



# Autonomous power measurement in road tests and on test benches

CSM web seminars

**CSM** **Xplained**  
measurement technology

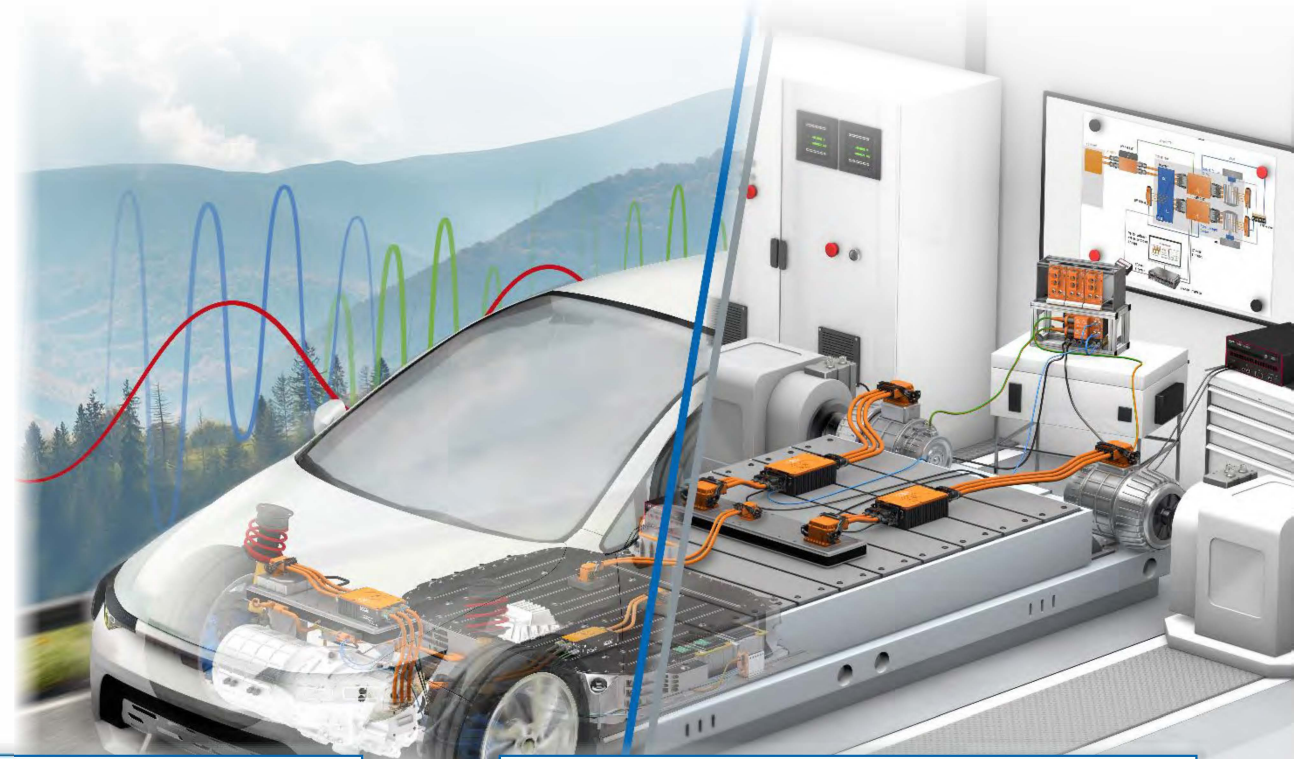
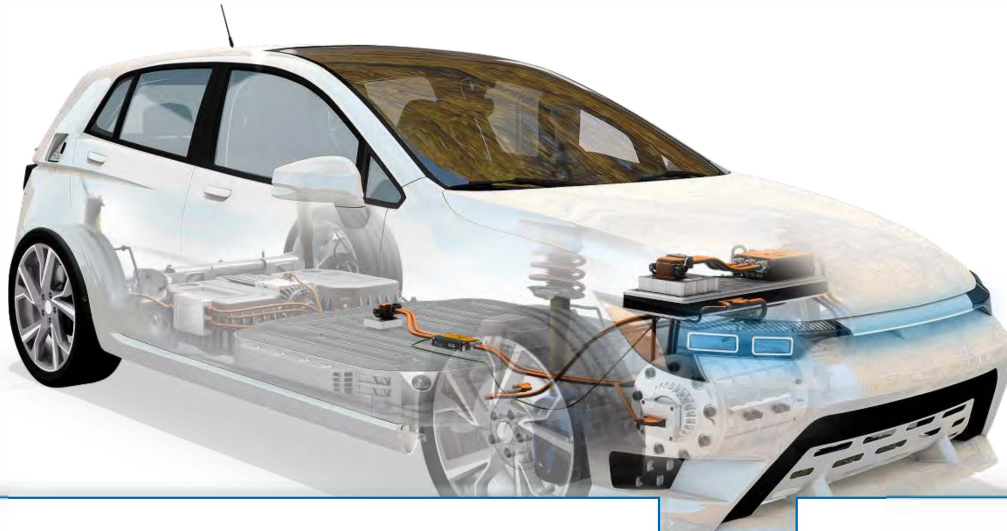


Innovative Measurement and Data Technology

# Power Measurement



# Power Analysis



**Different technical requirements  
of various applications**

**Different requirements for  
measurement equipment**

(including functions, measurement accuracy, range of application)

**Diverse budget requirements**

# Power Analysis

## Development and optimization of components and systems

### Measured values from two or more measuring points

- ▶ Cross-measurement module calculations
- ▶ Most accurate synchronization

### Higher-level computing unit

### Complex mathematical analyses

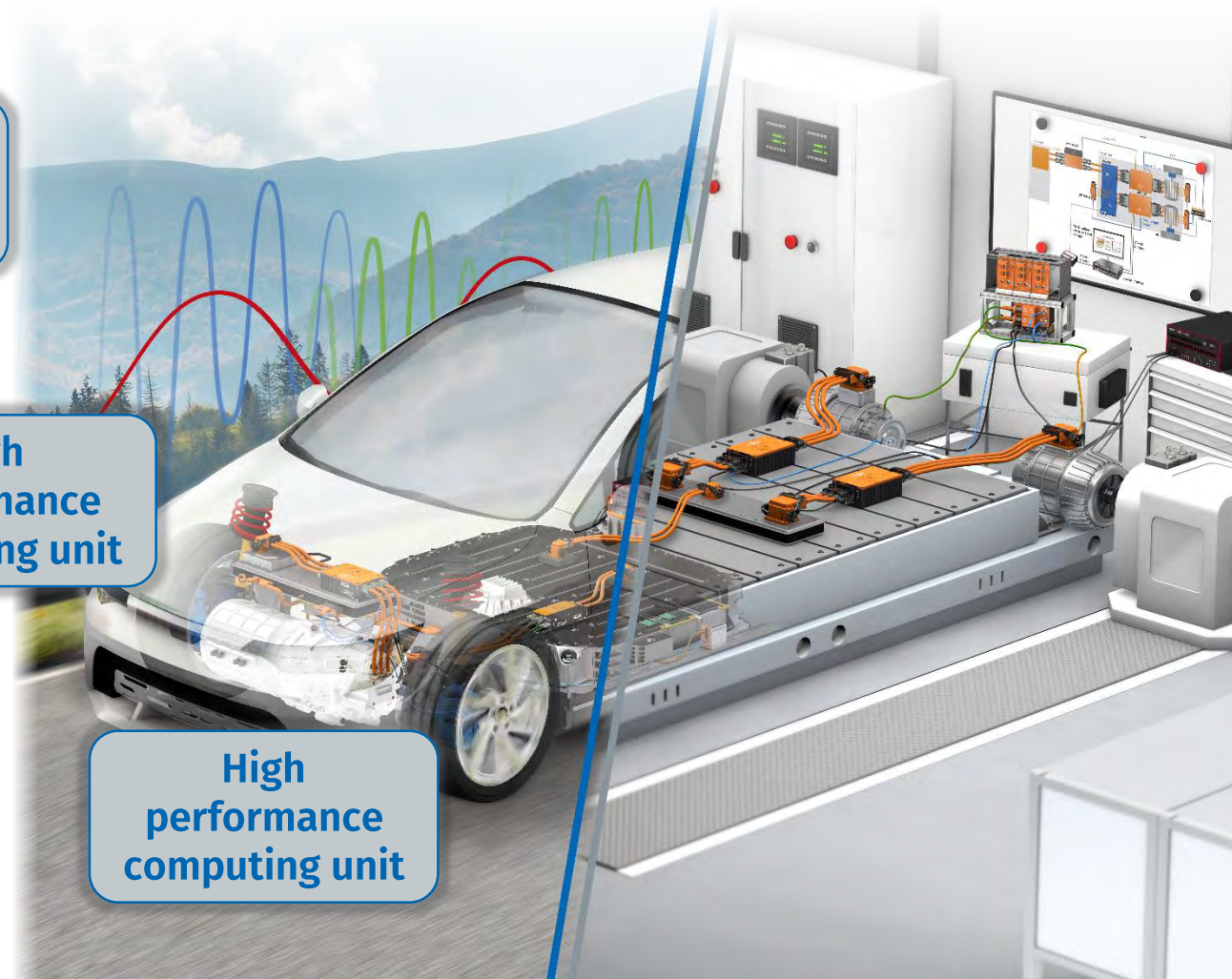
- ▶ Advanced, complex mathematics
- ▶ Transformations
- ▶ High accuracy

### High performance computing unit

### Investigation of highly dynamic processes

- ▶ Transient power analysis
- ▶ Period determination in real time
- ▶ Short integration intervals

### High performance computing unit



# Power Measurement

**"Wattmeter"**  
Determining a status quo

**Power output  
of energy sources**

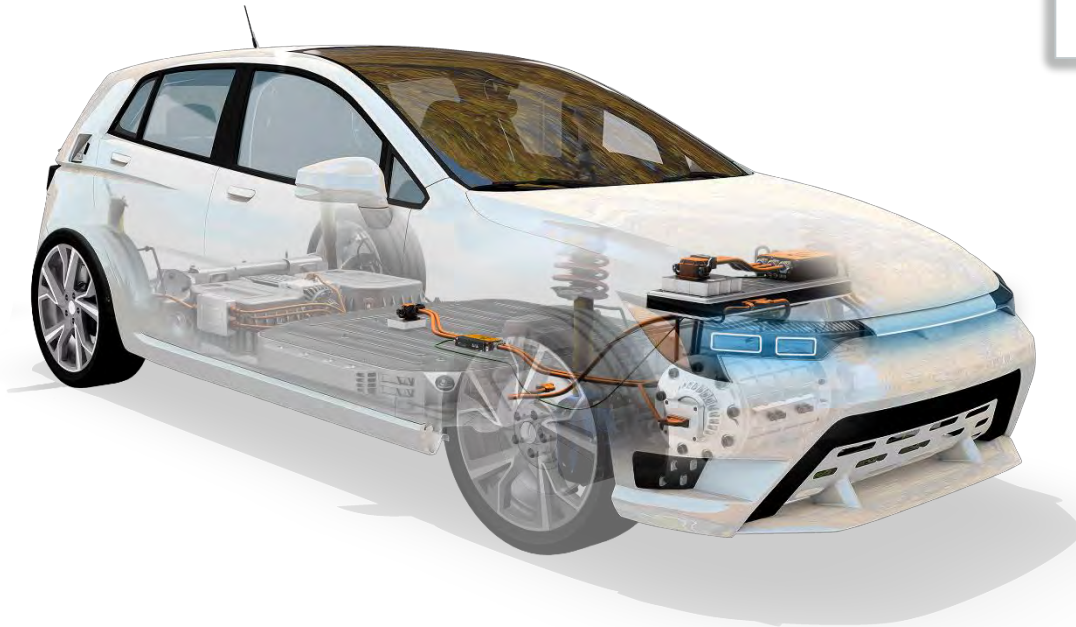
(e. g. HV batteries, fuel cell stack)

**Power consumption  
of electrical consumers**

(e.g. individual components, in cables)

**"Simple" calculation of  
key power values**

(active power, reactive power, apparent power, power factor)



# Power Measurement

Focus of this web seminar: Sufficient for many applications in the DC / AC range

Calculation of standard power values  
(e.g. active, reactive, apparent power, power factor, instantaneous power)

Energy consumption of individual components (e.g. benchmarking)

Consumption according to WLTP

Maximum power output of (HV) batteries, fuel cell stacks, ...

