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

Arjen van der Meer / TU Delft

(JRA2 work package leader)

EU H2020 Programme GA No. 654113

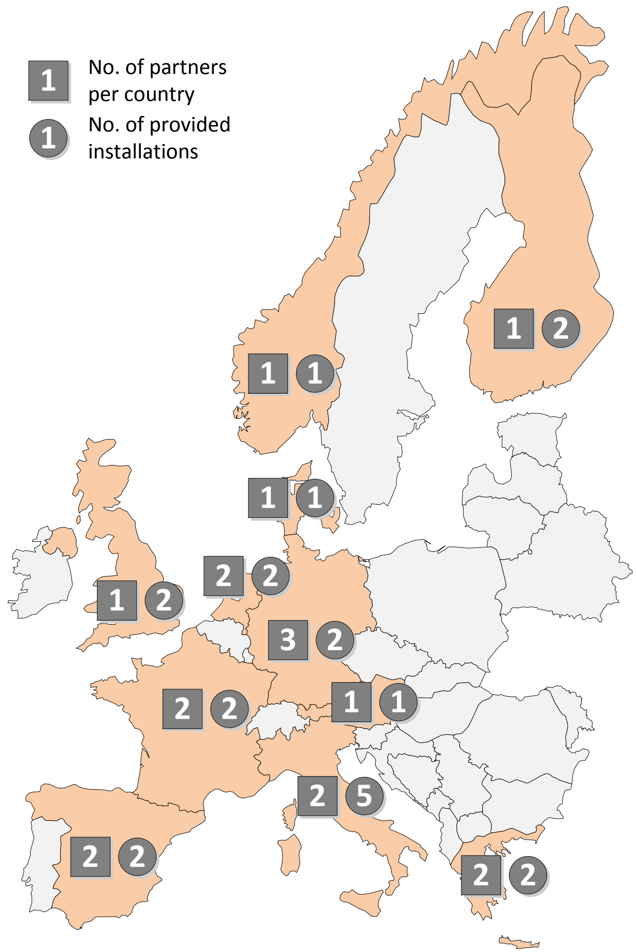
Contents

- Overview on ERIGrid project
- Holistic test description method
- Joint research activity 2: co-simulation based assessment methods
- Proof-of-concept test case

ERIGrid overview

ERIGrid Project Fact Sheet

- **E**uropean **R**esearch **I**nfrastructure 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

