

# Holistic Power Distribution System Validation and Testing

The Role of Digital Real-Time Simulation Systems

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*Session 3 – Insights from ELECTRA / ERIGrid*

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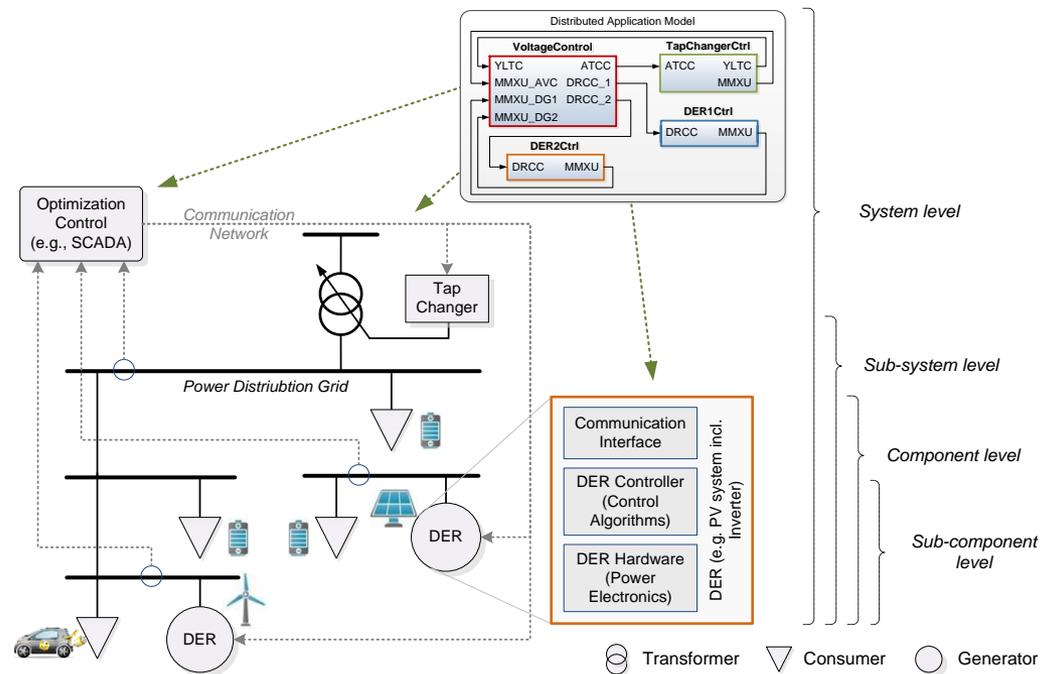


# Outline

- Background and Motivation
- Needs from the ELECTRA and ERIGrid European Projects
- The Role of DRTS in Smart Grid Design and Validation
- Future Research Directions
- Conclusions

# Background and Motivation

- Due to the increasingly higher complexity of smart grid configurations, the aspect of validation will play a major role in future technology developments
- The anticipated large scale installation and roll out of smart grid technologies and solutions requires holistic and integrated validation methods and tools
- An integrated approach for analysing and evaluating smart grid configurations, that addresses the power system as well as information, communication and automation/control aspects is currently still lacking



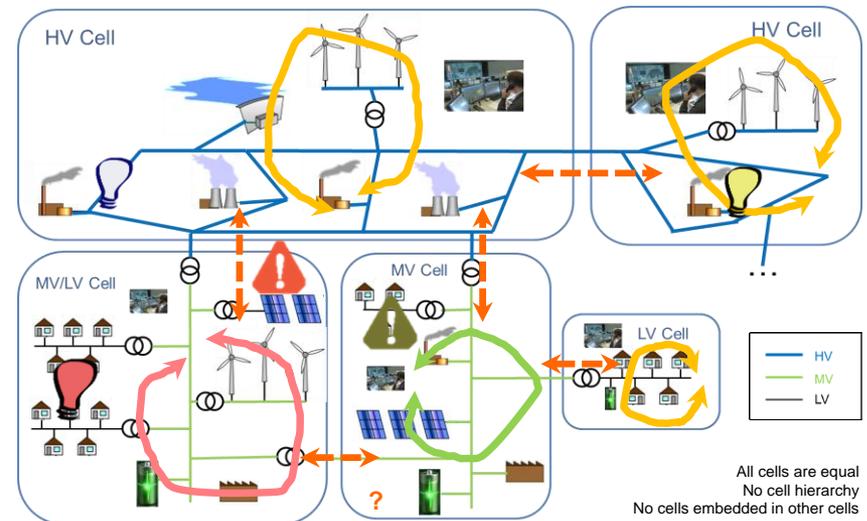
# Needs from the ELECTRA and ERIGrid European Projects

