Methods and Concepts for the System Level Validation of Power and Energy Systems

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"Power Directions in a Post-COVID World"

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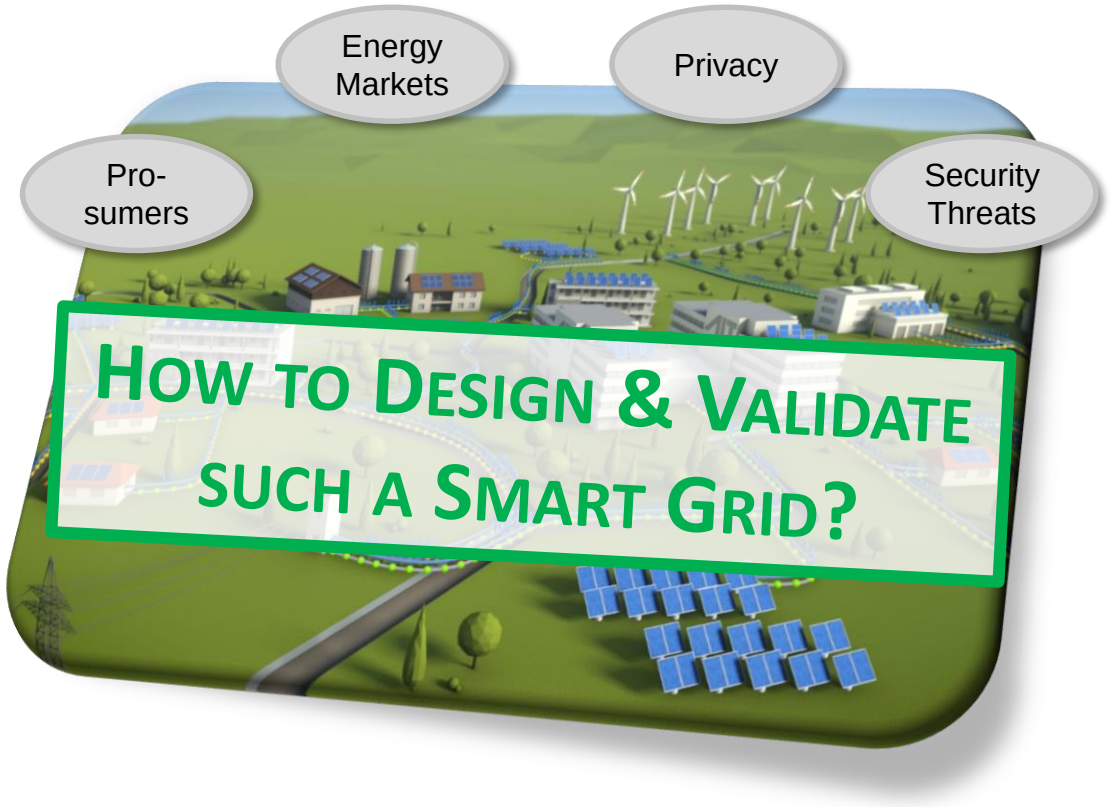
Background and Motivation

- Planning and operation of the energy infrastructure becomes more complex
  - Large-scale integration of renewable sources (Distributed Energy Res./DER – like PV, wind, etc.)
  - Controllable loads (battery storages, electric vehicles, heat pumps, etc.)
- Trends and future directions
  - Digitalisation of energy infrastructure
  - Deeper involvement of consumers and market interaction
  - Sector coupling (linking electricity, gas, and heat grids) for higher flexibility and resilience



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Needs and Requirements

- Separated design and validation of individual domains (power, ICT, heat, etc.) not sufficient anymore
- Integrated cyber-physical/multi-domain design and validation missing
- Reduction of manual steps necessary to handle complex system configurations
- Reduction of error sources due to manual steps required
- Improvement of application/software quality required
- Faster application development needed due to market behaviour and trends

	Req. & Basic Design Phase	***Detailed Design Phase***	***Implemen-tation and Prototyping***	***Deployment / Roll Out***
Software Simulation	+	++	o	-
Lab Experiments and Tests	-	-	++	+
Hardware-in-the-Loop (HIL)	-	-	++	++
Demonstrations / field tests, pilots	-	-	-	++