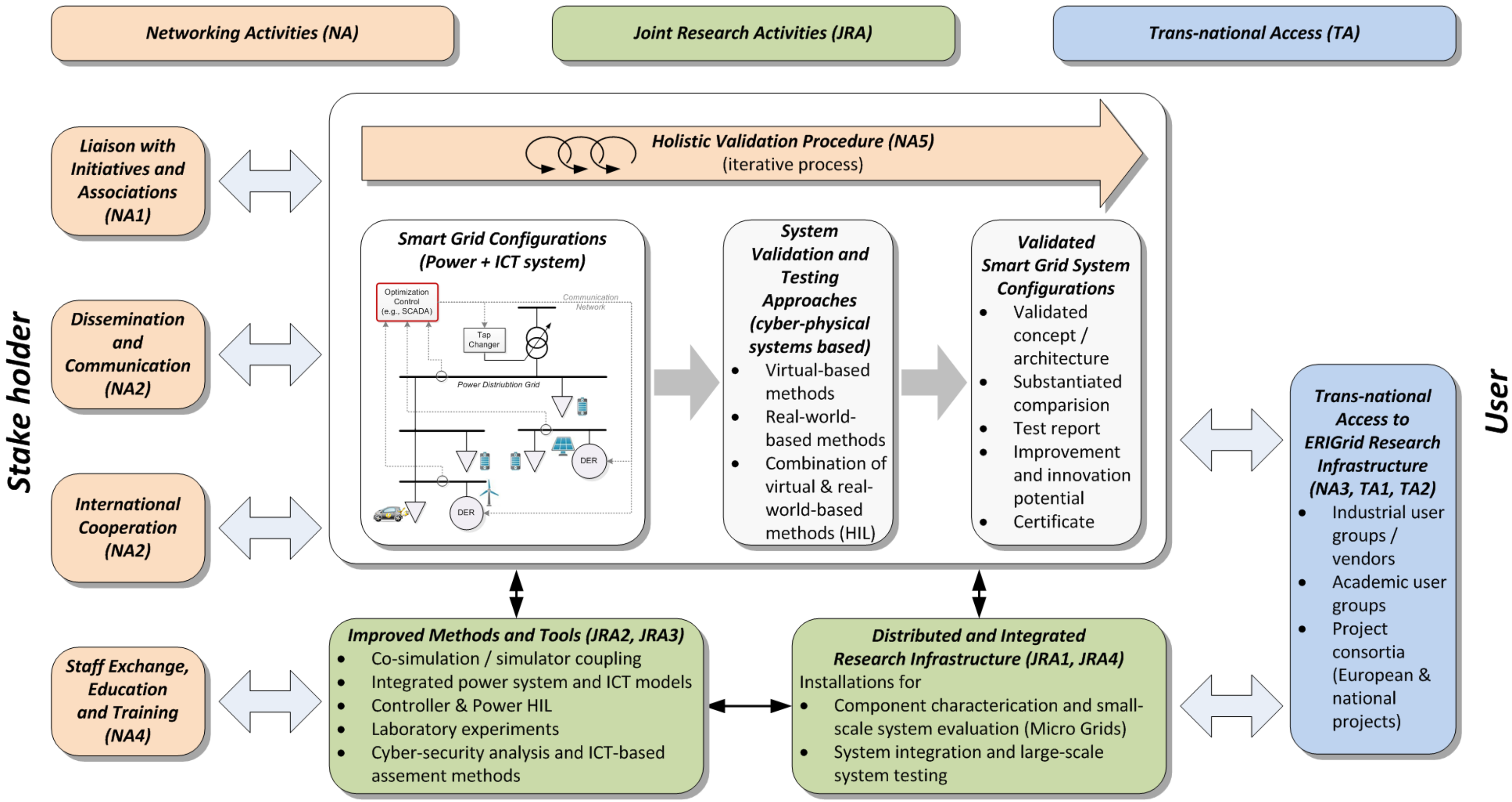


Main Goals

- 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

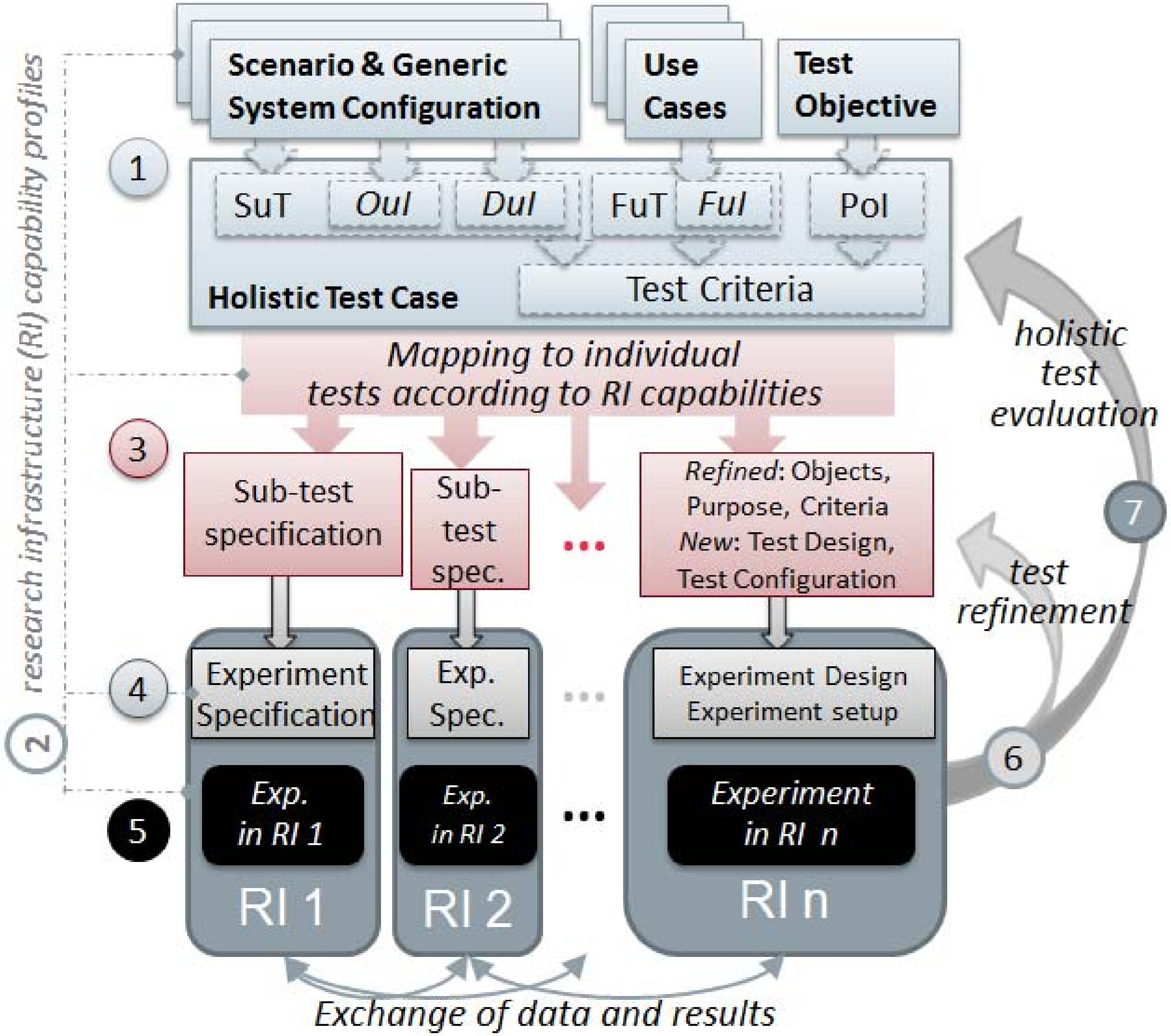


Holistic test case description method

