

Verification of High-Voltage Electrical Systems



HV Current and Voltage Measurement

The high-voltage electrical system in electric and hybrid vehicles is validated at every development stage and comprehensively tested for the series release. CSM's HV breakout modules for fast voltage and current measurement are especially suitable for these validation and acceptance tests. They are in accordance with the ISO 21498* standard, since these breakout modules can be used directly in the HV wiring of the on-board electrical system.

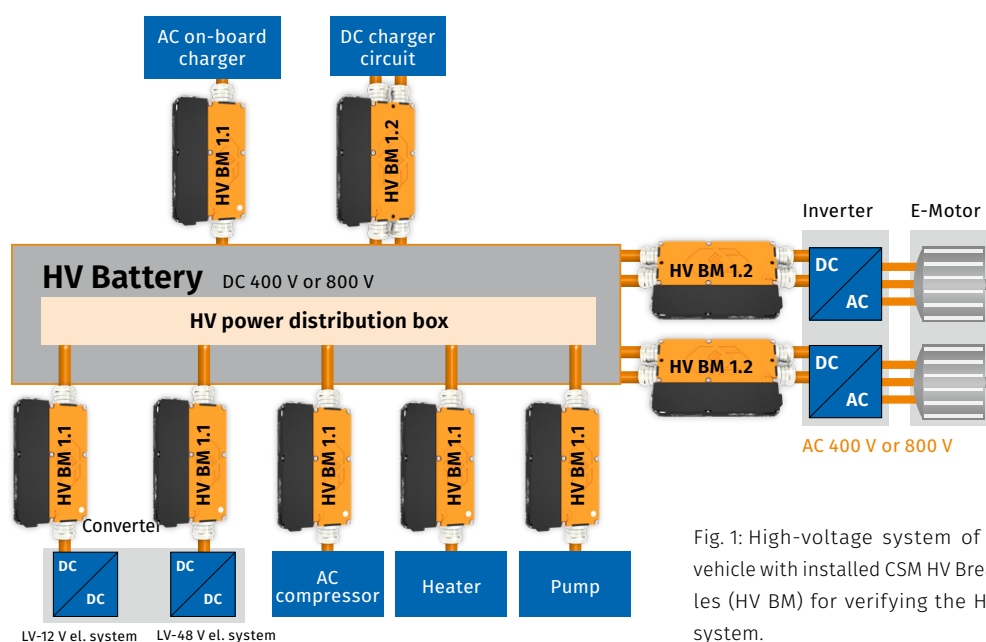


Fig. 1: High-voltage system of an electric vehicle with installed CSM HV Breakout Modules (HV BM) for verifying the HV electrical system.



Background

Vehicle manufacturers must ensure the quality of the HV electrical system to guarantee the operation of all the connected consumers with full functionality throughout the entire life cycle of the vehicle. The high-voltage electrical system installed in today's electric vehicles connects many different kinds of consumer systems to the powerful high voltage battery. However, all the inverters and converters with high-frequency switching power electronics used in the vehicle reciprocally cause a current and voltage ripple in the HV DC circuits. The significant voltage harmonic waves, called "ripples", are tested for their size and maximum dynamics (slope) in the development phase, and finally during the vehicle acceptance. Excessive voltage ripple causes component damage and failures. German automobile

manufacturers use proprietary standards, such as MBN LV 123 (Mercedes), GS 95023 (BMW) and VW 80303 (Volkswagen), as guidelines for the "Electrical properties and electrical safety of high voltage components in motor vehicles - requirements and tests". They define the precise test conditions for testing high-voltage components in electric and hybrid vehicles. During the vehicle acceptance phase before the release for series production, the complete high-voltage electrical system is verified with high-speed voltage and current measurements in operation.



* ISO 21498 Electrically propelled road vehicles – Electrical specifications and tests for voltage class B systems and components – Part 2 Electrical tests for components

Extended manufacturer-specific test conditions that go beyond these proprietary standards are also applied to ensure that the electrical system is robust enough for all everyday requirements.

Tests measure whether the voltage dynamics caused by switching power electronics and voltage ripple remain within their defined limits even in critical driving situations. Otherwise malfunctions, tripping of contactors or functional failures will be the

result. Voltage peaks can occur in certain driving situations. E.g. when the torque of the e-motor changes suddenly due to violent collisions with curbstones or driving on critical off-road terrain and over potholes. Such abrupt load changes cause extreme impact on the high-voltage electrical system with its consumers.

Challenge

One particular challenge is how to quickly and precisely record the voltage and current characteristics in the vehicle's high-voltage wiring system while driving. It is not reasonable not to measure while driving because test bench measurements cannot adequately simulate the critical driving situations that must be examined. Measurements have to be taken with a high sampling rate in the wiring not only downstream of the high-voltage battery, but also in the HV DC circuits of the respective consumers.

