



Testing of fuel cell drives on test benches and in road testing

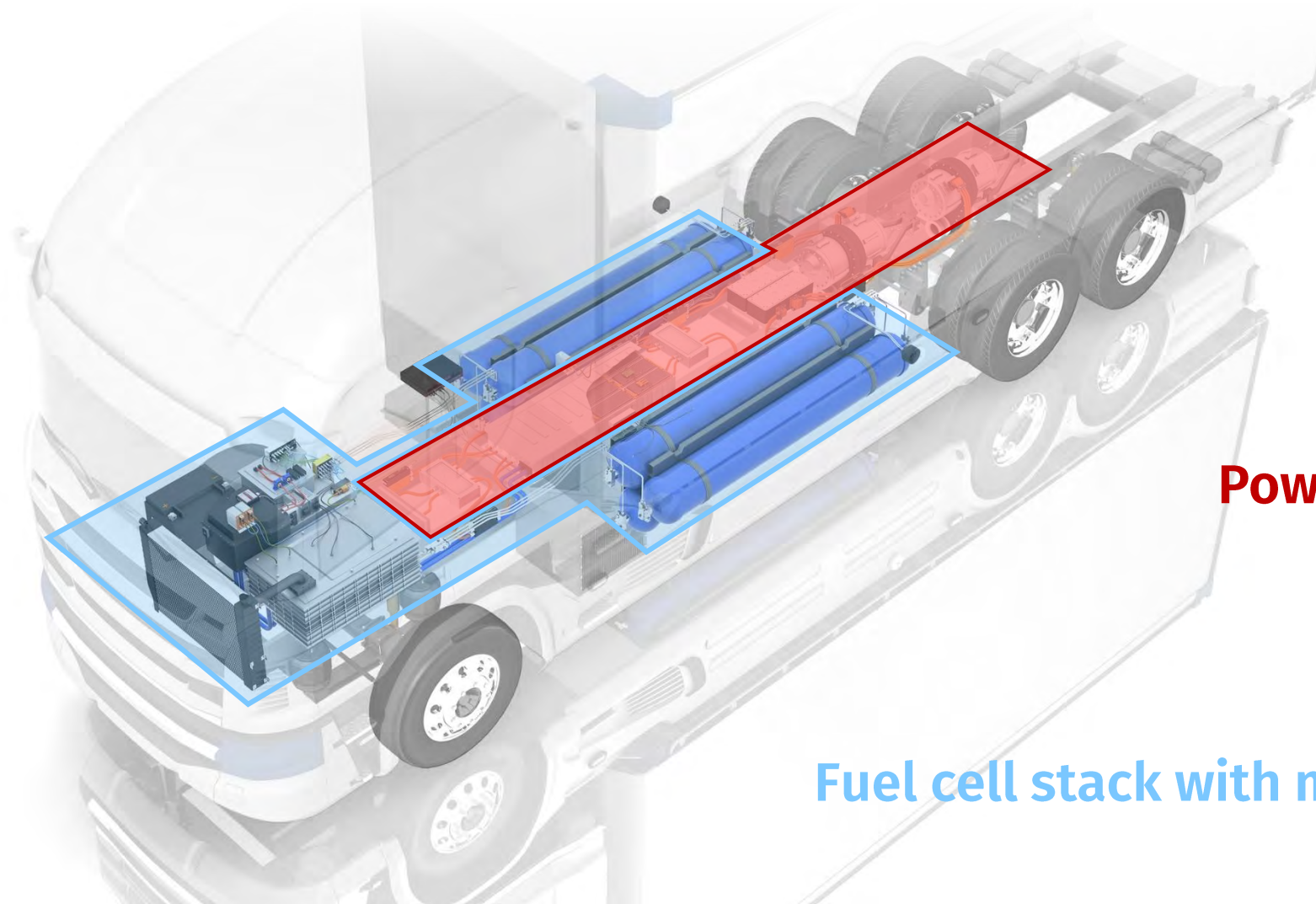
CSM web seminars

CSM **Xplained**
measurement technology



Innovative Measurement and Data Technology

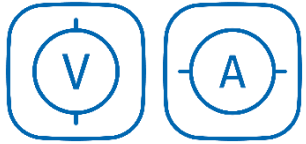
Measurements in fuel cell - electric drives



Powertrain

Fuel cell stack with media supply

Measurements at the fuel cell stack and media supply



Voltage, Current



Flow Rate



Pressure



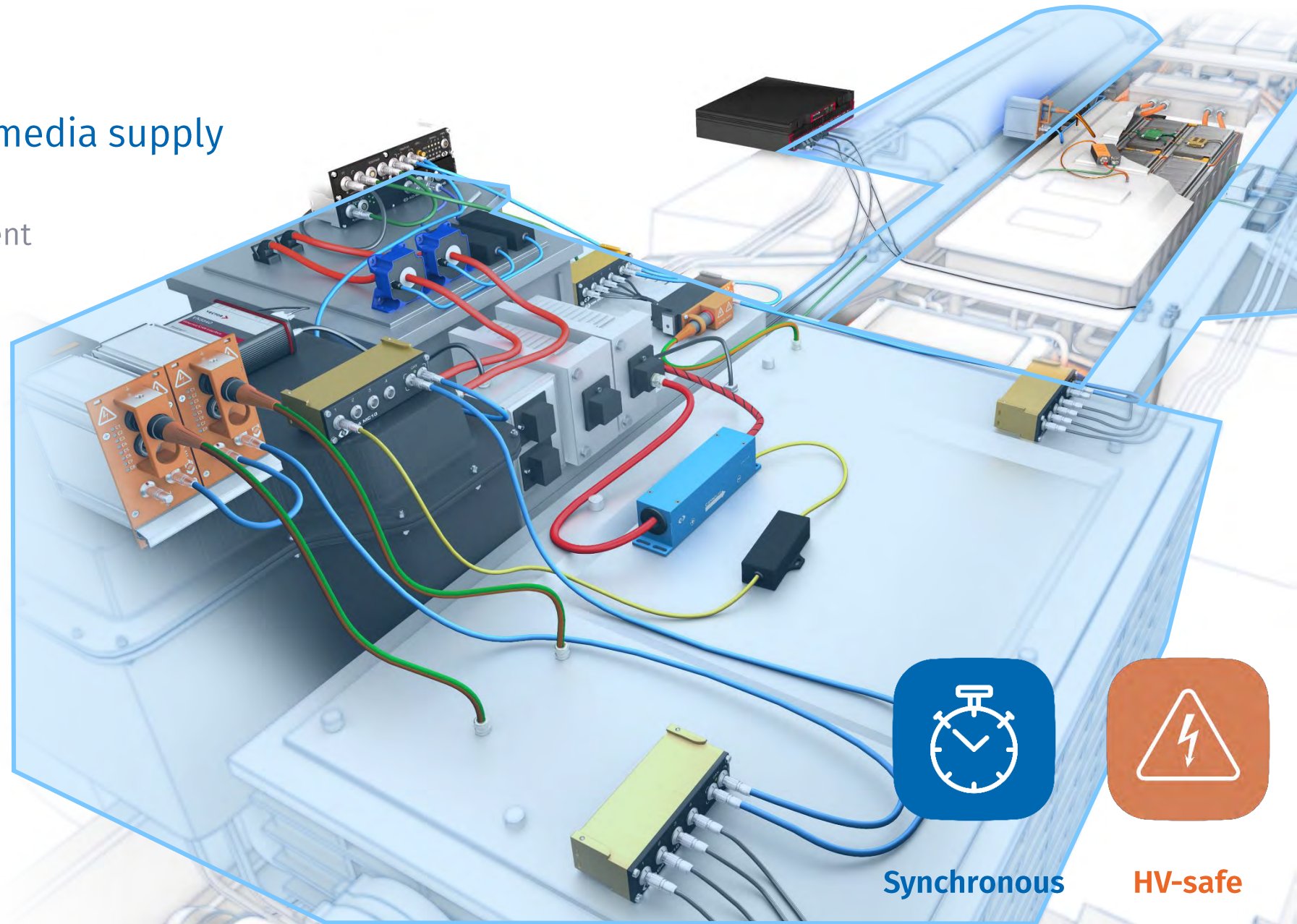
Humidity



Temperature



ECU Data



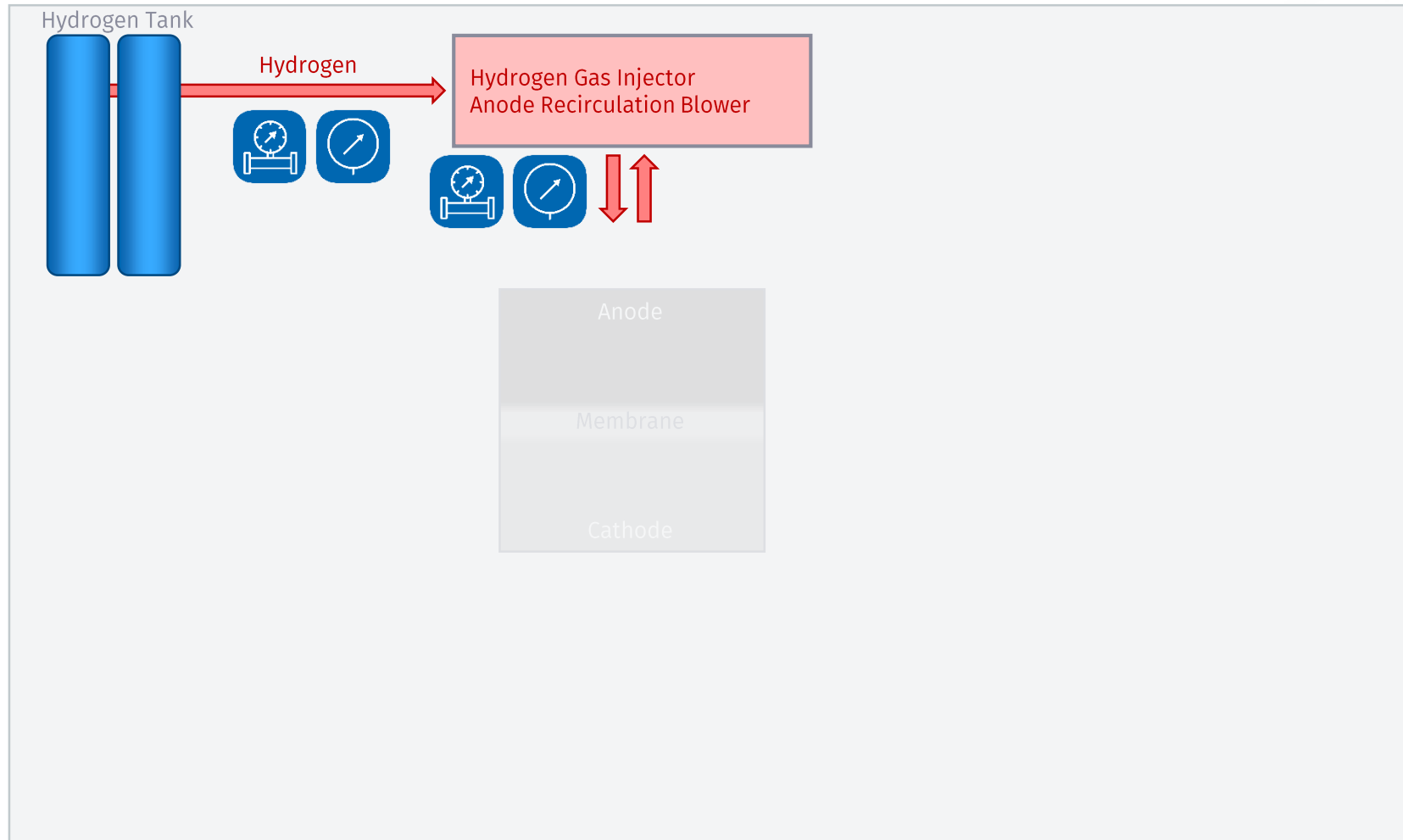
Synchronous



HV-safe

Measurements

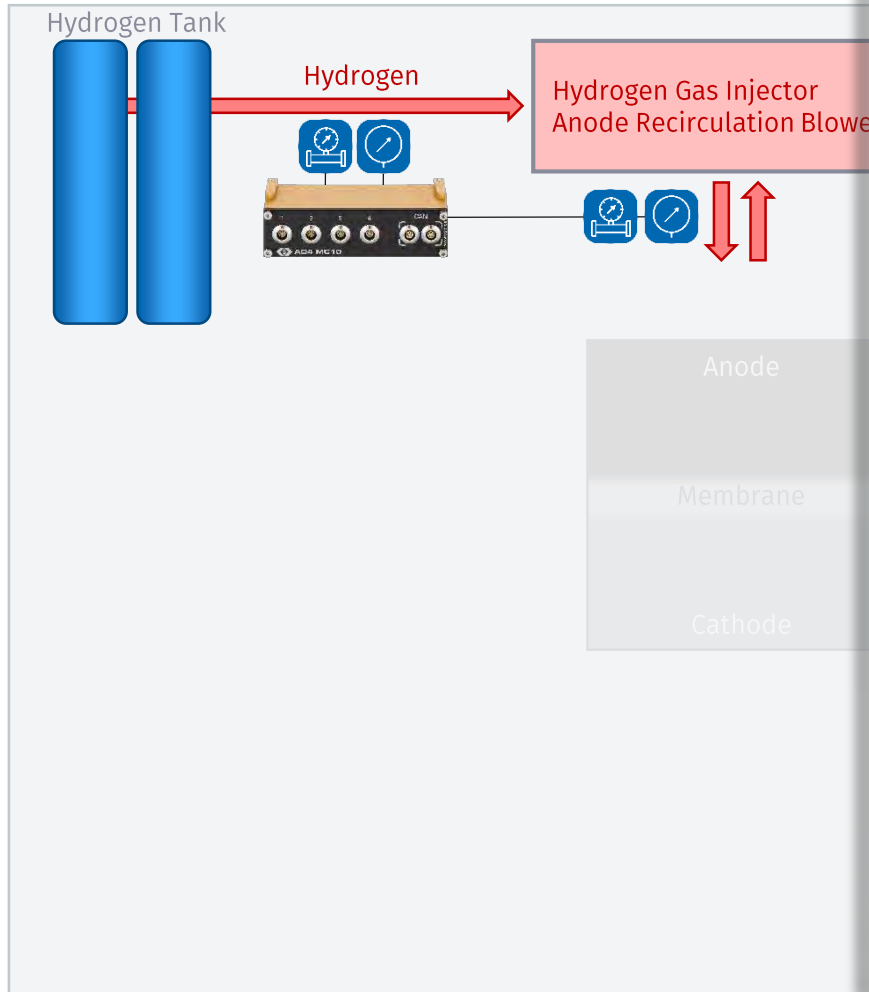
at the fuel cell stack and media supply



- ▶ Testing of flow rates and pressure in anode path
- ▶ Enable precise feed of hydrogen to fuel cell for proper operation
- ▶ Check of control parameters

