Connecting European
Smart Grid Infrastructures

Holistic Validation Procedure for Smart Grid Systems

The challenge of testing cyber-physical systems

Advanced automation, Information and Communication Technologies (ICT) are transforming the electric power system to a cyber-physical system, creating a strong coupling across domains, such as electricity, heating and ICT, both in scale and heterogeneity. This increased complexity poses a challenge to both engineering design and operation of critical infrastructure systems. Testing and validation, as an integral part of any engineering process, has to accommodate this deeper integration of electric power and ICT systems through systematic testing.

The challenge of formulating systematic testing is illustrated on the case in Figure 1. Testing standards today focus on specific domains and specific physical components and ICT functions. Interoperability and system integration are addressed only for the ICT systems. In practice, full integration is first experienced in field deployment.

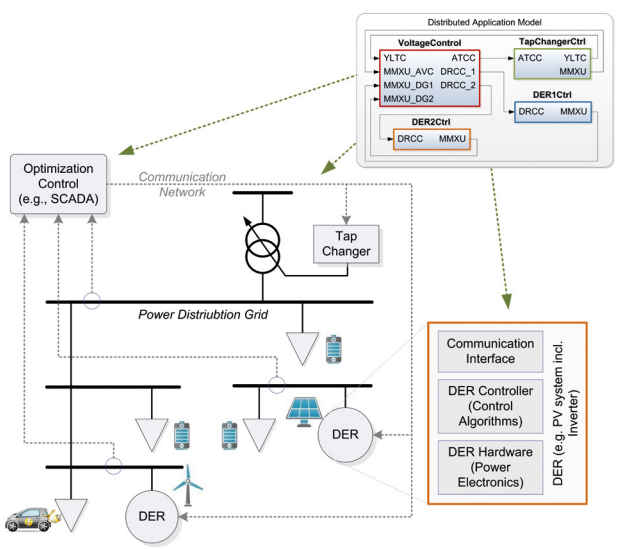

Figure 1: ICT and physical components as part of an integrated smart grid system deployment.

A systematic testing approach must address various reliability metrics and issues with heterogeneous life spans, cross-domain coupling phenomena and time scales, as well as cyber-security challenges.

The ERIGrid holistic testing vision widens the scope of conventional testing to:

- *Define* a systematic testing strategy for systems, components and their integration
- *Integrate* requirements for multiple domains in a single test case
- *Accommodate* distinct testing methodologies
- *Combine* independent tests in one framework
- *Interconnect* different means of testing.

The holistic system validation procedure

A method for framing a holistic approach to testing has been developed in order to capture the complexity of Smart Grid testing, striking a balance between formal definitions, existing standards, and the practical use and understanding of tests in the participating laboratories.

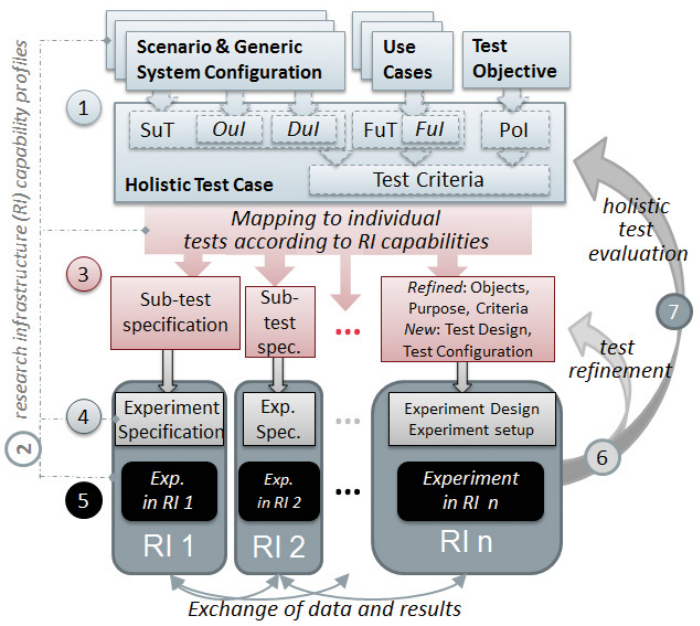

Figure 2: Main steps of the ERIGrid methodology: a 'holistic' test case (Step ①) is divided into sub-test specification (Step ③) which are then tailored to a specific RI in Step ④. The RI profiles represented in the RI database (step ②) are relevant in several stages, as the dashed grey line indicates. Guidelines for Steps 5-7 are under development.

