Co-simulation of Multi-Commodity Energy Systems

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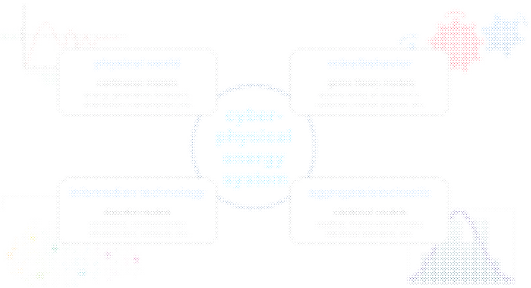

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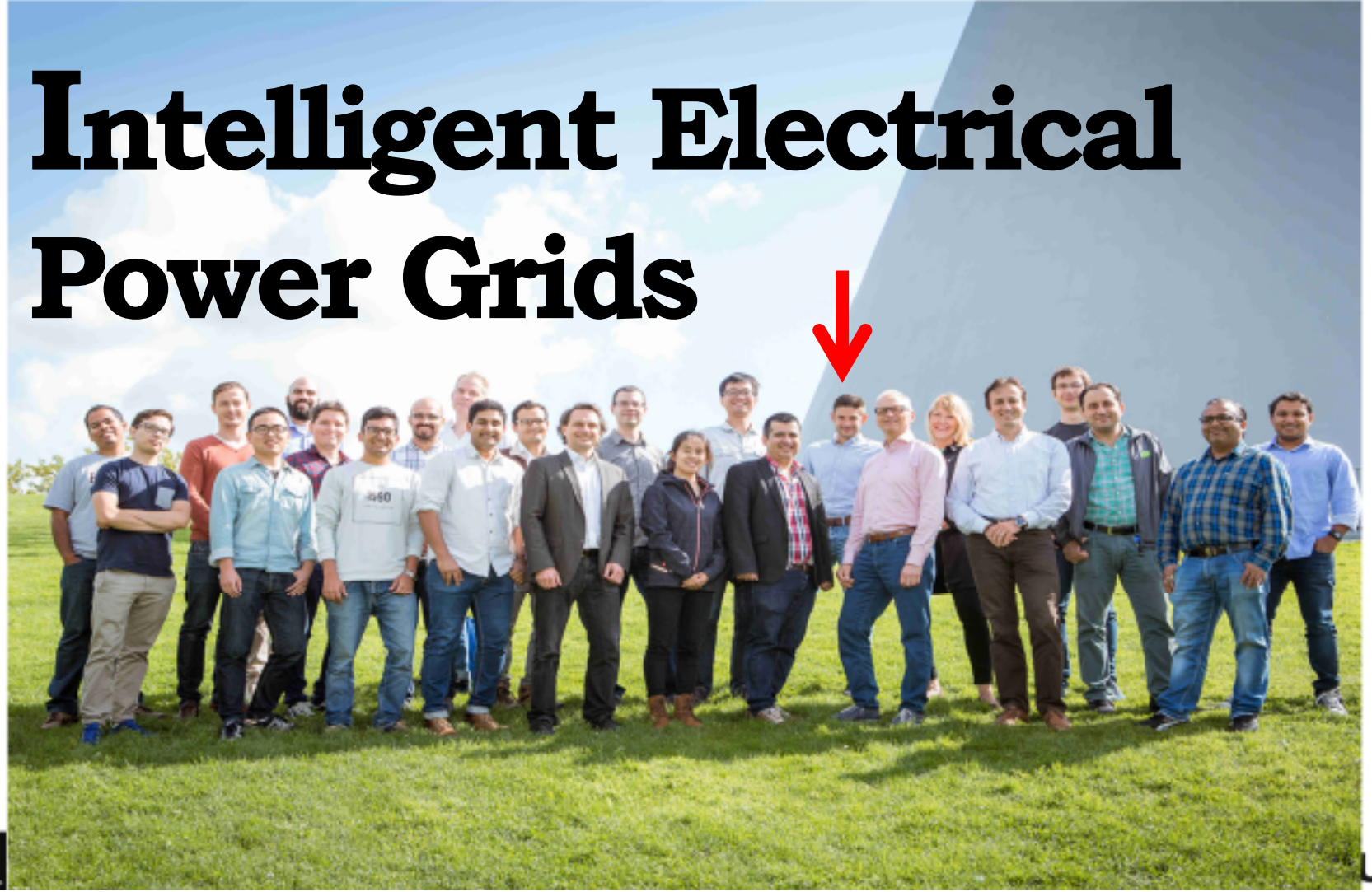
Intelligent Electrical Power Grids