Simple charging (DC fast charging, AC charging)

Functional tests

Acceptance and component test benches, dynamometers

Endurance driving test, mobile power meter

Benchmarks

System surveillance (monitoring)

# Power Analysis

More information: CSM Xplained Web Seminars on the Vector CSM E-Mobility Measurement System

Overall powertrain efficiency

Inverter efficiency, OBC efficiency

E-motor analysis incl. star-delta transformation

Transient power analysis of highly dynamic processes (engine run-ups, change of direction of energy flows during recuperation, torque vectoring)

Harmonic analysis

Work, energy flow, power loss

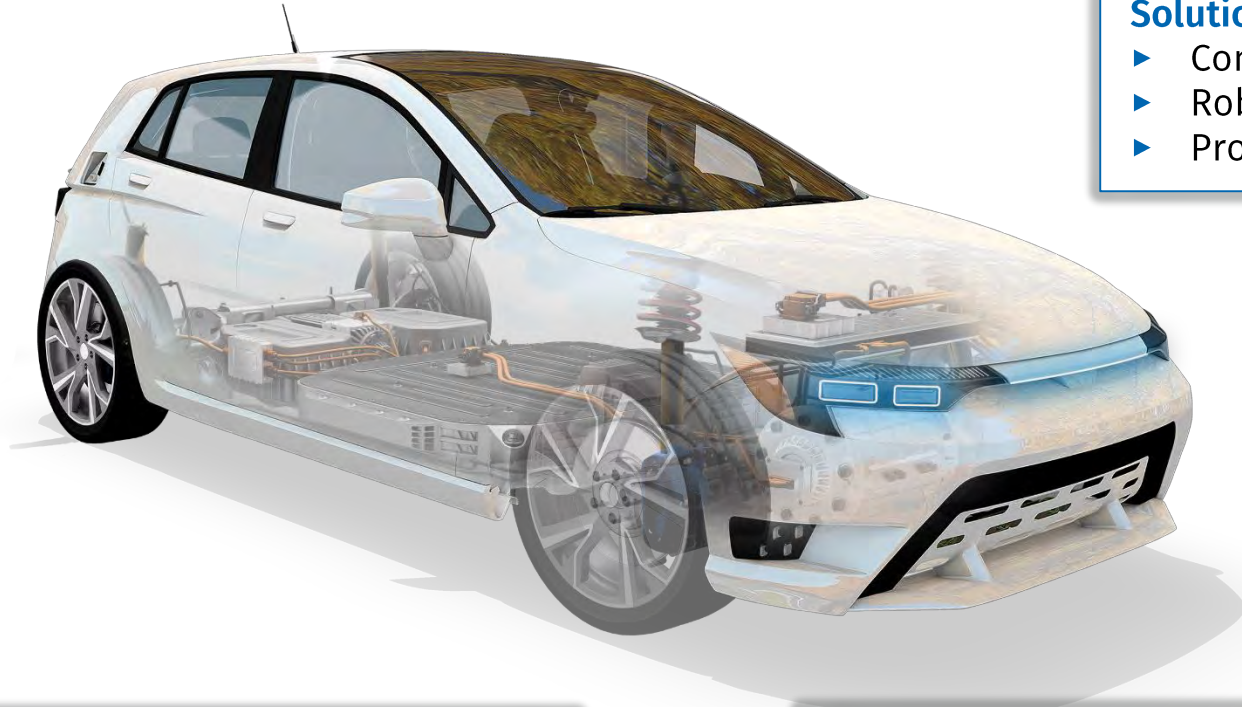
Clark transformation

Calculation of system parameters

PWM analysis

Calculation of complex physical parameters

# Power Measurement Requirements



## Solution for mobile application:

- ▶ Compact dimensions
- ▶ Robust housing
- ▶ Protection class IP 65 or higher

## Required values:

- ▶ Active power (P)
- ▶ Apparent power (S)
- ▶ Reactive power (Q)
- ▶ (Active) power factor ( $\lambda$ )

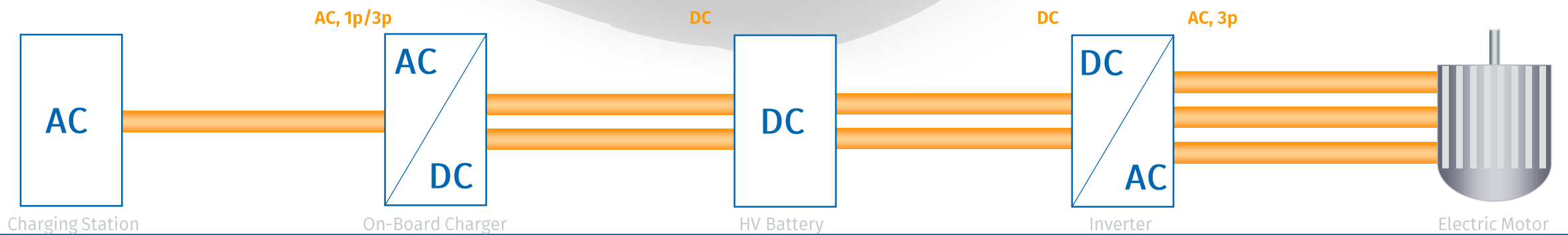
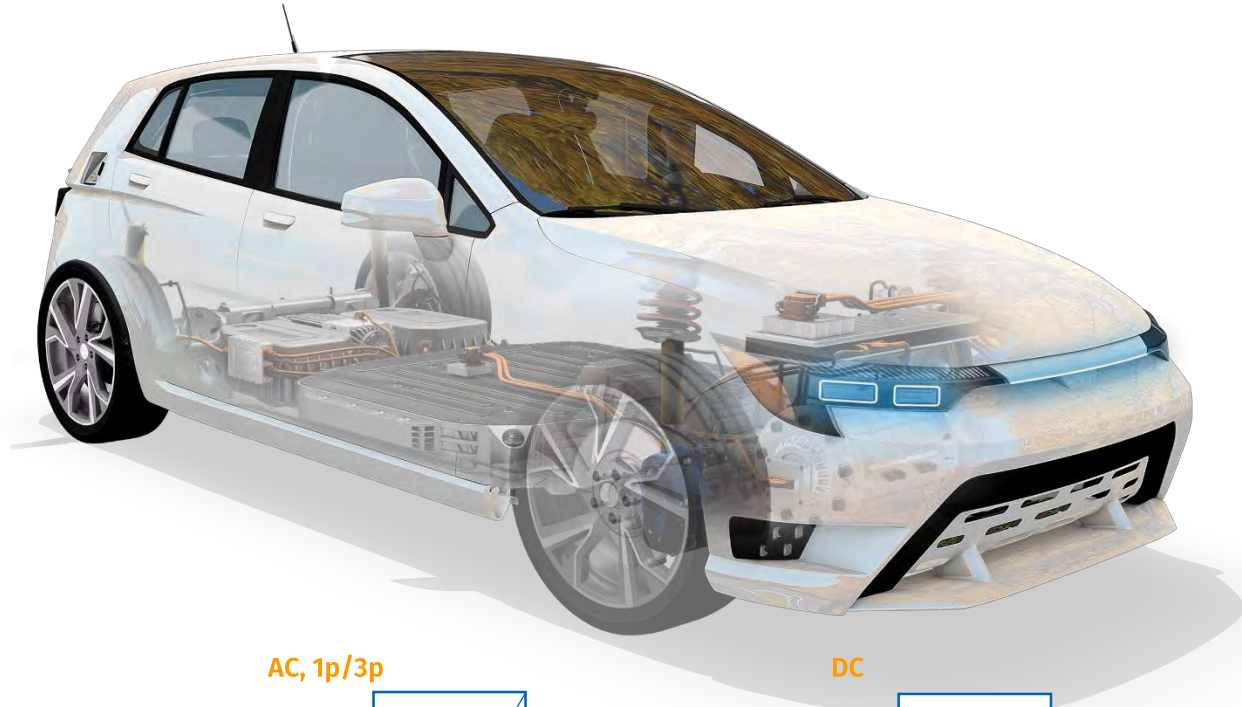
## Connectivity options:

- ▶ Standard (test bench) systems
- ▶ Data logger

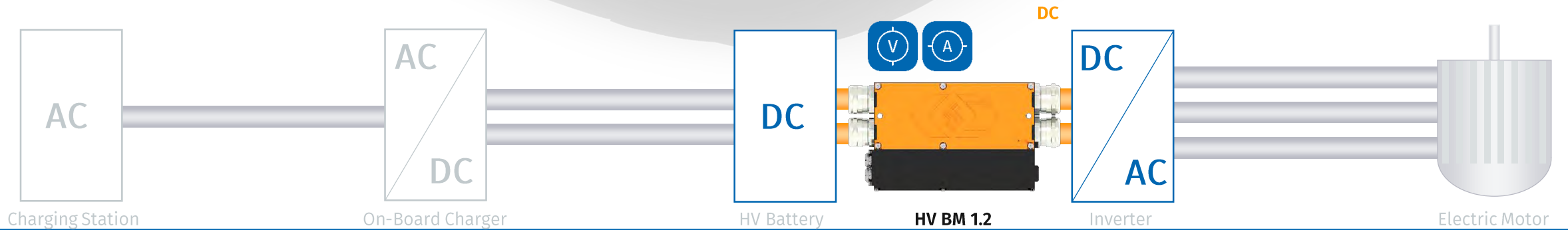
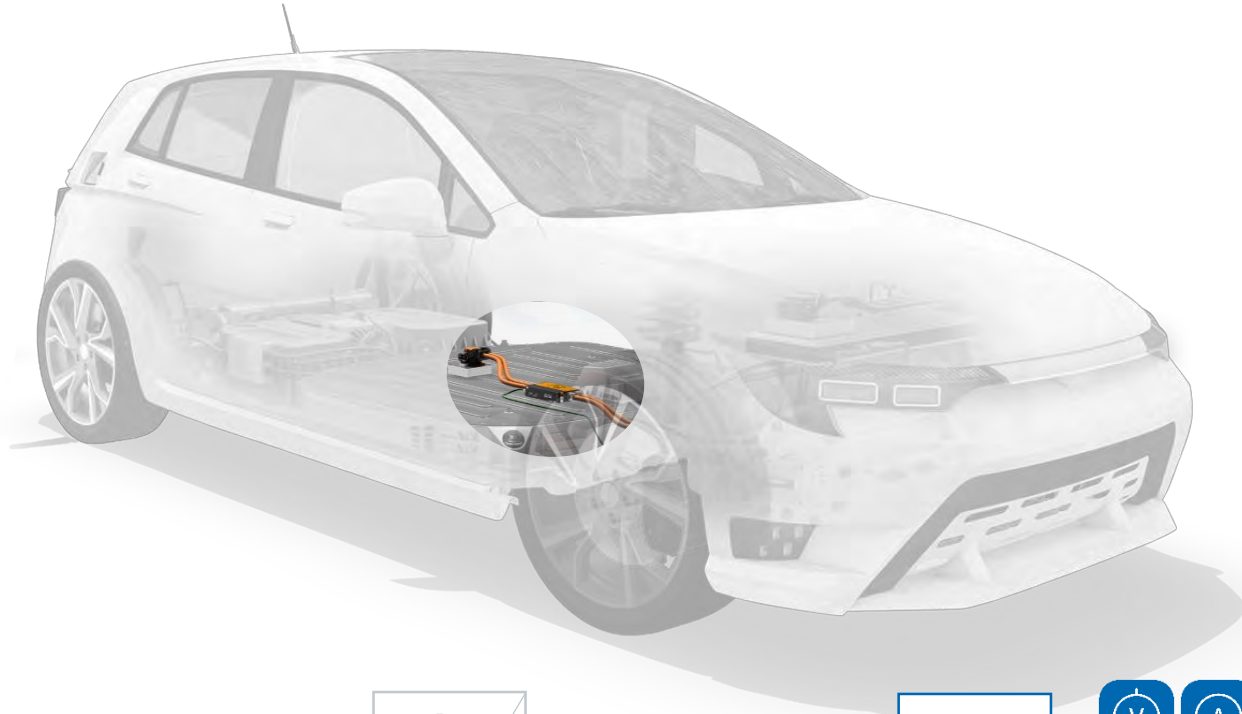
## Required:

- ▶ RMS values of current and voltage, even with AC overlays and current / voltage dips

# Power Measurement with HV Breakout Modules



# Power Measurement with HV Breakout Modules





### Solution for mobile application:

- ▶ Compact dimensions
- ▶ Robust housing
- ▶ Protection class IP 65 or higher

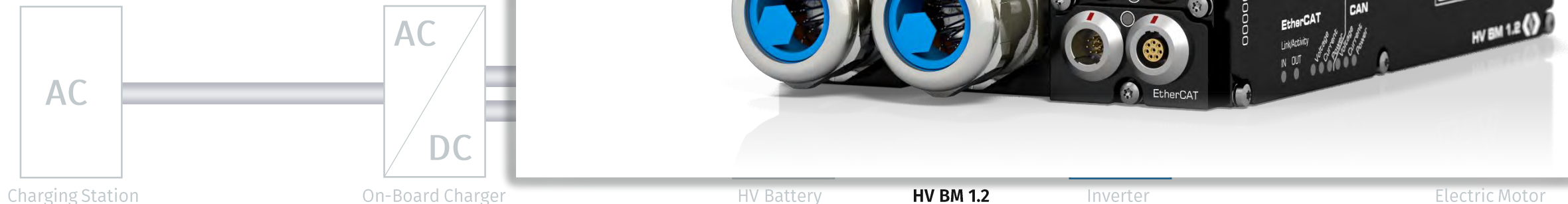
## HV Breakout Module 1.2

HV BM 1.2 on  
[www.csm.de](http://www.csm.de)



### Measurement of high currents and voltages

- ▶ All in one compact solution
- ▶ Measurement directly in the HV power cables
- ▶ For in-vehicle and test bench applications
  - IP67
  - Operating temperature range: -40 °C to +125 °C



# Power Measurement with



## HV Breakout Module 1.2

### Measurement of high currents and voltages

- ▶ Current measurement with shunt modules
  - Inner conductor current  $I_{nom}$  :  $\pm 50$  A up to  $\pm 2,000$  A
- ▶ Voltages up to  $\pm 2,000$  V
- ▶ Data rate up to 1 MHz per channel (EtherCAT®)
- ▶ Additional CAN interface



Charging Station



On-Board Charger

HV Battery

**HV BM 1.2**

Inverter

Electric Motor

# Power Measurement with



Charging Station

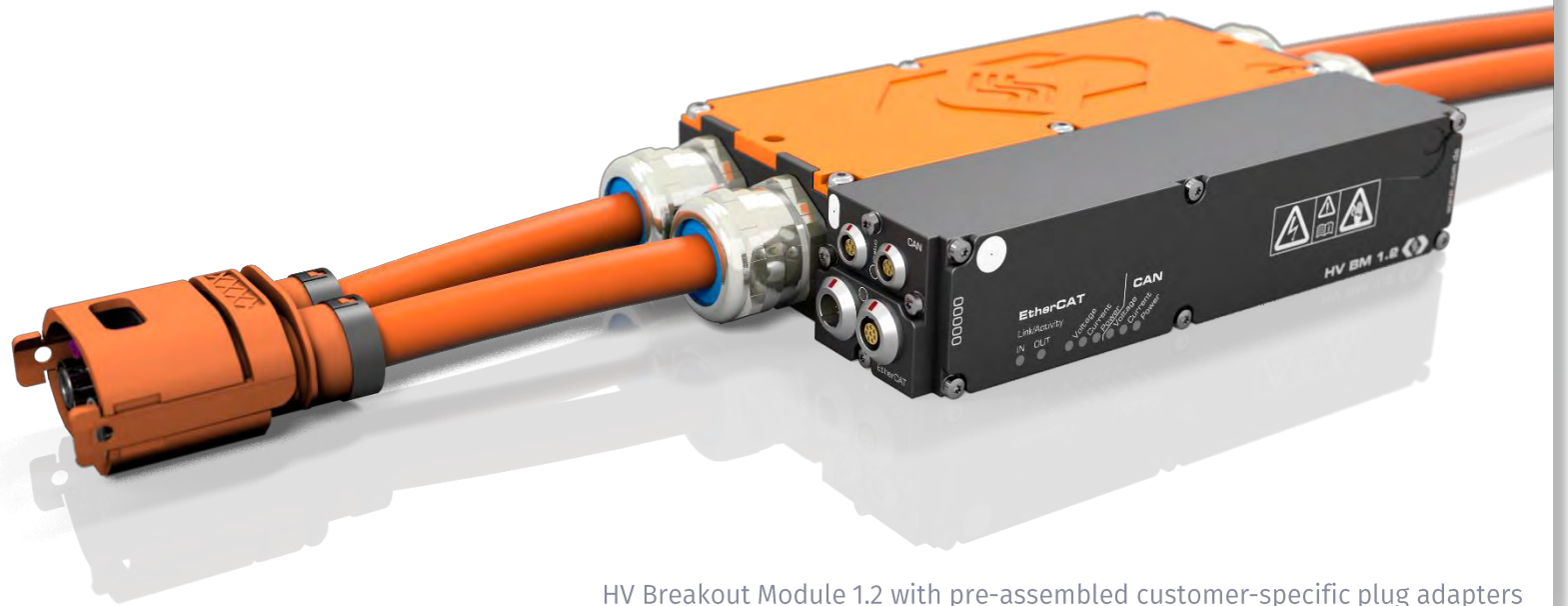


On-Board Charger

## HV Breakout Module 1.2

### Measurement of high currents and voltages

- ▶ Cable connection via
  - PowerLok connector system
  - Cable glands
    - Optional plug & play with customized plug adapters



HV Breakout Module 1.2 with pre-assembled customer-specific plug adapters

HV Battery

HV BM 1.2

Inverter

Electric Motor

### Required values:

- ▶ Active power (P)
- ▶ Apparent power (S)
- ▶ Reactive power (Q)
- ▶ (Active) power factor ( $\lambda$ )

## Power Channels HV BM 1.x

HV BM Power Channels on [www.csm.de](http://www.csm.de)

### The internally acquired signals of

- ▶ Current
- ▶ Voltage

### are used for the module-internal calculation of

- ▶ Active power **P** in W
- ▶ Apparent power **S** in VA
- ▶ Reactive power **Q** in var
- ▶ Power factor  **$\lambda$**



Charging Station



On-Board Charger

HV Battery

HV BM 1.2

Inverter

Electric Motor

### Required values:

- ▶ Active power (P)
- ▶ Apparent power (S)
- ▶ Reactive power (Q)
- ▶ (Active) power factor ( $\lambda$ )

### Required:

- ▶ RMS values of current and voltage even with AC overlays and current / voltage dips

## Power Channels HV BM 1.x

### The recorded internal signals of

- ▶ Current
- ▶ Voltage

### are used for the module-internal calculation of

- ▶ Active power **P** in W
- ▶ Apparent power **S** in VA
- ▶ Reactive power **Q** in var
- ▶ Power factor  $\lambda$
  
- ▶ TrueRMS value voltage  $\mathbf{U}_{\text{rms}}$  in V
- ▶ TrueRMS value current  $\mathbf{I}_{\text{rms}}$  in A



