Testing safely in high-voltage environments

Automated testing and evaluation of e-vehicle batteries

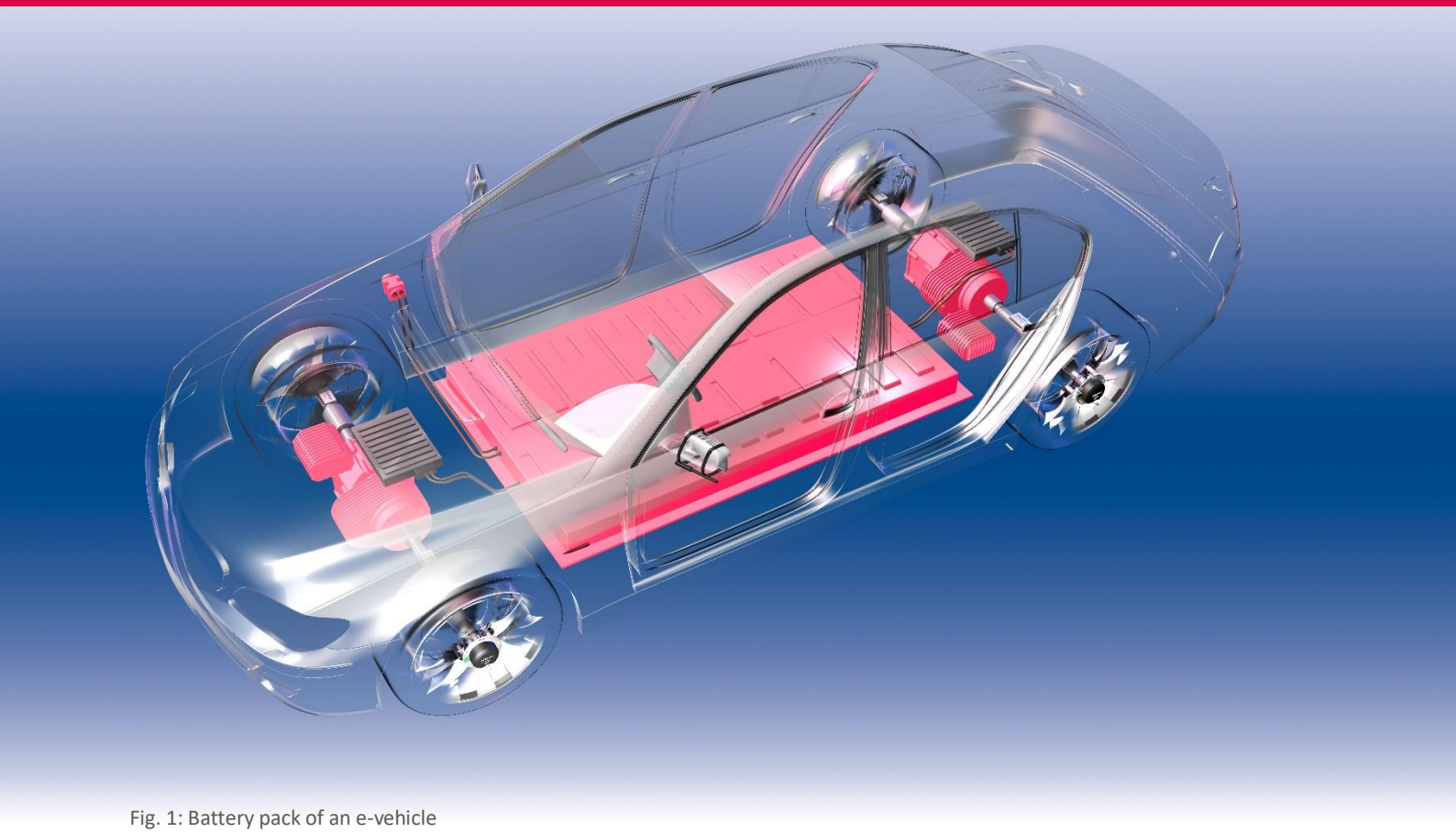


Fig. 1: Battery pack of an e-vehicle

When developing new batteries and battery management systems for electric vehicles, extensive tests and validations are the order of the day. This includes life cycle testing and misuse tests. These can be used to determine the load limits of battery cells, battery modules and complete battery packs. Investigations include charging and discharging cycles in climatic chambers as well as crash loads, penetration, compression, bending and vibration tests. These comprehensive tests require a flexible, automated test system, including data evaluation. The measurement technology acquires data safely and without disturbance in a high voltage environment. SK Innovation, one of the world's largest battery manufacturers, relied on the measurement technology from imc Test & Measurement and commissioned several measurement racks for battery tests.