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IEPG Research

Sectors / Applications / Technologies

Methods	Power Systems	Integrated Energy	Digital Grid
	Numerical (HPC, co-sim)		
	Stability & Control	Renewable integration	Data / Analytics
	Experimental (HW-in-the-loop)		
	Reliability	Infrastructure	Digital Substation
	Analytical, Fundamental		
	Protection	Efficiency	Cyber-Security

HPC: high-performance computing

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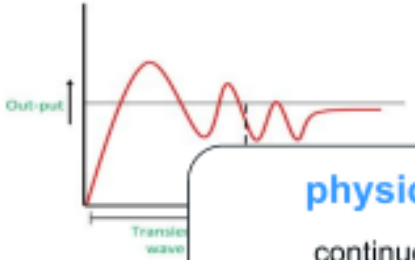
Domains, models



physical world

continuous models

energy generation, transport, distribution, consumption, etc.

roles/behavior

game theory models

agents acting on behalf of a customer, market players, etc.

cyber-physical energy system

information technology

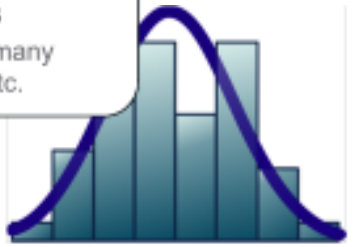
discrete models

controllers, communication infrastructure, software, etc.

aggregate/stochastic

statistical models

weather, macro-view of many individual elements, etc.



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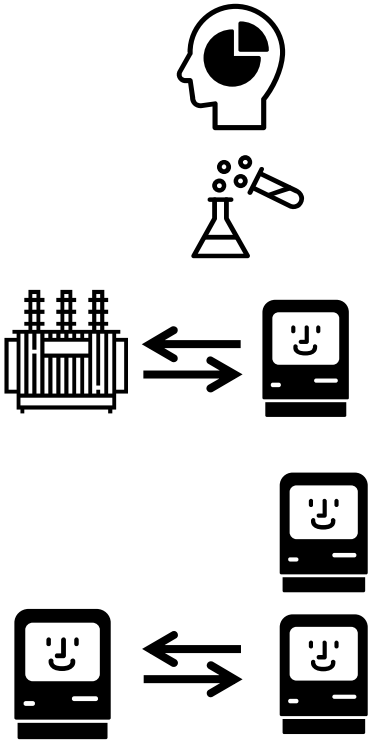
assessment paradigms



Analytic solution

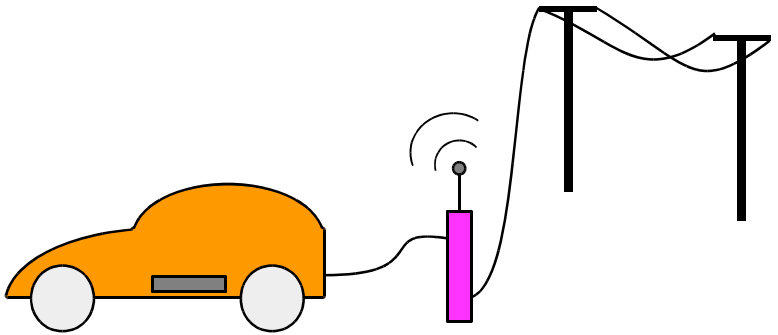
Hardware experiments

Emulation (hardware in the loop)