Measurements

at the fuel cell stack and media supply



CAN measurement modules



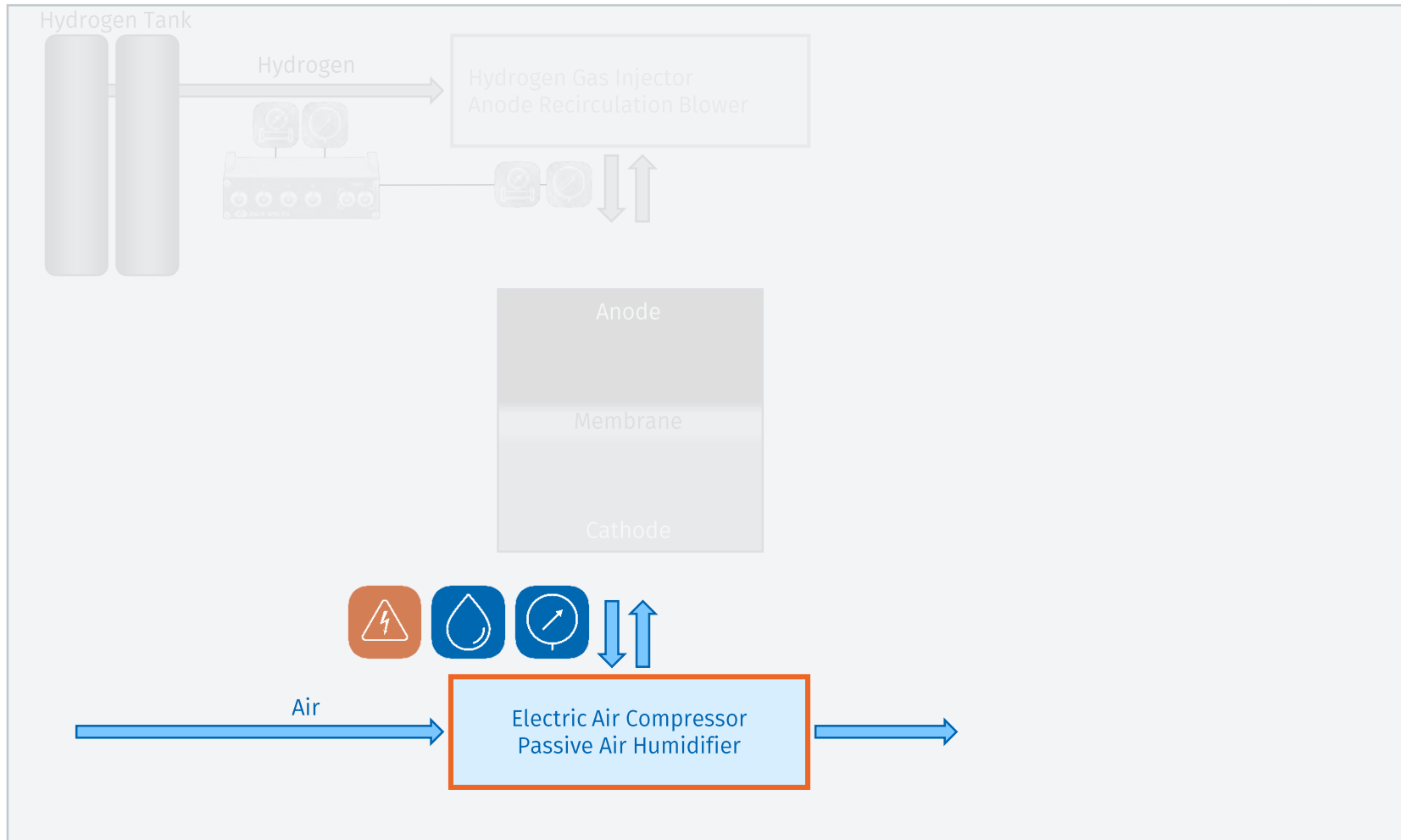
- ▶ Measurement of
 - ▶ **Flow rate**
 - ▶ **Pressure**
 - ▶ Temperature
 - ▶ Strain
 - ▶ Frequency
 - ▶ ...
- ▶ Installation close to measurement point minimizes interference



CAN Modules on
www.csm.de

Measurements

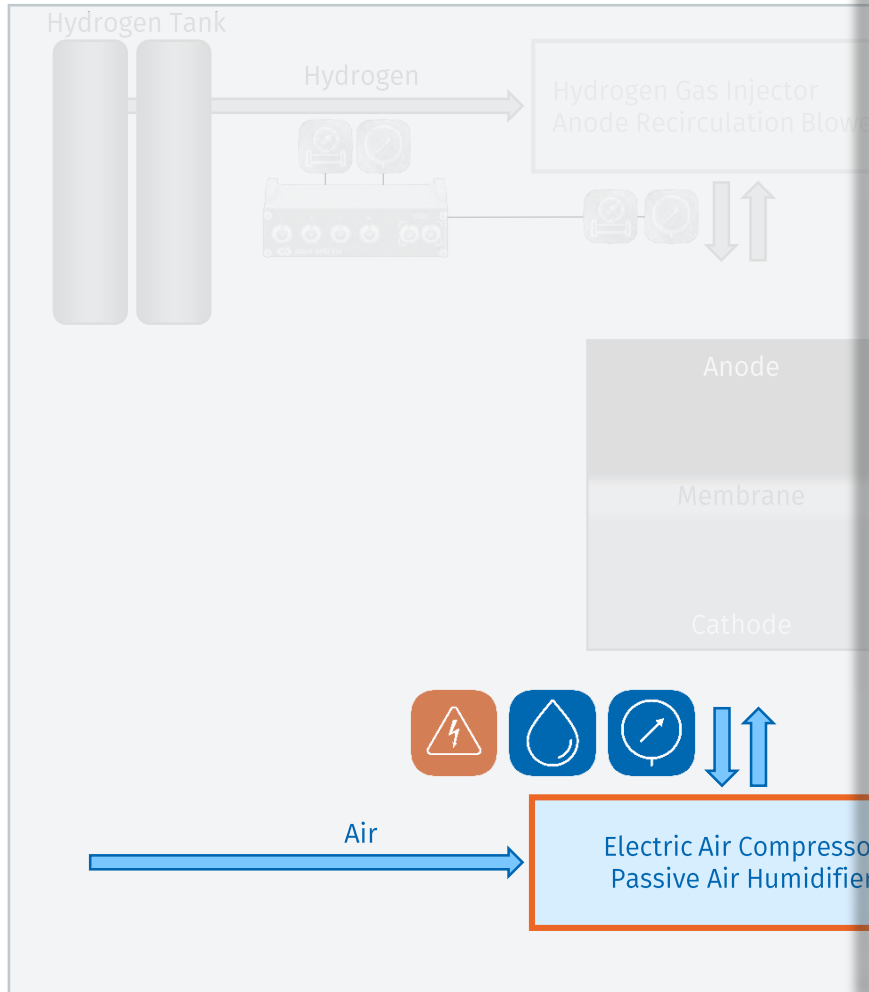
at the fuel cell stack and media supply



- ▶ Testing of flow rates and humidity in cathode path
- ▶ Enable precise feed of air to fuel cell for proper operation
- ▶ Check of control parameters
- ▶ Testing of specific system functions:
 - ▶ Cold start behaviour
 - ▶ warm-up phase duration
 - ▶ Operating points

