HYBRID TESTING SOLUTIONS

Instrumentation & Test Systems
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PRELIMINARY

The increasing demand on energy and the threat of climate change are forcing the Automotive Industry to reduce the fuel consumption along the whole vehicle fleet. The electrification of conventional powertrains is a major step to further improve the fuel efficiency of the vehicles. AVL supports the Automotive Industry by offering future-oriented simulation and test solutions for all relevant HEV components and their corresponding control units in order to meet the challenge of powertrain electrification.

AVL HYBRID TESTING SOLUTIONS

TASKS
Global regulations regarding the reduction of greenhouse-relevant exhaust gases, first and foremost CO$_2$, and high crude oil prices have an impact on individual, goods and public transportation. Therefore the Automotive Industry aims to reduce fuel consumption.

As a result of tightened regulations vehicle manufacturers are forced to develop and implement in to the series with new technologies, such as electrified powertrains.

The electrification of the powertrains offers saving potentials particularly in the field of urban traffic, which is characterized by a large number of acceleration and braking events. During the acceleration phase, an electric motor driven by the traction battery of the vehicle provides additional torque. This partially discharges the battery. During the braking phase, the electric motor is operated as generator and recharges the battery again.

In the development phase, each of the new components will be verified and validated for performance, reliability, durability and safety. Furthermore the electric motor and the battery are harmonized in order to optimize the electrical powertrain. AVL provides suitable methods and reliable test equipment to cover all the necessary development tasks.

APPROACH
The Automotive Industry has the challenge to keep the balance between requirements for fuel efficiency, emissions, driveability, reliability and cost efficiency. As a leading company within the Automotive Industry, AVL offers solutions for simulation and test of electrified powertrains. Based on a seamless integrated development approach ("office-lab-testbed-road") the complete vehicle simulation can be tested and developed on PC, in the control unit test laboratory as well as at different component and powertrain testbeds under real-time conditions.
ELECTRIC MOTOR TESTBEDS
OEMs and suppliers have to develop electric motors for new drive systems. These electric motors play a central role not only in mild, full and plug-in hybrid vehicles, but also in pure electric vehicles that use traction batteries or fuel cells as local energy supply. AVL provides complete development and testing environments for electric motors.

INVERTER TESTBEDS
Additionally to the tests of the energy storage system, electric motor and hybrid control units the electrification of conventional powertrains requires the validation and verification of the power electronics of the electric motor. For verification of single-stage and multi-stage inverters AVL offers a complete system consisting of test run control, energy recovering battery and electric motor emulator with cooling of the unit under test. The major advantage is to verify and validate the power electronics according to test procedures without availability of a real electric motor.

BATTERY TESTBEDS
In modern powertrain configurations such as hybrid vehicles, pure electric vehicles or fuel cell powered vehicles, batteries are used for electrochemical energy storage and conversion. These energy storage systems have to meet the market requirements such as long lasting high power and energy performance for high dynamic charge and discharge processes. The new lithium-ion technology offers the highest storage capacity at the present. The most important development tasks for energy storage systems are the optimization of life-time, safety, power, energy and costs. AVL offers accurate and reliable as well as innovative and efficient testing solutions.

HYBRID UPGRADES FOR EXISTING ENGINE & POWERTRAIN TESTBEDS
Powertrain development today is characterized by a rapid rise of complexity at system and component level. Additionally the networking of the different components with other vehicle control systems becomes increasingly more important. Experts are challenged to calibrate all powertrain components to fulfill the various customer demands and to achieve the objective of future CO₂ emission limits. To meet these challenges front-loading is absolutely essential to reduce development time and costs while providing a high quality development process.

BENEFITS AT A GLANCE
- Integrated product portfolio to simulate, verify and validate modern traction batteries, electric motors and electric powertrains
- Modularly expandable test systems
- Combined e-Storage simulator/e-Storage tester
- Testbed safety concepts proven by TÜV (Technical Inspection Authority)
- Hybrid upgrades for testing and development of battery, e-motor and hybrid control units
AVL ELECTRIC MOTOR TESTBEDS

OEMs and suppliers have to develop concepts for the electrification of powertrains to meet the market requirements.

The most important development tasks for electric motors are optimization of:
- Power and efficiency
- Reliability and durability
- Dynamic behavior
- Cold start and thermal characteristics
- Overload capacity

APPLICATIONS

AVL Electric Motor Testbeds function are as complete development, testing, verification and validation environments for electric drives and are used for determining and analyzing electrical, mechanical and thermal characteristics.