New battery systems for e-vehicles must be safe and reliable. For this reason, extensive tests are carried out in the development phase on individual battery cells, battery modules, and even the entire battery pack under a variety of conditions. Due to the high voltages of a battery of up to 800 V, measurement technology must be highly isolated. This prevents electromagnetic disturbance and ensures the safety of personnel during the test. It is not uncommon to have more than 100 measuring points when measuring temperatures and cell voltages with a high voltage potential.

imc measurement technology for high-voltage environments

Various highly insulated CAN measurement modules are used in the test racks commissioned for the battery test by SK Innovation at imc Korea. Of the seven imc CANSASflex-HISO8-L CAN measurement modules, each offers 8 highly isolated inputs for measuring cell voltages and temperatures (PT100 / thermocouples) up to a voltage level of 800 V (see Fig. 2). In total, up to 56 cell voltages can be measured simultaneously.

Twenty-four thermocouples can be operated at a voltage level of 800 V using 3 imc CANSASflex-HISO8-T-8L (Fig. 3) measurement modules. Furthermore, SK Innovation uses 2 imc CANSASflex-SCI16 modules to connect a further 32 thermocouples for temperature measurement. The module voltage is measured with imc CRONOSflex HV4U, which has a measuring range of up to 1000 V.

Highly isolated and safe

Measuring points in the high-voltage range are danger points. In the course of personal safety and occupational health and safety, various measures must be taken to minimize property damage and personal injury or to exclude liability issues in the event of a fault. On the one hand, only highly insulated measuring modules may be used; on the other hand, only trained personnel or those who have received additional training may carry out the installation and wiring of the measuring modules.
The imc CANSASflex-HISO8 modules used here have a high insulation resistance of 800 V CAT I and 300 V CAT II. The imc CRONOSflex / HV2 modules for direct measurement of 1000V even have an insulation resistance of 1000 V CAT II and 600 V CAT III and thus offer a safe and trouble-free acquisition of measurement data (Device safety standard EN 61010).

Fig. 2: HV measurement module imc CANSAS*flex*-HISO8-L

Fig. 3: HV measurement module imc CANSAS*flex*-HISO8-T-8L

System Overview

imc Measurement devices	Qty.
imc CRONOS*flex*(CRFX)	1
Modules	
imc CANSAS*flex*-HISO8-T-8L 8 highly isolated channels for measuring thermocouples up to a level of 800 V	3
imc CANSAS*flex*-HISO8-L 8 highly isolated channels for measuring temperature (PT100), voltage up to 100 V, current (20 mA), and resistance at a high common mode level of up to 800 V	7
imc CANSAS*flex*-SCI16 16-channel module for the isolated acquisition of voltage, current, and temperature.	2
imc CRONOS*flex*/HV2-4U 4 channels for high voltage up to 1000 V	1
imc Software	
imc Online FAMOS Pro Real-time data analysis platform for imc CRONOS devices	
imc STUDIO Pro Comprehensive measurement software for the entire test process: measurement, visualization, automation, data analysis	
imc FAMOS Enterprise Data post-processing, analysis, and visualization	

Fig. 4: Measurement module imc CANSAS*flex*-SCI16

Fig. 5: Measurement module imc CRONOS*flex*-HV2-4U

Endurance test with the imc test rack

The 19”-test rack captures all measured values on a battery module consisting of several individual battery cells. Cell voltage and temperature are measured and monitored during the test on each battery cell. For this, SK Innovation uses several 19” racks.
The test system also acquires the voltage of the battery modules and the entire battery pack. imc STUDIO software also controls and regulates the bidirectional DC source for the charging and discharging process and monitors measurement quantities (see Fig. 6).