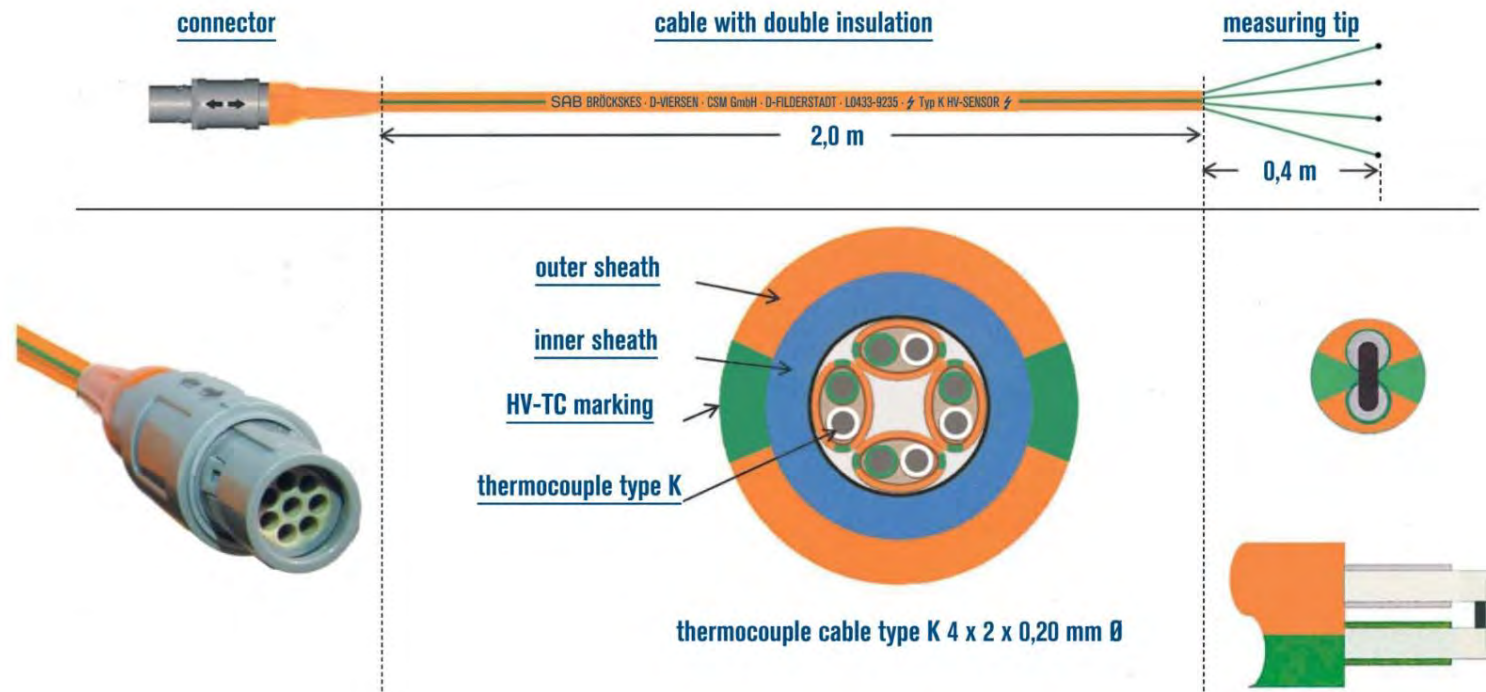
Measurements

at the fuel cell stack and media supply



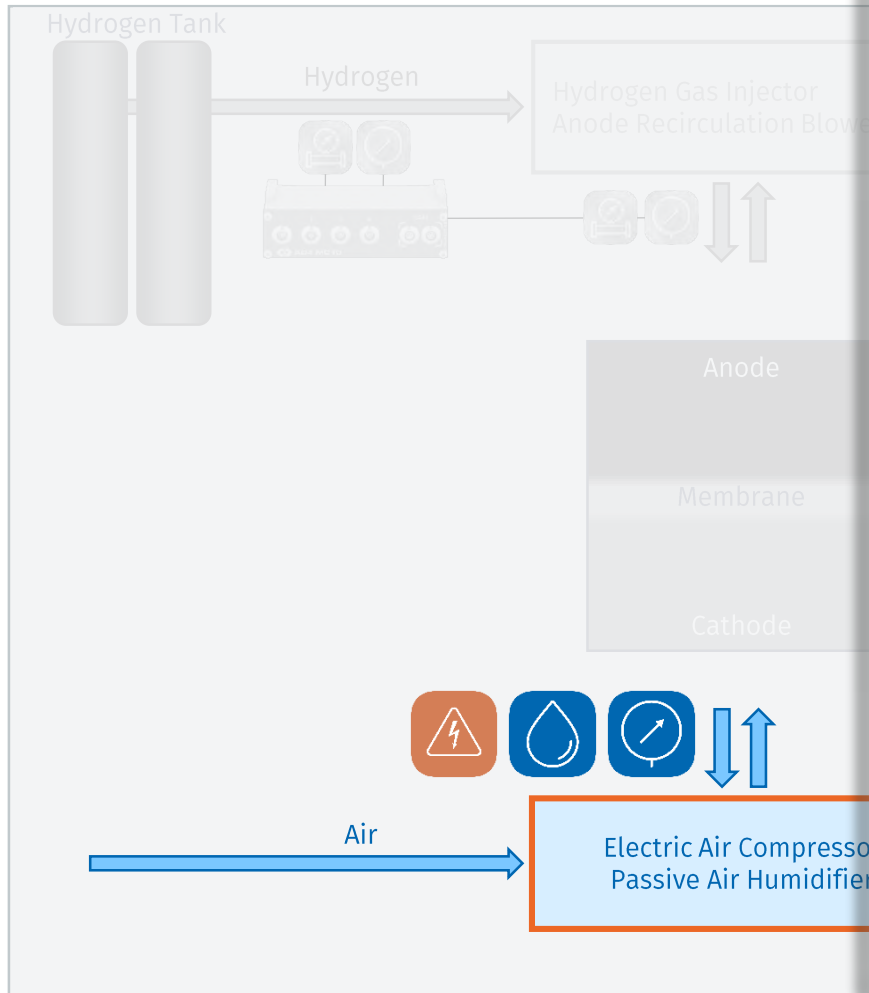
High-voltage safety concept

- ▶ HV-safe sensor cables



Measurements

at the fuel cell stack and media supply



High-voltage safety concept

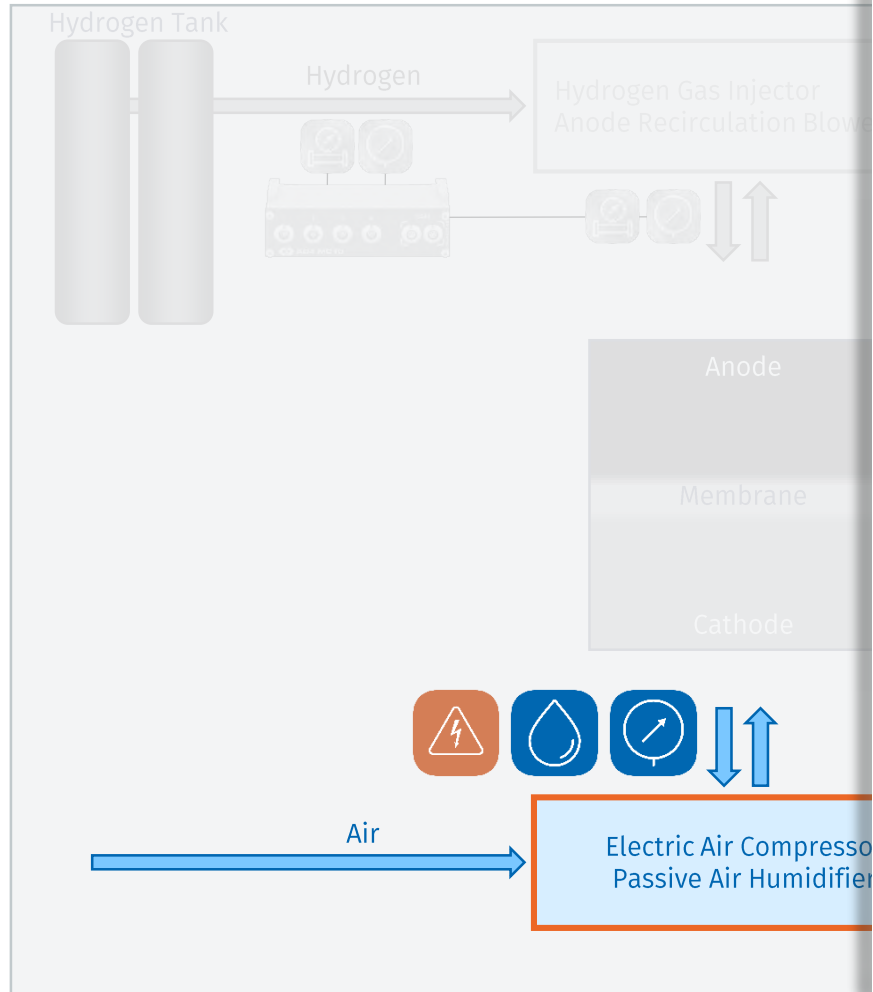


- ▶ HV-safe sensor cables
- ▶ **Protected and insulated connectors**



Measurements

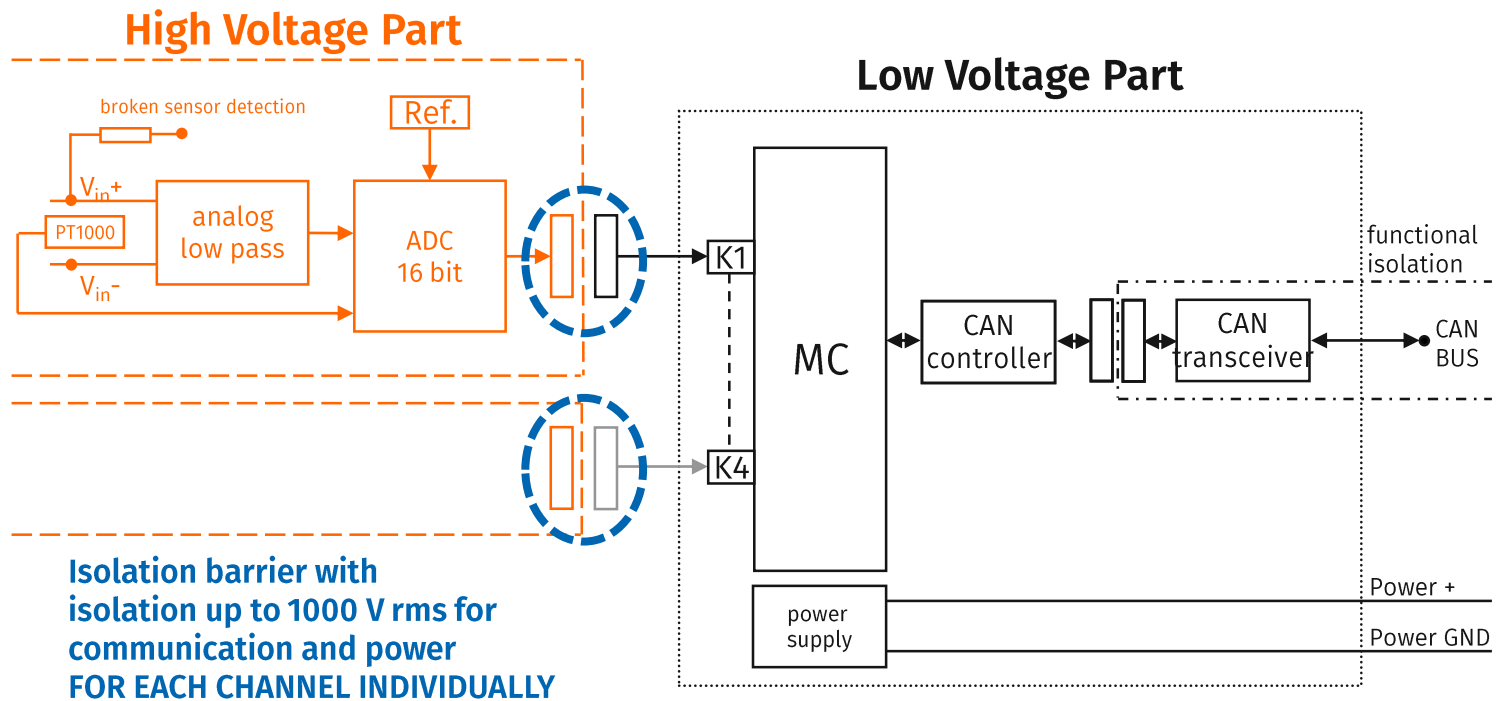
at the fuel cell stack and media supply



High-voltage safety concept

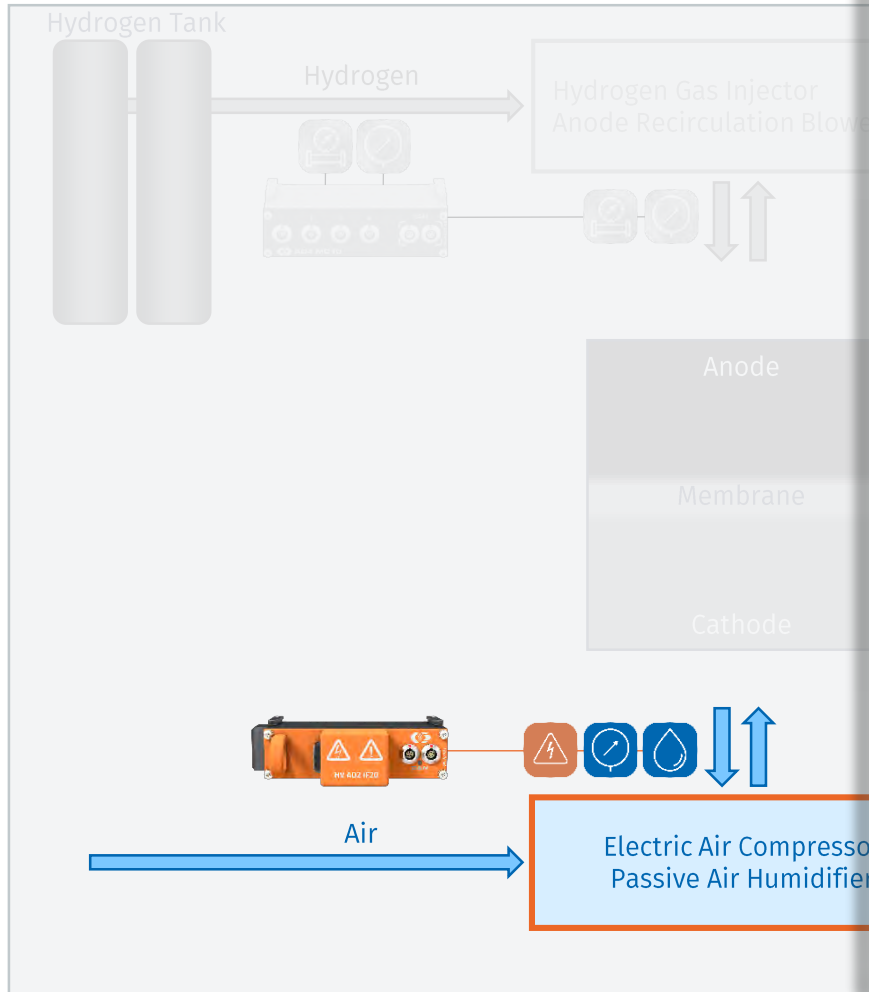


- ▶ HV-safe sensor cables
- ▶ Protected connectors
- ▶ **Isolation barriers in measuring device**



Measurements

at the fuel cell stack and media supply



HV AD CAN Measurement Modules

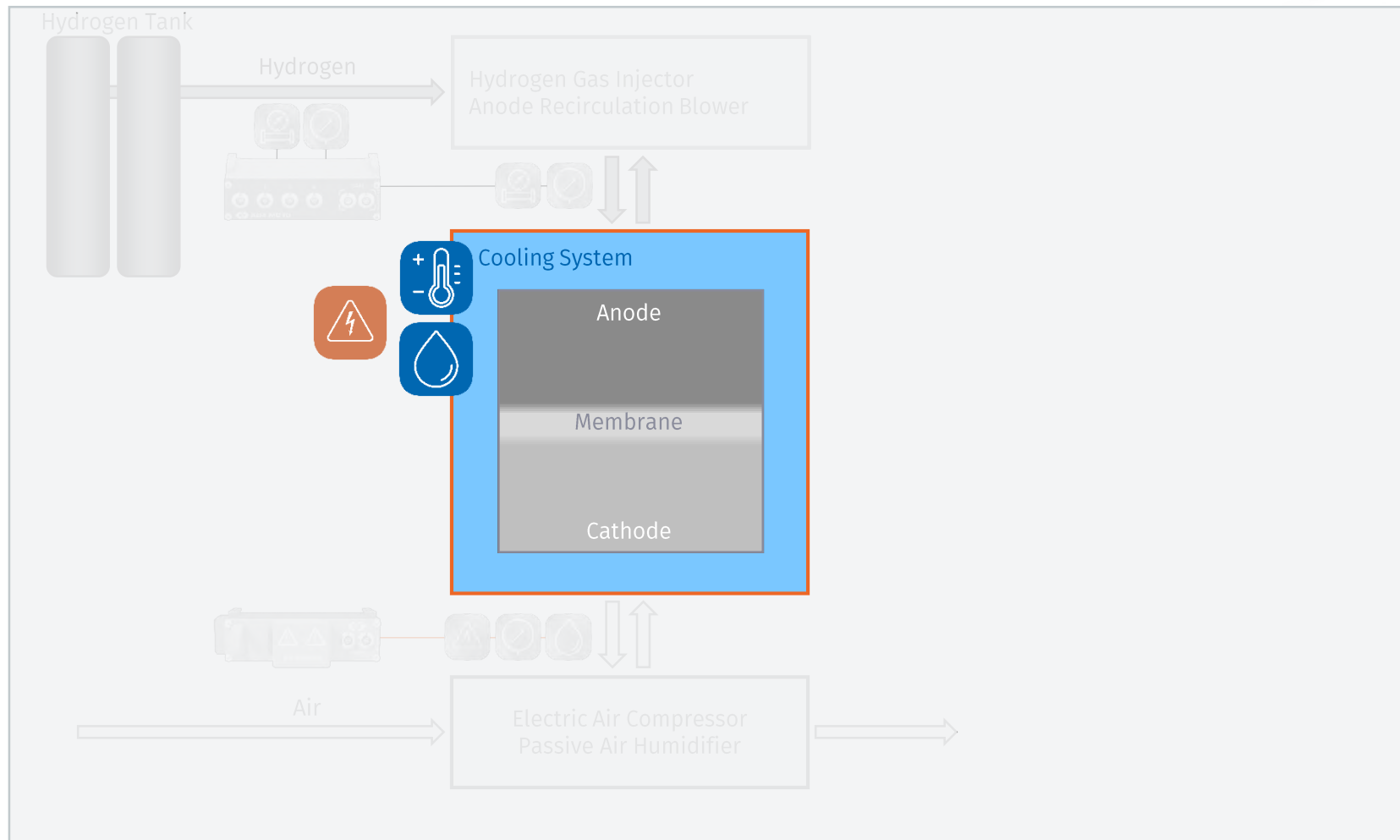


- ▶ Measurement of
 - ▶ **Flow rate**
 - ▶ **Humidity**
 - ▶ **Pressure**
- ▶ **Safe use of standard sensors** in HV environments
- ▶ Housings for use in vehicles (MiniModules) and on test benches (TBM)



Measurements

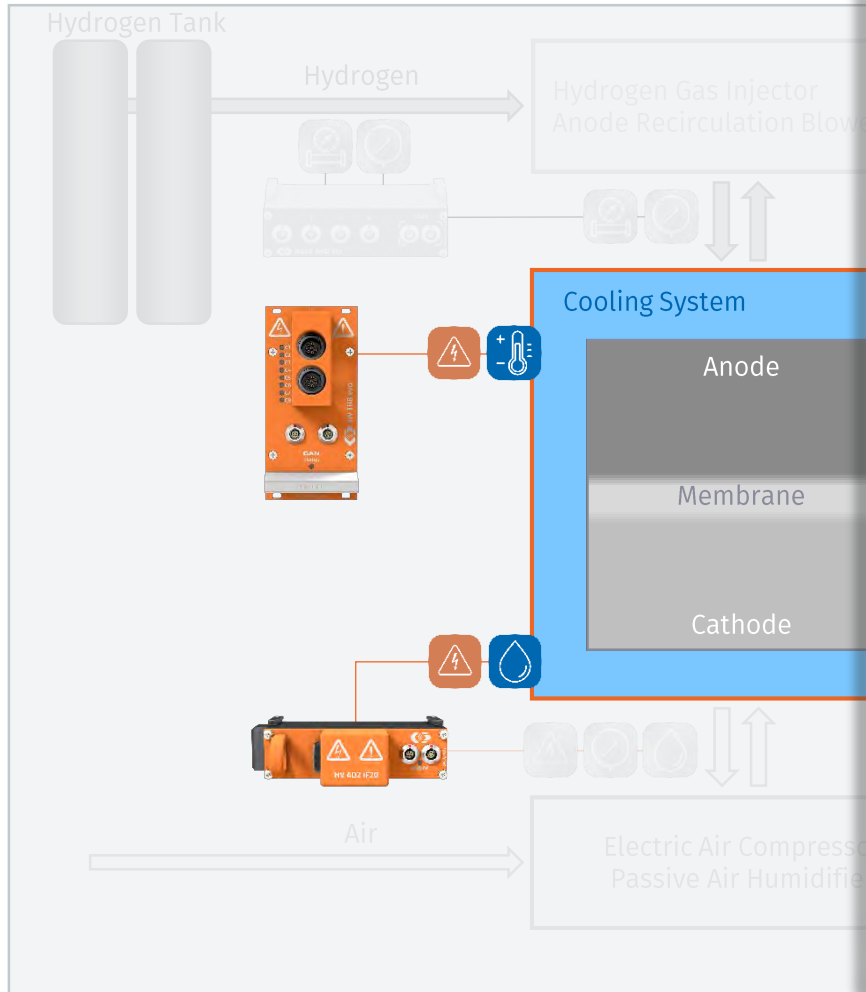
at the fuel cell stack and media supply



- ▶ Measurement of temperatures and humidity
- ▶ Ensure optimal temperature of fuel cell
- ▶ Testing of thermal management and cooling circuits

Measurements

at the fuel cell stack and media supply



HV Thermo measurement modules



- ▶ Temperature measurement
- ▶ **Safe use of standard sensors** in HV environments
 - ▶ Thermocouples
 - ▶ PT100 / PT1000 RTD sensors
 - ▶ IC sensors