Functionality, reliability and endurance tests as well as cold start performance measurements are implemented under real operation conditions. AVL offers based on its experience in drives from passenger car, heavy duty vehicle applications up to race car applications (KERS systems) electric motor and component testing.

Different electric motor types such as ISG (Integrated Starter Generator), BSG (Belt-driven Starter Generator) and Axle Drives can be fast and easily connected and tested with the dynamometer without modification of the testbed by using the unique AVL pallet system.

BENEFITS AT A GLANCE
- Standardized or customized test bed solutions
- Modular system based on harmonized and approved components
- Automation system with Integrated electrical test and measurement devices
- Continuous data measurement
- Virtual proving ground testing concept based on AVL InMotion™
- Worldwide sales and services

TESTBED CONFIGURATIONS

A dynamic dynamometer that has equal capability to brake and drive the electric motor together with conditioning units facilitates automated drive cycle performance and durability testing. The testbed dynamometer converter and the AVL High-End DC Power Supply™ converter (upgradable to an AVL e-Storage Simulator/Emulator™) are recovering all the energy within the intermediate DC voltage bus, that can be shared by both converters. As only the losses from the mains supply must be covered, this solution allows very efficient operation on the power grid, saving energy and enabling environmentally friendly operation. Furthermore the integration of power analyzers such as Yokogawa
WT3000 and others into the AVL Electric Motor Testbed automation system provides the possibility to execute fully automated test runs for all important test procedures.

The AVL’s Virtual Proving Ground Technology based on AVL InMotion™ enables very realistic test scenarios with all control units and the electric motor „in the loop“.

AVL OFFER PACKAGE

- AVL dynamometers
- AVL PUMA Automation Platform
- AVL e-Storage DC Power Unit™ or AVL e-Storage Emulator™
- AVL pallet systems for e-motors
- Coolant conditioning systems
- Climatic chambers
- Power measurements with fully integrated power analyzer
- AVL InMotion™
AVL INVERTER TESTBEDS

As the power electronics of hybrid and electric vehicles have to meet special requirements depending on the application, inverter testbeds have to be highly flexible. On the one hand battery and e-motor models have to be modified easily and quickly and describe the real system as good as possible. On the other hand different testing procedures in accordance with model control should be simply applicable and evaluable.

Special attention of the AVL solution is drawn to:

- Testing of the operational robustness and safety of the Inverter (UUT) at
  - wide DC input voltage range
  - change of the operating point (e.g. torque steps)
  - fault conditions (motor phase short circuit, defective rotor position signal, …)
- Optimize and verify the motor control for real dynamic operation
- Testing of the durability with parameterized load cycles
- Testing the thermal behavior of UUT at critical load and/or cooling conditions.
- Determine the efficiency map of UUT depending on the load point and DC link voltage.
- Product quality control in the production phase

TECHNICAL CHARACTERS

- Identical electrical interface like the original motor (Motor phases, Rotor sensor, other sensors)
- Identical electrical behaviors like the original e-motor
- Energy concept
- Emulation of mechanical and magnetic characteristics of the e-Motor
- Emulation of typical electric motor faults (impress of errors)
- Safety concept inclusive sequence processing and automation system

The AVL Automation System enables an easy parameterization of the whole testbed. The actual values are clearly represented by the GUI.
BENEFITS AT A GLANCE

- Flexible, easy to parameterize overall solution with automation system
- Reproducible charges of in- and outputs of the unit under test converter
- Compact solution without rotating shaft to the unit under test
- Test bed automation system with flexible interfaces for connection to customer-specific subsystems
- Efficient operation through energy recovery of the e-Storage and e-motor emulator into the main grid
- Interface for external battery models (Matlab / Simulink®) and electrical motor initialization
- Unit under test acceptance inclusive safety strategy

AVL OFFER PACKAGE

- AVL PUMA Automation Platform
- AVL e-Storage Emulator™
- AVL E-Motor Emulator
- UUT acceptance
- Conditioning Units
- Climate Chamber
- Performance measurement with integrated Power Analyzer
AVL BATTERY TEST BEDS

Energy storage systems have to meet the market requirements of future drive systems. At the present, the new lithium-ion technology offers the highest storage capacity and the proportions of size, weight and costs of traction batteries integrated in hybrid- and electric vehicles continue to evolve.

