Geographically Distributed Power-Hardware-in-the-Loop Coupling of a Physical Low Voltage Grid and a Real Time Simulation

O. Kraft, O. Pohl, U. Häger, C. Rehtanz, K. Heussen, O. Gehrke

Introduction

- Objective: Development of a testbed to test flexibility control algorithms for congestion management across multiple voltage levels with physical assets
- Implementation of a medium voltage (MV) grid with controllable DER at the Smart Grid Technology Lab (SGTL) at the TU Dortmund University (TUD) on an OPAL-RT real time simulator (RTS)
  - Radial structure with three switches allowing for the simulation of topology changes
- Hardware under test (HUT) in the form of a physical low voltage (LV) grid with flexible assets at the PowerLabDK SYSLAB of the Technical University of Denmark (DTU)
  - Realization of various LV grid topologies through changes in the breaker statuses

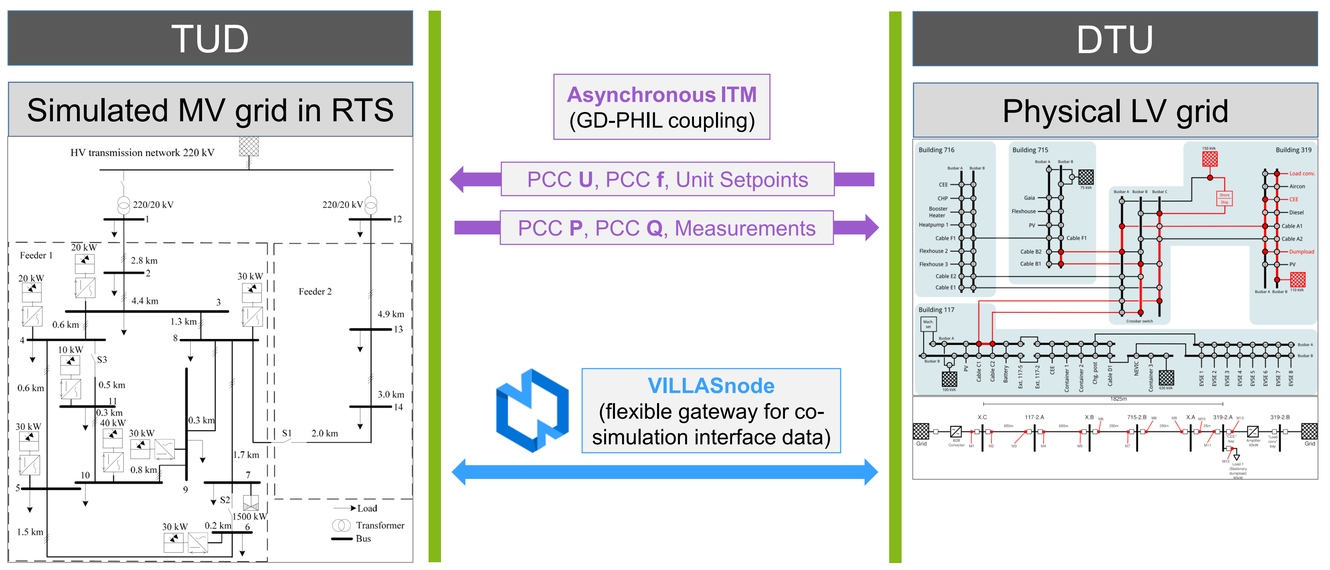
Electrical Coupling

- RTS-HUT coupling realized as a virtual remote electrical coupling at a point of common coupling (PCC) through the ideal transformer method (ITM) as interface algorithm (IA)
  - Measurements of the voltage and frequency at the PCC in the MV grid to be transmitted to SYSLAB, where the PCC is emulated through a voltage source
  - Measurements of active and reactive power are returned to the SGTL, so that a current source can emulate the PCC

