Strukton POWER

100kW soft switching inverter verliesarme metro-aandrijving

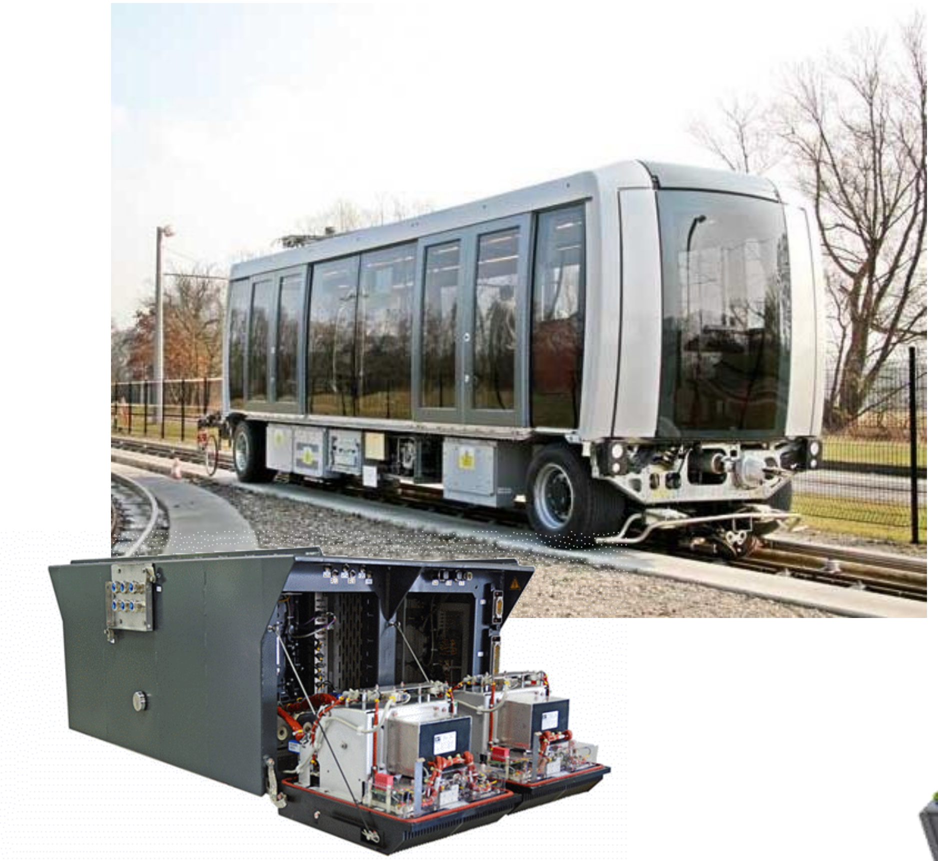
Strukton Power: rolling stock voorbeelden

Rolling Stock

India ≥1200 loc's

UK, Isle of Wight

Siemens Neoval



Monterrey

USA MARC loc

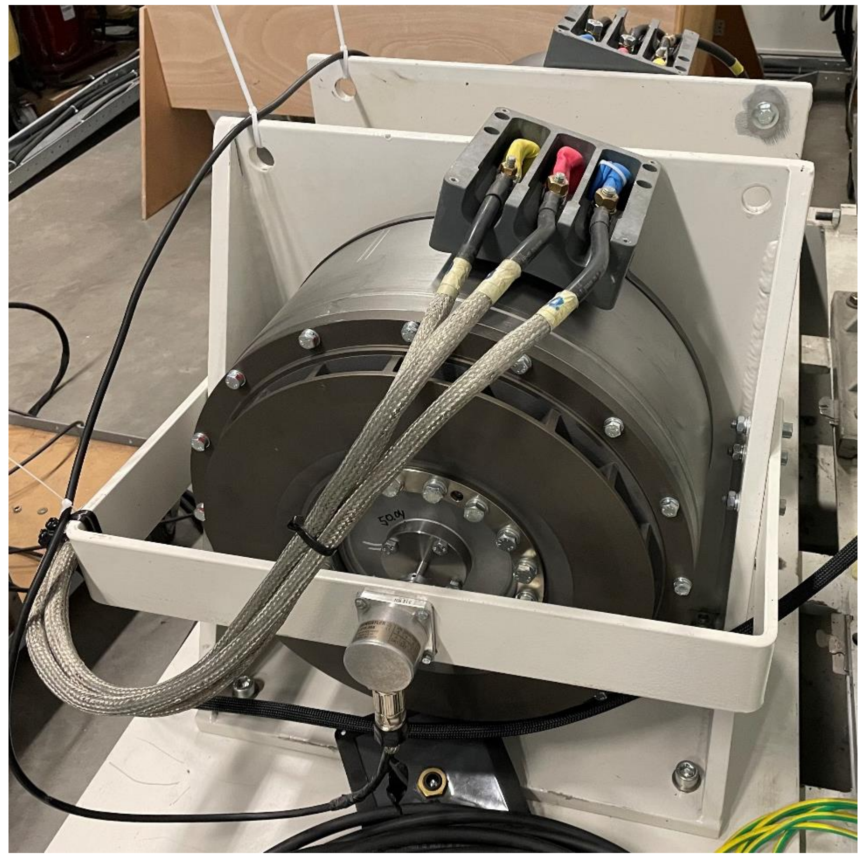
Duitsland

Matra Val

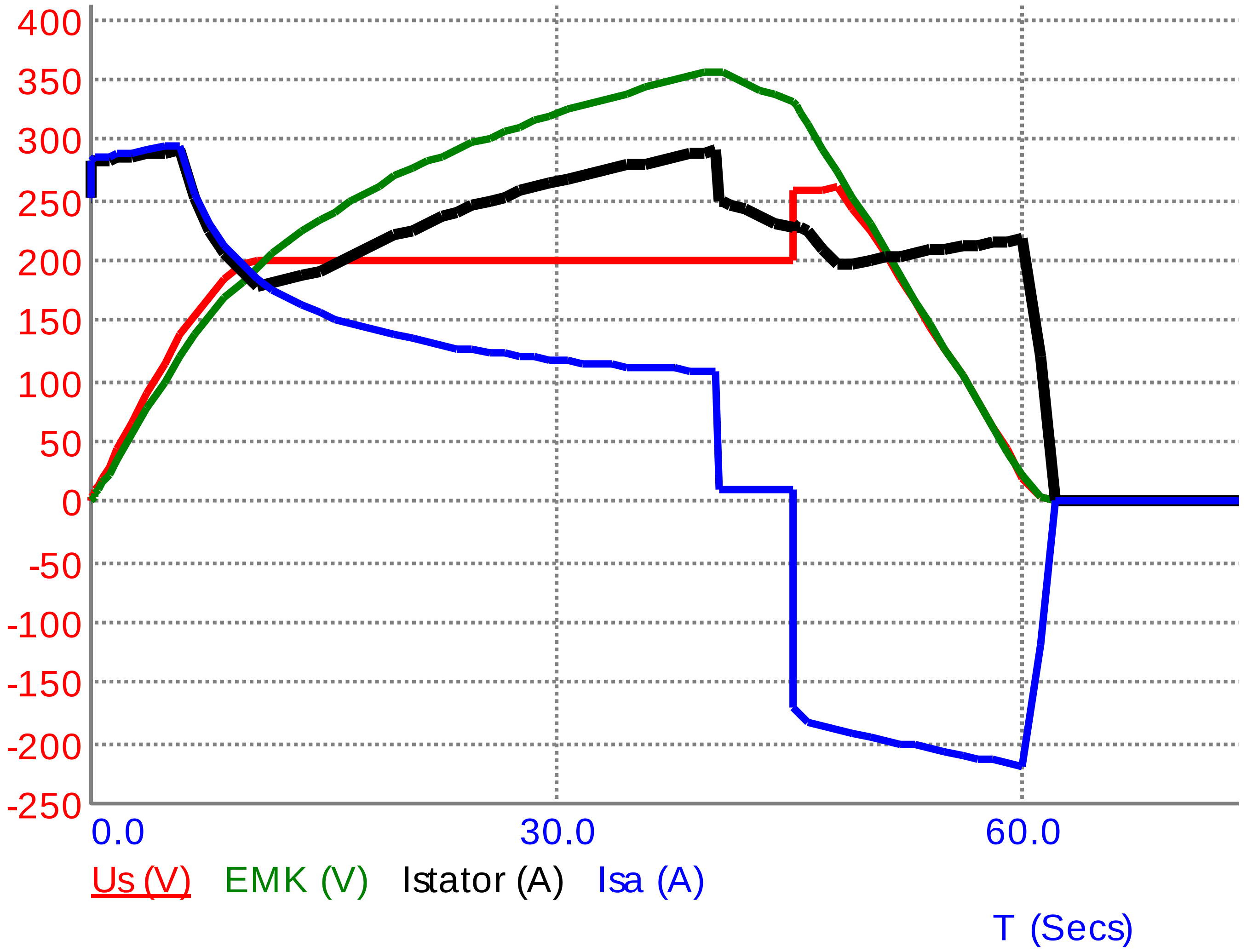
Strukton POWER

Val: dc-motor
Neoval: PM-motor => hoge schakelfrequentie
rijwindkoeling => lage verliezen

