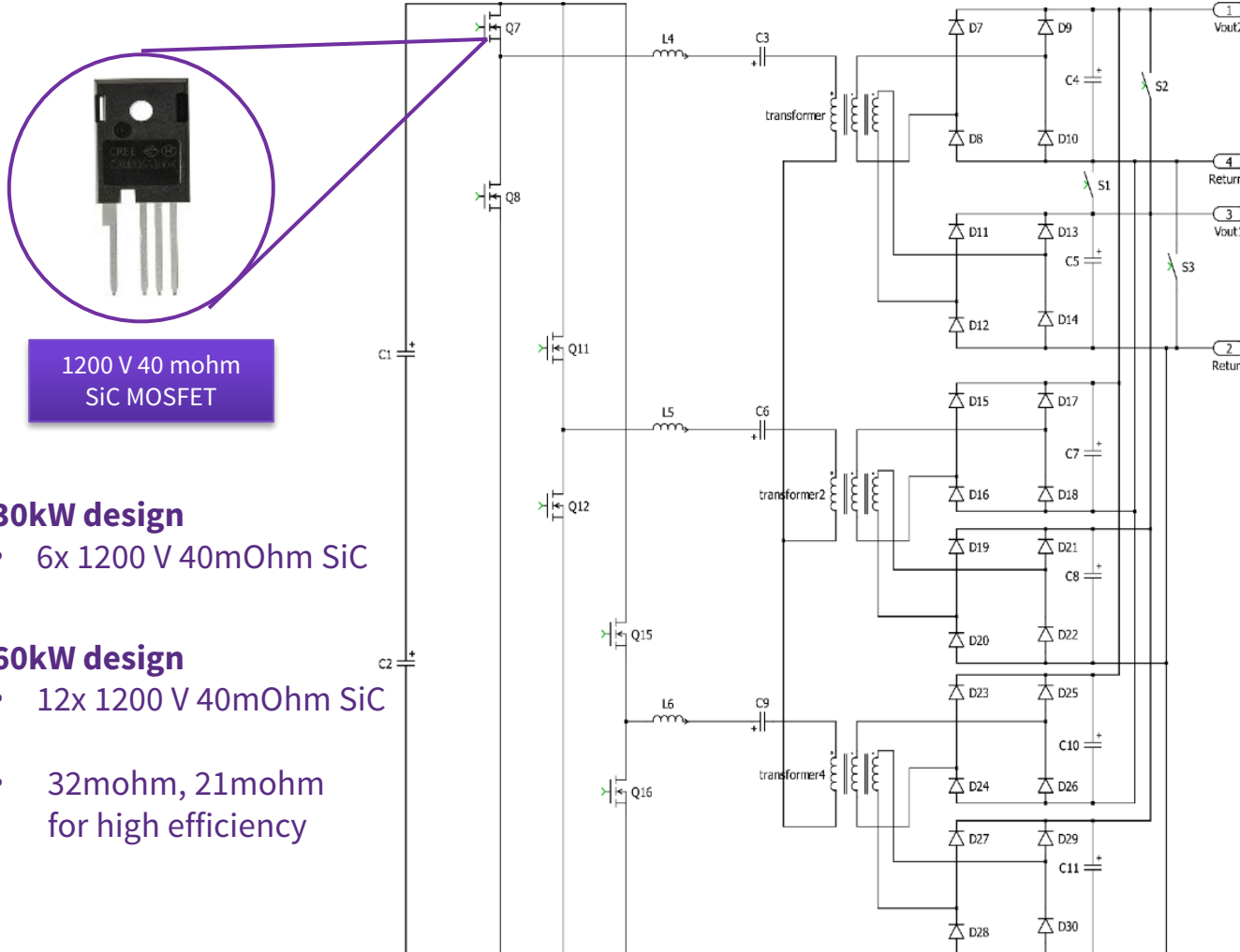
DC bus ripple current @300V/200A



POWER COMPONENTS SELECTION

The DC link voltage is up to 850 V, 26A max rms current.