- … less suitable, o … suitable with limitations, + … suitable, ++ … best choice

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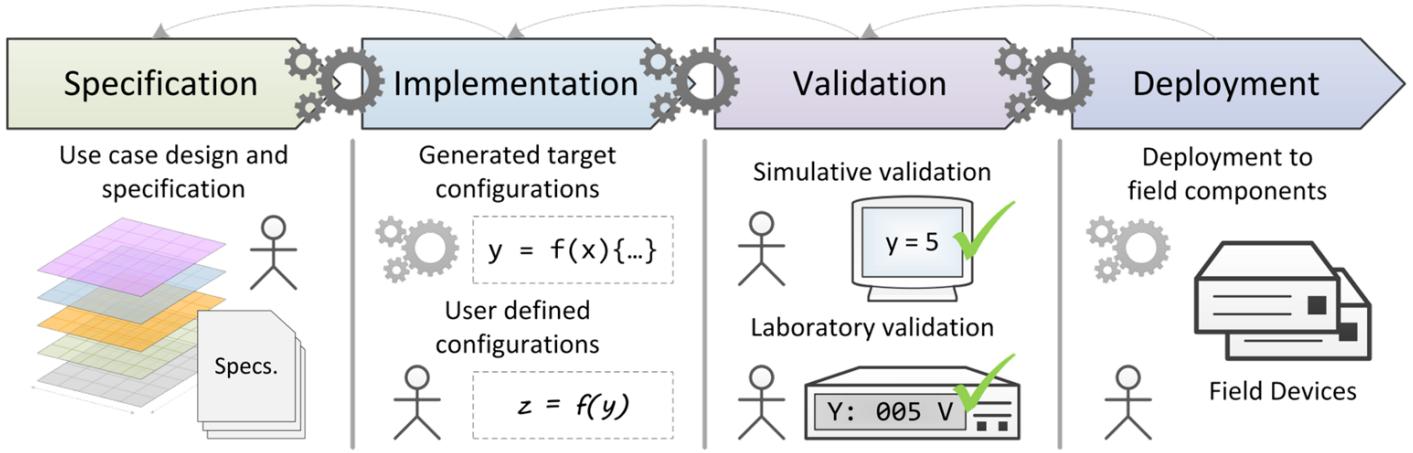
Vision and Research Directions

- Support for the integrated design, implementation, validation, and installation of smart grids and smart energy systems
  - Integrated system design
  - Validation and testing
  - Installation and roll out
- Future research needs
  - Improved development and testing services and tools
  - Extended and advanced research infrastructures and laboratories
  - Well educated researchers and engineers (“multi-domain understanding”)



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Integrated Smart Grid and Energy Systems RI's

- Long-term,
- Pan-European cooperation

2005

DERlab
European Distributed Energy Resources Laboratories

- GA-ID 5189299
- FP6 NoE (11/2005-10/2011)
- 3 Mio EUR funding
- 12 partner
- Networking of DER labs, pre-standardization

DERri
Distributed Energy Resources Research Infrastructure

- GA-ID 228449
- FP7 RI IA (09/2009-12/2013)
- 5 Mio EUR funding
- 16 partner from 12 countries
- TNA to DER labs, pre-standardization

ERIGRID
Connecting European Smart Grid Infrastructures

- GA-ID 654113
- H2020 RI IA (11/2015-04/2020)
- 10 Mio EUR funding
- 18 partner from 11 countries
- TNA to Smart Grid and DER labs, pre-standardization

ERIGRID 2.0
Connecting European Smart Grid Infrastructures

- GA-ID 870620
- H2020 RI IA (04/2020-09/2024)
- 10 Mio EUR funding
- 20 partner from 13 countries
- TNA & VA to Smart Grid, Smart Energy Systems and DER labs, pre-standardization

2024

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Smart Grid RI “ERIGrid” - Overview

- Applied research for validation of
  - Sustainable power and energy systems/smart grid systems
  - Distributed Energy Resources (DER)
- Tight collaboration of partners
  - 11 European countries involved
  - 18 Partners from research and industry
  - 19 top-class smart grid and DER labs