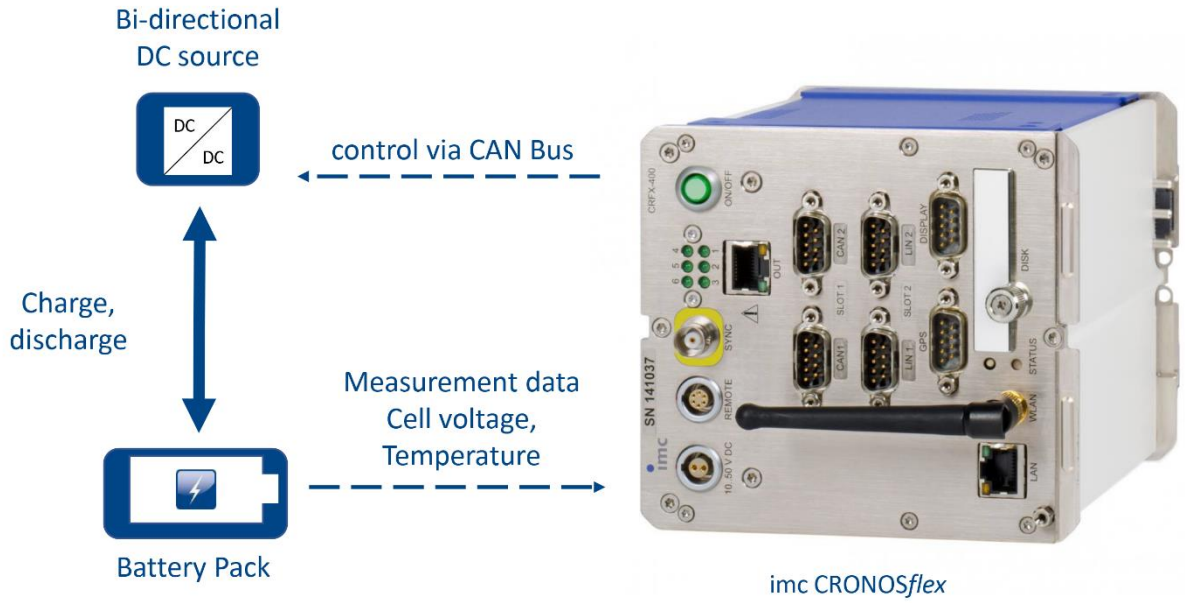


Fig. 6: Schematic structure of the measuring rack. The imc CRONOS*flex* measuring system measures, controls and regulates.

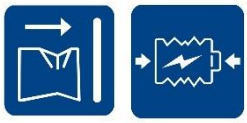
Life cycle and destruction tests

The various battery tests are used to determine the life cycle and reliability of the e-vehicle battery in different load situations, such as simulating an accident. Tests with crash, penetration, compression, and bending loads serve to provide information about the safety of a battery pack and are stipulated by standards.

Lithium-ion batteries require the correct test environment for the tests specified here, as the targeted destruction of the battery system leads to the dreaded “thermal runaway”.
The melting of the separator leads to an uncontrolled release of the stored energy of the cells. The oxygen content in the environment can lead to a fire or an explosion of the battery cells. The test environment must be designed to be fire-proof and explosion-proof, or pressure waves must be diverted in a targeted manner and the pollutants produced may only be filtered into the atmosphere.

Penetration Load Test
When testing penetration load, the imc test system records the battery cell voltage. The temperature is recorded with a thermal imaging camera. A film camera documents

destruction. All images and measurement data are stored synchronously for evaluation.



Misuse- and crash-Test

A thermal imaging camera and a high-speed camera are used for dedicated mechanical deformation tests on the battery pack (crash, compression, and bending loads). Here, too, the measurement data and camera images are stored synchronously.

Vibration-test

In the vibration test, the batteries are subjected to oscillations that occur during vehicle operation to analyze material loads on the system. A so-called “shaker” generates strong vibrations, while the test system monitors the condition of the battery pack during charging and discharging.

Life cycle test in a climatic chamber

The life cycle test of a battery pack includes charging and discharging cycles over several weeks to test the performance of a battery. The battery pack is exposed to various degrees of humidity and temperature profiles in a climatic chamber (Fig. 7).

Fig. 7: Connected third-party device: a climatic chamber for battery tests

Test stand control and data analysis with imc STUDIO

Based on imc STUDIO software, the test stand controller regulates the charging and discharge process of the bidirectional DC source in the various test environments using processed measurement quantities. It is also possible to end the test, switch off the test, and control other test stand components.

Other devices such as climate cabinets, shakers, and drives can be integrated into the test stand control via imc STUDIO. Measurement data is evaluated with imc FAMOS software. This allows analyzes to be carried out across different site locations to meet the high-quality requirements of battery production.

Outlook

SK Innovation uses several 19”-test racks from imc Test & Measurement at various development sites around the world. The functionality or complexity of the test task can be easily adapted to the desired test in imc STUDIO. SK Innovation also relies on measurement technology from imc Test & Measurement at new production sites, guaranteeing high quality in the manufacture of its e-vehicle batteries.

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imc Test & Measurement GmbH is a manufacturer and solution provider of productive test and measurement systems. imc implements metrological solutions for research, development, service, and production. imc has particular expertise in the design and production of turnkey electric motor test benches. Precisely outfitted sensor and telemetry systems complement our customer applications.

Our customers from the fields of automotive engineering, mechanical engineering, railway, aerospace, and energy use imc measurement devices, software solutions, and test stands to validate prototypes, optimize products, monitor processes and gain insights from measurement data. As a solution provider, imc offers its customers an attractive and comprehensive range of services. These include project consulting, contracted measurements, data evaluation, specialist deployment, customer-specific software development, and system integration. imc consistently pursues its claim of providing services for “productive testing”.

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