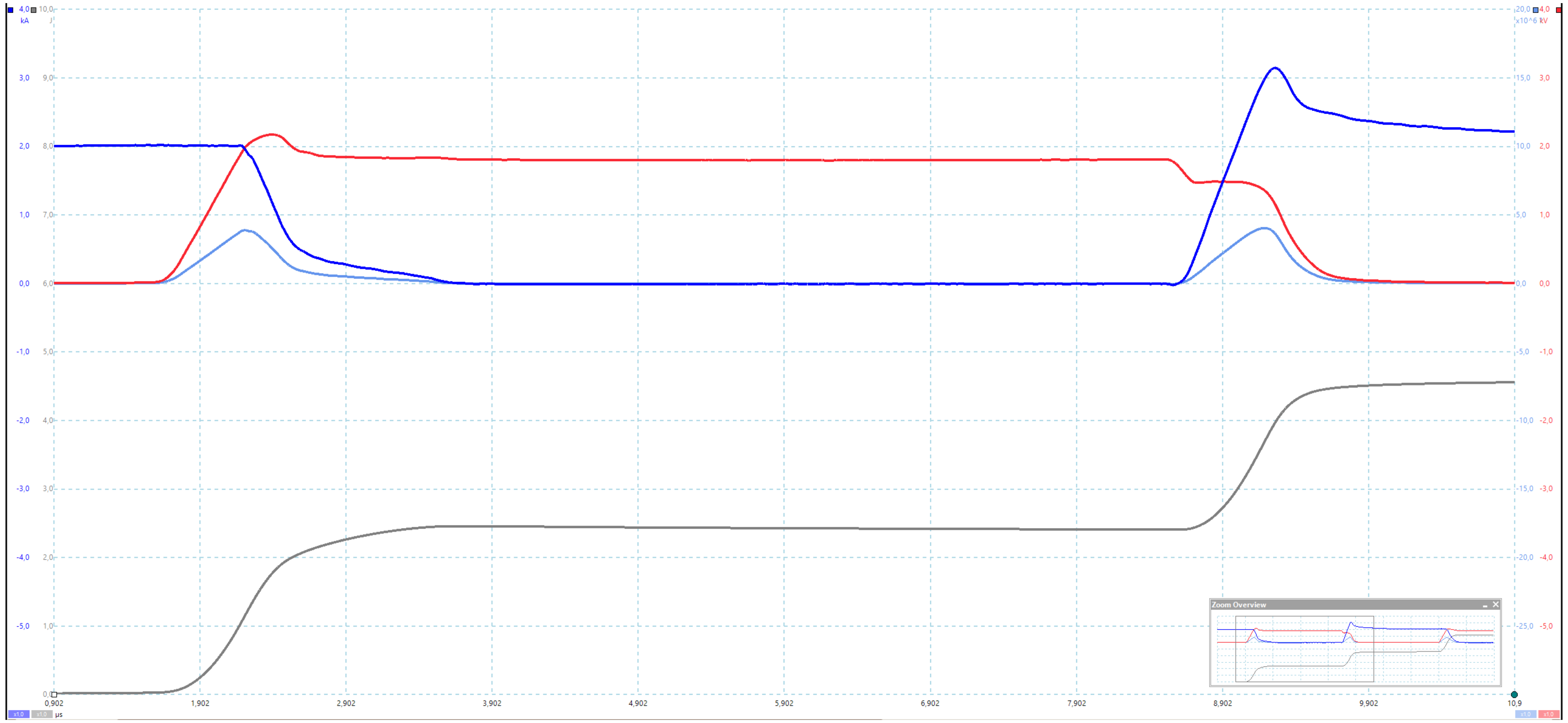
Conclusie: nieuwe powermodule nodig met weinig schakelverlies



specs:
Filterspanning: 750V
Fasestroom: 250Arms (PM-motor: aanzetten 100kW, remmen 170kW)
Schakelfrequentie: 3-5 kHz
Verlies per fase: < 600W



‘Hard‘ schakelen van een IGBT



Uce [1kV/div]
Ice [1kA/div]
P [5MW/div]

E [1J/div]

t [1µs/div]

Stroom en spanning overlappen tijdens de schakelmomenten => veel schakelverlies.
Uit berekening blijkt dat we maar 625Hz schakelfrequentie halen bij hard schakelen:
360W doorlaatverlies, 144W schakelverlies=>504W per fase

Literatuuronderzoek

Resonant Motor Drive Topology with Standard Modules for Electric Vehicles

Weight and volume reduction of the system have the highest priority in electric vehicles, which leads to high motor frequencies. To gain the advantage of high speed drives without the disadvantage of high power losses, resonant switching topologies are required, without becoming too complex and whilst still satisfying the required reliability. The automotive miracle of increased reliability at reduced cost has to become true again to make this vision real. A new standard component which supports an innovative switching topology might be an important step forward. **Michael Frisch, Vincotech, Munich, Germany**

The demand for electrical drive solutions for transportation applications has increased heavily. This is driven by the so-called mega trends such as mobility, energy efficiency, and reduction of CO_2 emissions.

Besides, the electrical drive technology offers additional functions and features for those applications. In the current situation the availability of technical solutions is the bottleneck for a realisation of the new applications which pop up in excessive numbers. The Swiss company BRUSA is one of the commercial know-how sources for the required drive system. It decided to develop a standard inverter with the purpose of covering multiple high-end applications with small volume, and having a proven and tested concept as a starting point for a development of high volume applications as hybrid car or electrical car.

Figure 1: 3~ inverter DMC144

Specification for a standard motor drive inverter

BRUSA developed a 3~ inverter which had to cover the requirements of the project, but also to provide the flexibility of possible usage in other applications (Figure 1).

The requirements for this motor drive system comprised two types of 3~ inverter with 100 to 500VDC and 200 to 1000VDC voltage, scalable output power in 40kW steps (e.g. 40kW, 80kW), compact outline, liquid cooled, IP65 protection grade, and efficiency >97%.

To achieve small size and weight goal the maximum motor speed will be high. When using a sinusoidal motor current the PWM frequency has to be relative high. The alternative of a rectangular pulsed phase current will cause a DC-current ripple and also a mechanical torque ripple (Figure 2). This ripple will cause several unwanted effects such as additional losses in the battery, audible noise, and vibration which might cause unpredictable problems in the whole electromechanical setup as a broken electrical interconnection or increased thermal contact.

A sinusoidal phase current will generate continuous torque without high frequency vibrations (Figure 4). On the other hand, an inverter with sinusoidal output current requires higher PWM frequencies. In order to avoid increased power dissipation in the inverter electronics, a solution for low switching losses in the inverter is needed.

