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ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

"Testing Methods and Certification Protocols"

Powered by ISGAN: SIRFN & DERlab

15th October, 2020

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

DERlab

SIRFN
ISGAN Annex 5

3:00 Workshop begins

3:00	**Welcome to International Smart Grid Action Network - ISGAN**	*Russell Conklin* *U.S. Department of Energy*
3:05	**The Smart Grid International Research Facility Network - SIRFN**	*Ron Brandl,* *DERlab e.V., Germany*
3:10	**Development of Interoperable DER Certification Protocols**	*Nayeem Ninad,* *CanmetENERGY, Canada*
3:20	**Microgrid Testing**	*Terence O'Donnell* *University College of Dublin, Irland*
3:30	**Power System Testing**	*Kai Heussen* *Technical University of Denmark*
3:40	**Advanced Laboratory Testing Methods**	*Efren Guillo-Sansano* *University of Strathclyde, UK*
3:50	**General Discussion**	*Ron Brandl* *DERlab e.V., Germany*

4:00 Workshop closing

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Welcome
to the “International Smart Grid Action Network”

Presenter:

Russ Conklin

U.S. Department of Energy

Vice Chair, ISGAN Executive Committee; Lead, ISGAN Annex 5: SIRFN

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International Smart Grid Action Network

Technology Collaboration Programme by iea

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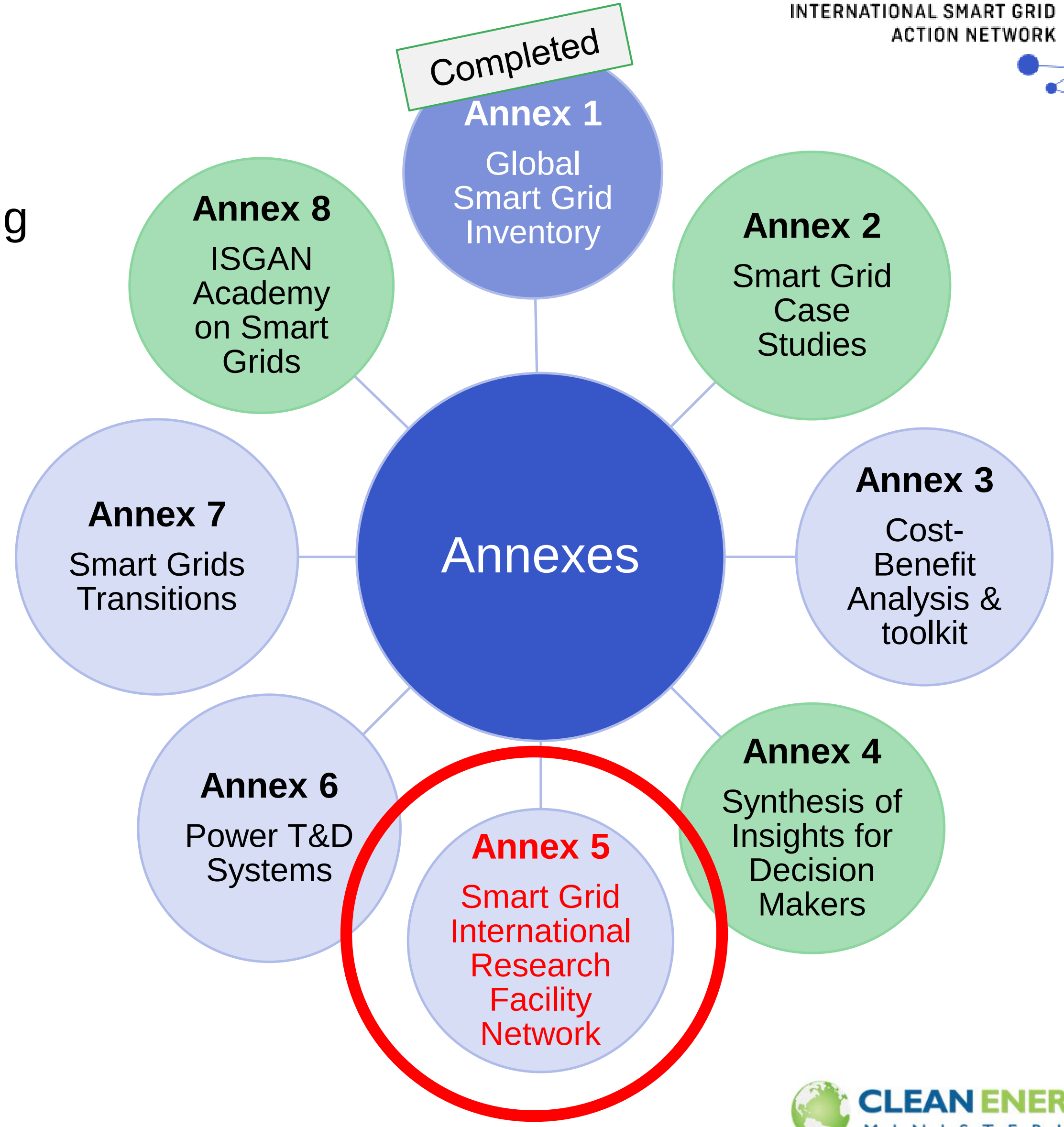
ISGAN's work

ISGAN's activities build a better understanding of smart grids, address gaps in knowledge and tools, improve peer-to-peer exchange and collaboration, and recognize excellence.

ISGAN's activities are organized into seven active "Annexes" plus ad hoc teams.

The Annexes are standing working groups with either functional or topical programs of work that are updated annually.

- Completed
- Topic-oriented Annexes
- Platforms for dissemination



ISGAN is a Community

Executive Committee and Operating Agents

Leadership Team

(left to right)

Arun Kumar Mishra
ISGAN Vice Chair
Director NSGM-PMU, India

Luciano Martini
ISGAN Chair
Ricerca Sul Sistema
Energetico S.p.A, Italy

Russell Conklin
ISGAN Vice Chair
U.S. Department of Energy

Maarten Noeninckx
ISGAN Vice Chair
Directorate-General Energy
FOD economie, Belgium

Not shown: ***The hundreds of others engaged in ISGAN Annexes, knowledge exchange, workshops, and other activities…***

Introduction to
"The Smart Grid International Research Facility Network" – SIRFN

Presenter:

Ron Brandl

DERlab e.V. / Fraunhofer IEE

Operating Agent, ISGAN Annex 5: SIRFN

The ISGAN-SIRFN Network

The Smart Grids International Research Facility Network (SIRFN) is a network of leading smart grid testing facilities in countries participating in the ISGAN technology collaboration programme (TCP).

