30kA Energy Extraction Semi-Conductor Switch

PRR: 29-01-2016SM18 -CLUSTER D

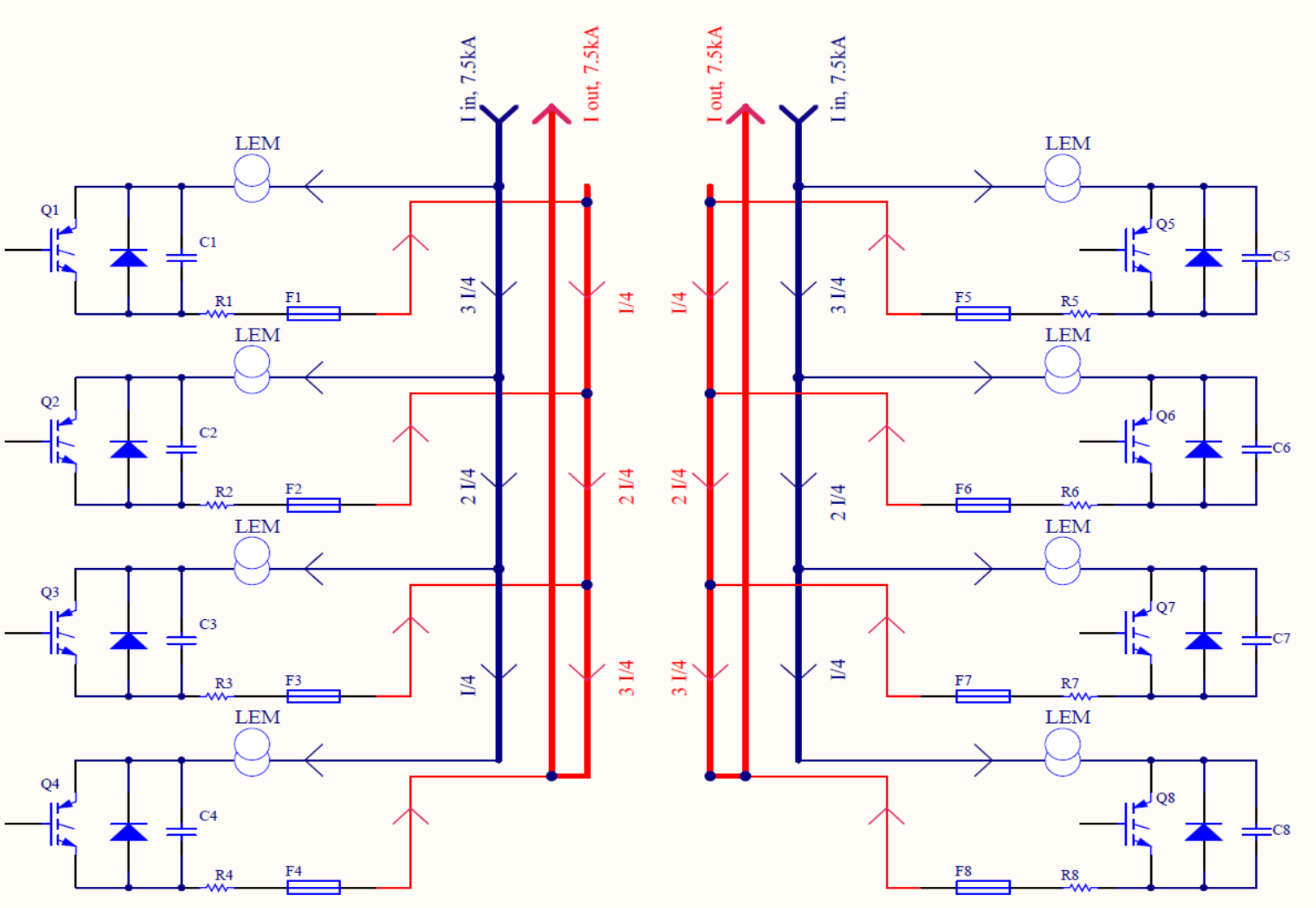
7.5 kA and 30 kA Topology - Critical Design Issues

Alexandr Erokhin
TE-MPE-EE

Design criteria

- Transient processes lead to high voltage spikes and potential over-currents through single IGBT
  - Stray inductance to be kept as low as possible
    - non compensated stray inductance will lead to high voltage spikes
  - Need for fully symmetrical design
    - Trade-off: efficient cooling, current distribution & stray inductance
  - Fully compensated design
  - Need for multi-level snubber compensation
  - Simultaneous switching of all 16 IGBTs (sub µs range)

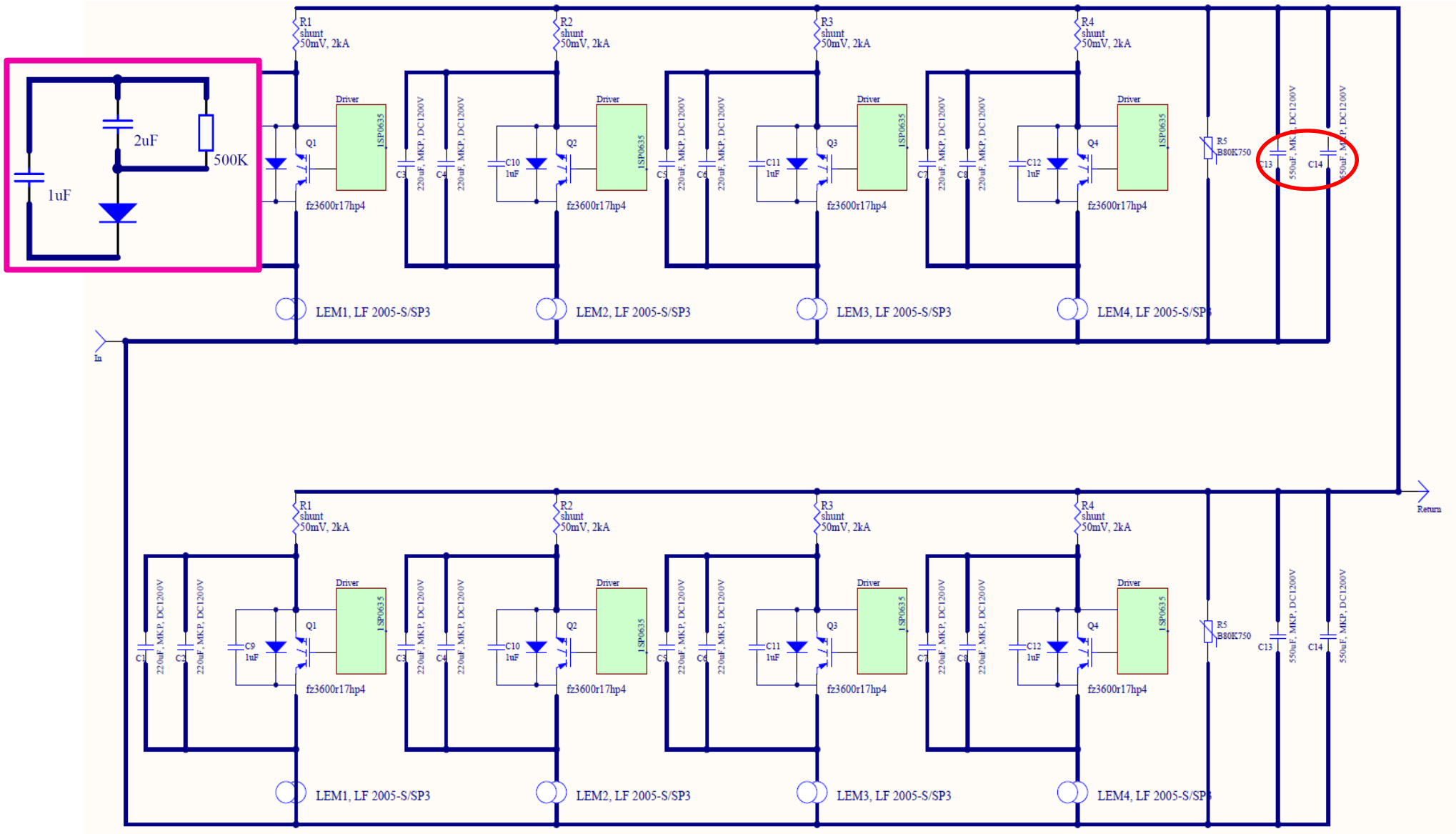
15kA Switch topology



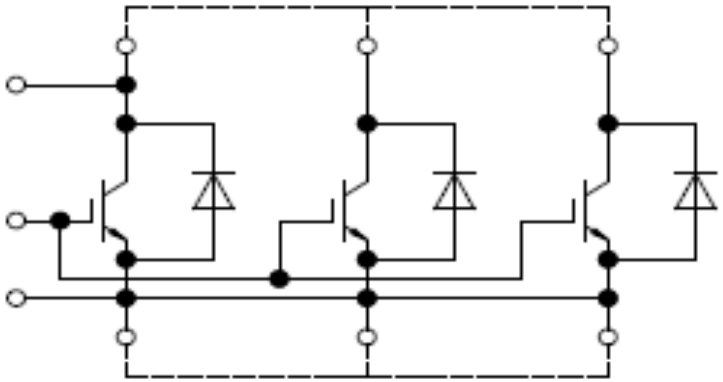
MAIN BUS-BARS TRIPLET:

1. Equal paths for all currents
2. Equal impedances
3. Low stray inductance
4. Low fields
5. Compact and cold

15kA Switch topology



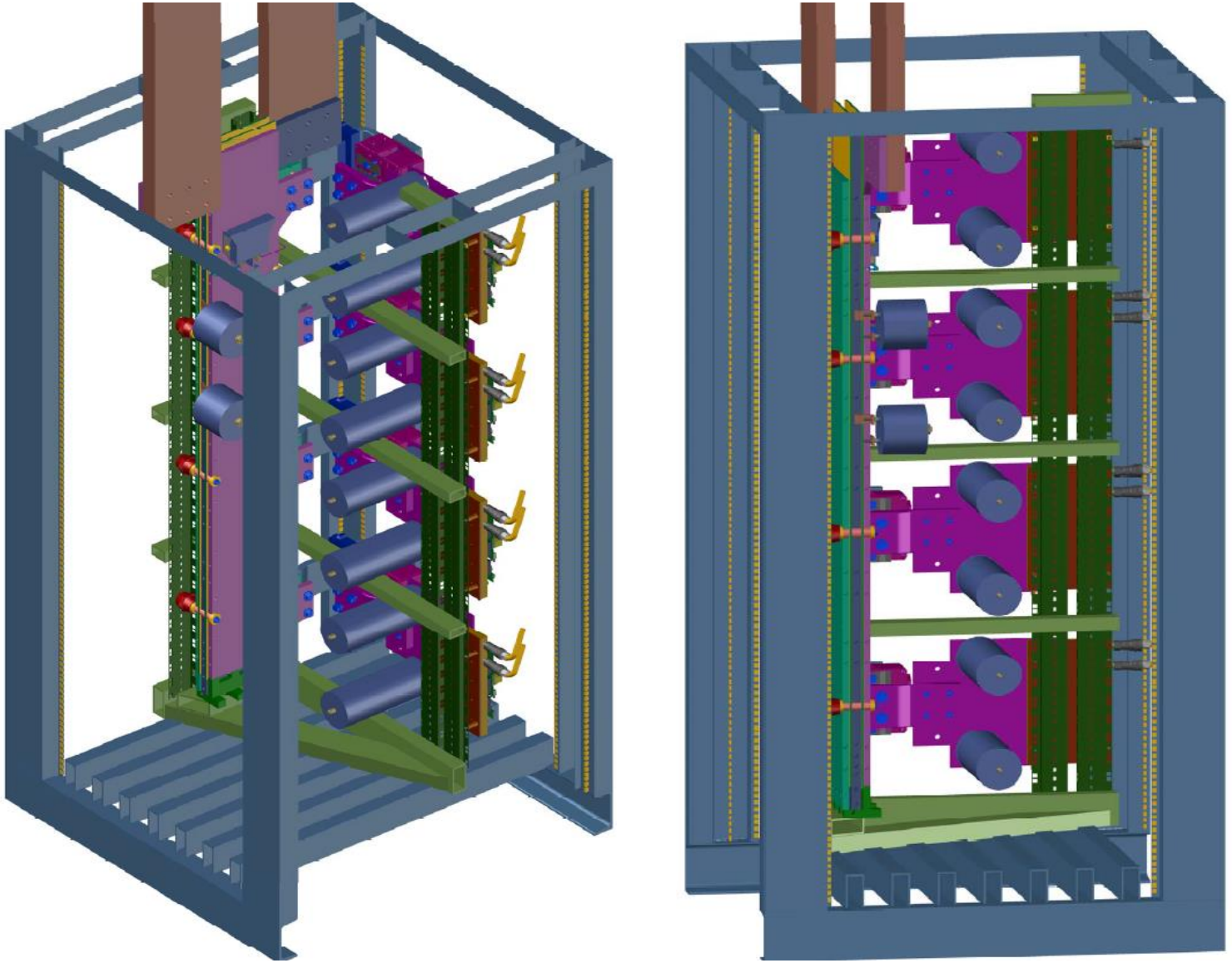
Main components



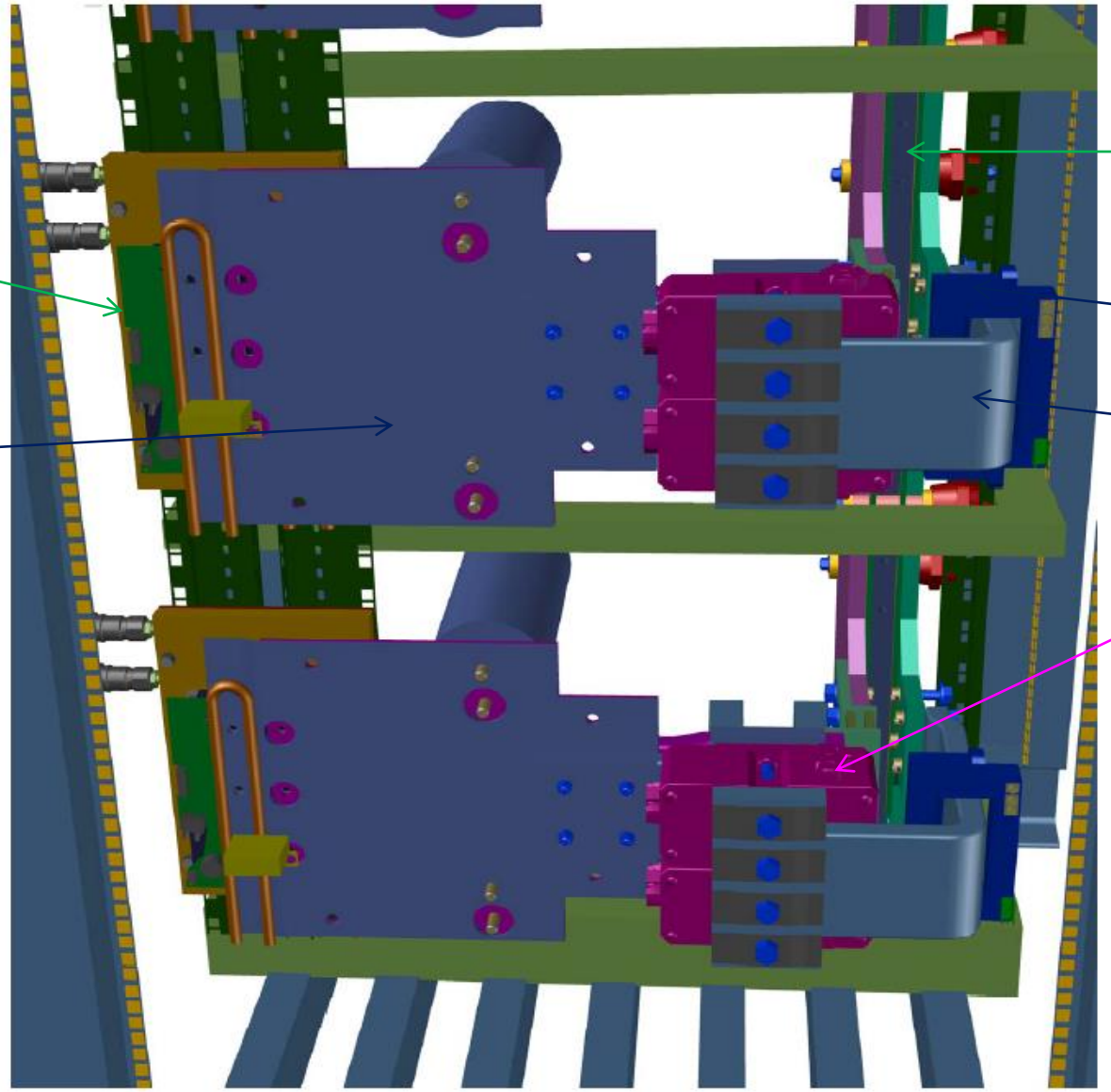
IGBT:
Infineon FZ3600R17HP4_B2 – the best available on the market

Vce_max = 1700V, Inom = 3600A
With I = 1875A (max possible current):
Vces =1.6V => Junction heat dissipation ~3000W per module
Junction temperature ~ 100-105°C
300 W dissipation for the terminals
_B2 version comes with AlSiC base plate adjusted to thermal expension of silicon and ceramics leading to longer lifetime due to thermal cycles