HV Thermo
Modules on
www.csm.de

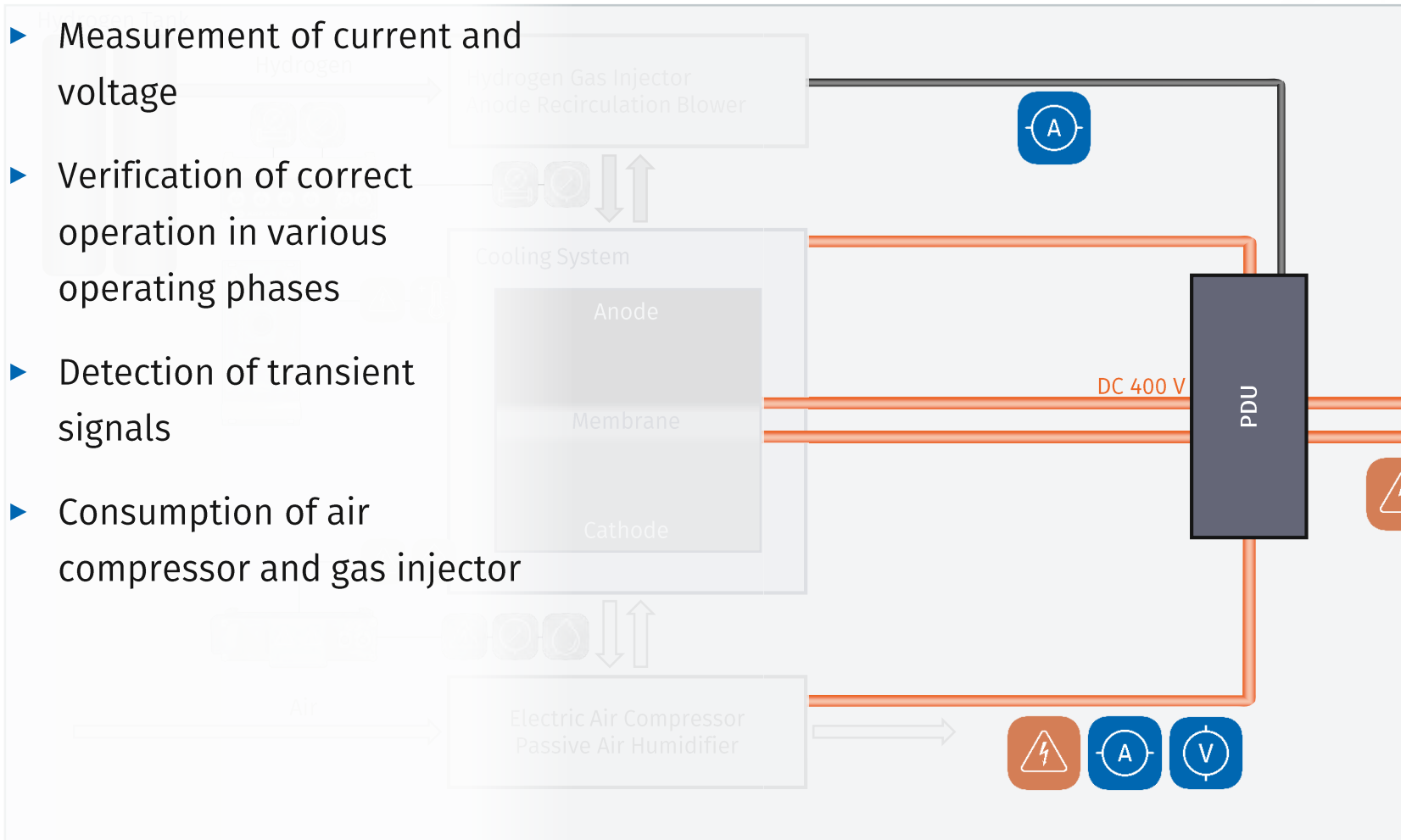
Measurements at the fuel cell stack and media supply

- ▶ Measurement of current and voltage

- ▶ Verification of correct operation in various operating phases

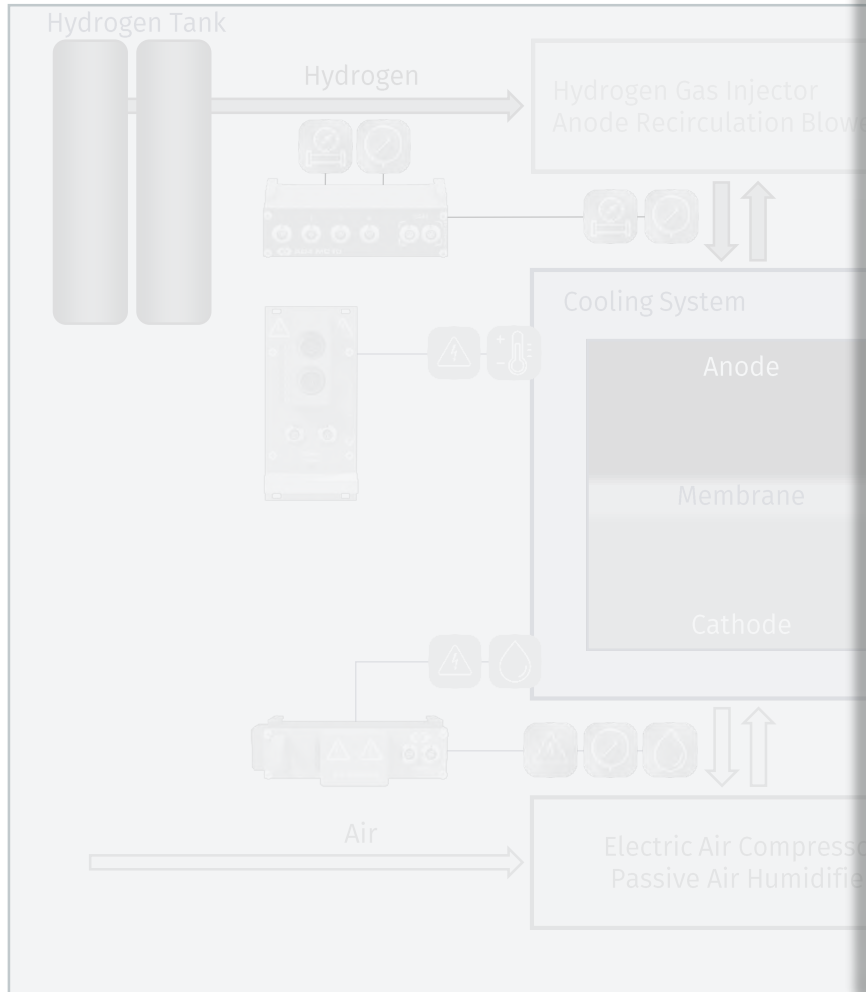
- ▶ Detection of transient signals

- ▶ Consumption of air compressor and gas injector



Measurements

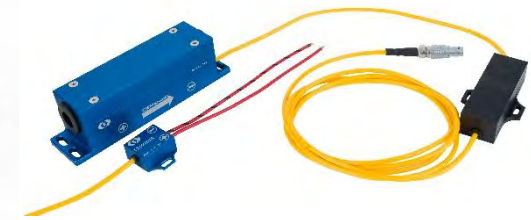
at the fuel cell stack and media supply



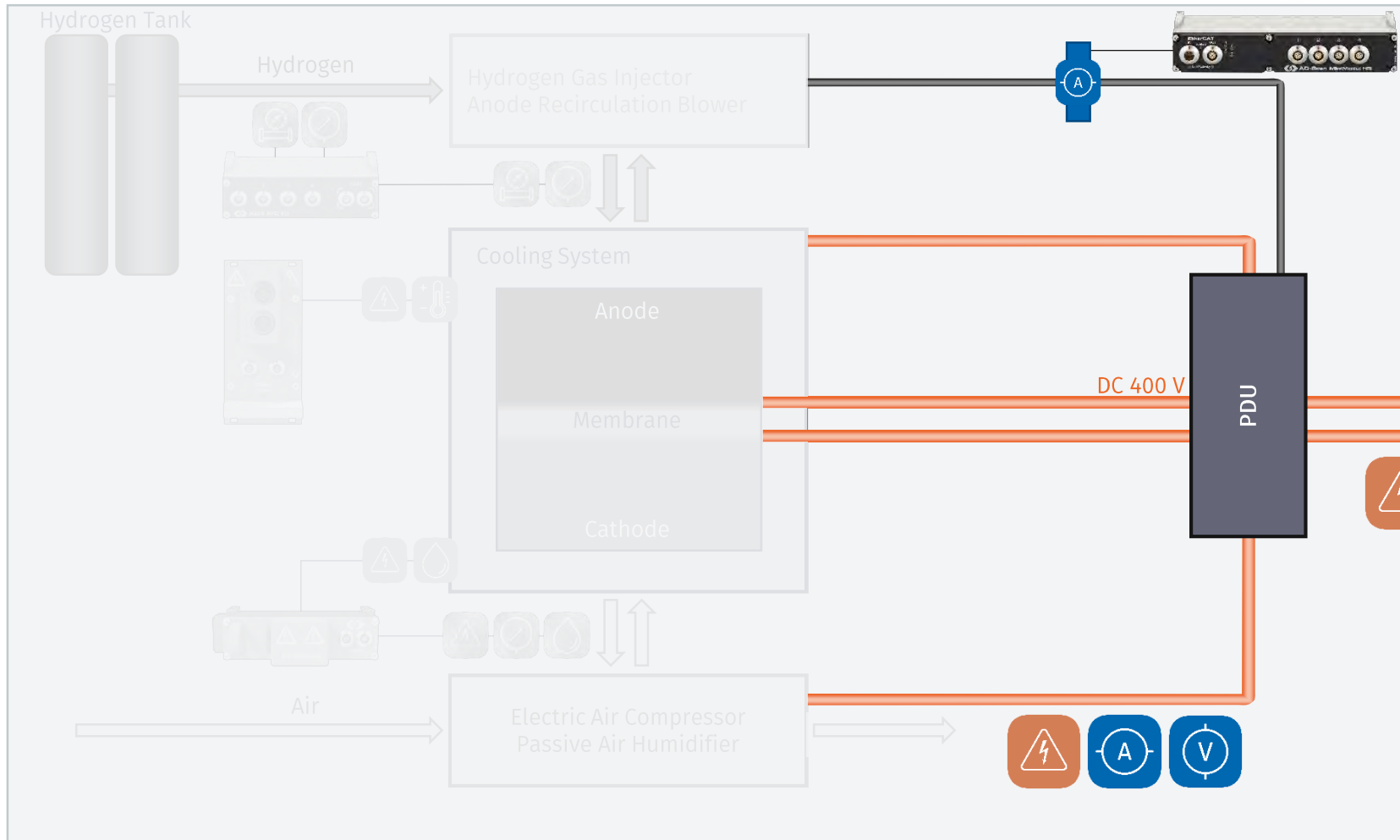
Current measurement in low-voltage environment



- ▶ Plug&Play current measurement
 - ▶ LEM Sensor Packages
 - ▶ CSM Current Clamp
 - ▶ CSMshunt
- ▶ Depending on application and available installation space
- ▶ In connection with AD measurement modules

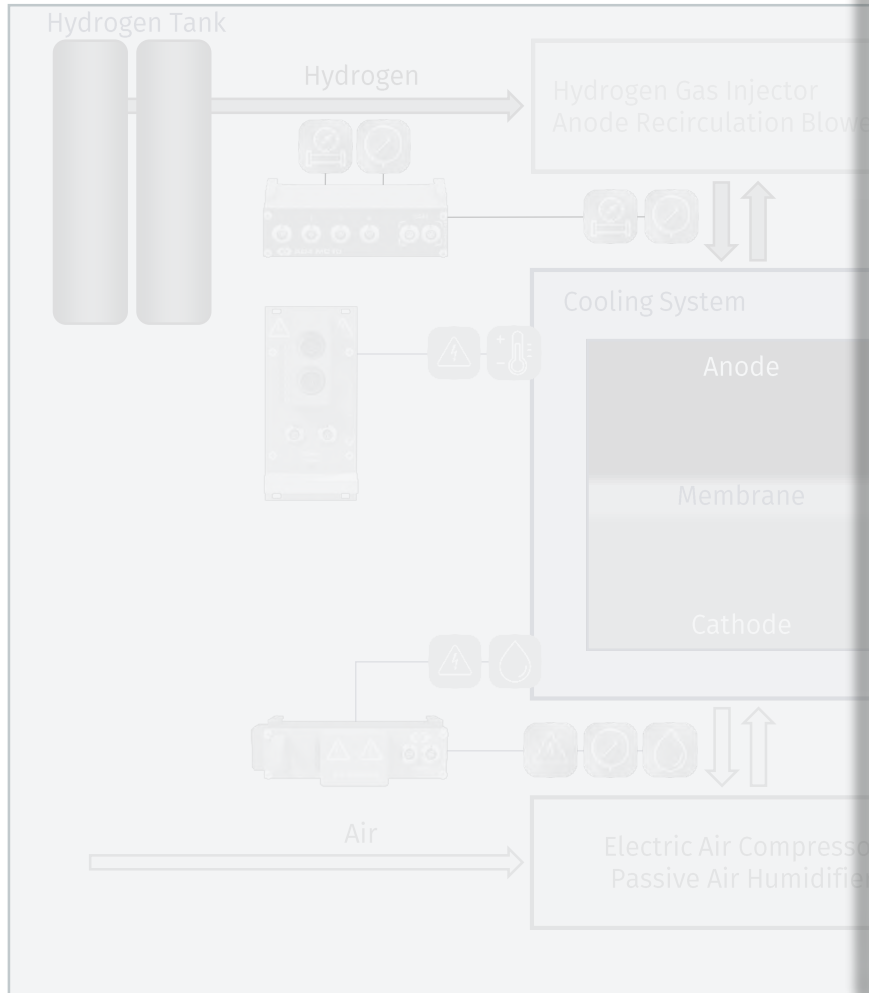


Measurements at the fuel cell stack and media supply



Measurements

at the fuel cell stack and media supply



High-voltage Breakout Modules



Measurement of high currents and voltages

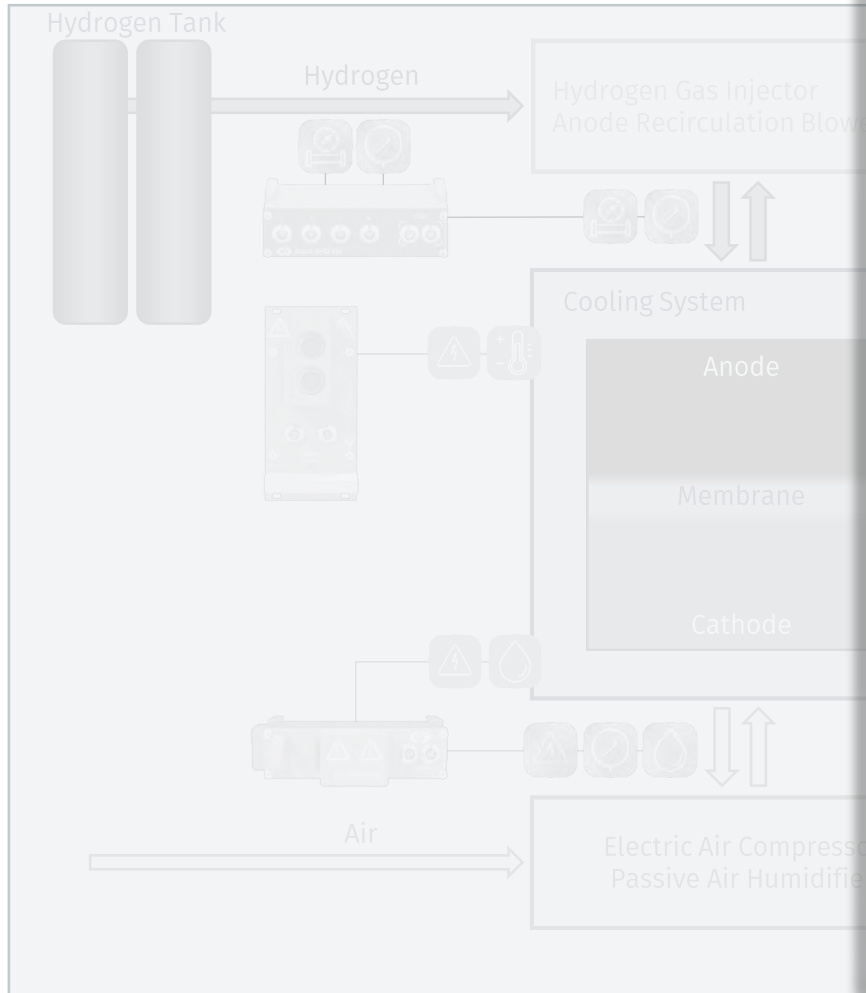
- ▶ Compact all-in-one housing
- ▶ Easy installation directly into HV power cables
 - ▶ Cable glands
 - ▶ PowerLok connector system



