Connecting European
Smart Grid Infrastructures

Co-simulation Based Assessment Methods for Cyber-Physical Energy Systems (CPES)

CPES comprise a complex and distributed infrastructure with a myriad of components and embedded functions interlinking various domains. The complexity of CPES requires various approaches for its holistic evaluation, among which heterogeneous modelling (i.e., multiple domains and tools), virtual, and non-virtual approaches. As for virtual testing, the validation of systems and its components is realised by coupled simulation (co-simulation), in which the system under test is split up into subsystems, each of which being modelled inside distinct, domain-specific simulators. This allows scrutinising the CPES behavior in a detailed and flexible fashion.

Application of Mosaik and the functional mock-up interface (FMI) specification:

- Flexible scenario and experiment setup creation
- Relying on existing quasi-standardised approaches backed by a large user community
- Spatially distributed implementation of experiment setups
- Fostering the co-operation of domain-specific experts
- Easy and flexible creation of a smart grid component library based on FMI

Mosaik

Mosaik is a co-simulation framework that is designed for easy integration of simulators and flexible creation of co-simulation scenarios. The execution of the experiment is managed by a discretely timed scheduling algorithm. In ERIGrid, Mosaik fulfills two roles:

- As an environment for exemplary co-simulation test cases
- As a testbed for a library of newly developed FMI compliant CPES component models

Functional Mock-up Interface (FMI)

FMI is a standard for the interfacing of simulators and simulation models and supports two types of interfaces:

- FMI for co-simulation (CS) defines stand-alone black-box simulation components, which can be directly coupled within a co-simulation framework.
- FMI for model exchange (ME) provides standardised access to the model equations, enabling simulation environments to exchange models.

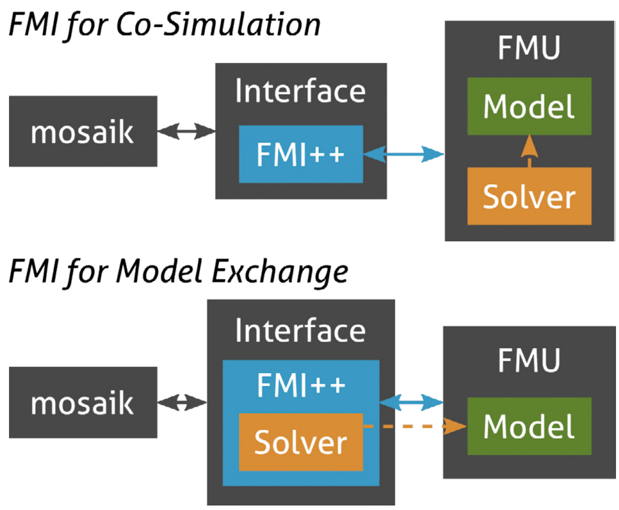

Figure 1: Application of Mosaik and the FMI standard

Creating an interface or model that complies with FMI-CS or FMI-ME generates a functional mock-up unit (FMU). Figure 1 shows how these interfaces can be coupled to Mosaik. In either case, the FMI++ toolset is used, which boasts convenient coupling functionality through its API.

Approach

ERIGrid establishes and proposes solutions for CPES-specific co-simulation functionality needs:

- Cyclic dependencies between simulators
- Hardware-software coupling with FMI
- Signal-based synchronisation

Outlook and next steps

- Multi-domain scenario creation and simulation
- Improved scalability (system sise and number of simulators)
- Readiness for cyber-security assessment

Project Duration:

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30 April 2020

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Real-time Simulation and Hardware-in-the-Loop Testing for Smart Grid Validation and Roll-out

Hardware-in-the-loop (HIL) technology allows validating hardware components, devices or system in real conditions and scale, where parts of the whole test components are simulated in a real-time digital simulator. HIL enables safe and repeatedly testing of a device in faulty and extreme conditions without damaging laboratory equipment, while providing also flexibility in setting up the test setup in transient and steady state network operation. Offering a wide range of possibilities, current HIL technology still has several limitations, which the ERIGrid project is dealing with: limited capacity of HIL simulation for complex systems, remote HIL and geographically distributed HIL for joint experiments, power interface stability and accuracy of Power-hardware-in-the-loop (PHIL) and lack of a general framework/standard for HIL testing.

ERIGrid focuses its HIL research on:

- **Technical improvement to HIL**:
  - Integration of HIL to co-simulation framework
  - Improvement on the capacity of HIL (stability and accuracy, capacity of Remote HIL)
- Contribution toward a **general framework for smart grid validation** with HIL test

Integration of HIL to co-simulation framework

Integration of HIL to co-simulation framework allows multi-domain experiments with realistic behaviors from hardware equipment under a variety of complex environments, co-simulated by several simulators from different domains. It will enable a complete consideration of electrical grid interconnected with other domains in a holistic manner. In ERIGrid, three approaches are proposed:

- Integration of HIL to "offline" co-simulation with Functional Mock-up Unit (FMU)
- Integration of HIL to co-simulation without signal synchronisation
- Integration of HIL to co-simulation with signal synchronisation via a master algorithm

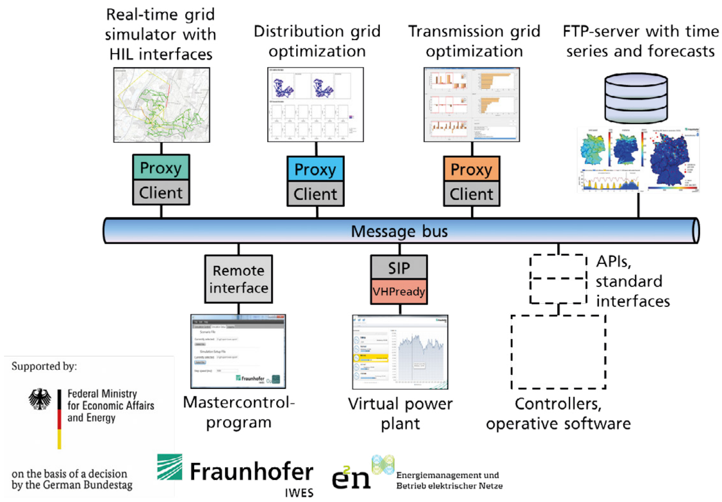

Figure 2: Possible integration of HIL and co-simulation with the OpSim environment. Image is based on the illustration from www.opsim.net.

PHIL stability and accuracy improvement

ERIGrid proposes two methods for stability analysis and assessment of PHIL test and synchronisation and compensation of loop delay:

- Stability analysis to determine the marginal parameters of a PHIL experiment
- Time delay compensation via phase shifting to improve accuracy

General framework for smart grid validation

The above contributions of ERIGrid are integrated into a general framework including co-simulation, Controller-Hardware-in-the-Loop (CHIL) and PHIL. It is an important contribution to the holistic approach for smart grid validation and roll-out. The development of the framework is ongoing and is subjected to further standardisation.

ERIGrid Project Partners

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