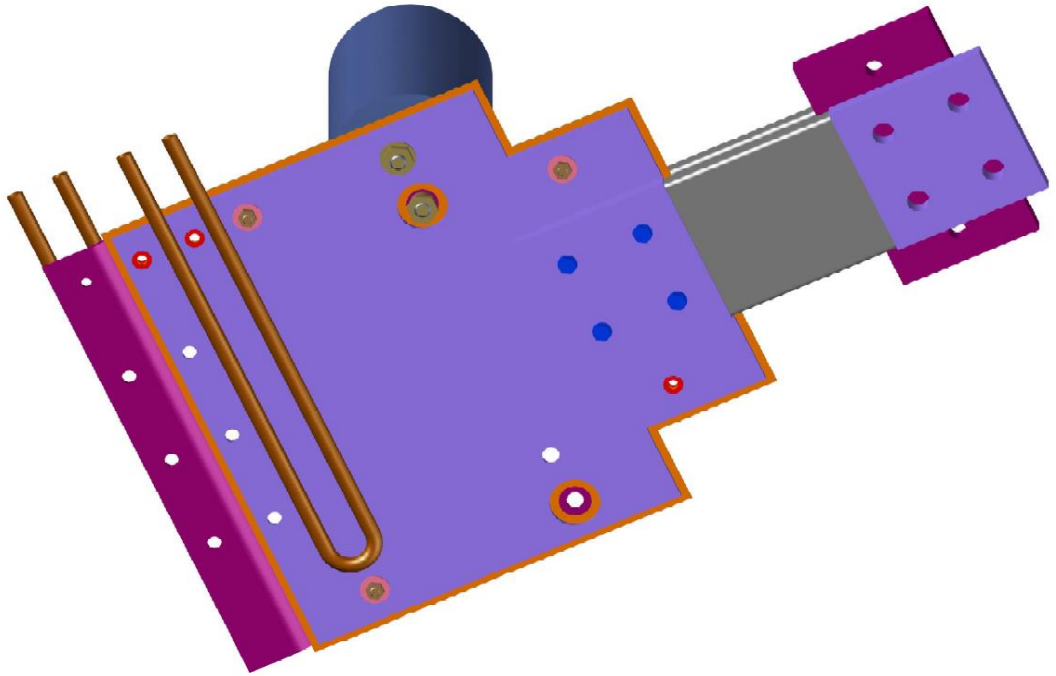
Design topology



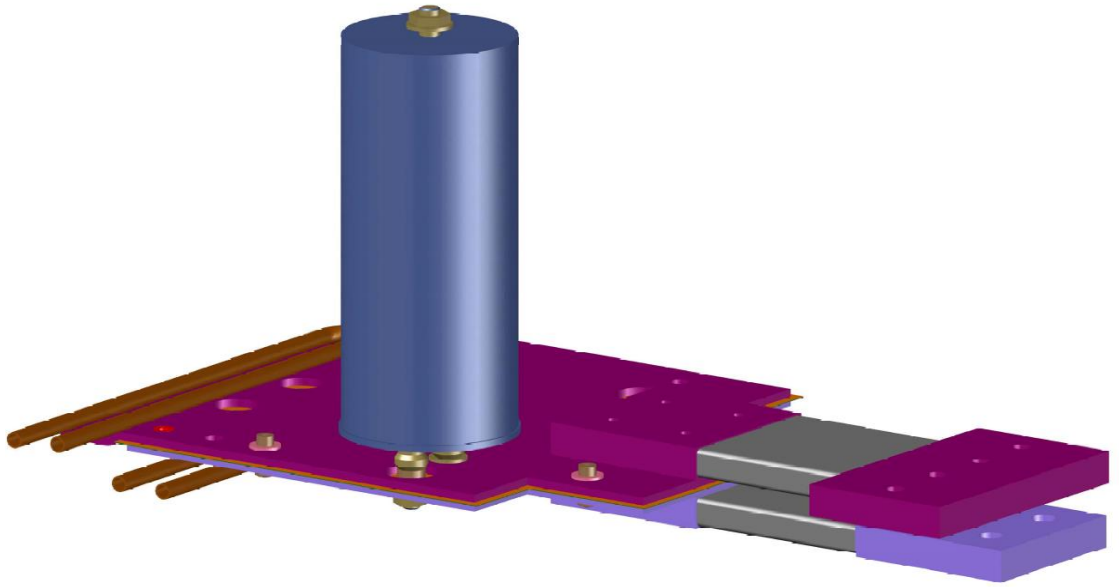
Design topology



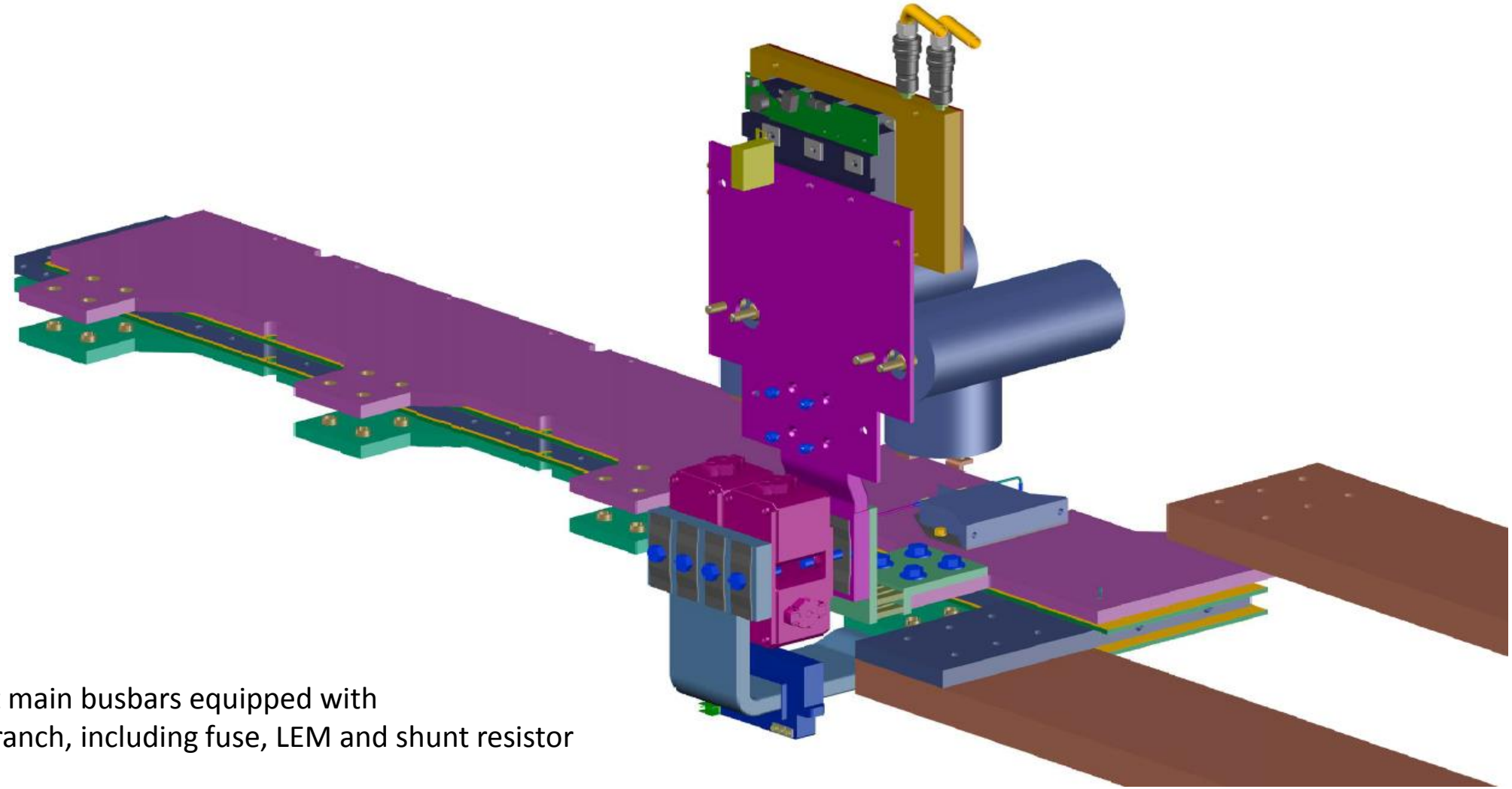
Design topology



Laminated busbars with flexibles and
Water cooling of the IGBT terminals

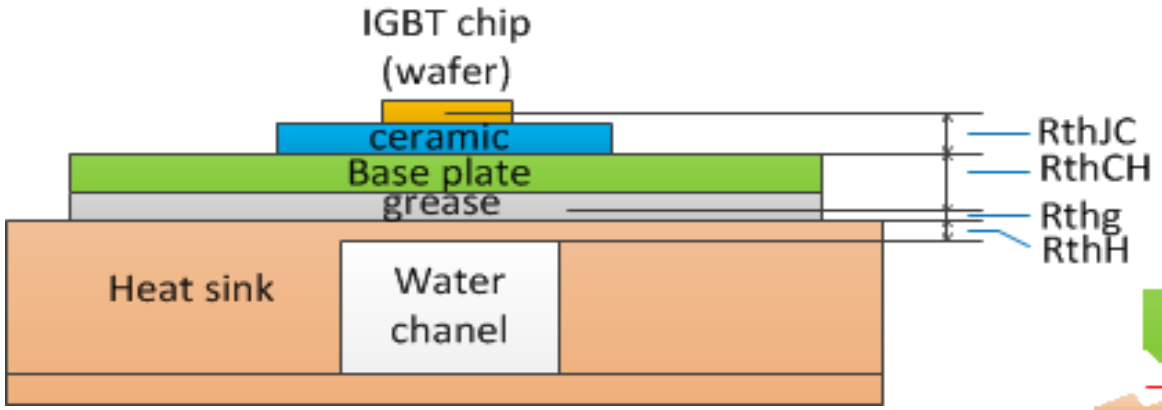


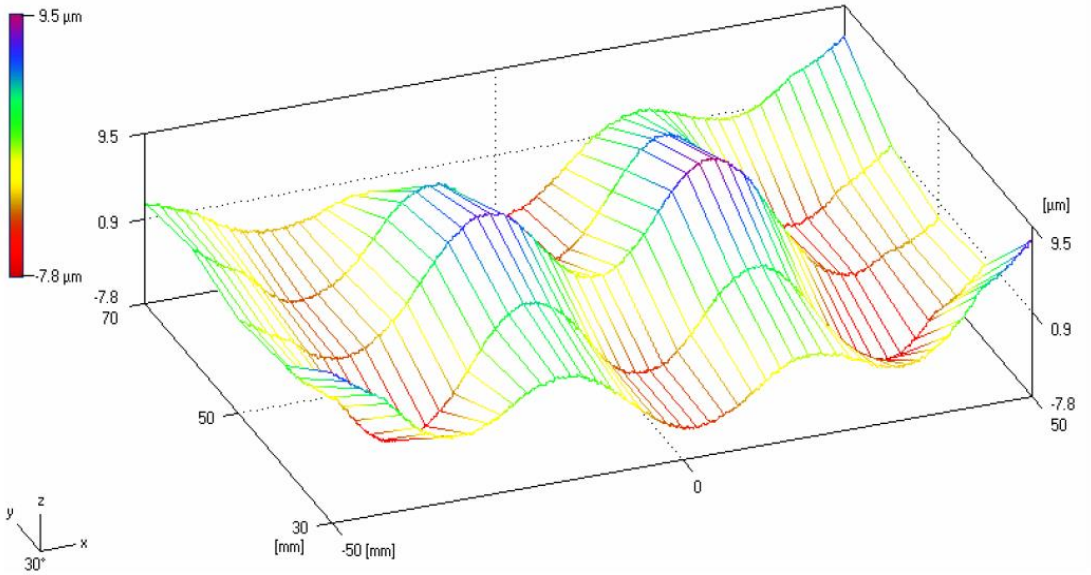
Design topology



Triplet main busbars equipped with
one branch, including fuse, LEM and shunt resistor

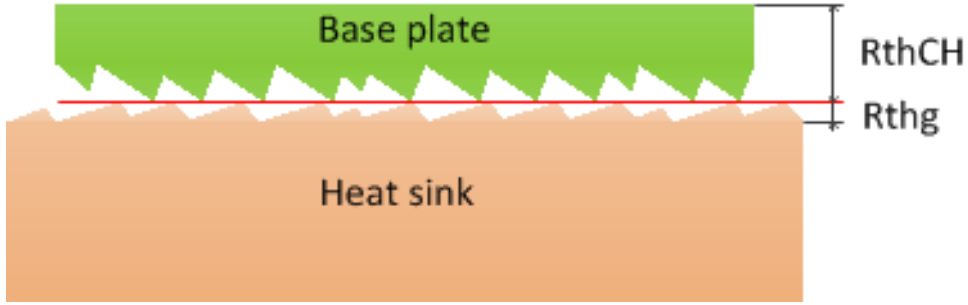
IGBT cooling plates





Thermal calculations

$$RthJC = 7.1\ K/kW$$
$$RthCH = 9.7\ K/kW$$
$$Rthg = 4\ K/kW$$
$$RthH = 3.3\ K/kW$$