The most important development tasks are:
- Durable (calendar life time and life cycle)
- Safety (in operation and under accidents)
- Power
- Energy storage capability
- Costs decreasing

APPLICATIONS

AVL Battery Testbeds are optimized for supporting the development tasks of performance evaluation and life-time investigations of electrochemical energy storage systems for hybrid and pure electric vehicles.

The modular test solutions are used in a wide range of applications:
- Examination of cells, modules and packs
- Characterization of various energy storage systems for different applications (for e.g. scooter, passenger car, light and heavy duty)
- Testing and Verification of supercaps, nickel-metal hydride and lithium-ion batteries

BENEFITS AT A GLANCE

- Turnkey AVL Battery Testbed solution
- Suited for R&D and production purposes through multifunctional layout
- Reduced time and effort in delivery and on-site installation
- Minimal operating costs due to intelligent testbed layout
- Saves development time through virtual proving ground approach (enables virtual fleet testing by using hardware-in-the-loop (HIL) technology)
- Worldwide sales and services

TESTBED CONFIGURATIONS

The plug-and-play AVL Battery Testbeds are designed as a freestanding test rig or as a complete containerized system. They can be used through the complete vehicle development process of energy storage systems starting from the first built prototype through preproduction and even final production validation.

All types of customer-specific as well as standardized testing procedures (ISO12405-2, VDA, EUCAR, FreedomCAR) can be easily defined and executed. AVL Battery Testbeds allow the state-of-the-art implementation of durability and performance cycles.
The highly dynamic and precise climatic chambers are specifically designed for testing energy storage systems up to automobile battery pack level under accurately simulated environmental conditions. These simulations are part of the test runs. The chambers are fully integrated in the TÜV certified AVL Safety Concept.

Furthermore the integration of AVL’s Virtual Proving Ground Technology based on AVL InMotion™ (hardware-in-the-loop (HIL) technology) provides a time and cost efficient development and testing environment for transferring integration, optimization and validation tasks to earlier development phases. Different features and models can be used in this environment. The unit under test is integrated into a virtual driving environment and tested in reproducible driving maneuvers.

**AVL OFFER PACKAGE**
- AVL e-Storage Tester™
- Climatic chambers for wide-range temperature simulation
- Explosion- and Overpressure protection of temperature chambers with chimney, explosion valve, flange
- AVL Safety Concept (TÜV certificate, fire protection surveys, VdS/COC standards)
- Gas alert & gas diluting systems
- Fire alert & fire extinguishing systems
- Pre-installed media supply network (electricity, air, water) with interface to facility technology
- Virtual proving ground approach based upon AVL InMotion™

AVL Battery Testbed in layout and realization – a turnkey test cell which includes several other subsystems, such as a full testing cell technology with e-Storage Tester™, one special climatic chamber for simulating the environmental impact and the TÜV certified safety concept.

The AVL e-Storage Tester™ is integrated in the AVL Battery Testbed. It supports the testing and validation of batteries and other types of energy storage systems for HEVs and EVs. All types of customer-specific as well as standardized testing procedures (ISO12405-2, FreedomCAR, EUCAR, VDA) can easily be defined and parameterized by AVL e-Storage Tester SW.
HYBRID UPGRADES FOR ENGINE & POWERTRAIN TESTBEDS

Electrified powertrains will be based on a high integration level of mechatronic systems such as internal combustion engines, transmissions, electric machines, power electronics and energy storage systems. Main development focus has to be drawn on these new components and on the vehicle integration. Furthermore all electronic control units have to be calibrated in a proper way to achieve optimal fuel efficiency and driveability. OEMs and suppliers are therefore in the need of new test equipment as well as upgrade packages for existing testbeds for development and base calibration of electrified powertrains.

APPLICATIONS
The application spectrum for different kinds of hybrids up to pure electric vehicles ranges from: engine start/stop, regenerative braking as well as acceleration support relating to vehicle stability, load shifting, durability testing and the controller adjustment of the electrified powertrains.