Inverter electronics at component level

Highest quality and reliability levels are a must in automotive applications. All subsystems have to be qualified and optimised to achieve the reliability and cost targets. All this has to be done with the available resources in reduced time to meet the time to market specifications. To increase the reliability and reduce cost in a high volume series production, it is important to minimise the complexity of the system. Repeating structures can be realised with identical functional blocks. This reduces development as well as qualification efforts and time. The repeating power electronics structure for drives and

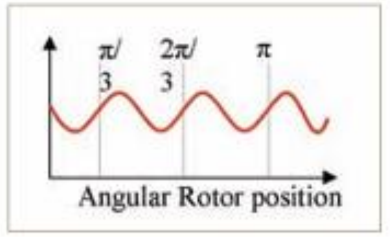


Figure 2: Torque ripple with rectangular pulsed phase current

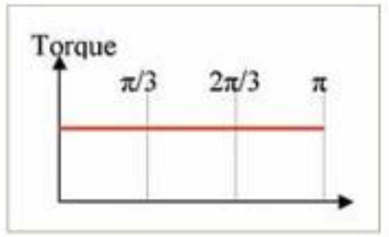
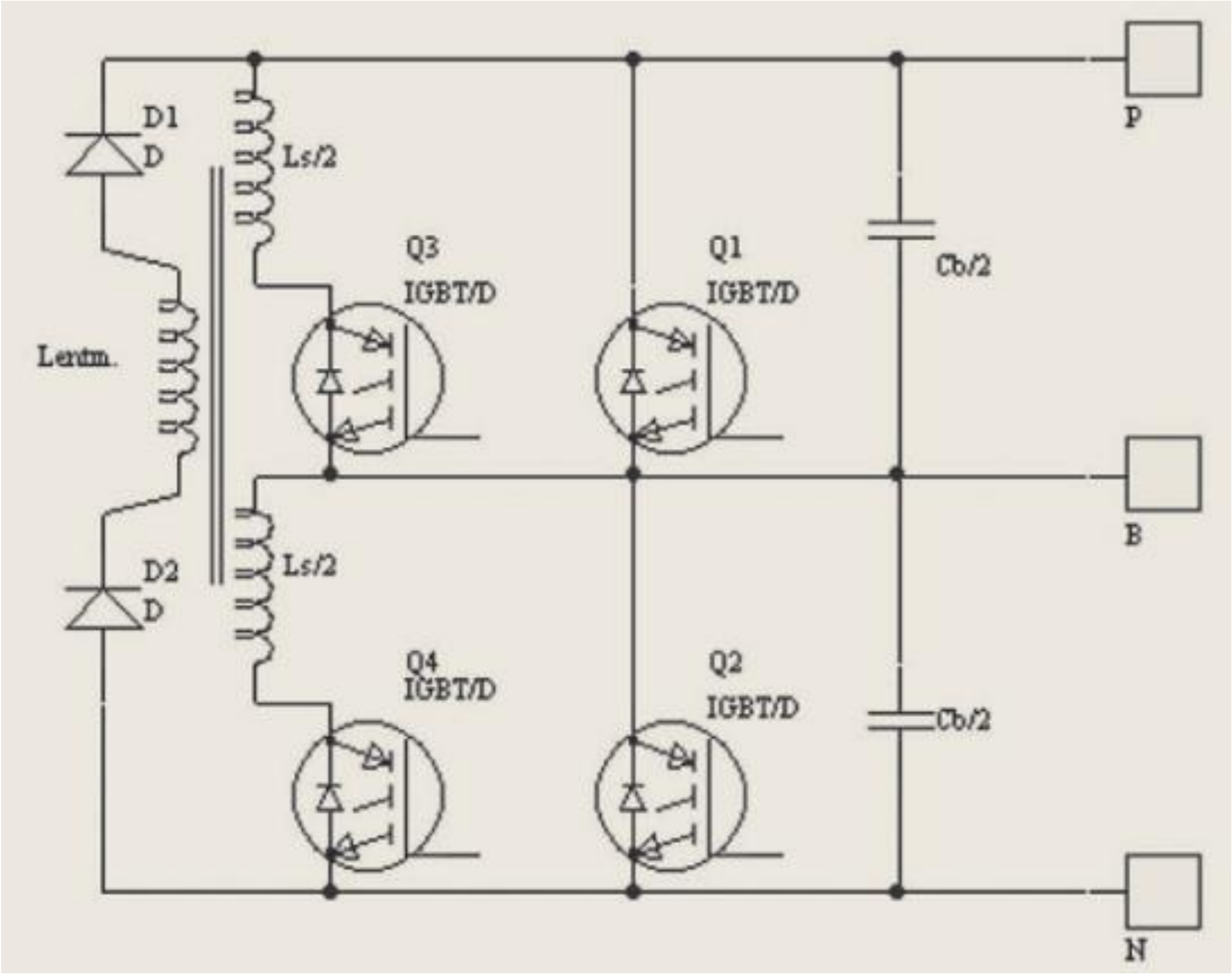
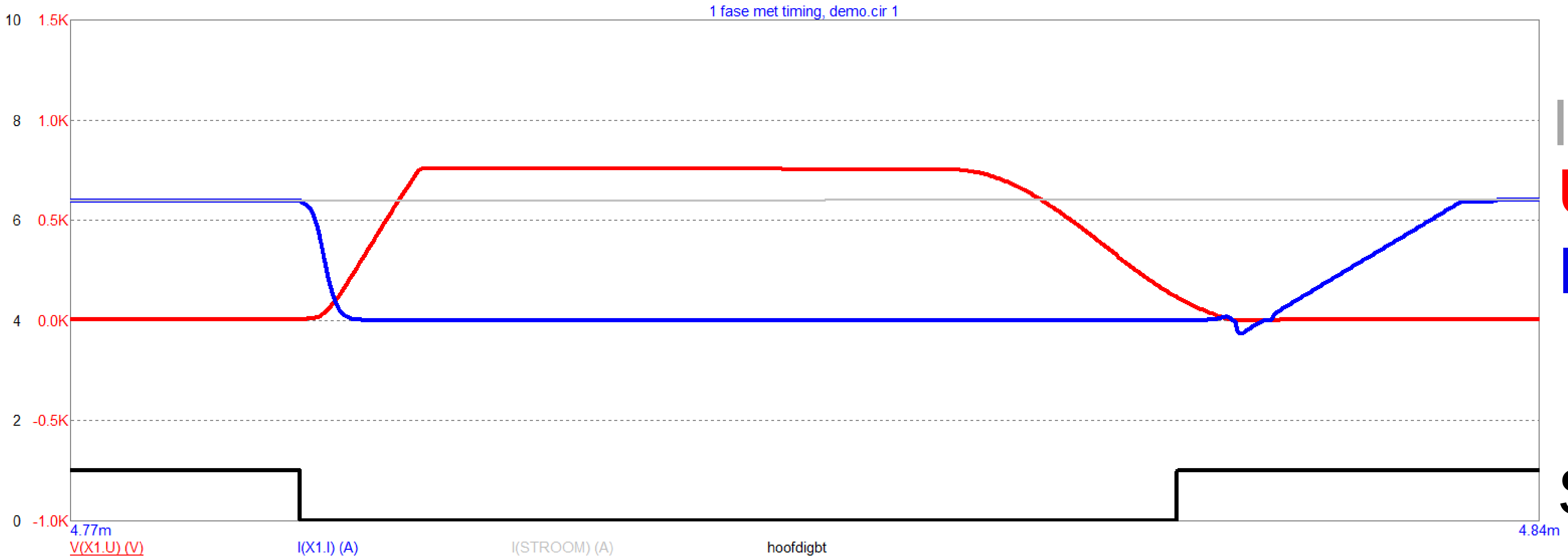


