On the test bench: the electrical powertrain of tomorrow

imc produces a testing and simulation environment for the Fraunhofer Institute (IFAM Bremen)

Optimized powertrain topology and design are essential for achieving progressive development of electric vehicles. On behalf of the Fraunhofer Institute (IFAM Bremen), imc Meßsysteme GmbH has developed a test station with two testing tracks and an integrated simulation solution, enabling the development and testing of new components for and models of electric motor powertrains.

Goals

To be able to optimize the efficiency and range of electric vehicles, rigorous testing of the electrical powertrain and its components under a variety of operating and environmental conditions is essential. For this purpose, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen commissioned imc with the design of an experimental test bench having two test tracks and an integrated simulation solution.

A major focus of the system comprises extensive testing and simulation of the battery's functioning, in order to closely investigate its response to a variety of ambient conditions. The results will provide the basis for optimizing the battery in terms of its capacitance, performance, weight, lifespan, reliability, and mechanical dimensions.

Goals – at a glance:

- Observation of all powertrain components in realistic e-Mobility conditions
- Investigation of aging processes; characteristics and optimization potential of batteries
- Measurements in a battery power simulation, in which both the charging and discharging processes are simulated in a reproducible manner
- Examination of batteries in extreme temperature conditions (-40°C to +140°C)
- Examination and optimization of braking energy recovery (recuperation)
- Improvement of the interplay of electric motors with frequency inverters
- Profiling of the continuous operation characteristics of electric drivetrain systems
- Improved interplay of individual components: comprehensive electromechanical optimization of the overall drive train

Integrated measurement, open- and closed loop control, and simulation

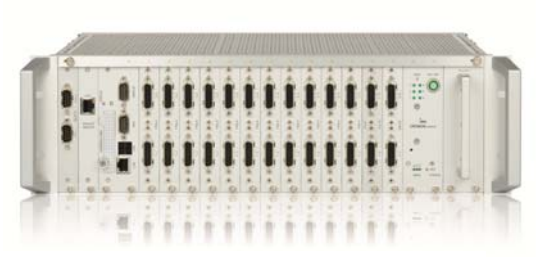
Since the data obtained from measurements performed in real test drives of prototypes and pilot editions of serial electrical vehicles are often not sufficient for sophisticated optimization purposes, vehicle data recorded on the test track are incorporated into a Matlab Simulink-model.

By varying these data and creating new, dynamic system modeling, it is possible to achieve targeted simulation of the toughest operating conditions on the test bench and thus to investigate the interactions of the powertrain's individual components, such as the battery, control unit, power electronics or electric motor. Furthermore, model-based development by means of a test bench saves

time and expense. Another important advantage is the reproducibility of static load and endurance testing.

Hardware-in-the-Loop

For the testing and simulation of powertrain components, IFAM uses the turnkey solution imc HiL. In this single system, imc unites data acquisition with open- and closed-loop control, plus simulation. Models created in Matlab Simulink can be directly integrated into the imc measurement system and are run in real time on a processor embedded in the measurement hardware (such as imc CRONOS*compact*).



Measurement system: imc CRONOS*compact*

Developing energy storage models

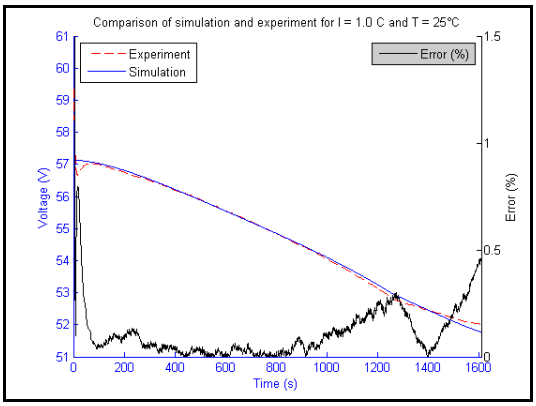
IFAM's research puts special focus on developing new models for simulating energy storage systems.

