ERIGrid – An Integrated Research Infrastructure for Validating Cyber-Physical Energy Systems

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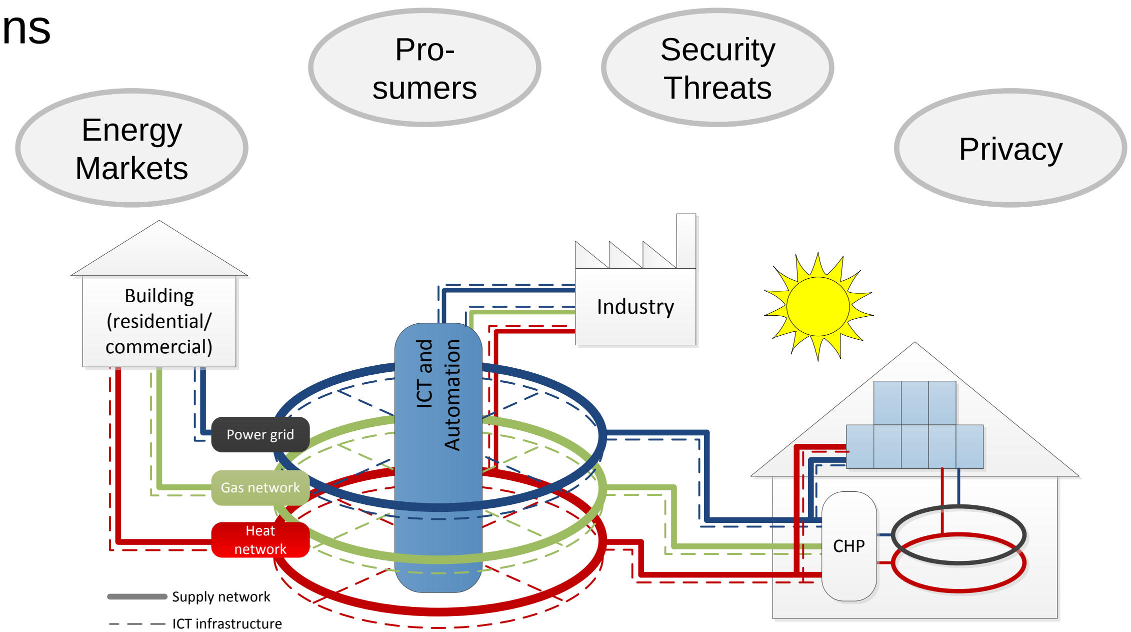
Smart Grid Cyber Security

Outline

- Background and Motivation
- Status Quo in Design and Validation
- Future Needs and Developments
- The ERIGrid Approach
- Application Example
- Conclusions

Background and Motivation

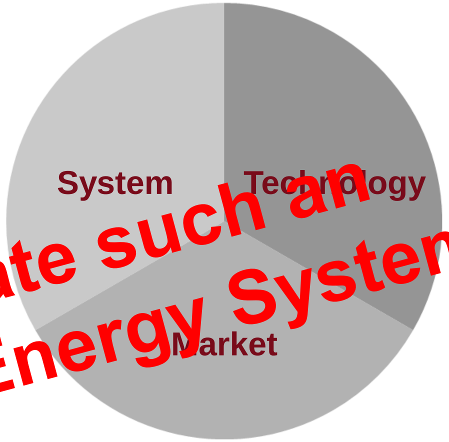
- Planning and operation of the energy infrastructure becomes more complex
  - Large-scale integration of renewable sources (PV, wind, etc.)
  - Controllable loads (batteries, electric vehicles, heat pumps, etc.)
- Trends and future directions
  - Digitalisation of power grids
  - Deeper involvement of consumers and market interaction
  - Linking electricity, gas, and heat grids for higher flexibility and resilience



→ *Integrated Cyber-Physical Energy System*

Background and Motivation

- Key elements of future integrated smart grids for mastering the increasing requirements and system complexity are
  - Power electronics
  - Advanced communication, automation and control systems
  - Smart algorithms
  - Monitoring and data analytics



How to design and validate such an Integrated Cyber-Physical Energy System?

EU H2020 Programme GA No. 654113

Status Quo in Design and Validation

- In the past individual domains of power and communication systems have been often designed and validated separately
- Available methods and approaches are

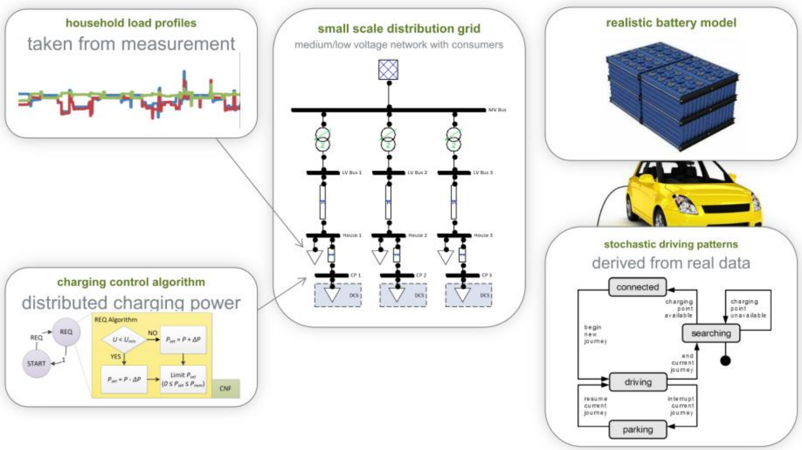
	Req. & Basic Design Phase	**_Detailed Design Phase_**	**_Implementation & Prototyping_**	**_Deployment / Roll Out_**
Software Simulation	+	++	O	-
Lab Experiments and Tests	-	-	++	+
Hardware-in-the-Loop (HIL)	-	-	++	++
Demonstrations / field tests / pilots	-	-	-	++