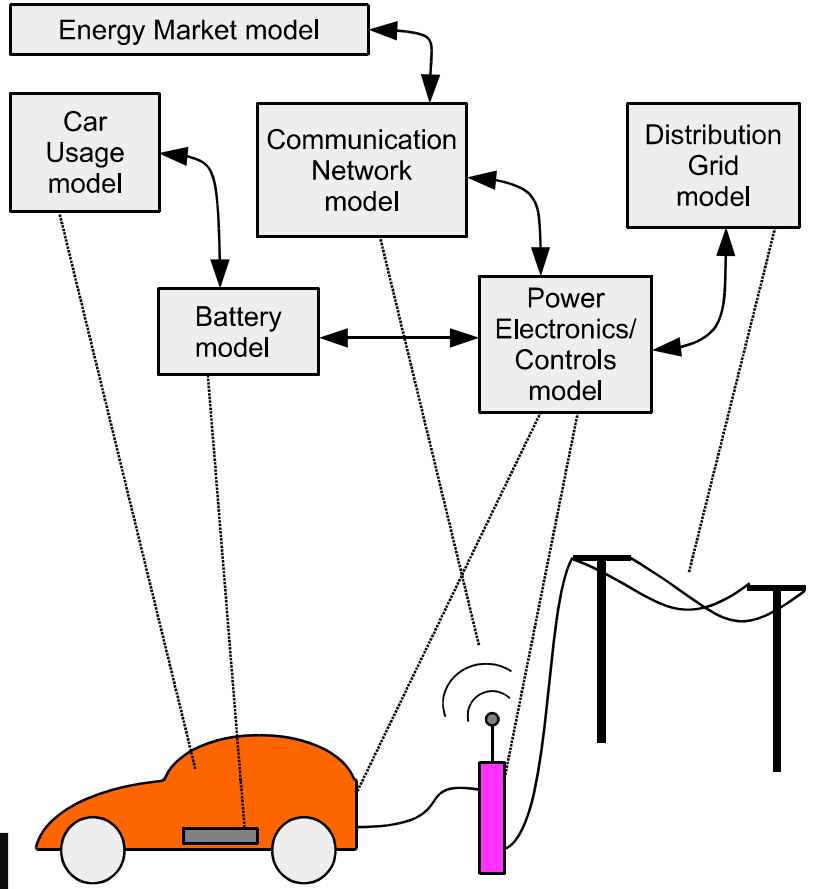
Simulation

Co-simulation

Models of smart grids



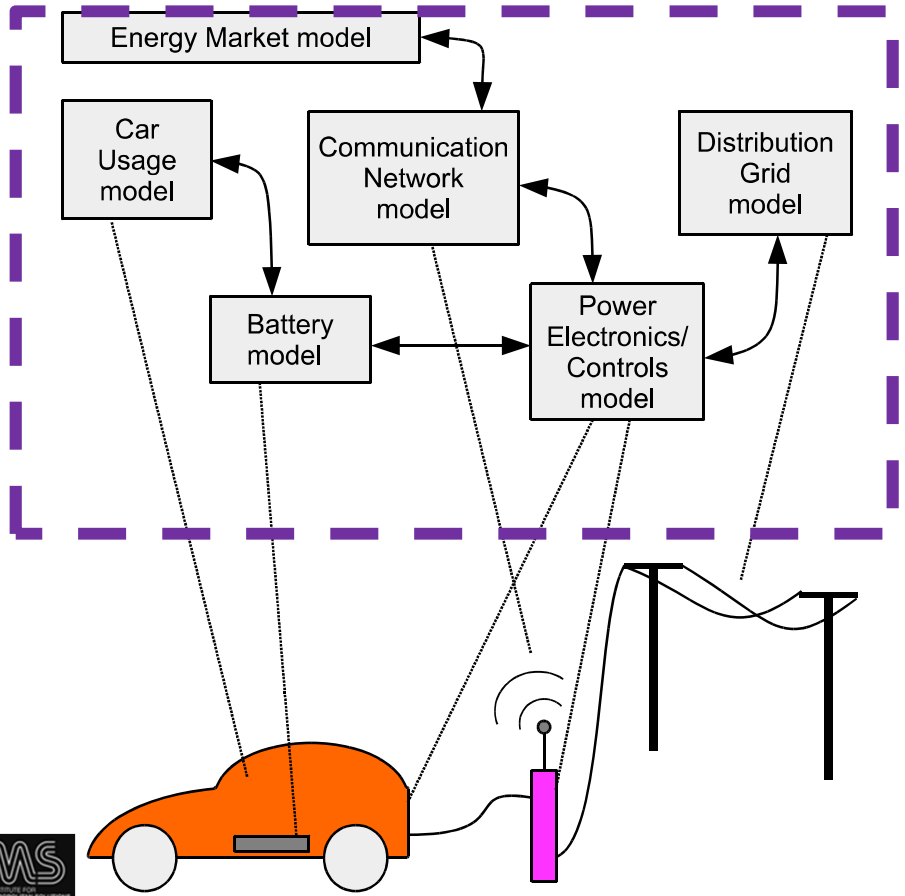
Models of smart grids



DATA NEEDS

- Topological
- Geographic (topographic)
- Behavioural
- Operating constraints
- Electricity price