- ELECTRA IRP
  - European Liaison on Electricity grid Committed Towards long-term Research Activities
- Funding instrument
  - FP7 Integrated Research Programme on Smart Grids
  - Combination of Collaborative Project (CP) and Coordination and Support Action (CSA)
- 21 Partners from 16 European Countries
- 10 Mio Euro Funding from the EC
- ~1000 Person Month



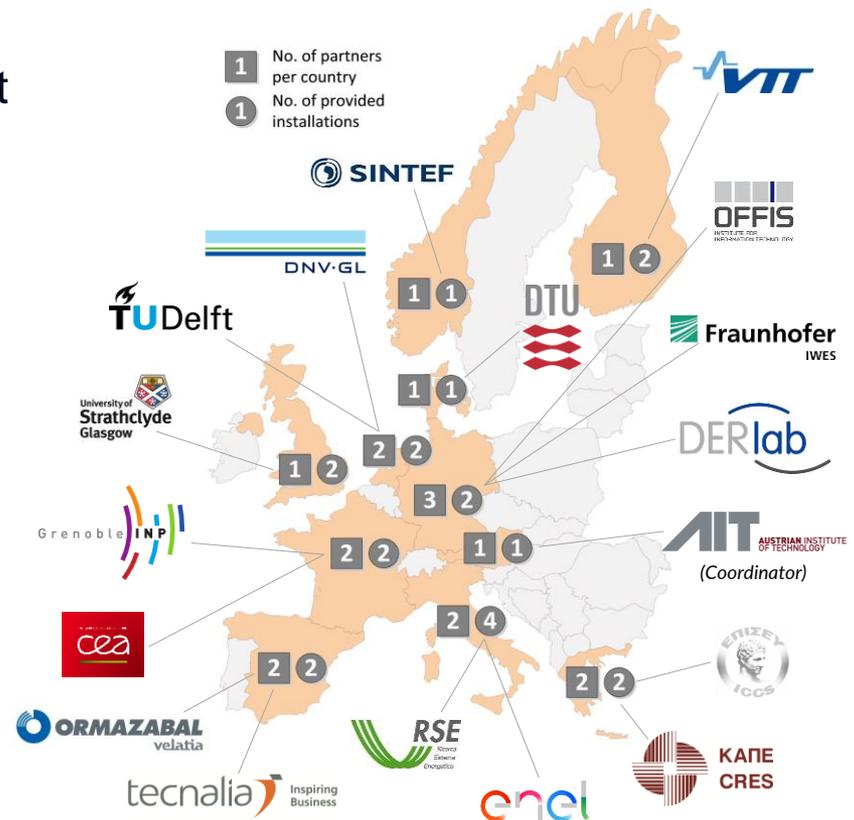
# Needs from the ELECTRA and ERIGrid European Projects

- ELECTRA IRP Web of Cells (WoC) Real-Time Operation Approach
  - Power system divided into, locally controllable cells
  - Cell = a group of interconnected loads, distributed generators and storage units, with well-defined electrical and geographical boundaries
  - Cells are connected to neighboring cells via tie-lines (one or multiple)
  - By opening/closing the inter-cells connections, the system is configurable
  - Inter-cell coordination used in order to support system-wide optimized reserves activation
  - Cells have adequate monitoring possibilities and local reserves capacity