BENEFITS AT A GLANCE
- Securing investments by using existing test facilities for hybrid development
- Time and cost efficient upgrade scenarios
- Powerful real-time simulation and development platform for complex electrified powertrains

TESTBED CONFIGURATIONS
The electrification of powertrains results in modified requirements on the conventional components, for example internal combustion motor. AVL supports it’s customers via offering upgrade packages for powertrain and engine testbeds to provide a complete development and testing environment based on existing test beds.

HYBRID UPGRADES FOR POWERTRAIN TEST BEDS

AVL e-Storage Emulator™
The e-Storage Emulator is a DC supply powering the inverter of the e-motor. It emulates the state of charge, affects of ambient temperature and the dynamic charge/discharge behavior of all important battery technologies.

AVL InMotion™
To handle the complexity of various independent components and control units (xCUs) a seamless integrated simulation platform is required. AVL InMotion™ integrates the unit under test (UUT) into a virtual driving environment. This environment enables straightforward testing and validation of the UUT with reproducible driving maneuvers. AVL InMotion™ supports realizing the virtual proving ground approach via hardware-in-the-loop (HIL) technology. The HIL test technique helps to reduce development costs and allows transferring integration, optimization and validation tasks to earlier development phases.
HYBRID UPGRADES FOR ENGINE TEST BEDS

Especially for parallel hybrid configurations with integrated starter generator systems (ISG), it is necessary to extend the above mentioned upgrade packages with an additional Mechanic Package to have an optimal development environment on conventional combustion engine testbeds available. This mechanic package mainly consists of a dummy gearbox to integrate the customer-specific ISG e-motor. In addition a shaft layout needs to be prepared.

AVL OFFER PACKAGE

- AVL e.Storage Emulator™
- AVL InMotion™
- Special "Hybrid Mechanic Package" (dummy gearbox, shaft layout, etc.)

AVL InMotion™ integrates the unit under test into a virtual driving environment. It supports realizing the virtual proving ground approach via hardware-in-the-loop (HIL) technology helps reducing development costs and allows transferring development tasks to earlier phases.

AVL e.Storage Emulator™ is used for powering the e-motors and for emulation of high-performance batteries as well as supercaps. It emulates the state of charge, affects of ambient temperature and the dynamic charge/ discharge behavior of all important battery technologies.
Product Descriptions
OVERVIEW

AVL ELECTRIC MOTOR TESTBEDS

AVL INVERTER TESTBEDS

AVL BATTERY TESTING SYSTEMS
- AVL e.Storage DC Power Unit™
- AVL e.Storage Emulator™
- AVL e-Storage Tester™
- AVL Battery Testbed

Hardware-in-the-Loop Testing TESTBED with AVL InMotion™
ELECTRIC MOTOR TESTBeds

AVL ELECTRIC MOTOR TESTBED
AVL EMT SERIES

Main Item Description
AVL Electric Motor Testbeds function as complete development, testing, and validation environments for electric drives and are used for determining and analyzing electrical, mechanical and thermal characteristics. Functionality, reliability and endurance tests as well as cold start performance measurements are implemented under real operation conditions. AVL offers based on its experience in drives from passenger car, heavy duty vehicle applications up to race car applications (KERS systems) electric motor and component testing.

Applications
- Power and efficiency measurement
- Reliability and durability tests
- Cold start performance measurement
- Dynamic measurements
- Overload capacity
- Torque analysis
- Short-circuits and idle test runs
- Parameter identification and passive loading tests
- Analysis of electrical and mechanical features
- Evaluation of thermal characteristics
- Blocking tests
Benefits

- Modular system based on verified and approved components
- Standardized or customized solutions in test rig or pallet system design
- Torque range: 5 to 5,500 Nm
- Power range: 2 to 800 kW
- Speed range: Up to 20,000 rpm (for KERS up to 40,000 U/min.)
- Use of active dynamometers (recuparation of energy to the main power supply)
- High-performance and flexible automation system (AVL PUMA OPEN)
- Integrated electrical voltage supply (expandable to the AVL e-Storage Emulator™)
- Integrated electrical test and measurement devices
- High-precision power analyzer for data logging
- Virtual Proving Ground Testing including real and virtual control units or power train components "in the loop"
- World-wide sales and services

Component Description

Typically AVL Electric Motor Testbeds comprise a direct current supply unit to supply the power electronic systems of the unit under test, a dynamometer with integrated control system, a flexible automation system, a conditioning unit and an optional climate chamber.