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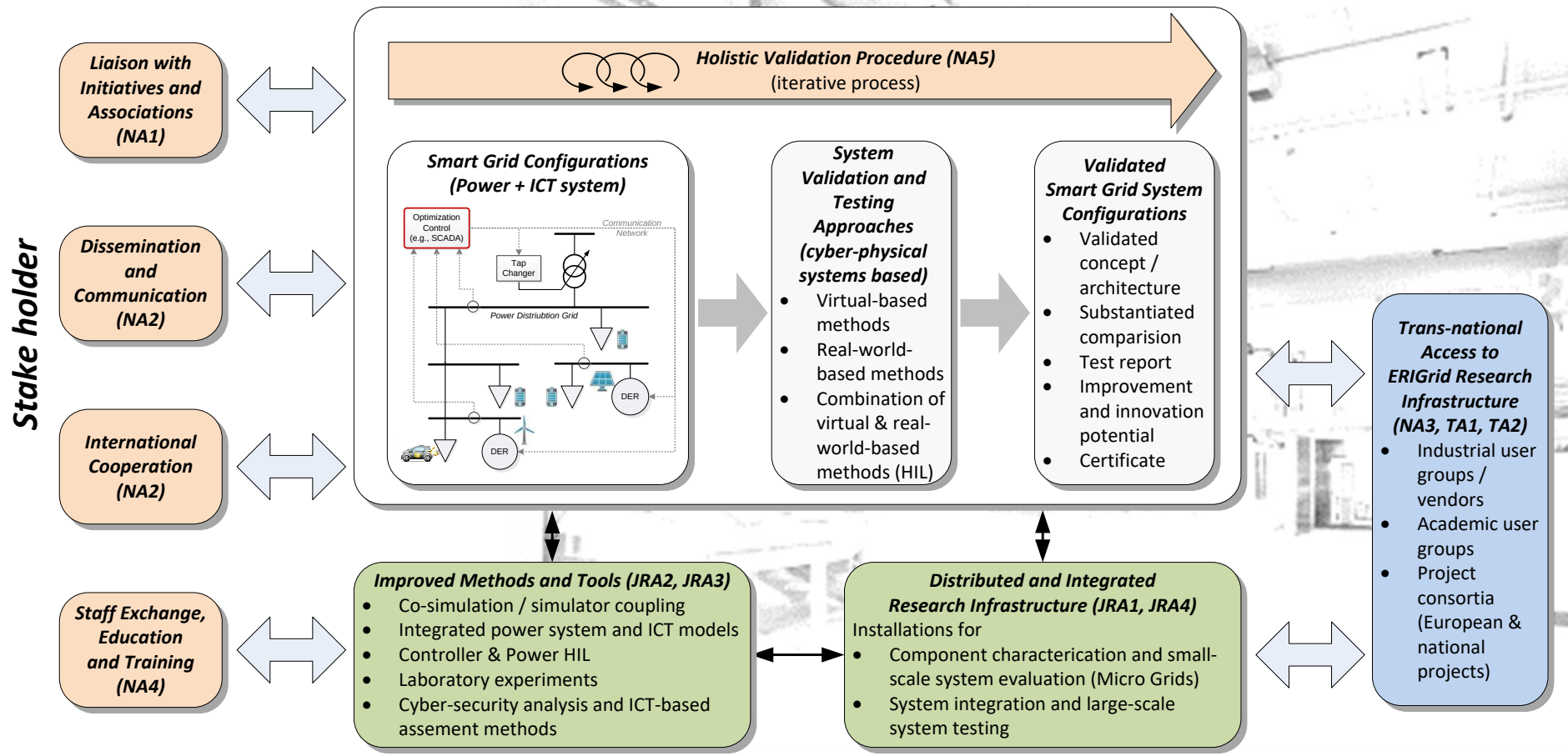
Smart Grid RI “ERIGrid” - Approach