Simulation of smart grids

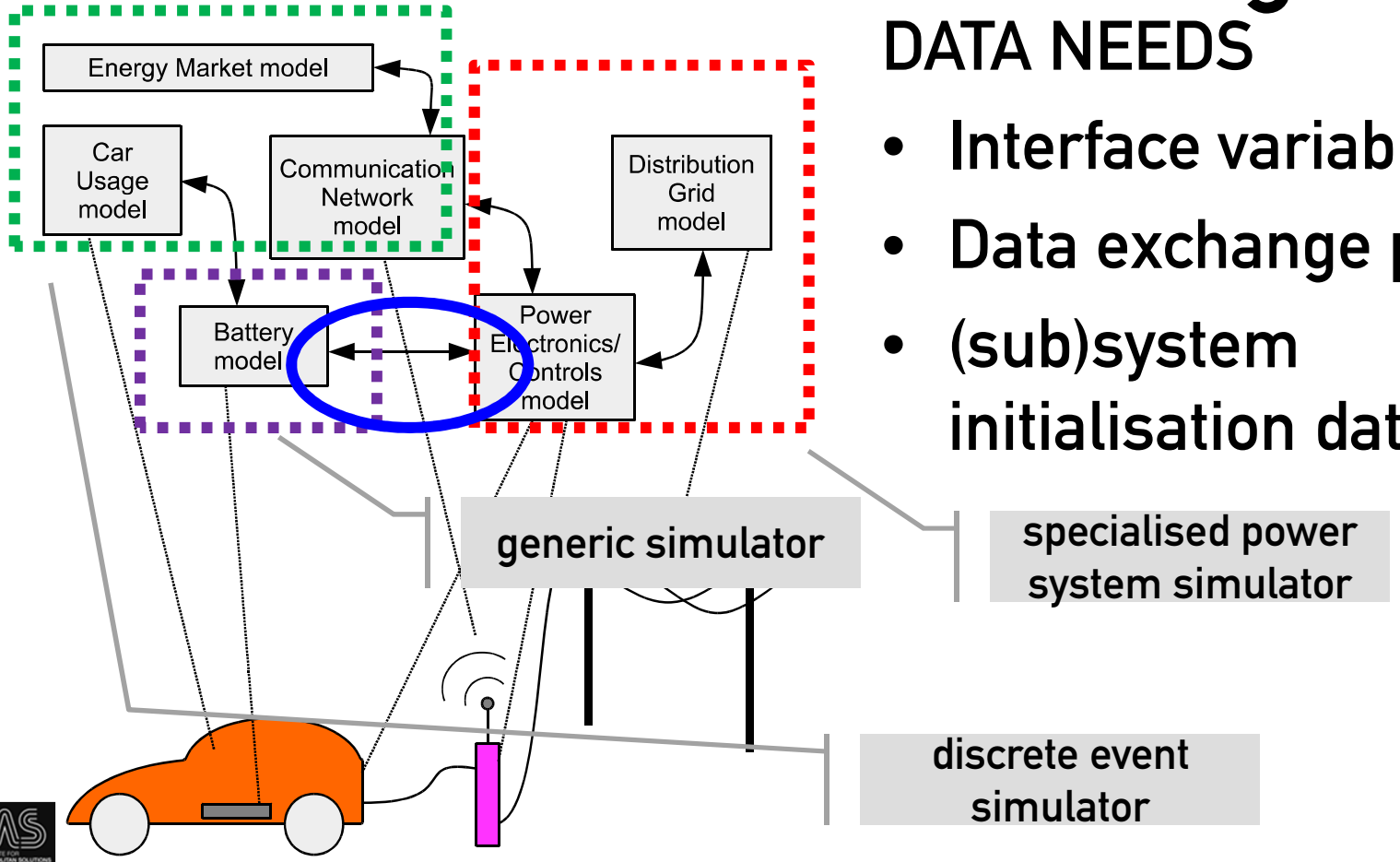


DATA NEEDS

- Operating conditions of physical system
- Simulation parameters

Generic simulation tool

Co-simulation of smart grids



DATA NEEDS

- Interface variables
- Data exchange protocol
- (sub)system initialisation data

Co-simulation challenges

Cross-domain coupling

Initialisation

Time-stepping (synchronisation)

