High-Voltage Power Measurement

Real-time efficiency measurement on inverter and electric motor

The range electric vehicles can travel before recharging must be increased for a widespread conversion to eMobility. For this to occur, the energy flow in the electric drivetrain must be optimized. The following example shows how to measure accurate real-time efficiency with the Vector CSM E-Mobility Measurement System.

Background

Range is an important factor in increasing the consumers' acceptance of electric vehicles, therefore the components of the electric powertrain must be optimized for maximum range per charge. The inverter plays an important part in this, because its function is to transfer as much energy as possible from the battery to the electric motor. The inverter transforms the DC current into three-phase AC current, and regulates the electric motor. During that process, some energy is lost due to PWM switching performance and waste heat.

The inverter also performs conversion in the opposite direction: during the braking process the motor acts as a generator of alternating current. This current is fed back to the battery as regeneration.

A fully optimized inverter is essential for maximized vehicle range. Therefore, measuring the inverter's efficiency provides a means of evaluating and verifying modifications to the design or control software.

For electromobility, test benches are being expanded or rebuilt in order to be able to meet the new requirements. The design or construction of these test benches should be carried out cost-effectively. The measurement system used should be highly accurate and scaleable, allowing for a wide range of applications. On the test bench, the complete drivetrain and individual components are tested under different operating conditions and their performance is analyzed.

This example shows how the efficiency of the inverter and the associated electric motor can be measured in real time with the Vector CSM E-Mobility Measurement System.

Challenge

In order to detect the high currents and voltages before and after the inverter the measurements haves to be performed synchronously with high data rates. For a precise power calculation, the measurement must be direct and phase accurate.

For comprehensive analysis other measurement values, such as temperatures in the inverter, have to be acquired synchronously in order to observe/capture the working thresholds of the device and determine the efficiency at a given temperature. Ideally the measurement module should be installed close to the sensors, avoiding the electromagnetic interferences (EMI) associated with long cables.

With these electrical and thermal measurements being taken in a high-voltage environment, the technology used must also ensure high-voltage safety to protect the device under test, the measurement equipment, and the user.