Charging Station



On-Board Charger



HV Battery

HV BM 1.2

Inverter

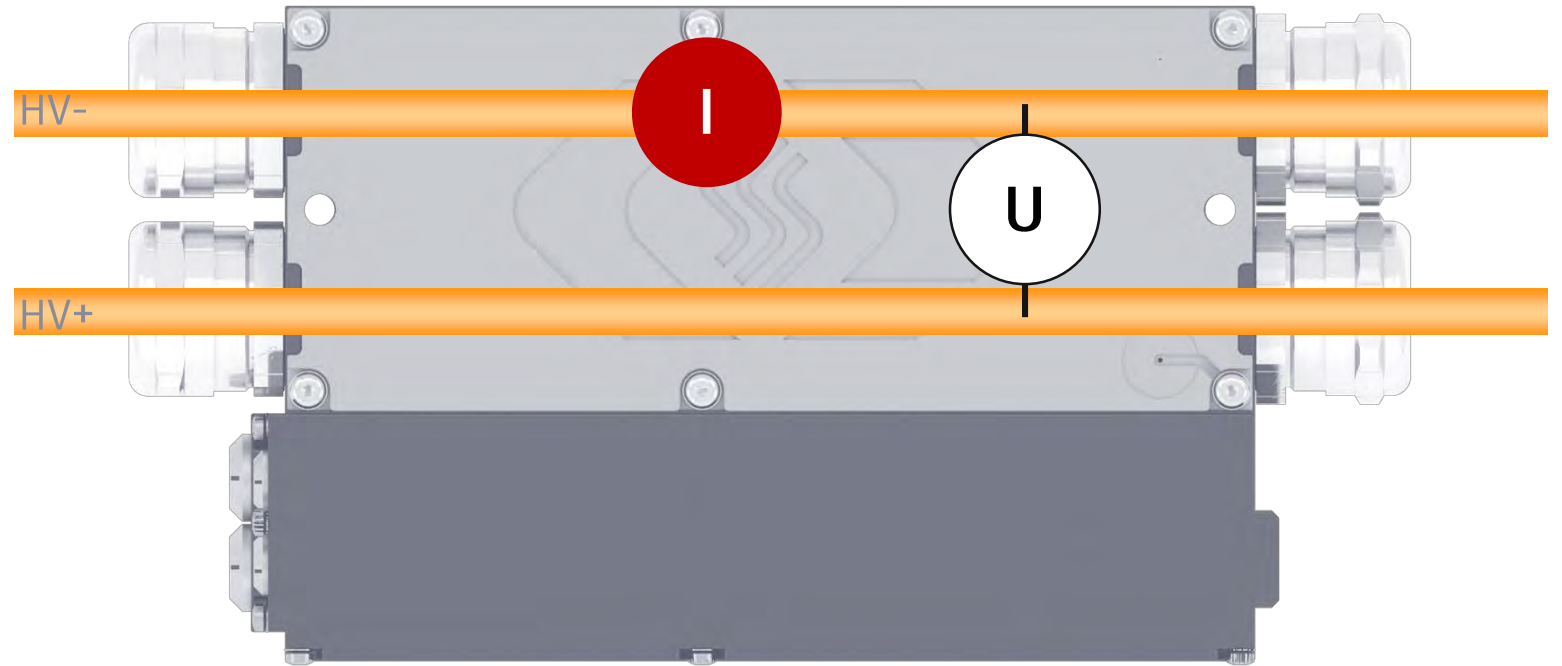
Electric Motor

# Power Measurement with



## Power Channels HV BM 1.x

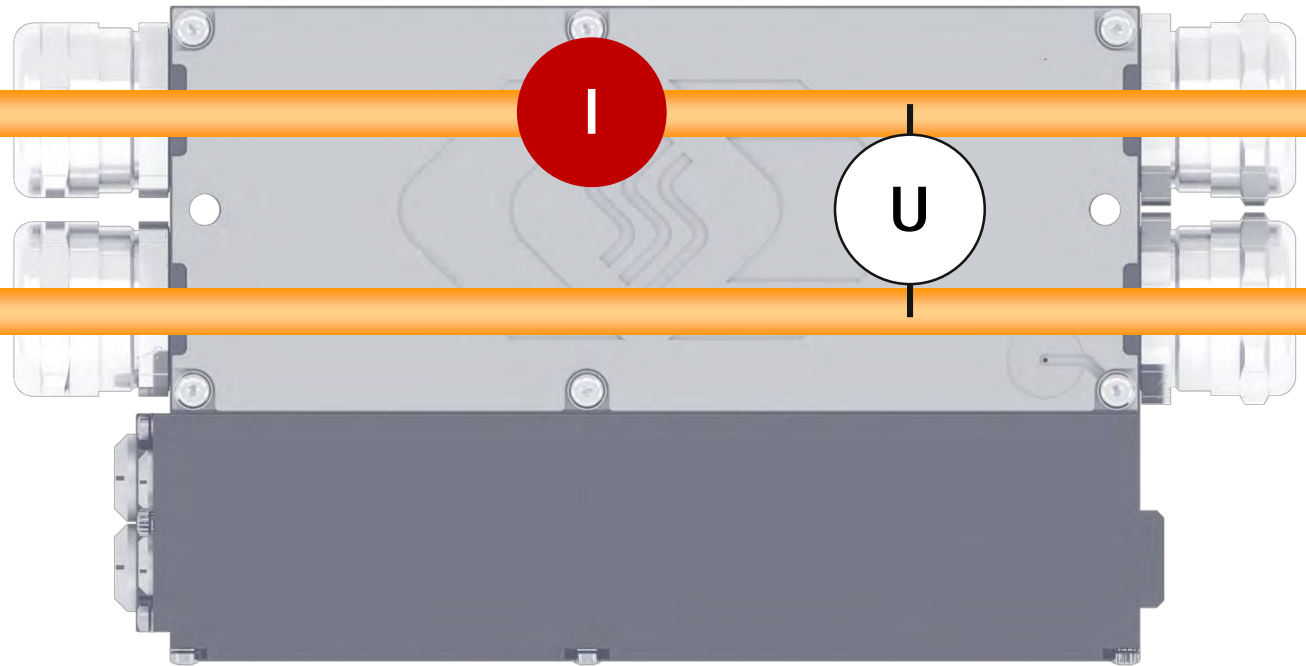
### Measurement circuit



Charging Station



On-Board Charger



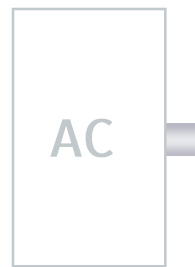
HV Battery

HV BM 1.2

Inverter

Electric Motor

# Power Measurement with



Charging Station



On-Board Charger

HV Battery

HV BM 1.2

Inverter

Electric Motor

## Power Channels HV BM 1.x



### ▶ Additional measurement channels

Device HVBM1\_00000

Settings

Device type: HV BM 1.x

Serial No.: n/a

Device name: HVBM1\_00000

Device number: 0

Channels/Rate: 9: U/I/p, RMS/Power 10 ms / 100 Hz

Data format: 9: U/I/p, RMS/Power

CAN

Identifier Base: 0x0600

Identifier step: n/a

Identifier range: 0x0600...0x0604

Built-in shunt types, nominal current(s)

Inner conductor: 50 A

Buttons: OK, Cancel, Measure, Read from device, Write to device

- CAN bus: 500000 Bits/s, 11-Bit frame
- HVBM1\_00000: HV BM 1.x, D/N 0, 9 channel(s), CAN identifiers: 0x0600...0x0604
  - HVBM1\_00000\_U: Display range -2000 V ... 2000 V, filter: Std ( 15 Hz) Butterworth
  - HVBM1\_00000\_I: Display range -100 A ... 100 A, filter: Std ( 15 Hz) Butterworth
  - HVBM1\_00000\_p: Display range -200000 W ... 200000 W, filter: Std ( 15 Hz) Butterworth
  - HVBM1\_00000\_U\_RMS: Display range -2000 V ... 2000 V, filter: 20 Hz Butterworth**
  - HVBM1\_00000\_I\_RMS: Display range -100 A ... 100 A, filter: 20 Hz Butterworth**
  - HVBM1\_00000\_P: Display range -200000 W ... 200000 W, filter: 20 Hz Butterworth**
  - HVBM1\_00000\_S: Display range -200000 VA ... 200000 VA, filter: 20 Hz Butterworth
  - HVBM1\_00000\_Q: Display range -200000 var ... 200000 var, filter: 20 Hz Butterworth
  - HVBM1\_00000\_Lambda: Display range 0 ... 1, filter: 20 Hz Butterworth

# Power Measurement with



Charging Station



On-Board Charger

HV Battery

HV BM 1.2

Inverter

Electric Motor

## Power Channels HV BM 1.x



- ▶ Additional measurement channels
- ▶ Integration times

Channel 6 of Device HVBM1\_00123, S/N 123, D/N 0

Channel Name:	<input type="text" value="HVBM1_00123_P"/>	...	<input type="button" value="OK"/>
Comment:	<input type="text"/>		
Sensor Name:	<input type="text"/>	...	<input type="button" value="Cancel"/>
Current Value:	<input type="text"/>	---	
CAN-Identifier:	<input type="text" value="per device"/>		
Range:	<input type="text" value="-200 .. 200 kW"/>		
		Mst.No.: <input type="text"/>	
		Integration time	<input type="text" value="100 ms"/>

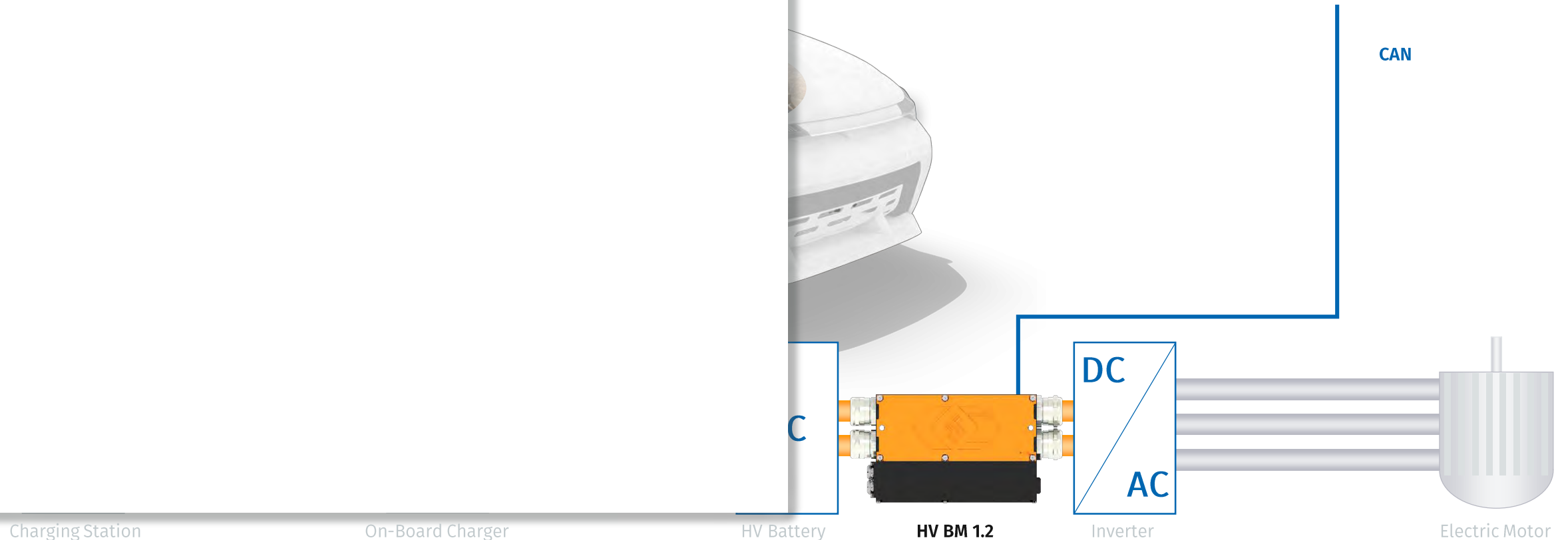
- ▶ Fixed integration intervals from 10 ms - 10 s
- ▶ Manually entered and not changeable for the measurement duration
- ▶ For expected significant frequency changes :
  - Long integration intervals necessary



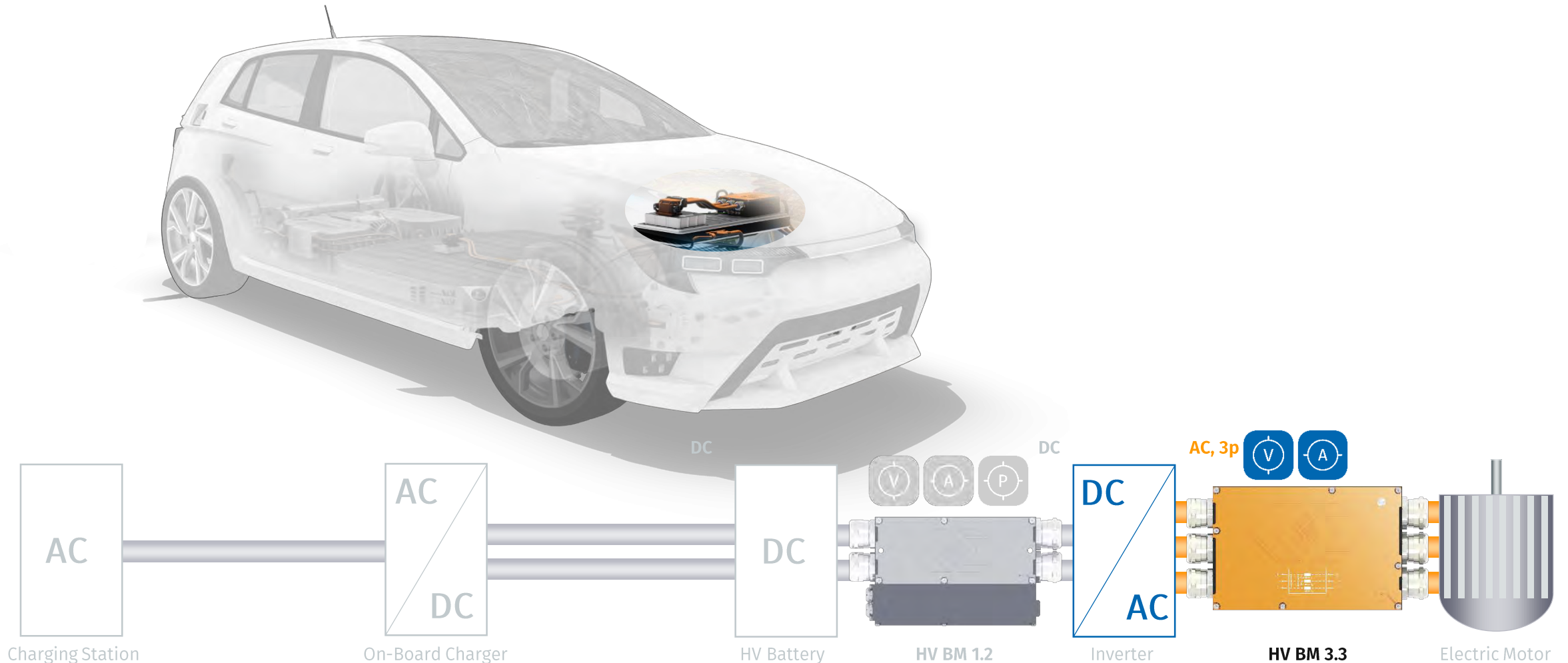
# Power channels HV BM 1.x

- ▶ Additional measurement channels
- ▶ Integration times
- ▶ Data output via CAN

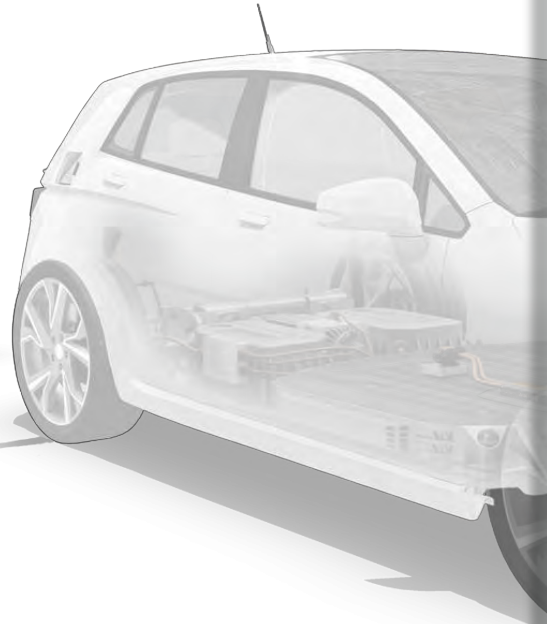
## Modules



# Power Measurement with HV Breakout Modules



# Power Measurement with



## HV Breakout Module 3.3

HV BM 3.3 on [www.csm.de](http://www.csm.de)