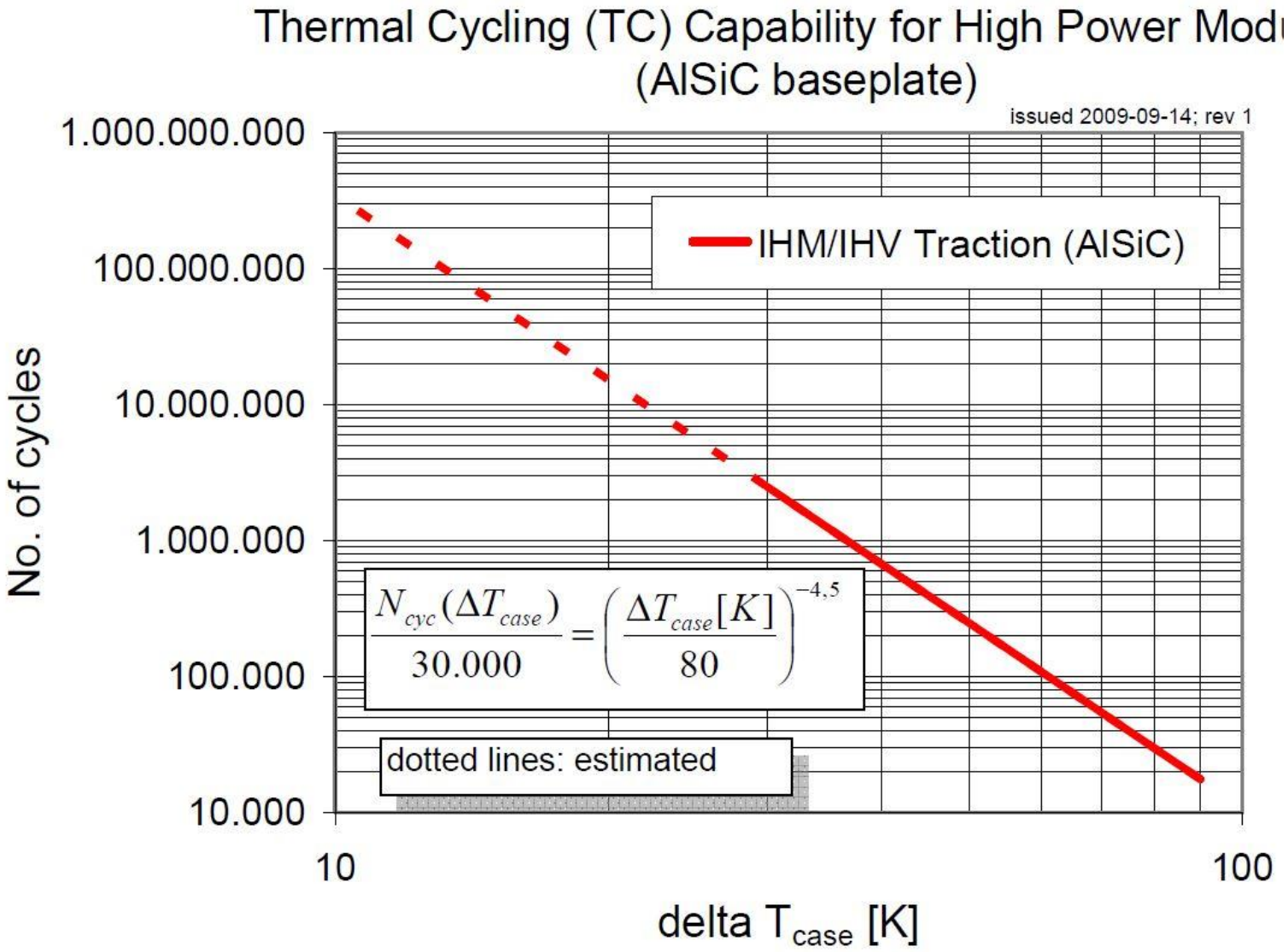
With a power dissipation ~ 3kW:

$$\Delta T = Rth * P = 24.1K/kW * 3kW = 72.3\ K$$

Water flow needed - 10 litres/min,
with 3kW dissipation ΔTwater = 6K

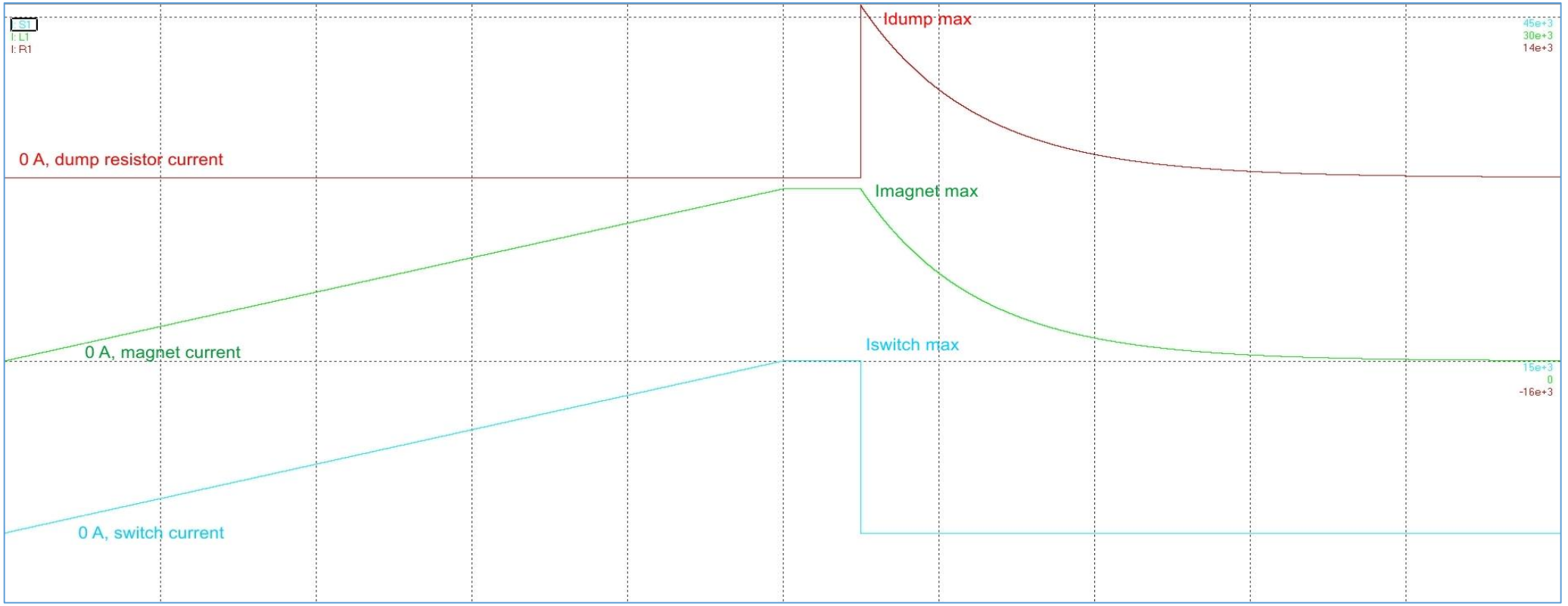
Therefore ΔTtotal ~ 80K, with the inlet water 20°C => IGBT chip temperature Tjunction = 100°C

IGBT cooling plates



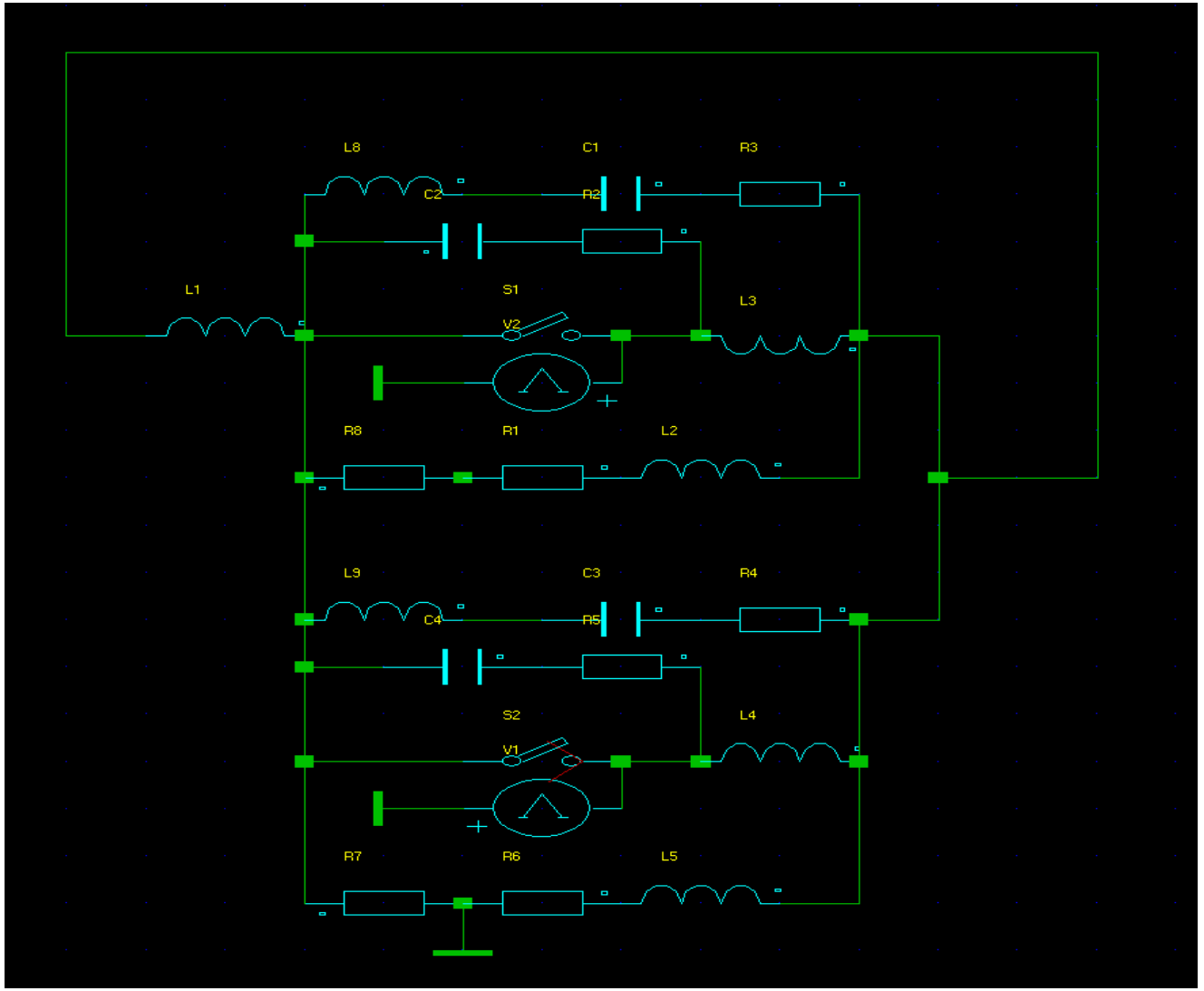
Power simulation

Complete power cycle (charge, discharge)