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

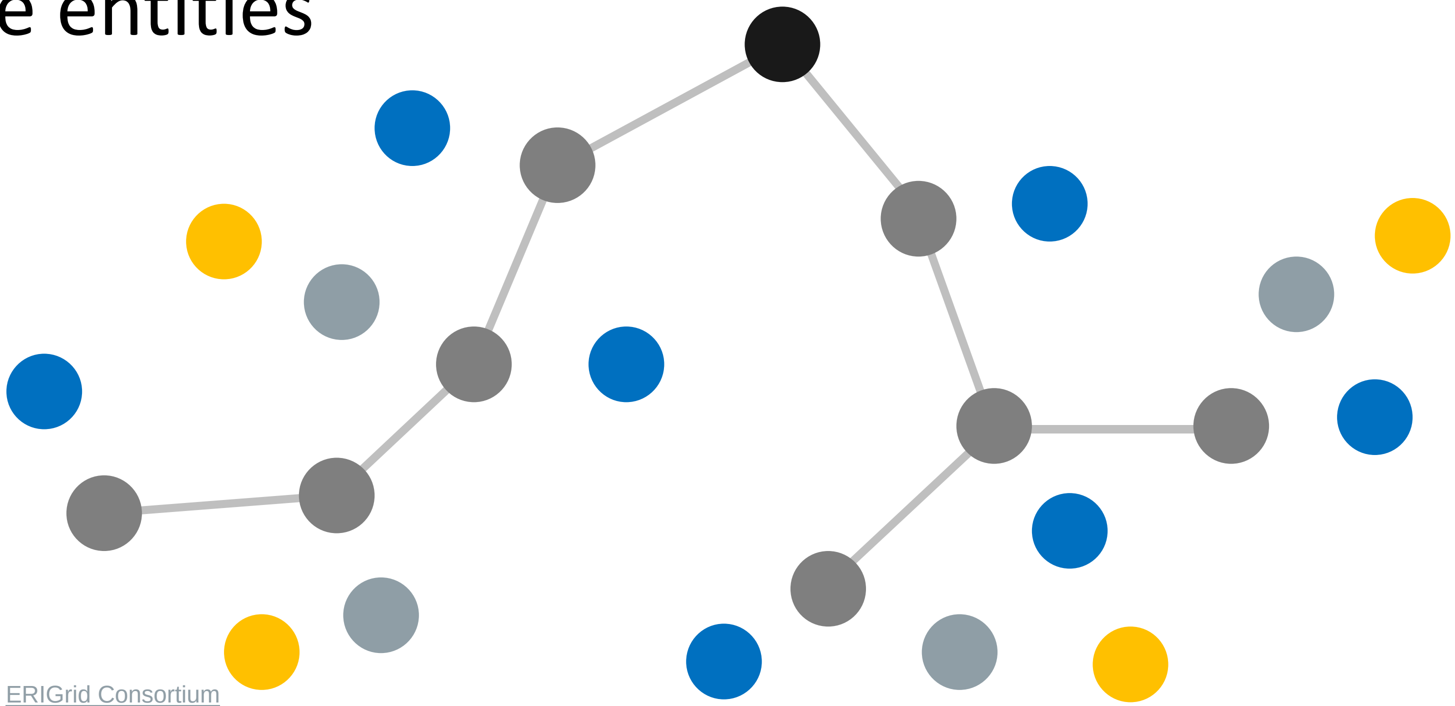
https://mosaik.offis.de/

Scenario Creation

List and initialize simulators

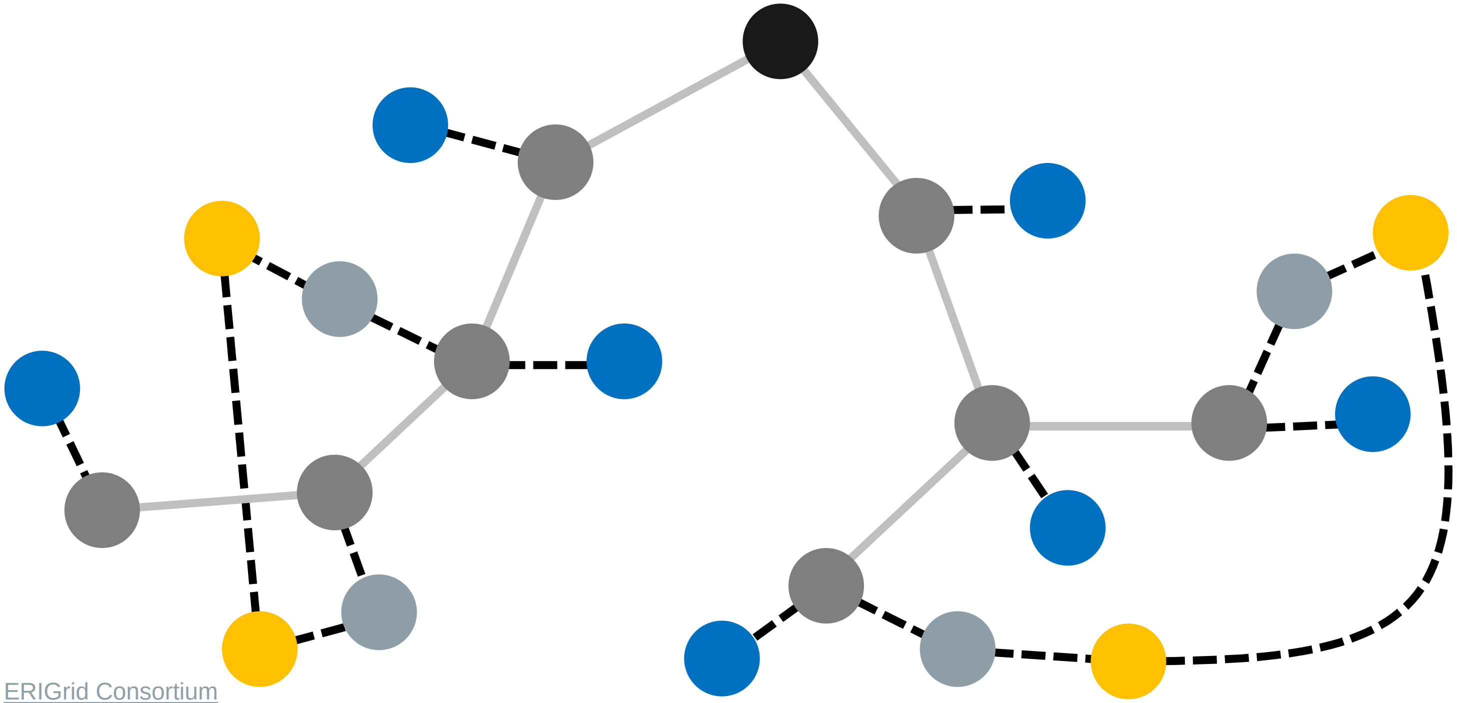
Scenario Creation