- ▶ Measurement of 3-phase currents and voltages
- ▶ Output of measurement data at a rate of up to 2 MHz per value via XCP-on-Ethernet



HV BM 3.3 Variants: Cable connection via cable glands or PowerLok connector system

Charging Station

On-Board Charger

HV Battery

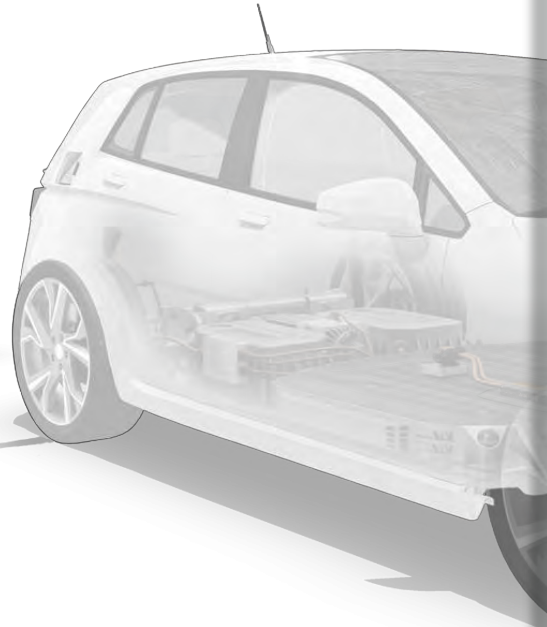
HV BM 1.2

Inverter

HV BM 3.3

Electric Motor

# Power Measurement with



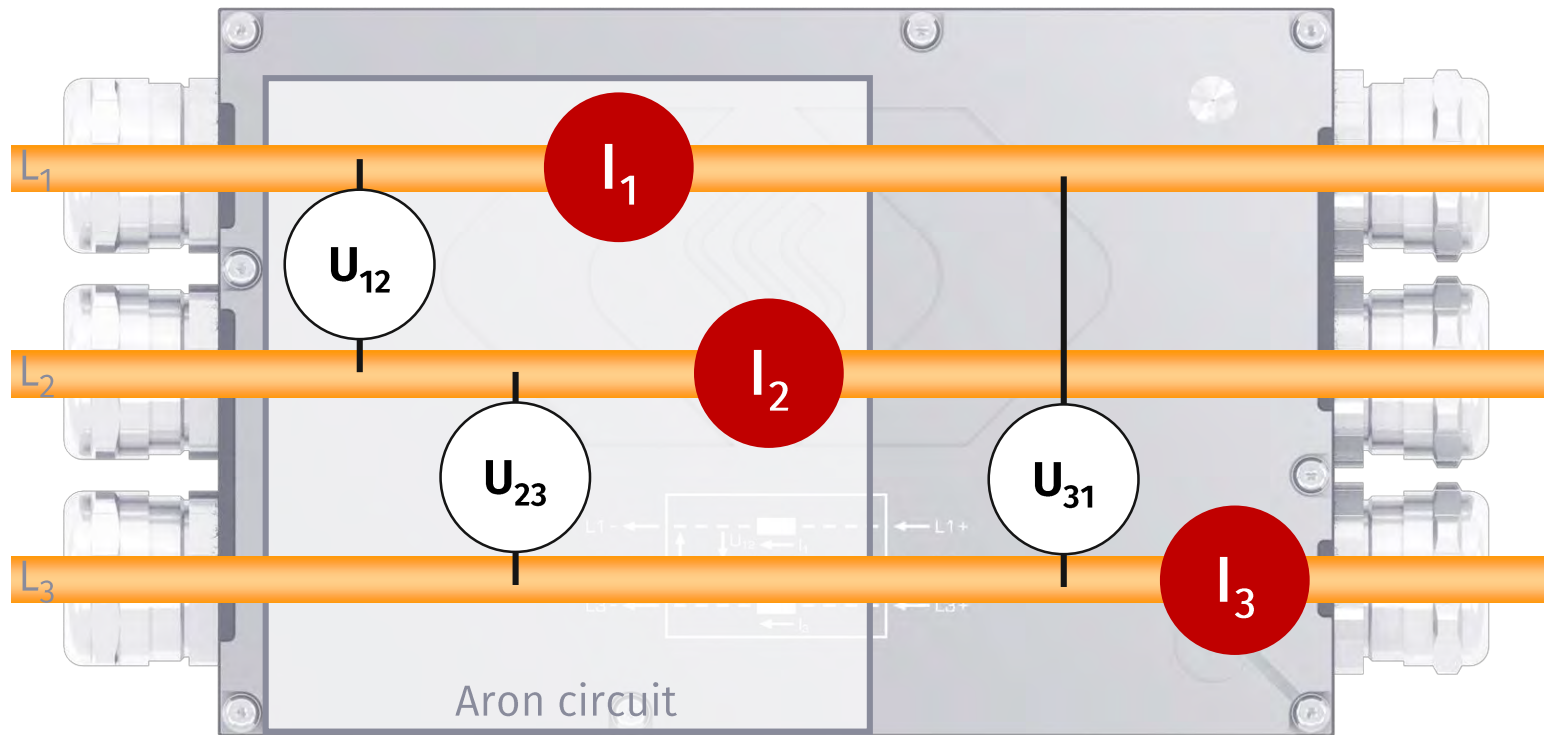
Charging Station



On-Board Charger

## Power Channels HV BM 3.x

### Measurement circuit 3P3W



### Two-wattmeter method

$$P = P(U_{12}, I_1) + P(U_{23}, I_2)$$

HV Battery

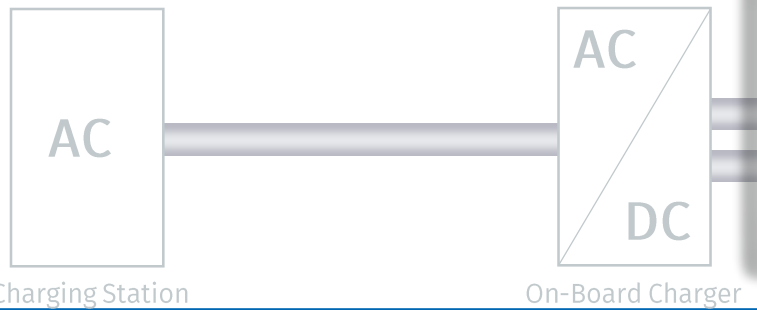
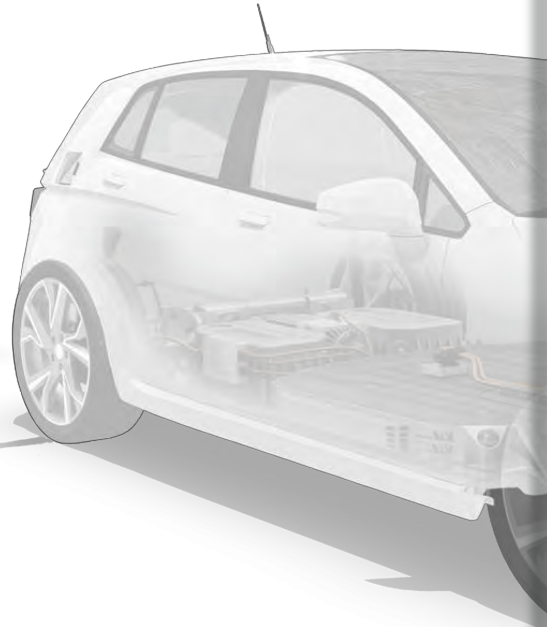
HV BM 1.2

Inverter

HV BM 3.3

Electric Motor

# Power Measurement with



## Power Channels HV BM 3.x



### ► Additional measurement channels

Device HVBM33\_00000

Settings

Device type: HV BM 3.3

Serial No.: 123

Device name: HVBM33\_00123

Device number: 0

Channels/Rate: 16: U/I, RMS/Power 10 ms / 100 Hz

Data format: INTEL

OK

Cancel

Measure

Read from device

HVBM33\_00123: HV BM 3.3, S/N 123, D/N 0, 16 channel(s), CAN identifiers: 0x0605...0x060D

- HVBM33\_00123\_U12: Display range -2000 V ... 2000 V, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_U23: Display range -2000 V ... 2000 V, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_U31: Display range -2000 V ... 2000 V, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_I1: Display range -100 A ... 100 A, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_I2: Display range -100 A ... 100 A, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_I3: Display range -100 A ... 100 A, filter: Std ( 15 Hz) Butterworth
- HVBM33\_00123\_U12\_RMS: Display range -2000 V ... 2000 V, filter: 20 Hz Butterworth
- HVBM33\_00123\_U23\_RMS: Display range -2000 V ... 2000 V, filter: 20 Hz Butterworth
- HVBM33\_00123\_U31\_RMS: Display range -2000 V ... 2000 V, filter: 20 Hz Butterworth
- HVBM33\_00123\_I1\_RMS: Display range -100 A ... 100 A, filter: 20 Hz Butterworth
- HVBM33\_00123\_I2\_RMS: Display range -100 A ... 100 A, filter: 20 Hz Butterworth
- HVBM33\_00123\_I3\_RMS: Display range -100 A ... 100 A, filter: 20 Hz Butterworth
- HVBM33\_00123\_P: Display range -200000 W ... 200000 W, filter: 20 Hz Butterworth
- HVBM33\_00123\_S: Display range -200000 VA ... 200000 VA, filter: 20 Hz Butterworth
- HVBM33\_00123\_Q: Display range -200000 var ... 200000 var, filter: 20 Hz Butterworth
- HVBM33\_00123\_Lambda: Display range 0 ... 1, filter: 20 Hz Butterworth



## Power Measurement with



## Power Channels HV BM 3.x

- ▶ Additional measurement channels
- ▶ Integration intervals
- ▶ Fixed integration times of 10 ms - 10 s
- ▶ Due to the measurement method
  - No measurement of leakage currents
  - No measurement of asymmetries



Charging Station



On-Board Charger

HV Battery

HV BM 1.2

Inverter

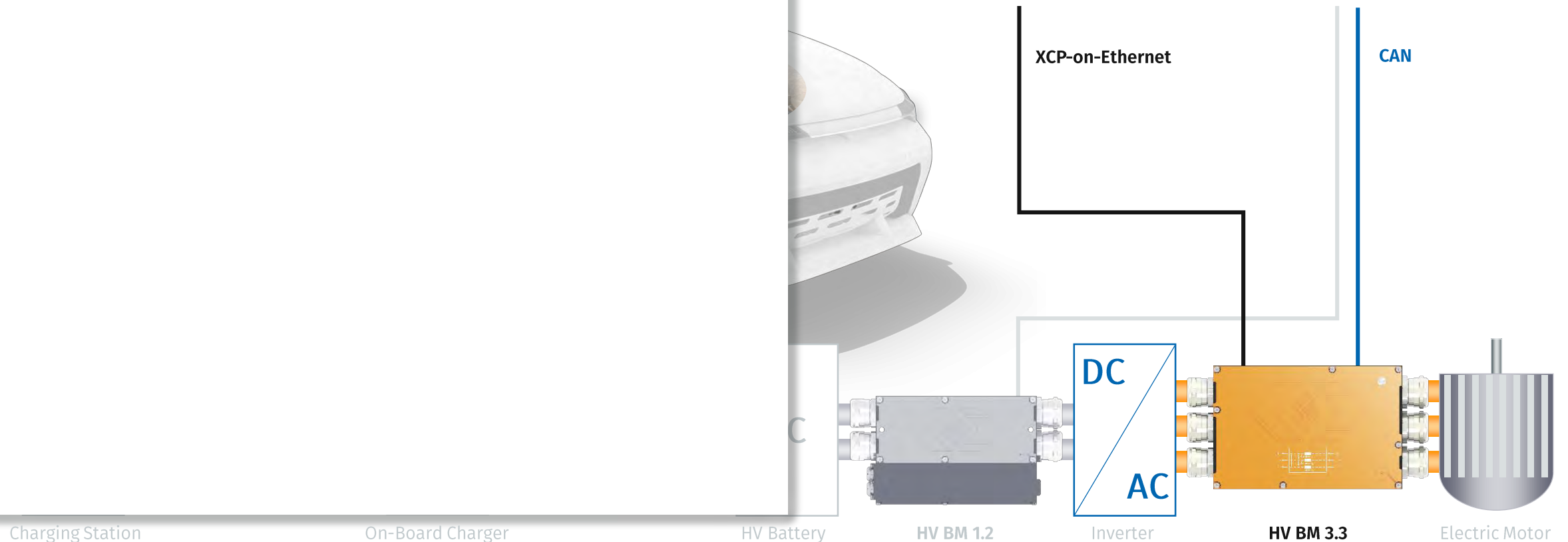
HV BM 3.3

Electric Motor

# Power Channels HV BM 3.x

- ▶ Additional measurement channels
- ▶ Integration times
- ▶ Data output via XCP-on-Ethernet and CAN