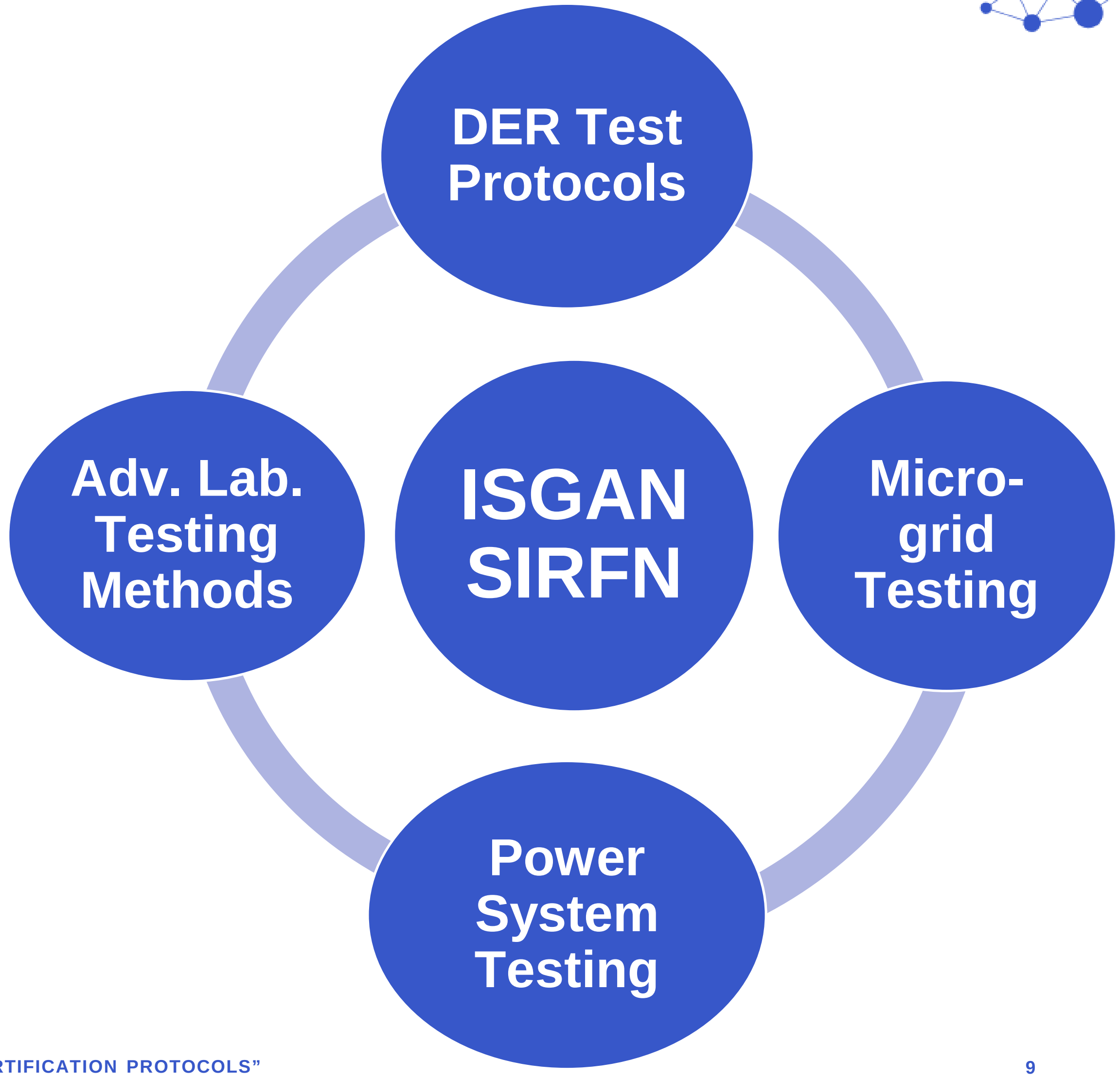
SIRFN participants coordinate joint testing-related activities relevant to development of “smart” electricity grids.

SIRFN’s collaborative testing and evaluation capabilities are meant to be leveraged by the international community to enable improved design, implementation, testing, and validation of smart grids.