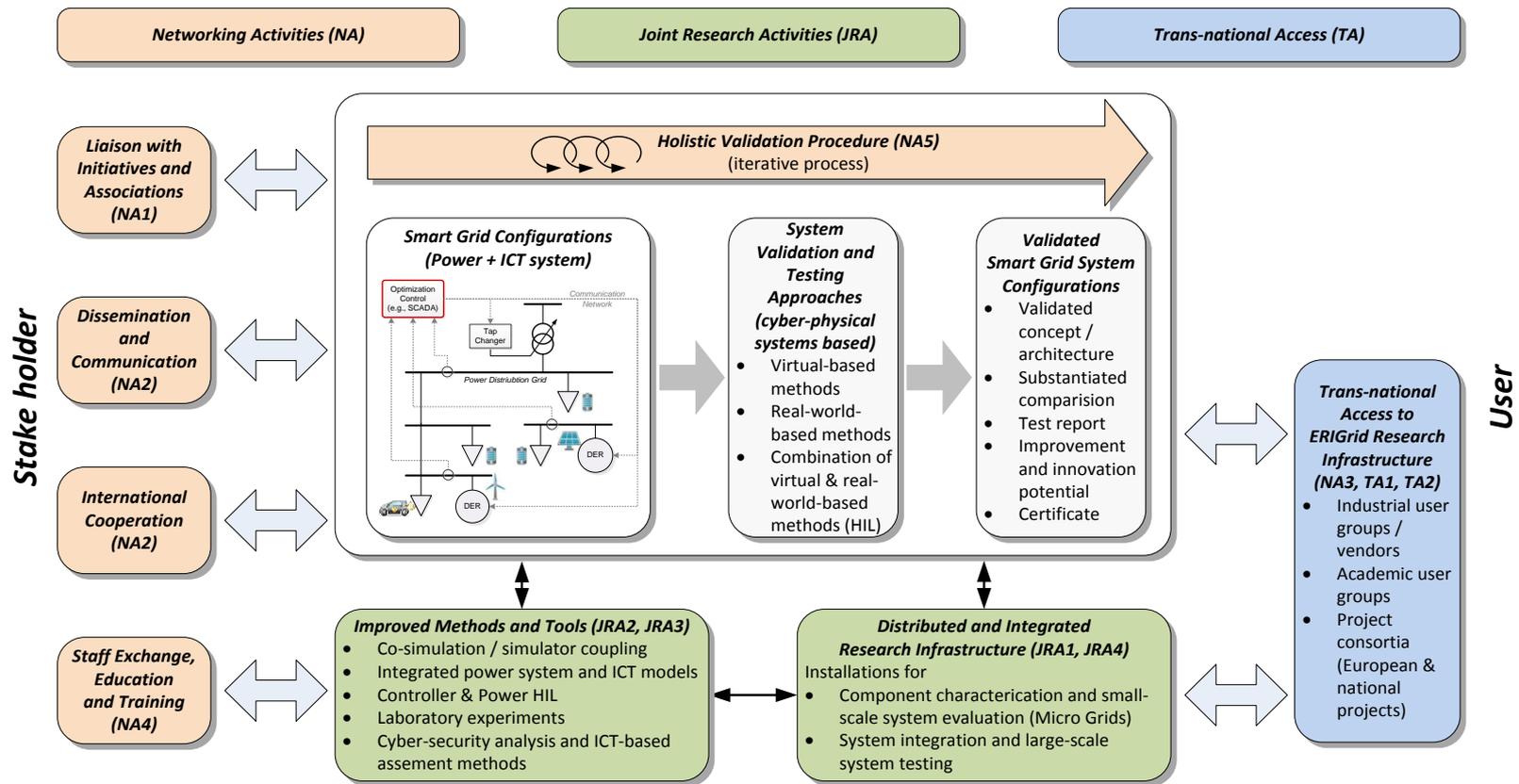
# Needs from the ELECTRA and ERIGrid European Projects