## Modules

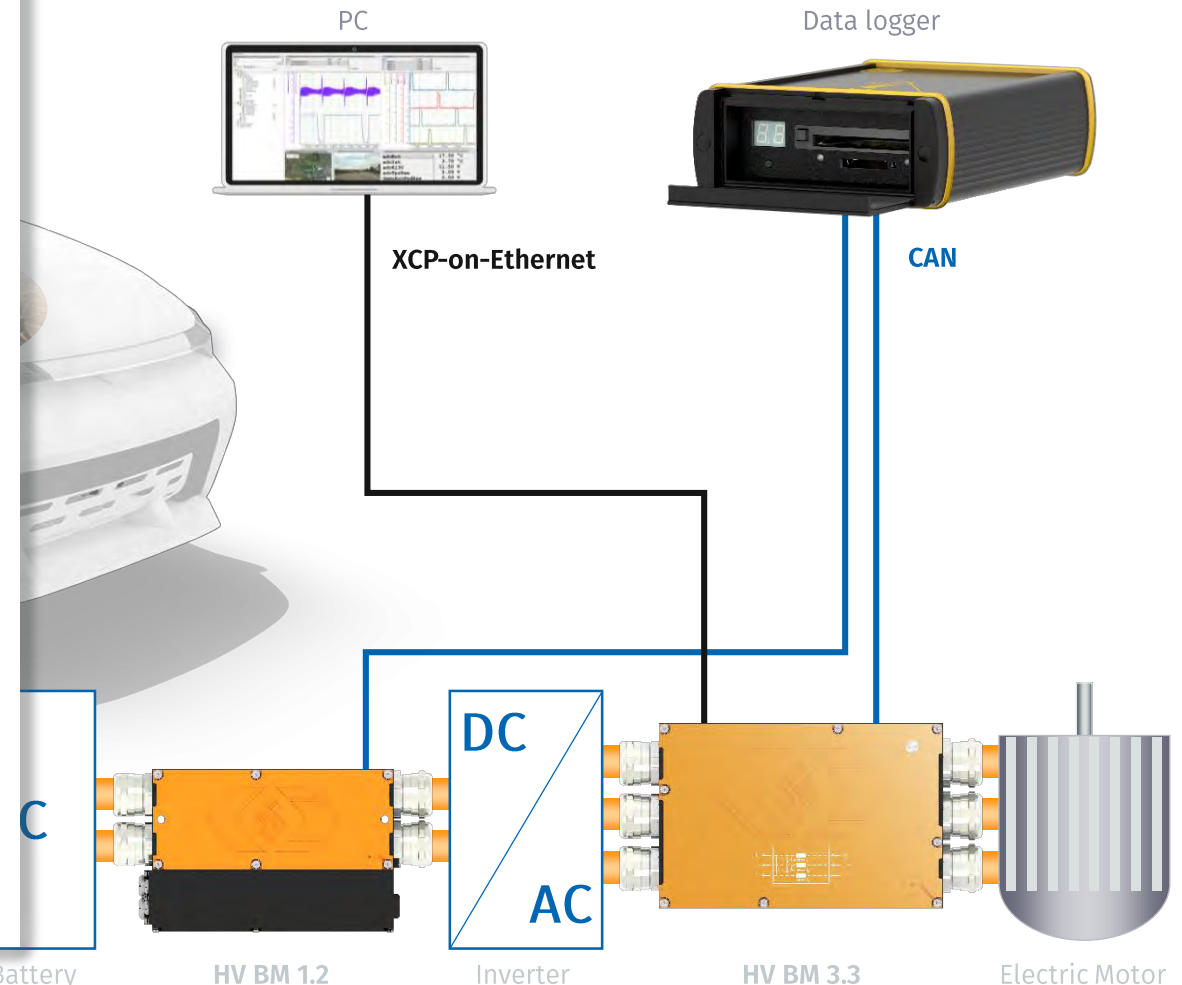


# Data output

## Measurement computer and data logger

- ▶ Output of power values together with values of current and voltage
- ▶ Via CAN and XCP-on-Ethernet
- ▶ Direct control on measurement computer
  - Reduced data stream
  - No additional load on the CPU of the computer
  - Direct further processing in the automation system
- ▶ Parallel recording on data logger

## Modules



Charging Station

On-Board Charger

HV Battery

HV BM 1.2

Inverter

HV BM 3.3

Electric Motor



# Data output

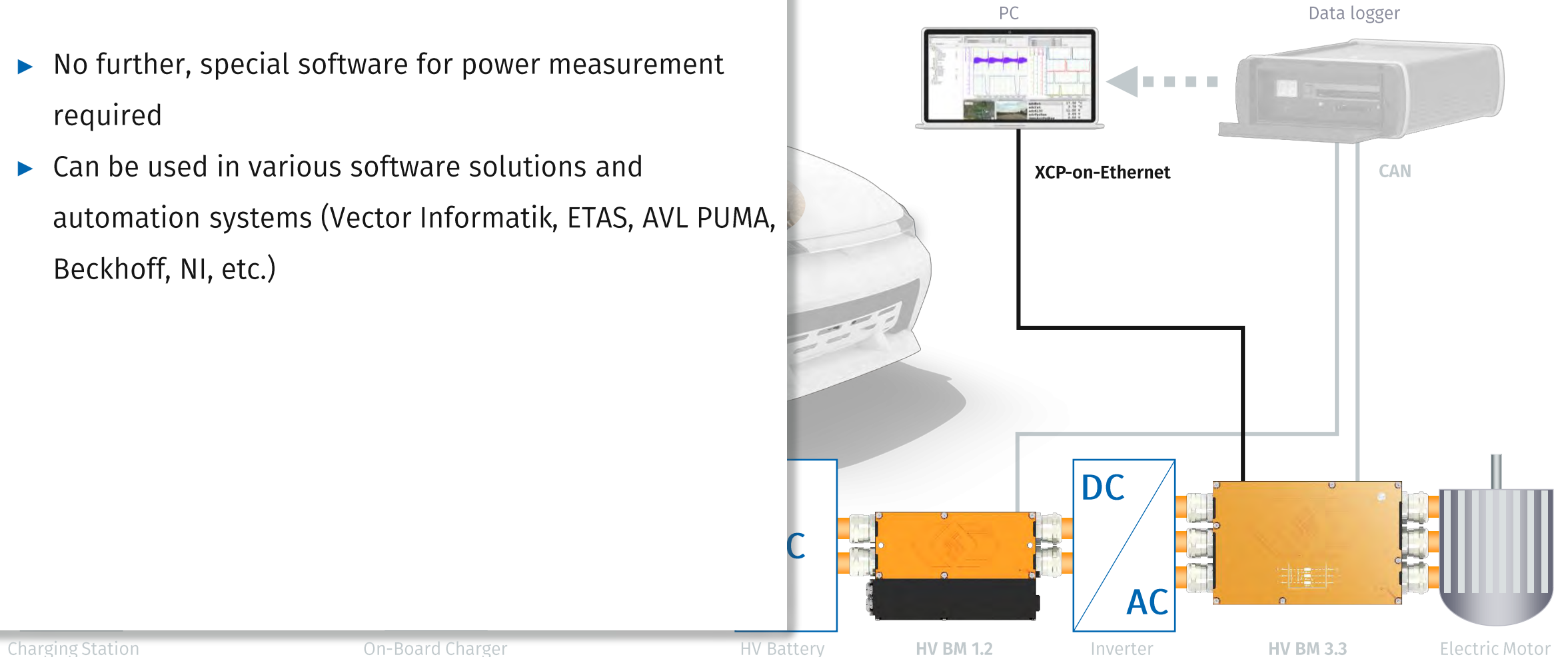
## Easy data integration into software solutions

- ▶ No further, special software for power measurement required
- ▶ Can be used in various software solutions and automation systems (Vector Informatik, ETAS, AVL PUMA, Beckhoff, NI, etc.)

## Modules

### Connectivity options:

- ▶ Standard (test bench) systems
- ▶ Data logger



# Data output

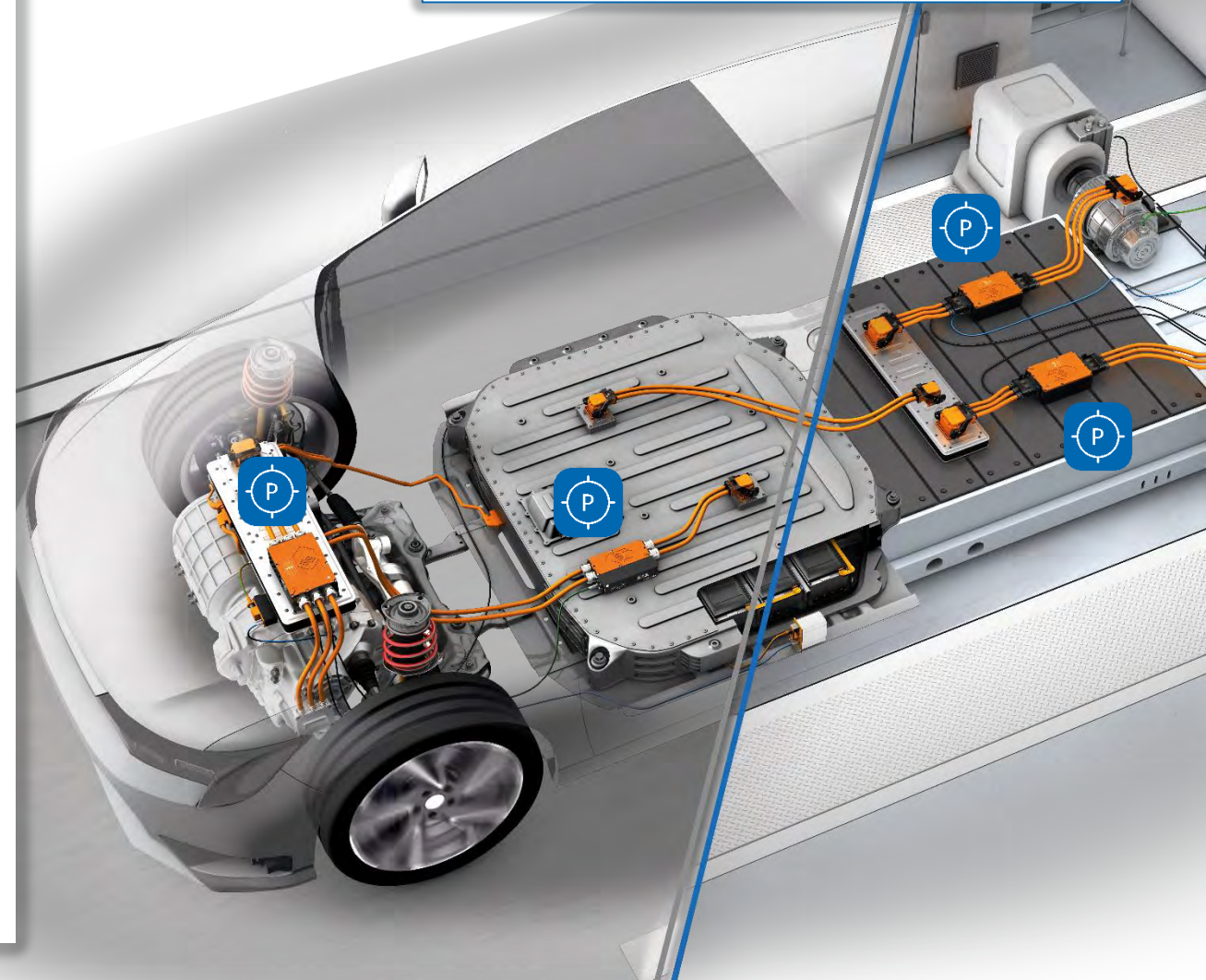
## Easy data integration into software solutions