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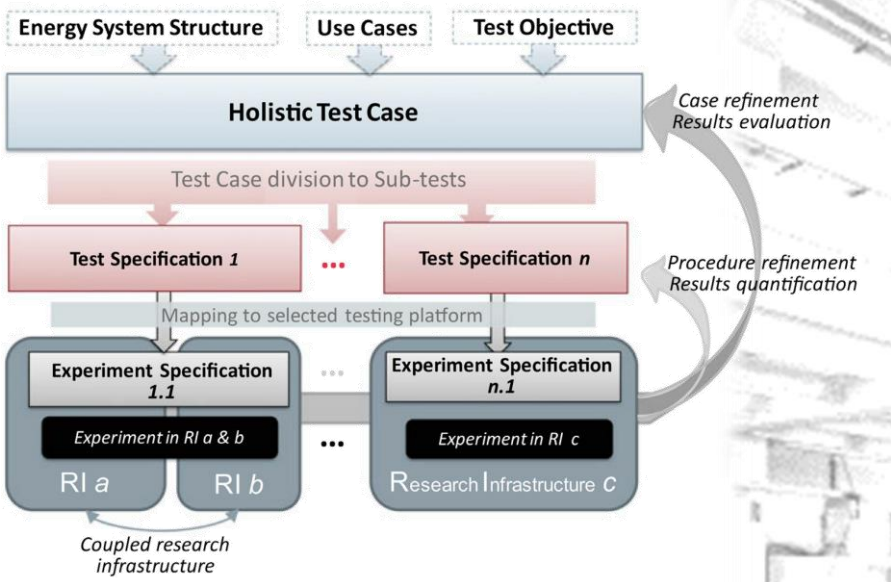
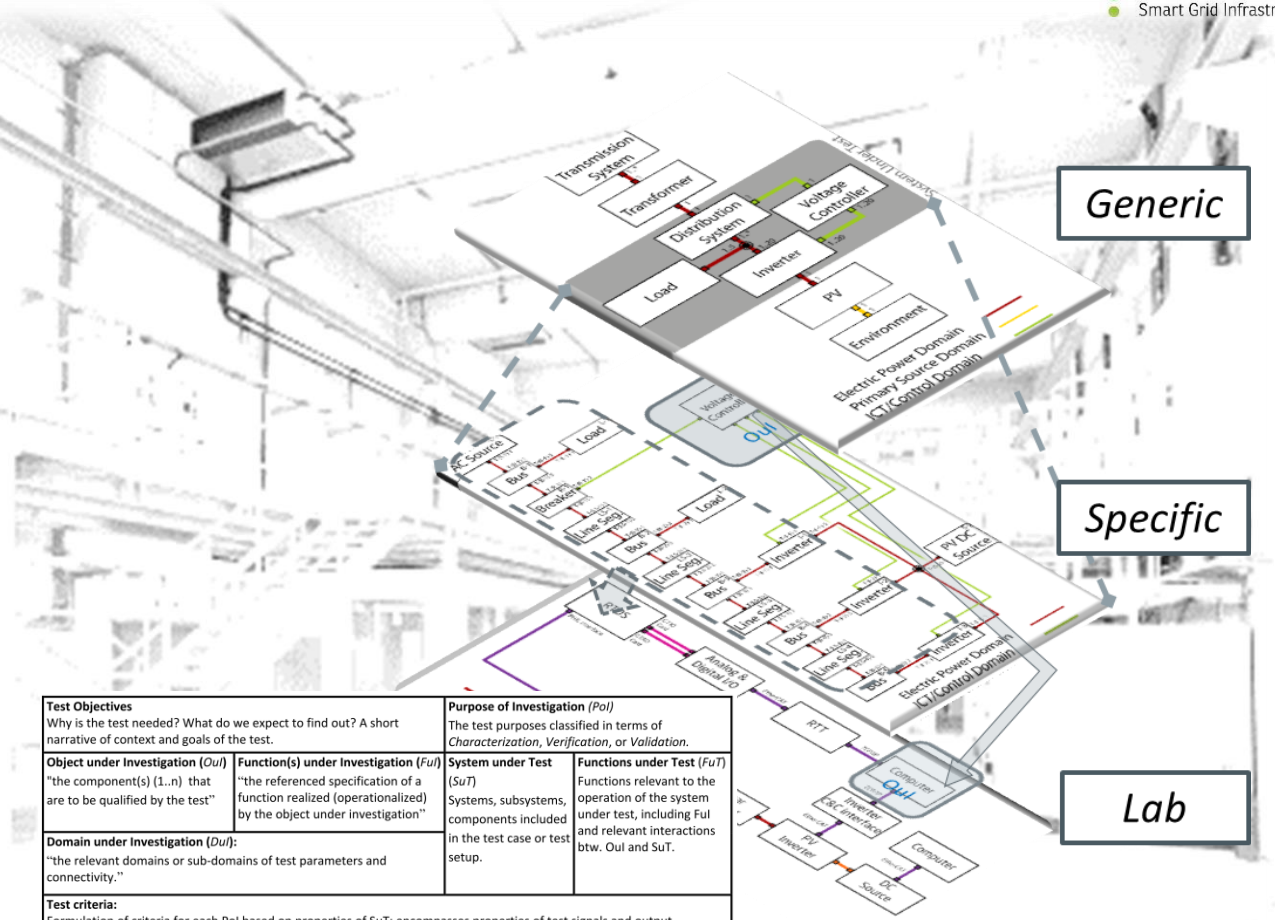
Smart Grid RI “ERIGrid” - Achievements





Advanced testing methods and tools

- Holistic validation approach for smart grids
- Approach for specifying test cases, test specifications and experiments

Test Objectives Why is the test needed? What do we expect to find out? A short narrative of context and goals of the test.		**Purpose of Investigation** *(PoI)* The test purposes classified in terms of *Characterization*, *Verification*, or *Validation*.	
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test"	**Function(s) under Investigation** (*FuI*) "the referenced specification of a function realized (operationalized) by the object under investigation"	**System under Test** (*SuT*) Systems, subsystems, components included in the test case or test setup.	**Functions under Test** (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.
Domain under Investigation (*DuI*): "the relevant domains or sub-domains of test parameters and connectivity."			
Test criteria: Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.			
target metrics Measures required to quantify each identified test criteria	**variability attributes** controllable or uncontrollable factors and the required variability; ref. to PoI.	**quality attributes** threshold levels for test result quality as well as pass/fail criteria.	

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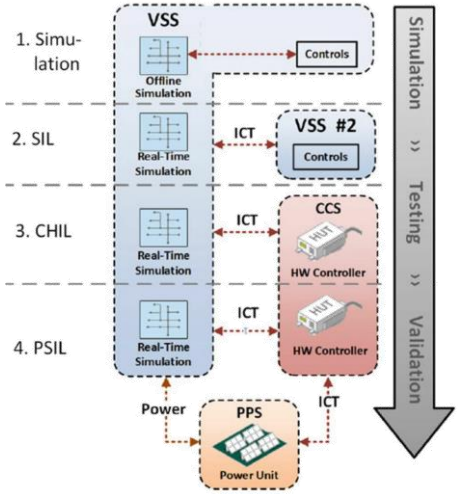
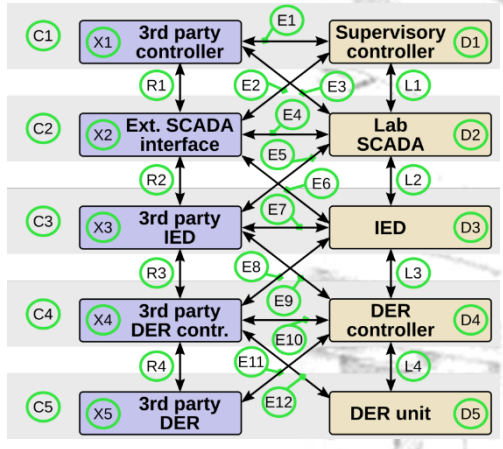
Smart Grid RI “ERIGrid” - Achievements