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

Status Quo in Design and Validation

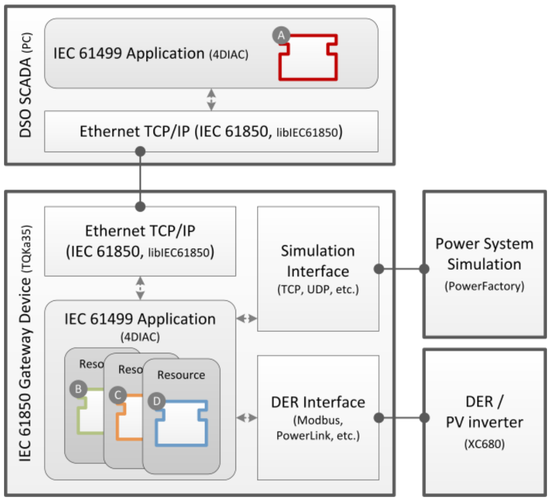
- Promising validation approaches
  - Co-simulation: coupling of domain-specific simulators

    (example: dynamic charging of electric vehicles)



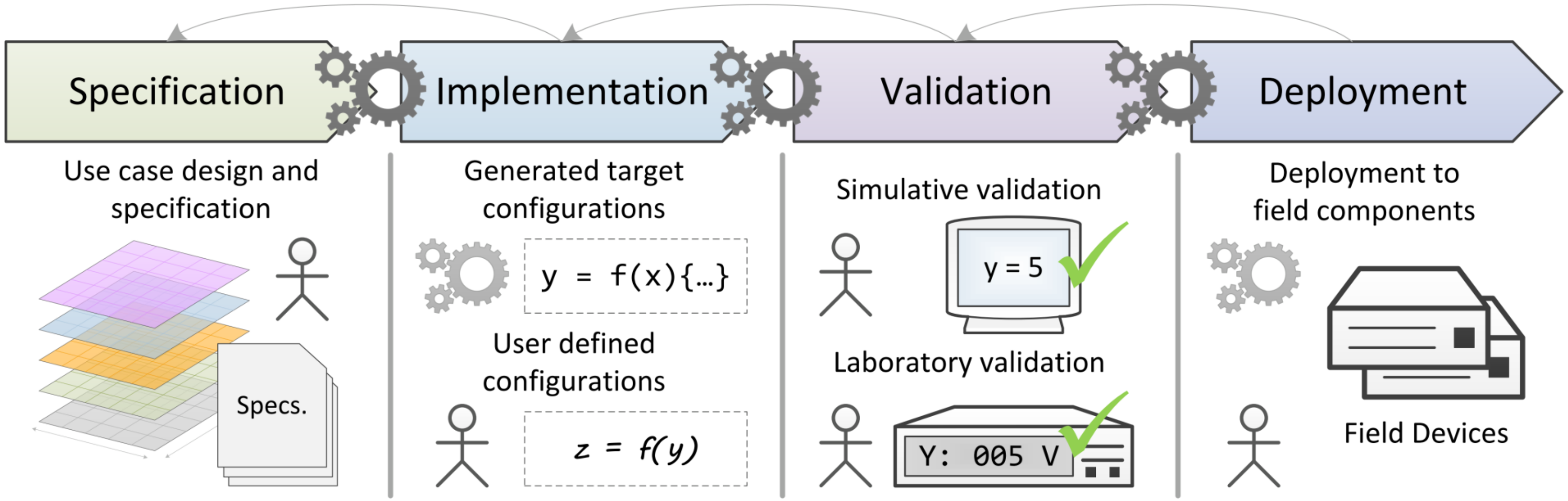
  - Hardware-in-the-Loop (HIL) experiments
    - Controller-HIL (CHIL)

      (example: remote control of inverter-based DER)
    - Power-HIL (PHIL)



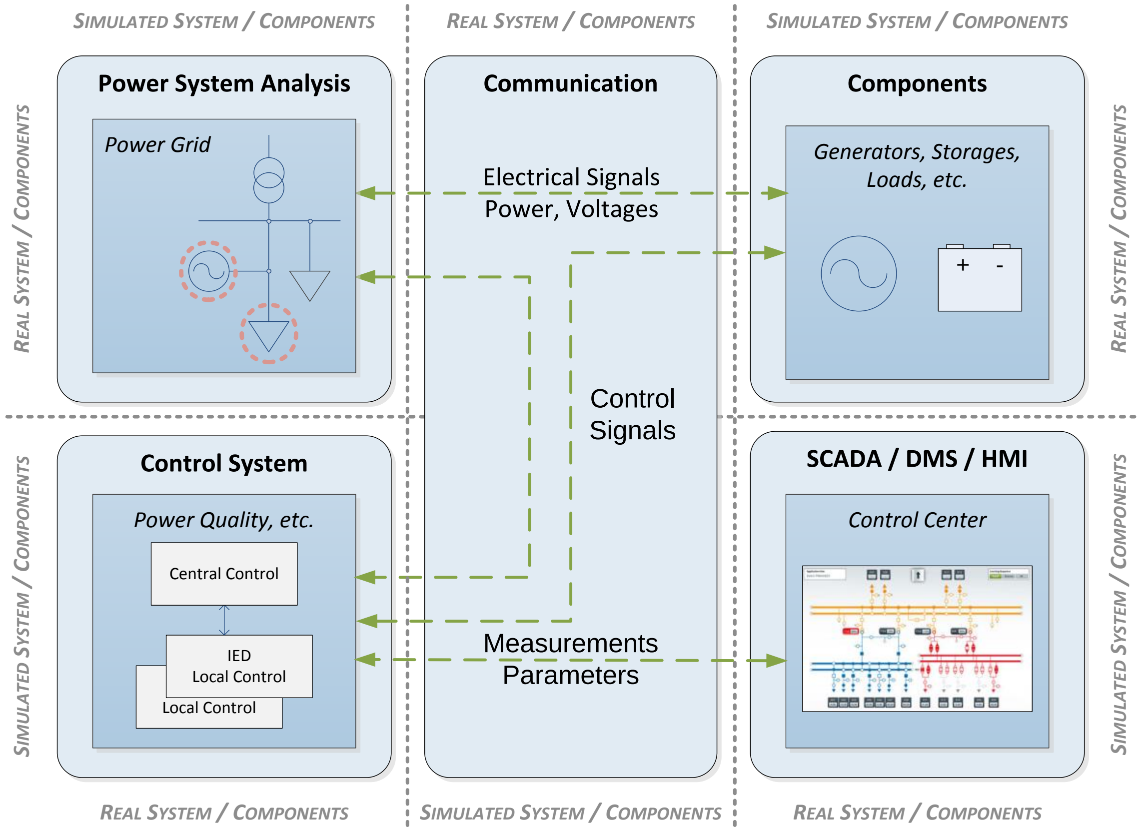
Future Needs and Developments

- Vision: *"Providing support from design to implementation & installation"*
  - Integrated system design
  - Validation and testing
  - Installation and roll out