Create entities

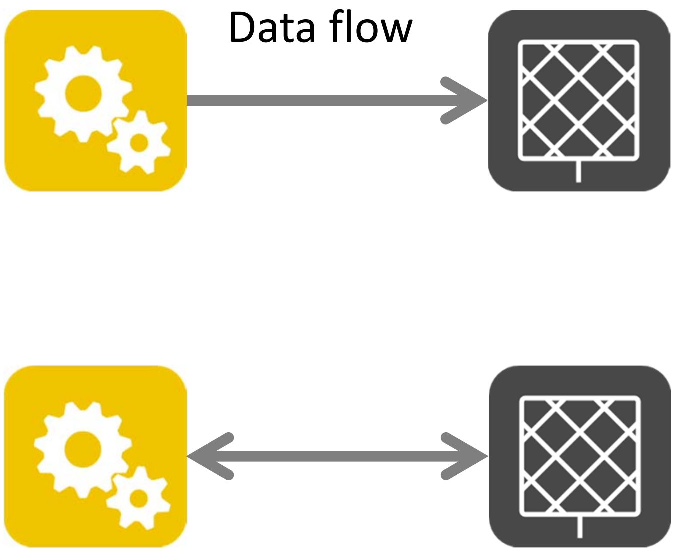


Scenario Creation

Connect entities



Cyclic Data Dependencies



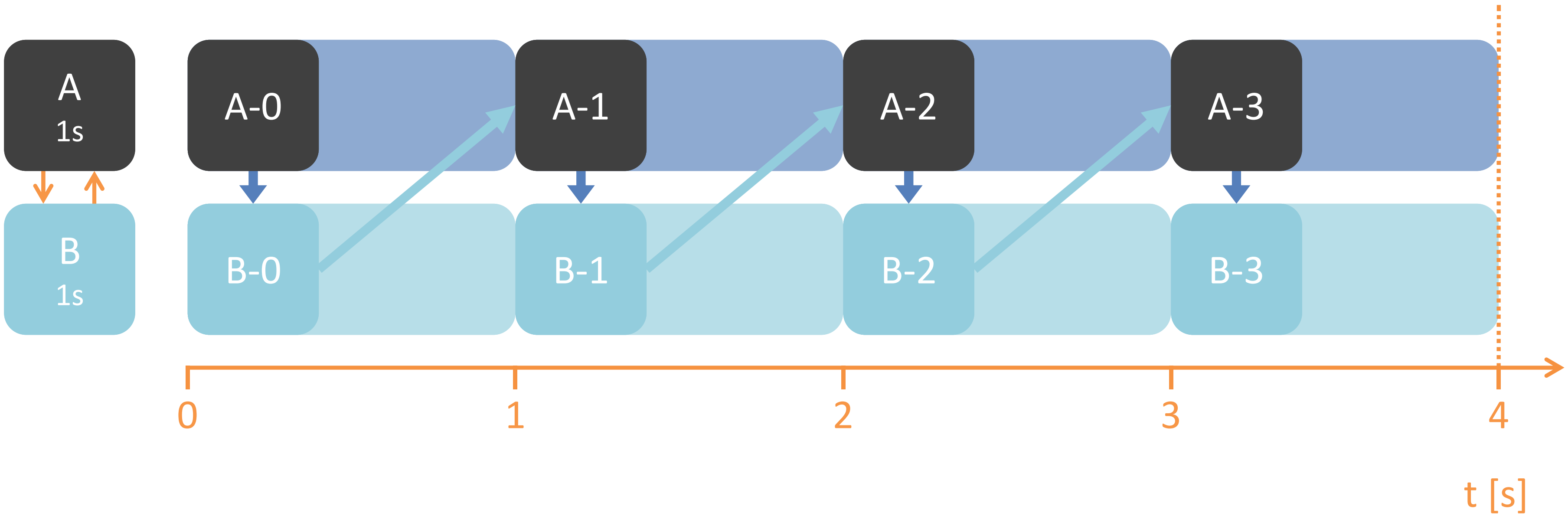
No problem

Problem
(Who comes first?)

