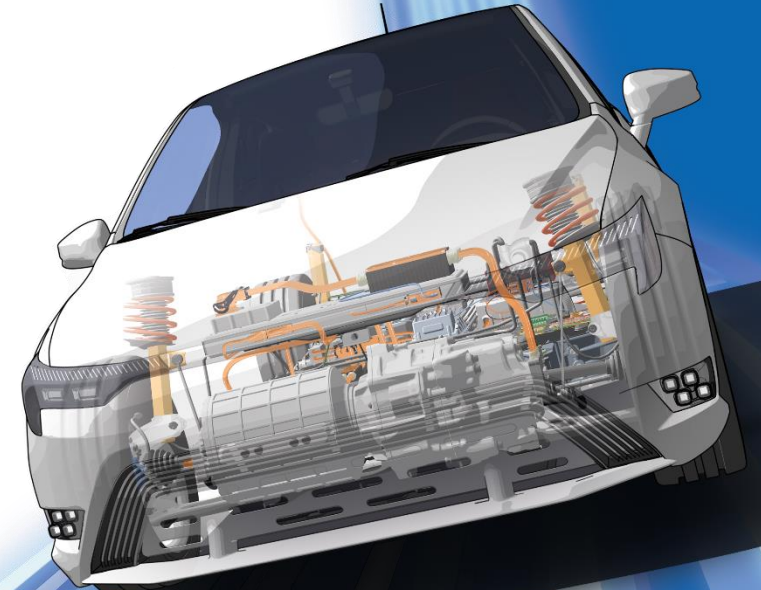
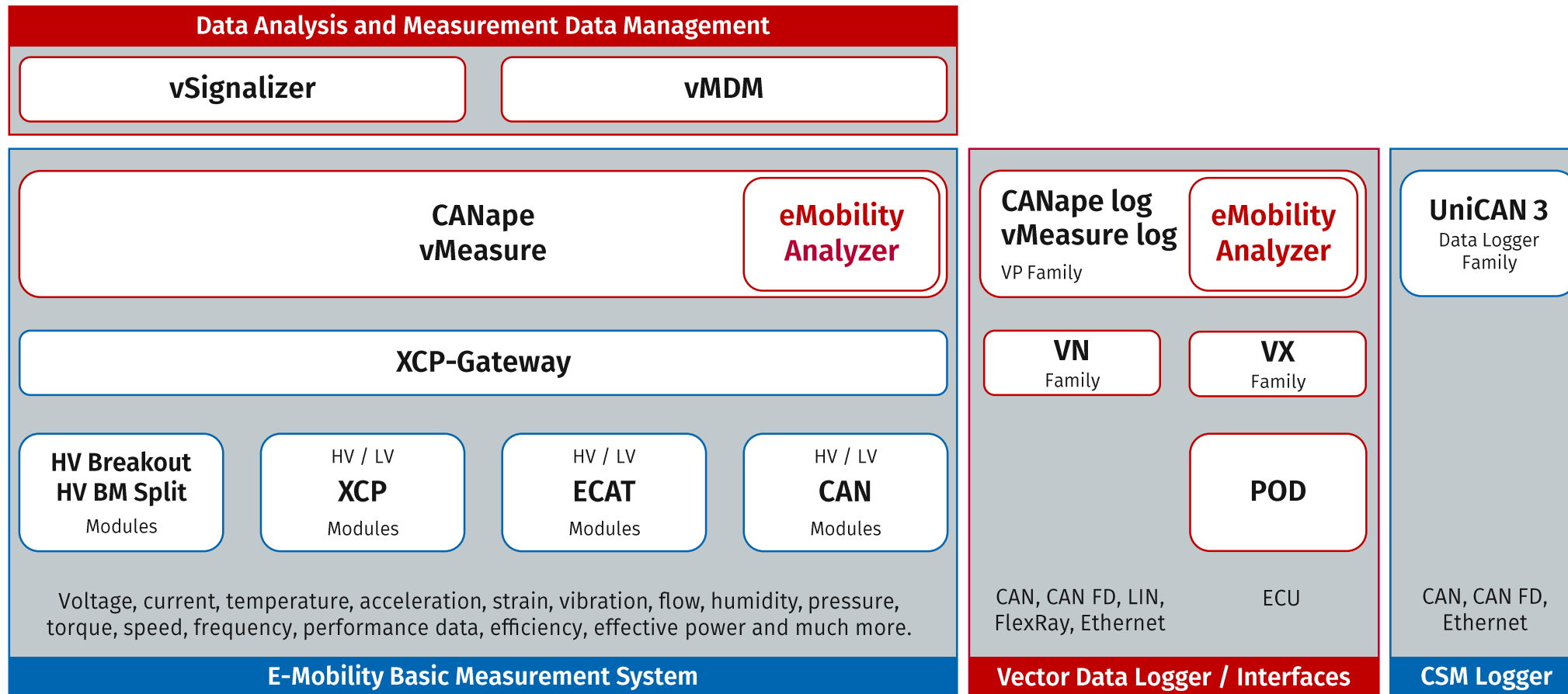


HV-sichere Messung von Strömen und Spannungen - Smarte Lösungen



Vector CSM E-Mobility Measurement System



Solutions for Safe Measurements of

Temperature

- ▶ Thermocouples
- ▶ High precision RTD sensors

Physical signals with standard sensors

- ▶ Humidity, pressure, acceleration, vibration, strain

Voltage and current

- ▶ V up to ± 20 V for sensors, ± 90 V for cells
- ▶ V up to 1 kV working voltage and up to 2 kV for spikes/transients
- ▶ I with precise Hall effect sensors or flux gates or CSM HV BM up to ± 1 kA nominal and ± 2 kA for spikes



CSM's HV-safe voltage measurements

Examples 1

HV AD4 XW1000

- ▶ To measure up to $4 \times U$
- ▶ Up to ± 1000 V,
 ± 2000 V for spikes
- ▶ ECAT up to 1 MS/s



HV AD2 IF20

- ▶ To measure up to $2 \times U$
- ▶ up to ± 20 V
- ▶ + sensor supply voltage
- ▶ CAN up to 20 kS/s



CSM's HV-safe voltage measurements

Examples 2

HV AD4 XW4000

- ▶ To measure up to 4x U
- ▶ up to ± 1000 V,
 ± 2000 V for spikes
- ▶ XCPoE up to 4 MS/s

HV AD8 OW20

- ▶ To measure up to 8x U
- ▶ up to ± 90 V
- ▶ CAN up to 20 kS/s



CSM's Current Clamp

CSM Current Clamp

- ▶ To measure one current
- ▶ $\pm 20 \text{ A} \dots \pm 1000 \text{ A}$
 - Analogue output $\pm 2 \text{ V}$
 - DC-supply $10 \text{ V} \dots 30 \text{ V}$