Figure 3: Torque signal at sinusoidal phase current

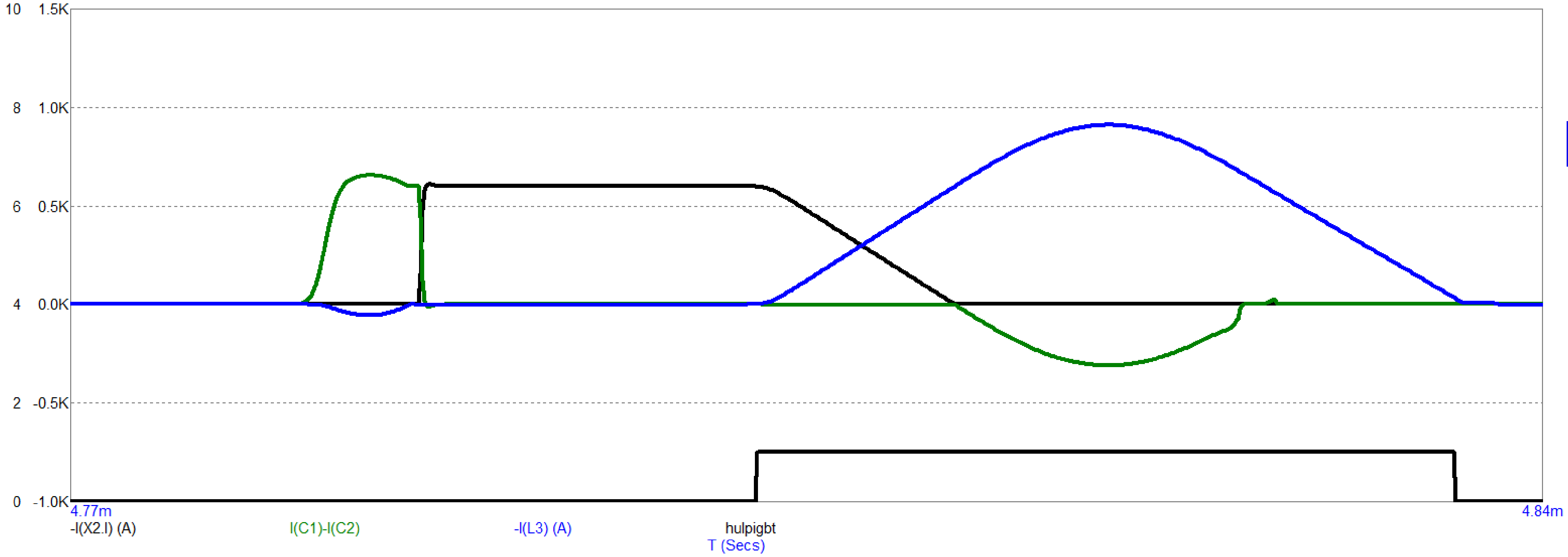


Principiële werking



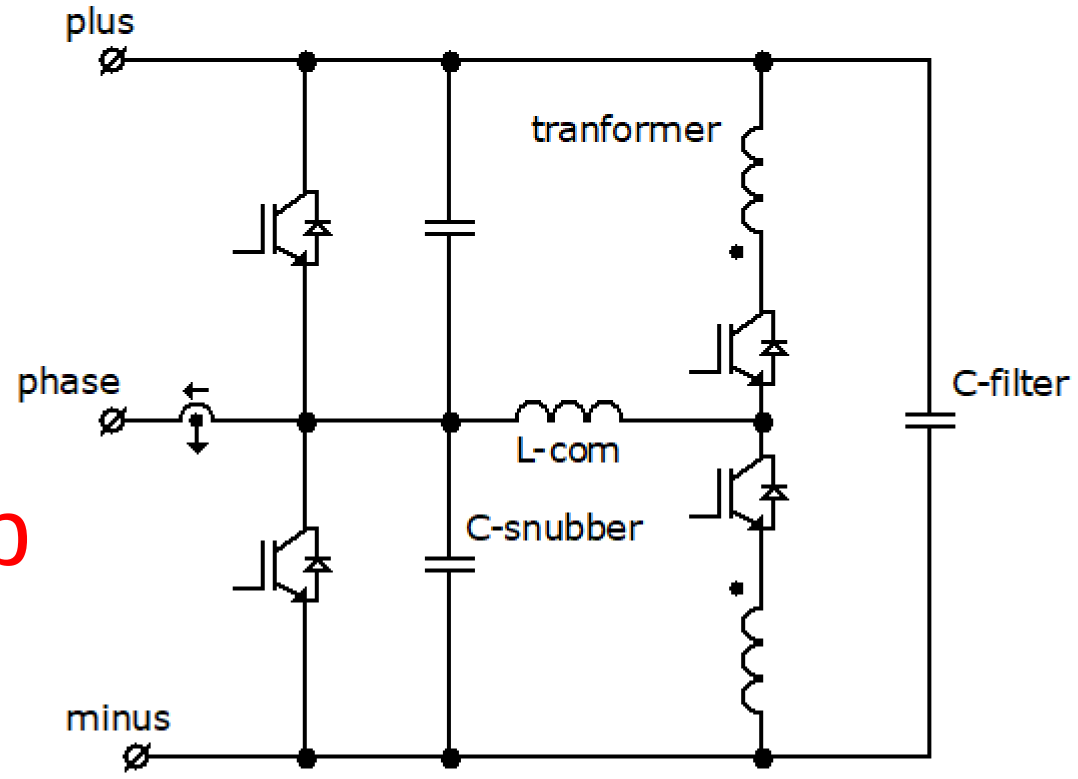
I fase
U hoofdIGBTtop
I hoofdIGBTtop

Sturing hoofdIGBTtop

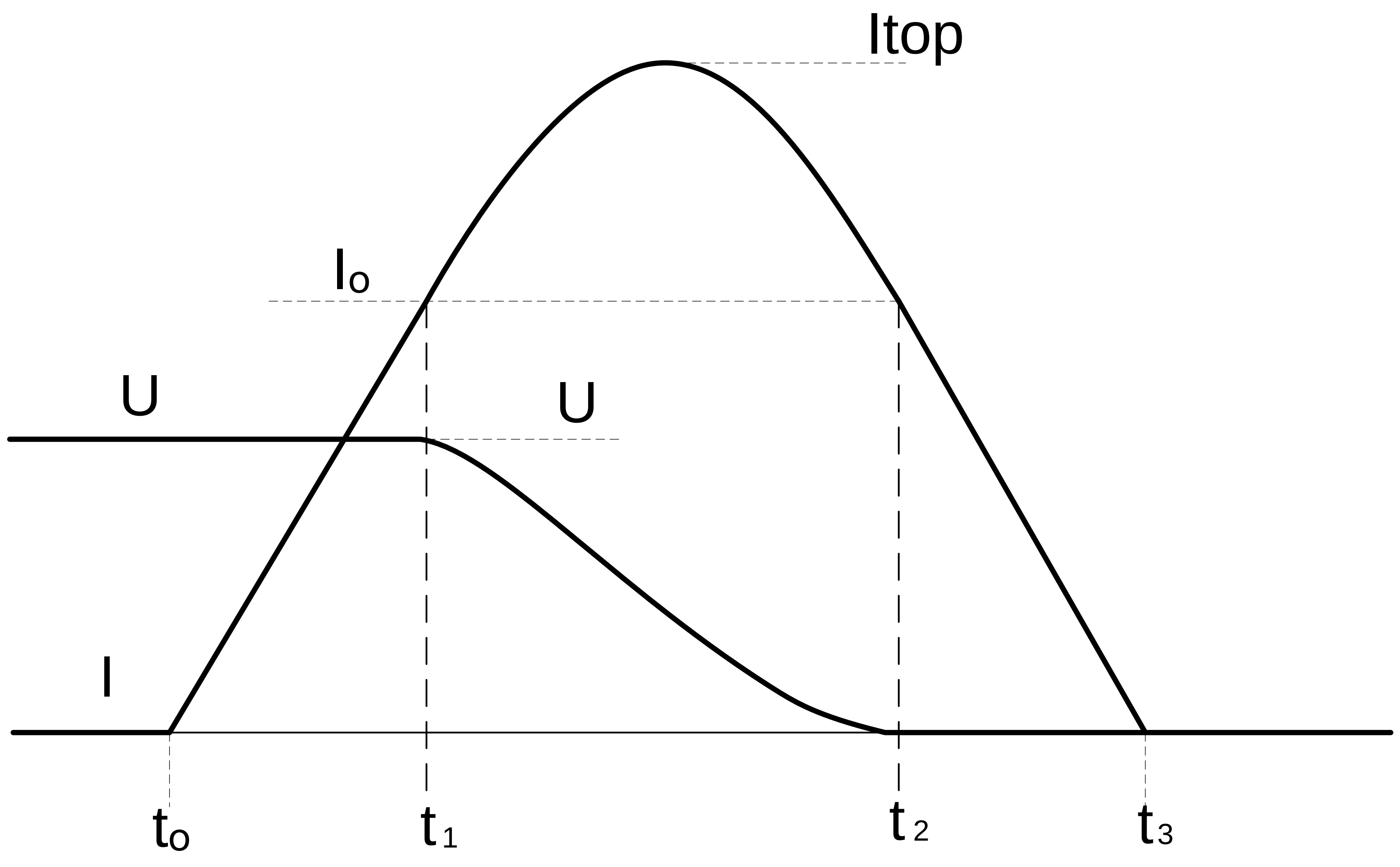


I L-com
I Csnubber (2x)
I hoofdIGBTbot

Sturing hulpIGBTtop



Timing



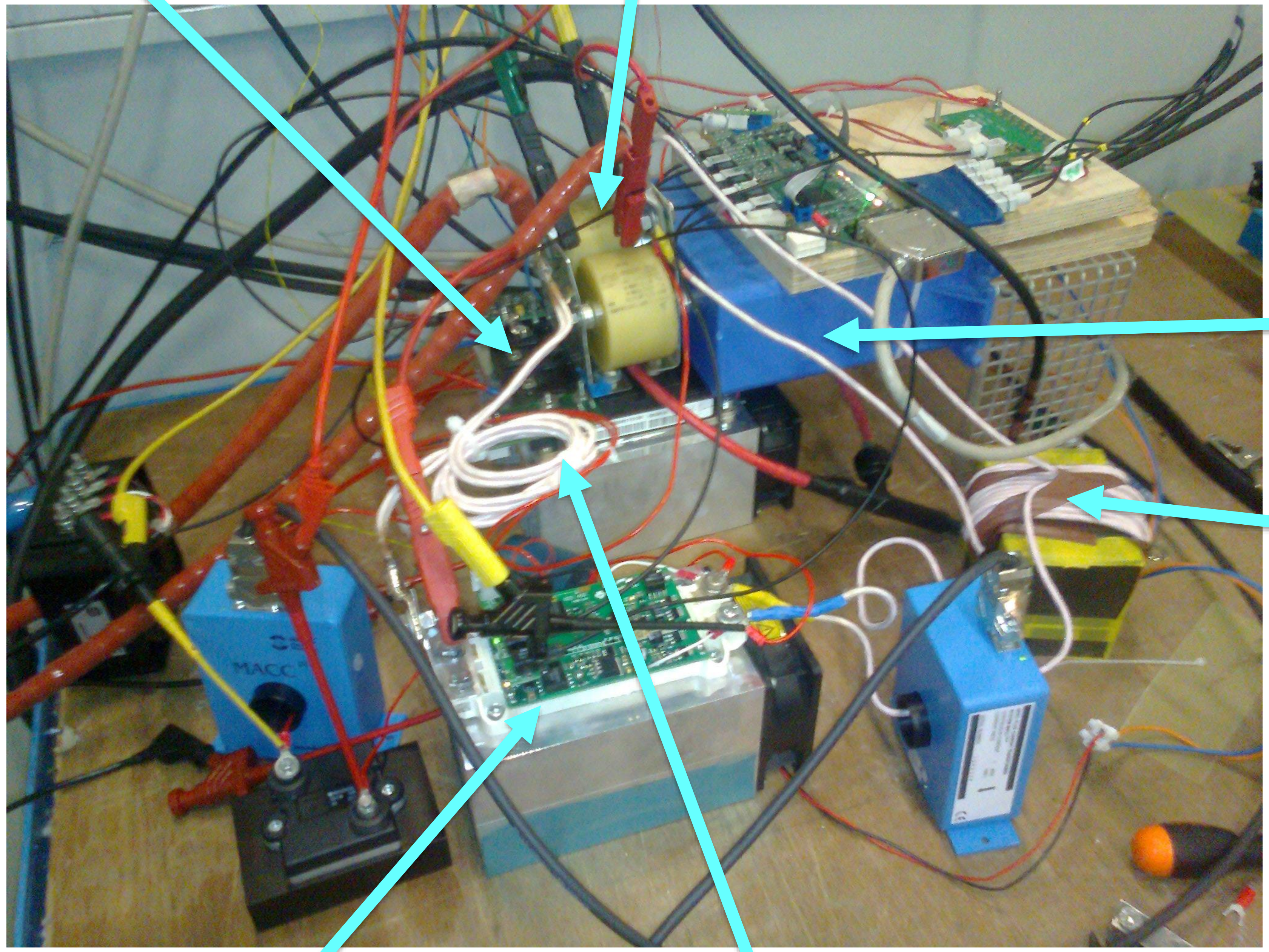
$$t_{0\text{-}1} = \frac{2.L_{com}.I_{load}}{U_{filter}}$$

$$t_{1\text{-}2} = \pi.\sqrt{2.\mathrm{C}_{\mathrm{snubber}}.\,L_{\mathrm{com}}}$$