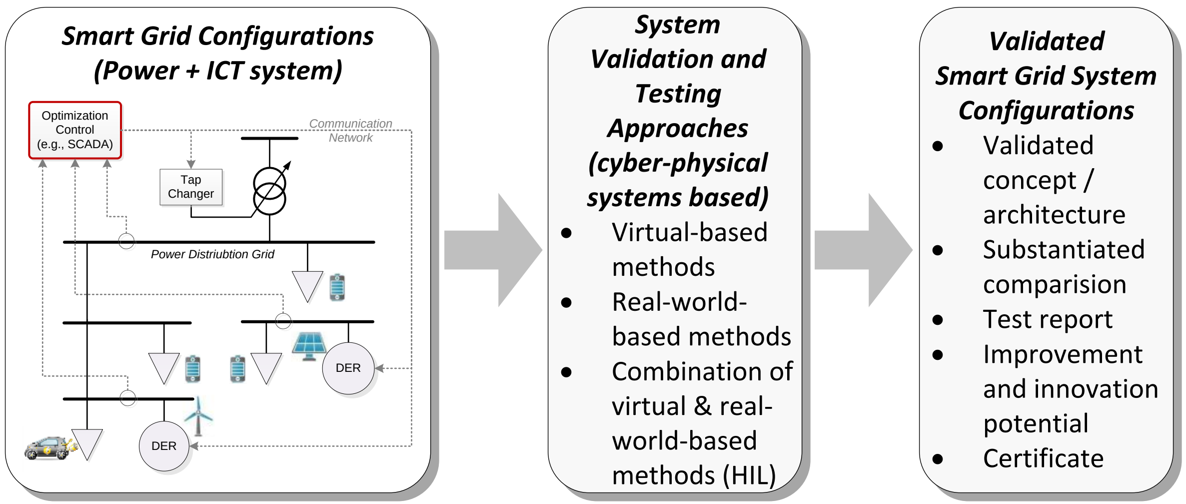
Future Needs and Developments

- A cyber-physical (multi-domain) approach for analysing and validating smart grids on the system level is missing today
  - Existing methods focusing mainly on component level issues
  - System integration topics including analysis and evaluation are not addressed in a holistic manner



Future Needs and Developments

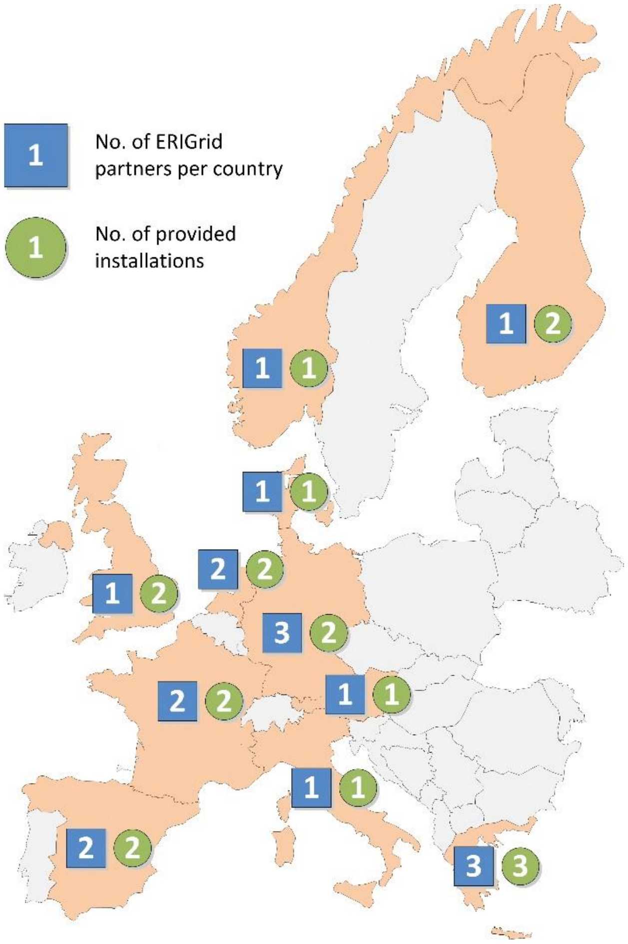
- A holistic validation framework and the corresponding research infrastructure with proper methods and tools needs to be developed



- Harmonized and standardized evaluation procedures need to be developed
- Well-educated professionals, engineers and researchers understanding integrated smart grid configurations in a cyber-physical manner need to be trained on a broad scale

The ERIGrid Approach

- H2020 call
  - INFRAIA-1-2014/2015:
    Integrating and opening existing national and regional research infrastructures of European interest
- Funding instrument
  - Research and Innovation Actions (RIA)
    Integrating Activity (IA)
- 18 Partners from 11 European Countries
  + 3 Third Parties involved
- Involvement of 19 first class Smart Grid labs
- 10 Mio Euro Funding from the EC
- ~1000 Person Month