- ▶ No further, special software for power measurement required
- ▶ Can be used in various software solutions and automation systems (Vector Informatik, ETAS, AVL PUMA, Beckhoff, NI, etc.)
- ▶ Same measurement technology in the road test as on the test bench
  - Measured values from both scenarios are directly comparable

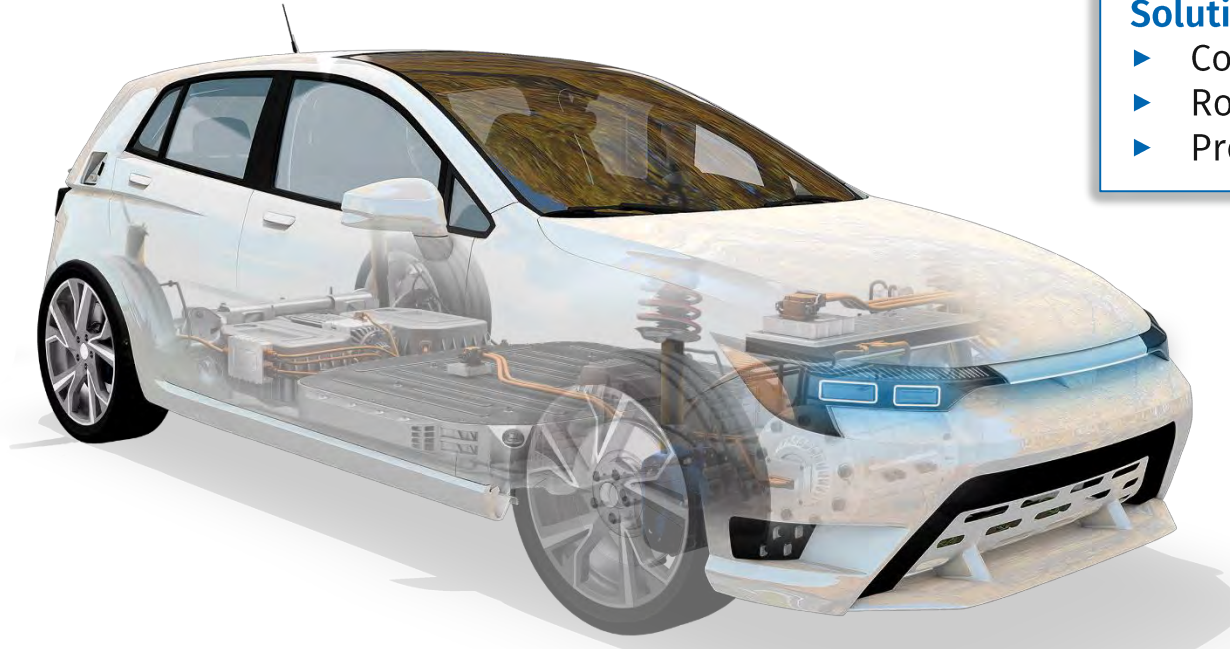
## Modules

### Connectivity options:

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# Power Measurement Requirements



## Solution for mobile application:

- ▶ Compact dimensions
- ▶ Robust housing
- ▶ Protection class IP 65 or higher

## Required values:

- ▶ Active power (P)
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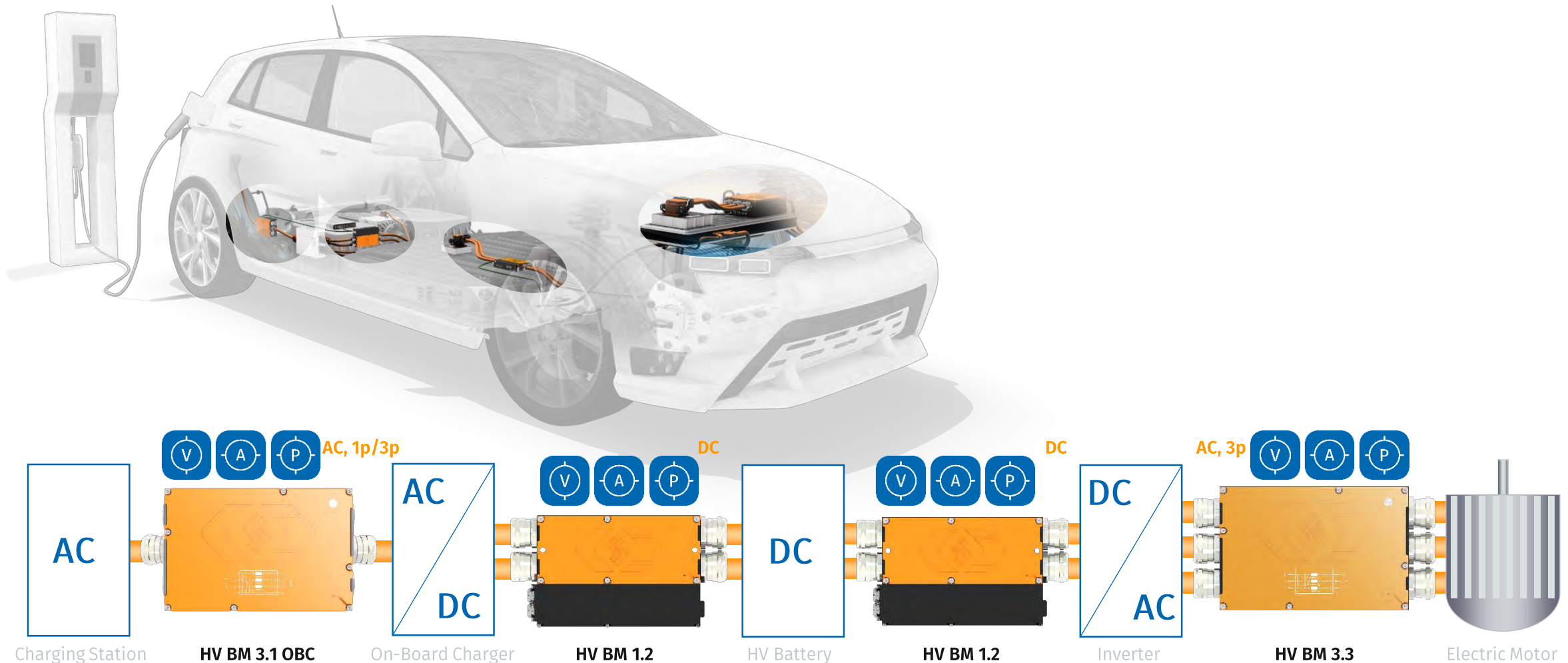
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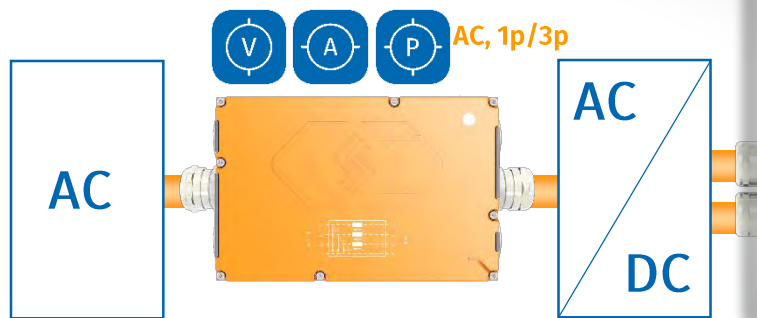
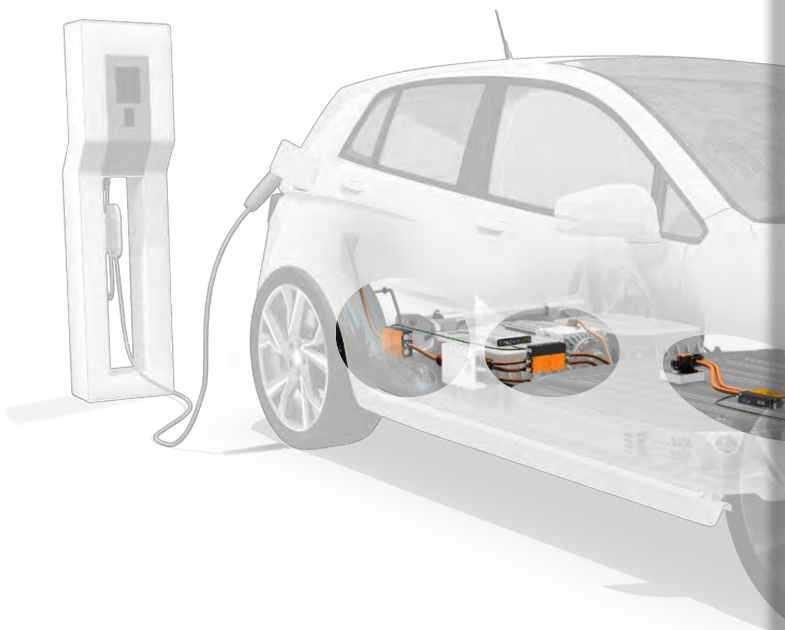
## Required:

- ▶ RMS values of current and voltage, even with AC overlays and current / voltage dips