Additionally, the entire measuring system must be designed to be flexible, resilient, high-voltage resistant and reusable. Today in an eSUV Type A, tomorrow in an ePremium limousine Type B, or in a

prototype vehicle that is only available for a short time.

Further challenges arise with the required test procedure. A real-time analysis of all the signals, up to 30 in some cases, is necessary so that the immediate effects of driving situations can be detected online. Smart triggering of the measurement and analysis system must also be possible for recording transient voltage peaks and events while driving together with all the ECU data. Ideally, the measurement and analysis system should be linked to a professional measurement data management system.

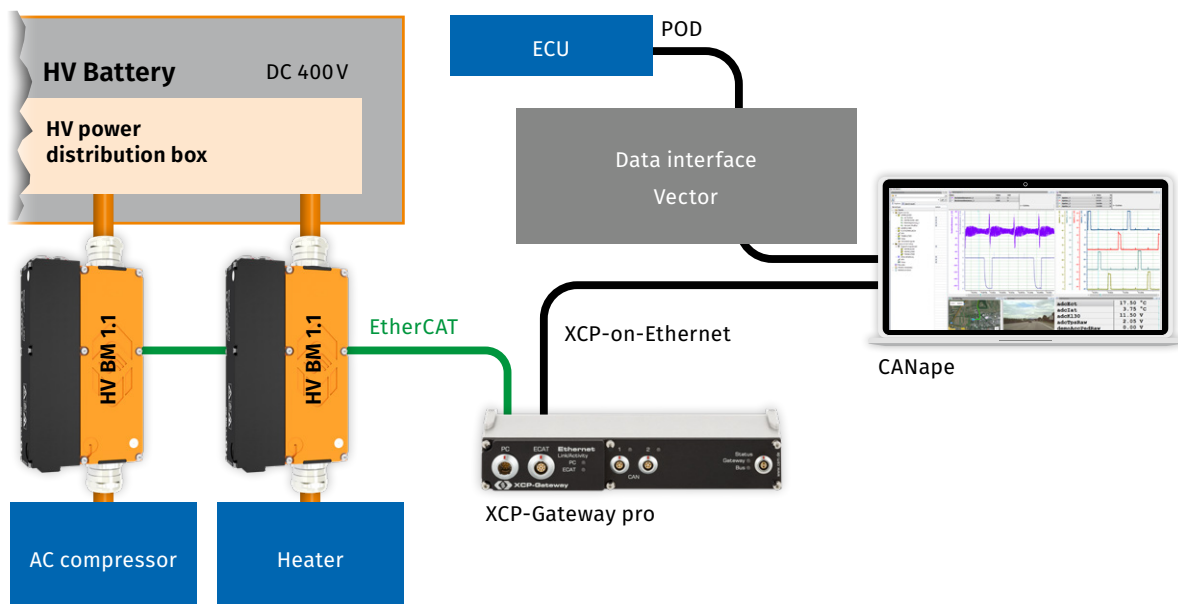


Fig. 2: The measurement setup

 **The CSM Measurement Solution**

Tests during the test drive are only possible with a perfectly harmonised tool chain comprising HV-safe and robust measuring modules, an ECU measuring system, software for synchronised measurement data acquisition and real-time data analyses. This measuring system was developed by CSM in collaboration with Vector Informatik and Daimler AG.

The CSM **High-Voltage Breakout Modules** have been specially designed for safe measuring applications in live high-voltage wiring systems under harsh mobile conditions. The HV BM can be optimally configured for the measuring task by selecting a suitable measurement shunt for measuring the current with variable voltage and current measurement ranges.

All the utilised HV BMs send the sampling readings either directly or via a Vector data interface to the analysis computer at a data rate of up to 1MS/s per channel. Currents and voltages are

recorded with high precision. Up to 30HV signals and all the required ECU measurement data are synchronously recorded by the Vector software vMeasure or CANape, and processed directly in real time. Time synchronisation of the various measuring channels is assured by the Precision Time Protocol (PTP) or alternatively by means of hardware synchronisation.

Users can trigger measurements in response to specific events or calculate other variables relevant to the test. In order to detect sporadic voltage peaks at the already existing fundamental ripple of the HV voltage, mathematical trigger conditions such as derivatives of the voltage signal over time can be applied. Triggering avoids the unnecessary storage of huge volumes of data. For example, all the signal and vehicle bus data for a configurable time window for the trigger event can be stored.

