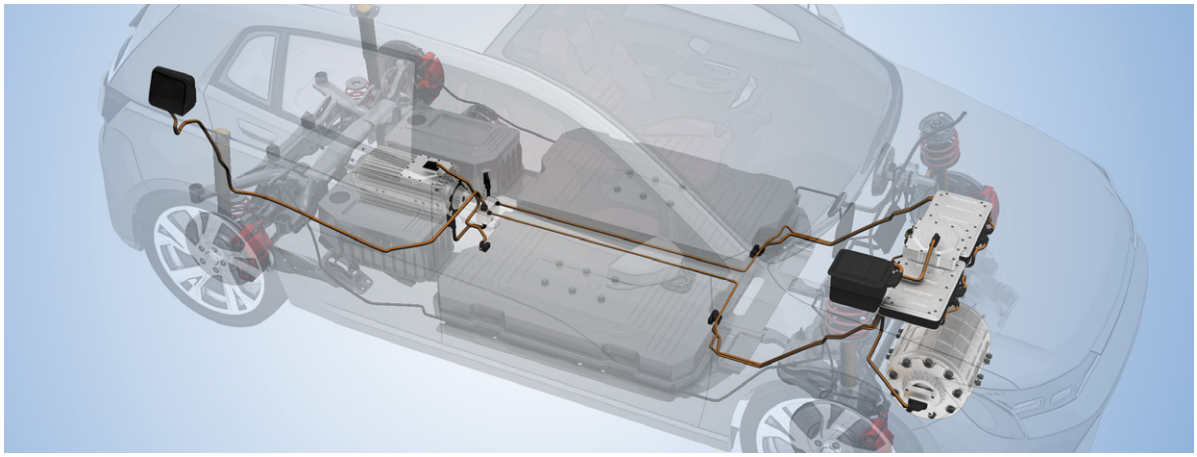
Fast Measurement of Voltage and Current Flows on E-Machines

HV Current and Voltage Measurement

This is a familiar use case in the design and development of the electric powertrain. Voltage and current flows need to be measured and analyzed at high sampling rates to detect disturbances such as overshoots. A real-world measurement setup is described in this case study. Voltages and currents of a three-phase, inductively and separately excited synchronous machine are recorded with CSM HV Breakout Modules. All charts display data measured on the test bench with a 1-µs time resolution.



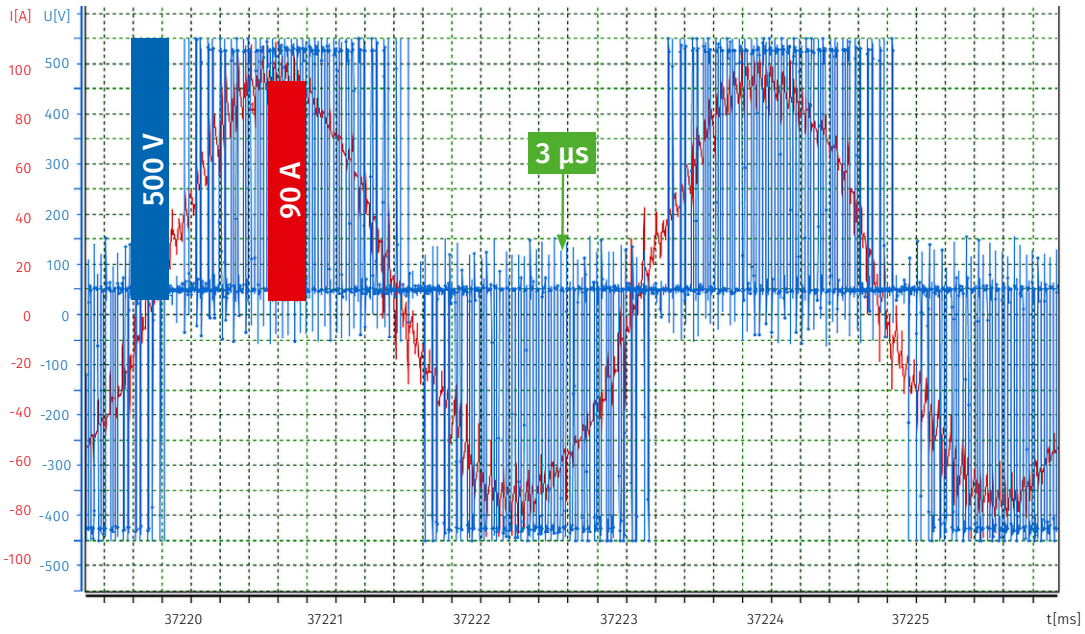


Fig. 1: Voltage and current curves of a single phase (at 4500 rpm and 37 Nm)

Background

High-voltage proof shunts, in this case CSM HV Breakout Modules (HV BM), were mounted in each of the phases of the three phase synchronous machine (Fig. 2) which had a power rating of 43 kW. The currents to be measured were in the range of ±90 A. The voltages of the three external conductors were measured too. The battery voltage was 480 V. The motor was exposed to different load scenarios on the test bench by varying the speed and the output torque.