The highly dynamic dynamometer and the unit under test are connected via a torsionally stiff drive shaft connection. The torque is measured by a high precision torque flange which is integrated in the drive shaft connection. By integration of a high-performance e-storage-Emulator, power can be supplied to the unit under test for emulation of the traction battery behavior in a real vehicle, concerning dynamics performance and durability.

By using a fully integrated high-precision power analyzer, automated test runs can easily be measured and post processed in one test environment. The power analyzer allows measurement the electric motor efficiency with high precision, simultaneous measurement of input and output, evaluation of torque speed characteristics, etc. Furthermore the possibility to execute and store data of automated test runs, especially for power and efficiency maps of e-motors and converters, is served by integration of the power analyzer. Furthermore with AVL TFMS™ (TestFactroy Management Suite) the productivity of a test field can be increased extremely.

Furthermore the integration of AVL’s Virtual Proving Ground Technology (AVL InMotion™) provides a time and cost efficient development and testing environment for transferring integration optimization and validation tasks to earlier development phases. Different features and models (driver, vehicle, 3D road, traffic, etc.) can be used in this environment. The unit under test is integrated into a virtual driving environment and tested with reproducible driving maneuvers.

A flexible pallet system is essential for the most productive use of the test bed. Based on an air cushion system which provides an easy movement inside the climatic chamber, fast alignment and media docking is possible in less than 30 seconds. Integrated Starter Generators (ISG) and Belt-driven Starter Generators (BSG) can be tested with the same base-plate.
AVL PRODUCT DESCRIPTION

INVERTER TEST BED

AVL INVERTER TEST BEDS
AVL EMT SERIE

Main Item Description
AVL inverter test bed offers a complete development, testing- and validation environment for electric inverter system. They will be applied for the researching and analyzing the electrical, mechanical and thermal properties. Functionality, reliability and endurance test as well as performance measurement are possible under defined operation conditions.

The models characterizing battery and electric motor describe the real system.

Special attention of the AVL solution is drawn to the following application areas:
- Testing of the operational robustness and safety of the Inverter (UUT) at
  - wide DC input voltage range
  - change of the operating point (e.g. torque steps)
  - fault conditions (motor phase short circuit, defective rotor position signal, …)
- Optimize and verify the motor control for real dynamic operation
- Testing of the durability with parameterized load cycles
- Testing the thermal behavior of UUT at critical load and/or cooling conditions.
- Determine the efficiency map of UUT depending on the load point and DC link voltage.
- Product quality control in the production phase
AVL PRODUCT DESCRIPTION

TECHNICAL CHARACTERS

- Identical electrical interface like the original motor (Motor phases, Rotor sensor, other sensors)
- Identical electrical behaviors like the original e-motor
  - Emulation of parameterized back – EMF (galvanic separated from GND)
  - Operation in all 4-Quadrants Quadrats
  - Simulate the Motor Phase Inductance (parameterized for Ld, Lq)
  - Simulate the phase resistors and ohmic loses
  - Galvanic isolated emulated Motor Sensor Signals: Resolver, Vogt, Encoder, Hall, NTC,
  - no necessity to synchronize with PWM Gate Signals of high frequency UUT-Inverter
- Energy concept
  - Energy recovery to mains at motor mode of EME
- Emulation of mechanical and magnetic characteristics of the e-Motor
  - Inertia torque
  - static friction, sliding friction
  - air-gap deviations
  - temperature dependence of the winding resistor
  - number of pols of e-motor
  - Motor inductance dependence of (angular deviation and temperature)
- Emulation of typical electric motor faults (impress of errors)
  - Asymmetric phase inductance (impedance error, winding break, winding short circuit)
  - demagnetization of permanent magnets at high temperature
  - rotor position faults (sensor signal perturbation, alignment errors,…
  - blocked rotor
- Safety concept inclusive sequence processing and automation system

BENEFITS AT A GLANCE

- Flexible, easy to parameterize overall solution with automation system
- Reproducible charges of in- and outputs of the unit under test converter
- Compact solution without rotating shaft to the unit under test
- Test bed automation system with flexible interfaces for connection to customer-specific subsystems
- Efficient operation through energy recovery of the e-Storage and motor emulator into the main grid
- Interface for external battery models (Matlab / Simulink®) and electrical motor initialization
- Unit under test acceptance inclusive safe concept