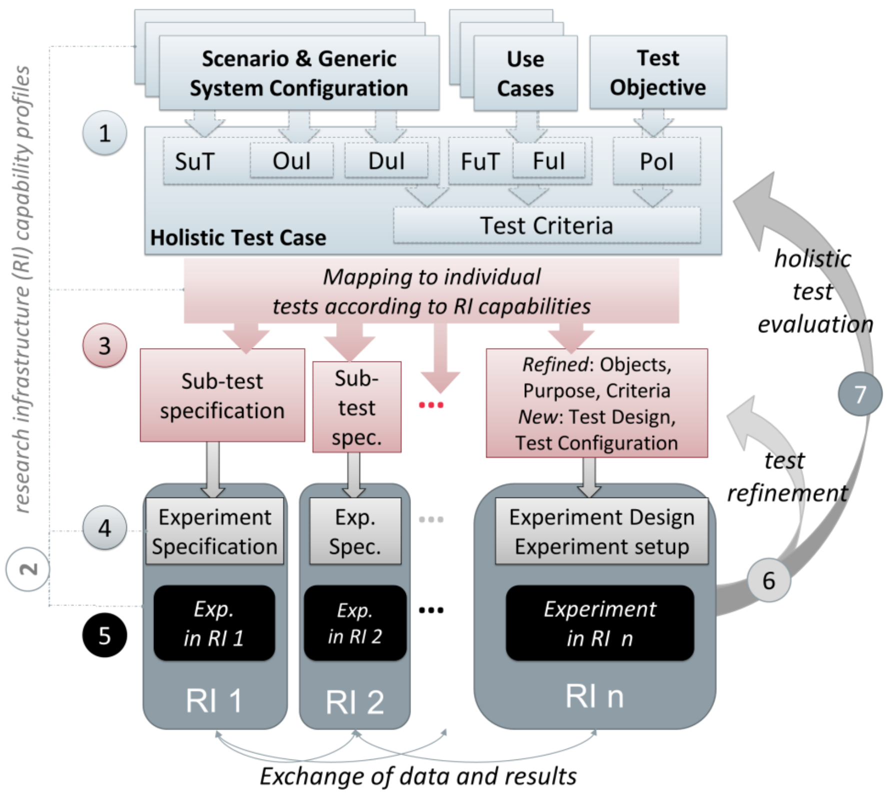
The ERIGrid Approach

- Main Goals
  - Supporting the technology development as well as the roll out of smart grid approaches, solutions and concepts in Europe with a holistic, cyber-physical systems approach
  - Integrating the major European research centres with a considerable, outstanding smart grid research infrastructure to jointly develop common methods, concepts, and procedures
  - Integrating and enhancing the necessary research services for analysing, validating and testing smart grid system configurations
  - Provision of system level support and education for industrial and academic researchers in smart grid research and technology development fostering future innovations
  - Strengthening the technical leadership of the European Research Area in the energy domain

The ERIGrid Approach

- Towards formalized validation

“From validation needs to evaluated integrated smart grid configurations”

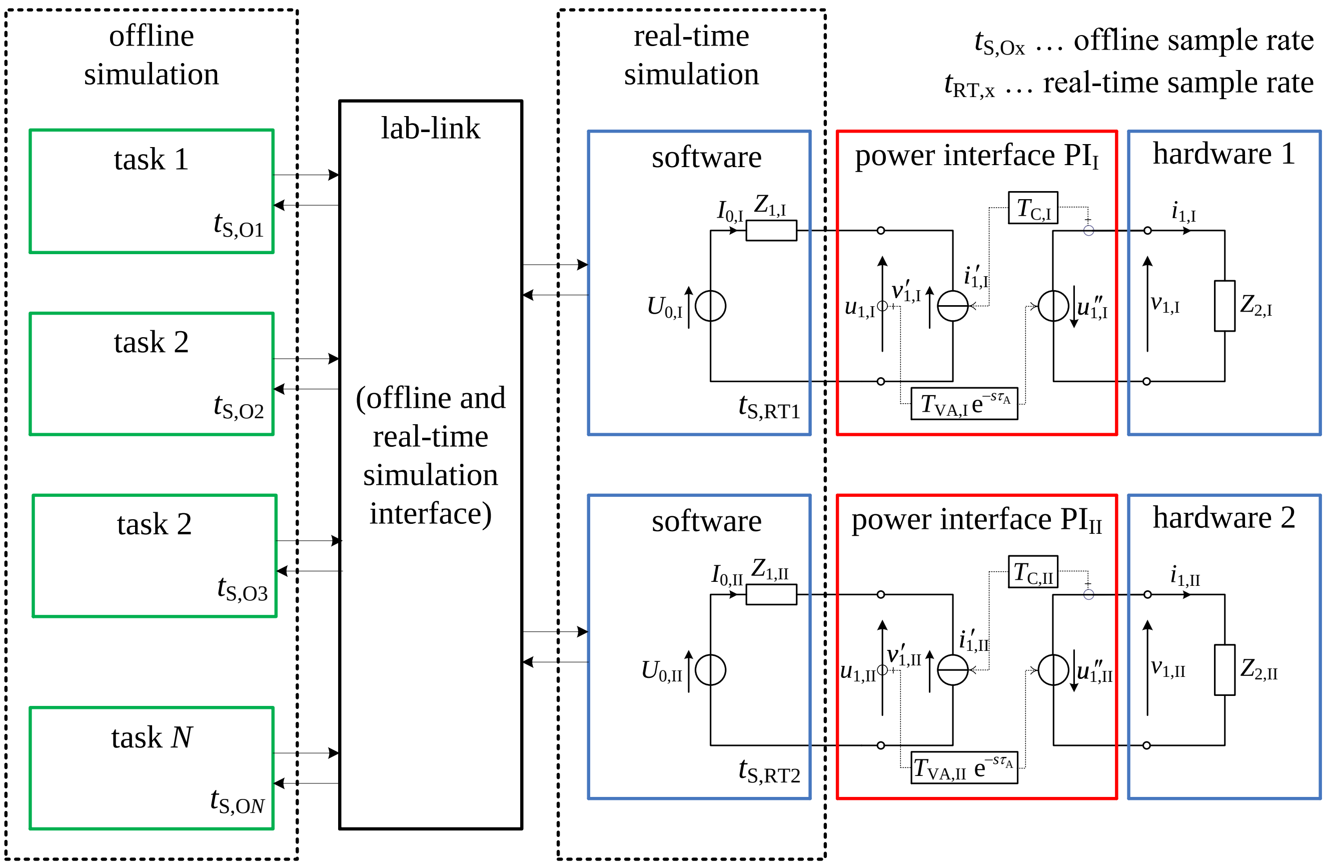


Legend:

- System under Test (SuT)
- Object of Investigation (OuI)
- Domain under Investigation (DuI)
- Function(s) under Investigation (FuT)
- Function(s) under Test (FuI)
- Purpose of Investigation (PoI)
- Research Infrastructure (RI)

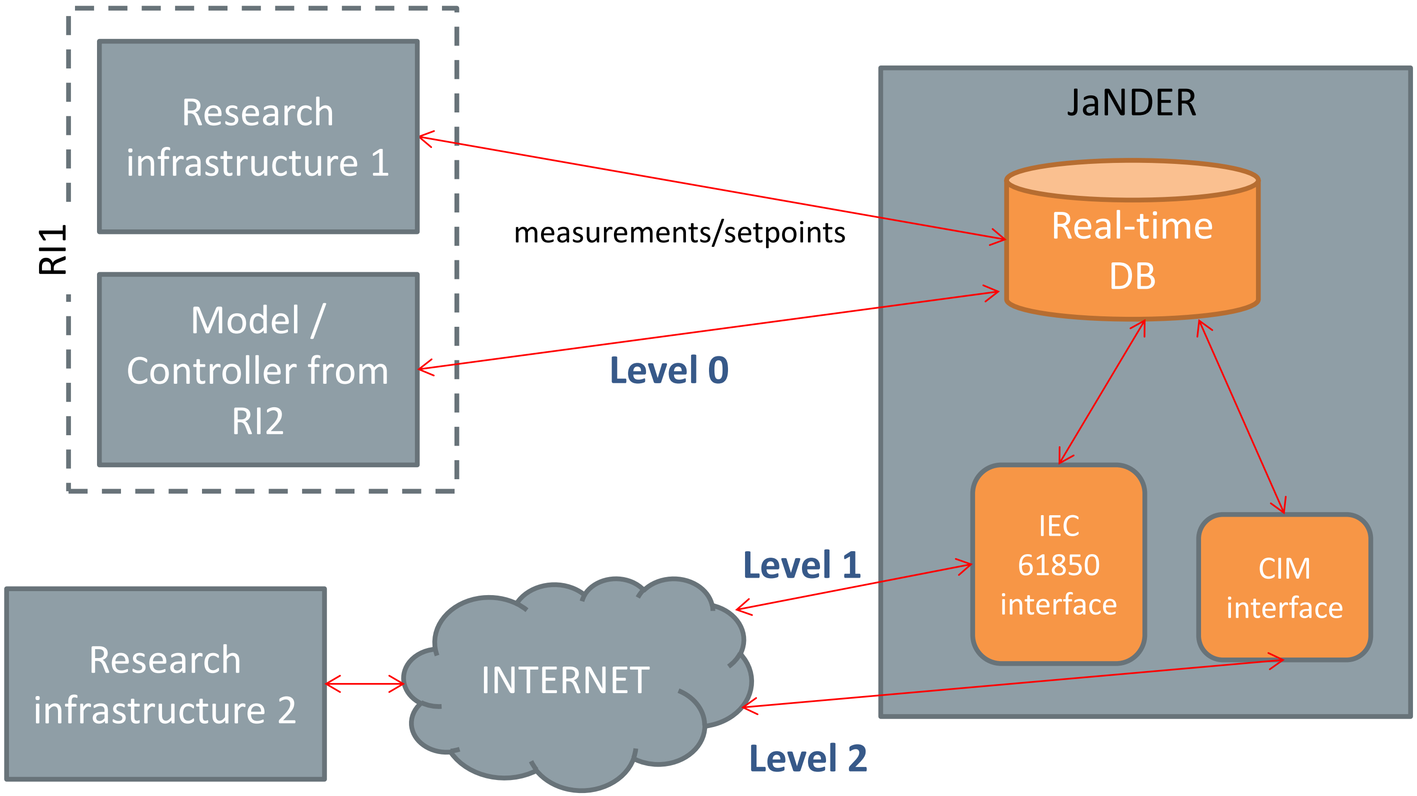
The ERIGrid Approach

- Improved validation and testing methods: focus on co-simulation and HIL



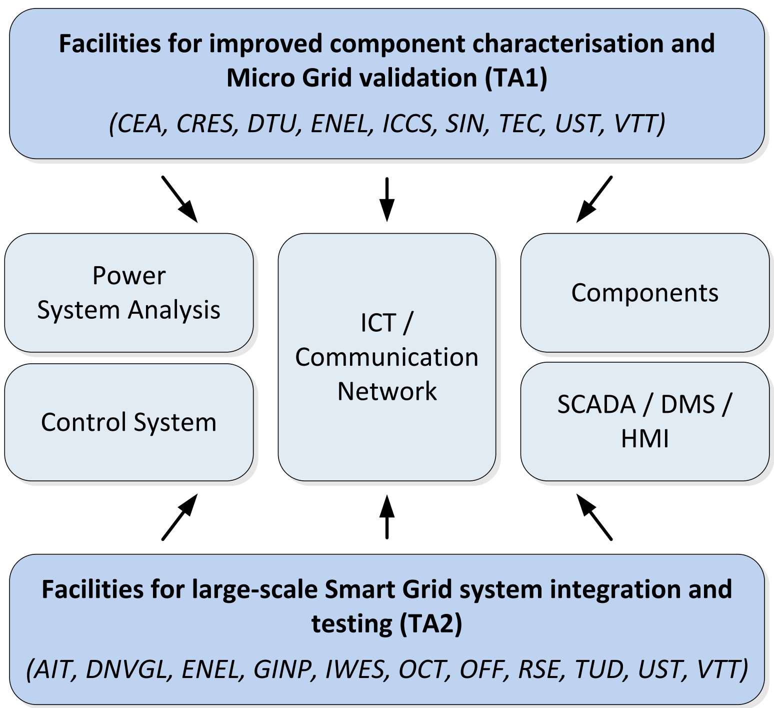
The ERIGrid Approach

- Coupling of research infrastructures for integrated and joint testing



The ERIGrid Approach

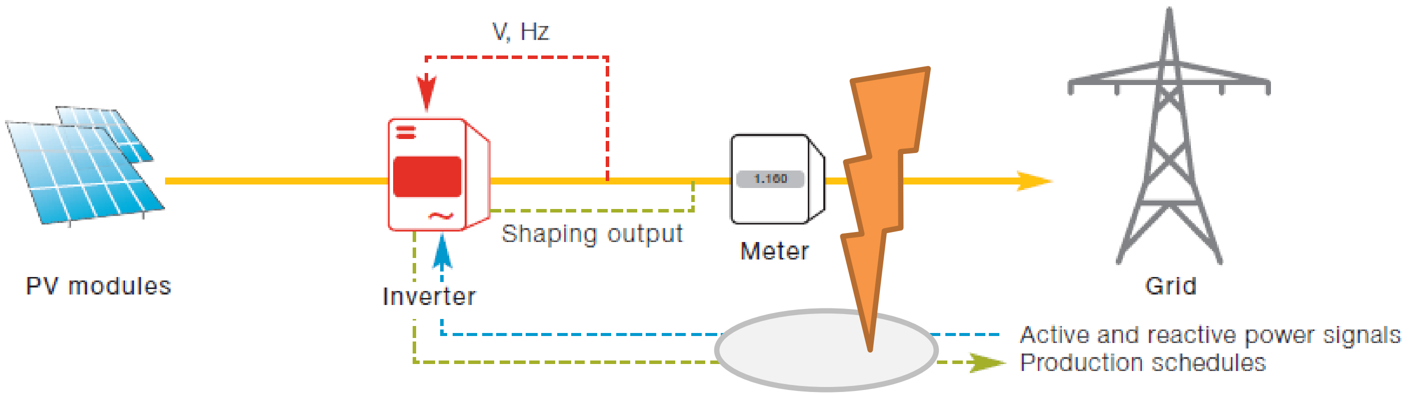
- Provision of user access to research infrastructures of the main players in the Smart Grids European Research Area



R&D topic	Provided services to external users
DER components	• PV-inverter tests (component, integration) • Storage, charging devices test (component, integration) • …
