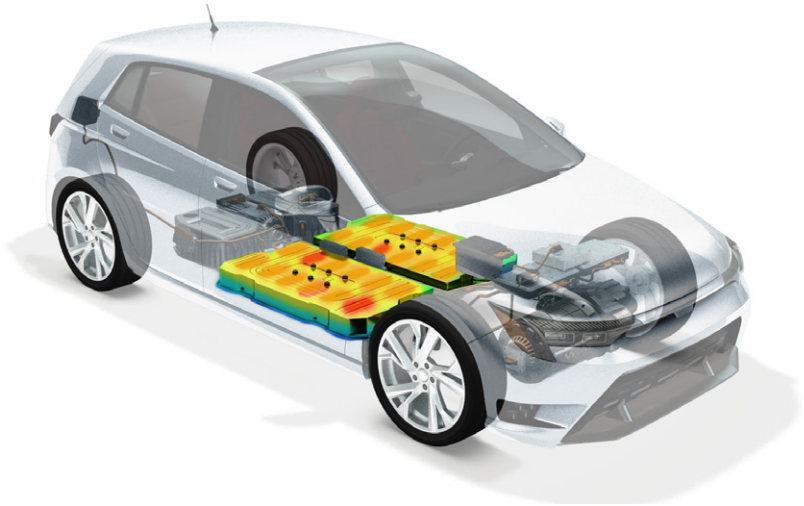
Investigation of the Thermal Runaway in Vehicle Batteries

HV Temperature Measurement

It does not take pictures of electric vehicle fires to know that the investigation of the thermodynamics in vehicle batteries has been a critical part of the development of battery systems. With the demand to design vehicle batteries for higher power and capacity requirements, the measurement of the thermal propagation within high-voltage batteries has gained special importance. The new HV DTemp digital temperature measurement system enables hundreds of precisely positioned digital sensors to investigate cell hotspot crystallization areas, which represent potential hazards for thermal runaways.



Background

Vehicle batteries are especially analyzed and tested for the potential danger of a thermal runway. If the unstoppable self-heating of a cell in a vehicle battery occurs, it can spread to other cells and lead to thermal propagation. This uncontrollable process can destroy the entire vehicle battery and endanger the passengers. Therefore, the individual scenarios that could lead to thermal runaways are being closely analyzed. In particular, these include the effect of temperature on neighboring cells and modules as well as the heat flow and congestion within the battery. Furthermore, misuse tests are carried out which could trigger a thermal runaway. An example is the nail test that initializes a thermal runaway (a so-called forced thermal runaway). Such tests are carried out in specially secured temperature test benches into which the powerful digital temperature measurement system, CSM HV DTemp, can be easily integrated.

Challenge

Precise pre-planning for systematic, metrological investigation with regard to the design and layout of the battery is an important aspect for a successful measurement on the real system. Battery and temperature simulation models show critical hotspot areas within the battery detected during the design and simulation phase. Precise positional measurements on cell, module and pack level are necessary to prove the operational safety and the effect of the constructive battery properties against the thermal runaway and to prepare an approval for product release. The packing density of cells and modules within the battery is a challenge for the positioning of the sensors: Due to the high packing density, often very little space in the mm range is available for them. In most cases, the sensors can only be inserted during the assembly process of the batteries. Instrumentation after assembly is not possible.

In addition, measurements must be taken on all other components, such as busbars, high-voltage connectors, electronic components and cooling and heating systems, since heating them can cause additional potential hazards.

So-called worst-case, misuse and defect scenarios are examined, in which cells are overheated or overcharged. On the other hand, the danger of aging effects must also be tested.

Since a thermal runaway is indicated by the occurrence of a hotspot at cell level, temperature measurement at cell level is important. It must be verified how fast the heat transfer to neighboring cells in the module progresses and how any cooling and insulation devices work.

The CSM Measurement Solution

The **HV DTemp measurement system** was developed for precise and easy to use thermal investigations of HV batteries and HV components. It allows the precise, digital and thus interference-free acquisition of up to 512 temperature measurement points via a single cable connection to the HV DTemp-P Central Unit outside the battery.

The **HV DTemp IC sensors**, available in different variants, are optimized for different positions within the HV battery. The size and shape of the sensor assemblies and the length of the sensor cables depends on the measurement points calculated in the simulations.

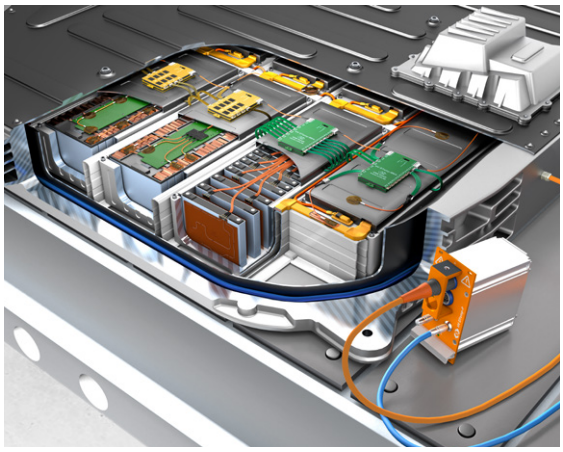


Fig. 1: HV DTemp measurement system installed in a HV battery

Use of the IC sensor technology for different applications within the high-voltage battery

IC single sensors are used to measure temperature on small separate components, e.g. connectors, electronic modules, coolant inlet and outlet or special housing points and crash structures.