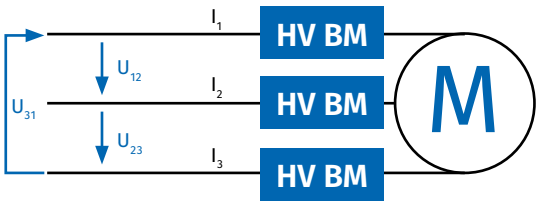


Fig. 2: Application of three HV BM devices at the e-machine

Challenge

The inverter operates with a fundamental frequency of 24 kHz (41.6 µs). This implies that a time resolution of the measured values in the microsecond range is required in order to correctly pick up the short PWM voltage pulses at small loads.

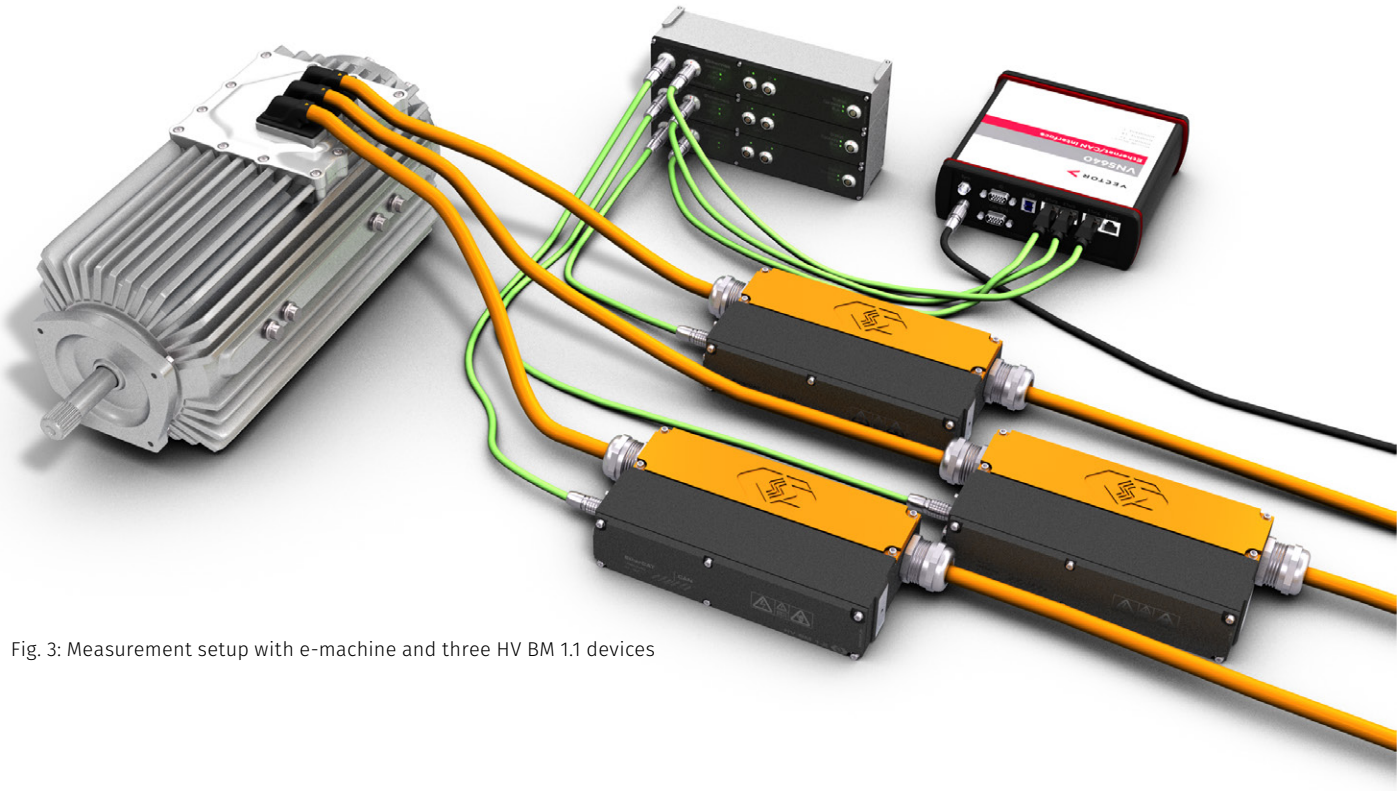


Fig. 3: Measurement setup with e-machine and three HV BM 1.1 devices

The CSM Measurement Solution

Based on the example of one phase, Fig. 4 illustrates that the high time resolution of CSM HV BM of 1 µs enables the precise recording of both current and voltage. CANape from Vector Informatik GmbH was used for data acquisition as this system allows the synchronous recording of the incoming measurement data via XCP-on-Ethernet at 16 MS/s (mega samples per second).

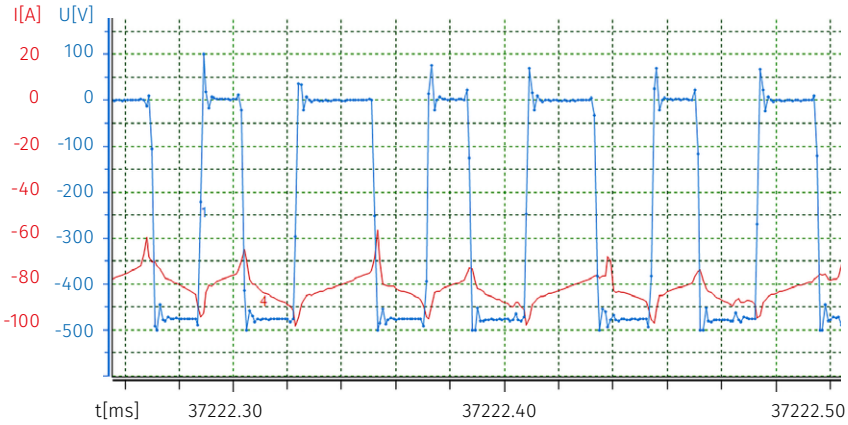


Fig. 4: Detail view of voltage pulses for a single phase (at 4500 rpm and 37 Nm)