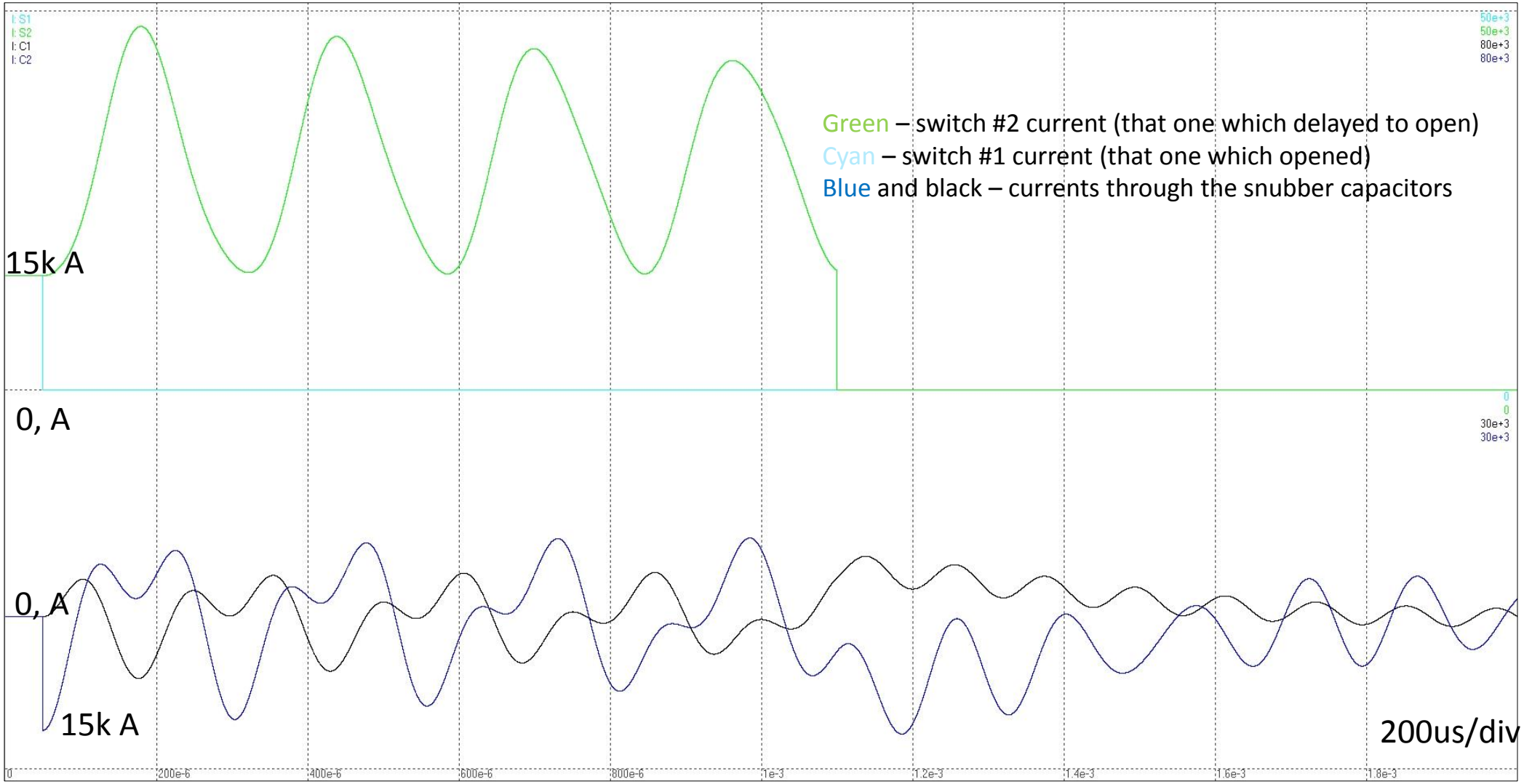
Power simulation

Two 15kA systems - opening details with the different synchronisation conditions



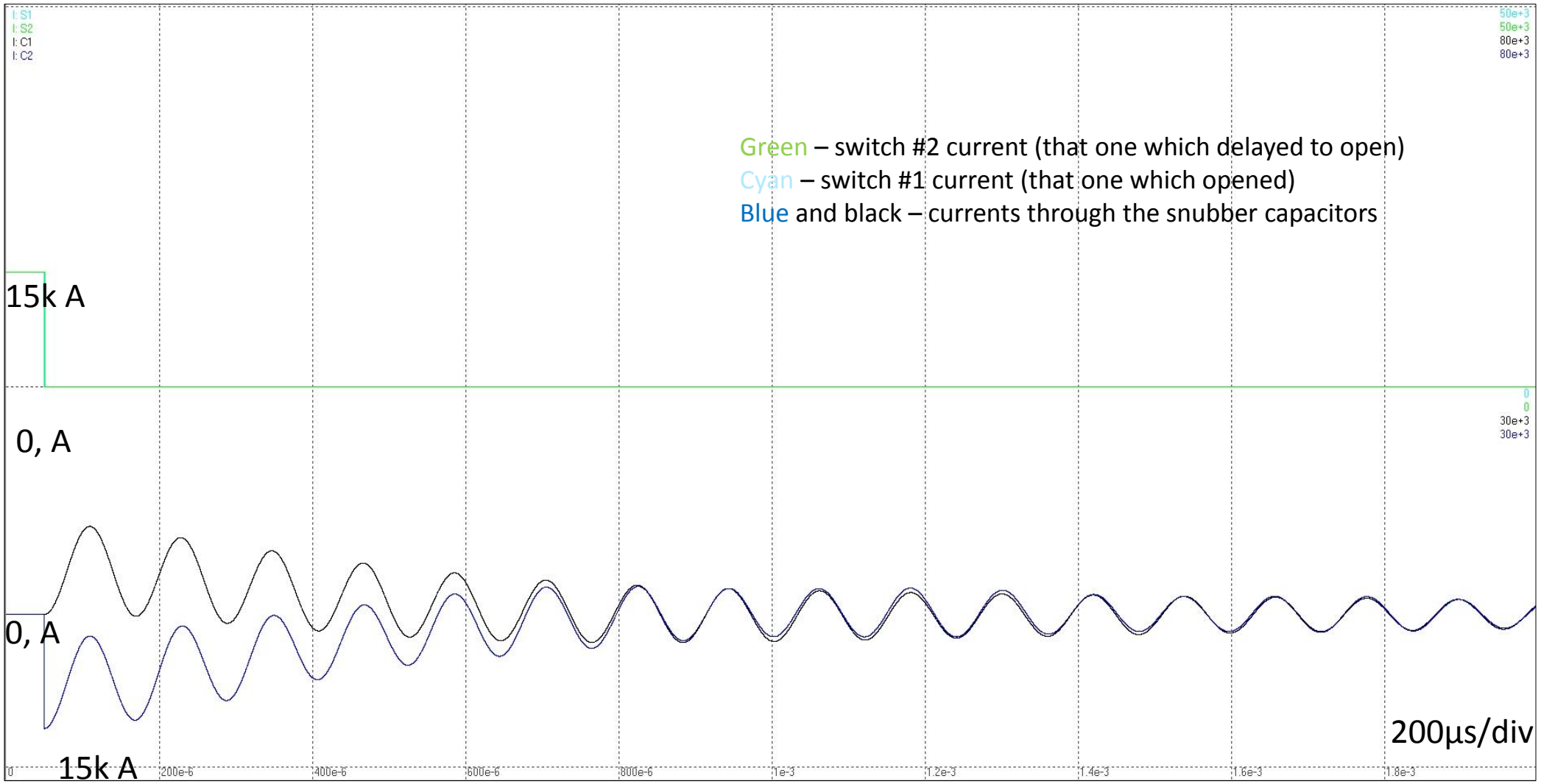
Power simulation

Delay: 1ms