Advanced testing methods and tools

- Test chain approach
- Coupling approach for smart grid labs
- Virtual Pan-European Smart Grid RI

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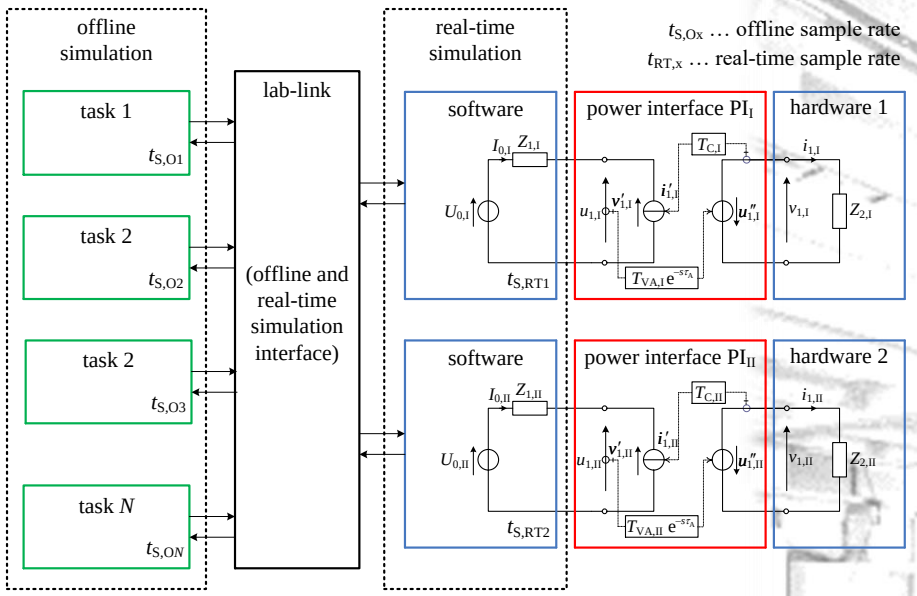