Mosaik solution: *Asynchronous Requests*

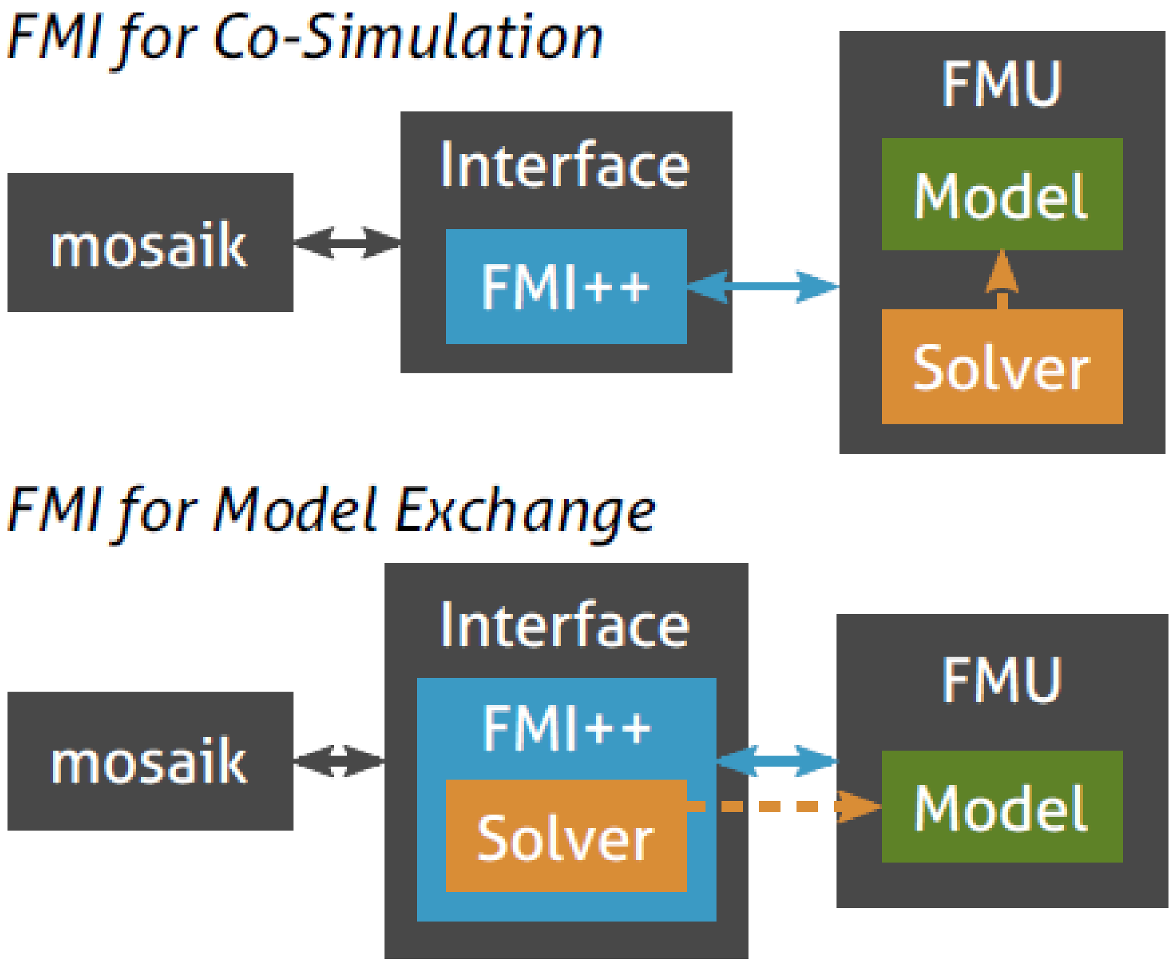
Cyclic Data Dependencies

- Establish data connection in one direction
- Include asynchronous request
- Cycle is resolved via a shift in time