Proefopstelling

HoofdIGBT

Snubbercondensator



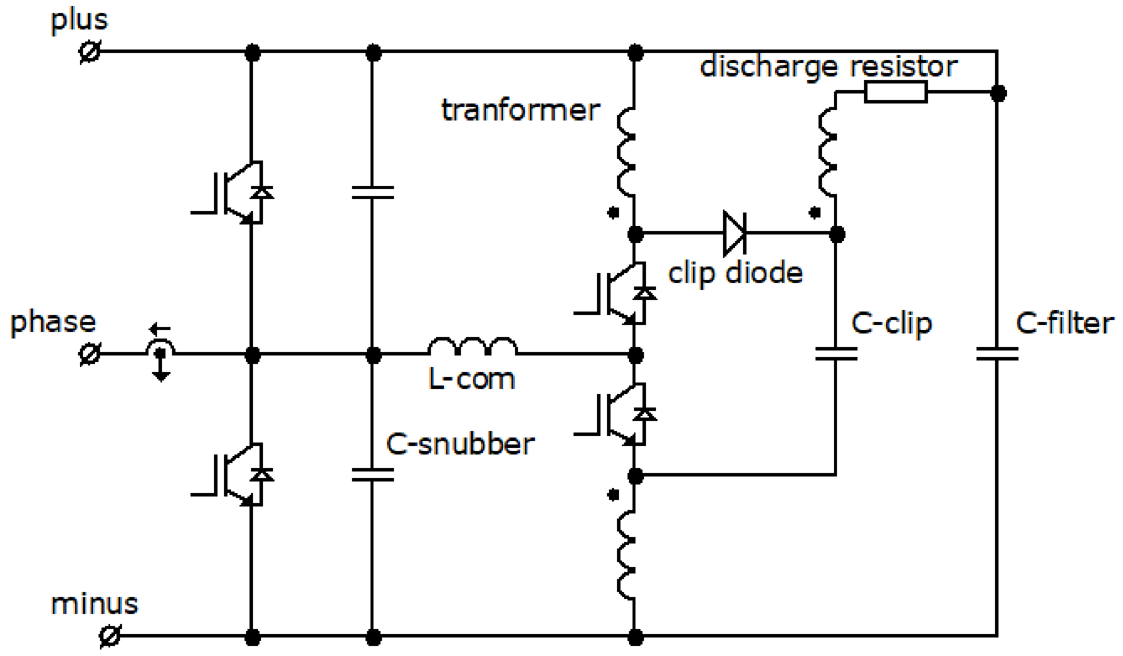
Filtercondensator

Transformator

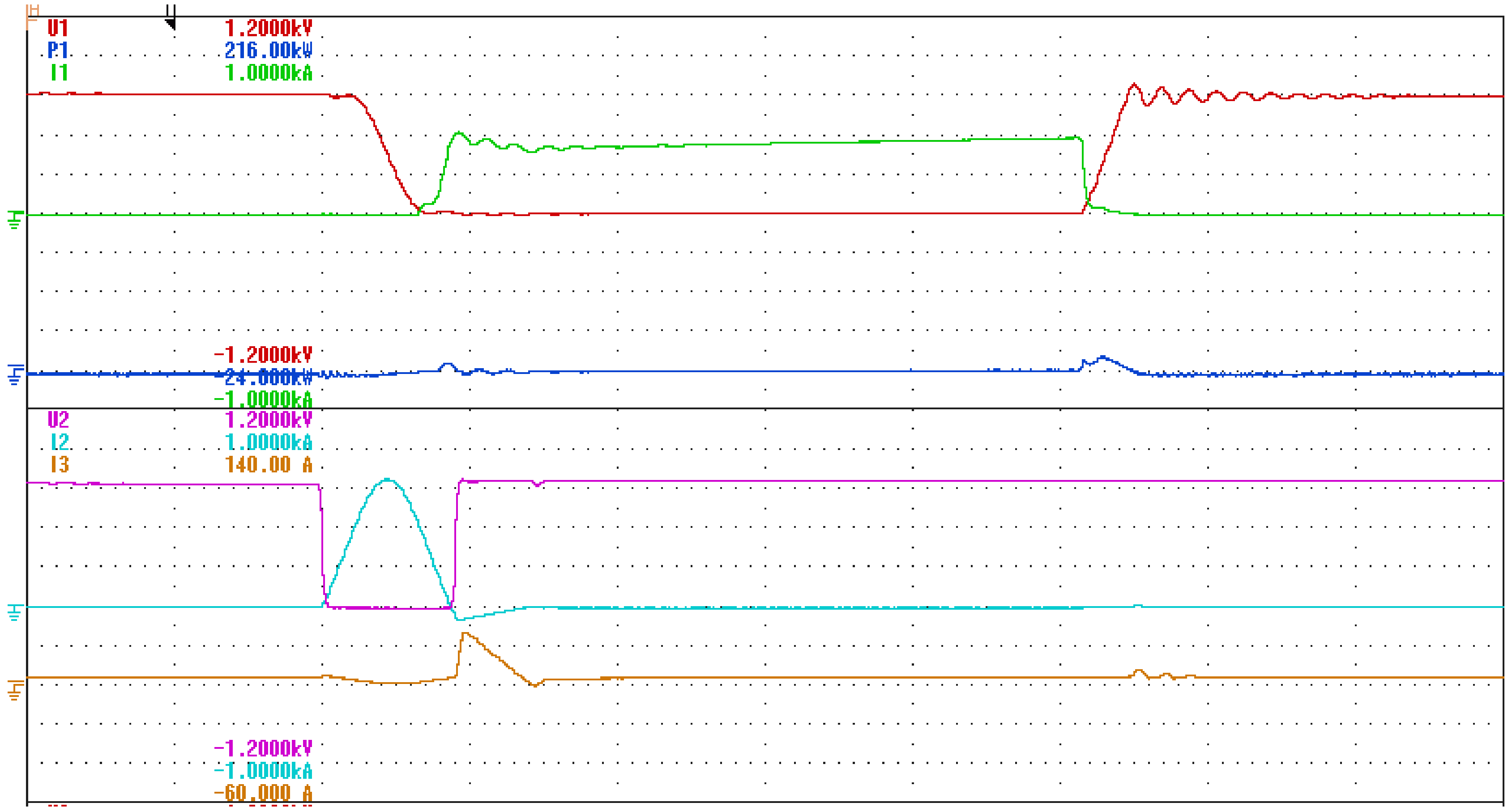
HulpIGBT

Commutatiespoel

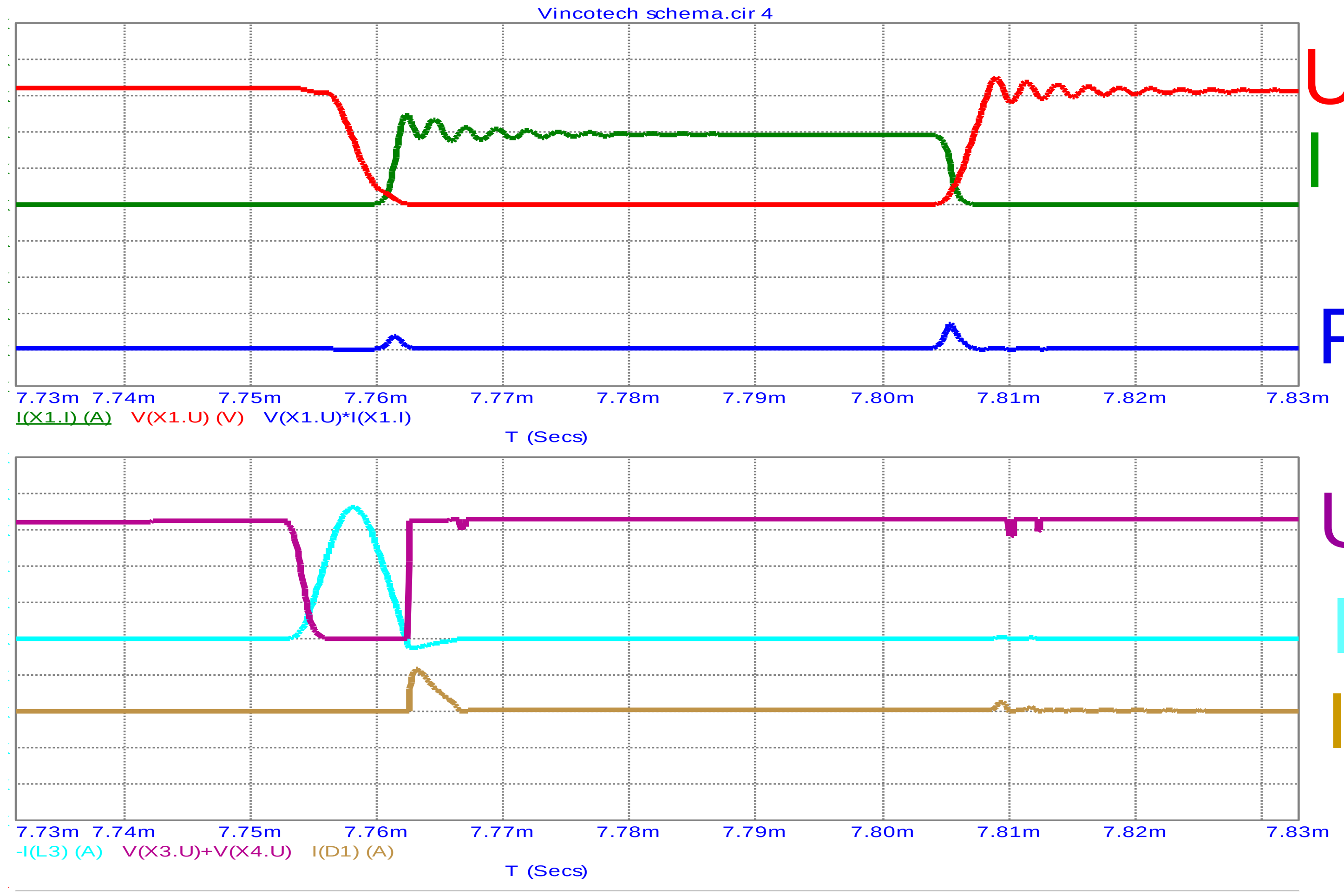
Realisatie, toevoegen klipcircuit



meting



simulatie