TECHNICAL DATA

<table>
<thead>
<tr>
<th>ELECTRICAL MOTOR EMULATOR</th>
<th>EME 400-150B</th>
<th>EME 400-250</th>
<th>EME 400-400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulated Motor phase voltage (U1 eff/peak)</td>
<td>0…163Veff / 230Vpeak</td>
<td>0…283Veff / 400Vpeak</td>
<td>Max.45kW</td>
</tr>
<tr>
<td>Line to line motor phase voltage (U12 eff/peak)</td>
<td>0…283Veff / 400Vpeak</td>
<td>Max.250Aeff</td>
<td>Max.400Aeff</td>
</tr>
<tr>
<td>Motor phase current (rms)</td>
<td>Max.150Aeff</td>
<td>Max.250Aeff</td>
<td>Max.400Aeff</td>
</tr>
<tr>
<td>Max. output power</td>
<td>Max.45kW</td>
<td>Max.75kW</td>
<td>Max.120kW</td>
</tr>
<tr>
<td>Motor current frequency</td>
<td>0… 5000 Hz</td>
<td>0…10Ohm</td>
<td>50uH … 10mH</td>
</tr>
<tr>
<td>Simulated phase resistor</td>
<td></td>
<td></td>
<td>nom. 100kHz</td>
</tr>
</tbody>
</table>
AVL PRODUCT DESCRIPTION

MOUNTING TABLE

- For electrical safe clamping of the UUT
- Connection device for water cooled UUT
- Device for placement of a coolant conditioning device in the cabinet
- Protection cap with locking
- Operator protection via locking mechanisms of the cap (opens if discharged)
- Tube for cooling water leakages of the UUT including float switch
- Emergency Stop button and gas alarm (on demand)
- Display of the operating states
- Grounded mounting device

AVL OFFER PACKAGE

- AVL PUMA Automation Platform
- AVL e-Storage Emulator™
- AVL E-Motor Emulator
- Conditioning Units
- Mounting Table
- Climatic Chamber
- Performance measurement with integrated Power Analyzer
Main Item Description
The recoverable DC supply is used for power supply of electrical components and for tests of battery powered devices on test beds as well as in laboratories. Based on modular assembled power electronic components and on a high performance control system with numerous equipment options, the DC supplies can ideally be adapted to customer-specific requirements.

A high level of dynamic performance, a wide voltage range and low ripple allow operating different units under test. Additionally these characteristics are highlighted by high safety and reliability. Excellent EMC characteristics with low noise levels enable using sensitive measurement sensors right next to the DC supply.

Benefits
- Intuitive LCD- display enables easy voltage-, current- and power-controlling as well as control mode change
- The modular system architecture affords the upgradeability of AVL e-Storage system functional enhancement
- The modular system architecture affords the upgradeability of AVL e-Storage system application enhancement to AVL e-Storage Emulator™ or AVL e-Storage Tester™
- Energy costs can be reduced by high efficiency recovery without influence to the mains grid quality.
- Prepared interface for ISO 13849-1 and IEC 62061 testbed new safety concepts for emergency stop and safe torque off.
Safety
The e-Storage system implies safety functions such as:

- Isolation monitoring (upgradeable)
- Integration into a superior Emergency-STOP system
- Galvanic isolation between main and load via isolating transformer

Main Components
The AVL e-Storage DC Power Unit™ consists of:

<table>
<thead>
<tr>
<th>VARIANTS</th>
<th>output voltage</th>
<th>output current</th>
<th>output power</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVL EST-DC/75</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>75kW</td>
</tr>
<tr>
<td>AVL EST-DC/100</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>100kW</td>
</tr>
<tr>
<td>AVL EST-DC/160</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>160kW</td>
</tr>
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<td>AVL EST-DC/250</td>
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<td>+/- 600A</td>
<td>250kW</td>
</tr>
<tr>
<td>AVL EST-DC/320</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>320kW</td>
</tr>
</tbody>
</table>

Maximum DC output voltage: up to 1000V
Parallel operation of up to 4 variants possible!

Maximum output current: up to 2400A
Maximum output power: up to 1280kW

Customer-specific adaption of the above mentioned system variants are offered on request.
BATTERY TESTING SYSTEMS

AVL E-Storage Emulator™
AVL E-Storage System

Main Item Description
The AVL e-Storage Emulator™ is used for power supply of electrical components like e-motor/inverter systems as well as for fuel cells running in test beds or laboratories. Additionally to the functions of a constant DC voltage supply the AVL e-Storage Emulator™ is able to show on the output terminals the similar behaviour as a real battery pack will do. For example: During a load step you can see the same voltage drop as on the real battery pack.