B.step(1) → 2

FMI and mosaik

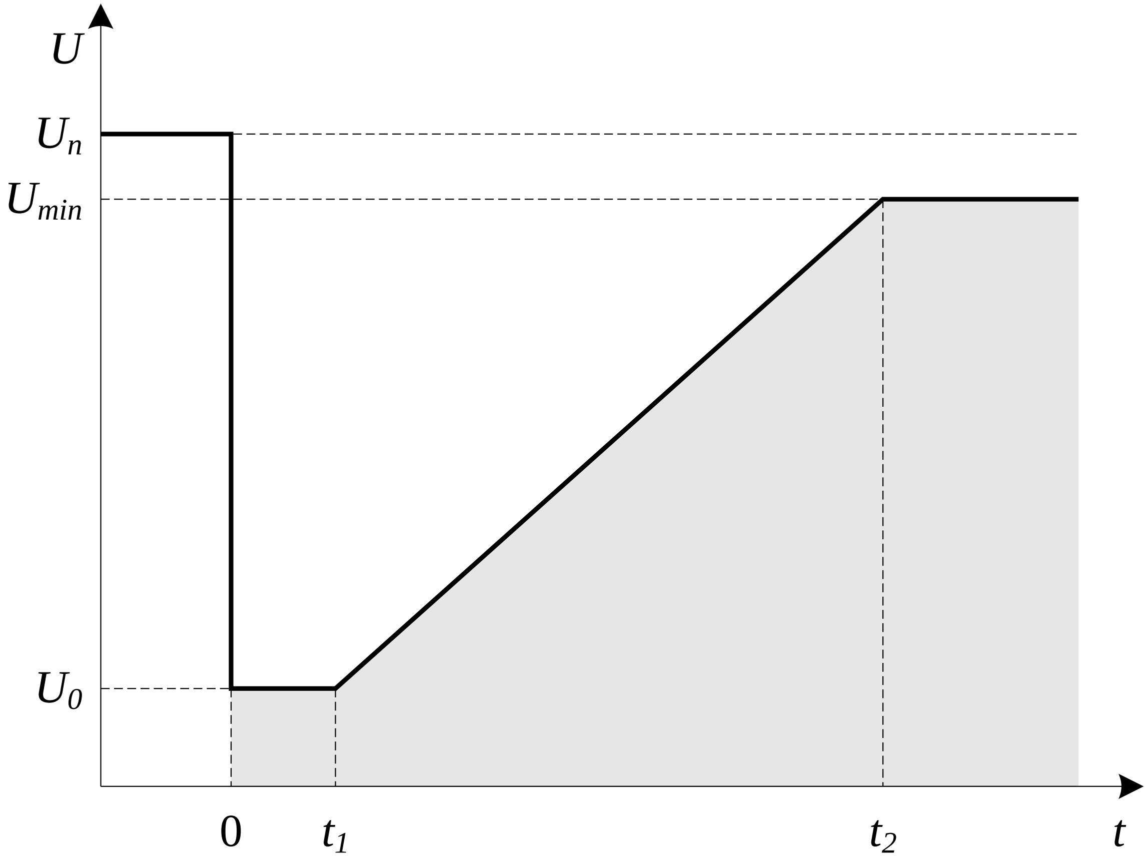


Proof-of-concept

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

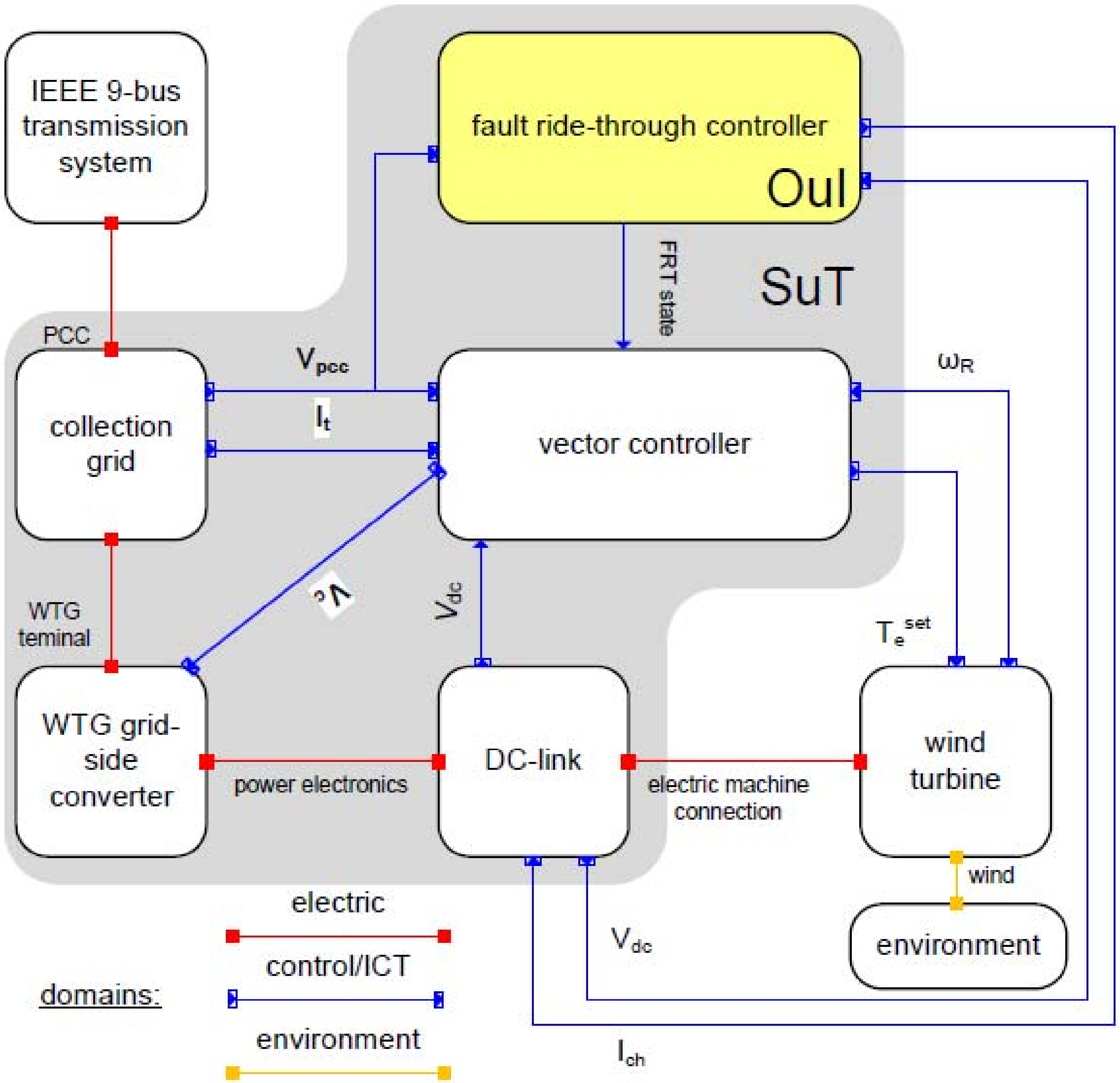
approach

- 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