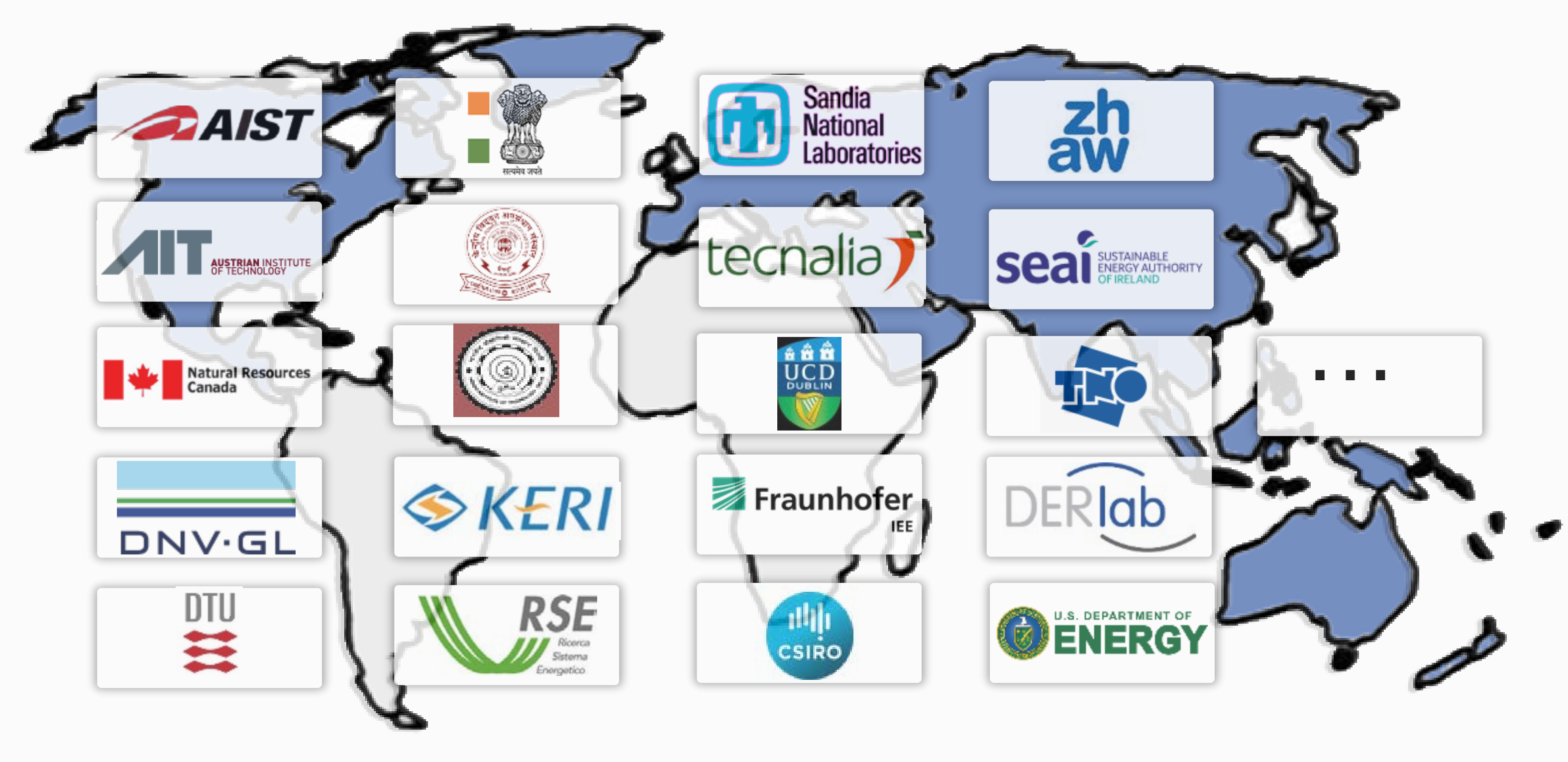
The ISGAN-SIRFN Network

SIRFN Technical Projects (Tasks)

Tasks bring together technical experts from world-class research facilities to consider the current state, identify issues for test facilities to resolve collaboratively, identify potential SIRFN users, and recommend and implement SIRFN activities to overcome obstacles.



The ISGAN-SIRFN Network



Facts and Figures

International Collaboration

- 20 active partners
- 15 countries
- America, Asia, Australia, Europe
- +12 external partners

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“Development of Interoperable DER Certification Protocols”

Presenter:

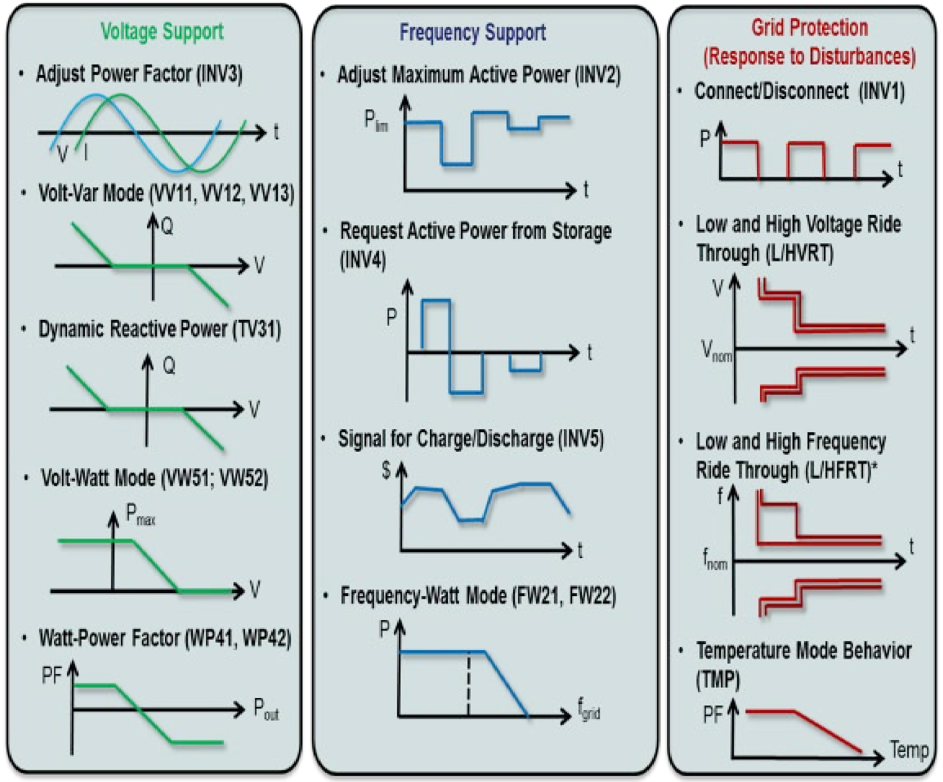
Nayeem Ninad

CanmetENERGY

Task Leader, SIRFN – DER Certification Protocols

Background & Objective

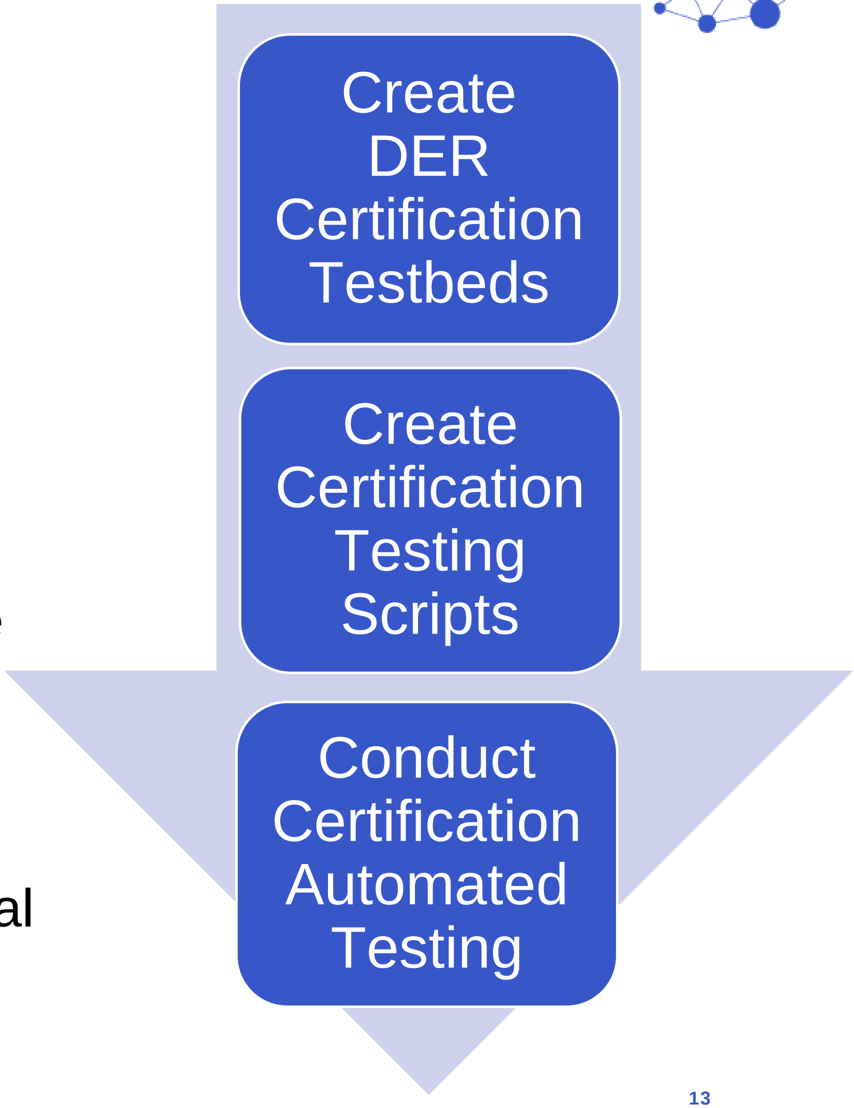
- Grid codes or interconnection standards are getting updated to include grid-support functions (GSFs) and interoperability requirements for DER devices.
- GSFs will allow voltage regulation, bulk system services, power system visibility, and other grid services.
- Stakeholders need proper tools and test protocols to verify the GSFs to ensure effective communication and power behavior
- Validating device behaviors for a range of conditions and corner cases are required in order to accelerate DER deployment.
- **Objective:** Develop consensus on interoperability testing protocols and test platform software for advanced inverter functions for adoption by international standard organizations



IEC TR 61850-90-7 Advanced Functions

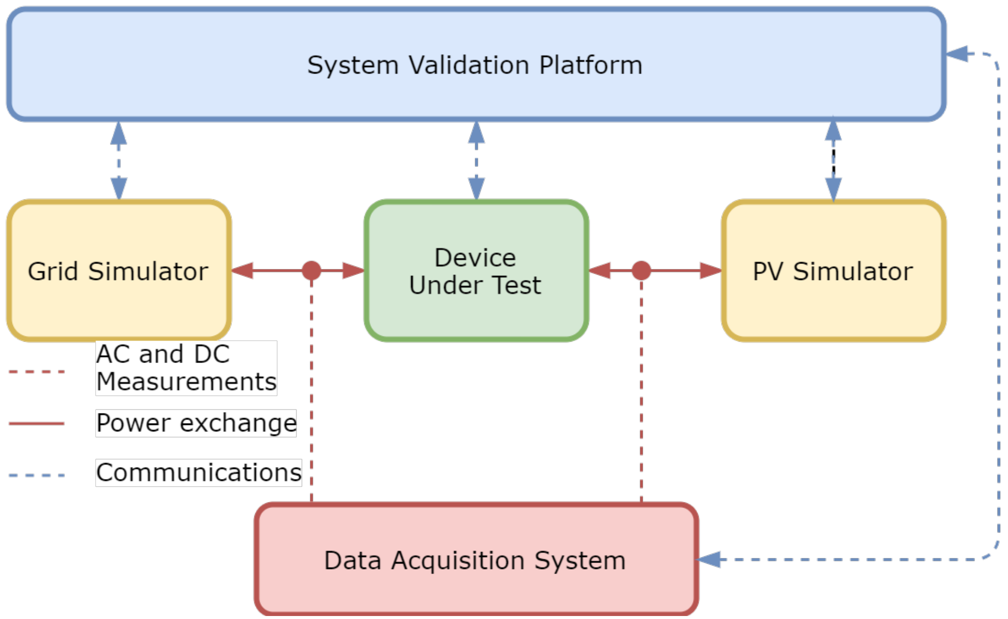
Activities

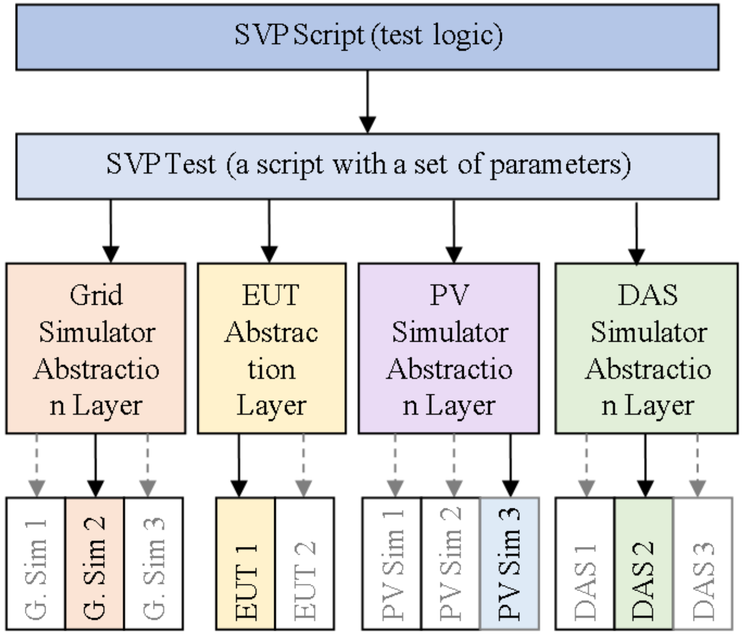
- Development of open-source certification test scripts for different test protocols and standards
- Establishment of automated testing procedures using the open-source testing platform software
- Automated certification testing of DER devices at different SIRFN laboratories.
- Sharing, comparing and analyzing the test results of multiple labs with the different setups for verifying common test protocol.
- Recommendations for procedures and parameters in the certification test protocols that will be implemented in National Grid codes or international standards.