In the first step, the engineers select the battery's chemical and electrical characteristics to be modeled. The battery chemistry determines such constraining factors as the operating temperature, maximum amperage, as well as temperature- and amperage-dependent capacitance profiles.

In the second step, the test engineers determine what simulations to run. Examples include voltage characteristics plotted over temperature and the selected discharge current.

In the third step, actual energy storage systems are tested in order to obtain data used in developing a theoretical model. In the pilot project, the team used a climate chamber to expose the battery to a variety of thermal stress profiles in which to observe the respective charging and discharging cycles.

In the fourth step, the simulation and the experiment are compared, and the model is refined by targeted optimization of parameters until it best reflects reality. The resulting theoretical model of the battery can be applied across a particular range of temperatures and amperages in order to perform real-time calculations on simulations of the battery's behavior in either actual operation or lab or field testing.



Comparison between simulation and test of a lead-acid battery

Conclusion

The demand for quick, applicable and conclusive results requires a high degree of productivity in terms of test and measurement per-

formance. The e-Mobility test bench developed by imc enables the researchers at the Fraunhofer Institute, as well as R&D engineers throughout the industry, to keep pace in a fast-changing market. The integrated measurement and control technology provided by imc is the key element. Software components tailored to the customer's needs simplify the task of achieving complex configurations and simulations. Additionally, standard software and hardware systems allow quick and versatile integration of external components such as climate chambers, battery simulators, or ECUs. In such a dynamic field of technology, adaptability to new conditions and equipment ensure that our measurement systems remain efficient and future proof.

Key Test and Simulation Bench Parameters

Two motor test stations for testing of drive axles in 4-quadrant operation (counter-/clockwise rotation, motor-/ generator operation).

- up to 8000RPM
- up to 600Nm
- 2 x 130kW mechanical

Voltage and amperage ranges in 2-quadrant operation

- up to 1,000 V
- up to +/-600 A
- up to 120 kW

Battery testing

- Hazard level 7 per Eucar
- Up to 1m³ temperature-controlled testing enclosure
- Temperature range: -40 °C to 140 °C

Software used

- imc STUDIO for test bench control, data acquisition and analysis
- MatLab/Simulink for theor. modeling
- Measurement system: imc CRONOS*compact* with HiL real-time simulation

Measurement variables (100 analog input channels)

- Voltage and amperage of the test article inverter
- Motor phase voltage and current up to 1000 V, +/- 600 A
- Torque
- RPMs
- Temperatures
- Triaxial oscillation measurement by means of ICP/IEPE-sensors
- Support of a variety of bus systems such as CAN, CANopen, FlexRay
- High-speed analog signals
- Freely configurable RPM- or counter inputs
- Generator ("brake") voltage and amperage in three phases

Data acquisition

- Measurement frequency: per channel sampling rate: up to 100 kHz
- Fixed data saving intervals/pre-set measurement frequency or event-triggered

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By focusing on test & measurement productivity, imc Meßsysteme GmbH creates tools which empower engineers to deploy data acquisition systems and test strategies efficiently, meeting the test and measurement challenges of development departments today, as well as tomorrow.

Specializing in an integrated approach to physical test and measurement, imc solutions are well suited for mixed signal testing of complex mechanical and electromechanical systems. In these situations, test engineers demands are for flexibility and scalable capabilities, especially when a company understands that testing productivity is all about the efficient use of testing resources.

From mobile and in-vehicle testing, to autonomous field data recording; from small modular component test stands to customized turnkey automation systems, imc solutions and services are geared to meet customers' test and measurement challenges: imc's family of integrated signal conditioning and real time hardware, combined with software analysis and test management products encompass all aspects of the measurement and control work flow, from signal conditioning, real time analysis and control, to automated test control and report generation.

Continuing a tradition of 25 years of hardware and software development inspired by the innovation of our customers, imc's adaptive approach to product development is guided by users in a range of industries including ground transportation, such as cars, commercial vehicles, and trains; to aerospace, power generation, and civil engineering.