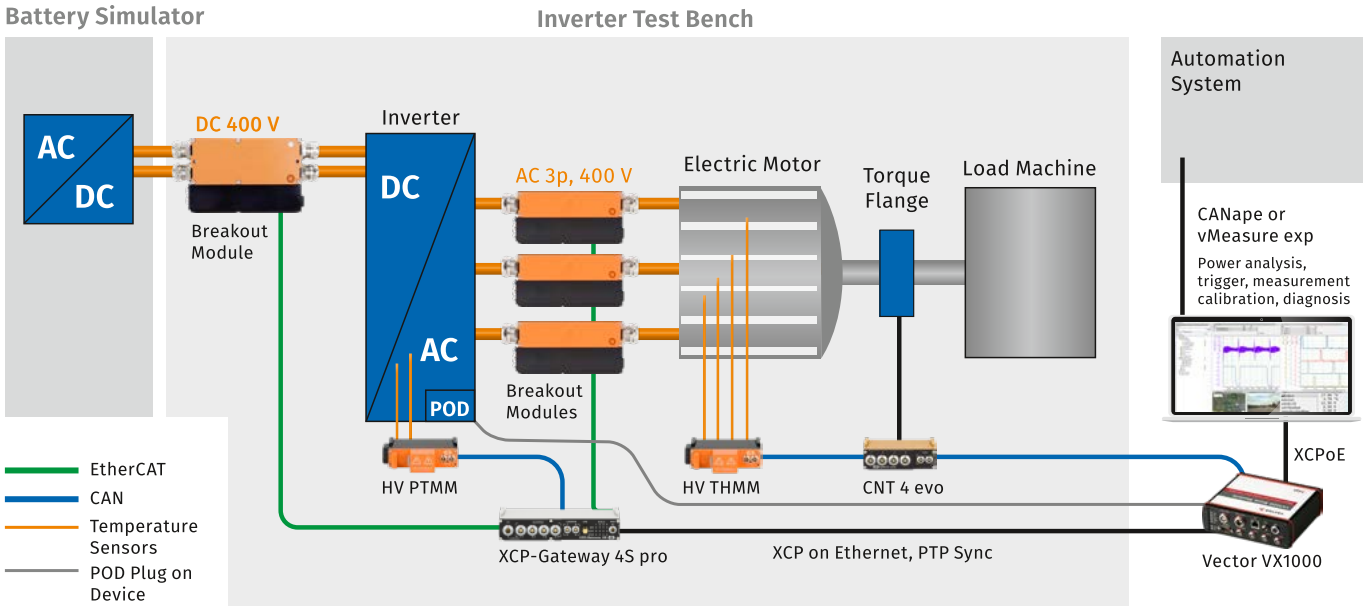

Fig. 1: Vector CSM E-Mobility Measurement System configuration for measuring powertrain efficiency

The CSM Measurement Solution

High-voltage Breakout Modules can be used to measure single- or three-phase voltages and currents synchronously at up to 1 MHz sampling rate,. This makes them the starting point for precise analysis, with the eMobilityAnalyzer function library for vMeasure exp software from Vector Informatik

- One CSM HV BM 1.2 is installed directly into the HV cables (HV+/HV-). When equipped the appropriate connectors, simple plug-and-play installation is possible.
- Three HV BM 1.1 units are installed in the cables between the inverter and electric motor to measure AC current and voltage on each phase. The data from each module is synchronized within 1 µs thus the three phases are precisely aligned.
- A high-voltage safe thermal module (HV PTMM) simultaneously detects relevant temperatures within the inverter.
- If the efficiency of the electric motor is to be determined, a counter measuring module (CNT 4 evo) is connected. The mechanical output power is recorded via a torque measuring flange and can be included as an input value to the efficiency calculation.
- All measurement modules are connected via EtherCAT® bus (HV BMs) and CAN bus (HV PTMM) to an XCP Gateway, which converts the signals into XCP-on-Ethernet and forwards them to a Vector interface, VX1000. This interface also collects data from electronic control units (ECU). All measurement data is synchronized by the VX1000 via the Precision Time Protocol (PTP). The Vector eMobilityAnalyzer function library for Vector's CANape or vMeasure exp software performs the desired real-time efficiency calculation.
- The e-Motor Power Analysis function within eMobilityAnalyzer determines the effective power, apparent power, and reactive power, power factor, electric speed and total energy of a 3-phase electric motor with a star or delta circuit. The efficiency is displayed as a ratio between 3-phase AC active power and DC input power. In addition to the power and efficiency calculation, the eMobilityAnalyser can perform other important analyses for driveline validation at the same time.