U hoofdIGBT [240V/div]
I hoofdIGBT [200A/div]
P hoofdIGBT [24kW/div]
U hulpIGBT [240V/div]
I hulpIGBT [200A/div]
I clipdiode [20A/div]

Verliezen @ 750V, 250Arms, 5kHz:

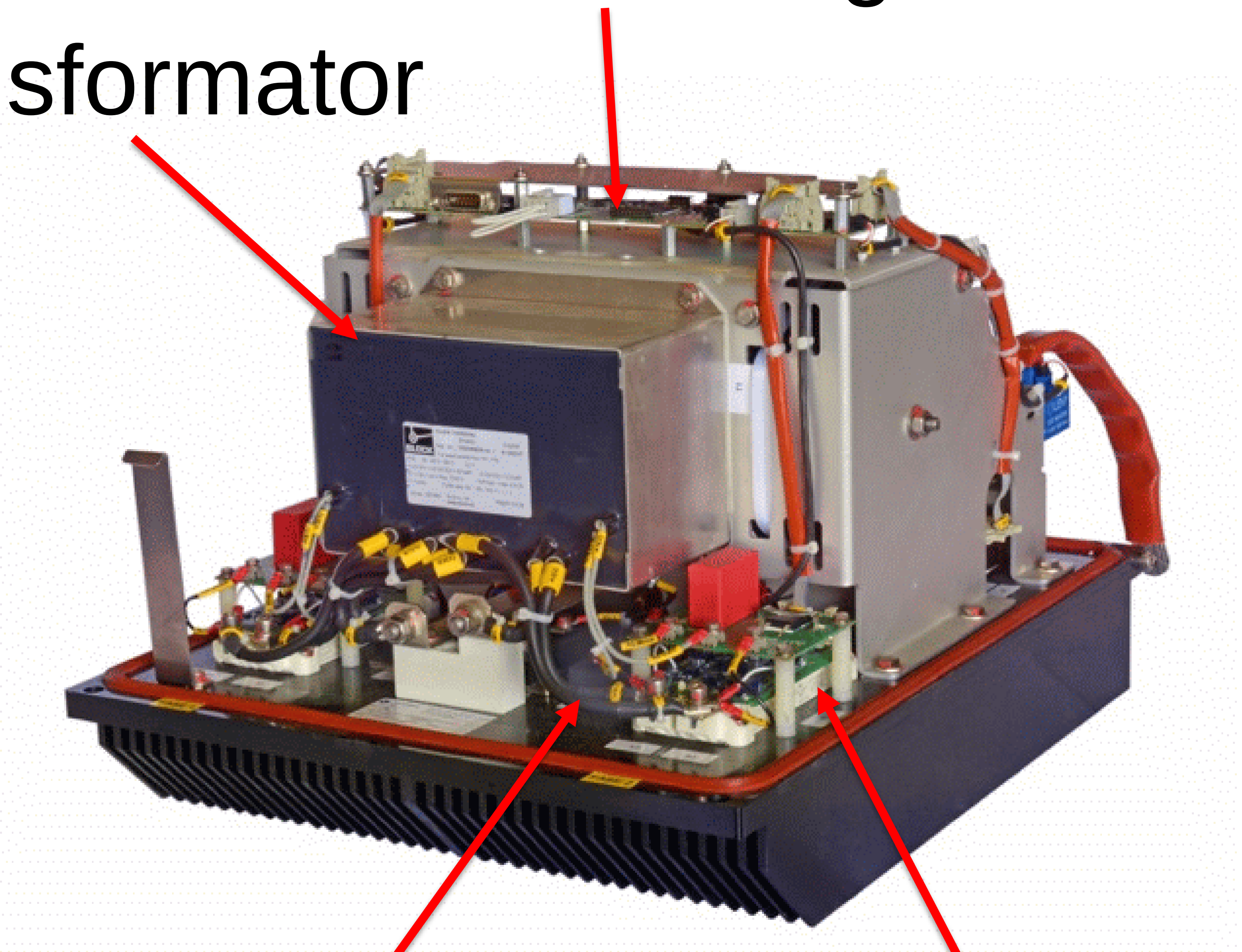
Soft switching
HoofdIGBT's: 527W
doorlaatverlies (berekend): 360W
Dus schakelverlies: 167W