Development of new network components	• Test of new component concepts • Validation of advanced control methods for components • …
Smart Grid ICT / Automation	• Valdiation of controller implementation and integration • Validation of communication protocols • Test of SCADA system developments and integration • Cyber-security assessment • …
Co-simulation	• Co-simulation tests power grid ↔ communication network • Co-simulation tests power grid ↔ components ↔ communication network • …
Real-time simulation and HIL	• Integration tests for inverter-based devices • Validation of new power electronic component topologies • …
…	…

Application Example

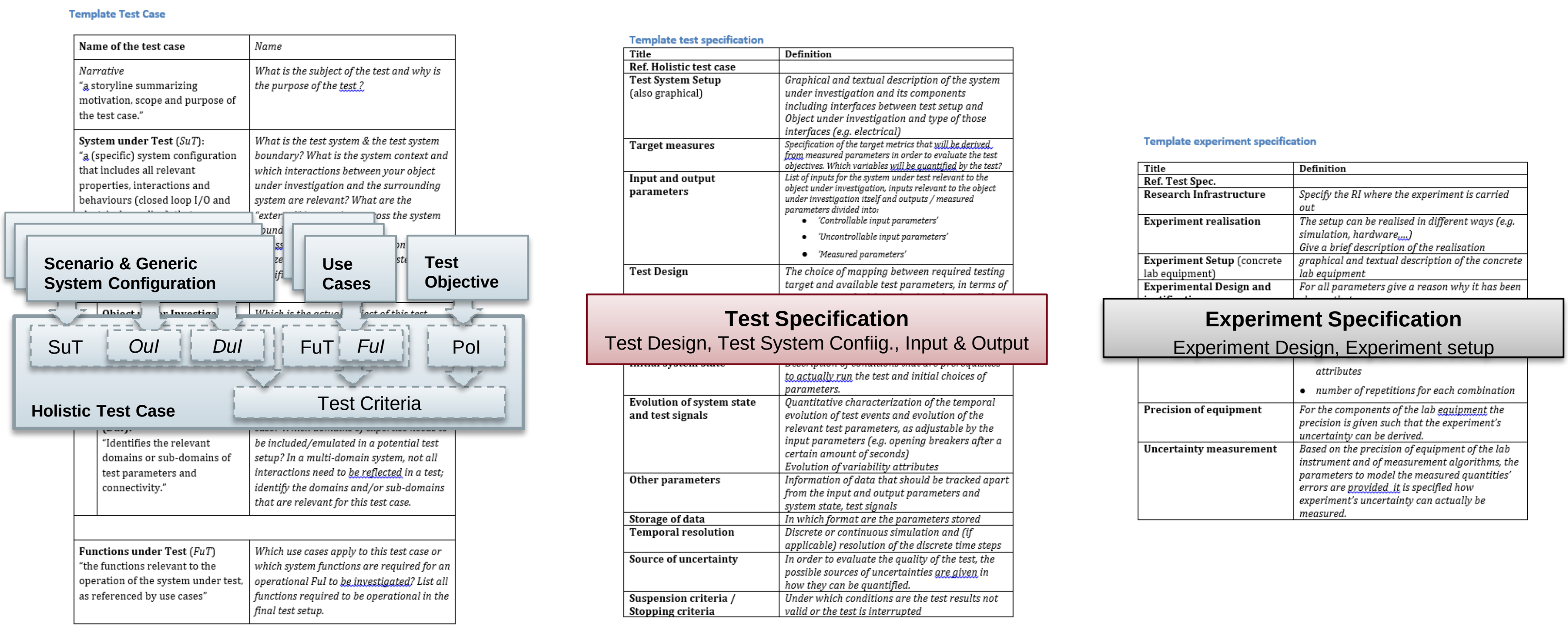
- Energy application
  - IEC 61850 remote controlled inverter-based DER
- Cyber-physical attacks investigation
  - Man-in-the-Middle attack scenario
- Validation goal
  - Analysing the influence of the attack on the energy infrastructure