HV Breakout
Modules on
www.csm.de

Measurements

at the fuel cell stack and media supply



High-voltage Breakout Modules



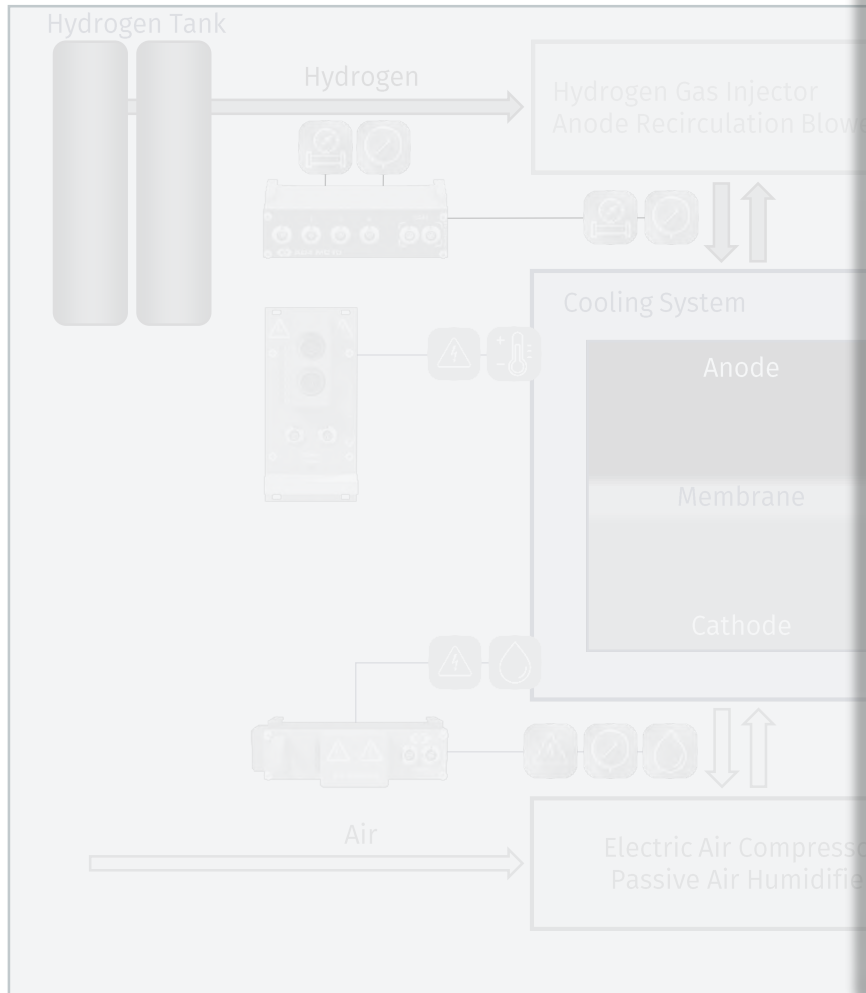
Measurement of high currents and voltages

- ▶ **Current measurement** with shunt modules
 - ▶ Inner conductor current up to $\pm 1,000$ A
 - ▶ Shield currents
- ▶ **Voltages** up to 2,000 V



Measurements

at the fuel cell stack and media supply



High-voltage Breakout Modules

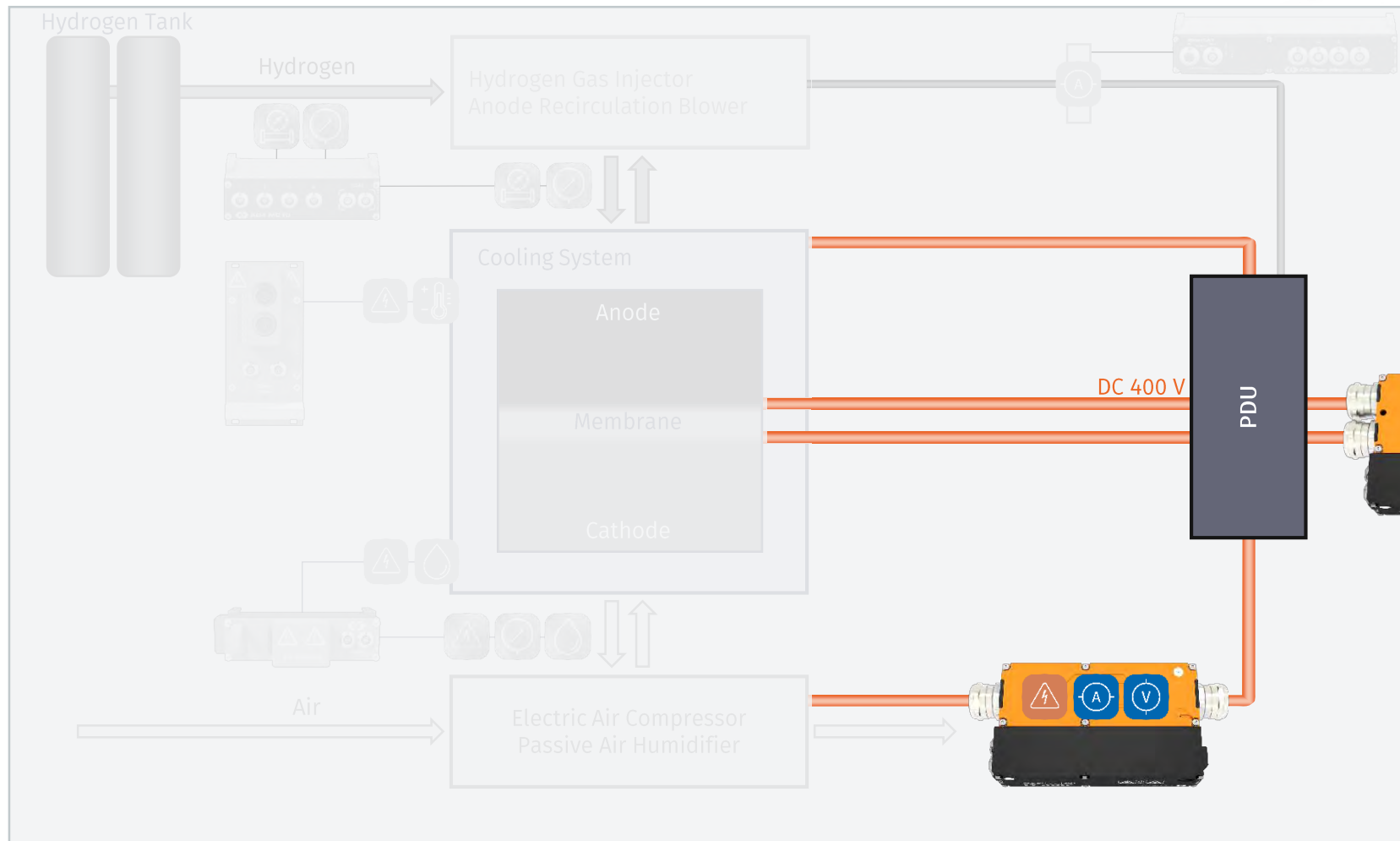


Measurement of high currents and voltages

- ▶ Data rate up to 2 MHz per channel
- ▶ Parallel EtherCAT® and CAN communication
- ▶ Calculation of RMS values, active power, reactive power, apparent power and more inside the module