Daisy chained IC sensor assemblies are suitable for measuring busbars, high-voltage connecting lines or coolant paths.

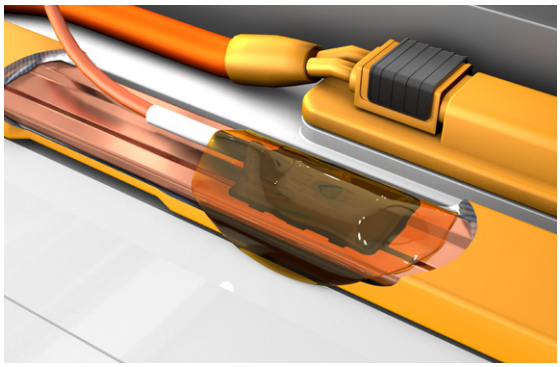


Fig. 2: Single sensor on bus bar.

IC sensor assemblies, which are connected via a small distribution board are used to investigate temperature flows on module and packaging surfaces as well as air gaps.

IC sensors on ultra-thin flexible circuits are used for temperature measurement between cells to measure at critical cell zones or crystallization points for hotspots. Between the individual cells they are also used to test the effect of spacers (insulating materials).

Large flexible circuits with IC sensor technology can also be used to measure thermal effects, for example on the underside between the cold plates and module pack. Perforated carrier foils can also be used here.

HV DTemp-Mx Controllers bundle the data from the IC sensors and forward it to the **HV DTemp-P Central Unit**. For this purpose, up to eight controllers are simply cascaded so that only one connecting cable must be led through the battery housing.

Forced Thermal Runaway

If a test is to be performed that provokes a thermal runaway by bursting a cell and letting electrolyte gas escape, measurements must be performed at very high temperatures. For this purpose, the area predicted by the simulation must be equipped with appropriate additional sensor technology. HV TH8 evo test bench measurement modules are suitable for this purpose, with which the hotspot area is equipped with additional temperature sensors. These temperature sensors are also very thin at their tip and are positioned with a Kapton foil strip according to the test.

Fig. 3: The sensor technology can also be easily installed between other battery cell types.

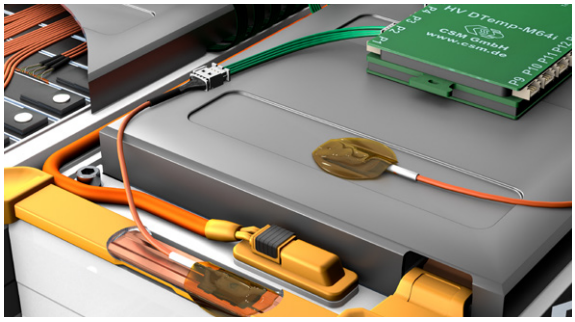


Fig. 4: Single sensor on a module housing for measuring temperature curves

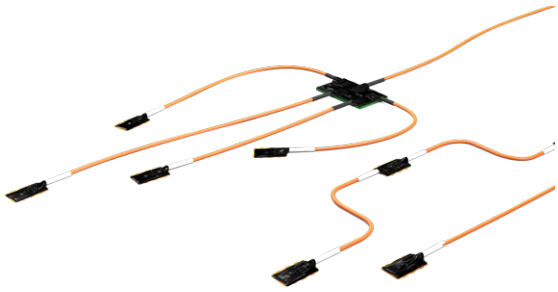


Fig. 5: HV DTemp IC Sensors: Connection via distribution board, daisy chained via connection cables and single sensor (from top to bottom)

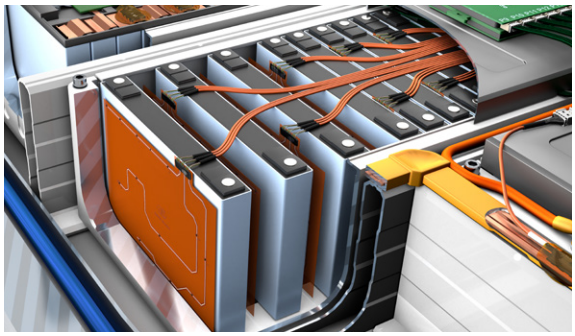


Fig. 6: IC sensors on ultra-thin flexible circuits are suitable for precise temperature measurement between the battery cells.