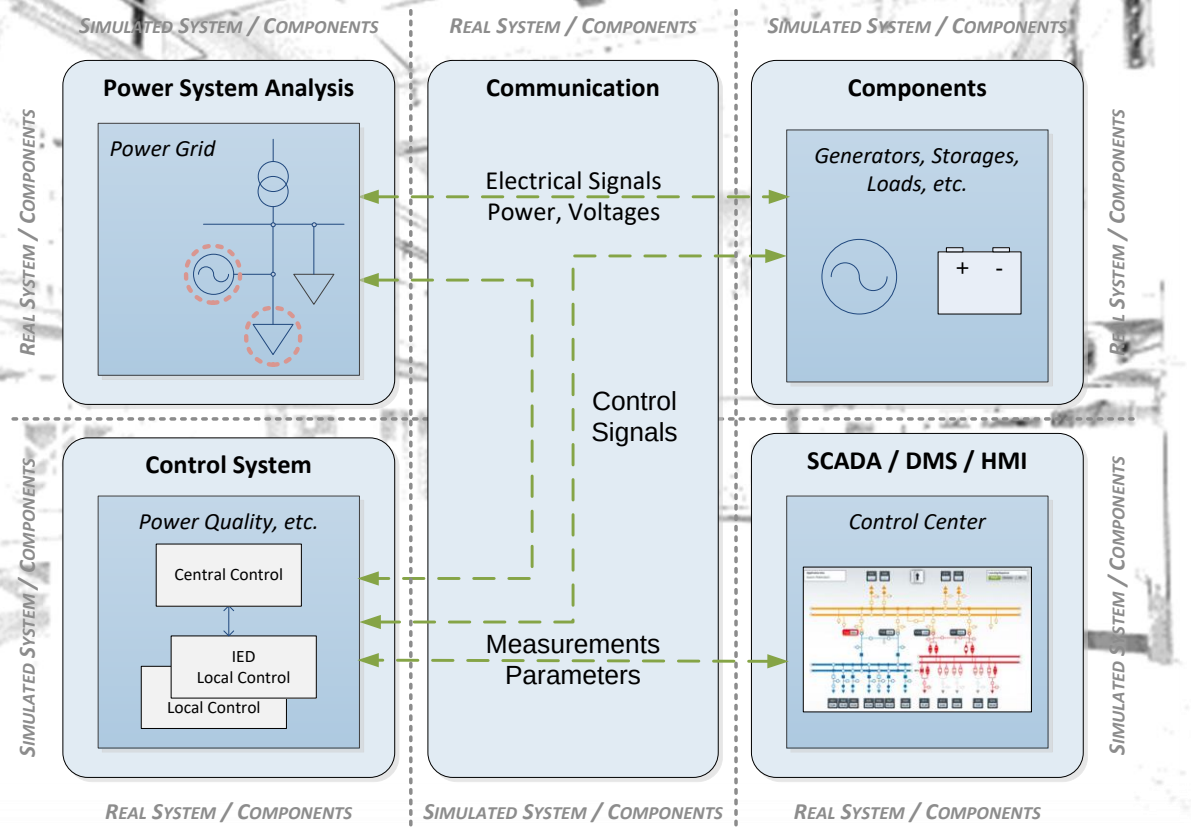

Advanced testing methods and tools

- Co-simulation and hardware-in-the-loop based system-level testing
- FMI-based simulation library

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Smart Energy Systems “ERIGrid 2.0” - Overview

ERIGrid 2.0 Connecting European Smart Grid Infrastructures

CONSORTIUM COORDINATED BY AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

- Extended and applied research based on ERIGrid topics and achievements for
  - Smart grid and smart energy systems
  - Digitalization with lab interfacing and data exchange for physical/virtual access
- Tight collaboration of partners
  - 13 European countries involved
  - 20 Partners from research and industry
  - 21 top-class smart grid, smart energy systems, and DER labs
  - 8 virtual facilities

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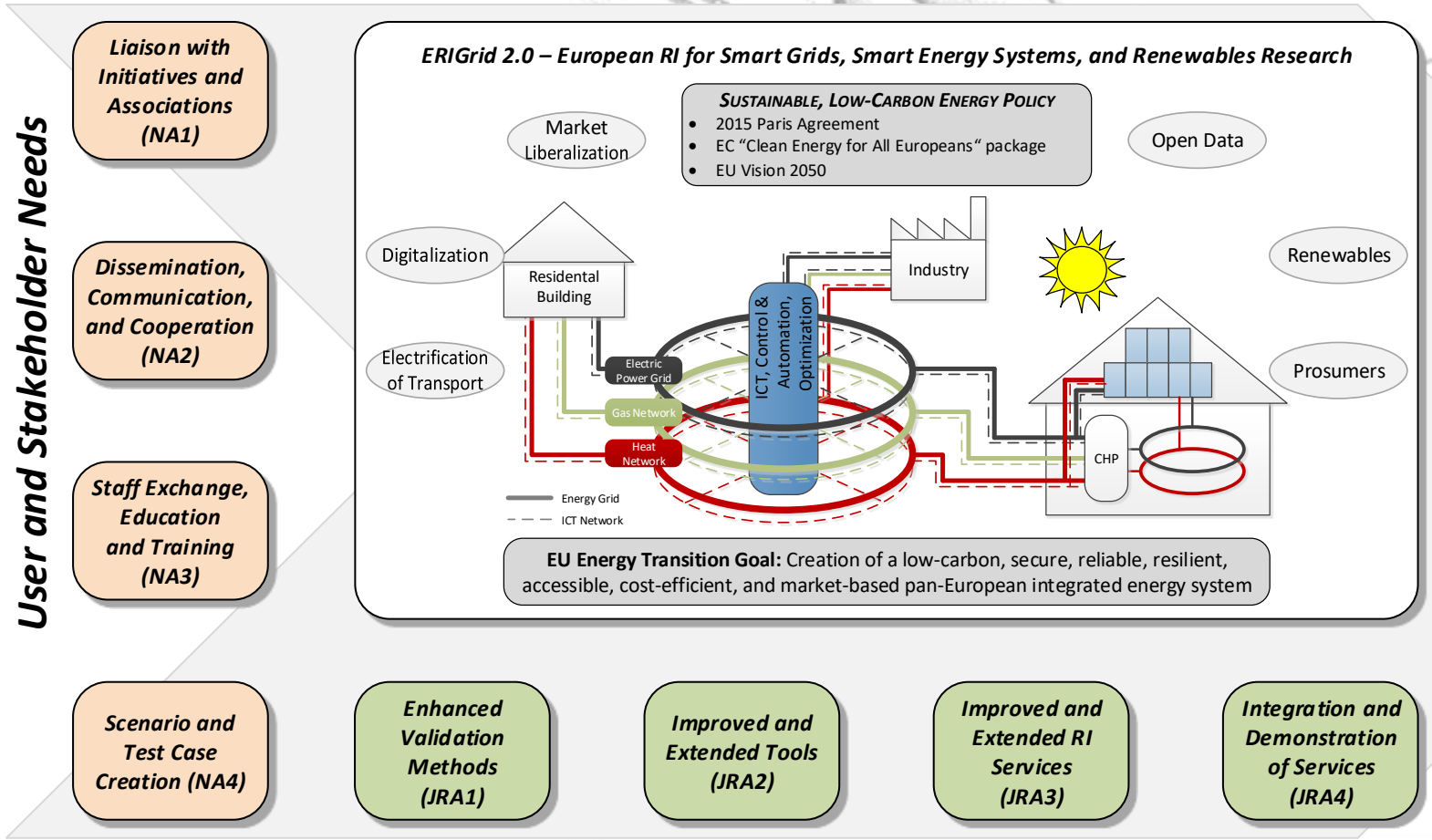
Smart Energy Systems “ERIGrid 2.0” - Approach