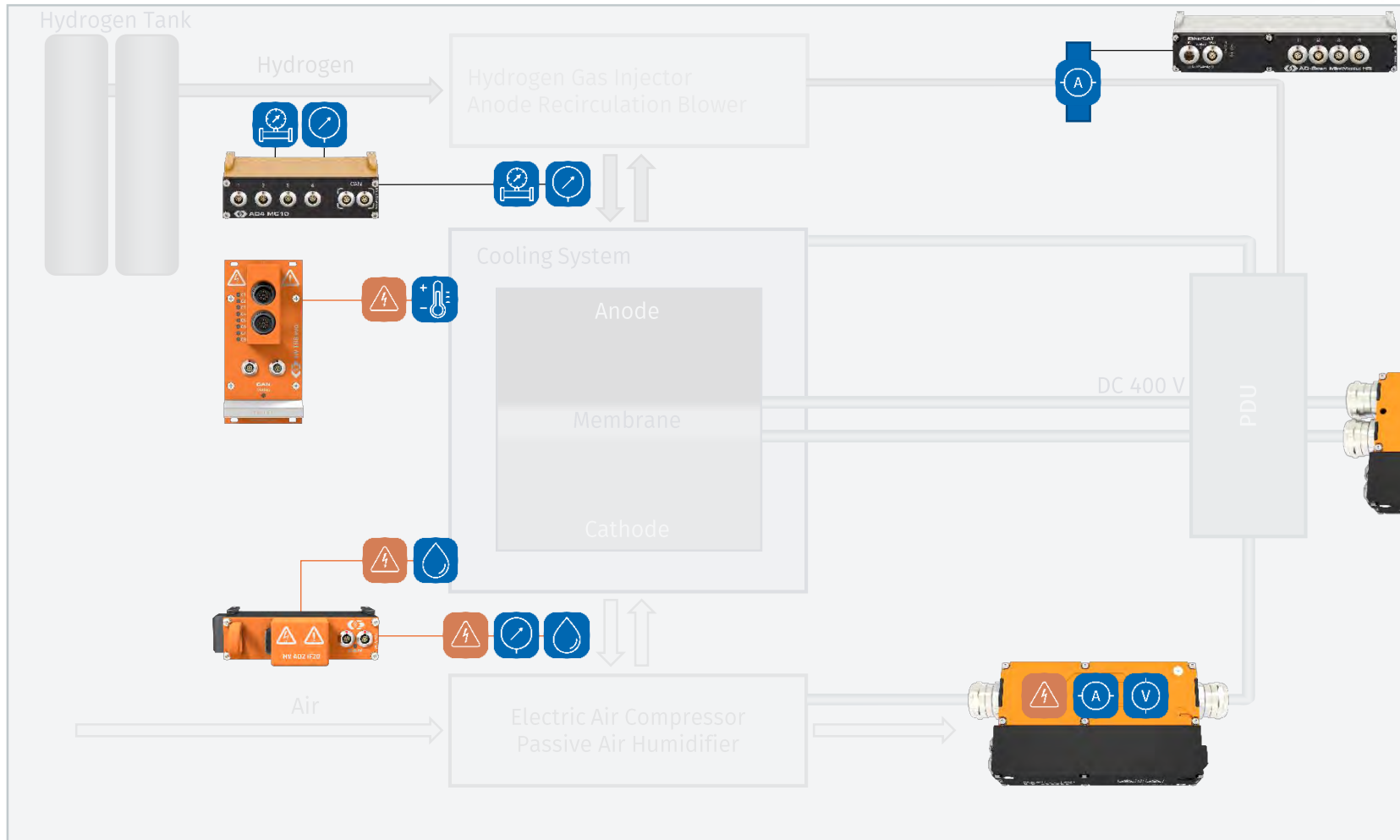


Measurements at the fuel cell stack and media supply



Measurements

Connection of the measurement setup

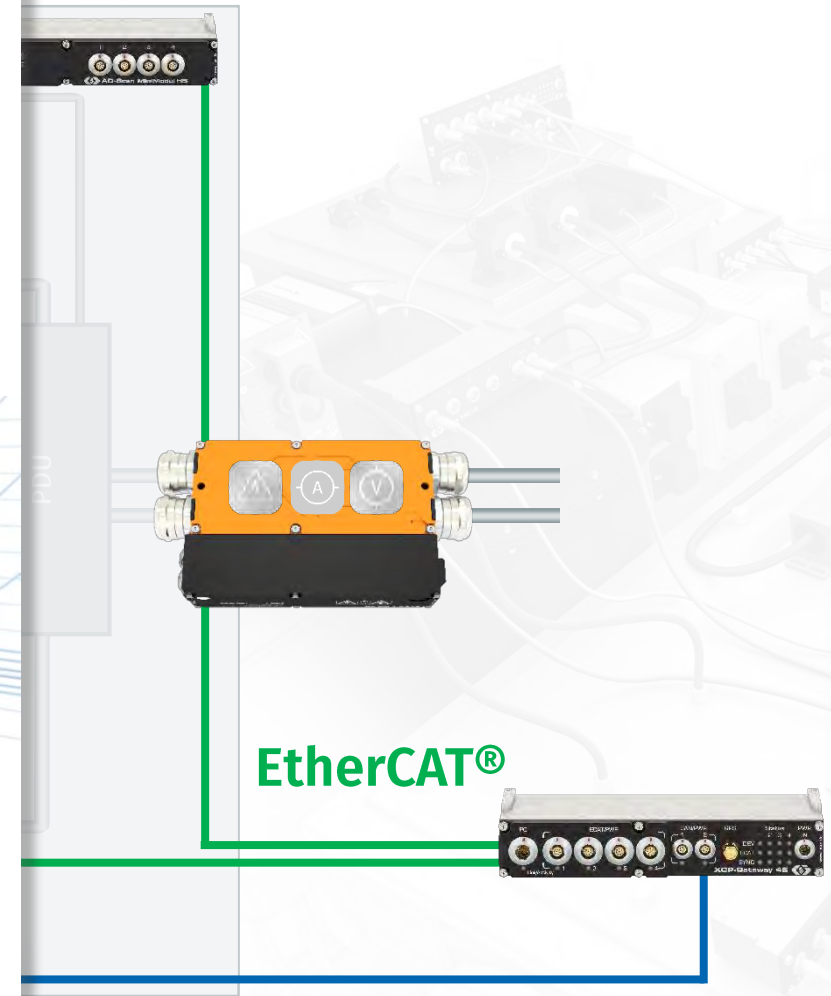


XCP-Gateway



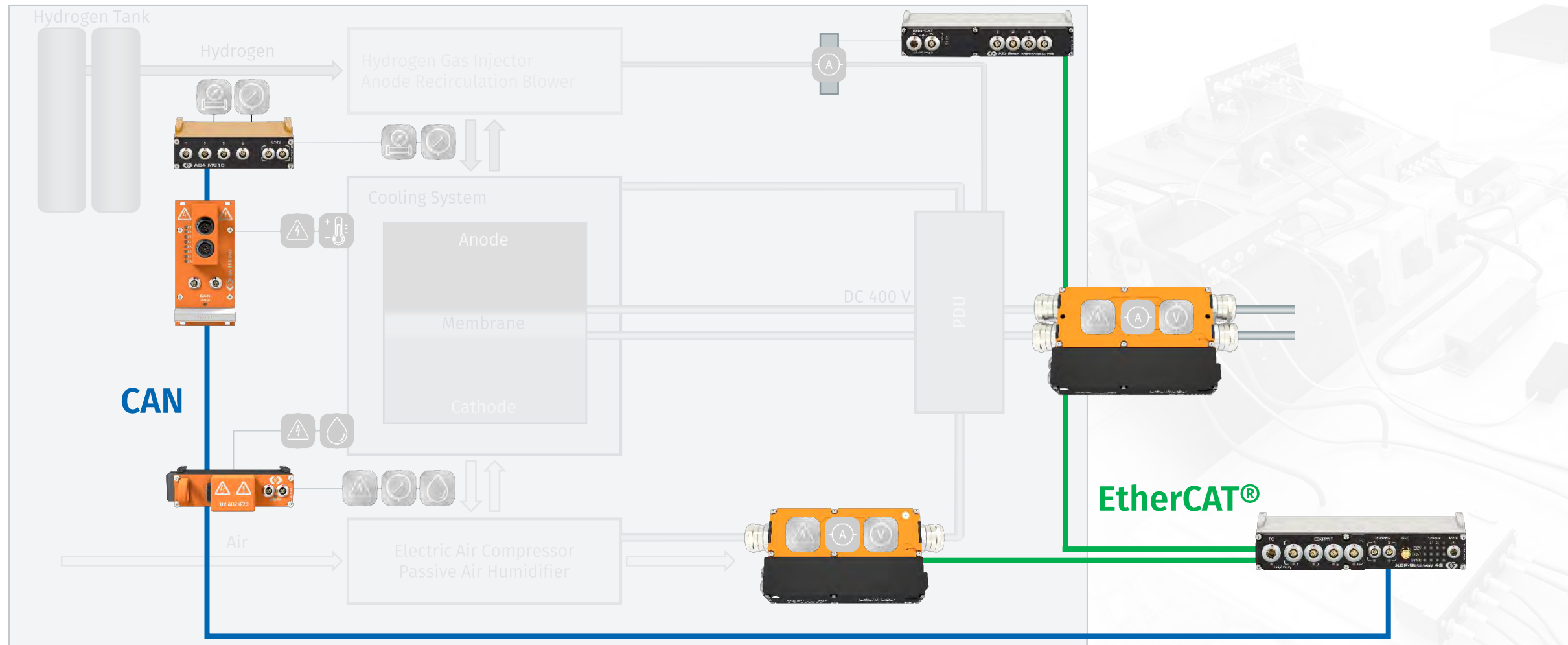
Synchronization and bundling

- ▶ EtherCAT® Master: Time synchronization for all EtherCAT modules (1 μ s)
- ▶ XCP-on-Ethernet slave with PTP (IEEE1588) time synchronization
- ▶ 1 or 4 EtherCAT ports
- ▶ 2 CAN ports
- ▶ 1 Ethernet port to PC

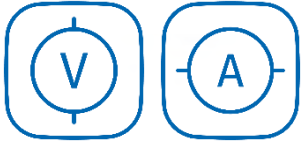


Measurements

Connection of the measurement setup



Measurements in the electric powertrain



Voltage, Current



Power



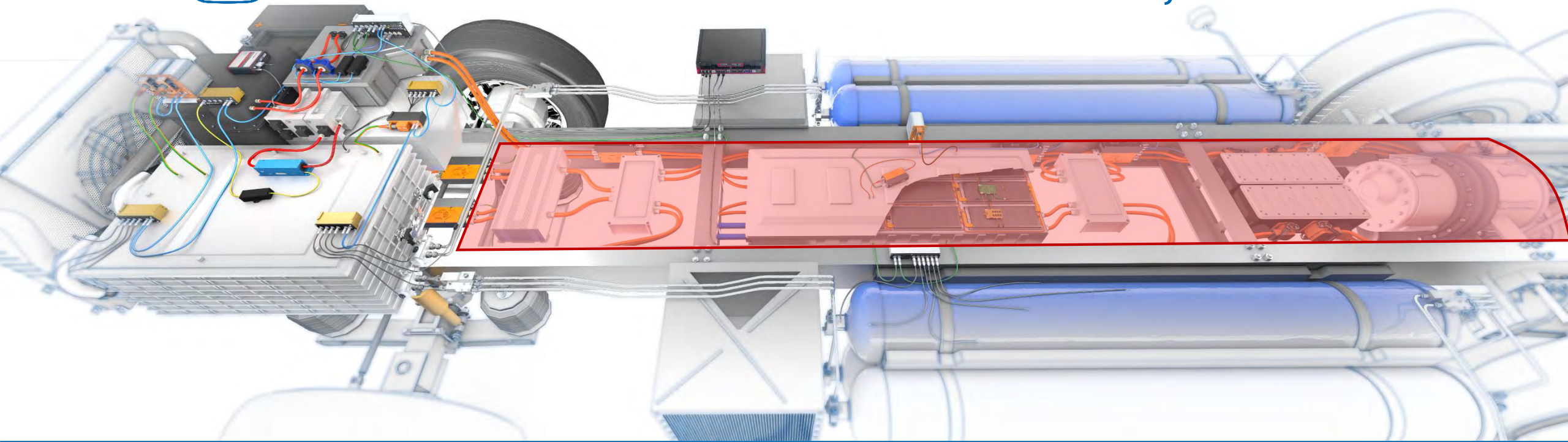
ECU Data



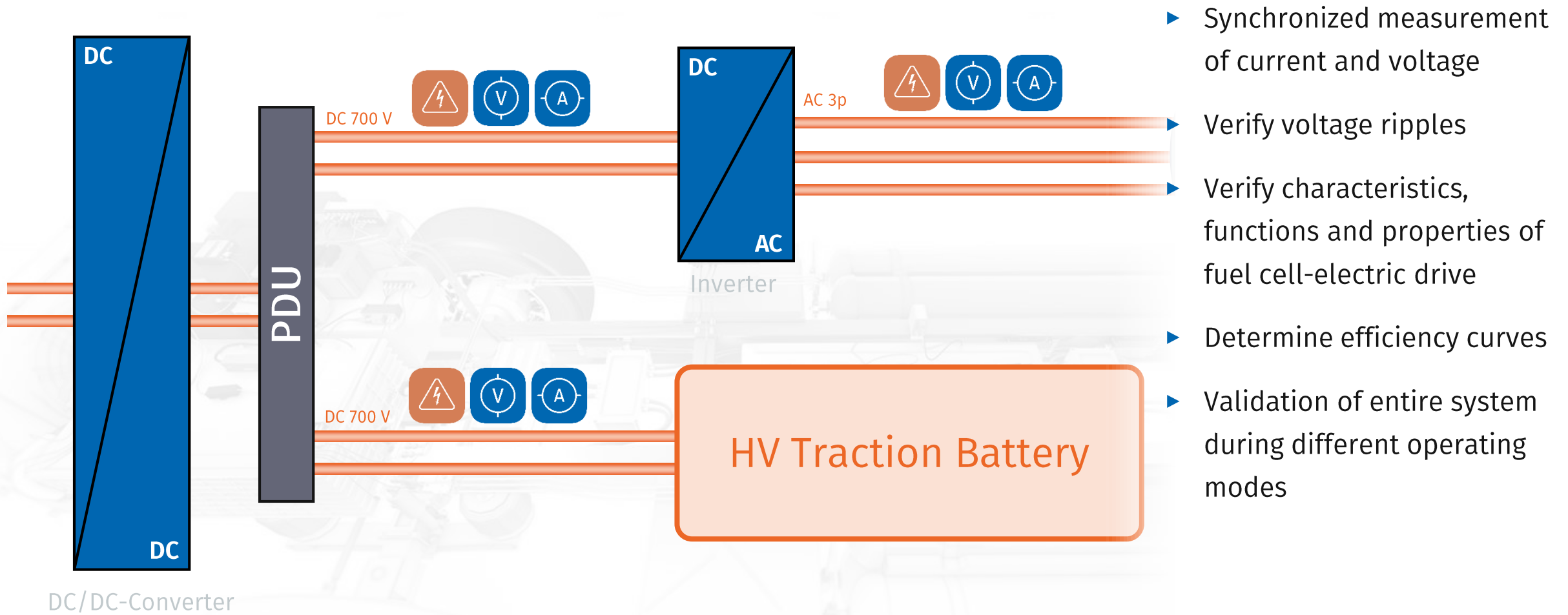
Synchronous



HV-safe

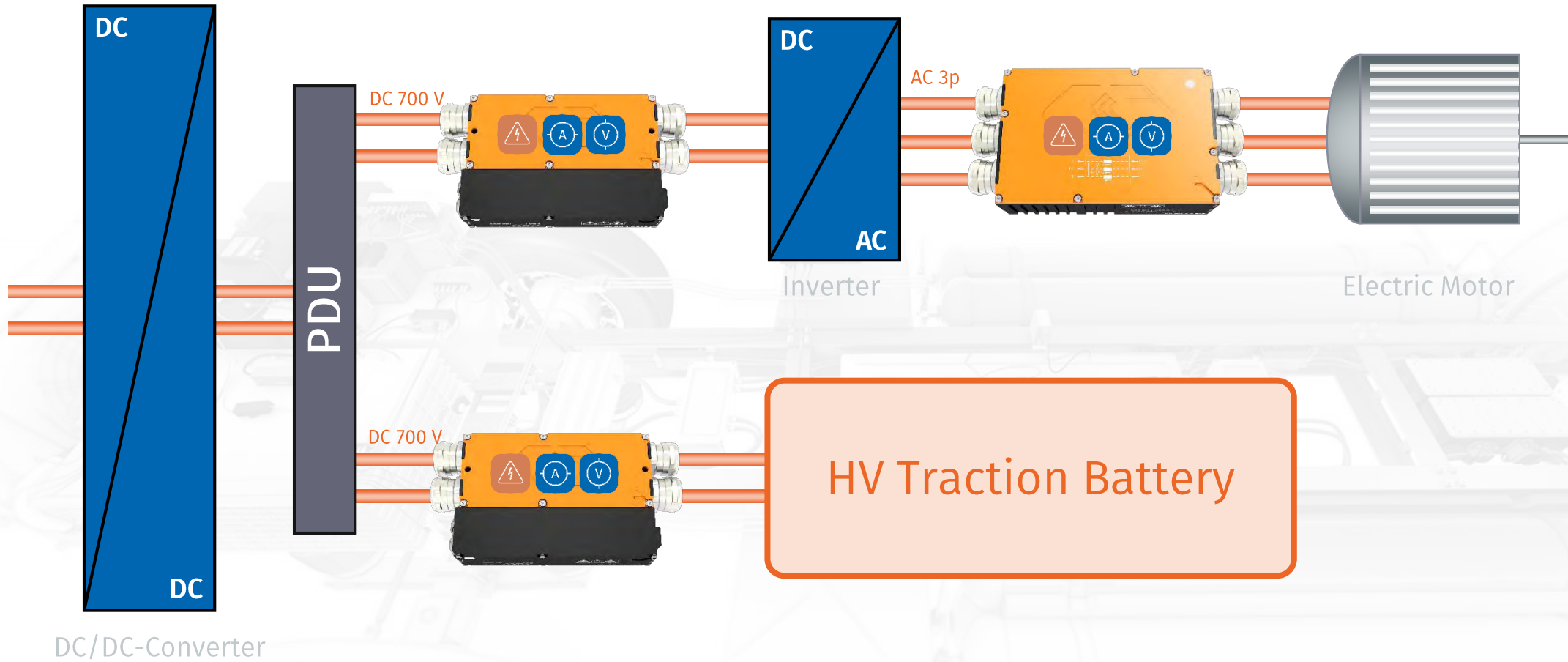


Measurements in the electric powertrain



- ▶ Synchronized measurement of current and voltage
- ▶ Verify voltage ripples
- ▶ Verify characteristics, functions and properties of fuel cell-electric drive
- ▶ Determine efficiency curves
- ▶ Validation of entire system during different operating modes

Measurements in the electric powertrain

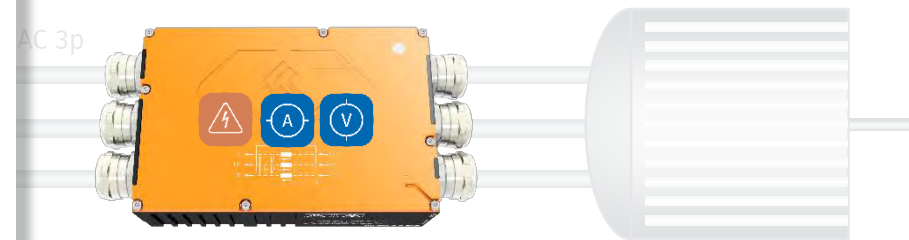


HV Breakout Module 3.3



Measurement of 3-phase currents and voltages

- ▶ Measurement data rate up to 2 MHz via XCP-on-Ethernet
- ▶ **XCP Gateway function** for connection of CSM CAN and EtherCAT® measurement modules
- ▶ PTP Synchronization (IEEE 1588)