DER Certification Testbeds

- The SVP **autonomously orchestrates** interconnection and interoperability **certification protocols.**
- It **automates the execution of tests/evaluations** by communicating to laboratory equipment as well as the Device under Test (DUT) in a laboratory test setup.
- The SVP uses **abstraction layers** to allow using the same scripts for **different laboratory testbeds** by merely changing the equipment drivers for each testbed.





Device Drivers: https://github.com/sunspec/svp_energy_lab

SVP: https://github.com/sunspec/svp

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Structure of the "System Validation Platform"

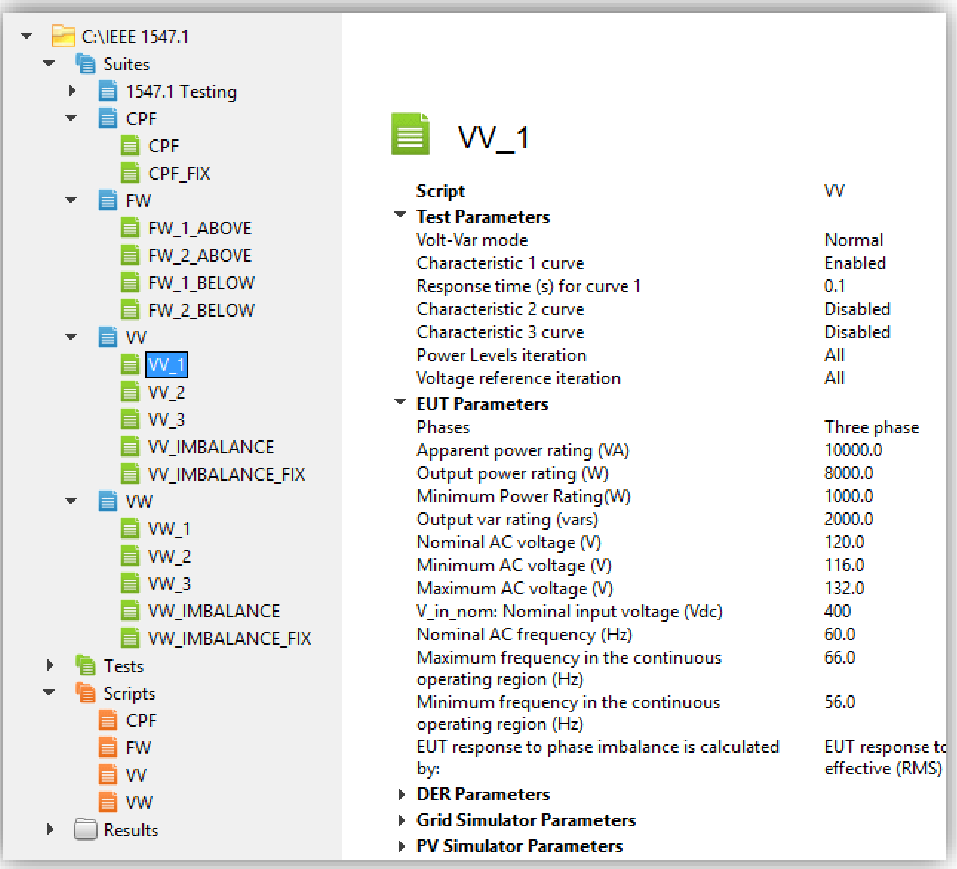
1. Lib: Library of abstraction layers and device drivers that communicates to the equipment. This directory is not shown in the GUI.

2. Scripts (orange): Python code that represents the test logic.

3. Tests (green): Set of parameters for a given script

4. Suites (blue): A collection of multiple tests or other suites that will execute sequentially.

5. Results (gray): Logs and results from a test or suite.

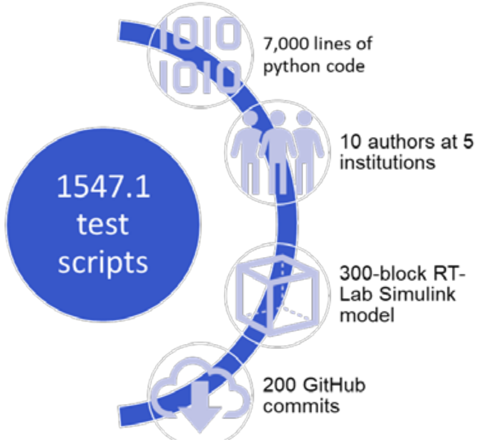


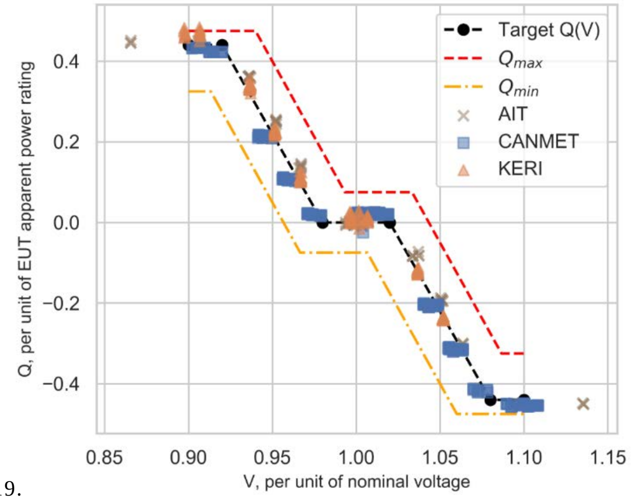
Screenshot of the SVP with parameters for the specified test.

Assessment of Test Protocols

IEEE 1547.1 standard

- The SIRFN group have been continuously analyzing the test procedures for different tests.
  - Constant Power Factor
  - Volt-Var
  - Volt-Watt
  - Frequency-Watt
  - Constant Reactive Power
  - Watt-Var
  - Limit Active Power
  - Prioritization
  - Phase Change Ride-Through
- Example:
  - Volt-Var test is required to be performed for three different characteristics.
  - Tests of each characteristic include 243 test points (17 steps × 3 power levels × 3 voltage references).
- All test-scripts are available in open-source. (https://github.com/jayatsandia/svp_1547.1)





1. "PV Inverter Grid Support Function Assessment using Open-Source IEEE P1547.1 Test Package," in 2020 IEEE PVSC, p. 7.
2. "Evaluation of Photovoltaic Inverters Under Balanced and Unbalanced Voltage Phase Angle Jump Conditions," in 2020 IEEE PVSC, p. 8.
3. "Development and Evaluation of Open-Source IEEE 1547.1 Test Scripts for Improved Solar Integration," presented at the 35th EU PVSEC, Marseille, France, 2019.