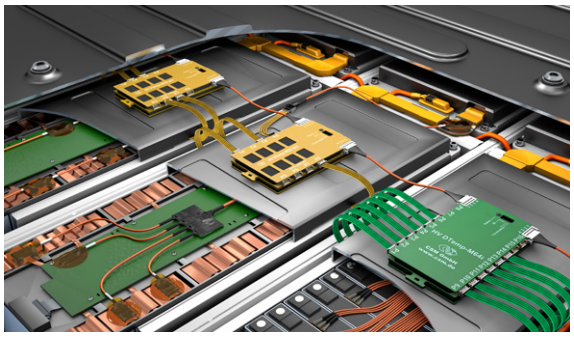


Fig. 7: HV DTemp-M64 Controller for the connection of up to 64 IC sensors

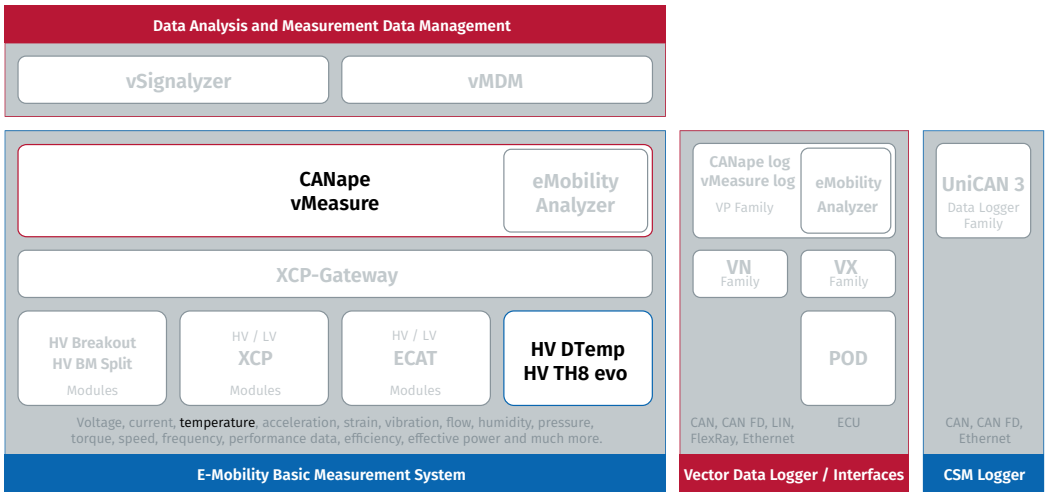


Fig. 8: The investigation of the thermal runaway in vehicles batteries in the systematics of the Vector CSM E-Mobility Measurement System

Benefits

Instrumentation and temperature measurement in high-voltage batteries with the CSM HV DTemp measurement system considerably shortens the test procedure. The installation can be planned into the assembly of the test battery. Test cycles for optimization steps are simplified by positionally accurate repeatability.

Hundreds of IC temperature sensors can be used with application-specific assemblies in a test battery with precise positioning.

The design of the IC sensor assemblies can be tailored exactly to the battery to be measured and its components. The assemblies can be precisely installed during battery production according to specifications.

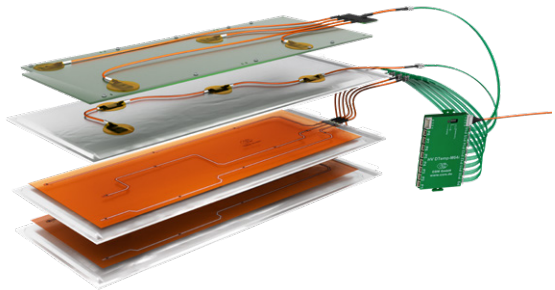


Fig. 9: During battery assembly, the IC sensor technology on flexible circuits can be easily pressed between the battery cells. In this way, temperatures can be precisely measured and the individual sensors can be precisely assigned their individual ID for simple data management.

Each measurement point is uniquely identifiable and assigned by its own CAN-ID. This simplifies measurement point planning and eliminates wiring errors. With a clear assignment, the overview is also maintained in a measurement setup with hundreds of sensors.

Only one high-voltage safe cable is required for connection to the HV DTemp-P Central Unit outside the high-voltage battery. Thus, more precise measurement results are achieved due to a low structural influence of the battery housing. In addition, the gas tightness of the battery remains guaranteed even during the measurement. This would not be possible with many sensor cables that have to be routed to measurement modules outside the battery housing.

With the positioning of the IC sensors on flexible circuits between individual cells, verification is guaranteed. If individual temperature sensors were inserted between cells, installation errors or inaccurate positioning as well as forgetting to position them would be a probable source of error.

The measurement system can be easily extended to include additional measurement values such as humidity, vibrations or torsion. For this purpose, the HV DTemp measurement system can be easily connected via CAN bus to further measurement modules from the Vector CSM E-Mobility Measurement System.

A test battery is often tested in different vehicles. The battery conversion to another test vehicle is very easy and timesaving with an integrated HV DTemp measurement system.

Featured Products

HV DTemp

The CSM HV DTemp measurement system is designed for the digital and precise measurement of up to 512 temperature measurement points via a single cable connection to the HV DTemp Central Unit. With the flexible and reproducible arrangement of the HV DTemp IC sensors, temperature profiles can be recorded precisely between the battery cells.

HV TH8 evo

The HV TH8 evo thermal measurement module allows high-voltage safe temperature measurements with thermocouples on high-voltage components. With its 19-inch slide-in housing and reinforced insulation up to 1,000 V RMS, it is particularly suitable for use in test benches.

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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