Based on the parameter of the battery model of the AVL e-Storage Emulator™ the behaviour of the battery could be adjusted. Customer can choose to use simple battery models, advanced battery models, external Matlab/Simulink® battery model interface or via interface which is customer defined energy storage system models.

Benefits
- Intuitive operable software and a high automation level enable fast, precise and easy real-time (RT) simulation of electrical energy storage systems.
- The modular system architecture affords the upgradeability of AVL e-Storege system functional enhancement
- The modular system architecture affords the upgradeability of AVL e-Storege system application enhancement to AVL e-Storage Tester™
- Prepared interface for ISO 13849-1 and IEC 62061 testbed new safety concepts for emergency stop and safe torque off.
- No extra hardware cost (e.g. dSPACE® hardware) for using external Matlab/Simulink® battery models
- BMS (Battery Management System) emulation can easily be integrated.
Safety
The e-Storage system implies safety functions like
• Integrated Fast-STOP scenarios
• Isolation monitoring (upgradeable)
• Integration into a superior Emergency-STOP system
• Galvanic isolation between main and load via isolating transformer

Main Components
The AVL e-Storage Emulator™ consists of the AVL e-Storage DC Power Unit™ with the real-time-e-Stor age-Emulator control unit.

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Maximum DC output voltage: up to 1000V
Parallel operation of up to 4 variants possible
Maximum output current: up to 2400A
Maximum output power: up to 1280kW

Customer-specific adaption of the above mentioned system variants are offered on request.
Main Item Description
The AVL e-Storage Tester™ is used for characterization, testing and validation of vehicle traction batteries and other energy storage systems (supercaps, nickel-metal hydride, lithium-ion and lead-acid batteries). Also customer-specific adaptations are taken into consideration for providing a customized AVL e-Storage Tester™.

Benefits
- Intuitive operable software and a high automation level enable fast and easy recording of battery data and further processing.
- The modular system architecture affords the upgradeable to AVL e-Storage Emulator™
- The modular system architecture affords the upgradeable to AVL e-Storage system function enhancement such as: zero option and the extension of current measuring area (100:10:1).
- The modular design affords the extension of power upgrade or upgrade to AVL e-storage Emulator™.
- Extension modules like datalogger, impedance spectroscopy and climatic chamber can be embedded easily.
- Energy costs can be reduced by high efficient recovery without influence to the main grid quality.
- Prepared interface for ISO 13849-1 and IEC 62061 testbed new safety concepts for emergency stop and safe torque off.
Safety
The e-Storage system implies safety functions like
- Isolation monitoring (upgradeable)
- Integration into a superior Emergency-STOP system
- Galvanic isolation between main and load via isolating transformer

Component Description
The AVL e-Storage Tester™ consists of the AVL e-Storage DC Power Unit™ and the automation system AVL Lynx with a central software package for parameterization, visualization and data evaluation.

<table>
<thead>
<tr>
<th>VARIANTS</th>
<th>output voltage</th>
<th>output current</th>
<th>output power</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVL ETS-BT/75</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>75kW</td>
</tr>
<tr>
<td>AVL ETS-BT/100</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>100kW</td>
</tr>
<tr>
<td>AVL ETS-BT/160</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>160kW</td>
</tr>
<tr>
<td>AVL ETS-BT/250</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>250kW</td>
</tr>
<tr>
<td>AVL ETS-BT/320</td>
<td>8V to 800V</td>
<td>+/- 600A</td>
<td>320kW</td>
</tr>
</tbody>
</table>

Maximum DC output voltage: up to 1000V
Maximum output current: up to 2400A
Maximum output power: up to 1280kW

Maximum different unit under tests with independent test runs: up to 4

Customer-specific adaption of the above mentioned system variants are offered on request.
BATTERY TESTING SYSTEMS

AVL BATTERY TESTBED
AVL BTS SERIES

Main Item Description
The way towards electrification of power trains requires innovative solutions for development and testing of hybrid electric vehicles. In this context, the type of integrated battery technology used for energy storage and for energy supply of the e-motor/inverter system plays a key role. Energy storage systems with long lasting high power and energy density for high-dynamic charge and discharge processes as well as long lifetime are required. To fulfill the range of new driving functions such as boost operation, recuperation or “pure electrical driving” the AVL Battery Testbed offers a new “plug&play” turn-key testing solution in a secure environment.

