Analysis and Classification of Validation Environments

A Case Study in Advanced Engineering of Electric Traction Drives

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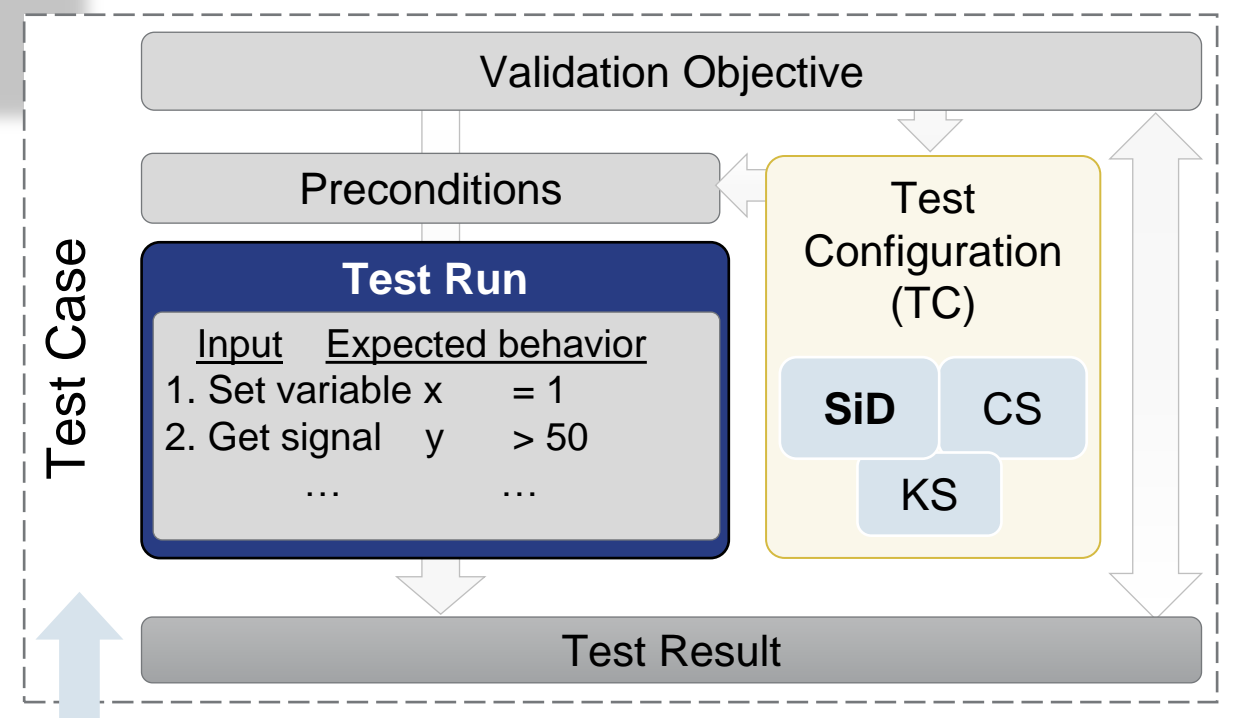[2] *IPEK – Institute of Product Engineering, Karlsruhe Institute of Technology (KIT), Karlsruhe*
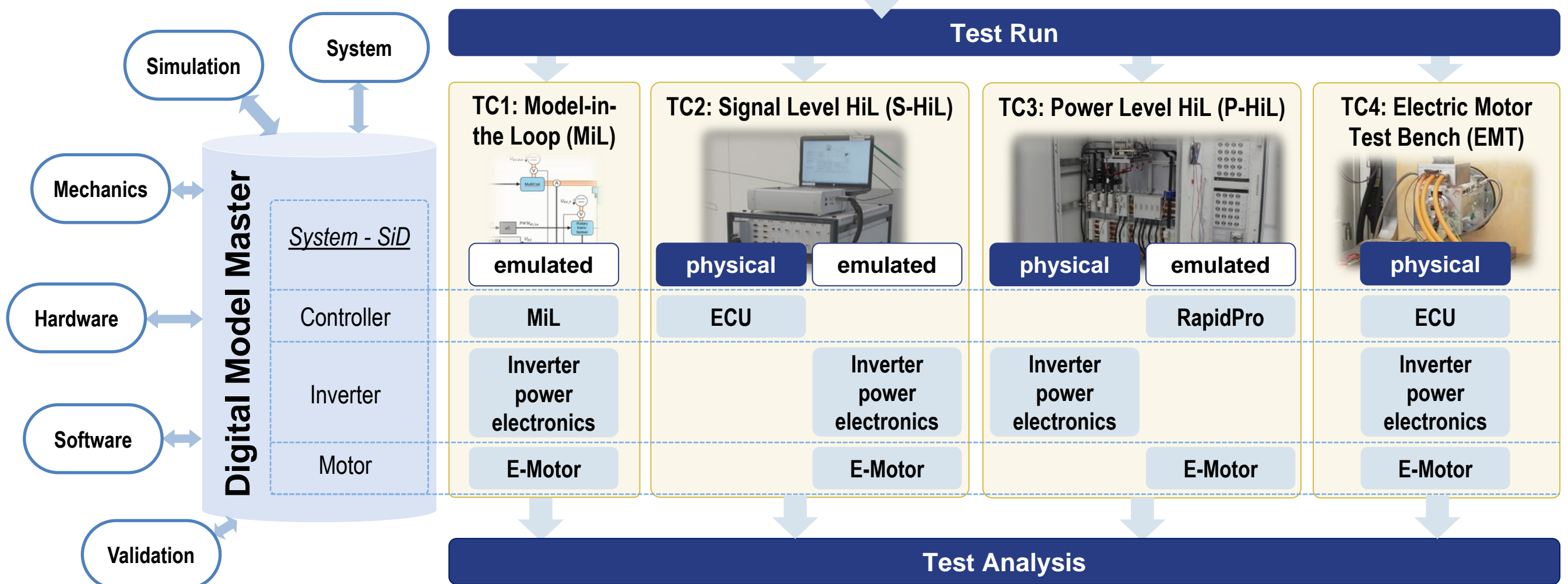
Motivation