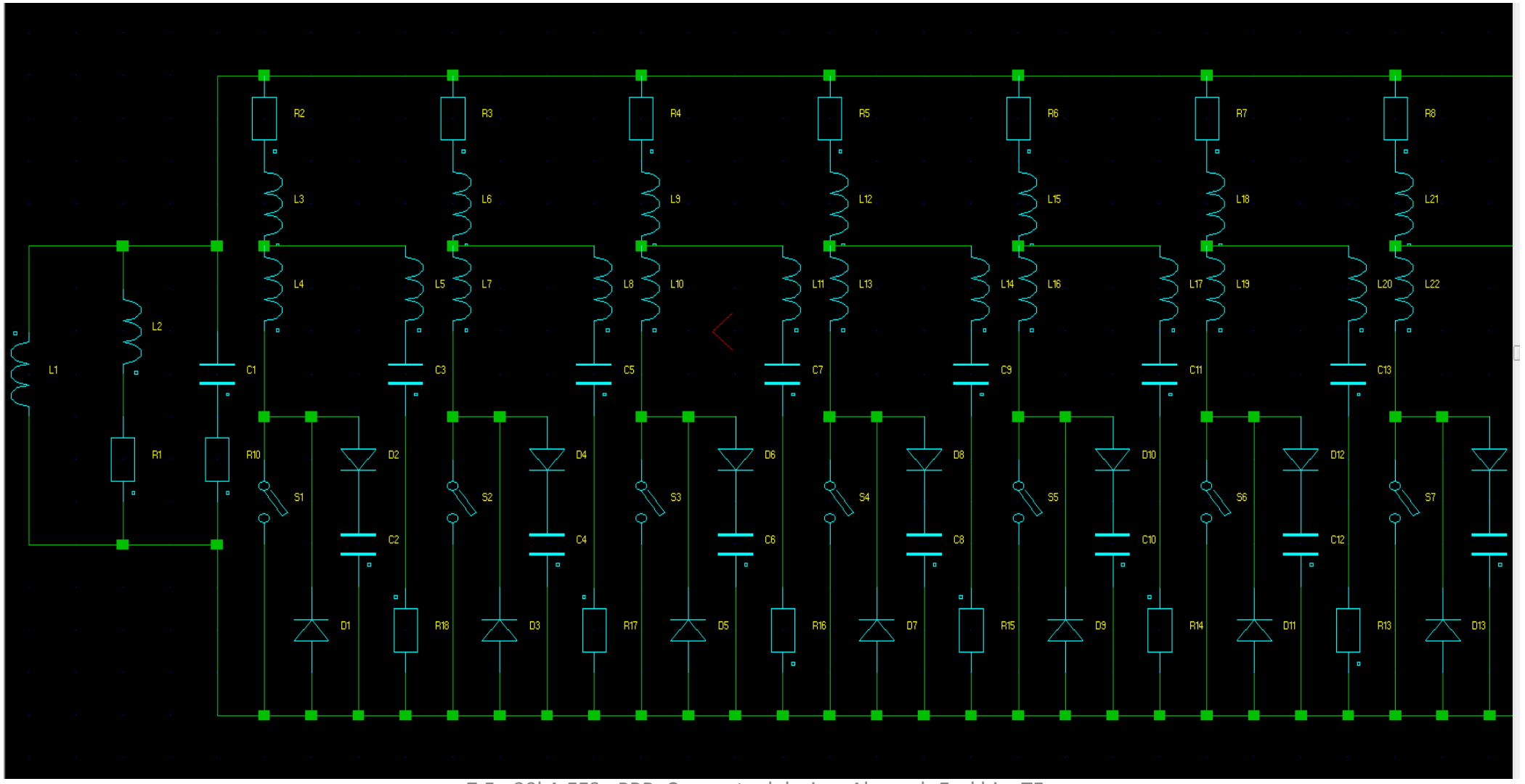
Power simulation

Delay < 1µs

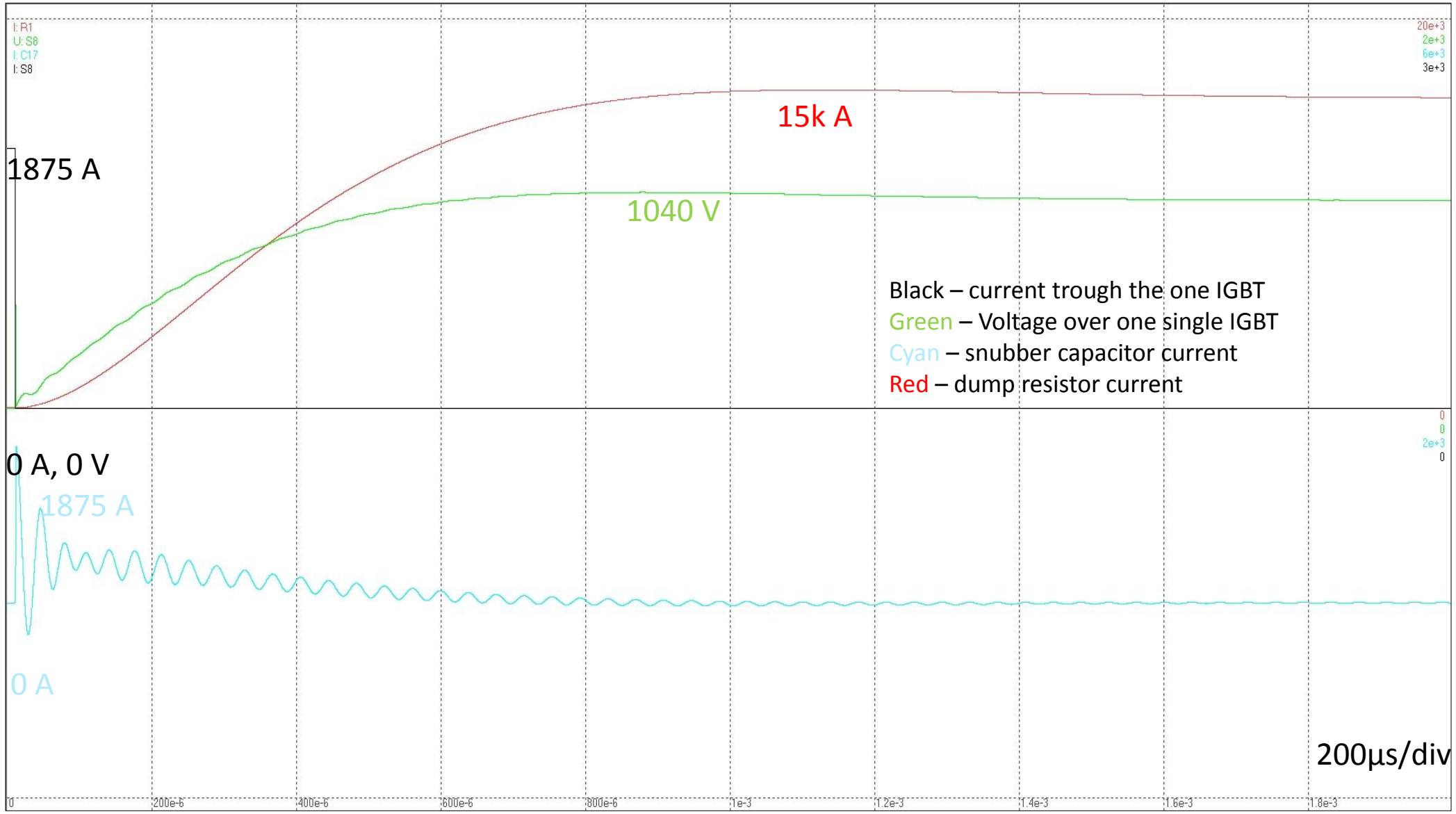


Power simulation

One 15kA system - opening details with all parasitical and protection elements taken into account

