Designing and Analysing Power Electronics Systems Using Simscape and SimPowerSystems

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Agenda

- Overview of Power Electronic Converters
  - Principle Task & Applications of Power Electronic Converters
  - Functional Principles
  - Physical Structure

- Trends

- Challenges

- Model-Based Design of Power Electronic Converters
Principle Tasks of Power Electronic Converters

- Conversion of Electric Energy with respect to
  - Voltage in/out
  - Current in/out
  - Variable load
  - Frequencies in /out
  - Different load types (R,L,C)
  - Compensation of reactive power
  - Feedback of energy
  - 3-phase
  - ...

![Diagram of power electronic converter](image)
Applications with Power Electronic Converters

- **Motor Drives**
  Inverters with variable frequency, current control

- **Power Supplies**
  Often with variable input voltage amplitude and frequency

- **Inverters for Regenerative Energy Production**
  Wind turbines, solar farms

- **Voltage Support & Power Transmission Equipment**
  FACTS (flexible AC transmission systems) – reactive power compensators
  HVDC (high voltage DC transmission)
  Coupling of grids

- **Automotive & Trains**
  (Hybrid) electric vehicles, trains
ABB Accelerates Application Control Software Development for Power Electronic Controller

Challenge
Adopt a more efficient development process using tools that accelerate the design of new application software for a high-powered electronic controller for power converters

Solution
Use MathWorks tools to design and validate their control algorithms while streamlining the application software development process for the controller

Results
- Development times and costs reduced
- Development process improved
- Highly accurate code generated

“Our system engineers can program, simulate, and verify the AC 800PEC controller’s regulation software very rapidly in MATLAB and Simulink.”

Fritz Wittwer
ABB
Functional principles

- Periodic energizing & de-energizing an energy store (inductors or capacitors)
- Power electronic switches like IGBTs, MOSFETS used for periodic switching
- Switches driven by PWM or similar more advanced algorithms
Physical structure

- **Power Unit**
  - Power electronic switches
  - Driver electronics

- **Control Unit**
  - Current/voltage control algorithms (Field oriented control)
  - Controller output drive PWM
  - Supervisory logic (Overheating, prevent Shortcircuit switching)

- **Current/voltage sensors**
  - Reading sensors via ADCs
  - Filtering sensor signals
Trends

- **System integration**
  - Multidomain systems (electronical, thermal, controls, mechanical)

- **Energy Efficiency**
  - Decreasing Switching Power Losses by short switching times
  - Local Energy Stores for energy feedback

- **Increasing power & power density in switching device**
  - Series connection of IGBTs $\rightarrow$ multilevel converters
  - Cooling concepts

- **Rapid & flexible control concepts**
  - Highly dynamic control
  - Robustness for varying operating conditions (load, voltages …)
Challenges

- Predicting system behavior in early development state
- Underestimating system complexity
- Duration of iteration cycles in development
- Time consuming testing
- Expert know-how hidden in undocumented code
What is the Most Expensive Project Stage to Find Errors In?

Errors introduced early but found late in the process are expensive to fix!

Errors introduced in:
- coding phase
- design phase
- requirements phase

Start Testing on Day One
Early Verification of Concept

- Predict dynamic system behavior by simulating
  - Less physical prototypes

- Use of simulation results for system design
  - What / if studies
  - Short iteration cycles

DESIGN

Environmental Models
Mechanical | Thermal | Electrical
Control Algorithms
Supervisory Logic

Idea

Simple model

Detailed model
Appropriate Methods of Modeling

- Environmental Models
  - Mechanical
  - Thermal
  - Electrical
- Control Algorithms
- Supervisory Logic

DESIGN

Control & filter algorithms (Simulink)

Control & Supervisory Logics (Stateflow)

Electronical, thermal, mechanical systems (Physical Modeling)

Reuse of legacy code & engineering data from
- Cosimulation
- Exiting algorithms in C, MATLAB
Integrated Control Design

- Reuse of the model for extracting plant description directly from model
- Automated creation of a linearized small signal equivalent model at selected operating points
- Interactive and automatic control design according Linear Control Theory

- Robust control design by considering converter behavior at several operating points in parallel
Test and validate in real-time

Rapid Prototyping of Control Algorithms
- Fast implementation of algorithms in C & HDL for functional testing in RT

Hardware-In-The-Loop Testing of Plant
- Capability of testing critical scenarios without risk of damaging HW

RESEARCH
REQUIREMENTS

DESIGN
- Environmental Models
- Mechanical
- Electrical
- Control Algorithms
- Supervisory Logic

IMPLEMENTATION
- C, C++
- VHDL, Verilog
- Structured Text
- MCU
- DSP
- FPGA
- ASIC
- PLC
Automatic Production Code Generation

**General**
- Code generation in C/C++, HDL, IEC61131-Structured Text
- Fast implementation by automatic code generation from models
- Support of fixed point data format in simulation and code generation
- Prevention of implementation errors
- Algorithm development independent of implementation HW

**C-Code**
- Integration of Legacy C/C++-Code
- Automated integration with variety of Embedded IDEs and µP/DSP
Traceability from Requirements to Code

- Linking Requirements with Model Blocks and generated Code
  - Find corresponding locations easily in model and code
Benefits of Model-Based Design

- Predict system behavior in early development state
- Handle system complexity
- Short iteration cycles
- Less physical prototypes
- Fast implementation by automatic code generation
- Reuse of test cases

**Diagram:**
- Environment Models: Mechanical, Thermal, Electrical
- Supervisory Logic
- Control Algorithms

**Implementation:**
- C, C++
- VHDL, Verilog
- Structured Text
- MCU, DSP, FPGA, ASIC, PLC

**Integration:**

**Research**

**Requirements**

**Design**

**Test & Verification**