C3M0040120K 1200 V 40mohm Silicon Carbide MOSFET is selected for primary MOSFET of LLC converter based on electrical stress and thermal design. It is for cost-effective. 6 devices provide 30kW output. Lower Rdson device can be considered for higher efficiency.



30kW design

- 6x 1200 V 40mOhm SiC

60kW design

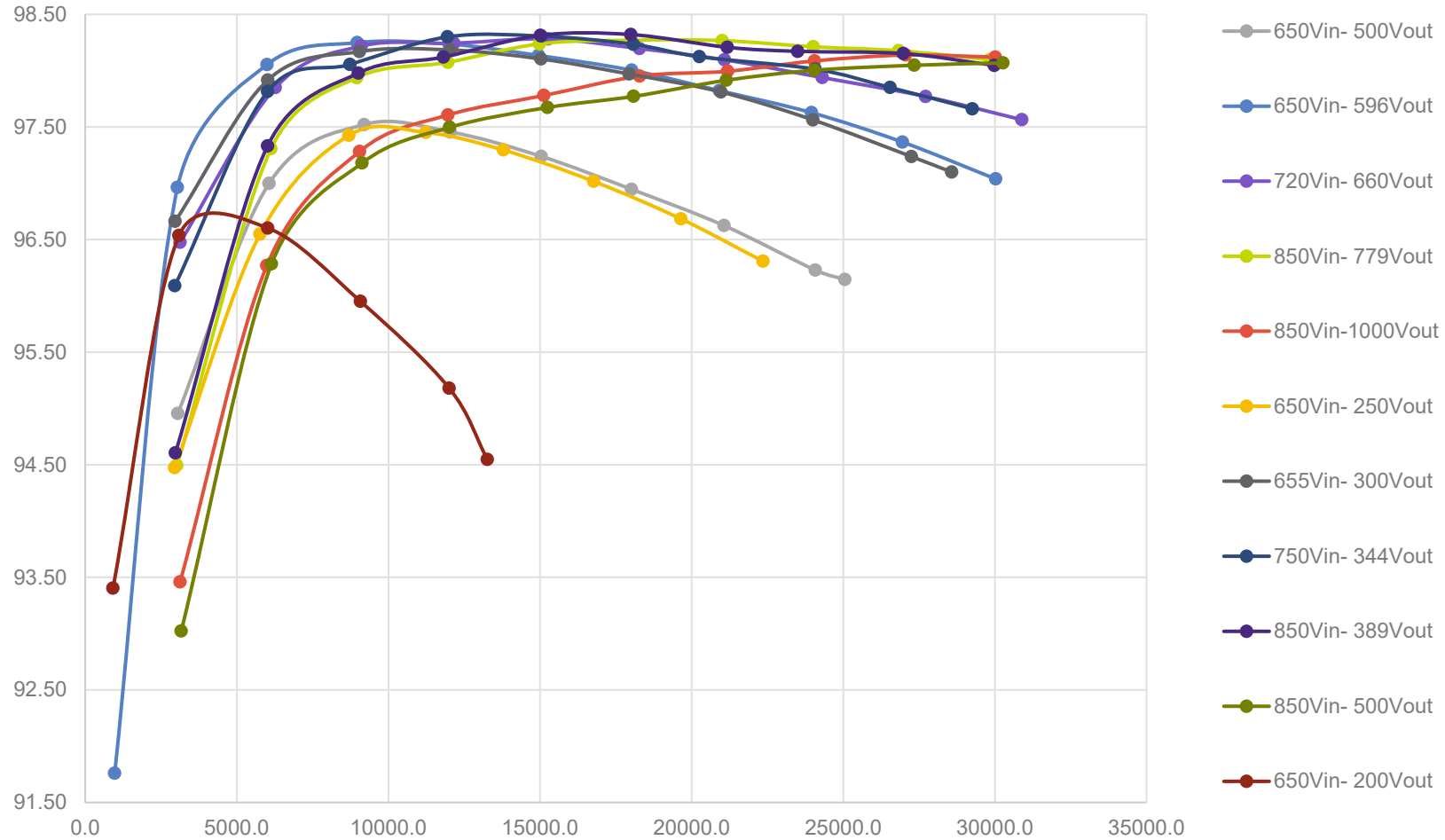
- 12x 1200 V 40mOhm SiC
- 32mohm, 21mohm for high efficiency

Why Silicon Carbide?