AD4 IG1000

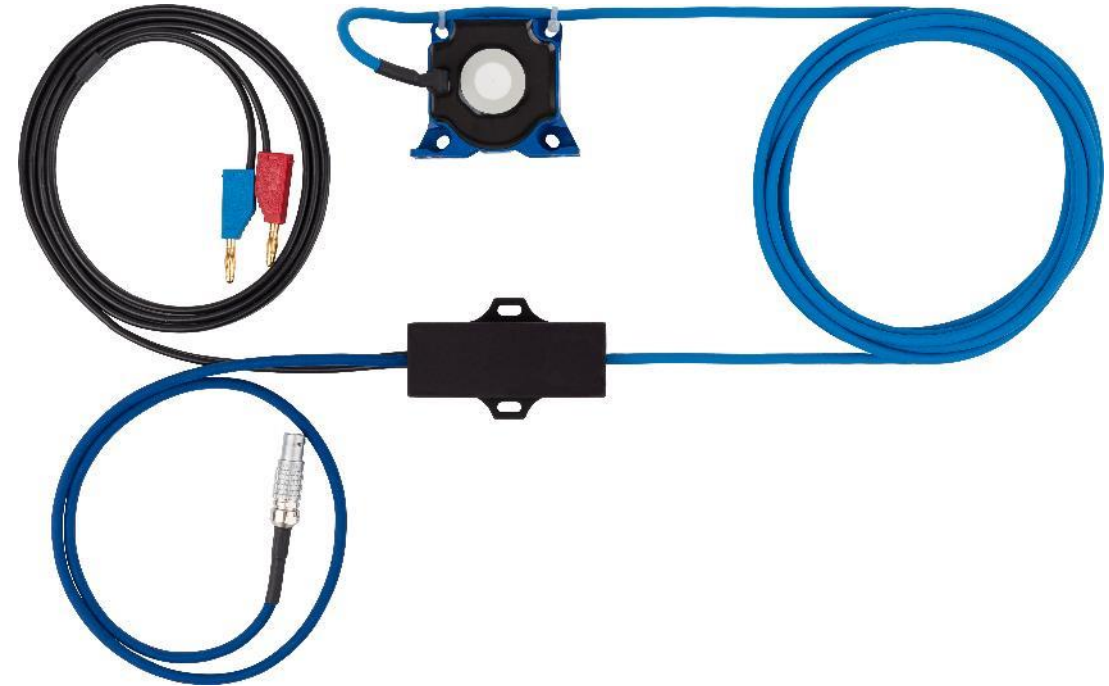
- ▶ To measure 1 .. 4 voltages



CSM's LEM Sensor Package

LEM Sensor Package

- ▶ To measure one current
- ▶ $\pm 5\text{ A} \dots \pm 1250\text{ A}$
 - Analogue output $\pm 5\text{ V}$
 - DC-supply $9\text{ V} \dots 36\text{ V}$
- ▶ Loop is potted



AD4 IG1000

- ▶ To measure 1 .. 4 voltages



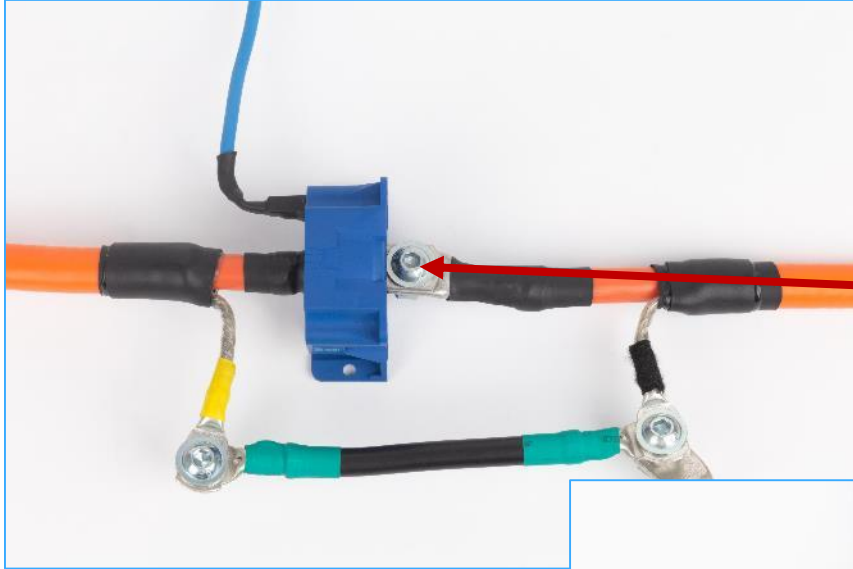
Installation of a closed loop sensor on an HV-cable

Shielded Cable

- ▶ Sensor measures the sum of the inner current and the shield current
- ▶ Shield has to be routed around the sensor
- ▶ Cable should be centered
- ▶ Set-up should be in enclosure

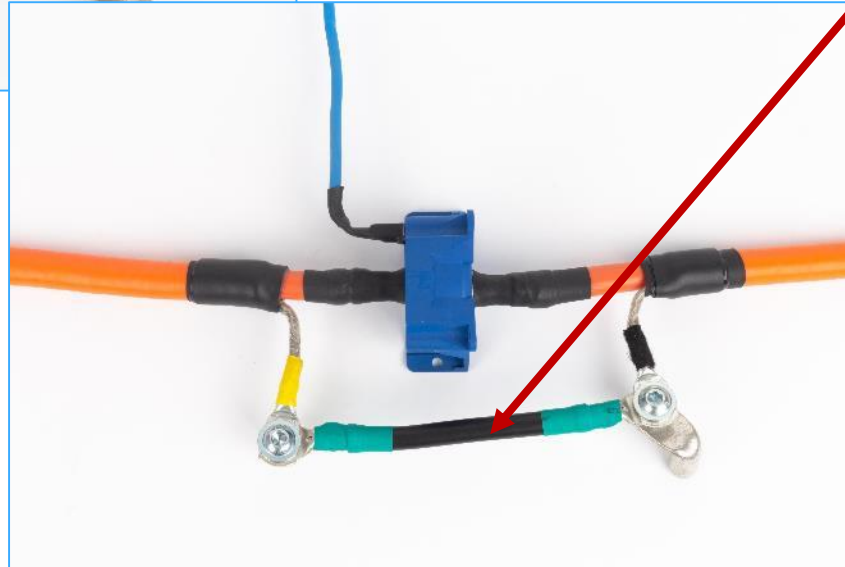


Installation of a closed loop sensor on an HV-cable



Shielded Cable, connector too big

- ▶ Connector does not fit through closed loop
- ▶ Joint needs to be in cable
- ▶ Shield has to be routed around the sensor



CSM HV Measurement Modules - active Breakout Modules

HV Breakout Modules (BM) for in vehicle testing and dynamometer measurements

- ▶ Safe measurement of voltages up to ± 2 kV
- ▶ Safe measurement of currents up to ± 2 kA
- ▶ CAN and ECAT output, up to 1 MHz
- ▶ Comprising 1 or 3 shunts



HV BM 3.1



HV BM 1.1

HV BM 1.2

CSM HV Breakout Modules to measure I and V and to calculate P

Various breakout modules available

- ▶ Measurements of 3 phases
 - V up to 1 kV working voltage
 - I_{peak} with shunt up to ± 50 A
 - $I_{\text{nom}} : \pm 32$ A_{rms}
- ▶ EtherCAT output up to 500 kHz per channel
- ▶ Optional CAN output for data loggers
- ▶ Calculation of instantaneous power in real time for EtherCAT® and CAN output



CSM HV Breakout Modules to measure I and V and to calculate P

Shunts are calibrated inserts

- ▶ Adaption to current range
- ▶ Calibration data stored on shunt PCB
- ▶ Temperature compensation



CSM HV Measurement Modules - Special Versions

HV Breakout Modules (BM) for in vehicle testing and dynamometer measurements

- ▶ HV BM 1.x+ U to measure balance/isolation of battery
 - U (HV+ -> HV-)
 - U (HV+ -> PA)
 - U (HV- -> PA)



