Power-Hardware-in-the-Loop
High Performance Electric and Mechatronic Test Benches from dSPACE
Johannes-Martin Hördler, Munich, November 20th, 2019
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Introduction
# Hardware-in-the-Loop Testing Systems

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Power-Hardware-in-the-Loop

Controller | Power Stage | Electric Motor | Mechanics

Electric Power Level | Mechanical Power Level
Simulation on Power Level – Challenges

Test System Demands
- Handling of full energy flow of the device under test
- Highest dynamics to assure realistic behavior of the test bench
- Powerful software environment for flexible application

Special Demands
- Proper cooling of all power components
- Assuring health and safety requirements
- Assuring electromagnetic compatibility (EMC)
What is an electric test bench?
Electric Test Bench Principle

Example Automotive Traction Drive:
- High-voltage battery
- Inverter (device under test)
- Electric motor
Electric Test Bench Principle

Part 1: Battery Emulation

- Replace real battery by suitable power electronics to handle energy flow
- Use a suitable battery model to get realistic behavior
Electric Test Bench Principle

Part 2: E-Motor Emulation

- Replace real motor by suitable power electronics to handle energy flow
- Use a suitable motor model to get realistic behavior
Electric Test Bench – Use Cases

Devices under Test:
- Automotive traction inverters
- Industrial back-to-back inverters
- Chargers
- DC/DC converter

Emulated Parts:
- Electric motor
- Battery
- AC-grid
What is an electric test bench?

- A combination of...
  - battery emulation
  - motor emulation
  - grid emulation

- Plus all other components usually found on test benches:
  - Safety equipment
  - Measurement equipment
  - Temperature and humidity simulation
  - Cooling media conditioning
  - Control, monitoring and automation tools

...
Electric vs. Mechatronic Test Bench
Differences Of Electric and Mechatronic Test Benches

- Electric test benches interface on electric power level – no moving parts
- Mechatronic test benches include the real motor and further mechanical parts – greater test depth

Advantages Electric Test Bench
- Switch machine characteristics via model download
- Test parameter variation by mouse-click
- No mechanical or load machine related limitations

Advantages Mechatronic Test Bench
- Test complete mechatronic setups
- Test highly integrated systems
- Endurance tests
Power-HIL – dSPACE Solutions

**Electronic Loads**
- 60V / 50A\textsubscript{RMS}
- 800V / 75A\textsubscript{RMS}

**Digital Inverter Interface**
- Low-latency connection
- 8kHz communication rate

**Electric Power Level Simulation**

**Mechanical Level Simulation**
High-Voltage Testing Systems by dSPACE
High-Voltage Electronic Load Module

Key Features

- Modular hardware with parallel multilevel inverter topology
- Patented technology
- $75A_{\text{RMS}}$ per module
- Current and voltage sink and source
- Designed for parallel operation
- Supports power recovery
- Liquid-cooled for high power density
High-Voltage Electronic Load Module – Performance

**Emulation of Variable Inductance**
- Parameter variation by mouse-click
- High emulation quality with low THD
- Current emulation down to the simulated current ripple
Scalable System Power – Tailored to Your Needs

Phase Current:
1xRack: $300A_{\text{PEAK}}$
2xRacks: $600A_{\text{PEAK}}$
3xRacks: $900A_{\text{PEAK}}$
4xRacks: $1200A_{\text{PEAK}}$
High-Voltage Inverter Testing – System Concept

Power grid

HV e-load supply

HV e-load

HV e-load

HV e-load

Device under test (DUT)

DC+

DC−

Uref

Imes

Umes

Iref

Position

Battery model

Motor model
High-Voltage Inverter Testing – Application Example
High-Voltage Inverter Testing – Success Story

Electric City Bus Virtualization

- Emulation of wheel hub motor phase currents
- Emulation of DC-link battery voltage

"The electronic high-voltage test system from dSPACE enables us to precisely emulate an electric motor and a battery at power level. This lets us perform reliable tests of power control units under real electrical conditions."

Andreas Döhr, ETS, ABB Transportation Systems AG
Mechatronic Test Benches
Mechatronic Test Benches from dSPACE

- More than 10 years experience in this application area
- Well known for high performance steering and braking system test benches
- More than 150 systems delivered – world-wide
Test Benches for Your Needs

Examples
- Steering test benches
- Brake System test benches
- Auxiliary drive benches
- 3D motion platform
- Radar test benches

Exhibition #17
Mechatronic Test Benches from dSPACE

- High performance interface for linear and rotating drives
- Scalable, open control models
- Well proven standard system designs
- High degree of customization on customer request
- Seamless integration for complete virtual vehicle HIL systems
Key Takeaways

- **One stop supplier** for power-Hardware-in-the-Loop systems
- **Continuous toolchain** from Controller-HIL to Power HIL
- **Open simulation models** for processor and FPGA platforms
- **High performance** software and hardware solutions
- **Standard** system designs as well as **complete customer specific** designs
With us, mobility switches to electric even faster.
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