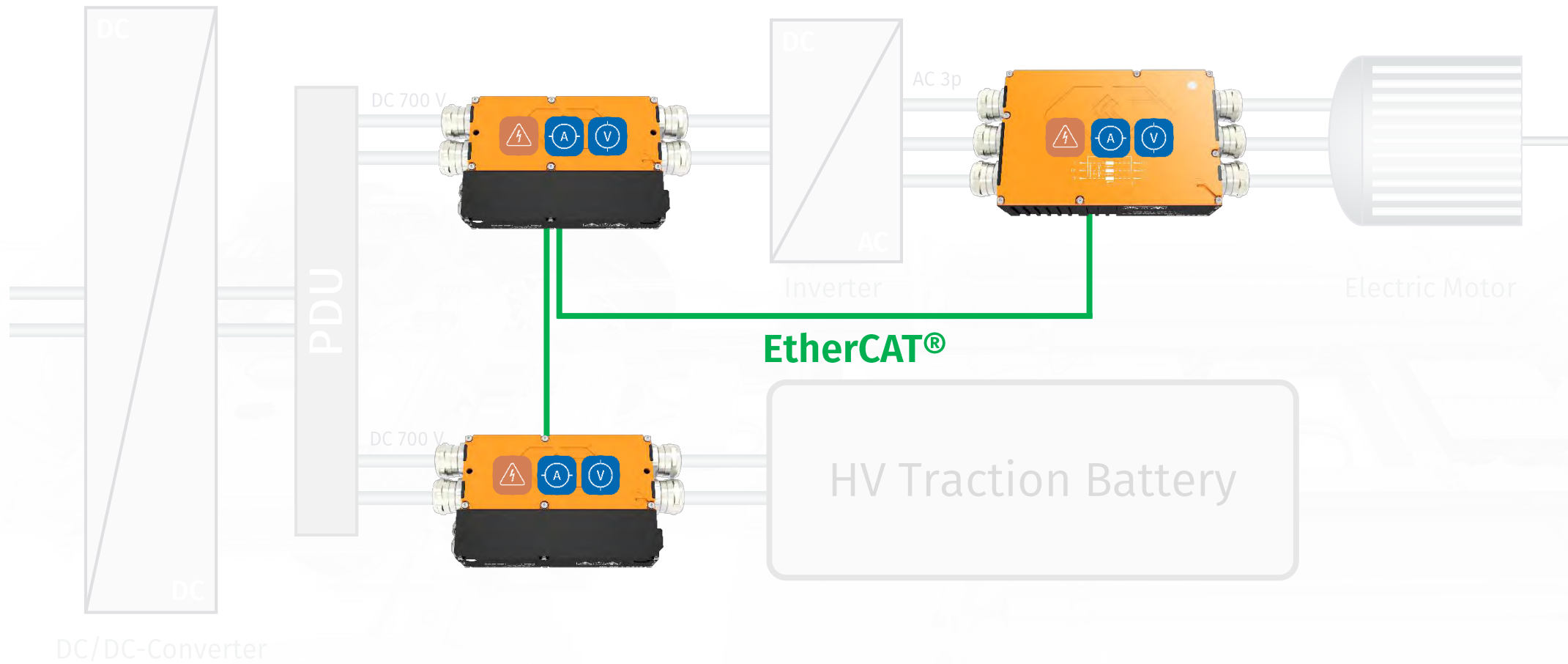


Electric Motor

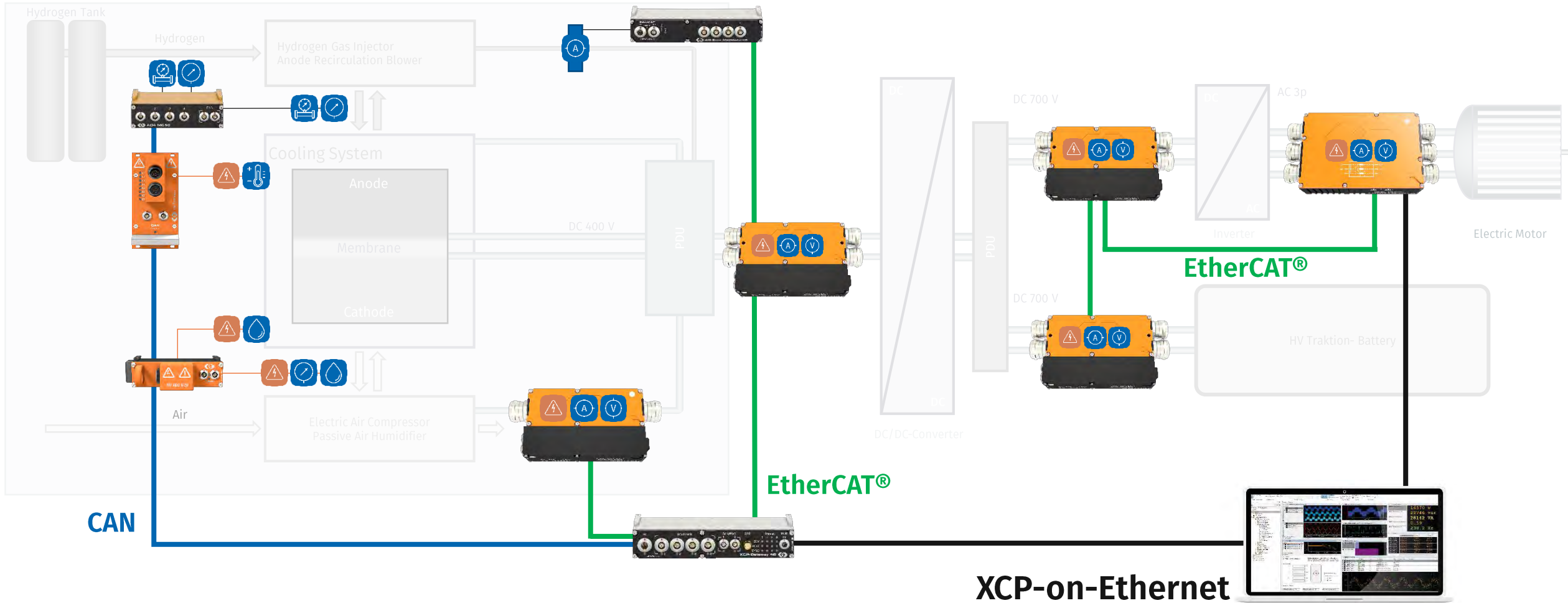
raction Battery

Measurements

Connection of the measurement setup

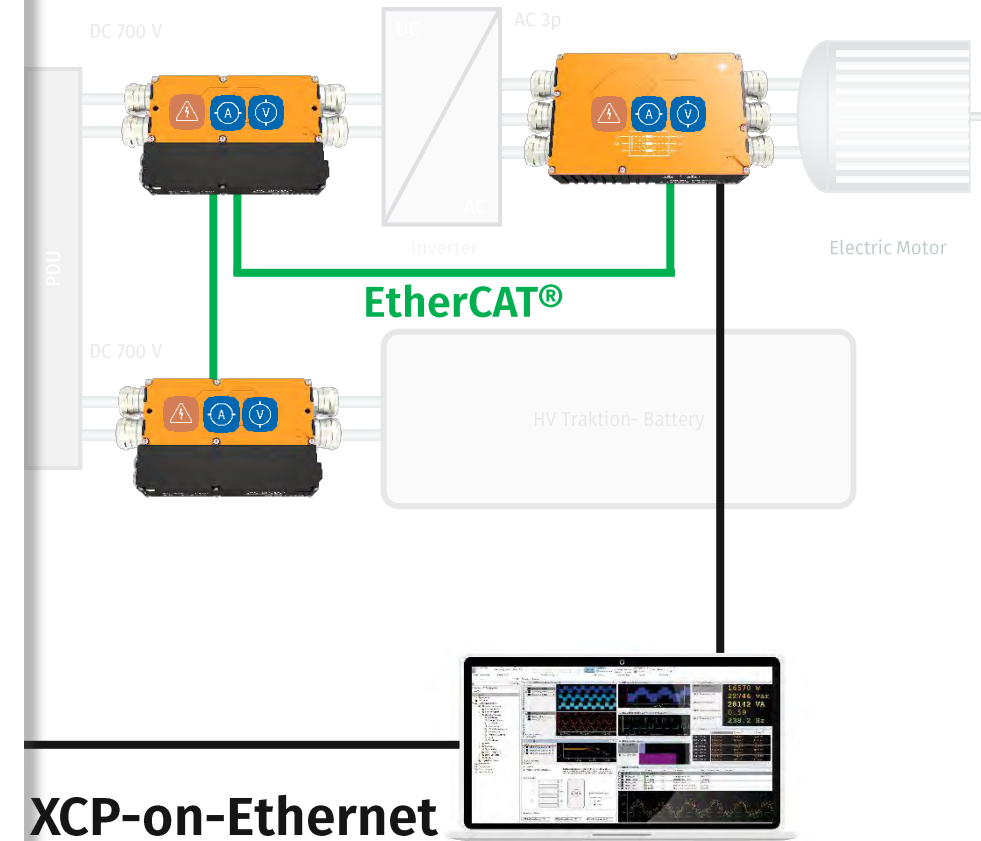
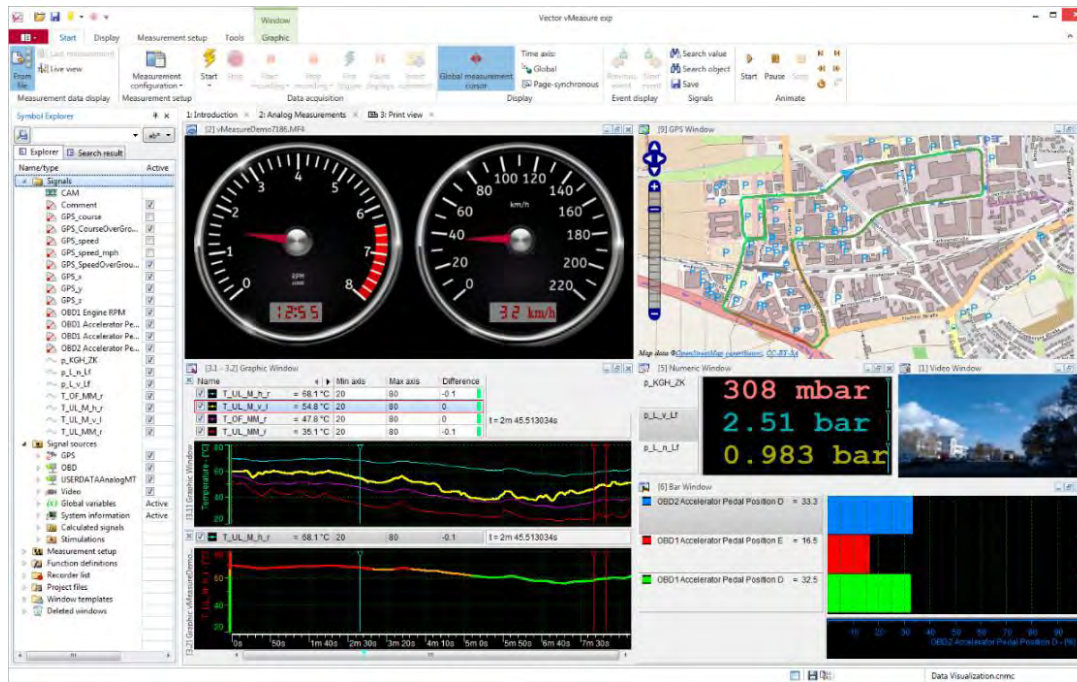


Testing of the complete fuel cell-electric drive

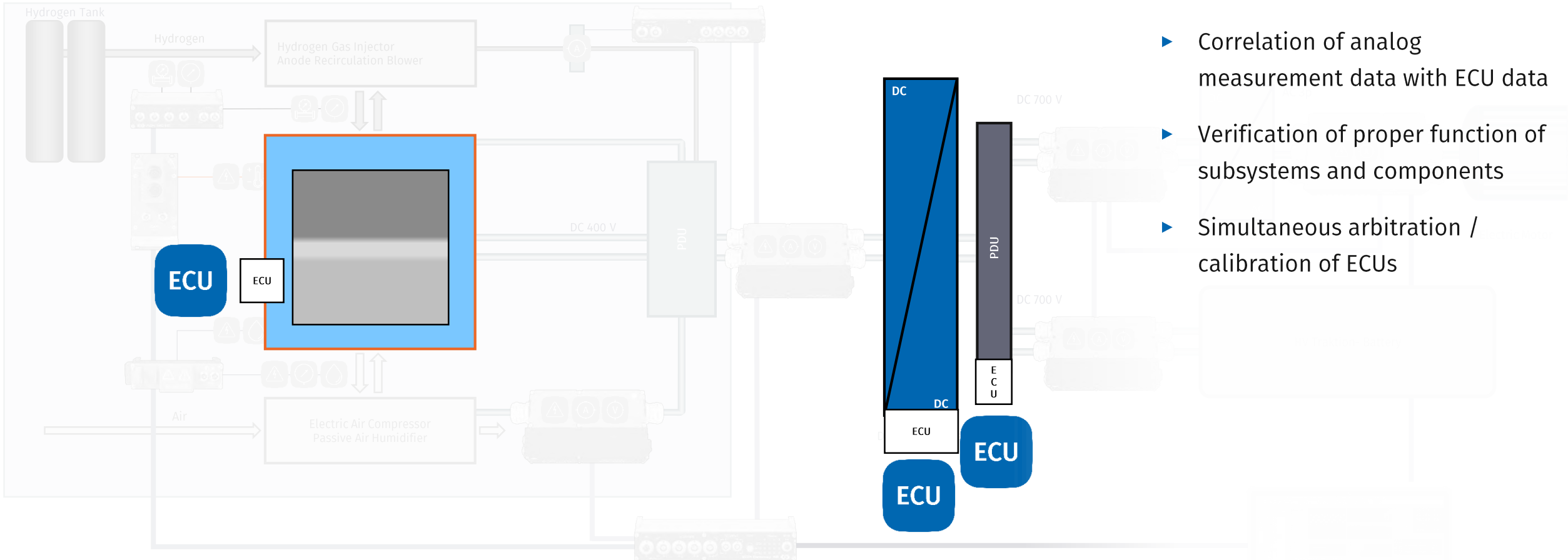


vMeasure – Data Acquisition Software

- ▶ Multithreading functionality
- ▶ Time synchronized data acquisition from
 - ▶ CSM measurement modules
 - ▶ Vehicle buses
 - ▶ ECUs
 - ▶ Video, GPS
- ▶ Powerful online real-time calculations
- ▶ Multiple visualization options

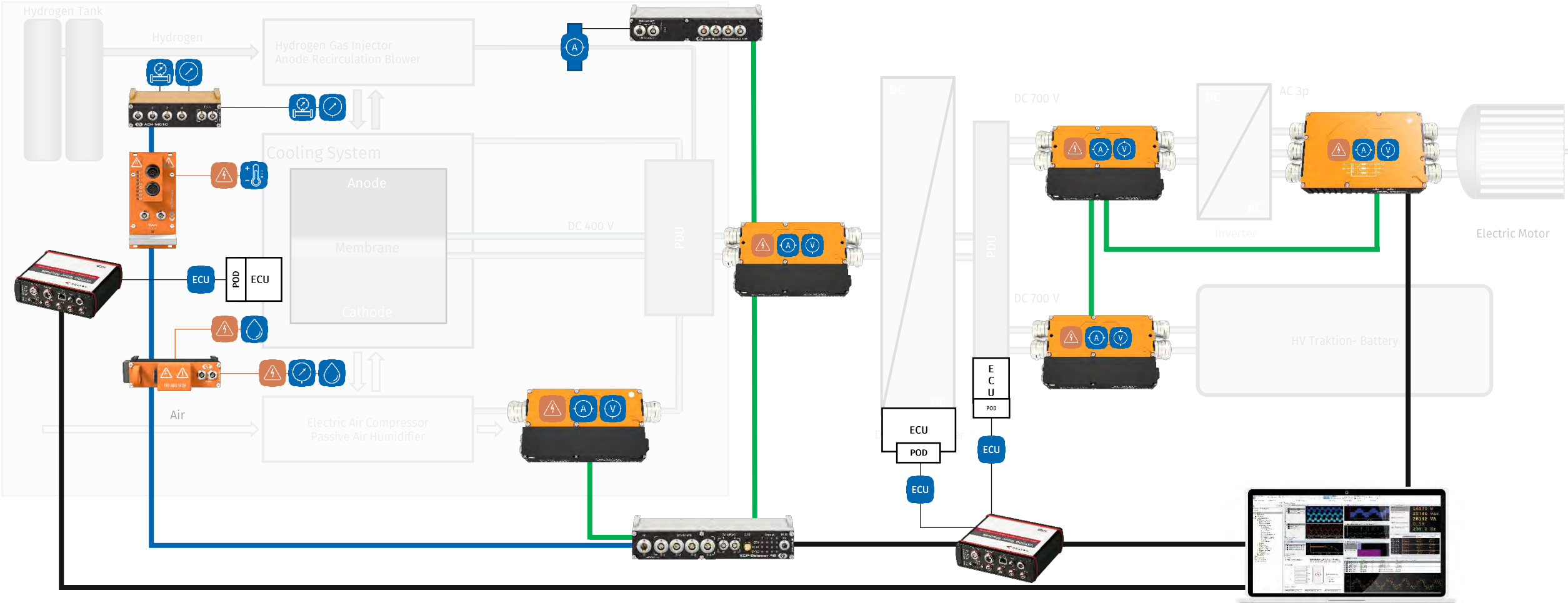


Acquisition of ECU Data



- ▶ Correlation of analog measurement data with ECU data
- ▶ Verification of proper function of subsystems and components
- ▶ Simultaneous arbitration / calibration of ECUs