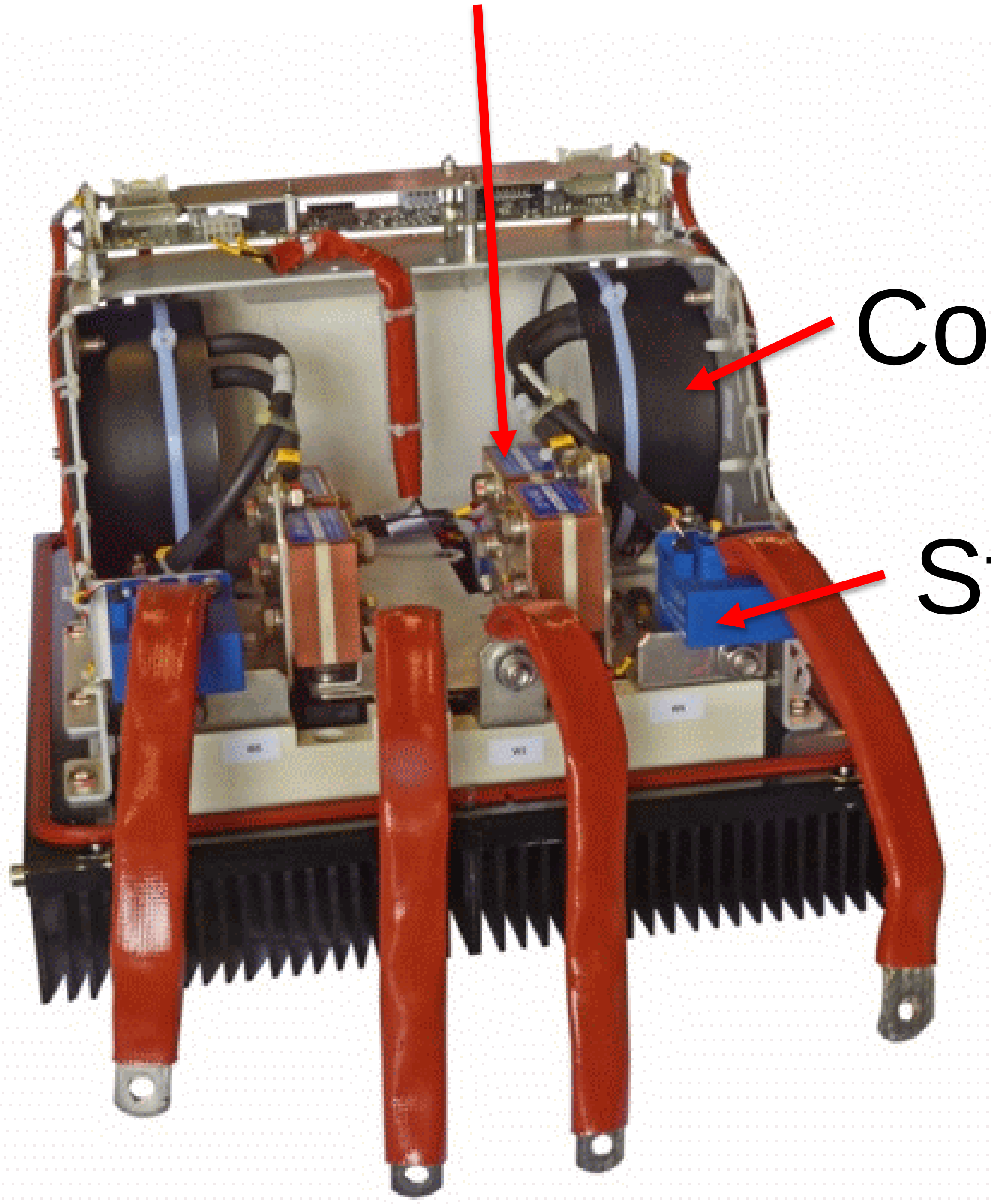
HulpIGBT's: 154W

Hard switching
HoofdIGBT's: 1512W
doorlaatverlies (berekend): 360W
schakelverlies (berekend): 1152W

Schakelverliesreductie: ≈ 85%

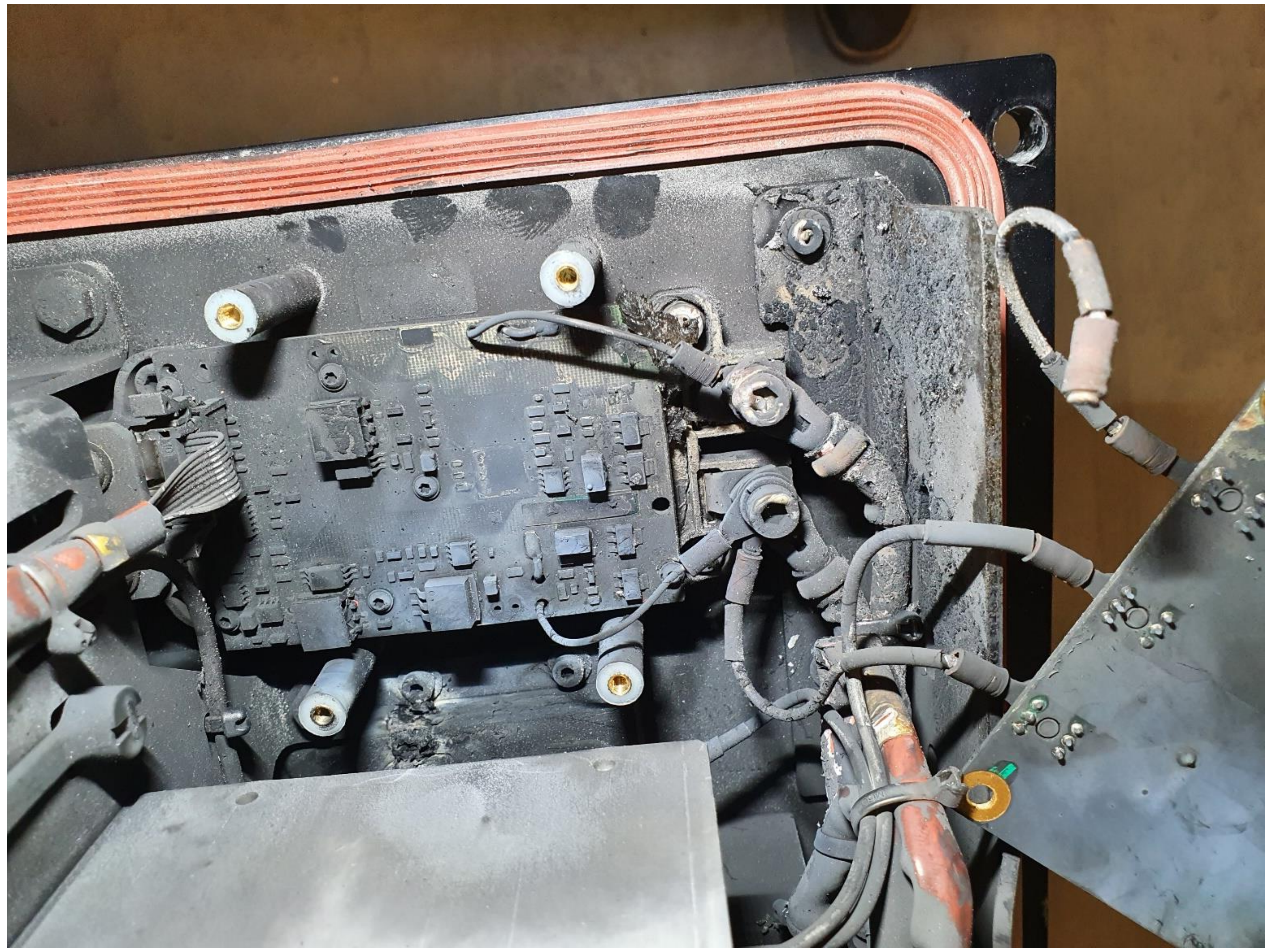
Definitief ontwerp, 2 fasen op 1 koelluik





