Measuring Shield Current of High-Voltage Cables in Electric Vehicles

Electric vehicles have a complex high-voltage (HV) electrical system including highly specialized power cables. For both safety and mitigation of electromagnetic interference, these cables have a braided shield between the inner and outer insulators (Fig. 2). This shield carries its own current, which can be affected by the magnitude of the current and ripples within the inner conductor. These effects increase with the length of the cable and the size of the conductor. In vehicles that have a high current draw, such as high-performance sports cars or heavy commercial vehicles, it is important to measure these effects in order to determine if the cable shield is adequate for the demands of the system.

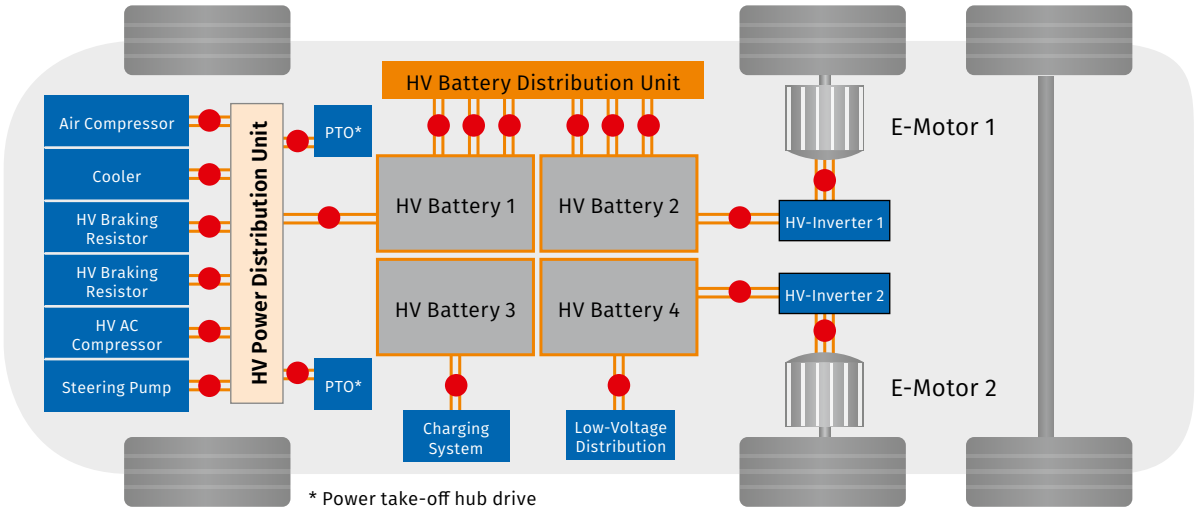

Fig. 1: Shield current measurement on an electric truck. The length of the cables causes different shield currents in the different areas of the high-voltage electrical system. At the measuring points marked in red, the shield current is measured in the individual HV cables with CSM HV breakout modules.

Background

An electric vehicle may have several batteries to power multiple electric motors that drive the axles and other components, plus pumps, brake resistors and cooling systems; all these systems must work in parallel. The sheer number of synchronized components in any electric vehicle can cause a significant voltage ripple in the on-board high-voltage electrical system, increasing the current carried by the braided cable shield.

It is likely that these combined effects may exceed the shield's capacity. This may cause overheating, melting the cable insulator, and damaging the cable. Another side effect of sustained high shield currents is the premature aging of cable glands and the associated components in the harness connector.

Replacing parts damaged by excessive shield currents in the cables of a production vehicle is expensive and time consuming. Shield currents should be measured in all circuits of electric vehicles during their development. Every circuit must be measured simultaneously so that the mutual influence of adjacent components can be monitored under every load condition.

Until now, measuring shield current has been complex and difficult to accomplish. Traditional instrumentation was not optimized for in-vehicle packaging or the working environment. Furthermore, obtaining accurate shield current measurements synchronized with working current in

a single cable was challenging; attempting to measure shield currents simultaneously in all circuits throughout the vehicle was even more cumbersome and time consuming.

As is typical with the successful introduction of innovations, users will identify applications for the technology beyond the scope of the original design. Such is the case with the CSM High-Voltage Breakout Module. This module was originally intended to simultaneously measure voltage and current for eMobility, but one customer identified the ability to measure shield current with only minor modifications to the HV BM design.