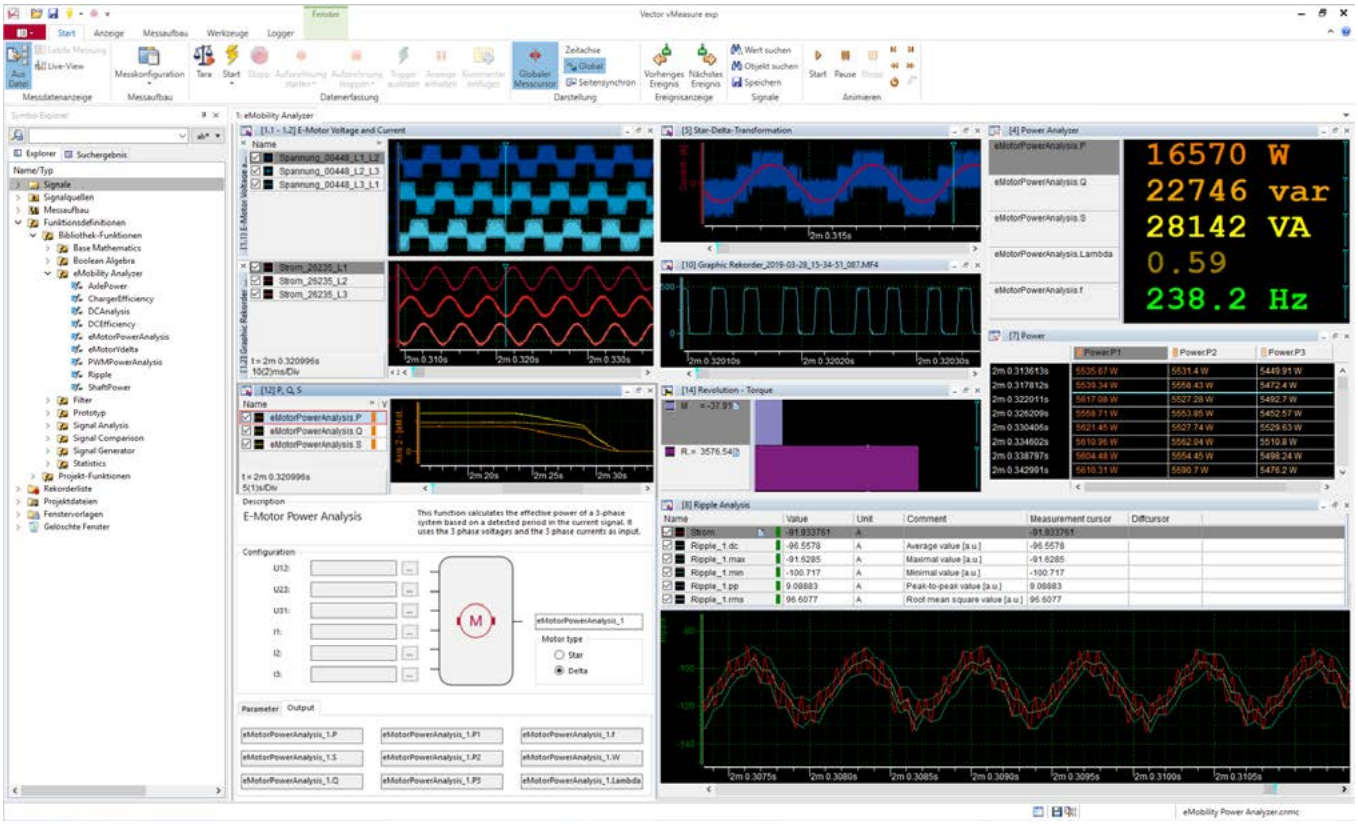

Fig. 2: Vector software vMeasure exp with opened function library eMobilityAnalyzer and power analysis.

Benefits

The major advantage of the Vector CSM E-Mobility Measurement System lies in the ability to perform distributed measurements on the test bench or in a vehicle. Vector interfaces and software precisely process the parallel data acquisition from CSM measurement modules and ECUs. This simplifies cabling on the test bench, and allows the synchronized, simultaneous, and precise analysis of powertrain efficiency to optimize range and performance.

The acquisition of current and voltage values via simple breakout modules, and the real-time calculation of AC and DC power eliminates the cumbersome classic power analyzers and current converter systems.

The Vector CSM E-Mobility Measurement System ensures high-voltage safety from the sensor to data acquisition and is extremely easy to scale. This makes it simple to include additional measurement modules if required. The synchronicity is always guaranteed. The real-time efficiency calculation allows a quick and easy inspection and optimization of the components in the electric drive bench, and saves valuable time in development. In addition, the robust CSM measurement modules are also suitable for use in-vehicle. Values from the test bench can thus be easily compared with real conditions on the road.

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.

HV PTMM 2

CSM's HV PTMM 2 measurement module with 2 measurement inputs in 4-wire technology for PT100 or PT1000 sensors was specially designed for precise temperature measurements in a high-voltage environment.

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®.

CNT4 evo

CSM's CNT4 evo is a high-precision measurement module for measuring frequencies up to 300 kHz, for determining duty cycles or PWM signals, for determining period and pulse duration as well as up and down counting. Speeds can be recorded directly in the module and output as a value on the CAN bus. In addition, the time offset between adjacent channels can be measured.

The ECAT connection cable K400.1, the ECAT interface cable K420.1 and the CAN connection cable K70 were used as accessories in this example.

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.csmproductsinc.com or via e-mail info@csmproductsinc.com.

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