HV BM 1.2 +U



HV BM 1.1 +U

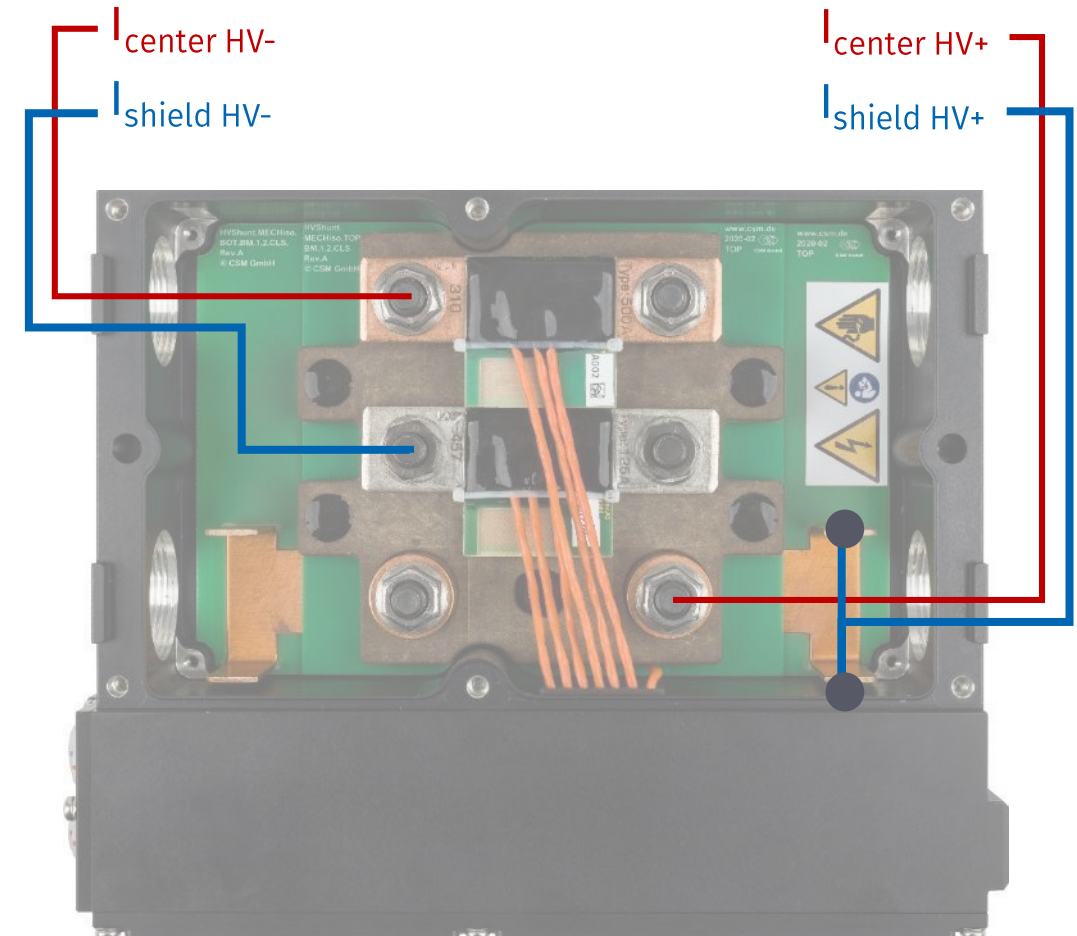
PA / PE

CSM HV Measurement Modules - Active Breakout Modules

HV Breakout Module HV BM 1.2 +S

to measure shield current and center current

- Shield is isolated from enclosure



CSM HV Measurement Modules - Active Breakout Modules

HV BM 3.3 to measure 3 lines simultaneously

- ▶ Up to ± 1400 A, up to ± 2000 V
- ▶ 3 voltages -> 3 line voltages

XCP-port and ECAT-port

- ▶ Sending rate up to 2 MHz of 3xI + 3xU
- ▶ Up to 12 MS/s (6 channels, 2 MHz each)
- ▶ Plus 4 MS/s from ECAT

Plus one CAN-port

- ▶ Up to 1 Mbit/s for CSM-Modules



HV BM 3.3



HV BM 3.3C

CSM HV Measurement Modules - Active Breakout Modules

HV Breakout Modules (BM) with connectors for easy change of DUT

- ▶ HV BM 1.2C for DC and single phase AC
- ▶ HV BM 3.3C for three phase AC
- ▶ CAN and ECAT output, up to 2 MHz



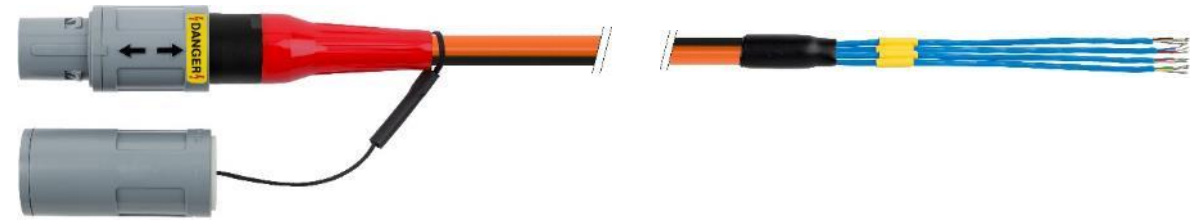
Accessories for HV measurements of U, I

Plug-in solutions for Breakout Modules

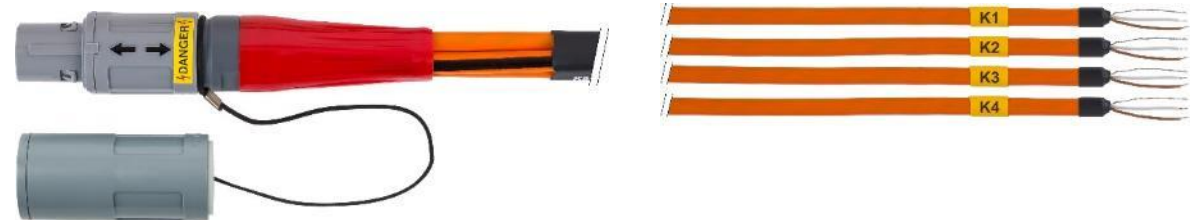


HV CA HVR200 + HV BM 1.2 + OEM HV cable

Measure up to 4 voltages in one HV-enclosure, K910



Measure up to 4 voltages in different HV-enclosures, K913



System Setup: HV BM vs CSM's LEM Sensor Package

LEM Sensor Package to measure current

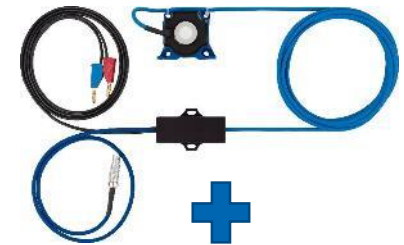
- ▶ Connector of HV-cable does not fit through the loop
- ▶ => Connector has to be disassembled or HV-cable has to be cut
- ▶ Shield has to bypass the sensor
- ▶ => HV-safe enclosure is needed