This use-case introduces the HV BM 1.2 /S for a simplified and synchronized measurement of shield currents on high-voltage cables throughout an electric vehicle.

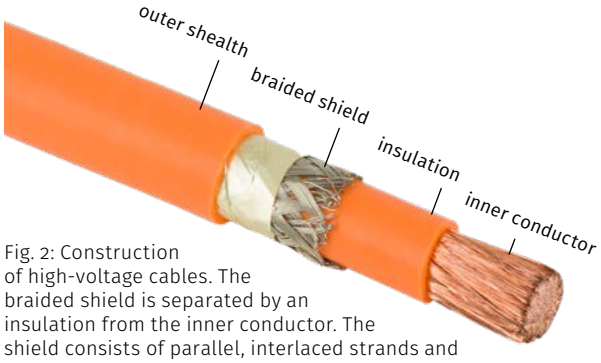

Fig. 2: Construction of high-voltage cables. The braided shield is separated by an insulation from the inner conductor. The shield consists of parallel, interlaced strands and a film screen. AC components in the inner conductor induce currents in the shielding braid.

The CSM Measurement Solution

Shield currents are measured via the internal shunt of the HV BM. In order to achieve accurate measurement of the shield current, a well-constructed, low impedance connection of the shield braid to the measuring shunt is required. For this purpose, the coaxial shielding is separated above the insulated inner conductor and connected to the shunt. The sampling rate must be at 1MHz to detect all the high-frequency shield current peaks.

Fig. 1 shows the dynamometer measurement setup for shield currents in the HV cable network of an electric commercial truck being developed by a major OEM. Every auxiliary unit is powered by several HV batteries, and switched on simultaneously during operation. Multiple HV BMs are securely installed on the vehicle frame at all the necessary points in the HV on-board electrical system, as indicated by red dots. The shield current measurements are performed synchronously in all circuits during a specified dynamometer driving cycle to obtain an accurate picture of the maximum shield currents.

CSM HV Breakout Modules

For the measurement of shield currents on high-voltage cables, CSM specially developed the HV breakout module type HV BM 1.2 /S. Like all our HV BM products, they are designed for safe measurement applications in high-voltage cables for rough, mobile use. Using proprietary isolation barriers , measurement technicians and downstream equipment are protected from high -voltage short circuits. The HV BM housing is IP67 rated, protecting the cable connections, shunts, and measurement electronics inside the unit. The HV BM modules are highly configurable with various cable gland sizing options, and shunt amperages ranging from 50-800 A (1400 A peak).

The HV BM transmits the measured data (U, I, calculated P) to the analysis converter at a data rate of up to 1 MHz (1 µs) per channel via an EtherCAT® interface. Currents and voltages are sampled with high precision and synchronicity . Lower transmission rates can also be output via the CAN interface.

The Vector-CSM Measuring System

Fig. 3 shows a subset of the entire measurement system where the shield current data and temperature data are transmitted to the analysis software via CSM XCP-Gateway. For applications requiring high sampling rates, such as shield current measurement, CSM HV BMs are networked via EtherCAT®.

Other measurements that do not require high sampling rates, such as thermal data, are taken with CSM's CAN-based HV miniModules.

The high-speed data via EtherCAT® and the low-speed data via CAN are both channeled through the XCP-Gateway. This gateway is a converter from EtherCAT® protocol to the popular XCP-on-Ethernet protocol for use in data analysis software. In this example the software used is vMeasure exp or CANape from Vector, allowing for real time analysis while the data is recorded on the analysis computer. The user can define certain events, such as current peaks, to trigger the recording of data.

The Vector CSM measuring system can detect up to 40 measuring channels. Each channel can have up to 1 MHz per second sampling rate and can be synchronized to within 1 µs.

The measurement system can be extended with a Vector interface if the vehicle is to be calibrated via the serial POD interface (Plug on Device) with the analysis computer. The advantage here is that variables from the control unit are recorded simultaneously with the measured values of the CSM modules.

In conclusion, CSM's measurement modules for High-voltage applications provide the speed, accuracy, and performance required for optimizing electrified vehicles. Being rugged and durable, they are ideal for on-vehicle use and well suited for test bench applications.