Several levels of test description are associated with the holistic procedure:

1. Test Case (TC) ① – in analogy to 'use case': a holistic test case describes the test objective and context of a specific Smart Grid solution.
2. Test Specification (TS) ③ – defining the test system for a specific aspect of the test case.
3. Experiment Specification (ES) ④ – mapping the test specification for its implementation in a specific Research Infrastructure (RI).

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Detailed templates and examples for each stage of description are freely available in [1].

A core aspect of the holistic test description method is to support multi-domain system configurations (SC). To this end, a domain-independent SC description method has been defined, based on existing conventions in the Power Systems Common Information Model (CIM: IEC 61970/ 61968) and UML / SysML (Unified / Systems Modelling Language). This description method is applied to formulating system configurations in several contexts, so that for each test description template a related system configuration type is defined (Test Case Generic Context Model (TC-GSC), Test System (TS-SC), Experiment Setup (E-SC)), as illustrated in Figure 3.

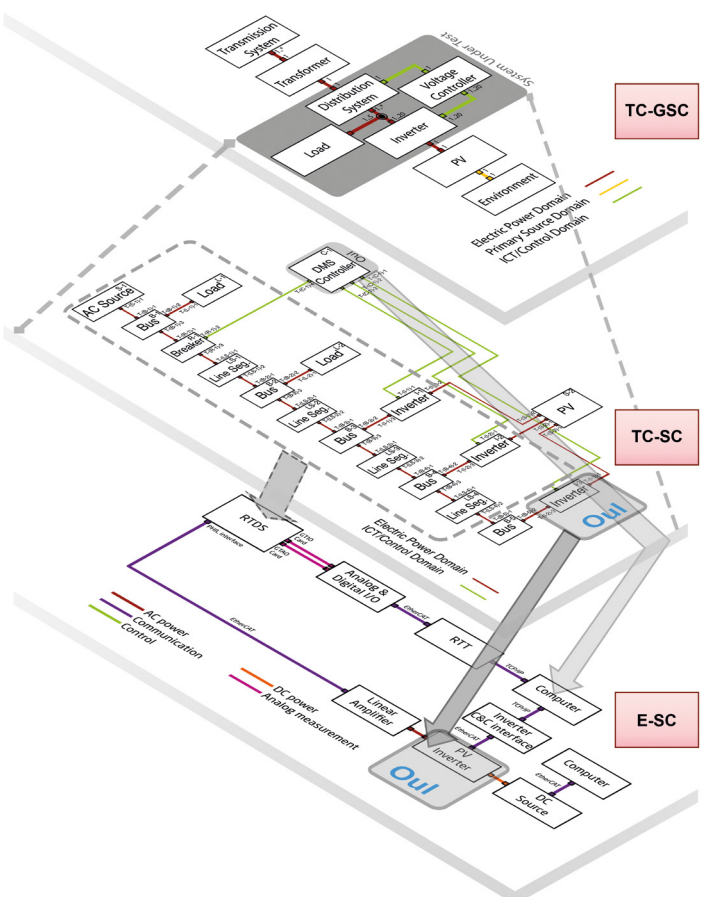

Figure 3: Illustration and intuitive layering of the TC-GSC, TS-SC and mapping to E-SC for one test description.

Outlook and next steps

ERIGrid's approach to holistic testing may be considered as a vision of a pre-standardised process, also enabling the mutualisation of resources from multiple RIs to conduct parallel, sequential and integrated tests.

The feasibility of a complete holistic testing methodology will be demonstrated in upcoming work:

- Development of a mapping concept, which will provide guidelines for application of this description methodology to the formulation of holistic test cases,
- The development of principles, guidelines and tools for the application of DoE methods,
- Concrete applications to jointly simulated and mixed hardware / software test,
- The demonstration of the overall method with application to test cases with experiments spanning several research infrastructures.

Sponsored lab access and support

The ERIGrid Transnational Access (TA) initiative enables applicants to perform experiments in ERIGrid Research Infrastructures. In this context, collaboration with the RI host is facilitated through the formulation of test specification and experiment plans in accordance with the defined test procedure.

Further reading

[1] D-NA5.1 Holistic Method description
(available at https://erigrid.eu/dissemination/)

[2] D-NA5.2 RI descriptions
(will be available at https://erigrid.eu/dissemination/)

[3] M. Blank, S. Lehnhoff, K. Heussen, D. E. M. Bondy, C. Moyo, and T. Strasser, "Towards a foundation for holistic power system validation and testing," in 2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA), 2016, pp. 1–4.

ERIGrid Project Partners

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