- ✓ Fast switching and low switching losses for 1200 V device. Enabling high-frequency switching
- ✓ Smaller output capacitance, easier to achieve ZVS for LLC resonant converter
- ✓ Less temperature dependence of Rdson and low conduction loss at high temperature
- ✓ Low reverse recovery body diode enables reliability in case of hard-commutation

EFFICIENCY TEST RESULT

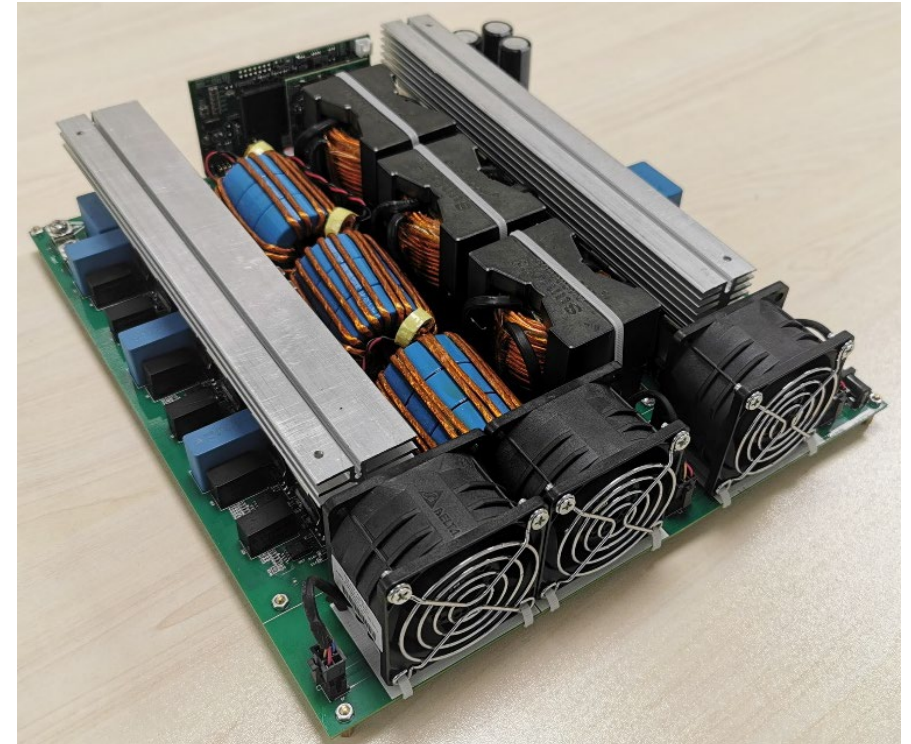
Efficiency under different output voltage



SUMMARY

Thanks to the low power loss of C3M 1200 V Silicon Carbide MOSFET and the flexible control scheme, all the design targets are achieved.

- ✓ Low cost, 6 pcs TO-247-4 1200 V 40mohm Silicon Carbide MOSFETs to cover 30kW
- ✓ High Power Density, $f_r=180\text{kHz}$ 6.5kW/L
- ✓ High Efficiency 98.3% peak efficiency
- ✓ Wide output voltage range 200Vdc-1000Vdc
- ✓ Easy to extend to 60kW by using 12 pcs MOSFETs



A large, stylized grey silhouette of a wolf's head is positioned in the background, facing right. The silhouette is composed of several sharp, angular shapes that define the wolf's profile, including its ears and snout. The text "THANK YOU" is centered over the wolf's snout area.

THANK YOU