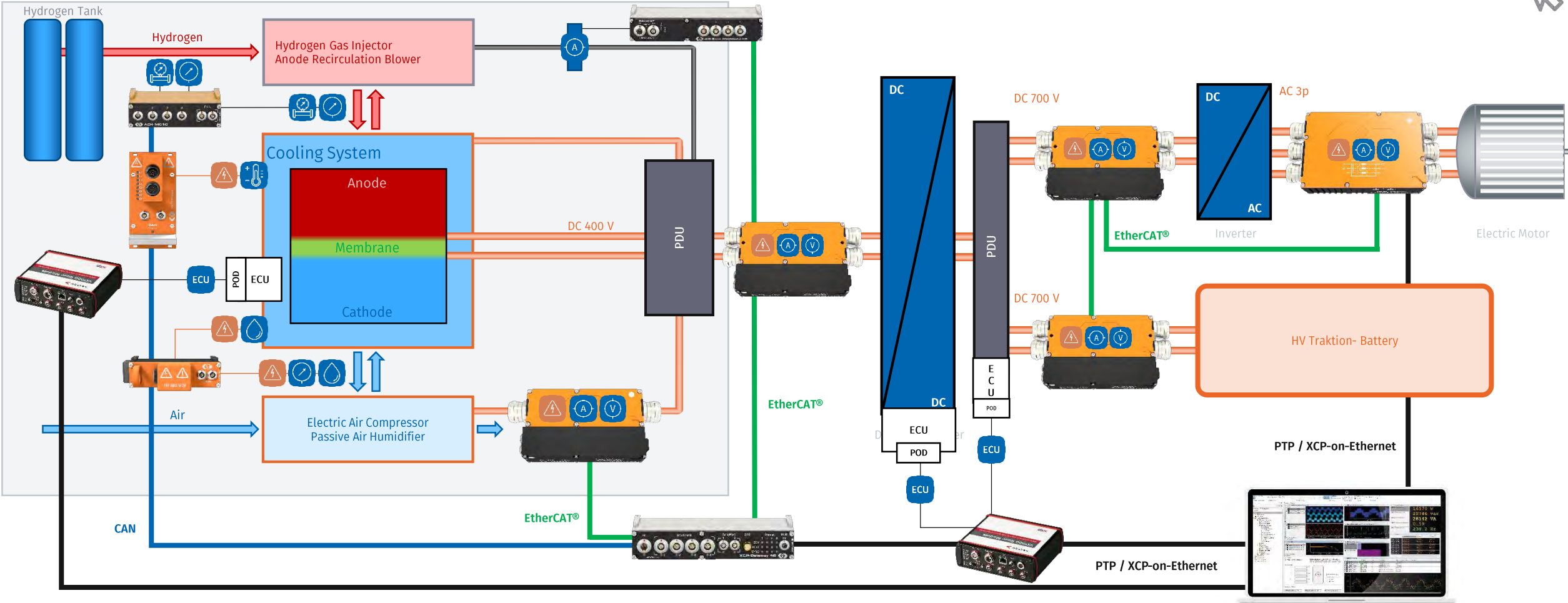
Acquisition of ECU Data



PTP / XCP-on-Ethernet

Read the use case on www.csm.de

Testing of fuel cell-electric drives



The Vector CSM E-Mobility Measurement System

General Overview

Data Analysis and Measurement Data Management



vSignalizer



vMDM



vMeasure exp



eMobility Analyzer



XCP-Gateways



HV Breakout Modules



HV ECAT Modules



ECAT Modules



HV CAN Modules



CAN Modules

voltage, current, temperature, acceleration, strain, vibration, flow, humidity, pressure, torque, speed, frequency, performance data, efficiency, effective power and much more.

E-Mobility Basic Measurement System



VP Family
vMeasure log

eMobility Analyzer



UniCAN 3
Data Logger Family



VN Family



VX Family



POD

CAN, CAN FD, LIN,
FlexRay, Ethernet

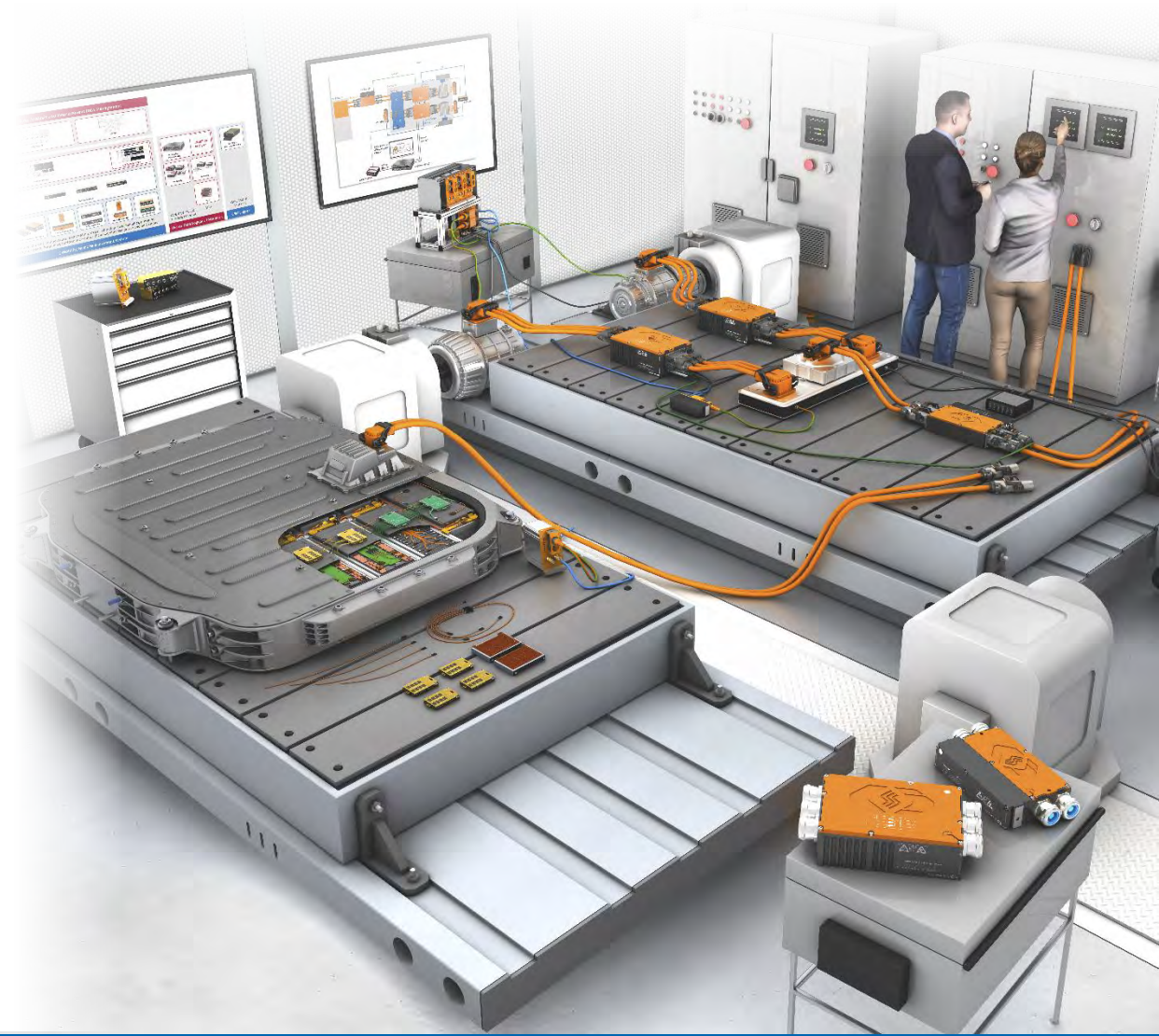
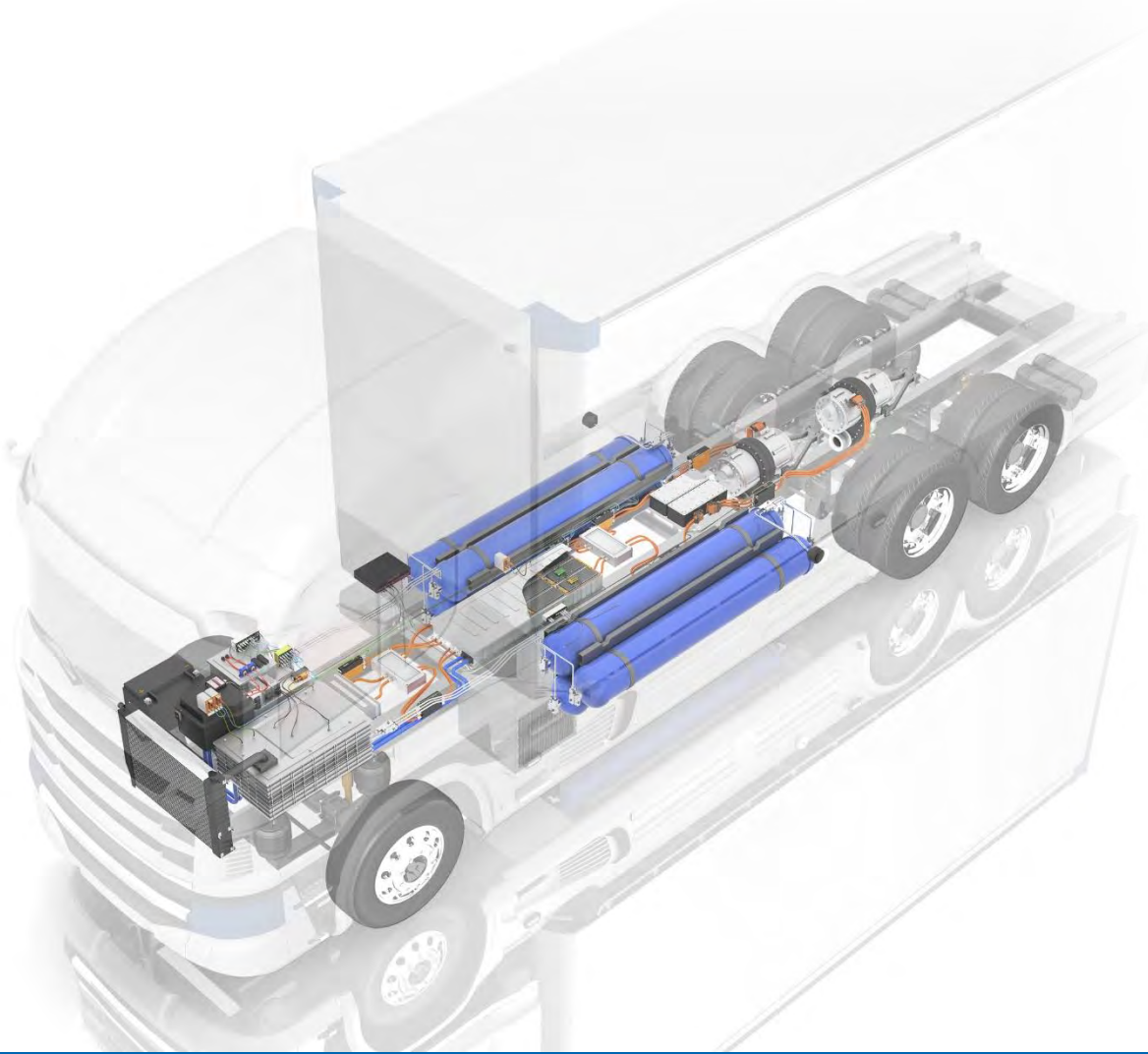
ECU

CAN, CAN FD,
Ethernet

Vector Data Logger / Interfaces

CSM Logger

In test vehicles and on test bench



About CSM

CSM has been setting technological standards for decentralized measurement technology in vehicle development for over 35 years. Our CAN bus and EtherCAT® measurement devices support worldwide renowned vehicle manufacturers, suppliers and service providers in their developments.

Continuous innovation and long-term satisfied customers are our guarantee for success. Together with our partner Vector Informatik, we have developed an easily scalable and powerful E-Mobility Measurement System for hybrid and electric vehicles and are constantly expanding the areas of application. With our high-voltage safe measurement systems designed for fast and synchronous measurements and power analyses, we actively accompany the change to **E-Mobility**.

CSM GmbH (Germany, International)

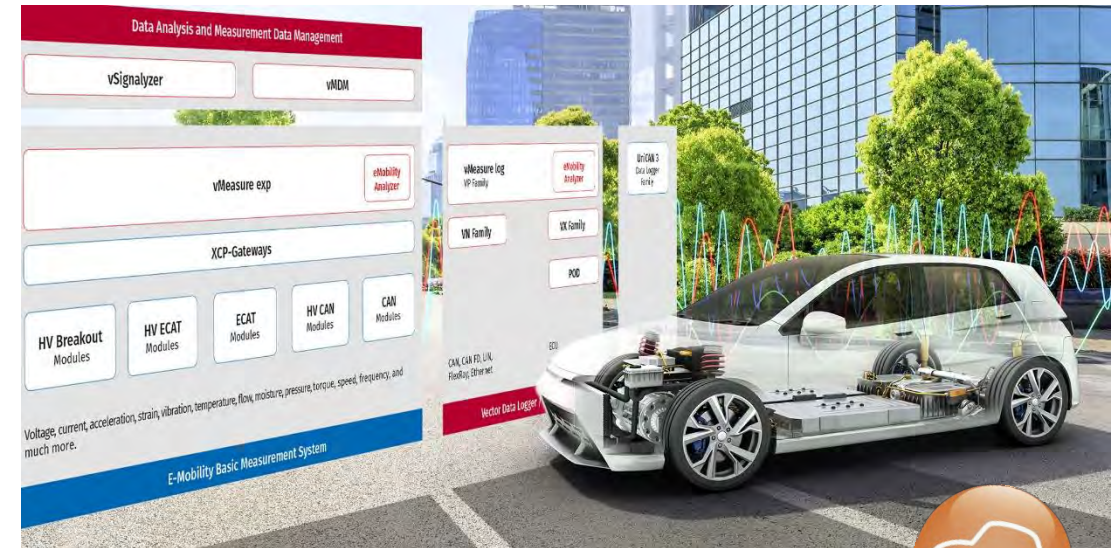
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measurement technology