Fig. 5 displays the three phase-to-phase voltages and the three phase currents of the e-machine, each of them recorded at a 1-MHz sampling rate. The time synchronization of the different measurement points is in the microsecond range and can be implemented both via hardware and PTP (Precision Time Protocol, IEEE 1588). This allows to analyze efficiency and to carry out high-precision efficiency or power calculations.

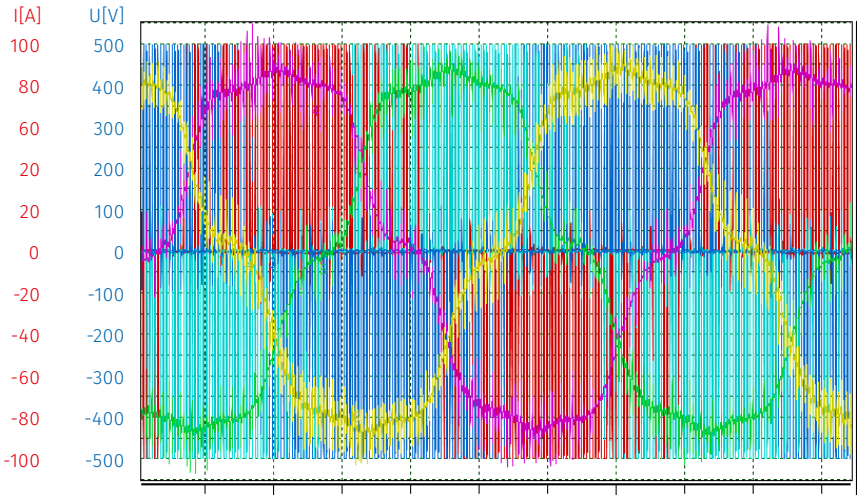


Fig. 5: Current and voltage curves for all three phases (at 2000 rpm and 37 Nm)

Mathematical and physical models that are used for electric powertrain development have to be verified experimentally, hence precise measurements with detailed time resolution are needed The three HV BM measurement devices from CSM deliver the needed accurate and synchronized values of voltage and current with a down to 1 µs time resolution (Fig. 6). Unwanted effects or faults can be detected as well with this measurement system.