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

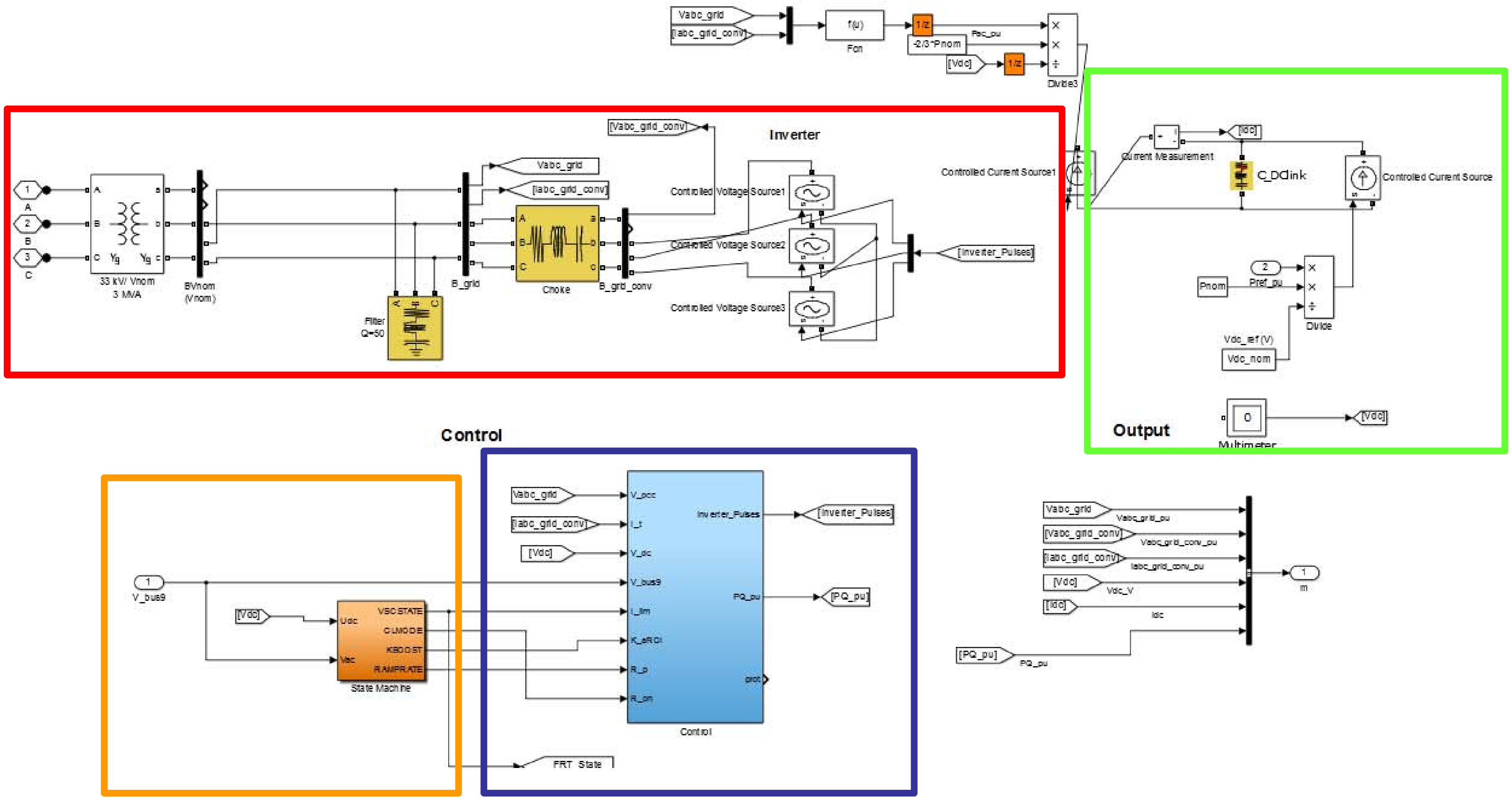
Test system configuration



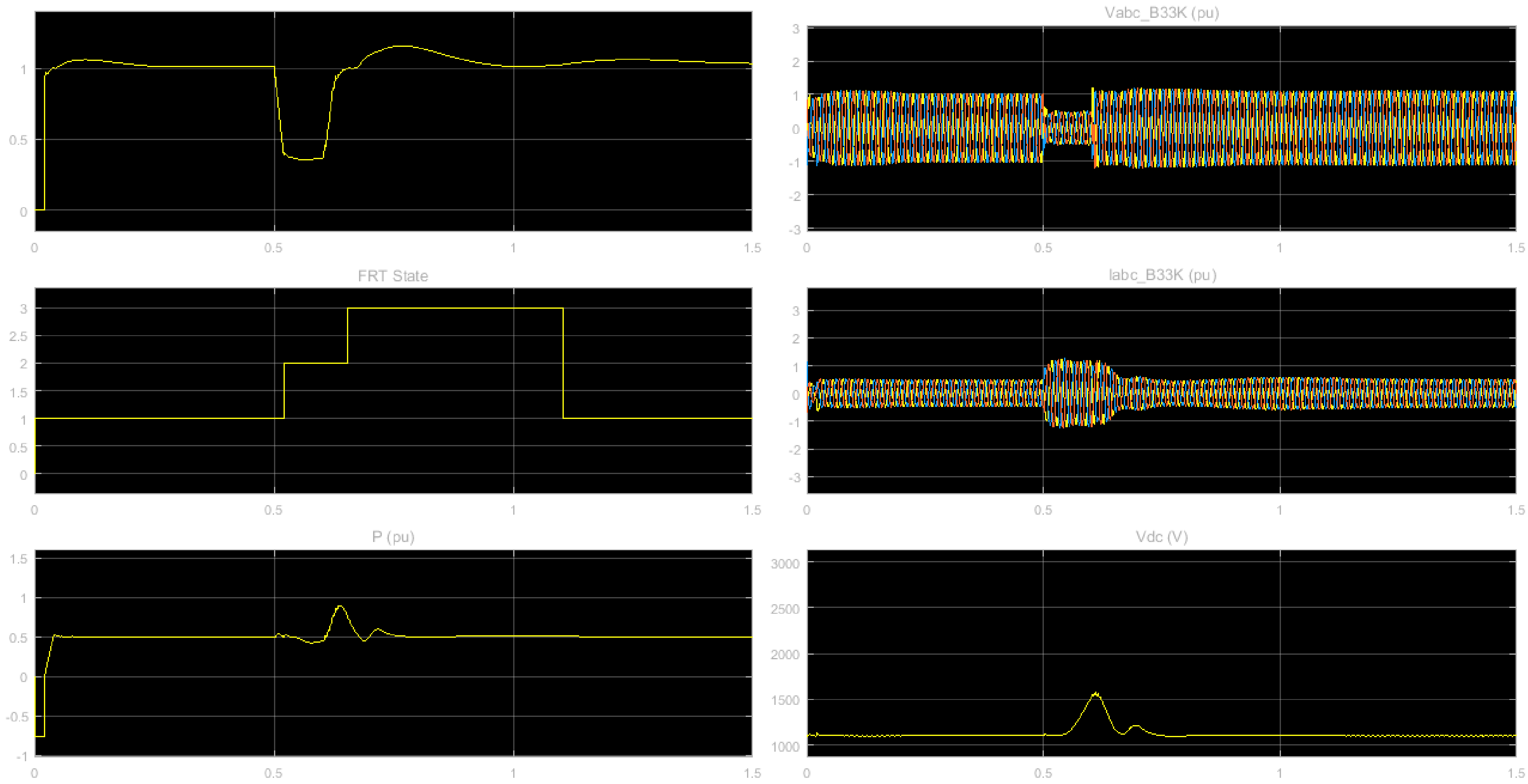
approach

- 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

Reference experiment



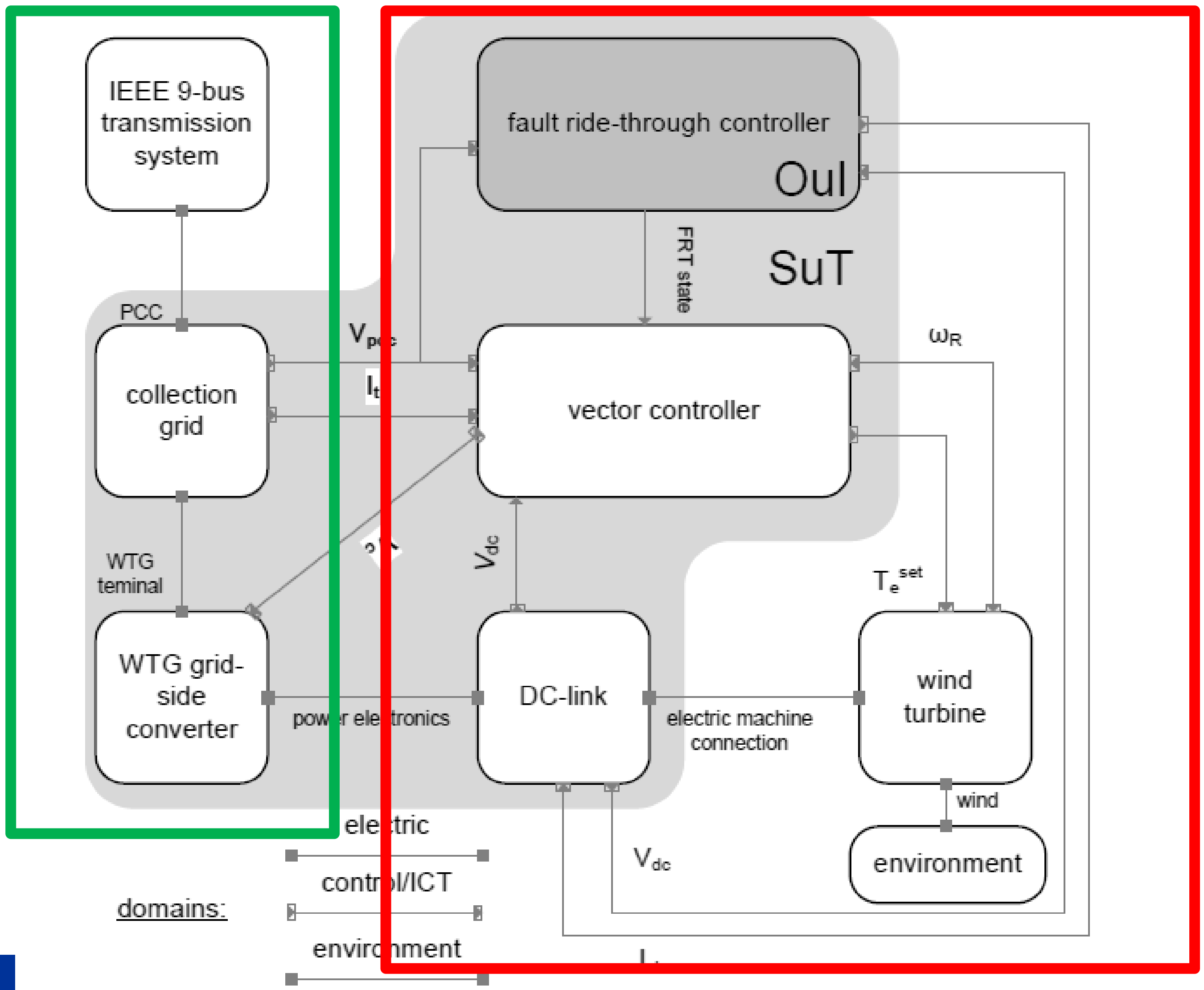