- **Flexibility & consistency** in the Advanced Engineering of mechatronic systems like the MAHLE Inductive Externally Excited Synchronous Motor (IEESM)

- Consistency in:
    - Test cases → Test Run Framework
    - Models and parameters → Digital Model Master
    - Test results → standardized postprocessing approach

- Improving **reproducibility** and development efficiency

- Which systematic approach supports the consistent and traceable validation?

- How can test configurations be analyzed and classified to increase suitability of validation environments?

Test Run Framework

- Generic test run implementation & test configuration specific signal assignment allows standardized postprocessing

Test Case flow: Validation Objective → Preconditions → Test Run → Test Result; Test Configuration (TC) with SiD, CS, KS

Test Run
Input | Expected behavior
1. Set variable x = 1
2. Get signal y > 50
… …

Approach for Consistent and Traceable Validation

Test Run

Digital Model Master connects: Simulation, System, Mechanics, Hardware, Software, Validation

	TC1: Model-in-the Loop (MiL)	TC2: Signal Level HiL (S-HiL)	TC3: Power Level HiL (P-HiL)	TC4: Electric Motor Test Bench (EMT)
System - SiD	emulated	physical / emulated	physical / emulated	physical
Controller	MiL	ECU	RapidPro	ECU
Inverter	Inverter power electronics	Inverter power electronics	Inverter power electronics	Inverter power electronics
Motor	E-Motor	E-Motor	E-Motor	E-Motor