HV AD4 XW 1000 to measure voltage

- ▶ Tap into HV-cable to get contact
- ▶ => HV-safe enclosure is needed

LEM Sensor Package

1 .. 4 pcs => 1 .. 4 x I



AD4 IG1000

1 pce => 1 .. 4 x I



HV AD4 XW 1000

1 pce => 1 .. 4 x U



K913

1 pce => 1 .. 4 x U



System Setup: HV BM vs CSM's LEM Sensor Package

HV BM to measure current and voltage

- ▶ Shield is routed internally
- ▶ HV-safe enclosure



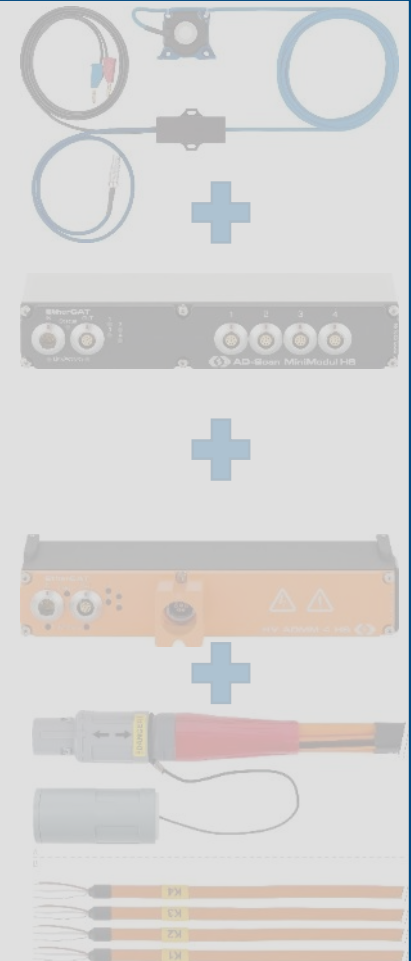
HV BM 1.2
1 pce => 1 x I, 1 x U

LEM Sensor Package
1 .. 4 pcs => 1 .. 4 x I

AD4 IG1000
1 pce => 1 .. 4 x I

HV AD4 XW 1000
1 pce => 1 .. 4 x U

K913
1 pce => 1 .. 4 x U



LEM Sensor Package vs HV BM measuring shield current

LEM Sensor Package + HV AD4 XW1000

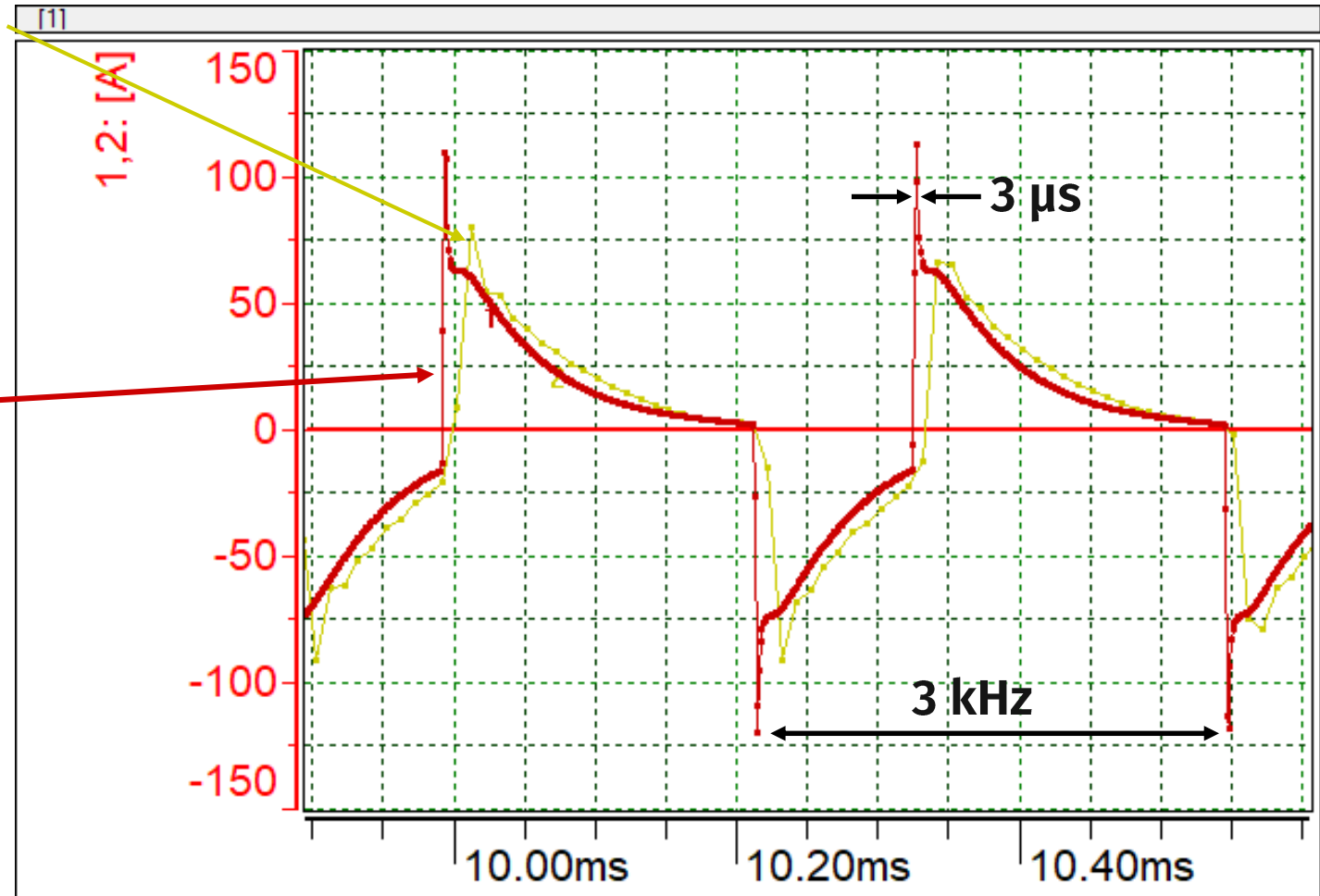
- ▶ Bandwidth for U >> 300 kHz
- ▶ Bandwidth for I ~ 100 kHz
- ▶ Bandwidth of I too small to resolve spikes
- ▶ Delayed current signal

HV BM

- ▶ Bandwidth for I and U > 200 kHz

Measured current maxima on shield:

- ▶ $I_{\min}$: LEM = -91 A | HV BM -120 A



CSM HV Measurement Modules - Active Breakout Modules for small spaces

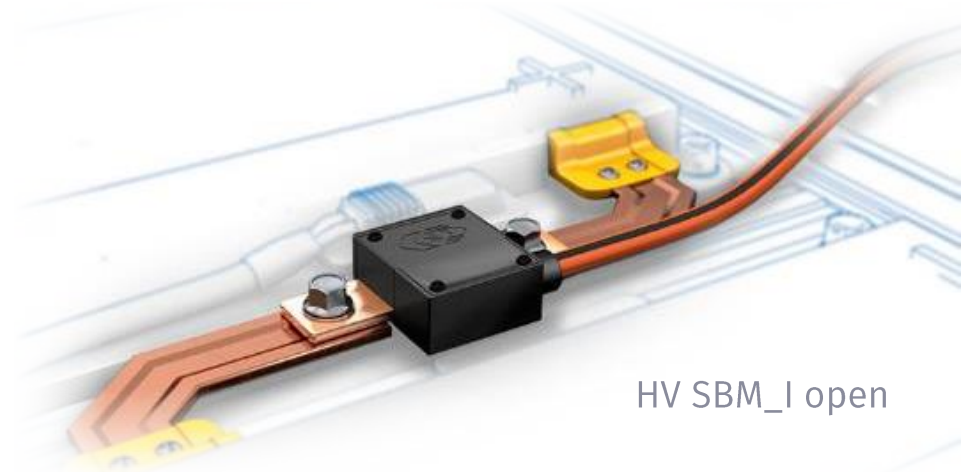
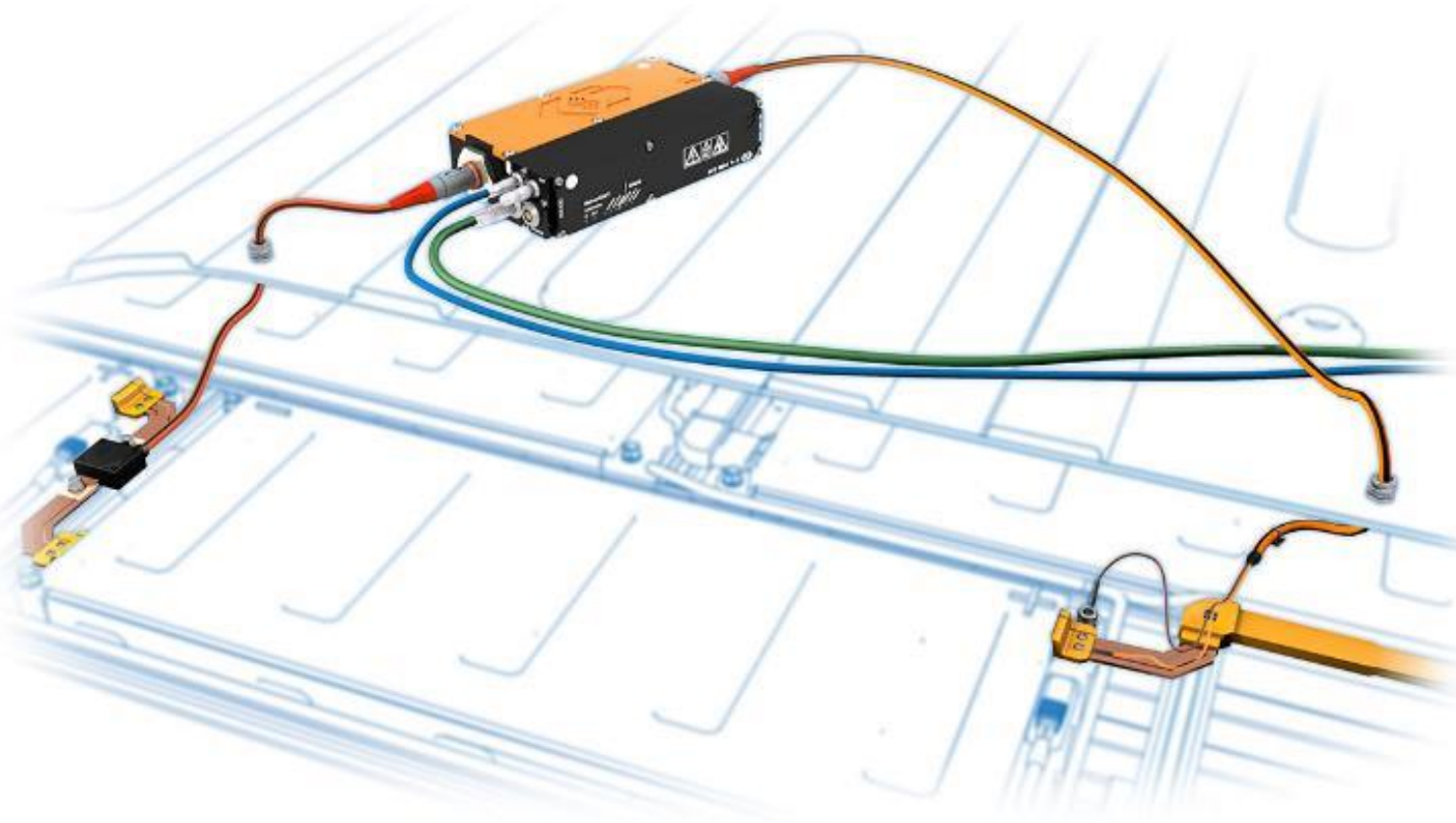
HV Breakout Modules (HV SAM/HV SBM) for in vehicle testing

Split Acquisition Modules:

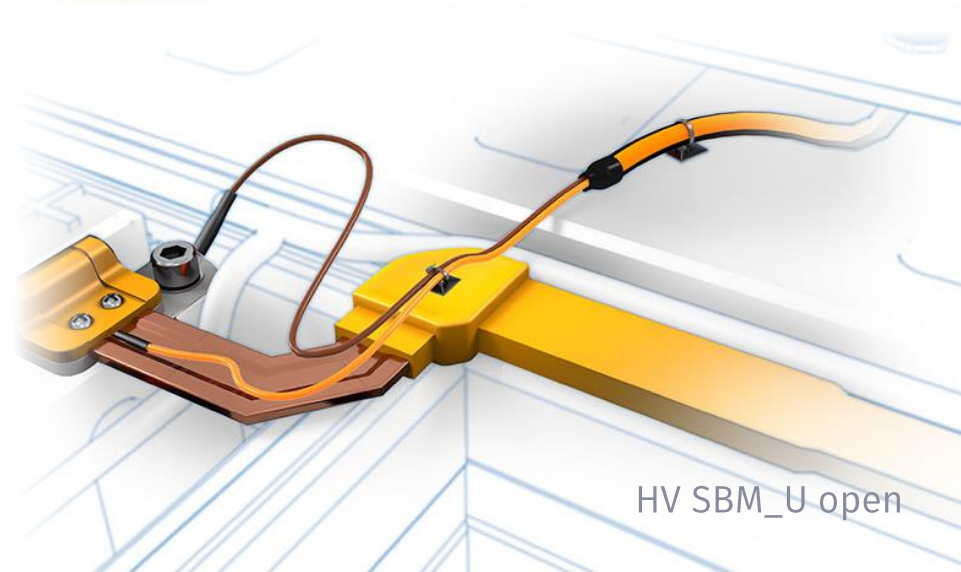
- ▶ HV SAM HV Split Acquisition Module
for one or three phases
- ▶ HV SBM_I HV Split Breakout Module
Current pick-up with enclosure
- ▶ HV SBM_I open HV Split Breakout Module
Current pick-up without enclosure
- ▶ HV SBM_U HV Split Breakout Module
Voltage pick-up