Based on the AVL e-Storage Tester™ the complete AVL Battery Testbed with climate chamber, subsystems and TÜV certified AVL Safety Concept is realized in test rig or “plug&play” container design. AVL Battery Testbeds allow a safe and time-efficient testing of different battery chemistries. This solution is expandable with virtual real-time vehicle simulation to do a virtual fleet testing.

AVL Battery Testing Systems are designed for cell, module and pack testing level. The main architecture of AVL systems is the modular product concept that allows very easily upgrading existing systems to higher performance or enhance for further development and testing tasks.
Application
The AVL Battery Testbed is used for research, development and verification of all kinds of energy storage systems as well as for quality assurance testing within the production process. It executes all types of customer specific as well as standardized drive procedures.

Function Summary
• Test and characterization of traction batteries and other energy storage systems (supercaps, lead-acid, nickel-metal hydride and lithium-ion batteries)
• Quality assurance within the production process
• System for different kind of tests (e.g.: durability test, performance tests, calendar life and cycle life tests, driving cycle tests, virtual fleet testing)
• Realization of different environmental conditions (temperature, humidity) as part of the test runs
• Scalable for cells, modules und packs
• Interaction of Battery Management system within the test procedures

Benefits
• Modular system in test rig or containerized plug&play design
• Implemented TÜV certified AVL safety concept for battery testing
• Reduced time and effort in delivery and on-site installation
• Minimal operating costs due to intelligent test bed layout
• Saves development time trough virtual proving ground approach (enables virtual fleet testing)

System Components
AVL Battery Testbeds for battery pack testing (test and operator room) typically consist of:
• AVL e-Storage Tester™
• Climatic chamber for wide-range temperature simulation
• Overpressure protection of temperature chamber with chimney, explosion valve and flange
• AVL Safety Concept (e.g. TÜV certificate, fire protection surveys, VdS/COC standards)
• Gas alert & gas diluting systems
• Fire alert & fire extinguishing systems
• Facility management interface via test bed PLC
• Operator desk with operator facility and cabinet trolley
• Interface to sewerage system
• Mounting platform for unit under test
• Junction box
• Air conditioning system for test and operating room
• Pre-installed media supply network (electricity, air, water)
• Available for HEV module and cell testing according the specific energy storage system technologies (optional)
AVL INMOTION

HARDWARE-IN-THE-LOOP TESTING
TESTBED
AVL INMOTION SERIES

Main Item Description
The maneuver based and consistent testing of motor and drive systems on the test benches will be enabled via the combination of powerful hardware-in-the-loop (HIL) system with dynamic components or system testing beds. Additionally to engine, transmission, electrical motor, battery and drive train can also be integrated with the control unit (HCU, MCU or ESP) in the form of a hardware or a model, which is also with the possibility of switching between real and virtual components.

Function Summary
The solution bases of the IPG CarMaker®, IPG TruckMaker® and IPG Motor cycle Maker®, which are also the software products of AVL InMotion production line. It dissipates the dynamic engine / Powertrain test beds in a highly flexible simulation and testing environment for areas of efficiency, fuel consumption, emissions and driving behaviors (with AVL Drive™ and VSM). In addition, it offers an interface to the test bed. Therefore different features and models (driver, Vehicle, 3D road, traffic) can be used in this environment. The unit under test is connected in a virtual driving environment and can be tested reproducible and automatable in the longitudinal, transverse and vertical direction in dynamic driving maneuvers.
Applications
The HIL simulation on dynamic test benches offers the continuous developing of intelligent/coupled powertrains. With this solution these combination can be completed and tested in combination with the help and stability functions as well as functions for driving behaviors. Additionally fuel consumption and emissions could be evaluated via the application of the realistic 3D driving cycle (Auto racing).

Benefits
- Maneuver and route based Testing on dynamic motor or powertrain test bed.
- Professional solutions for virtual road testing based of one power and tested technology
- Combined “know-how” in the area of powertrain, suspension, test bed technology and simulation in one tool
- Open platform: individual models can be easily and fast integrated
- Flexible switchover (on and off) of real components and the model during the test run