Voordelen:
Weinig schakelverlies
Lage dV/dt => EMC

Nadelen:
Complexe schakeling => duur
Kortsluiting is lastig

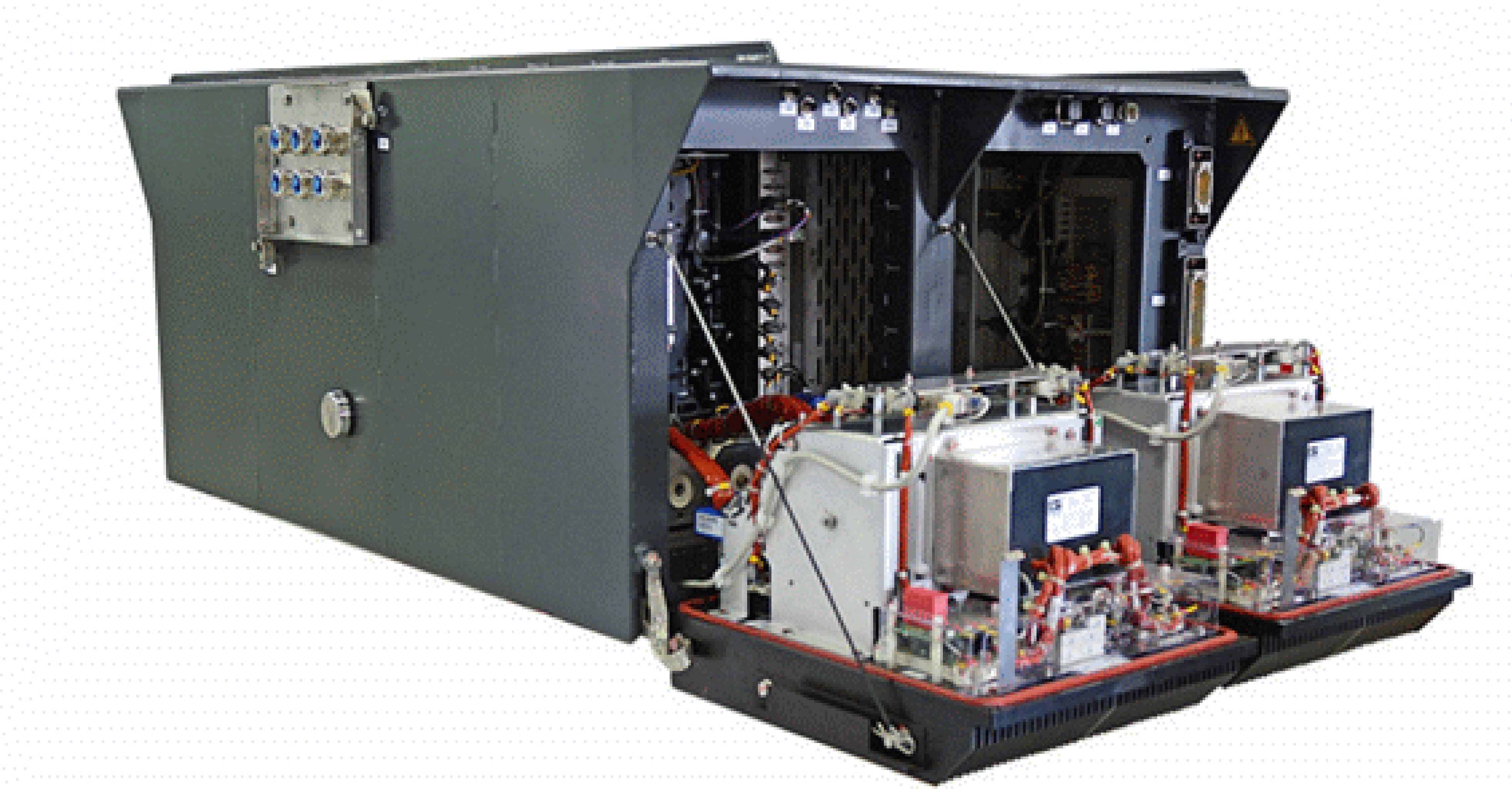


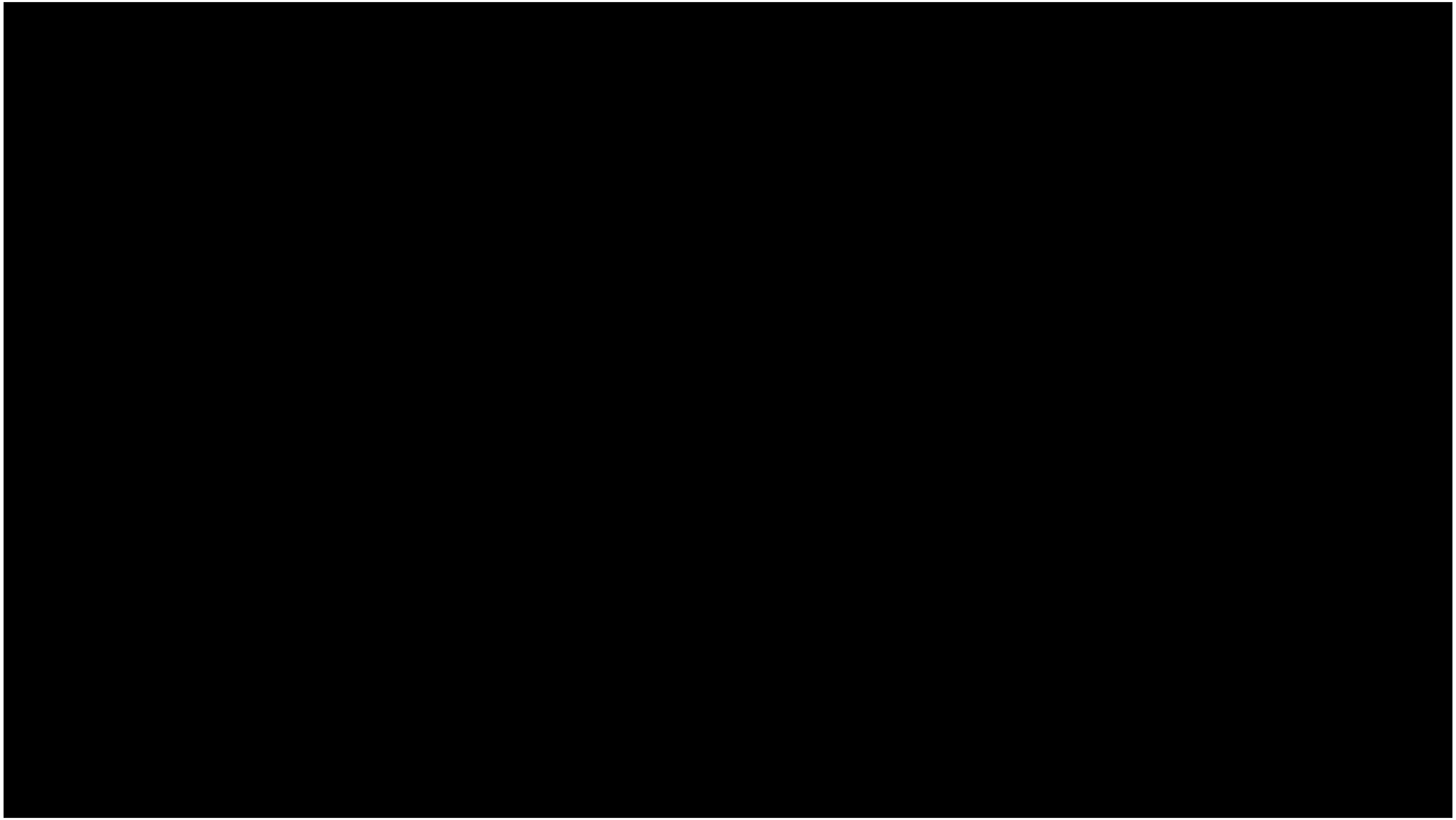
Strukton POWER

Power Electronics & Energy Storage event
POWER ELECTRONICS
ENERGY STORAGE
27 juni 2023 | 1931 Congrescentrum 's-Hertogenbosch

Voertuig

Tractiekast, 2 inverters





Vragen?

wim.platschorre@strukton.com