Tutorial

Title

Designing and Validating Cyber-Physical Energy Systems

Abstract

A driving force for the realization of a sustainable energy supply is the integration of renewable energy resources. Due to their stochastic generation behaviour, energy utilities are confronted with a more complex operation of the underlying power grids. Additionally, due to technological developments, controllable loads, integration with other energy sources, changing regulatory rules, and market liberalization, the system's operation needs adaptation. Proper operational concepts and intelligent automation provide the basis to turn the existing power system into an intelligent entity, a smart grid. While reaping the benefits that come along with those intelligent behaviours, it is expected that system-level developments and testing will play a significantly larger role in realizing future solutions and technologies. Proper validation approaches, concepts, and tools are partly missing until now.

This tutorial aims to tackle the above-mentioned requirements by introducing validation methods and tools for validating smart grids and energy systems.

Duration

Two hours

Motivation

During the last two decades, a growing number of various research, technology development, and innovation activities have already been carried out in this domain. Various demonstration projects have already shown the applicability of the proposed smart grid approaches. Also, the extension of the smart grid concept which focuses on electric energy to multi-domain energy – towards smart energy systems – has been carried out during the last years.

While reaping the benefits that come along with those intelligent behaviors, it is expected that system-level design and testing will need to play a significantly larger role in the development and roll-out of future solutions and technologies. Design and validation approaches, concepts, and corresponding tools for smart grids and smart energy systems (also referred to as cyber-physical energy systems) are still not mature enough for effective usage. A key element in this context is the human factor as well as educated professionals, engineers, and researchers understanding the needs

and methods for complex smart grids and smart energy systems validation in a multi-domain and cyber-physical manner. This is partly lacking today.

In summary, the following research and development topics are not sufficiently covered:

- Domain-specific adaptations of previously developed abstract design and validation procedures and corresponding concepts, methods, and tools are required to address advanced applications (low-inertia grids, microgrids, hybrid grids, etc.),
- Common and well-understood reference scenarios, use cases, and test case profiles for cyber-physical energy systems need to be provided to power and energy systems engineers and researchers; also, proper validation benchmark criteria and key performance indicators, as well as interoperability measures for validating cyber-physical energy systems, need to be developed, extended, and shared with engineers and researchers in Europe,
- Harmonization and standardization of multi-domain cyber-physical systems-based evaluation and testing procedures are necessary, and
- Well-educated professionals, engineers, and researchers understand cyber-physical energy systems configurations in a multi-domain and cyber-physical manner addressing the upcoming energy transition need to be educated and trained on a broad scale.

This tutorial aims to tackle the above-mentioned requirements by introducing proper methods and tools for designing and validating cyber-physical energy systems which are currently being developed in the European project ERIGrid 2.0 as well as the Austrian project PowerTeams.

This tutorial is well in line with the IEEE SMCS topics:

- Cybernetics
- Systems Science and Engineering

and is supported by the:

- IEEE SMC TC on Intelligent Industrial Systems
- IEEE SMC TC on Distributed Intelligent Systems

Expected audience

The tutorial is foreseen/valuable for the following persons (not limited to):

- Researchers/academics dealing with power and energy systems
- Engineers active in the domain of power and energy systems

Outline of contents

The tutorial is structured as follows:

- Introduction to smart energy systems
- The ERIGrid 2.0 and PowerTeams vision and approach
- Validation and testing approaches
  - Requirements for testing smart energy systems
  - System-level validation and testing
  - Interoperability Testing
- Methods and tools
  - Pure simulation-based assessment methods
  - Real-time simulation and HIL concepts
  - Distributed lab-based testing of energy systems
- Selected validation examples

Key references

[1] T. Strasser, E. de Jong, M. Sosnina (ed.): "European Guide to Power System Testing: The ERIGrid Holistic Approach for Evaluating Complex Smart Grid Configurations"; Springer Nature, Cham, Switzerland, 2020, ISBN: 978-3-030-42274-5; 141 pages.

[2] Benigni, T. Strasser, G. De Carne, M. Liserre, M. Cupelli, A. Monti: "Real-Time Simulation-Based Testing of Modern Energy Systems: A Review and Discussion"; IEEE Industrial Electronics Magazine, 14 (2020), Vol. 2; 28 - 39.

[3] J. Resch, B. Schuiki, S. Schöndorfer, C. Brandauer, G Panholzer, F. Pröstl Andren, T. Strasser: "Engineering and validation support framework for power system automation and control applications"; e & i Elektrotechnik und Informationstechnik, issue 8 (2020), Volume 137; 470 - 475.

[4] T. Strasser, E. Jong, M. Sosnina, J. Rodríguez-Seco, P. Kotsampopoulos, D. Babazadeh, K. Mäki, R. Bhandia, R. Brandl, C Sandroni, K. Heussen, F. Coffele: "Achievements, experiences, and lessons learned from the European research infrastructure ERIGrid related to thevalidation of power and energy systems"; Elektronik & Informationstechnik (e&i), issue 8 (2020), Volume 137; 502 - 508.

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[8] F. Pröstl Andren, T. Strasser, W Kastner: "Engineering Smart Grids: Applying Model-Driven Development from Use Case Design to Deployment"; Energies, 10 (2017), 3.

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List of speakers

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Thomas I. Strasser received a master's and a Ph.D. degree from the Technische Universität Wien (TU Wien) and was awarded the Venia Docendi (habilitation) in the field of automation from the same university. He has been a senior scientist in the Center for Energy of the AIT Austrian Institute of Technology for several years. His main responsibilities involve the strategic development of smart grid automation and validation research projects as well as the mentoring/supervising of junior scientists and Ph.D. candidates. Before joining AIT, Dr. Strasser spent more than 6 years as a senior researcher investigating advanced and reconfigurable automation and control systems at PROFACTOR research. He is also active as a docent at TU Wien.