EU H2020 Programme GA No. 654113

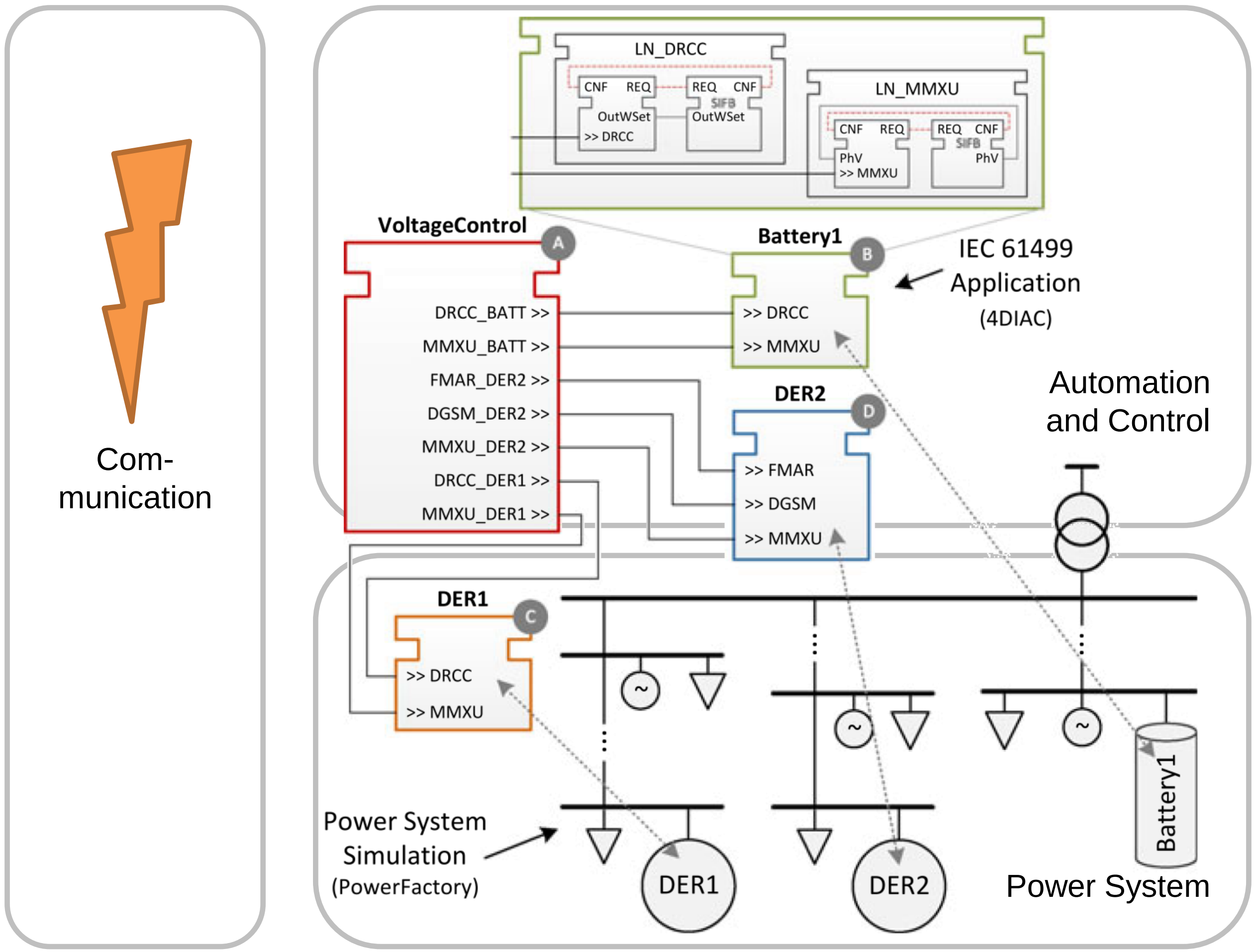
Application Example

- Formal test case description



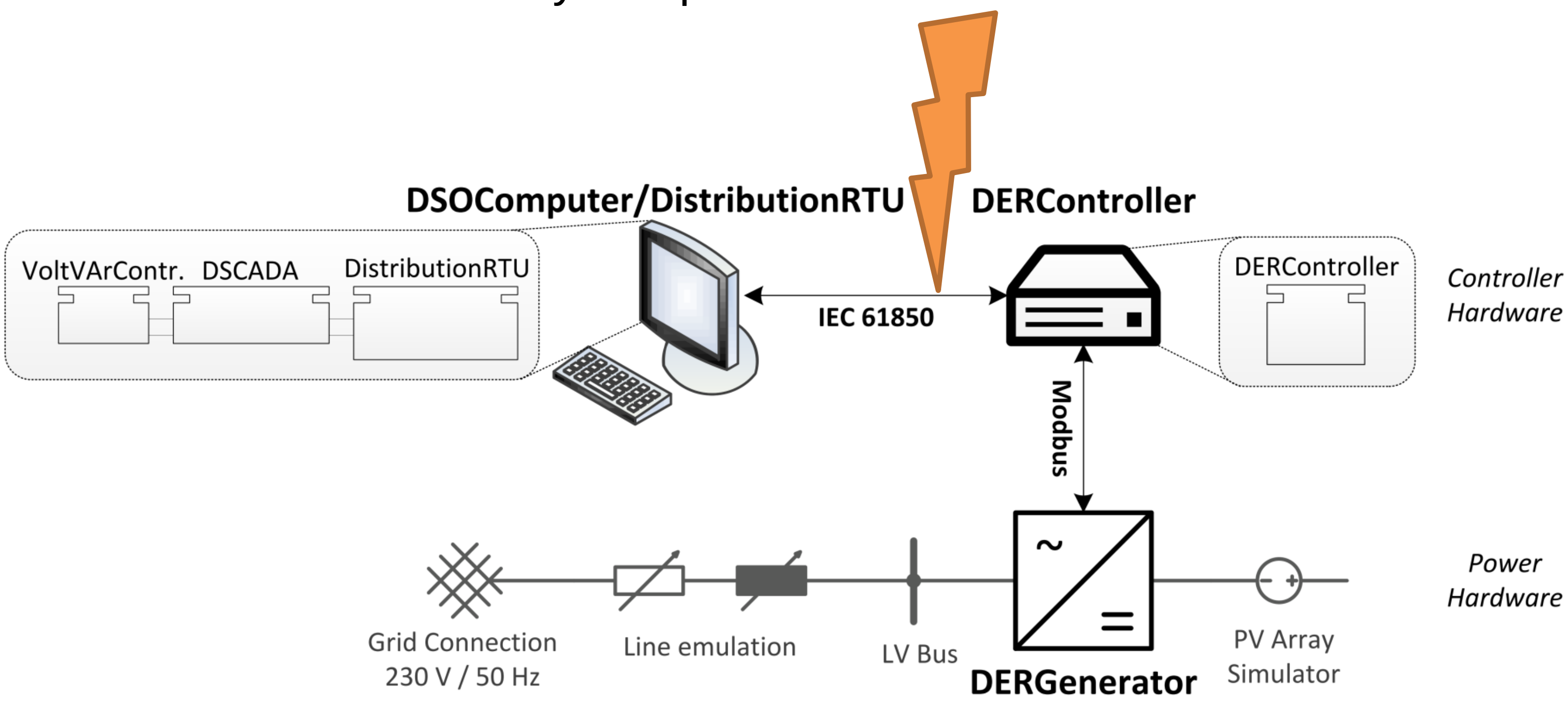
Application Example

- Simulation-based analysis
  - Coupling of different domains (power, ICT, control & automation)



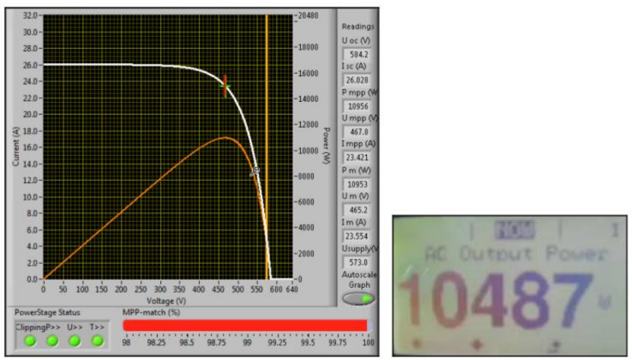
Application Example

- Lab-based analysis
  - AIT SmartEST laboratory setup

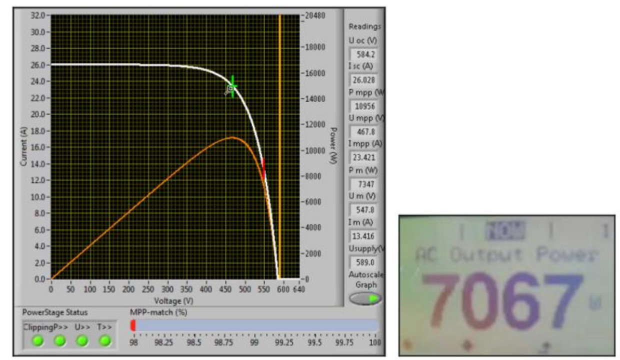


Application Example

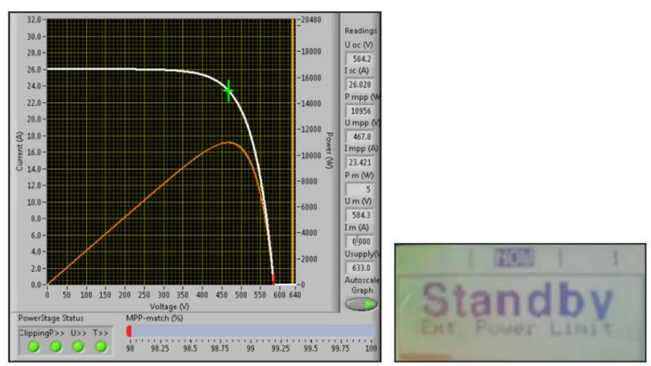
- Lab-based analysis
  - Attack (manipulation) of inverter set-points (active power)



(a) 100% of power limitation by the operator



(b) 60% of power limitation by the operator



(c) 10% of power limitation by the attacker

Conclusions

- A large-scale roll out of smart grid solutions, technologies, and products can be expected in the near future
- New technologies, suitable concepts, methods and approaches are necessary to support system analysis, evaluation and testing issues of integrated approaches
- Advanced research infrastructures are still necessary
- Flexible integration of simulation-based methods, hardware-in-the-loop approaches, and lab-based testing looks promising for overcoming shortcomings

Conclusions

- Future activities and research should be focused on
  - Improvement and integration of design and validation tools from different domains (power system + ICT + markets + consumer behaviour)
  - Development of system level validation procedures and benchmark criteria
  - Improvement of research infrastructures supporting system level validation
  - Education, training and standardization is also a key factor

Free Access to European Smart Grid Labs Apply Now!

Connecting European Smart Grid Infrastructures

ERIGrid calls for free transnational access:

1st call: 15 September - 15 December, 2016
2nd call: 15 March - 15 June, 2017
3rd call: 15 August - 15 November, 2017
4th call: 15 February - 15 May, 2018
5th call: 15 August - 15 November, 2018
6th call: 15 February - 15 May, 2019

erigrid.eu/transnational-access

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