Simulation of Electric Drives
Flexible Environment for Enhanced Testing
Matthias Deter, Munich, November 20, 2019
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Introduction
Signal Level Motor Simulation

Advantages
- Most flexible and scalable approach
- Most cost-efficient approach
- No special safety restrictions
- Low space and power requirements
dSPACE Hardware-in-the-Loop Testing Systems

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dSPACE World Conference 2019
General Considerations
Electric Drive Simulation – Motor

Requirement Identification
- Motor-specific characteristics
- Control-specific model demands
- Application-specific precision demands

The Challenge
- Finding the right degree of precision for drive virtualization
- Balancing real-time performance, flexibility, and simulation fidelity
- Optimal cost-benefit outcome
Electric Drive Simulation - Inverter

Relevant Components
- Infeed or battery
- DC link
- Inverter

Basic Considerations
- Overall topology
- Applied power switches

Simulation Requirements
- Motor operation
- Generator operation
- Simulation of losses
- Simulation of faults
Signal Level Simulation
**Hardware-in-the-Loop Simulation of Electric Drives**

- **ASM Electric Components**
  Electric drive models for processor-based simulations

- **XSG Electric Components**
  Electric drive models for FPGA-based simulations

- **dSPACE Generic Drive Model (GDM)**
  Advanced Electrical drive models for FPGA-based simulations

**Hardware**

- **SCALEXIO real-time hardware**
  - Cutting-edge processors
  - Latest XILINX FPGA technology

**Software**

- **Emulator**
  - High-performance
  - Parallel operation
  - Power recovery
  - 60 V up to 10 kW (19” unit)
  - 800 V up to 500 kW (control cabinet installation)

- **Test bench**
  - High-performance
  - Low-latency connection
  - 8 kHz communication rate
  - Turn-key benches for steering and braking systems as well as ECUs with integrated sensors

**Signal Level Simulation**

**Power Level Simulation**

**Mechanical Level Simulation**
**Signal Level Simulation of Electric Drives**

**Internal signals of the ECU have to be accessible**

- Power electronics control (e.g., gate driver signals)
- Current sensor feedback (e.g., simulation of hall transducer feedback voltage)
- Position sensor feedback (e.g., interfaces for resolver simulation)

**Real-Time Platforms**

- Processor
- FPGA

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**Fidelity**

- FPGA-based Simulation
- Processor-based Simulation
Processor-Based Simulation - SCALEXIO EMH Solution

All-in-one I/O solution
- Outstanding I/O dynamics
- Scalable I/O count
- Flexible I/O mapping
- Easy to apply

Extensive function library
- Pulse-width modulation
- Angular processing unit
- Position sensor simulation
- General-purpose I/O
Processor-Based Simulation - ASM Electric Components Library

Features at a glance
- **Ready-to-use** mean value models for electric drive simulation
- **Immediate results** with preconfigured demo models
- **Simple parameterization** thanks to ModelDesk

Main model components
- PMSM (d/q-frame)
- PMSM nonlinear (d/q-frame)
- BLDC (α/β-frame)
- SCIM (d/q-frame)
- Three-phase inverter
- Three-level three-phase inverter
- **Controller** (BLDC, PMSM, SCIM)
FPGA-Based Simulation - SCALEXIO FPGA Base Boards

Features at a glance

- User-programmable FPGA
- Modular concept for application specific I/O
- Constant technology renewal
- 4 Multigigabit transceivers 1)
- 4 GByte external RAM on board 2)

1) Optional available for DS6601 & DS6602
2) Available for DS6602 only
FPGA-Based Simulation - XSG Electric Components Library

Features at a glance

- Completely **open models** for Simulink® and Xilinx® System Generator
- Includes **e-drive models** and mandatory I/O functions
- **Demo models** including controller, power electronics, electric motor, and sensors

Main model components

- **PMSM** (d/q-frame)
- **BLDC** (α/β-frame)
- **SCIM** (α/β-frame, d/q-frame)
- **Three-phase inverter**
- **Positon Sensors** (e.g., resolver, encoder)
- **Mechanics model**
dSPACE Electric Drive Models

Processor-based simulation
- PWM-synchronous mean value models of established 3~ drives
- Full traceability of model signals

FPGA-based simulation
- Quasi-continuous calculation of established 3~ drives models
- Control of electronic loads possible

Additional features
- Multi-phase drives
- Nonlinear effects simulation
- Failure simulation
FPGA Model Improvements - Motivation

Identified Trends

- **New motor topologies** applied to fulfill increasing demands, e.g., for safety critical applications
- High-performance current and torque controller consider **spatial harmonics**
- Fail-safe tests require **physical correct simulation of electrical faults**
- **Sensorless motor control** more and more established for cost and weight reduction
dSPACE Generic Drive Model - Overview

Addressed model features

- Support of multi-phase drives (≥3) including two-level inverter model
- Support of various motor types (PMSM, IPM, BLDC, SCIM, EESM, etc.)
- Simulation of position-dependent and saturation effects (higher harmonics)
- Consideration of asymmetric effects (multisaliency)
- Physically correct simulation of dedicated electrical faults in the inverter and the motor
- Parametrization via preprocessing either with FEM data or linear parameters
- Scalable real-time performance

➡ Continuous GDM development, preliminary versions available from engineering
dSPACE Generic Drive Model - Demo at World Conference

Demo Features

- **Six-phase** synchronous motor with external excitation (EESM)
- Inverter model with **discontinuous conduction** mode support
- Resolver and **encoder** simulation
- Embedded on the latest SCALEXIO FPGA base board (DS6602)

→ See you at the demo
Key Takeaways

- Cutting-edge simulation platforms for highest dynamic
- Ready-to-use model and function libraries for processor and FPGA
- Seamless testing at all development stages
- Simulation of various position sensors
- High scalability due to modular SCALEXIO real-time hardware
With us, mobility switches to electric even faster.
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