Standardisation of data protocols

Benchmarking and Validation

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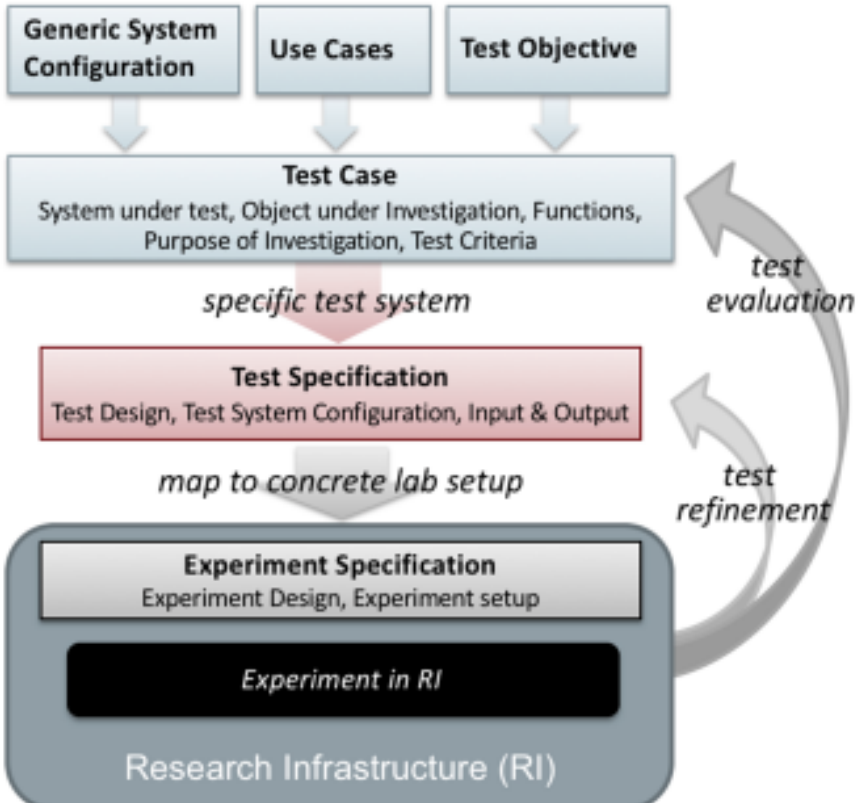
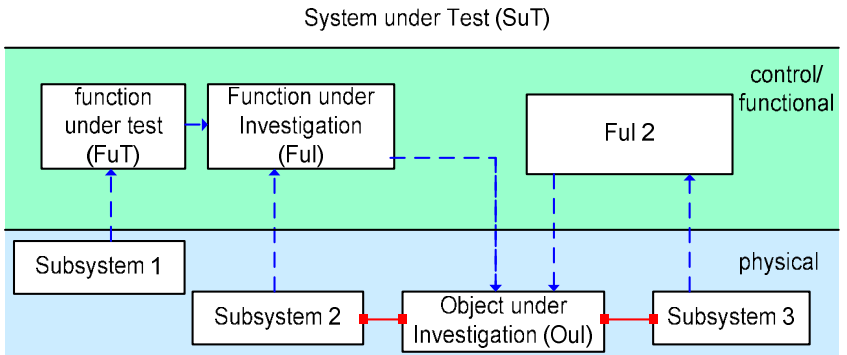
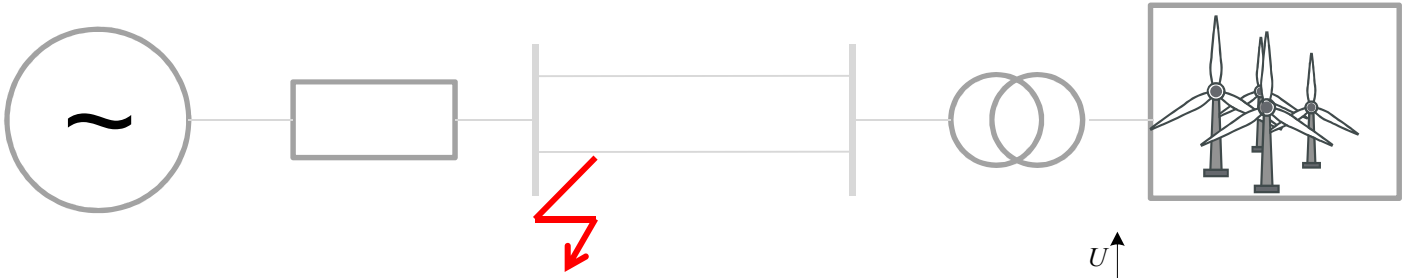
Example: ERIGrid

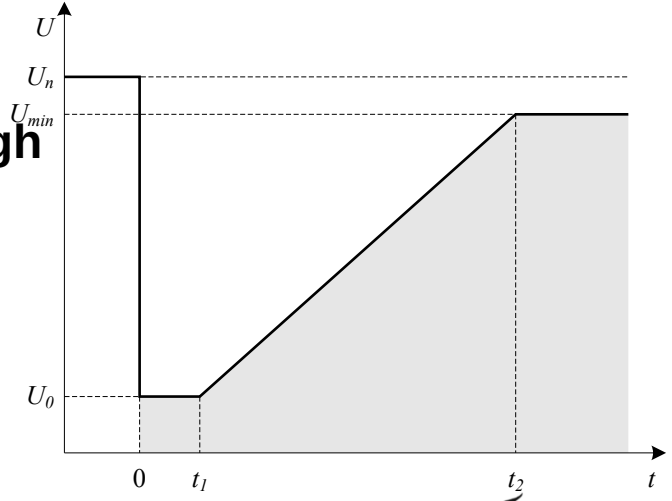




- <u>test case</u>: general system and function specification (**why&what**)
- <u>Test specification</u>: **how** to test the test case
- <u>Experiment specification</u>: how to implement the test specification inside a particular lab