- H2020 Research Infrastructure (RI) project
  - 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
- Involvement of 21 first class SG labs
- 10 Mio Euro Funding from the EC
- ~1000 Person Month



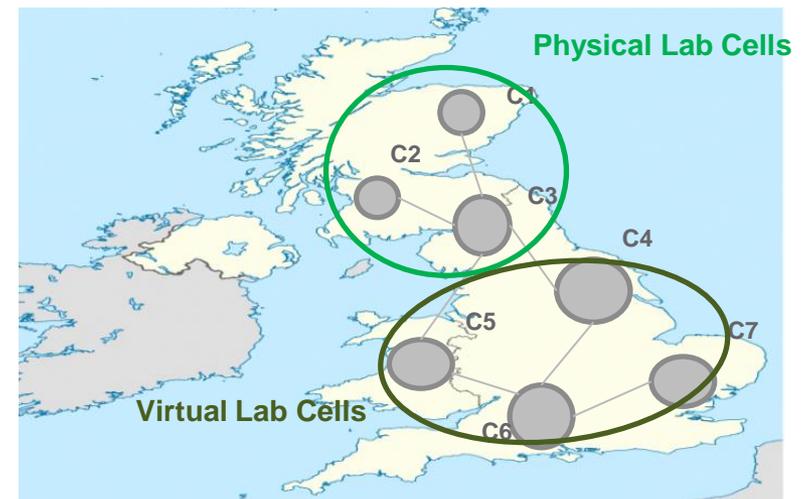
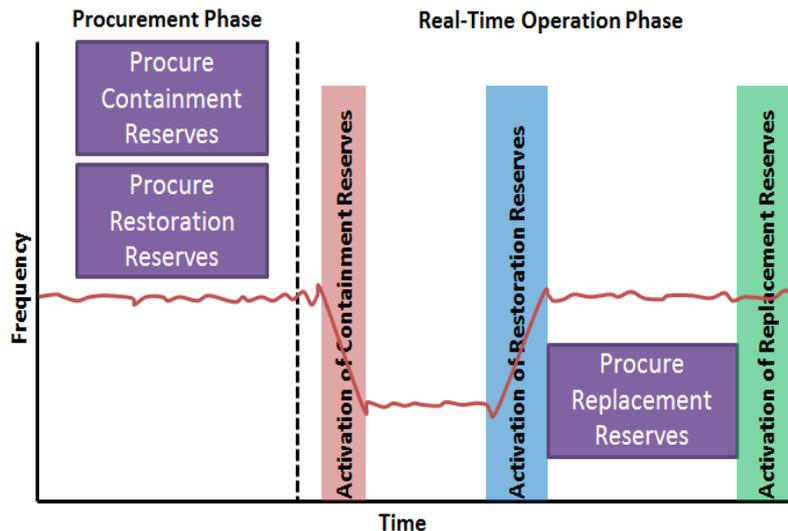
# Needs from the ELECTRA and ERIGrid European Projects