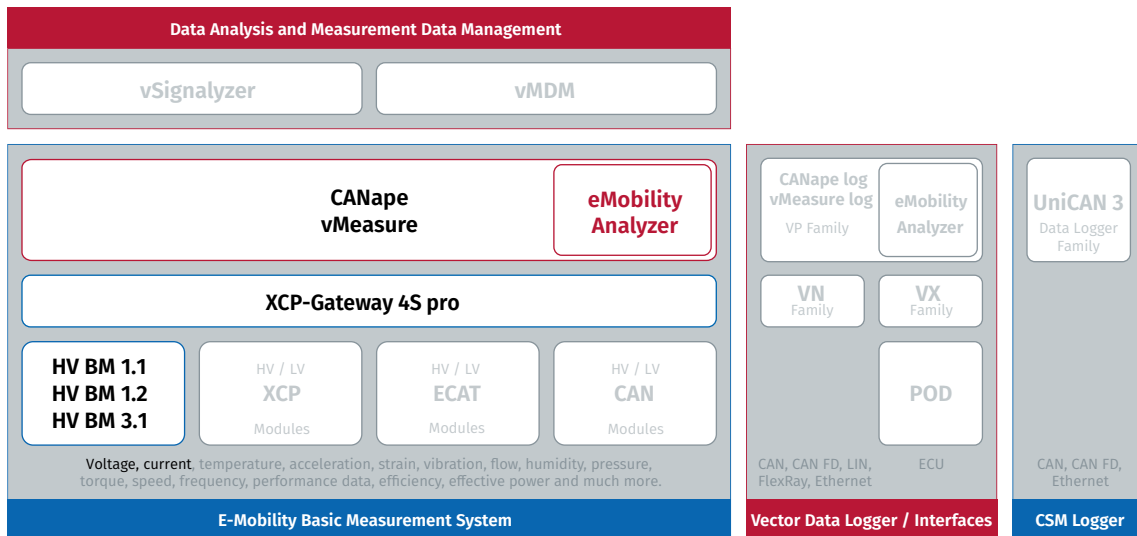


Fig. 3: The verification of high-voltage electrical systems in the systematics of the Vector CSM E-Mobility Measurement System

Benefits

Innovative HV measuring system for validation measurements and verification of the on-board HV electrical system during road tests and on test benches.

- ▶ CSM HV Breakout Modules installed in the vehicle allow the distributed measurement of high currents, voltages and powers in the HV wiring (up to 95 mm²) while driving. With the HV cables connected in the module and the closed lid, the measuring device is enclosed for water-tightness and high-voltage protection.
- ▶ The CSM HV measuring system can be used in the same manner on component test benches or climatic roller test stands. This enables the test engineers to accompany the development of the high-voltage wiring system through the different generations of a vehicle.
- ▶ In practice, further measurements are frequently required for verification purposes. They are simply conducted using additional CSM measurement modules, e.g. for monitoring the voltage ripple in the 12V / 48 V electrical system or measuring the temperature of the HV wiring under sustained extreme loads.
- ▶ Parallel to the real-time analysis of all the signals from the HV DC circuits of a HV electrical system, the data from all the vehicle buses and control units can also be analysed. This allows the cause of an event to be precisely examined.
- ▶ CSM can also supply custom Breakout Modules with HV cables, connectors and sockets in the required length for simple and reusable installation in vehicles. This allows fast measurements to be conducted on a test vehicle that is only temporarily available.
- ▶ Connection options with PowerLok plug-in system are available for measurements on test benches. This allows test objects to be changed quickly and safely, e.g. if several components and correlations are to be tested.



Fig. 4: CSM HV Breakout Module with connected cables, connectors and socket as a ready prepared, HV-safe plug-in system. The CSM HV BM system allows the distributed measurement and real-time analysis of high currents, voltages and outputs in the HV cables while driving at a sampling rate of up to 1MHz/signal.



Featured Products

HV Breakout Module - Type 1.1 | 1.2

CSM's HV Breakout Modules (BM) Type 1.1 and 1.2 have been specifically designed for safe measurement applications on high-voltage cables. Current and voltage are measured and the instantaneous power is calculated online in the module.

The HV Breakout Module 1.2 is available in two versions for connection via cable glands or PL500 plug-in system (HV BM 1.2C).



HV Breakout Module - Type 3.1

The HV Breakout Module (BM) Type 3.1 was developed for the three-phase determination of power, current and voltage on high voltage carrying cables with currents up to ± 32 A. The three-phase measurement with only one measurement device offers enormous cost and space advantages.



XCP-Gateway Series

The protocol converters of the XCP-Gateway Series were specially developed for CSM EtherCAT® measurement modules and for measurement tasks with many measurement channels and high measurement data rates. The XCP-Gateway is available in "Basic" and "pro" versions. The latter has two CAN interfaces via which CAN-based CSM measurement modules can be connected and integrated into the XCP-on-Ethernet measurement data protocol. In the "pro" version, temperature data from the HV Breakout Modules can also be transferred directly via EtherCAT®.



Complete solutions from a single source:

CSM provides you with comprehensive complete packages consisting of measurement modules, sensors, connecting cables and software - customized to your individual needs.

Further information on our products are available on our website at www.csm.de or via e-mail sales@csm.de.



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