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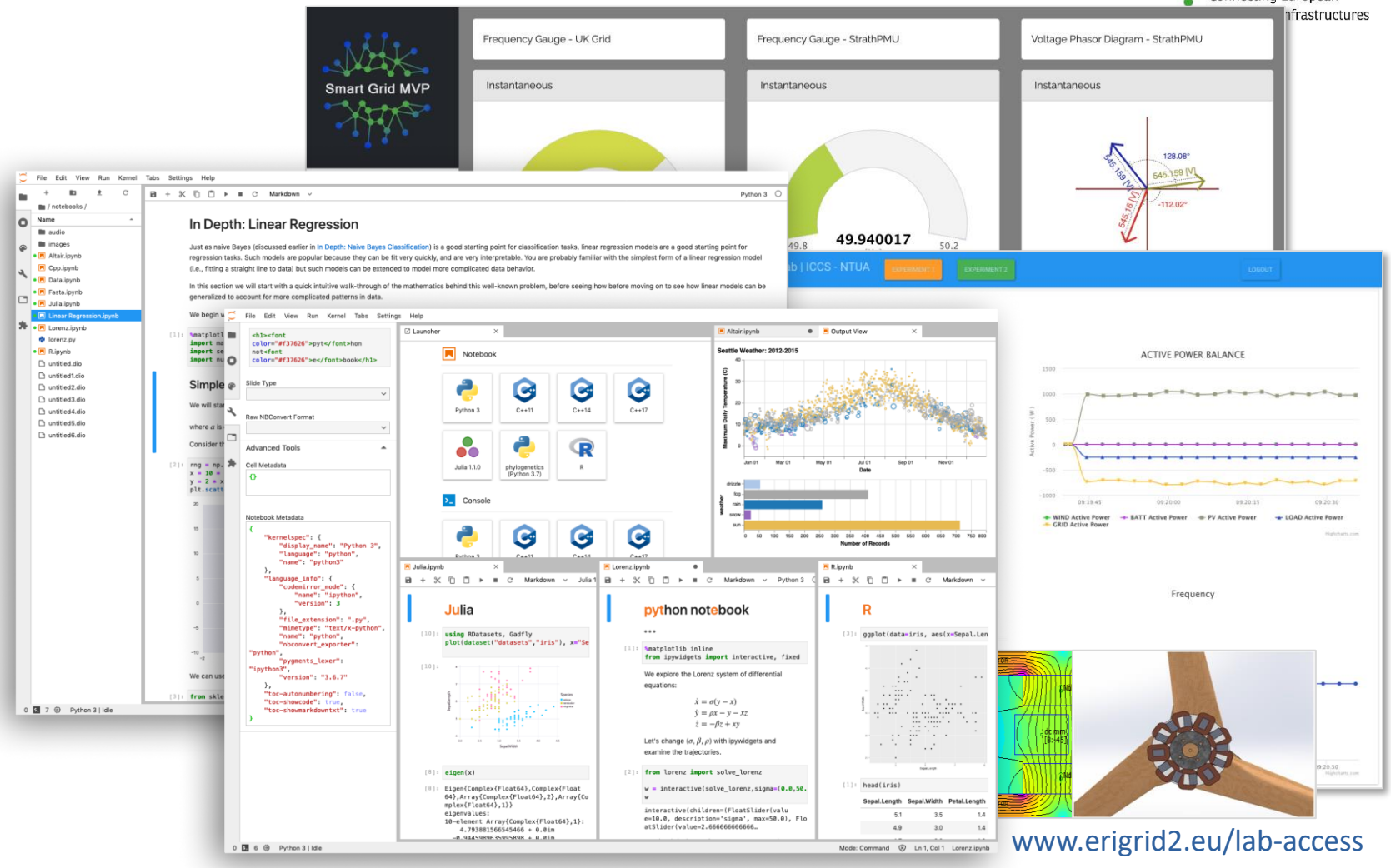
Smart Energy Systems “ERIGrid 2.0” - Virtual Services