Summary

- Other Test Protocols
  - UL 1741 SA Standard (https://github.com/jayatsandia/svp_UL1741SA)
  - DR AS/NZS 4777.2 Standard (https://github.com/BuiMCanmet/DR_AS-NZS-Scripts)
  - SIRFN ESS Protocol (https://github.com/sunspec/svp_directories)
  - Sandia Inverter Test Protocol (https://github.com/sunspec/svp_directories)
- This task deals with following topics to enhance Smart Grid infrastructures:
  - Controlling and managing of DER testbed components for DER function testing
  - Automated test procedures for DER certification
  - Monitoring and data acquisition during/after testing
  - Validation of test certification scripts
  - Creation and update of current certification script pool according to new Grid Codes

“Microgrid Testing”

Presenter:

Terence O’Donnell

University College of Dublin

Task Leader, SIRFN – Microgrid Testing

Microgrid Testing Task: Context

- **Microgrid trends**
  - Improving network resilience: Multiple microgrids as part of larger networks
  - Renewable based microgrids
  - Inverter dominated operation
  - DC microgrids
- **Leads to new functionalities**
  - Market participation and energy trading
  - Peer to peer energy trading
  - Supplying system services
  - Forecasting and optimal operation
- **New functionalities need testing and validation**

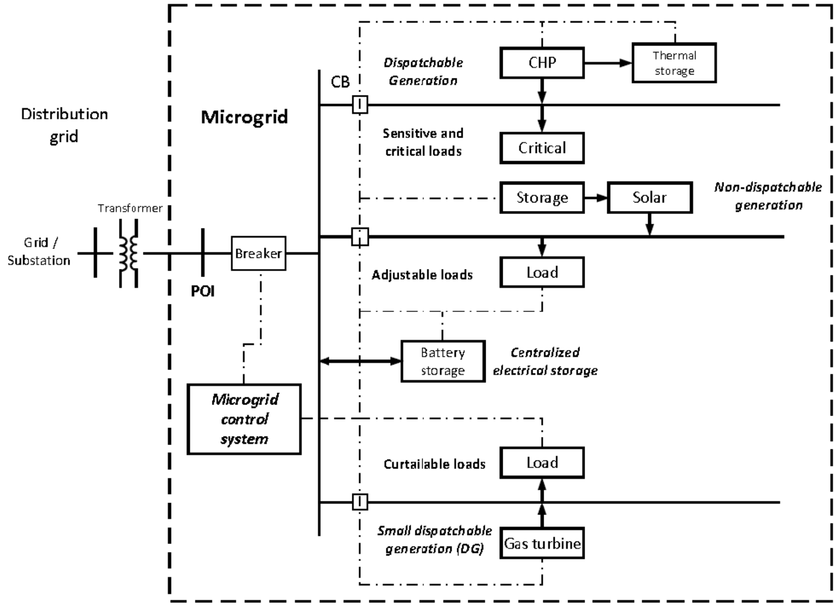
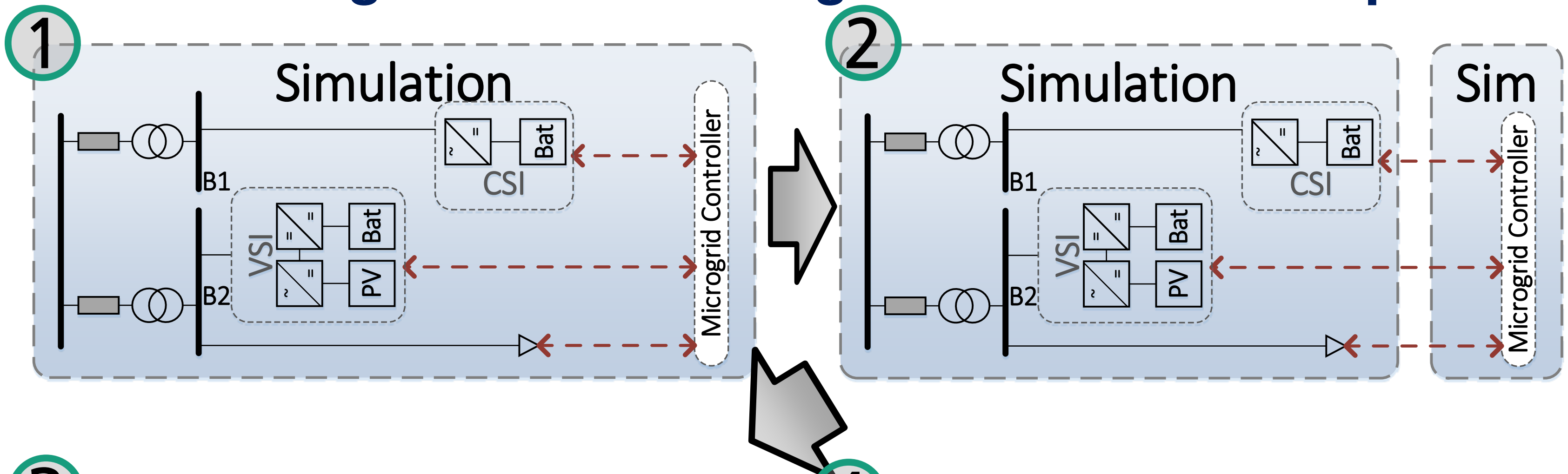


Figure A.1—Microgrid structure and components

"A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode"