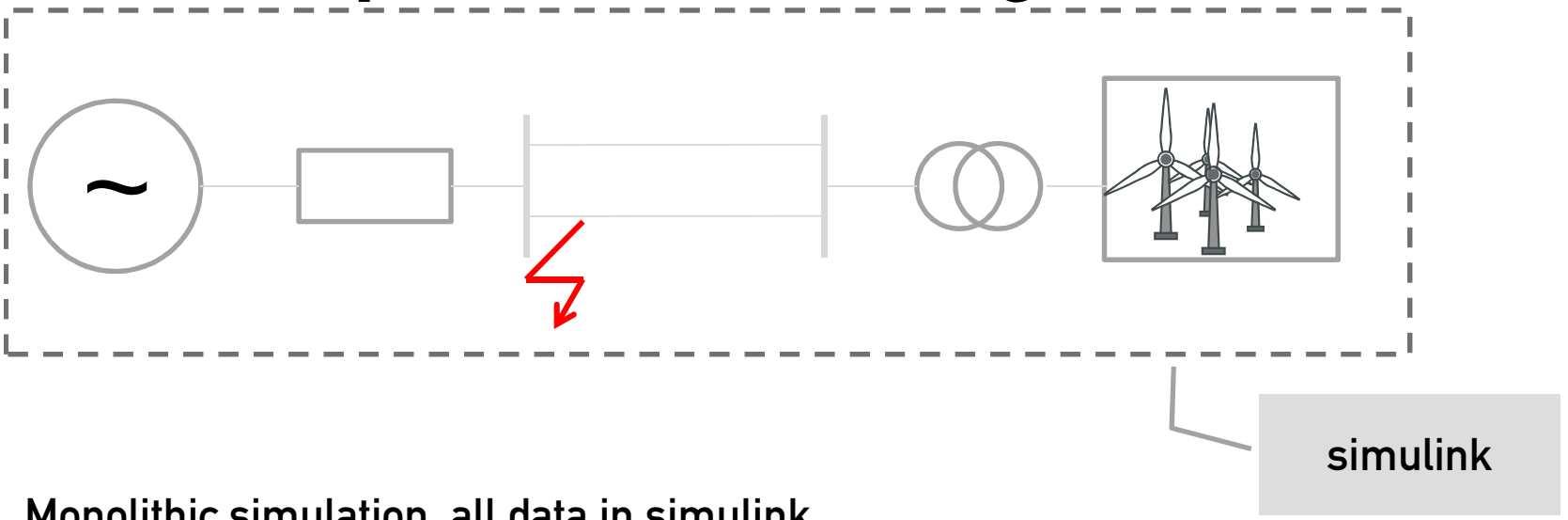
ERIGrid test case: wind park





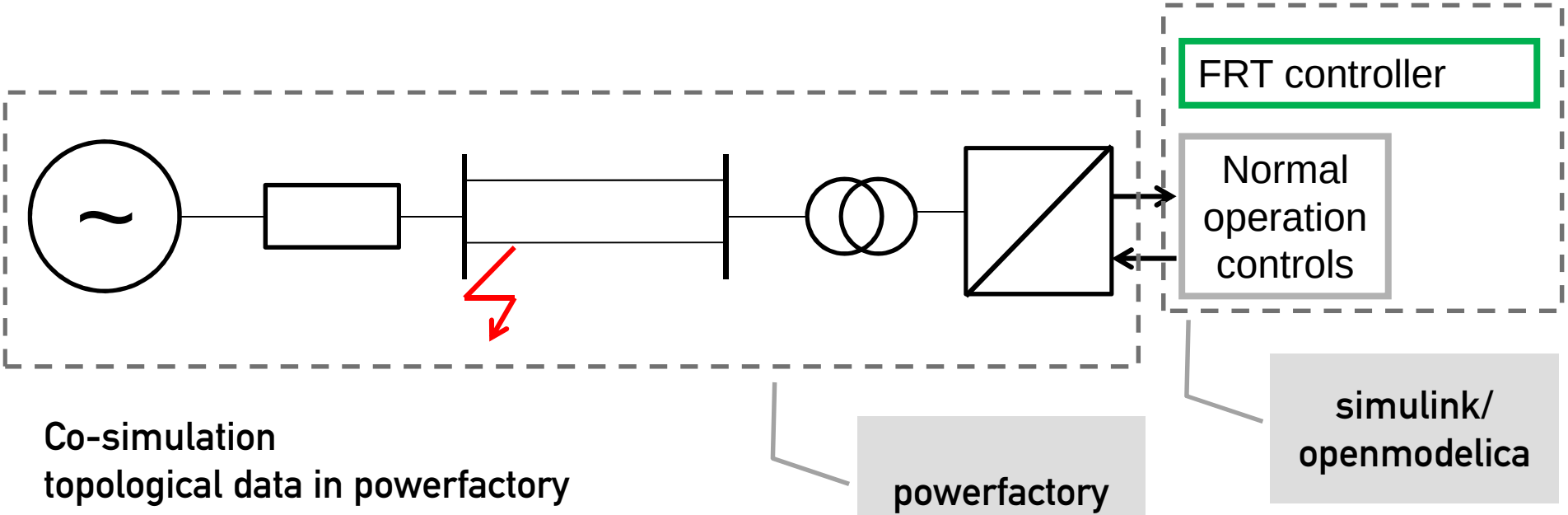
- Use case: **voltage control and fault ride-through**
- **Continuous** + **discrete** models
- wide time-scale spectrum (us to s)
- Ideal for testing co-simulation accuracy