CSM HV Measurement Modules - Active Breakout Modules for small spaces

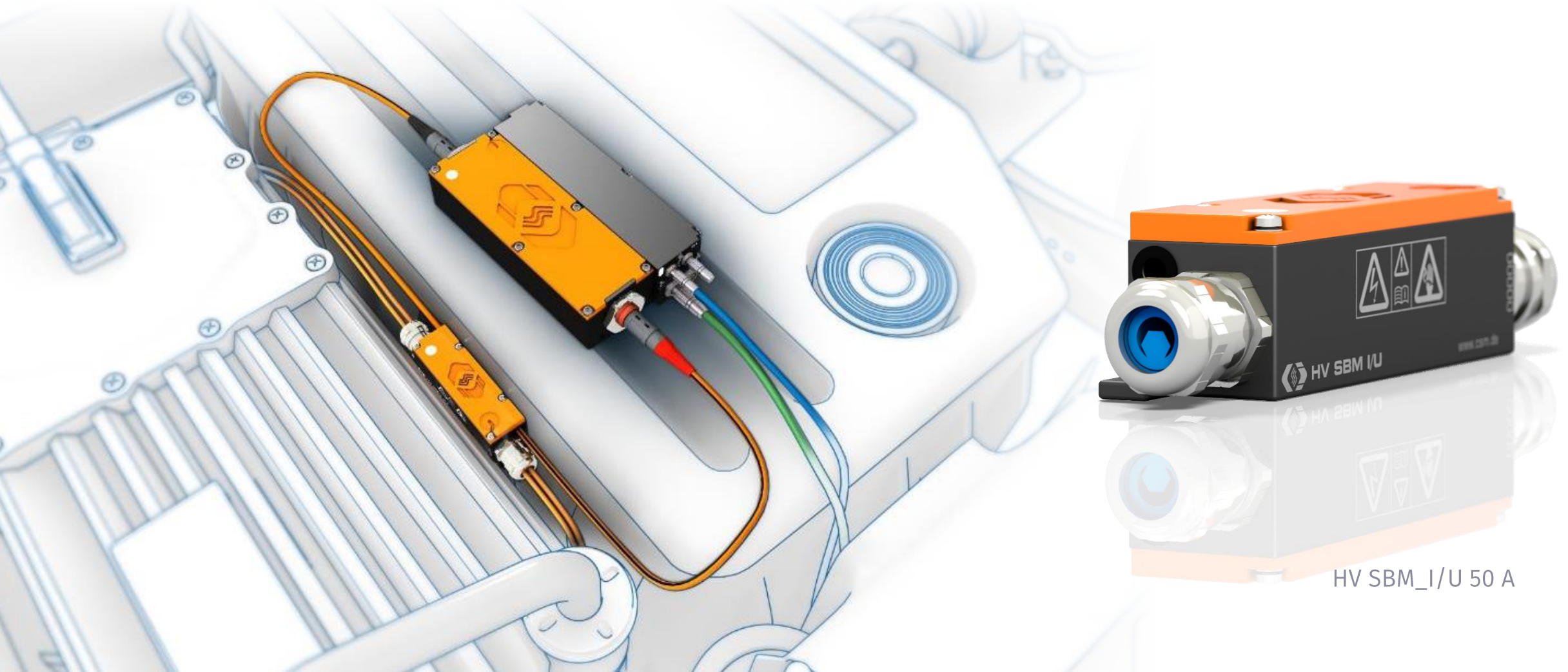


HV SBM_I open

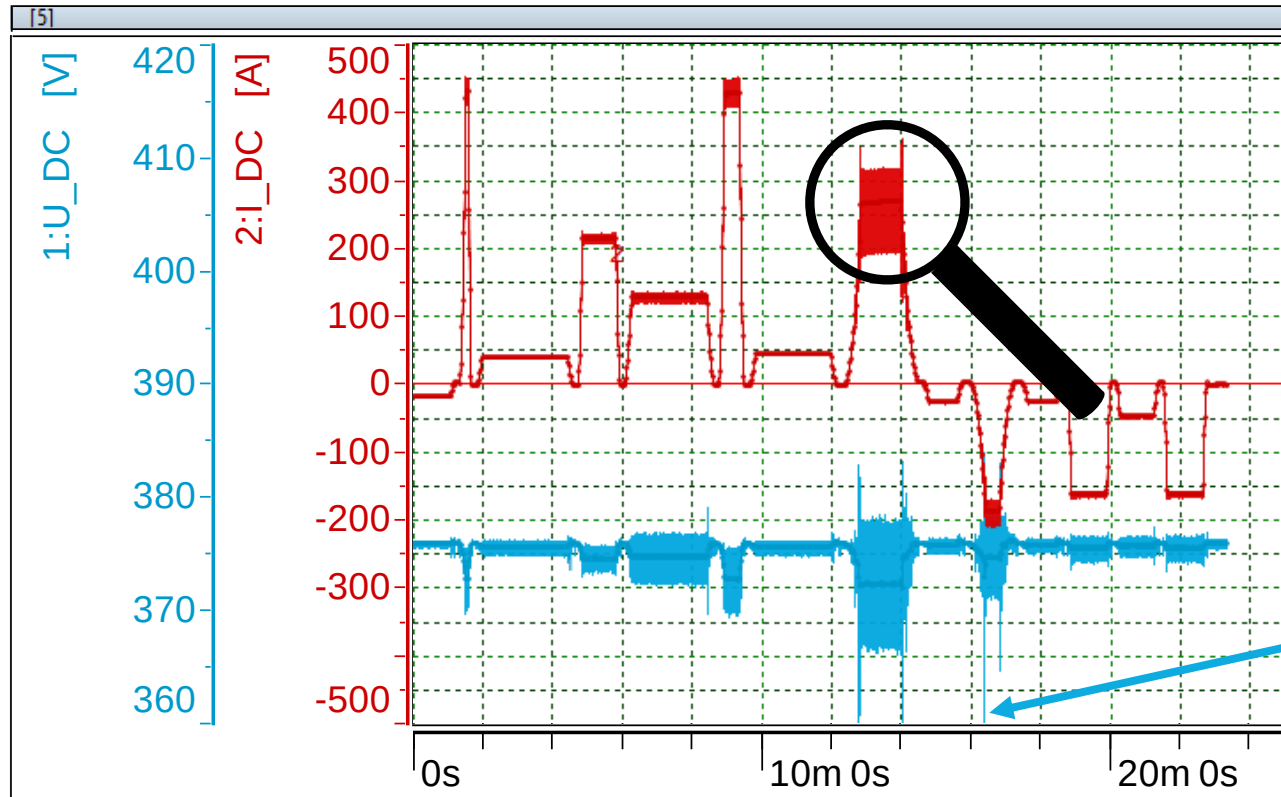


HV SBM_U open

CSM HV Measurement Modules - Active Breakout Modules for small spaces

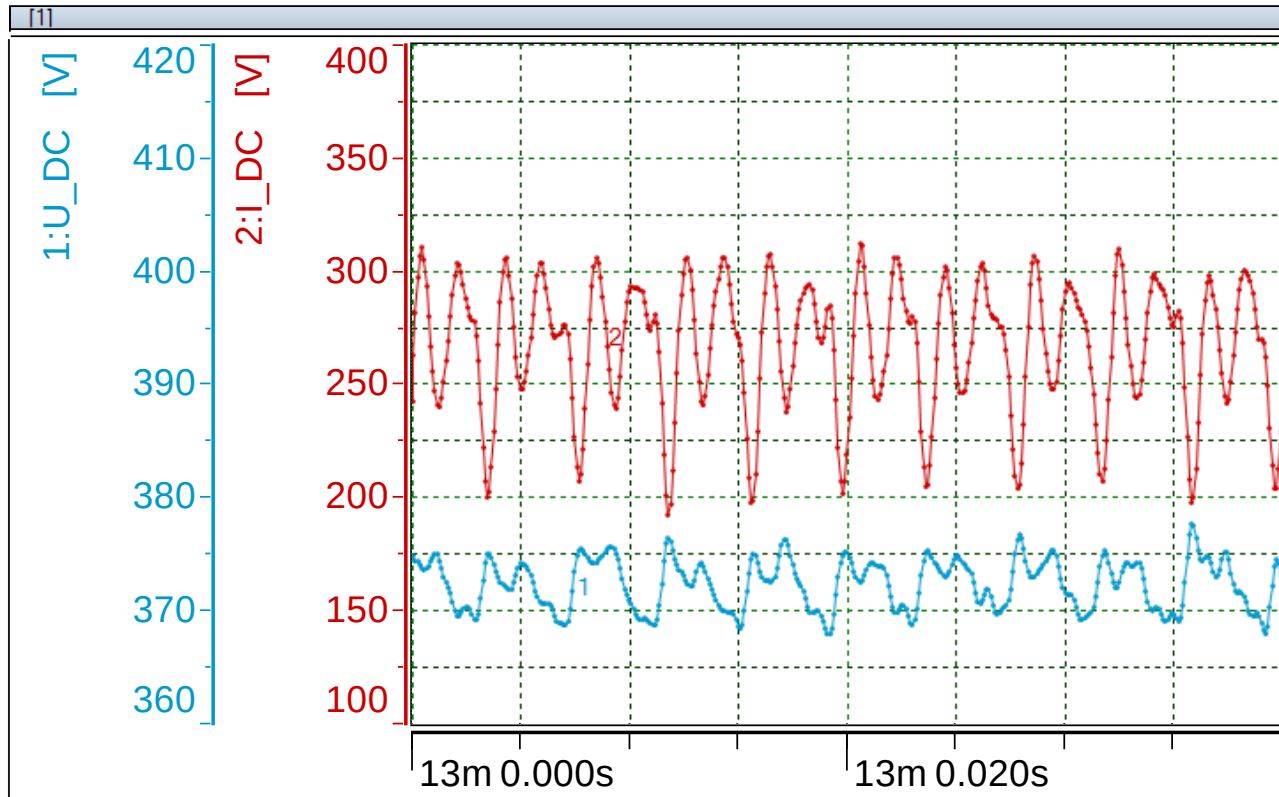


DUT: Electric Axle, HV BM 1.2, Measured Current and Voltage



- ▶ Test cycle
- ▶ Different load situations
- ▶ Driving ($I > 0\text{ A}$)
- ▶ Regenerative braking ($I < 0\text{ A}$)