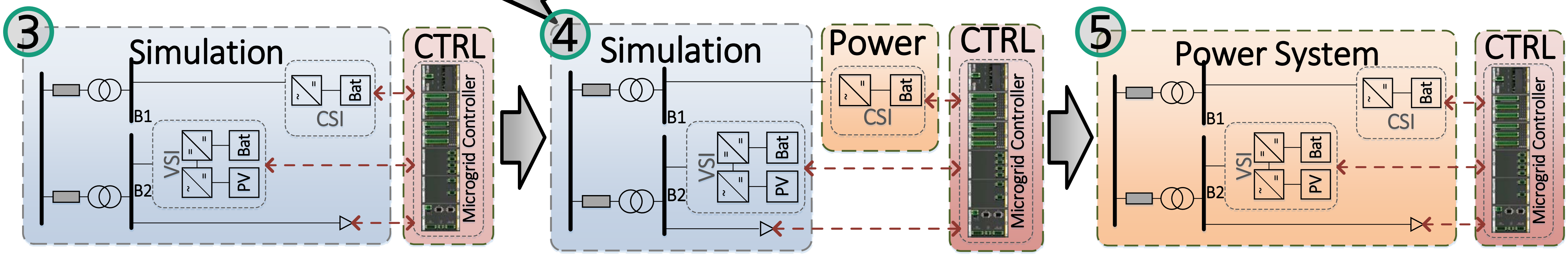
Microgrid Testing

Testing Chain of Microgrid Control Development



Microgrid control function:

- International standards for planning operation and testing of Microgrids, e.g. IEEE 2030.7, 2030.8, 2030.9, IEC TS 62898-2:2018, 62898-1:2017
- Dispatch & Transition functions
- Scenarios: - Grid-connected and islanded mode
- Automatic transition between both states
- Resynchronization
- Energy management
- Ancillary services provision



The Microgrid Testing Task in SIRFN

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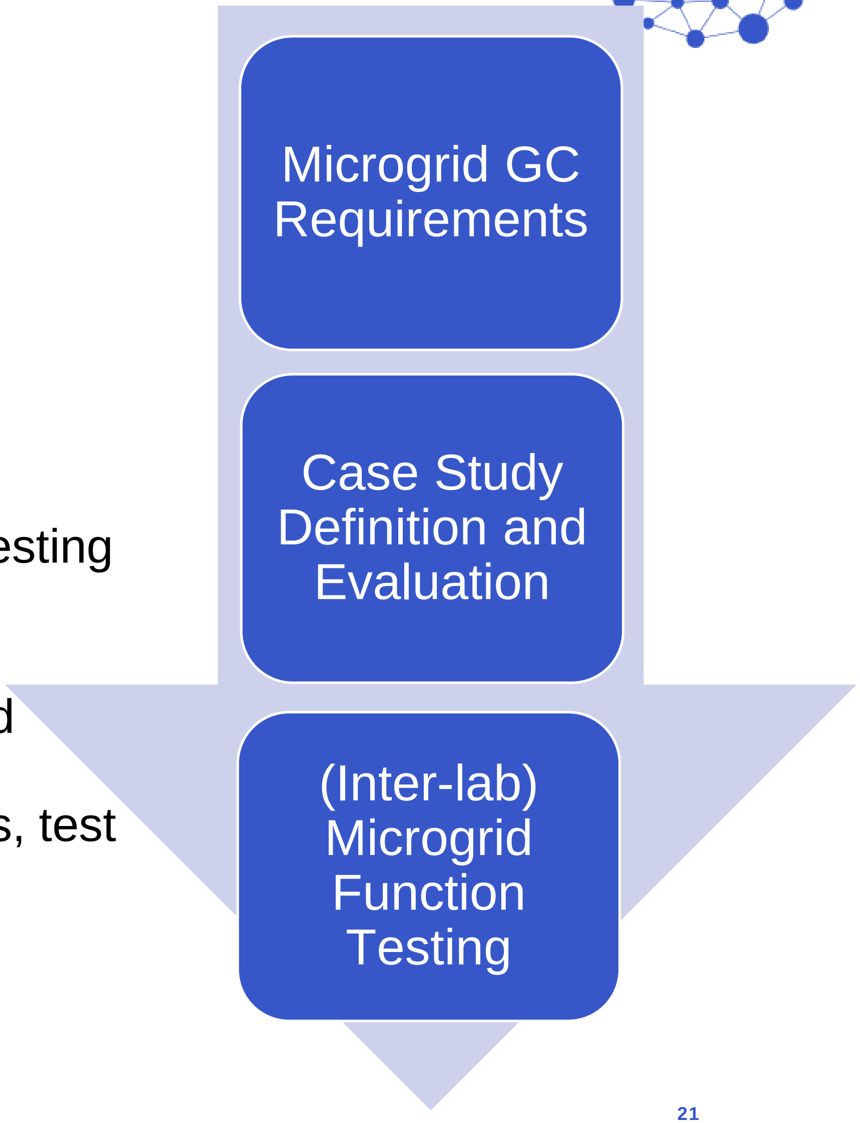
What is it?

- Network of test laboratories with experience and capabilities for the testing of microgrids.
- Evaluate microgrid requirements (on-/off-grid/blackstart operation)
- Propose testing procedures for microgrid basic functionalities

What do we aim to do?

- Share experiences in testing related to microgrids
- Review and advance the State of the Art with respect to Microgrid testing
- Identification, execution and recommendation of new innovative Microgrid requirements/functions
- Proposing, testing and evaluation of methods for on-grid and off-grid operation
- Development of test procedures (benchmark systems, metrics, KPIs, test equipment capabilities and requirements)
- Validation through inter-lab testing
- Strengthen inter-laboratory collaboration through common research activities



General Workplan

Define Microgrid functionalities → KPIs for testing, Benchmark Testing Networks → Test Cases & Implementation → Testing Procedures → Round-robin testing

- Specific functionalities defined by member interests & activities
- Topics of common interest to more than one member

Outputs:
- Benchmark Test set-ups
- Documentation of testing procedure
- Recommendations for improved testing practices
- Joint publications

Current Activity

- Task currently has 12 participants
  - Laboratories from Germany, Switzerland, USA, Japan, Ireland, Austria, Spain, Italy, UK, Poland, Denmark, Canada.
- Working on a joint publication as a focus for bringing together participant experiences and interests.
- "*Review of Laboratory Based Microgrid Controller and Functionality Testing in the Context of International Standards*"
- Review of State of the Art for Test Platforms
- Microgrid Benchmark Systems
- Testing Standards
- Identification of gaps in testing
  - Issues not covered by Standards
  - Recommendations
  - Research Opportunities

A view of an ISGAN member test facility: The Microgrid test laboratory at Technalia, Spain.