Simulation results



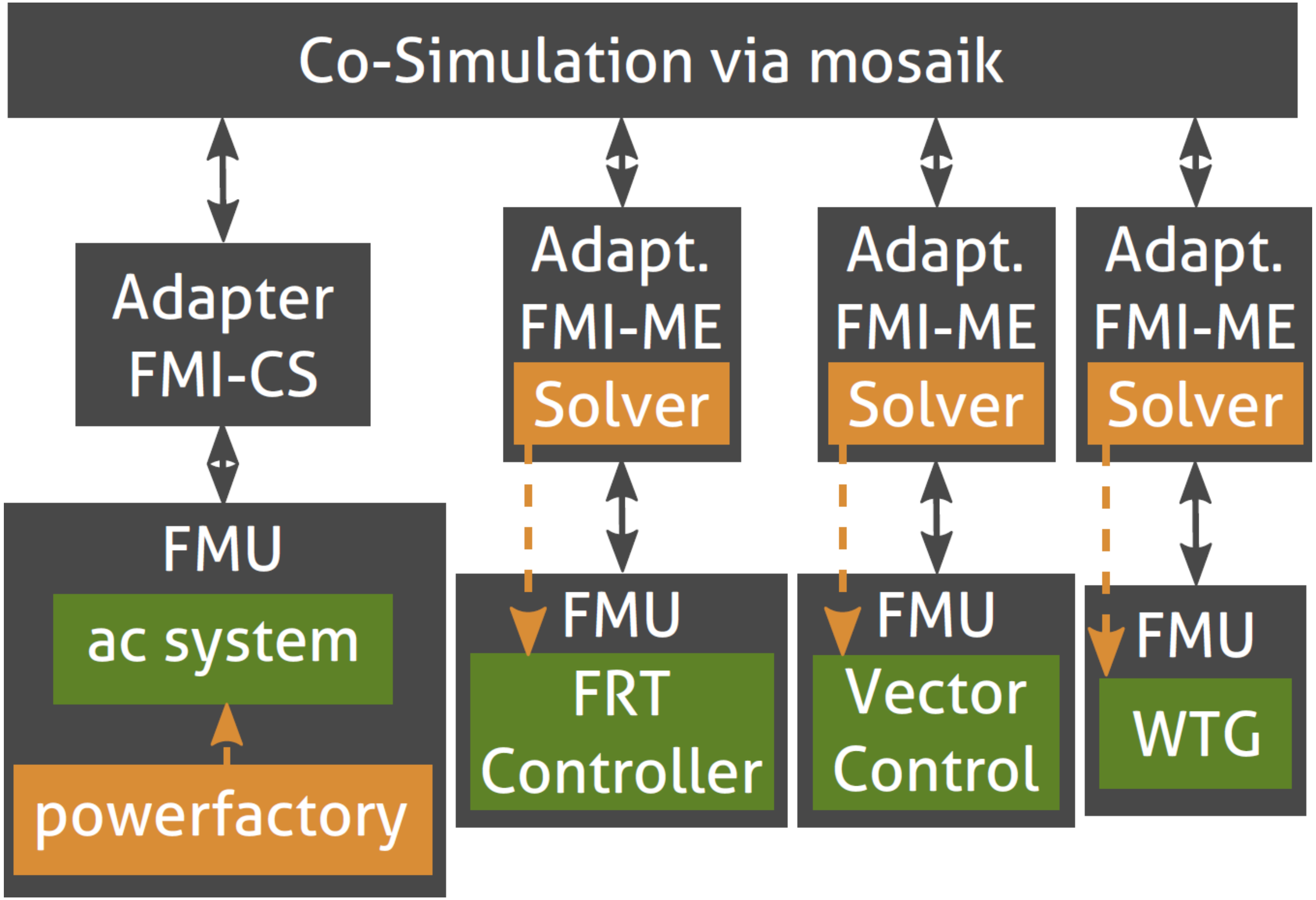
approach

- 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

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

Arjen van der Meer

Ph.D. Candidate

Delft University of Technology

a.a.vandermeer@tudelft.nl