Cyber-Physical Energy Systems Modeling, Test Specification, and Co-Simulation Based Testing

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- Holistic test description method
- Joint research activity 2: co-simulation based assessment methods
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ERIGrid overview
ERIGrid Project Fact Sheet

- European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out
- H2020 research project
  - INFRAIA-1-2014/2015: Integrating and opening existing national and regional research infrastructures of European interest
- 18 Partners from 11 European Countries + 3 Third Parties involved
- Involvement of 21 first class Smart Grid labs
- ~1000 Person Months
Main Goals

- Roll-out of smart grid approaches in a **holistic** fashion
- **Integrating** the major European research centres
- Integrating & enhancing the research services for analysing, **validating and testing** Smart Grid configurations.
- support and education for industrial and academic researchers in Smart Grid research
- Strengthening the technical leadership of the European Research Area in the energy domain
Overview ERIGrid Approach

- Leading research infrastructure in Europe for the domain of Smart Grids
Holistic test case description method
Requirements for holistic testing

- Considered systems are multi-domain, tools are domain specific
- Validation and testing can be conducted
  - virtually and non-virtually
  - Across multiple research institutions
- Use case may yield various experimental setups
- Experimental setups may serve multiple use cases
- Need to formally distinguish between test specification and experimental implementation
- ERIGrid: Hierarchical, holistic test case description
Holistic testing methodology
JRA2: cosimulation based assessment methods
JRA2: co-simulation based assessment methods

- Focus on **virtual** testing and validation of components and systems
- Co-simulation of multi-domain systems using:
  - the **mosaik** smart-grid co-simulation framework
  - the **functional mock-up interface**
- Smart-grid model library based on FMI-ME
- Scalability assessment methods of smart-grid co-simulations
- Scalability improvements for smart-grid co-simulations
Summary of mosaik

- Mosaik is a co-simulation tool
- Main functionalities:
  - Organize data exchange
  - Synchronization
- Main use cases:
  - Create scenario
  - Connect simulators

https://mosaik.offis.de/
Scenario Creation

List and initialize simulators
Scenario Creation

Create entities
Scenario Creation

Connect entities
Cyclic Data Dependencies

Data flow

No problem

Problem
(Who comes first?)

Mosaik solution: *Asynchronous Requests*
Cyclic Data Dependencies

- Establish data connection in one direction
- Include asynchronous request
- Cycle is resolved via a shift in time
B.step(1) → 2
FMI and mosaik

- **FMI for Co-Simulation**
  - mosaik
  - Interface
  - FMI++
  - FMU
    - Model
    - Solver

- **FMI for Model Exchange**
  - mosaik
  - Interface
  - FMI++
  - Solver
  - FMU
    - Model
Proof-of-concept
Grid integration challenge

- Wind turbines
  - Dynamic behavior differs from conventional generators
  - Dynamics determined by power electronics
  - Reactive current injection during faults possible

- Grid codes
  - Harmonize technical requirements for generators
    - Low-voltage ride through
    - Reactive power support

- Current rating of wind turbine converters is limited
Low-voltage ride through

Sometimes also referred to as fault ride-through (FRT)
Challenges for simulation experiment

- System under test exhibits a strong coupling between
  - Wind turbine behaviour during faults
  - Voltage and frequency response of the external grid
- Large grids commonly modelled by RMS-type simulators
- Sophisticated converter models require EMT-type tools
- co-simulation is an attractive option
- SuT split at wind park coupling point
- Cyclic-dependency between both simulators
approach

- Formal description of the test case
- Build reference experiment in Matlab/Simulink
- Export wind turbine models as FMUs for model exchange
- Develop FMI-based interface for Powerfactory
- Model external grid (IEEE 9-bus test system) in Powerfactory
- Couple Powerfactory to mosaik through FMI-CS
- Couple wind turbine model to mosaik through FMI-ME
- Run co-simulation
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Test system configuration
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Reference experiment
Simulation results
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- Run co-simulation
Test system configuration
Co-simulation implementation
Follow-up

- Foster the application of the formal specification methods
- FMI-based RMS and EMT-type simulation coupling
- FMI-based coupling of discrete-event simulators and power system simulators
- Integration of FMI into hardware-based coupling
- Multi RI co-simulation
- Assessment of large-system behaviour (many simulators, that is)
Thank you

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