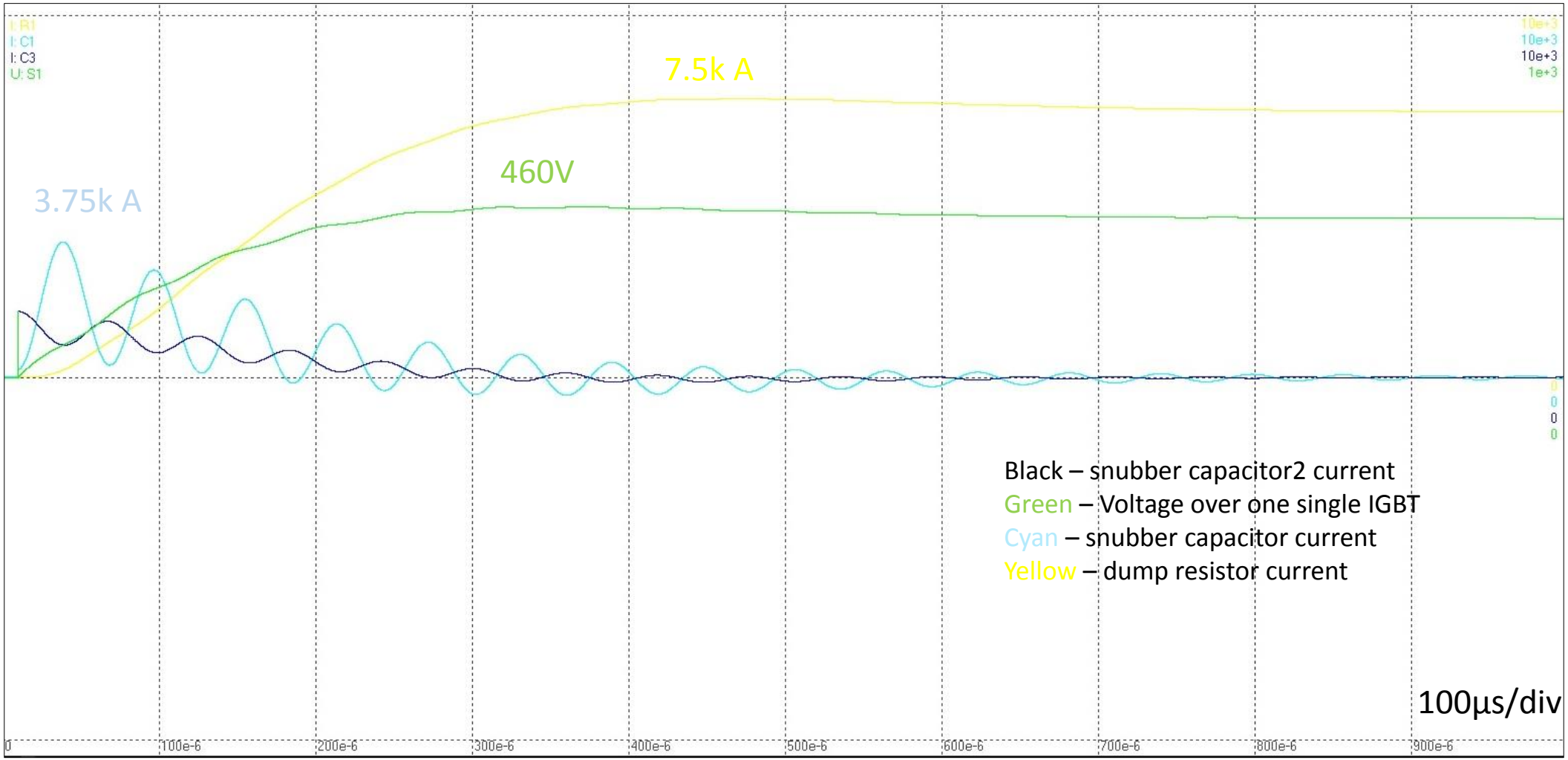


Power simulation



Power simulation

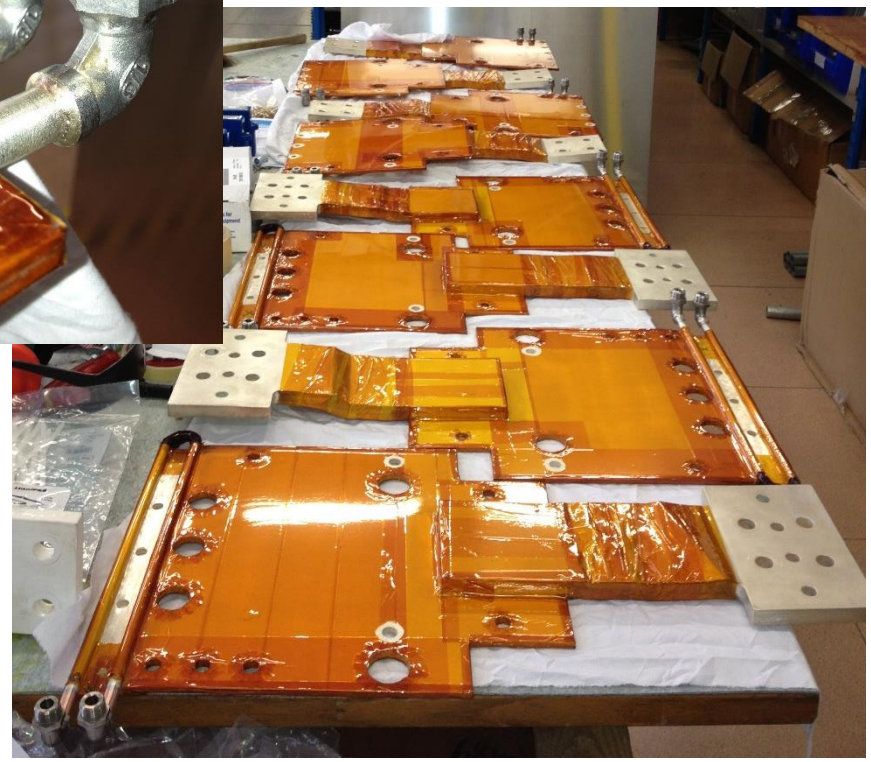
7.5kA opening



Progress for 7.5 kA Prototype

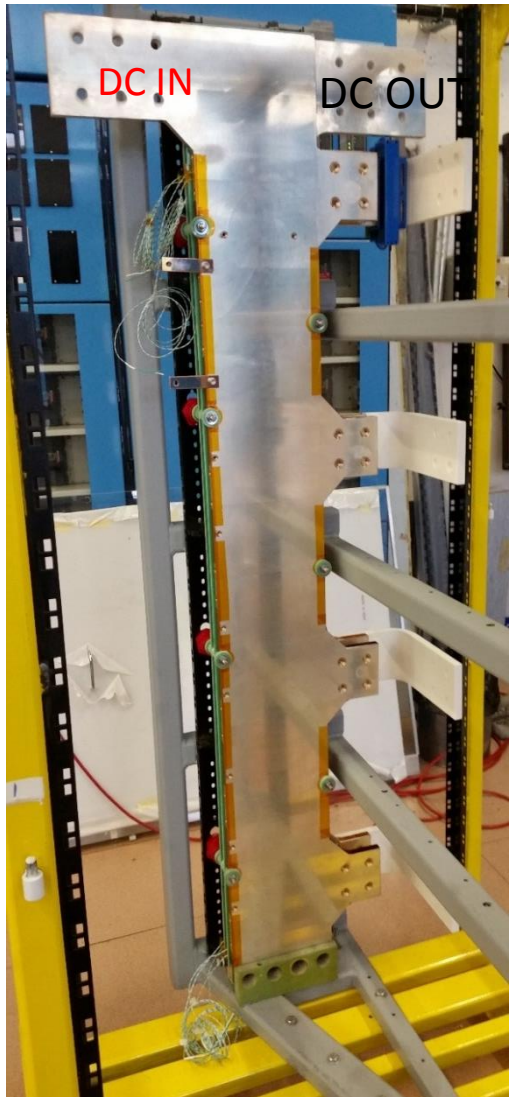
IGBTs on the heatsinks

Laminated busbars



Progress for 7.5 kA Prototype

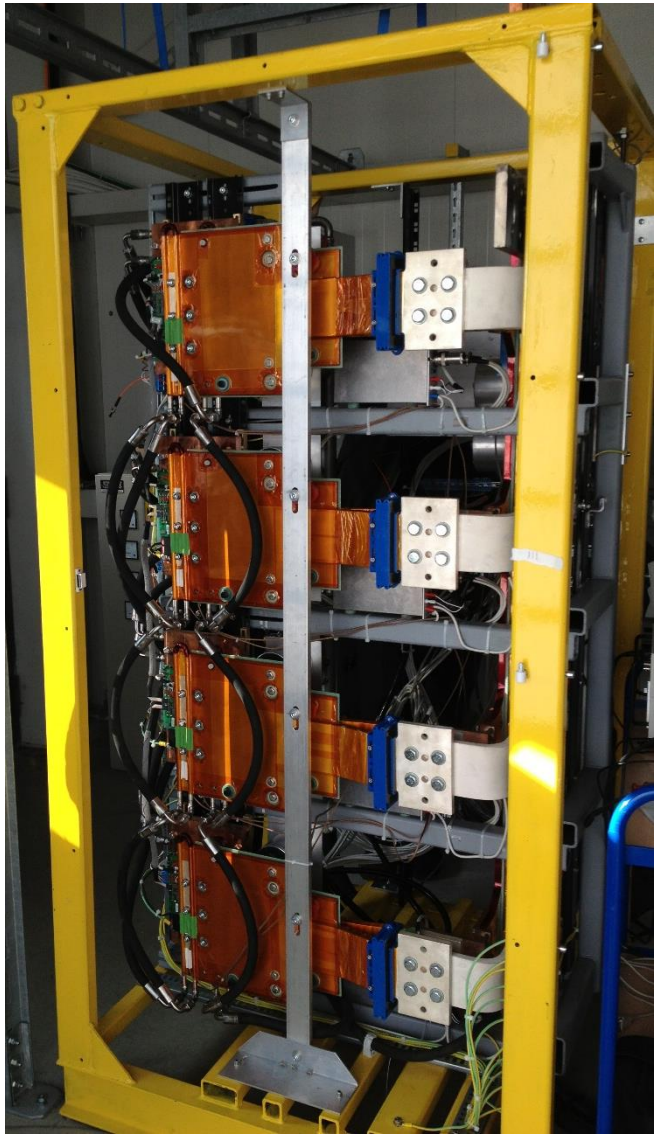
Rack assembling



Progress for 7.5 kA Prototype

Front view to the rack

IGBTs, connection plates



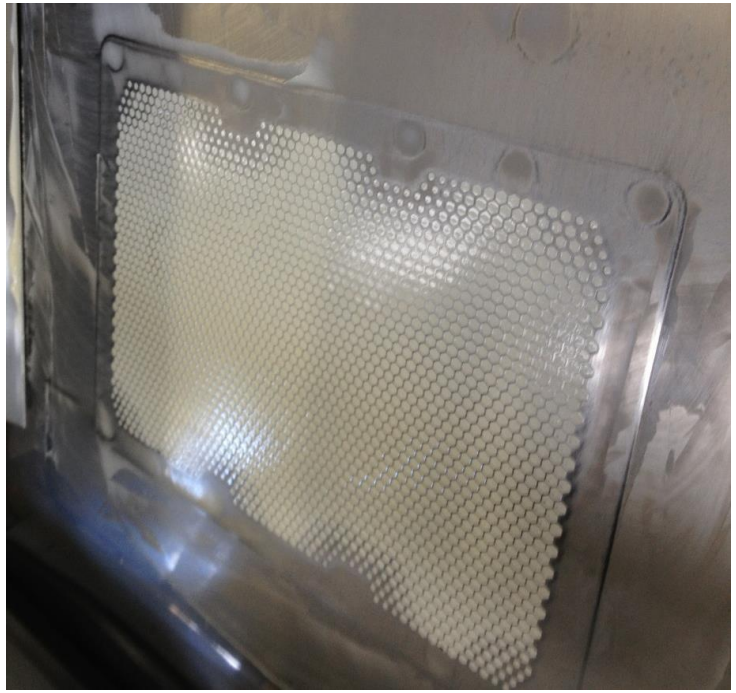
Left side view to the rack

Cooling water distribution

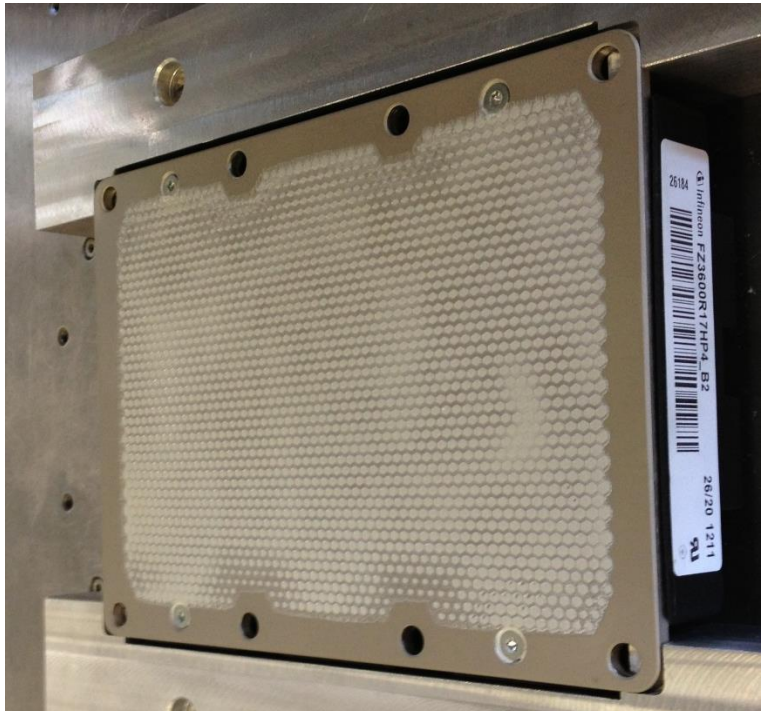
Progress for 7.5 kA Prototype

Thermal studies

Printing the grease trough the stencil



Grease pattern on the IGBT after printing

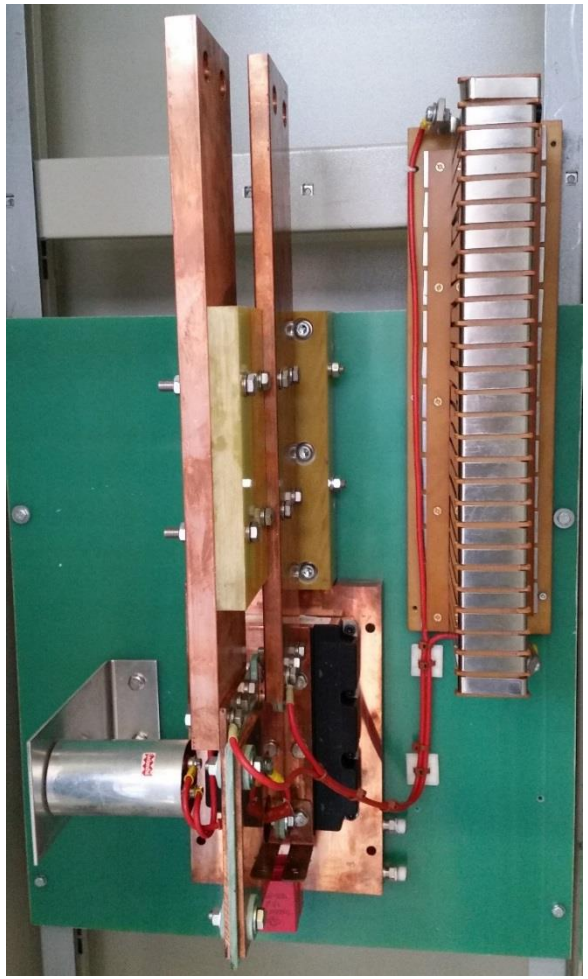


Stencils with the thickness from 60um till 120um were tried, after the pattern analysis the 80um was chosen

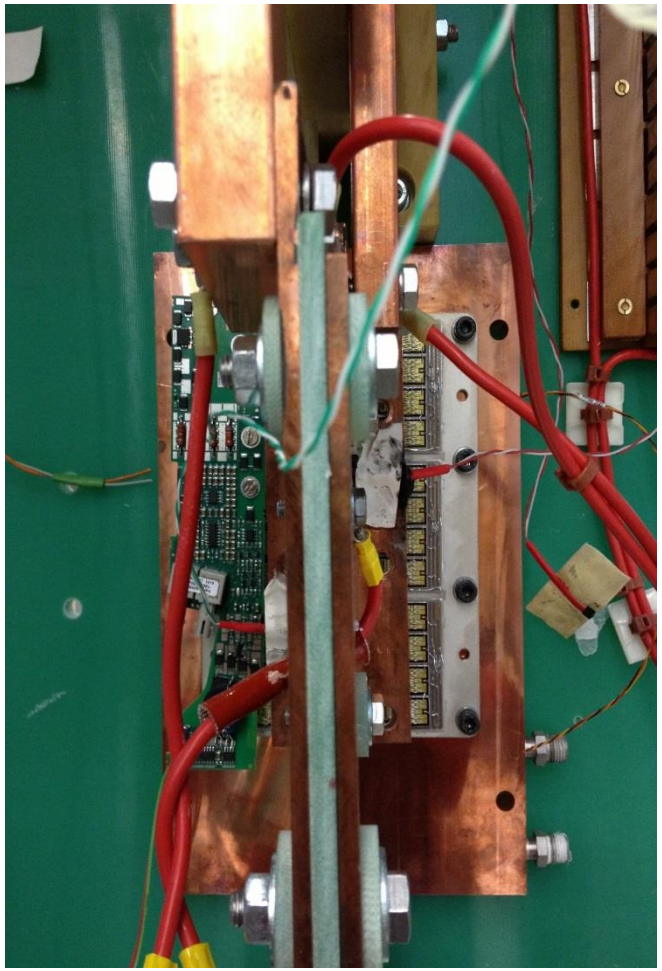
Progress for 7.5 kA Prototype

Test stand for the thermal studies

With the “normal” IGBT



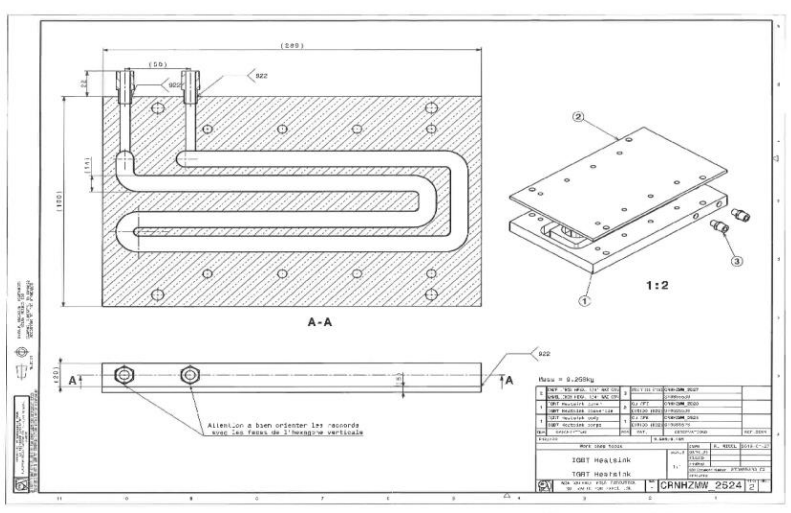
With the “open” IGBT



Progress for 7.5 kA Prototype

Thermal studies, heatsinks (cooling plates)

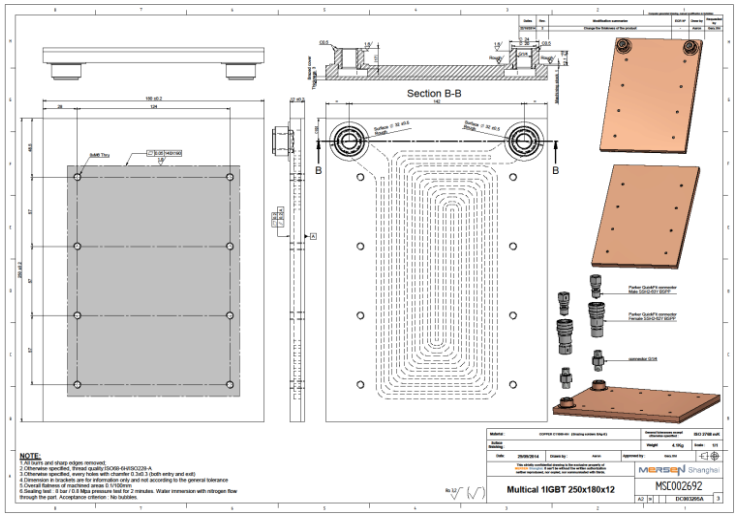