Experiment design (1)



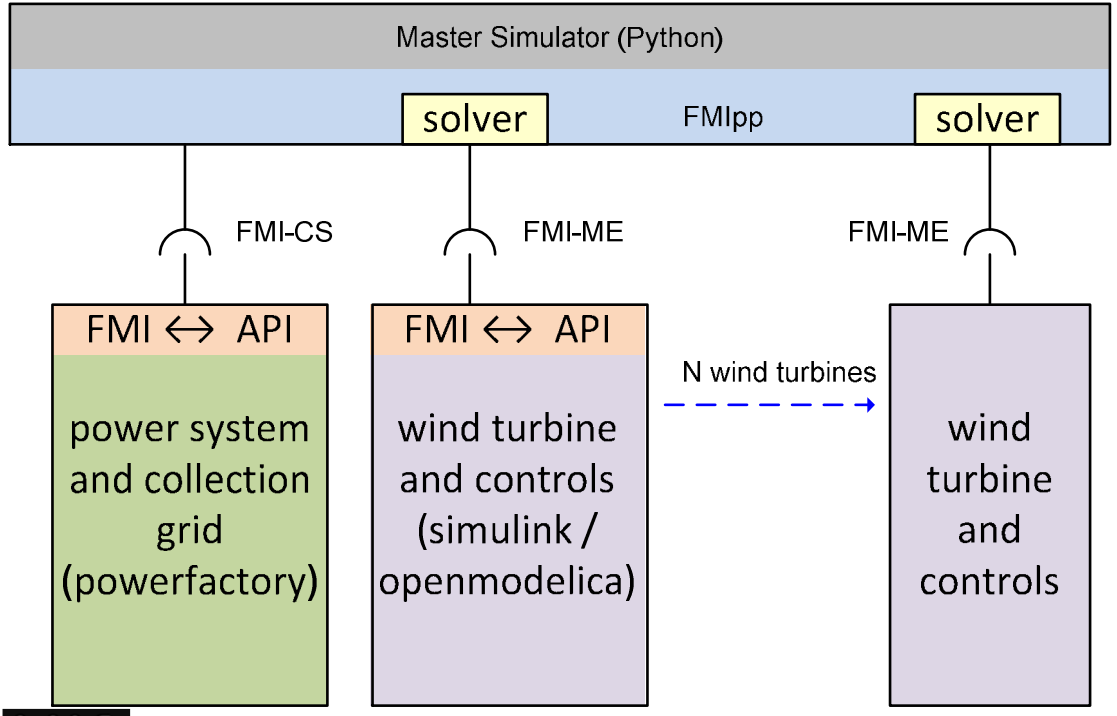
Monolithic simulation, all data in simulink

Experiment design (2)



Co-simulation
topological data in powerfactory
Model data in simulink
Separate master script provides the glue