- Leading research infrastructure in Europe for the domain of SG



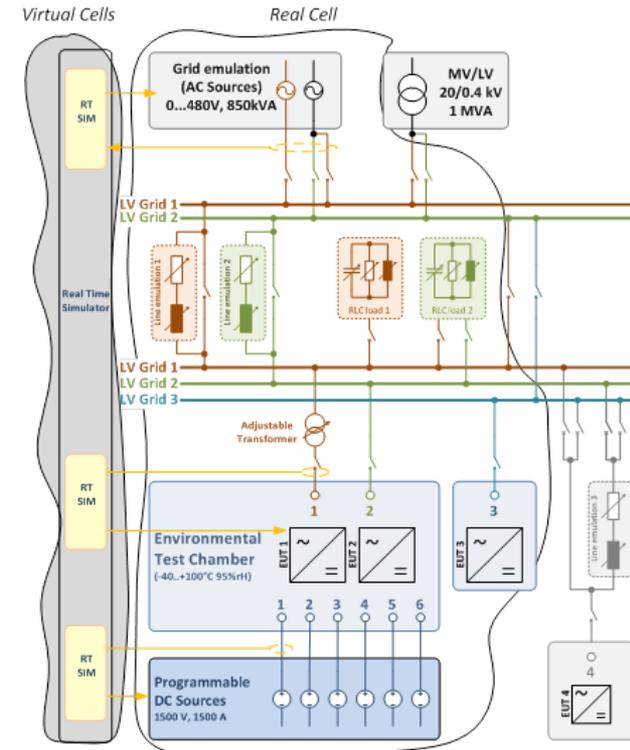
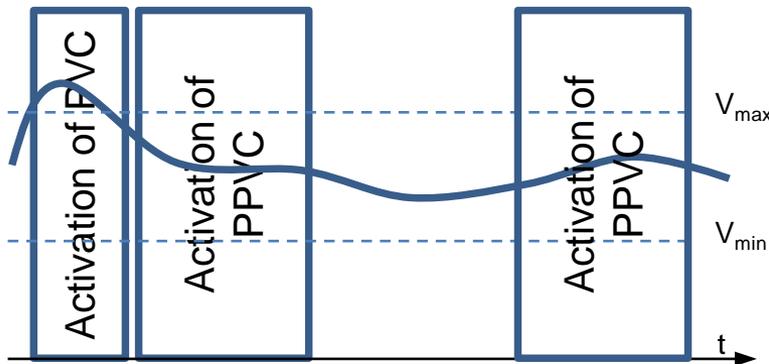
# Needs from the ELECTRA and ERIGrid European Projects

- ELECTRA IRP/ERIGrid: System-level validation of smart grid (ctrl) solutions
  - Example USTRATH: Frequency Containment Control (FCC) + Balance Restoration Control (BRC) + Balance Steering Control (BSC)



# Needs from the ELECTRA and ERIGrid European Projects

- ELECTRA IRP/ERIGrid: System-level validation of smart grid (ctrl) solutions
  - Example AIT: Post Primary Voltage Control (PPVC) + Primary Voltage Control (PVC)



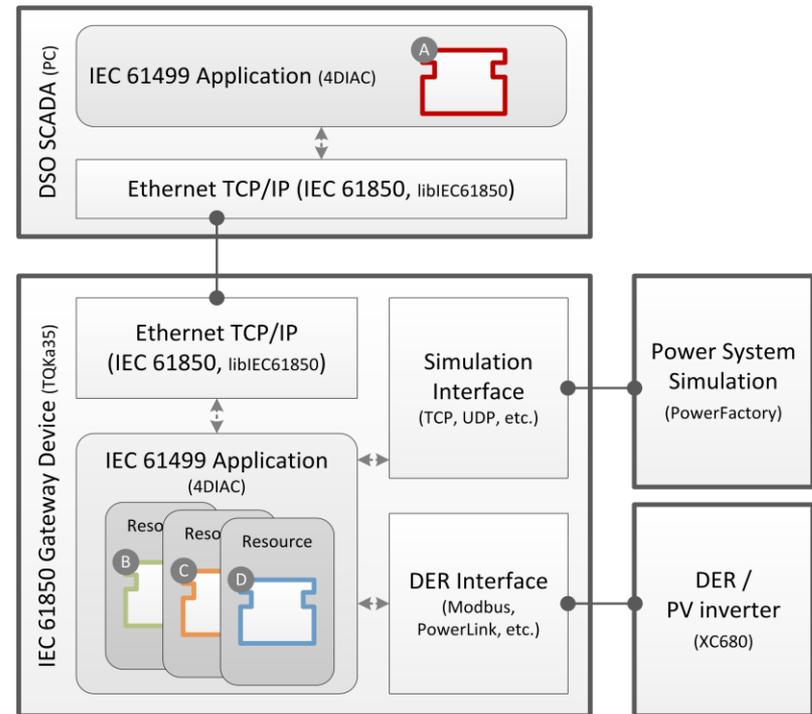
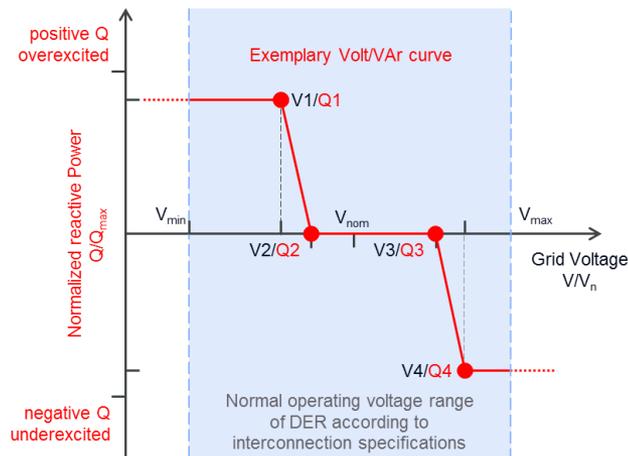
# The Role of DRTS in Smart Grid Design and Validation