Test Analysis

Analysis and Classification Approach

Definition of validation objective → Identification of KPIs & test cases → Perform testing at defined test configurations → Evaluation of model credibility
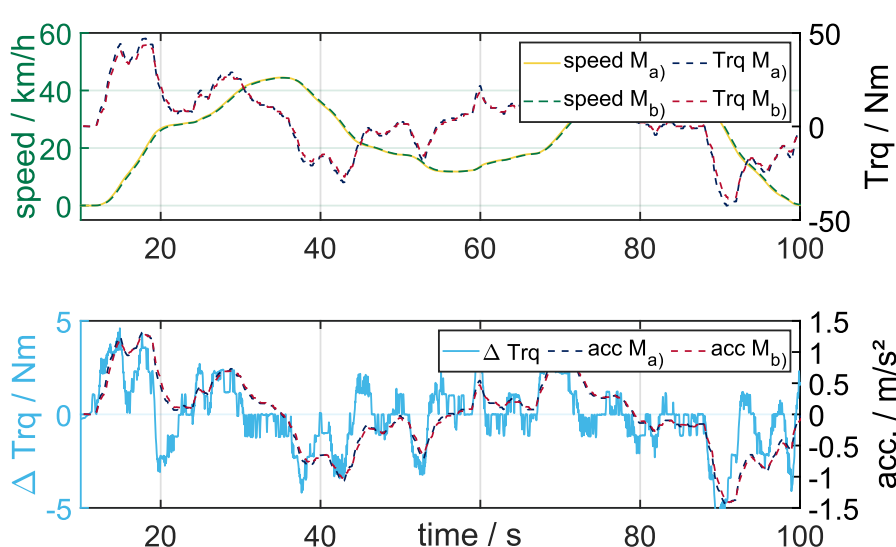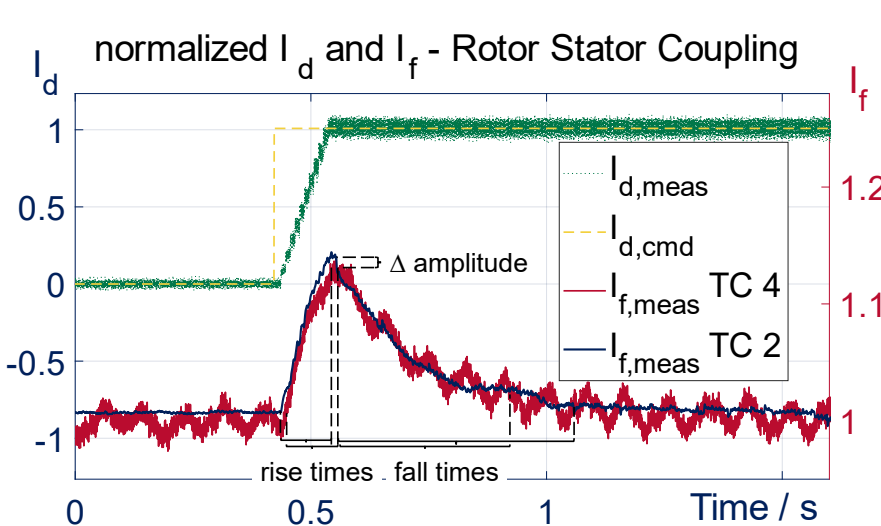
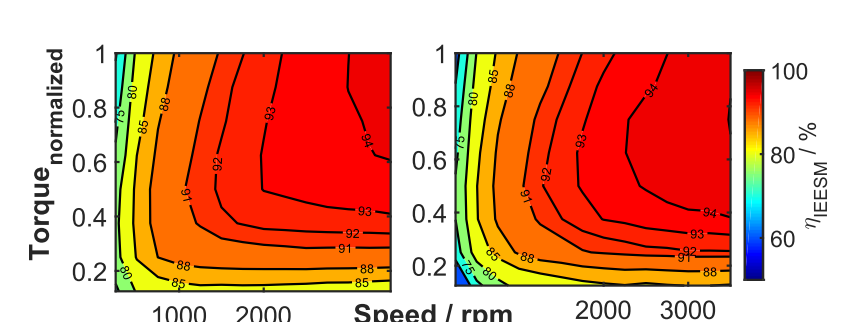## Case Studies at the MAHLE Advanced Engineering Department

- **WLTP drive cycle** power analysis of 48V TDS in MAHLE MEET application

- IEESM rotor-stator coupling behavior & **rotor current control**

normalized I_d and I_f - Rotor Stator Coupling

- Efficiency analysis of **torque control algorithms** at IEESM

→ presented approach supports highly **flexible** testing and enables **consistency & traceability**