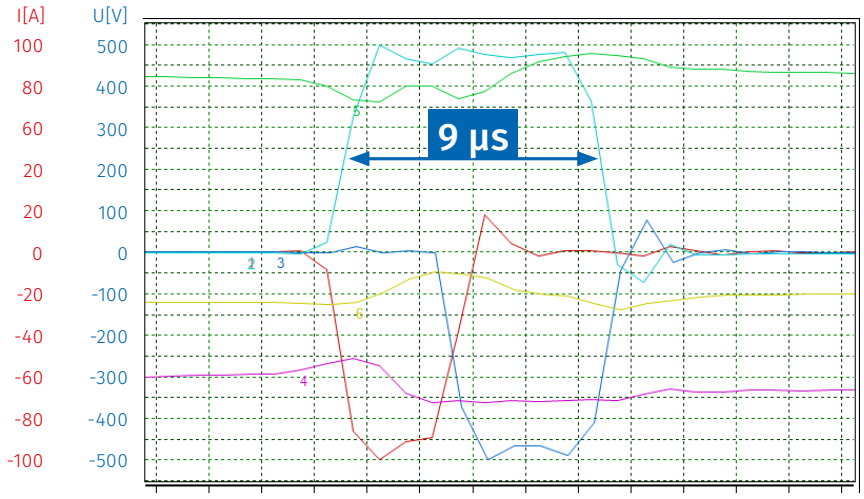


Fig. 6: Detail view of the three PWM voltage curves and phase currents (at 2000 rpm and 37 Nm)

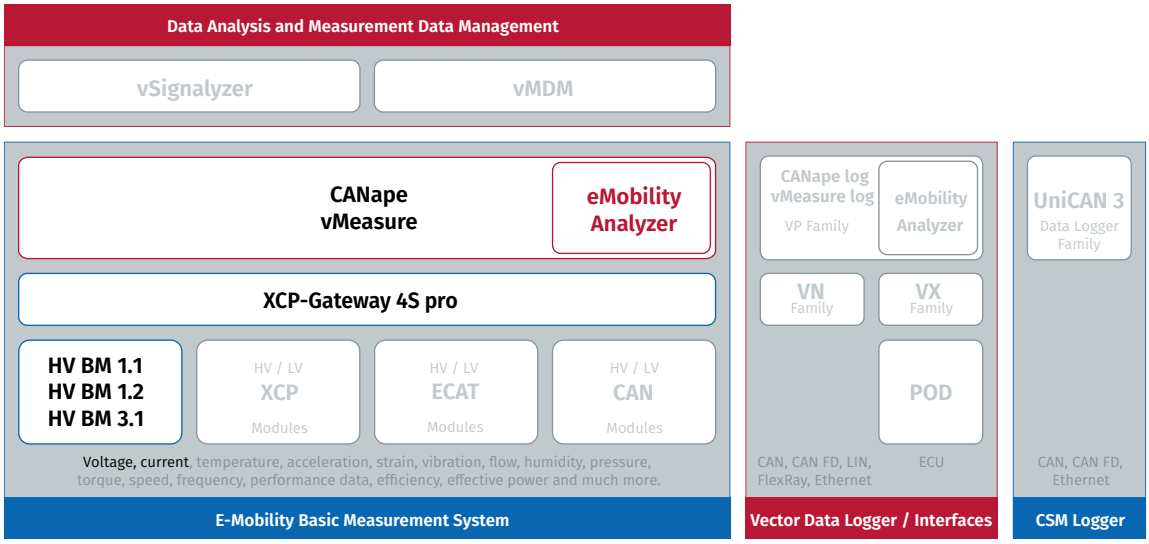


Fig. 7: The fast measurement of voltage and current flows in e-machines in the systematics of the Vector CSM E-Mobility Measurement System

Benefits

CSM HV Breakout Modules (HV BM) are designed to be used for safe measurement tasks on live high-voltage cables. Current and voltage are synchronously recorded in the HV BM and the instantaneous power can be calculated in the module in real time if required. The HV BM outputs the measured data (U, I, P) at a data rate of up to 1 MHz (1 µs) via the EtherCAT interface, thus meeting the requirement for microsecond time resolution. By selecting a suitable shunt for the current measurement and thanks to the adjustable ranges for voltage and current measurement, the HV BM can be perfectly configured for the measurement task. HV BM modules allow current and voltage measurement accuracies better than 0.2 %. Due to the protocol converter XCP-Gateway, the EtherCAT-based HV BM devices can communicate via the XCP-on-Ethernet measurement data protocol with the connected computer on which the data acquisition software is running, in this case Vector CANape.

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).

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®.

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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