- Brief overview of validation methods

	<i>Req. / basic design</i>	<i>Detailed design</i>	<i>Impl. / prototype</i>	<i>Deployment / roll out</i>
Software simulation (incl. co-sim, SiL)	+	++	0	-
Lab tests	-	-	++	+
Hardware-in-the-Loop (HIL)	-	-	++	++
Demonstrations / field tests / pilots	-	-	-	++

# The Role of DRTS in Smart Grid Design and Validation

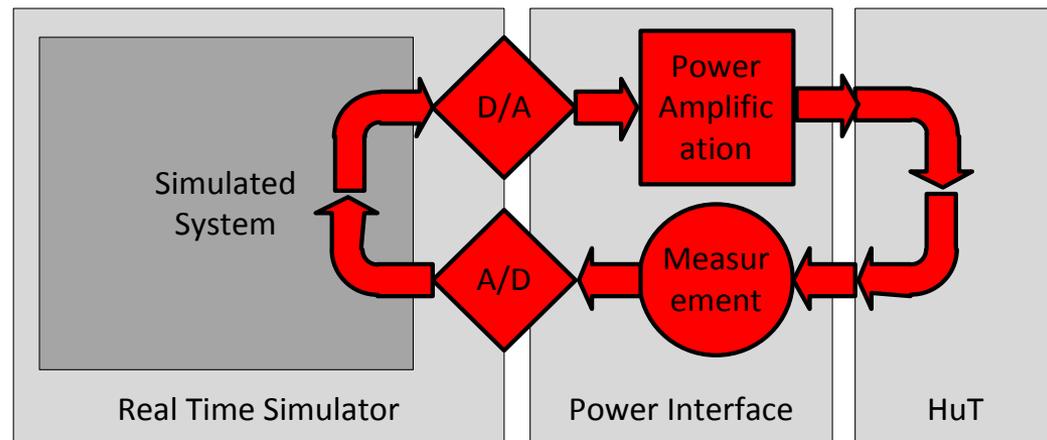
- Controller Hardware-in-the-Loop (CHIL)
  - Suitable for investigations of the control board only (pre-standardisation, communication test procedures, etc.)
  - Highly automated test sequences possible
  - No risk of high power flows



# The Role of DRTS in Smart Grid Design and Validation

- Power Hardware-in-the-Loop (PHIL)