“Home-made” heatsink



Cooling efficiency - OK
fully compatible with the design;
capable to be improved (design is ready);
manufacturer is found (not expensive!)

30% heavier then others
IGBTs should be mounted manually

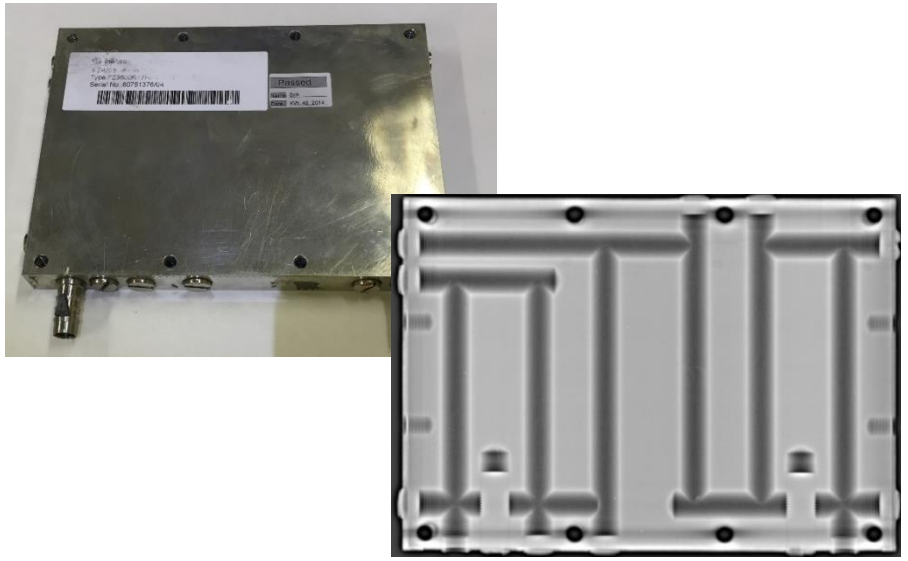
“Mersen” heatsink



Cooling efficiency - OK
manufacturer exists

not compatible with the design;
guaranteed by manufacturer to 10 bars;
IGBTs should be mounted manually

“Infineon” heatsink



Cooling efficiency - OK
Mechanically compatible with the design;
In case of availability IGBTs are already mounted

Water connections are not compatible
This part is obsolete

Chosen topology is correct, grease interface is correct, theoretical calculations are confirmed by the measurements!

Conclusions

- ***Prototype is assembled***
- ***List of observations is done: design bugs, production non-conformities, improvements***
- ***Drawings for the serial production are modified***
- ***Manufacturers are known***
- ***Thermal studies are done***
- ***Rack itself is quite compact, power parts are well accessible***
- ***Tests are ongoing (presentation is coming)***

Thanks for your attention!