Communication

- Realized through the open-source tool VILLASnode, which is a flexible gateway for GD-RTS and GD-PHIL co-simulation interface data and can convert multiple protocols to and from various geographically distant destinations.
- Implementation of a VILLASnode supernode with a UDP- and a WebSocket-interface at each laboratory on a dedicated server in order to integrate the HUT/RTS
- Exchange of live data through a WebSocket connection between the supernodes via the internet
- Set points to be sent from SGTL to flexible SYSLAB-devices via this setup with LV grid measurements going back to SGTL

Laboratory Coupling

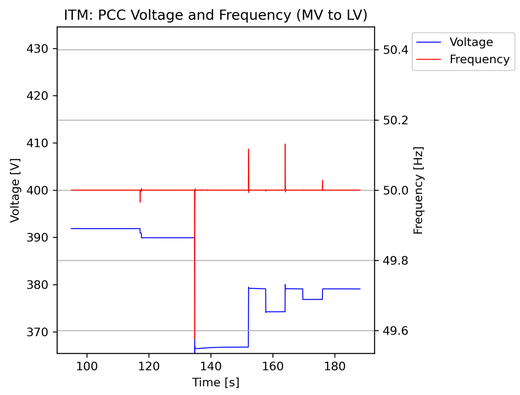


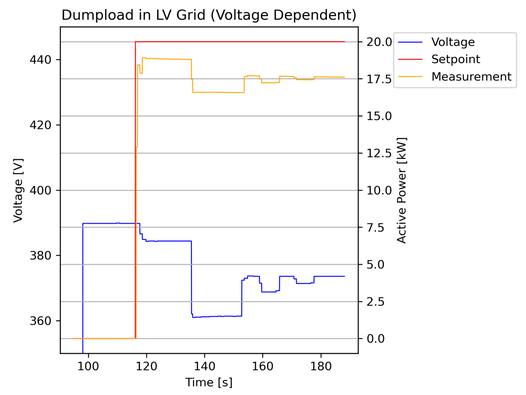
Testing Results

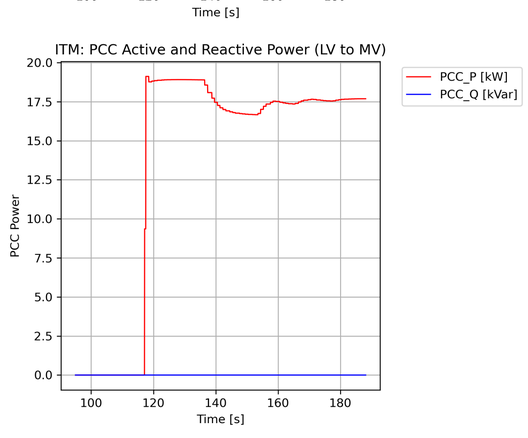
Setup:

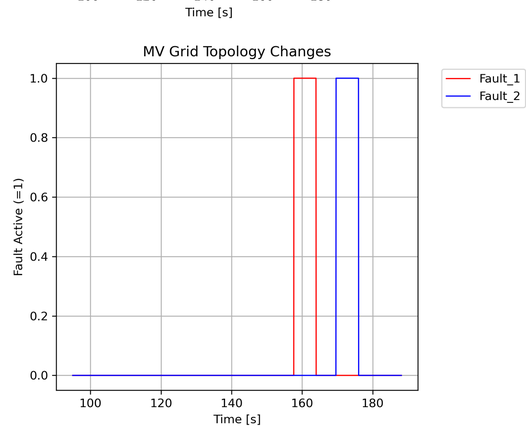
- Simplified SYSLAB Basecase setup
- One feeder with one flexible, controllable load
- Simulation of load jumps in MV grid
- Topology changes in the MV grid

t [s]	Control Action
116	Setpoint to flexible load
134	+200kW load jump in MV
152	-100kW load jump in MV
157	MV topology change 1 start
163	MV topology change 1 end
170	MV topology change 2 start
177	MV topology change 2 end









Institute of Energy Systems, Energy Efficiency and Energy Economics

Smart Energy Systems ERA-Net

Federal Ministry for Economic Affairs and Climate Action