# WLTP Measurement



# WLTP Measurement



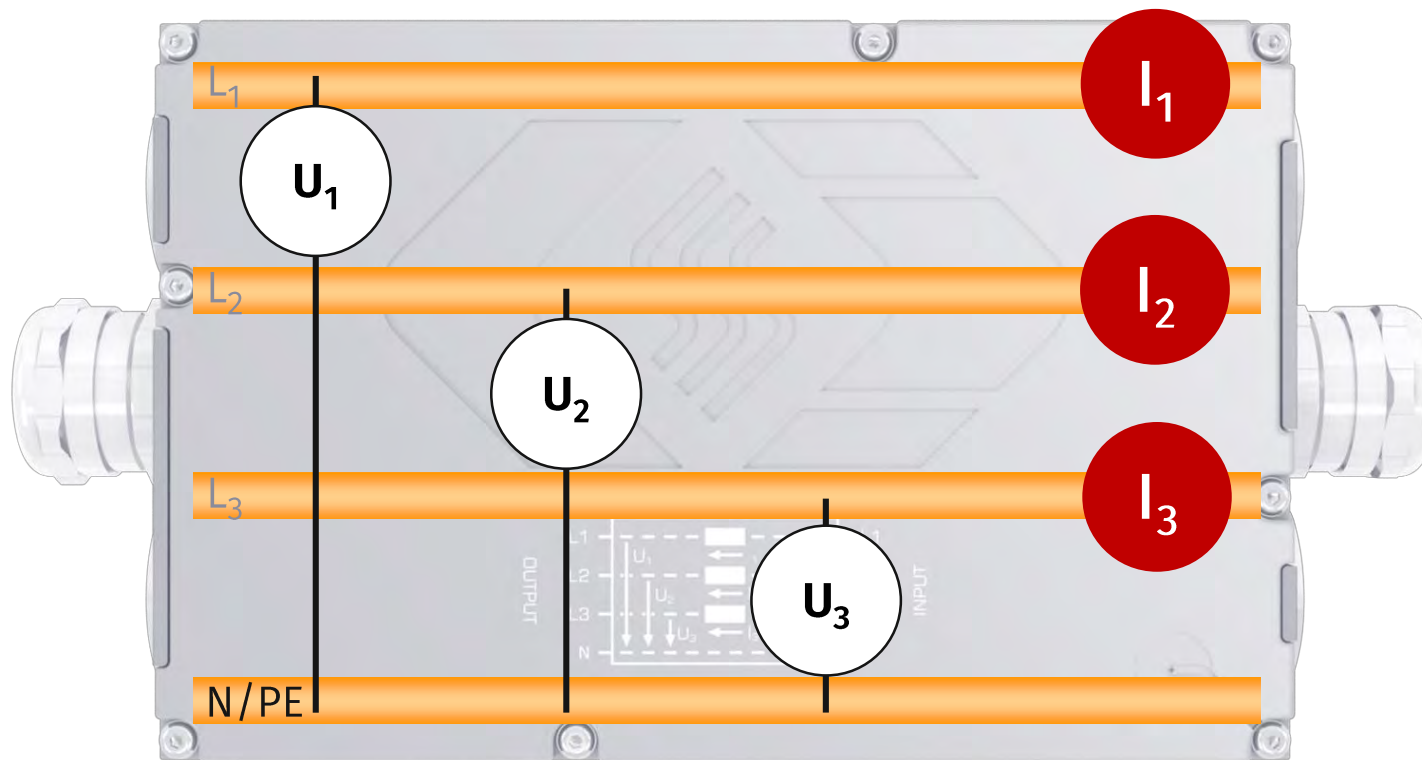
Charging Station

HV BM 3.1 OBC

On-Board Charger

## Power Channels HV BM 3.x

### Measurement circuit HV BM 3.1 OBC



HV BM 1.2

HV Battery

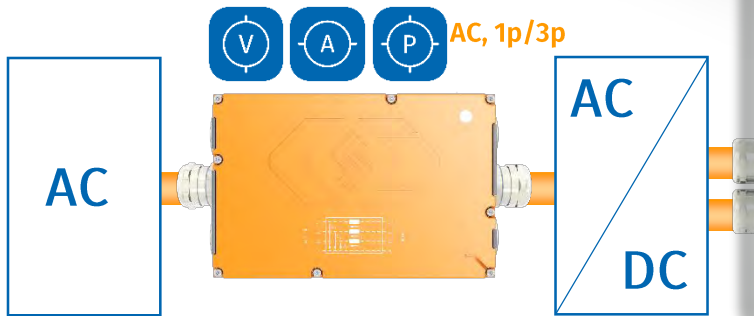
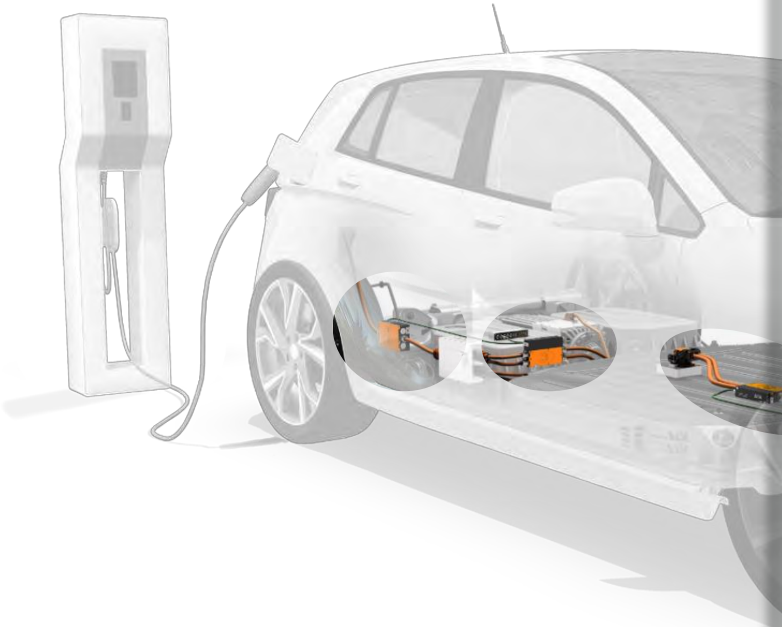
HV BM 1.2

Inverter

HV BM 3.3

Electric Motor

# WLTP Measurement



Charging Station

HV BM 3.1 OBC

On-Board Charger

HV BM 1.2

HV Battery

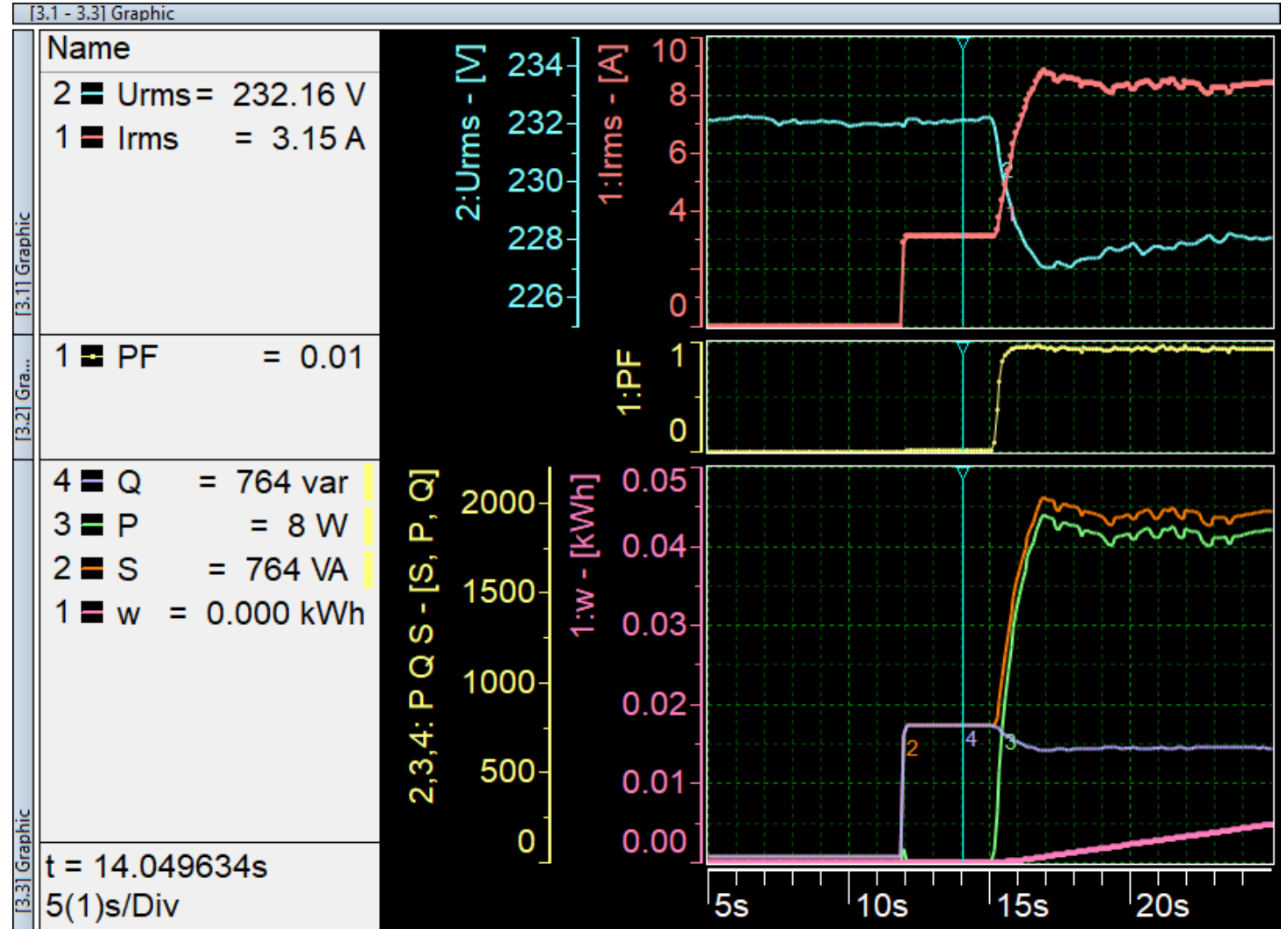
HV BM 1.2

Inverter

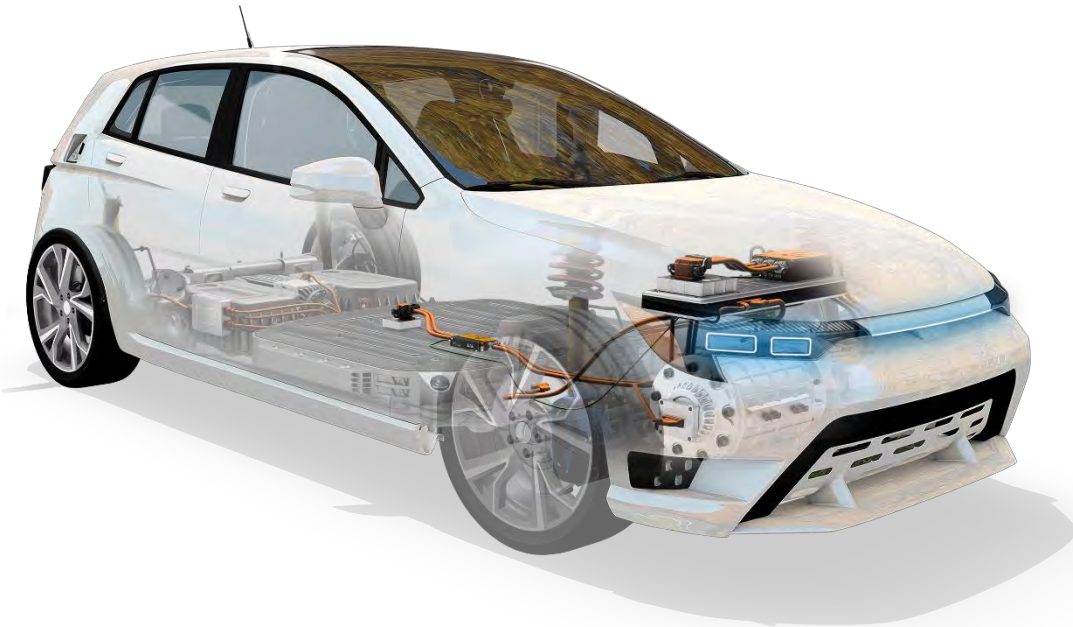
HV BM 3.3

Electric Motor

# 1-phase charging process of E-vehicle



# Power Measurement



## Other possible applications

- ▶ Energy consumption of individual components (e.g. during benchmarking)
- ▶ Maximum power output of (HV) batteries, fuel cell stacks, etc.
- ▶ Simple charging processes (e.g. DC fast charging, AC charging)
- ▶ Functional tests
- ▶ Acceptance and component test benches, dynamometers
- ▶ Endurance driving test
- ▶ Benchmarks
- ▶ System surveillance (monitoring)

# 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)

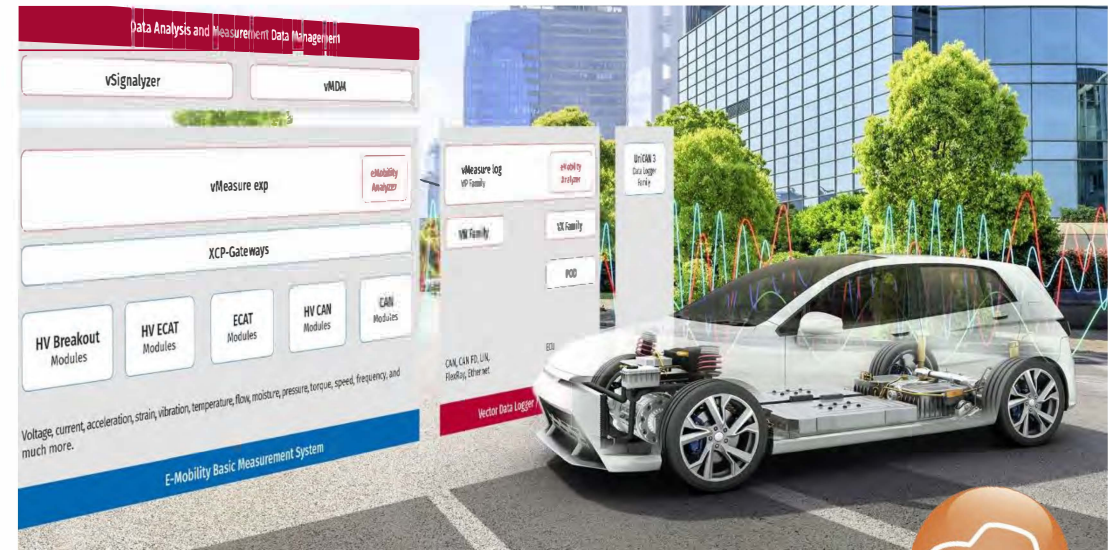
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[www.csm.de/webseminars](http://www.csm.de/webseminars)



**CSM** **Xplained**  
measurement technology