DUT: Electric Axle, HV BM 1.2, Measured Current and Voltage

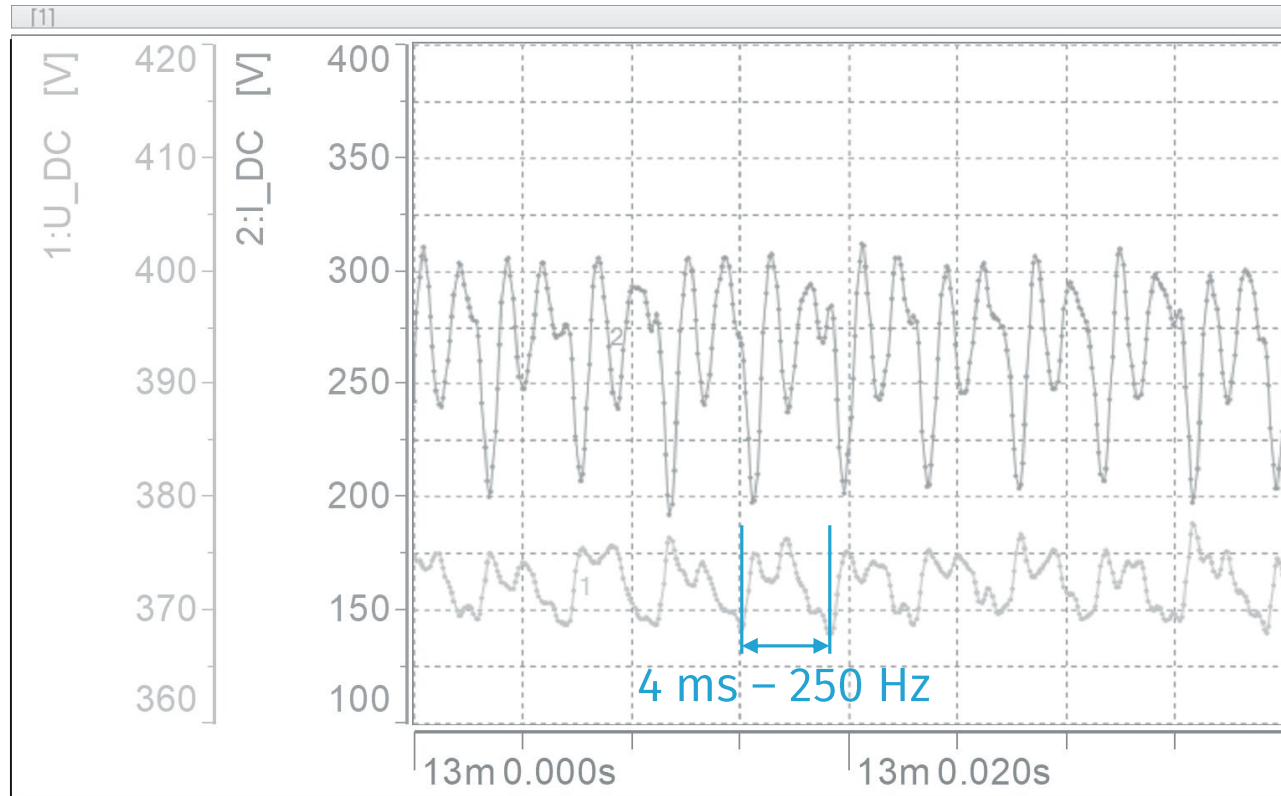


@ $P_{el} \sim 100 \text{ kW}$

- ▶ Large ripple of I
- ▶ Acceptable ripple of U here
 - ISO/DIS 21498-1 and 21498-2

▶ I_{dc}	=	268 A
▶ I_{min}	=	195 A
▶ I_{max}	=	312 A
▶ I_{pp}	=	117 A
▶ U_{dc}	=	372 V
▶ U_{min}	=	368 V
▶ U_{max}	=	377 V
▶ U_{pp}	=	9.5 V