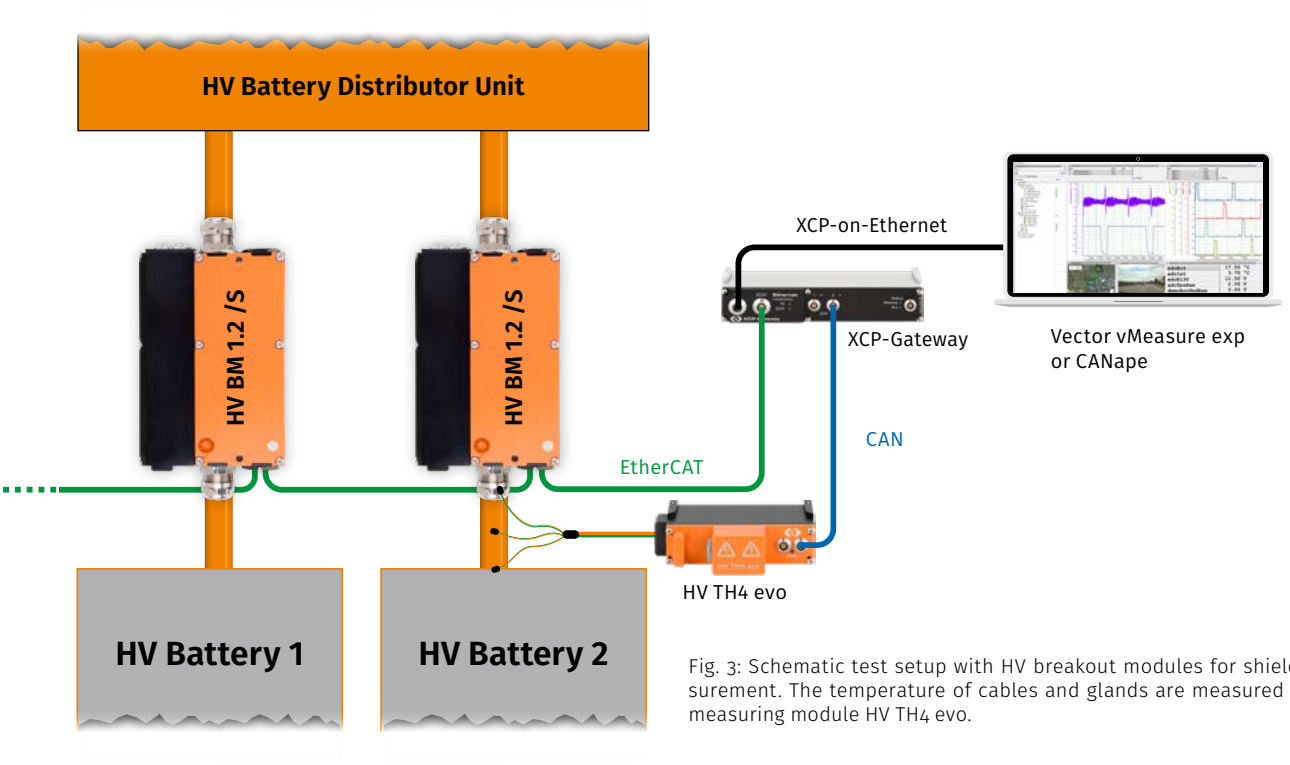

Fig. 3: Schematic test setup with HV breakout modules for shield current measurement. The temperature of cables and glands are measured with a thermal measuring module HV TH4 evo.

Featured Products

HV Breakout Module - Typ 1.2 /S

The HV Breakout Module (BM) Type 1.2 /S has been specially developed for shield current measurement on cables carrying HV voltage.

XCP-Gateway Series

CSM's XCP-Gateway Series protocol converters were specially developed for CSM EtherCAT® measurement modules and for measurement tasks with multiple measurement channels and high measurement data rates. The XCP-Gateway is available in "Basic" and "pro" versions. The "pro" version 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®.

HV TH4 evo

CSM's HV TH4 evo measurement module allows safe temperature measurements with thermocouples on high-voltage components. Thanks to its compact design and reinforced insulation up to 1,000 V RMS, it is particularly suitable for decentralised use in road tests.

CSM provides you with comprehensive complete packages consisting of measuring 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.

Innovative Measurement and Data Technology

CSM Products, Inc.
1920 Opdyke Court, Suite 200 • Auburn Hills, MI 48326 • USA
Phone: +1 (248) 836-4995 • Fax: +1 (248) 836-4997
info@csmproductsinc.com • www.csmproductsinc.com