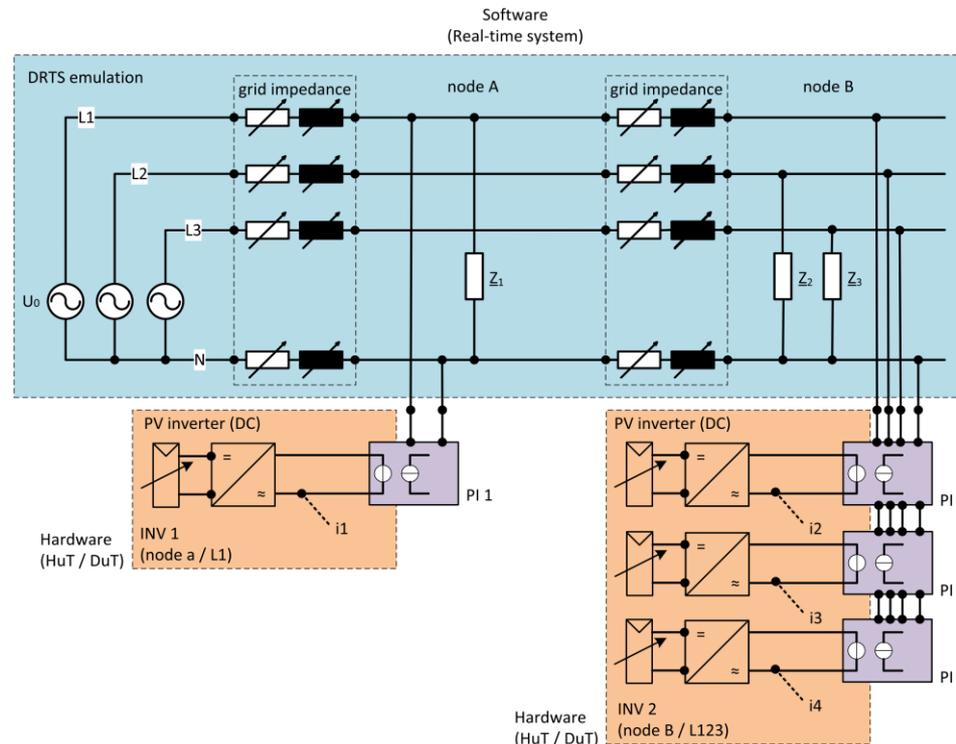
- Suitable for investigations on Hardware-under-Test (HuT) with feedback of the true power signals



- Dynamic behaviour of the Power Amplifier (PA), choice of Interface Algorithm (IA), measurement equipment
- Stability considerations (Nyquist, Popov, Ljapunow criterion)
- Measurement equipment used (I/O, transducers)

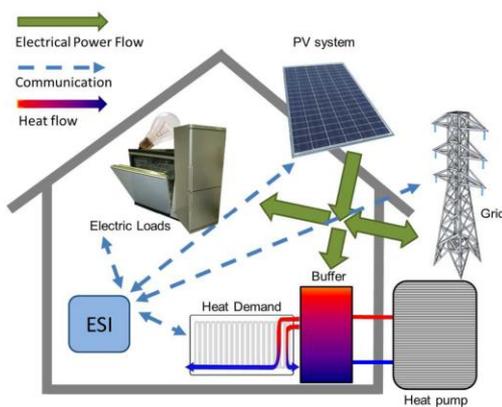
# The Role of DRTS in Smart Grid Design and Validation

- Power Hardware-in-the-Loop (PHIL)
  - DRTS-based PHIL simulation test setup of grid-connected PV inverters to investigate active/reactive power controls

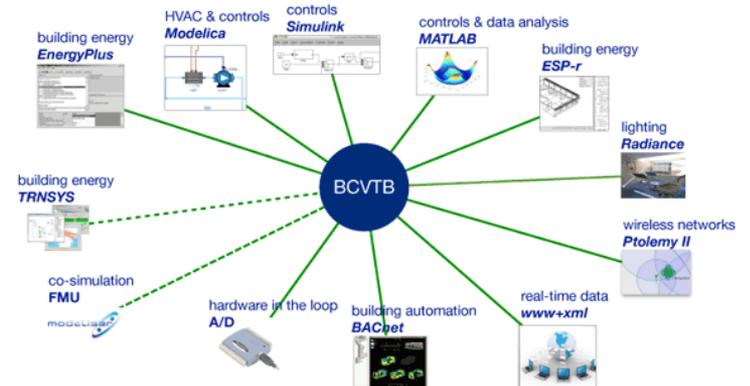
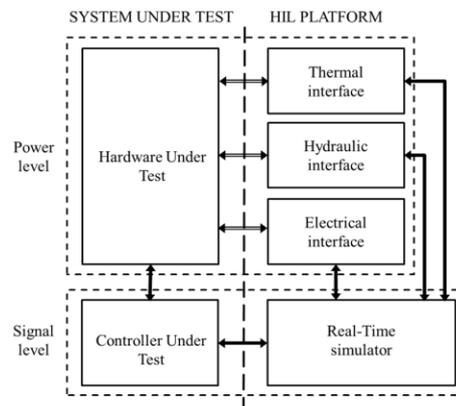