- Focus on
  - Simulation-as--a-Service (SaaS)
  - Open data, Data- as-a-Service (DaaS)
  - Virtual labs



www.erigrid2.eu/lab-access

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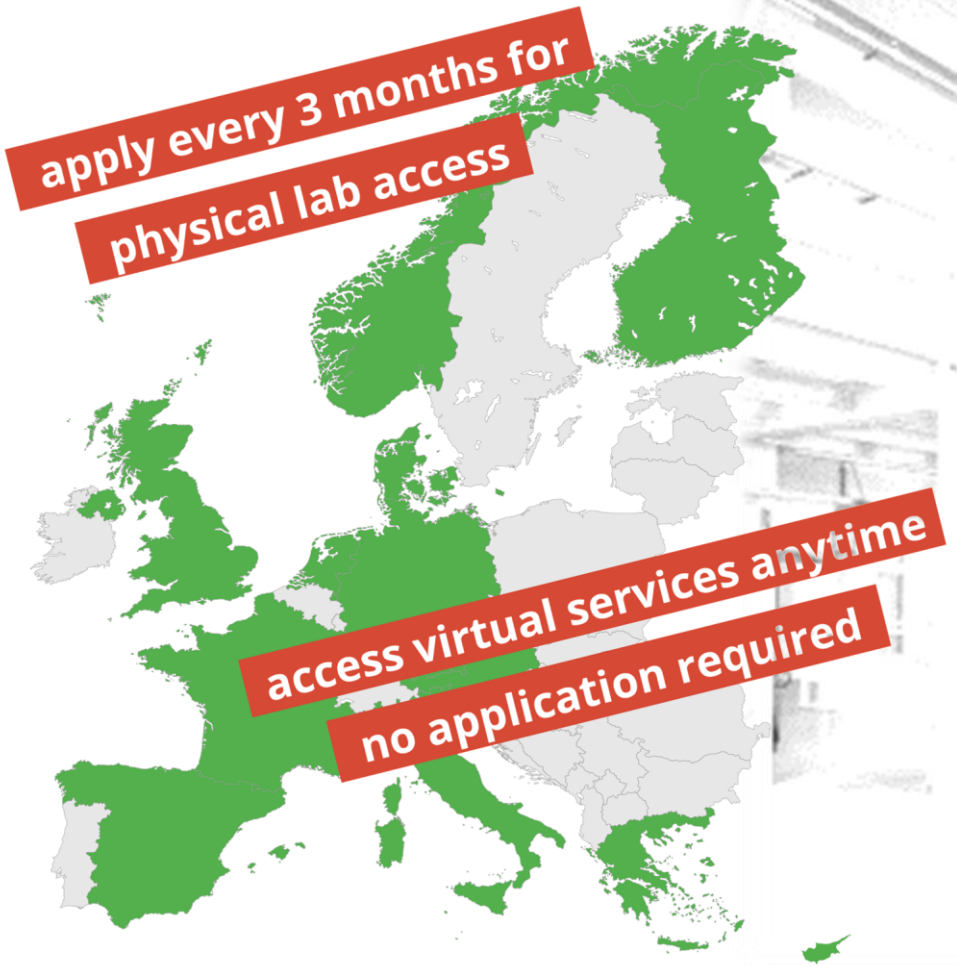

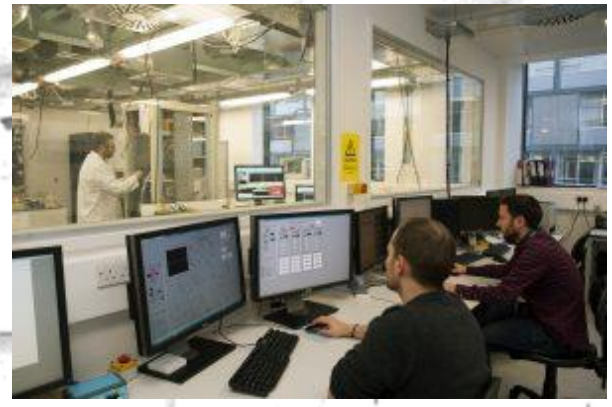

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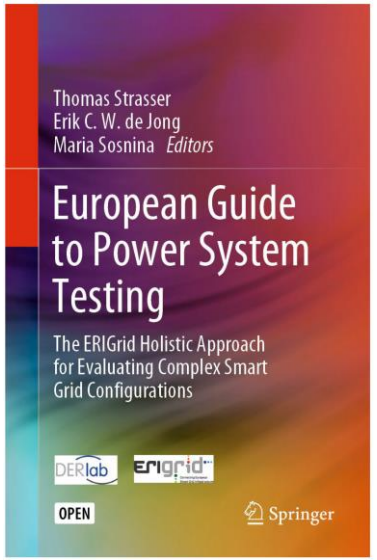
Conclusions

- Integrated analysis and multi-domain, cyber-physical systems based approach needed for mastering the complexity of smart energy systems
- Methods and tools for system-level testing as well as rapid configuration of lab-setups required
- Flexible combination of simulation and lab-based approaches beneficial
- Smart grid, smart energy systems, and DER research and development services (incl. physical labs) are necessary
- Harmonization and standardization necessary (e.g., IEEE P2004 on HIL)



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@ERIGrid 2.0 Project

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