Tutorial Title

Design and Simulation of Three-Phase Grid-Tied Converters: From Modeling to Real-Time HIL Testing

Instructor Team

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Abstract

The increasing penetration of power-electronic converters is significantly changing the structure and dynamic behavior of modern electrical grids. As power systems move toward more decentralized and converter-dominated configurations, the design and implementation of converter control systems must address increasingly demanding requirements related to stability, dynamic performance, and grid integration. These developments also call for systematic approaches to modeling, controller design, implementation, and experimental validation.This workshop introduces a design and validation workflow for three-phase grid-connected converters, combining offline simulation with real-time Hardware-in-the-Loop (HIL) testing. The proposed approach integrates the different stages of converter development, allowing control concepts to be evaluated in simulation before being transferred to the target controller and tested under real-time operating conditions.A three-phase grid-connected voltage-source converter is used as the main case study. Starting from the converter and grid models, the workshop addresses the design and simulation of the control system and examines its behavior under representative operating conditions. TyphoonSim™ is used for offline simulation, followed by controller implementation through automatic code generation for a target microcontroller. The resulting control implementation is then evaluated using a Typhoon HIL real-time platform. Through this example, participants will follow the complete development path from mathematical modeling and controller design to embedded implementation and HIL validation. Particular emphasis is placed on the relationship between simulation, implementation, and experimental testing, illustrating how an integrated workflow can reduce development time while providing a systematic environment for assessing the performance of grid-connected converters.

Tutorial Outline

Part 1 – Introduction to the Methodology: (Estimated time: 30 minutes)

- Why Model-Based Engineering and Hardware-in-the-Loop testing?
- Challenges of real-time simulation for state-of-the-art power electronics converters.
- Product development cycle and different simulation methodologies.
- The challenges of fragmented development cycles.
- Typhoon HIL's integrated simulation environment.

Part 2 – Application Example and Hands-On Offline Simulation (Estimated time: 60 minutes)

- Introduction to the application: Control of three-phase grid-tied converters
- Model and control implementation.
- Hands-on: Offline simulation using TyphoonSim™.

  Offline simulation using Typhoon VHIL.

Part 3 – Controller Hardware-in-the-Loop (Estimated time: 60 minutes)

- Introduction to the automatic code generation tool.
- Control implementation in a Texas Instruments LaunchXL-F28379D using the HIL TI LaunchPad Interface.
- Real-time C-HIL testing using the HIL101 real-time simulator.

Part 4 – Conclusions (Estimated time: 30 minutes)

- Conclusions and Q&A session.

Tutorial Style and Requirements

The tutorial will begin with a conceptual overview of both the methodology and the application, followed by software and hardware demonstration. Interactive hands-on sessions throughout the tutorial will allow participants to interact directly with the software toolchain and validate the concepts being presented with simulations. For attendees wishing to participate actively in these hands-on sessions, we kindly ask you to bring their laptops and ensure the software is installed and running prior to the training (made available at no cost). Detailed instructions and event-specific trial software licenses will be provided in advance. Attendees will receive high-quality slides and example models, which will support the tutorial content and enhance the overall experience. In addition to personal laptops (optional for hands-on participation), a projector and a suitable space to accommodate this arrangement with tables and power outlets, no special requirements are anticipated. The

demonstrations and hands-on activities are simulation-based and do not include real power. **The number of participants will be limited to 15 due to the number of HIL 101 devices and DSP kits available. Priority will be given for PhD students.**