# The Role of DRTS in Smart Grid Design and Validation

- Multi-Domain Simulation/Co-Simulation (MD/Co-Sim):
  - Suitable for investigations of various other control/communication circuitry integrated into the test system
  - High degree of flexibility, possibility of integrating various control loops into CHIL/PHIL environment



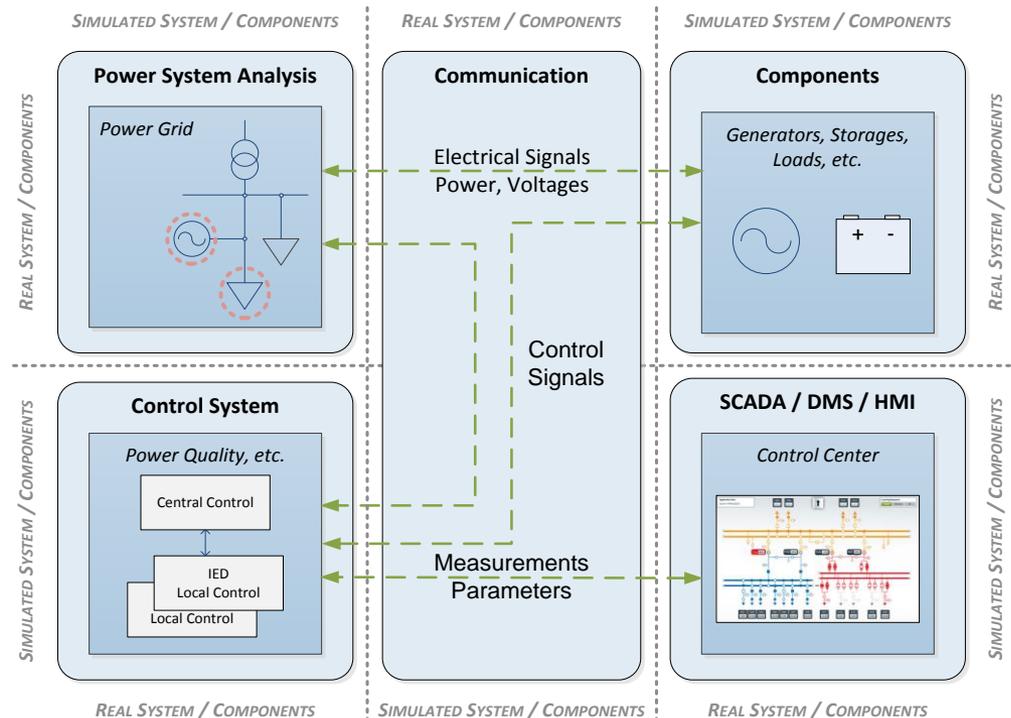
Source: RWTH Aachen



Source: Lawrence Berkley National Laboratories

# Future Research Directions

- Integrated methods and tools
- Systems level validation procedures and benchmark criteria
  - A cyber-physical (multi-domain) approach
  - A holistic validation framework
- Development of advanced research infrastructures
- Education and training



## 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
- Flexible integration of simulation-based methods, hardware-in-the-loop approaches, and lab-based testing looks promising for overcoming shortcomings

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Smart Grids Joint Programme

**Electra** Turn On The Grid of the Future

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Working with the top smart grid experts and impacting

**Thank you!**  
Time for discussion

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