The glue: FMI and Python



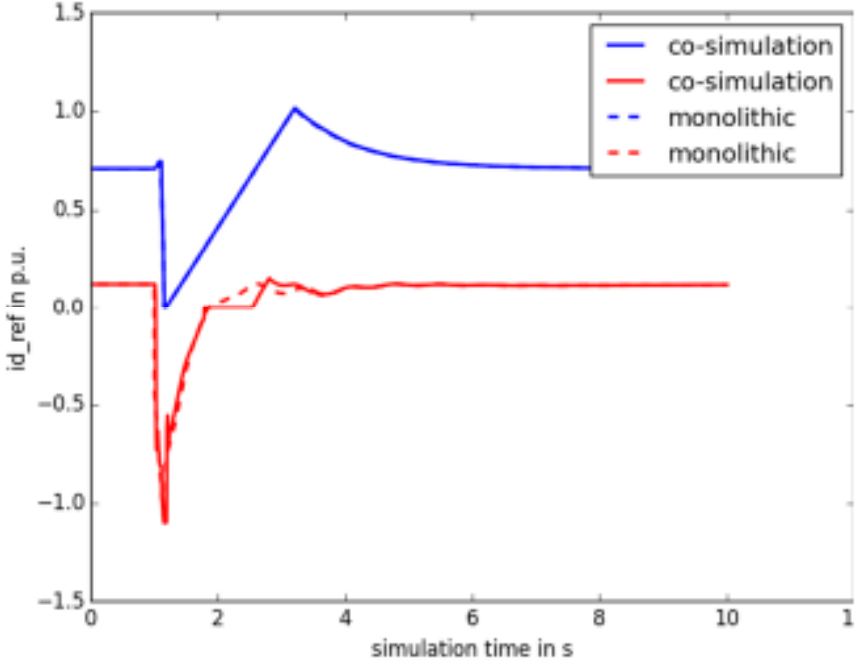
Master implemented in mosaik:
https://mosaik.offis.de/

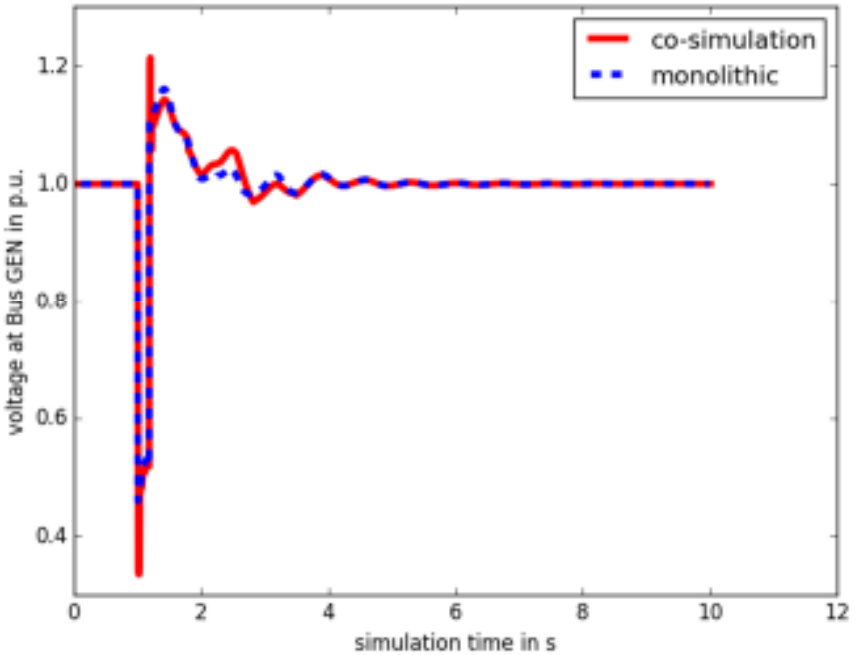
FMI wrapper for Python: FMIpp
https://pythonhosted.org/fmipp/

FMIpp Powerfactory wrapper:
https://sourceforge.net/projects/powerfactory-fmu/

FMI: functional mockup interface
CS: co-simulation
ME: model exchange
PF: powerfactory

Illustration of simulations





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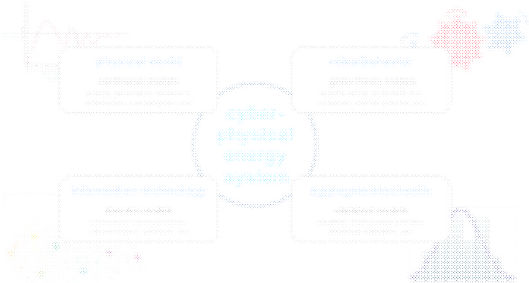

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Summary of data needs

- Cross-domain data format
- Topological and topographical data
- Allow for inclusion of code (like modelica)
- File refs, time series, system variations

Thank you!

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