

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



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	+	++	0	-
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)



- 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





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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





- 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







- 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





Towards formalized validation

"From validation needs to evaluated integrated smart grid configurations"







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





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Coupling of research infrastructures for integrated and joint testing







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 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





- 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







Formal test case description

Template Test Case



Template test specification	n
Title	Definition
Ref. Holistic test case	
Test System Setup (also graphical)	Graphical and textual description of the system under investigation and its components including interfaces between test setup and Object under investigation and type of those interfaces (e.g. electrical)
Target measures	Specification of the target metrics that <u>will be derived</u> , from measured parameters in order to evaluate the test objectives. Which variables <u>will be quantified</u> by the test?
Input and output parameters	List of inputs for the system under test relevant to the object under investigation. inputs relevant to the object under investigation itself and outputs / measured parameters divided into: • Controllable input parameters'
	'Uncontrollable input parameters' 'Measured parameters'
Test Design	The choice of mapping between required testing target and available test parameters, in terms of

Test Specification

Test Design, Test System Confiig., Input & Output

to actually run the test and initial choices of parameters.
Quantitative characterization of the temporal
evolution of test events and evolution of the
relevant test parameters, as adjustable by the
innut narameters (e.a. onenina hreakers after a
certain amount of seconds)
Evolution of variability attributes
Information of data that should be tracked apart
from the input and output parameters and
system state, test signals
In which format are the parameters stored
Discrete or continuous simulation and (if
applicable) resolution of the discrete time steps
In order to evaluate the quality of the test, the
possible sources of uncertainties are given in
how they can be quantified.
Under which conditions are the test results not
valid or the test is interrupted

Template experiment specification

Title	Definition
Ref. Test Spec.	
Research Infrastructure	Specify the RI where the experiment is carried
	out
Experiment realisation	The setup can be realised in different ways (e.g.
	simulation, hardware,)
	Give a brief description of the realisation
Experiment Setup (concrete	graphical and textual description of the concrete
lab equipment)	lab equipment
Experimental Design and	For all parameters give a reason why it has been

Experiment Specification

Experiment Design, Experiment setup

	attributes
	number of repetitions for each combination
Precision of equipment	For the components of the lab <u>equipment</u> the precision is given such that the experiment's uncertainty can be derived.
Uncertainty measurement	Based on the precision of equipment of the lab instrument and of measurement algorithms, the parameters to model the measured quantities' errors are provided it is specified how experiment's uncertainty can actually be measured.



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- Simulation-based analysis
 - Coupling

 of different
 domains
 (power, ICT,
 control &
 automation)







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- Lab-based analysis
 - AIT SmartEST laboratory setup







- 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



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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



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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

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