DUT: Electric Axle, HV BM 1.2, Measured Current and Voltage

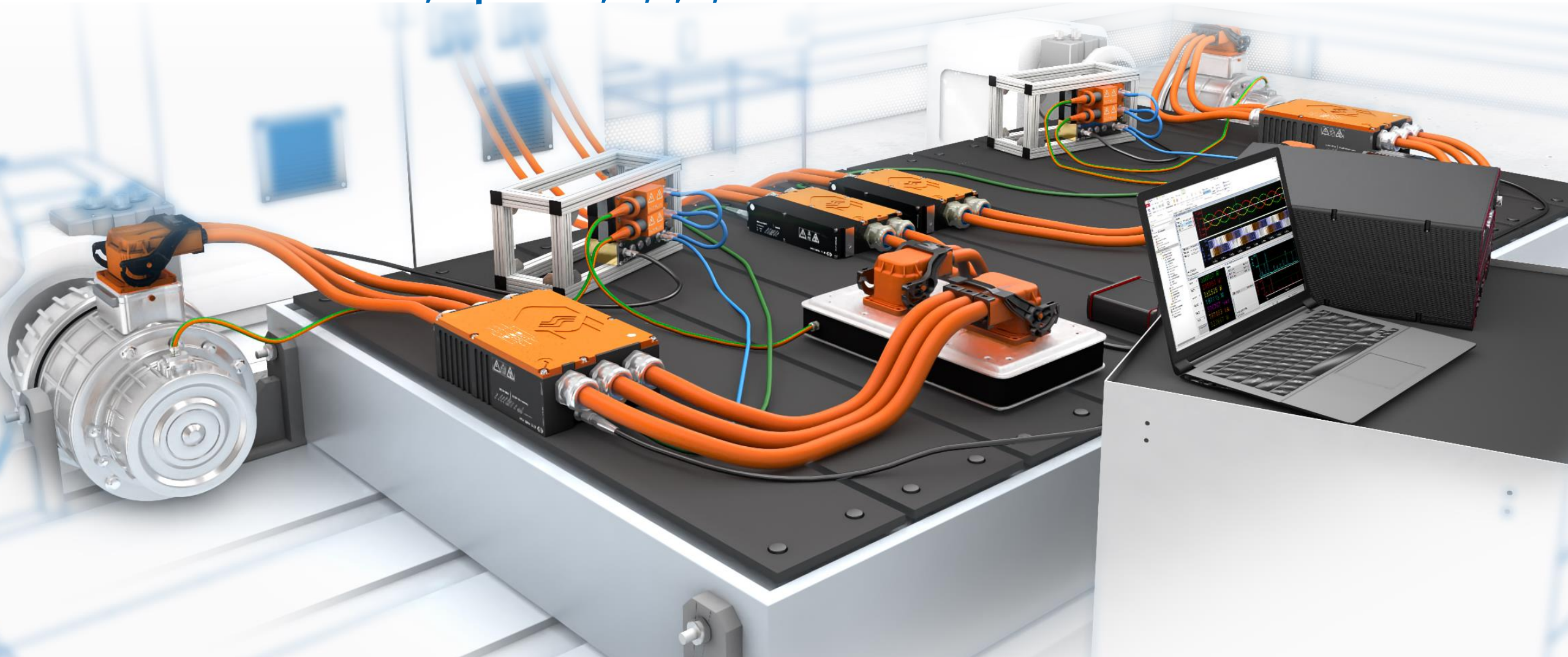


@ $P_{el} \sim 100 \text{ kW}$

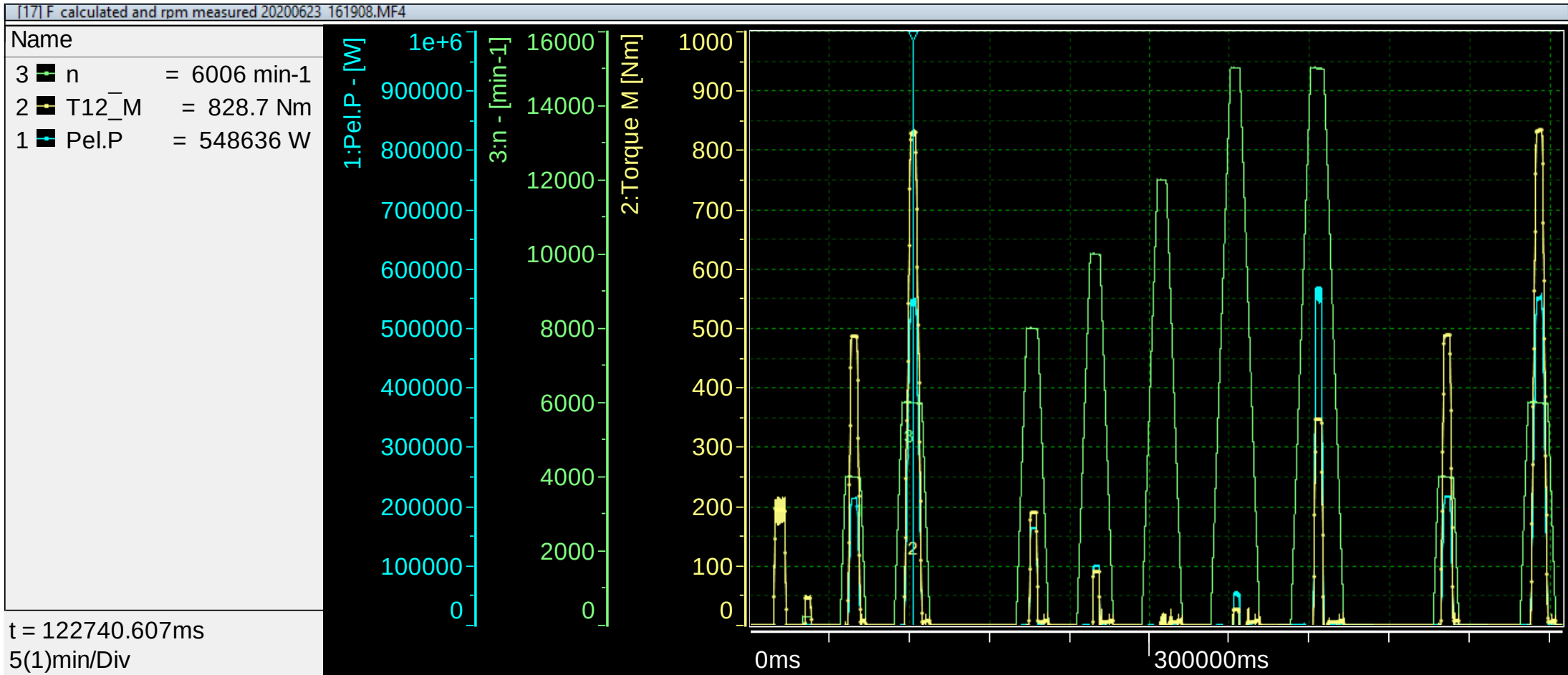
- ▶ Large ripple of I
- ▶ Acceptable ripple of U here
 - ISO/DIS 21498-1 and 21498-2

▶ I_{dc}	=	268 A
▶ I_{min}	=	195 A
▶ I_{max}	=	312 A
▶ I_{pp}	=	117 A
▶ U_{dc}	=	372 V
▶ U_{min}	=	368 V
▶ U_{max}	=	377 V
▶ U_{pp}	=	9.5 V

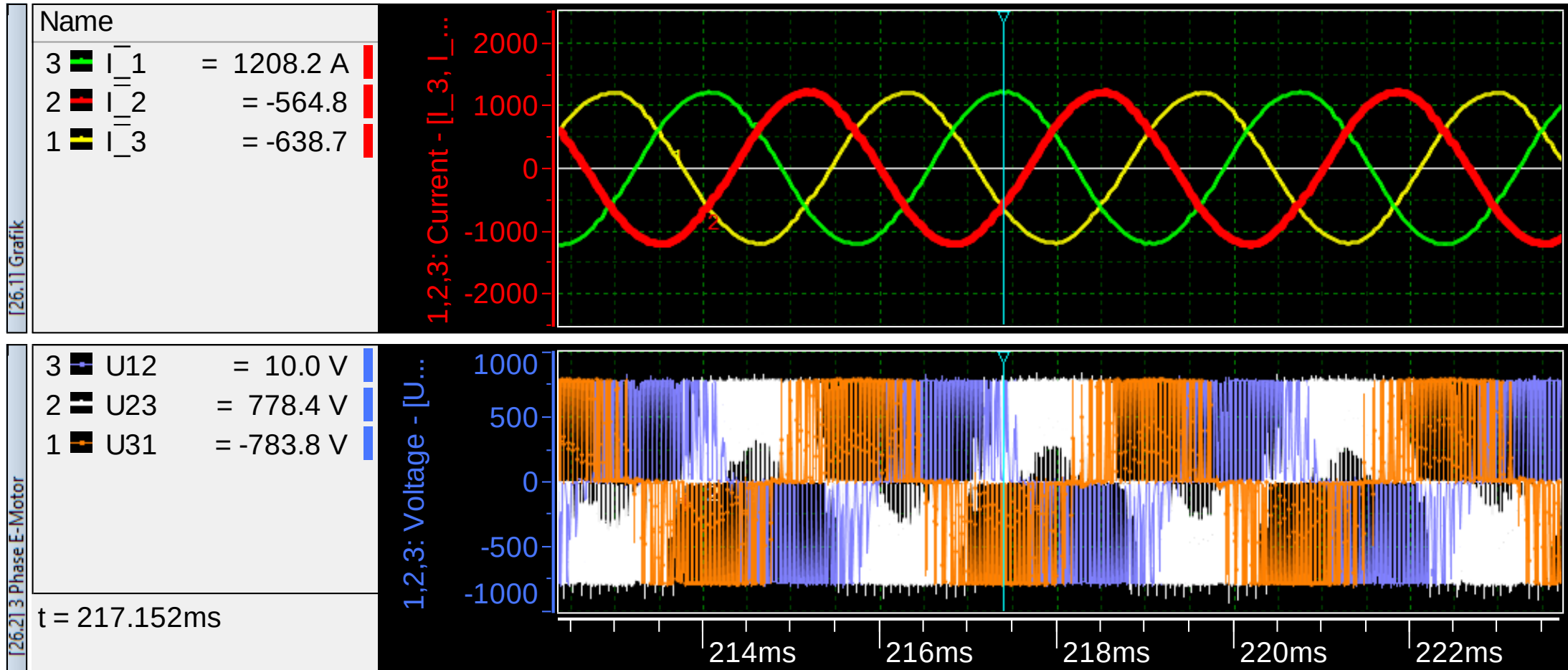
DUT: Electric Motor, 3 phases, U, I, P, ...



DUT: Electric Motor, 3 phases, P_{el} and mechanical data



DUT: Electric Motor, 3 phases, U, I, I_{rms} up to 860 A



After Sales Support – HV Isolation Testing Station

Proper function of HV isolation of modules should be monitored during lifetime

- ▶ Recommend yearly and after dedicated incidents
- ▶ CSM HV Isolation Testing Station:
 - PC based Isolation Test Software to execute Isolation Test automatically
 - Self-Test Adapters
 - All necessary accessories
 - High potential tester (optional)



More detailed Information requested?

Refer to

- ▶ Datasheets of CSM HV Modules and Accessories
- ▶ Technical Information: Operation of CSM HV Modules
- ▶ Our Website: www.csm.de