For experiences in testing according to IEEE standards see

- CIGRE SEERC Conference 2020: "*Analysis of the applicability of the IEEE 2030.8 standard for testing a microgrid control system*"
- https://erigrid.eu/wp-content/uploads/2020/08/ERIGrid_TA_MGCS-LTV_Technical-Report_v01.pdf

“Microgrid Testing: Summary”

Participation in the task offers:

- Opportunities to collaborate with research labs working on microgrid testing
- Identification of similarities, general requirements and functions of microgrid control systems
  - For non-isolated microgrids mode: On-grid | Island | Mode transition
  - Based on current and upcoming international and national microgrid requirements
- Test case definition for microgrid control function testing
- Test setup and procedures definition of microgrid control function testing
  - Microgrid controller HIL
  - Benchmark microgrid real-time model for single hardware device testing
- Advancing the state of art in microgrid testing.

“Power System Testing”

Presenter:

Kai Heussen

Technical University of Denmark

Task Leader, SIRFN – Power System Testing

“Power System Testing” - Motivation

Major challenges for power systems:

1. **“low-inertia systems”**
   power systems dynamics reliant on digitally controlled electronics
2. **“cyber-physical energy system”**
   Increasingly digital and distributed control architectures – relying on communication

Gap: widely accepted test systems missing for:

- power electronics behaviours & interactions
- “communication-in-the-loop”
- Multi-layered & distributed control systems testing (specifications for control structures)

→ Accepted test systems, procedures and benchmarks are lacking.
→ Difficult to align on suitable testbeds to validate & scrutinize solutions before roll-out.

“Power System Testing”

Scope and Objectives

Goal:

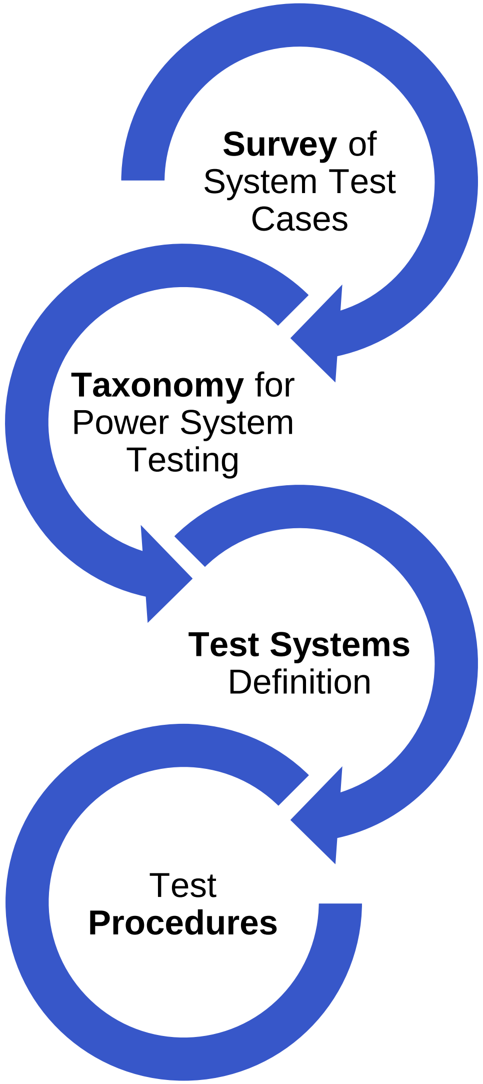
Devise strategies for testing of *system aspects* of digitized, renewables-based, cyber-physical power systems.

Scope:

Emerging test cases for intended and unintended interactions of control structures, considering *horizontal* (cross-functional), *vertical* (cross-layer), and *multi-faceted* (cross-domain) interaction phenomena.

Objectives:

- Identification and classification of relevant “system test cases”
- Creation of benchmark cases for such power system test cases
- Development & replication of testing procedure



Survey: Various Drivers for System Testing

CL1	**Coordinated P & Q Control**	• Distributed control with communication dependency
CL2	**Microgrids & Converter-Dominated Distribution Networks**	• Multiple control levels • interactions of Inverter-control
CL3	**Distribution Grid Protection & Reconfiguration**	• Reconfiguration & stability • Quantify resilience benefits for networked microgrids
CL4	**Stability of Low-Inertia Transmission Interconnections**	• Wide-area control systems with converter-based and demand-side resources

Example for expected outcomes

CL3 → Benchmark for Networked Microgrids: test system with parameters and metrics for stability, reliability and resilience studies

ALAM *et al.*: BENCHMARK TEST SYSTEM FOR NETWORKED MICROGRIDS

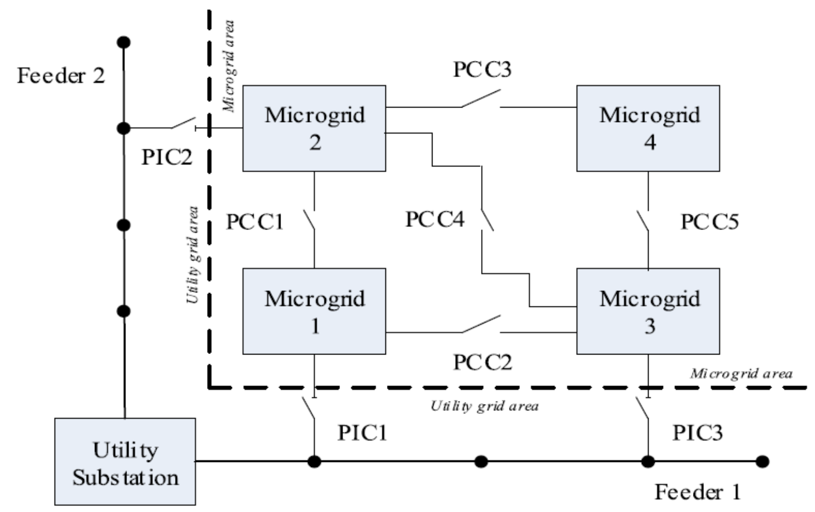


Fig. 2. Block diagram of the benchmark test system for MCPUIC.

Alam, M.N., Chakrabarti, S., and Liang, X., *A Benchmark Test System for Networked Micro-grids*, IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 16, NO. 10, 2020

Birds-eye view on “Power System Testing”

Power systems always used to exhibit new phenomena that later found an explanation by means of modeling and hypothesis testing.

Test procedures are a detection method aimed to stimulate possibly pathological situations and identify a system response on a predefined and observable metric.

Approach & Work in progress:
A Taxonomy for Power System Testing & Test Case inventory

“Power System Testing” - Background

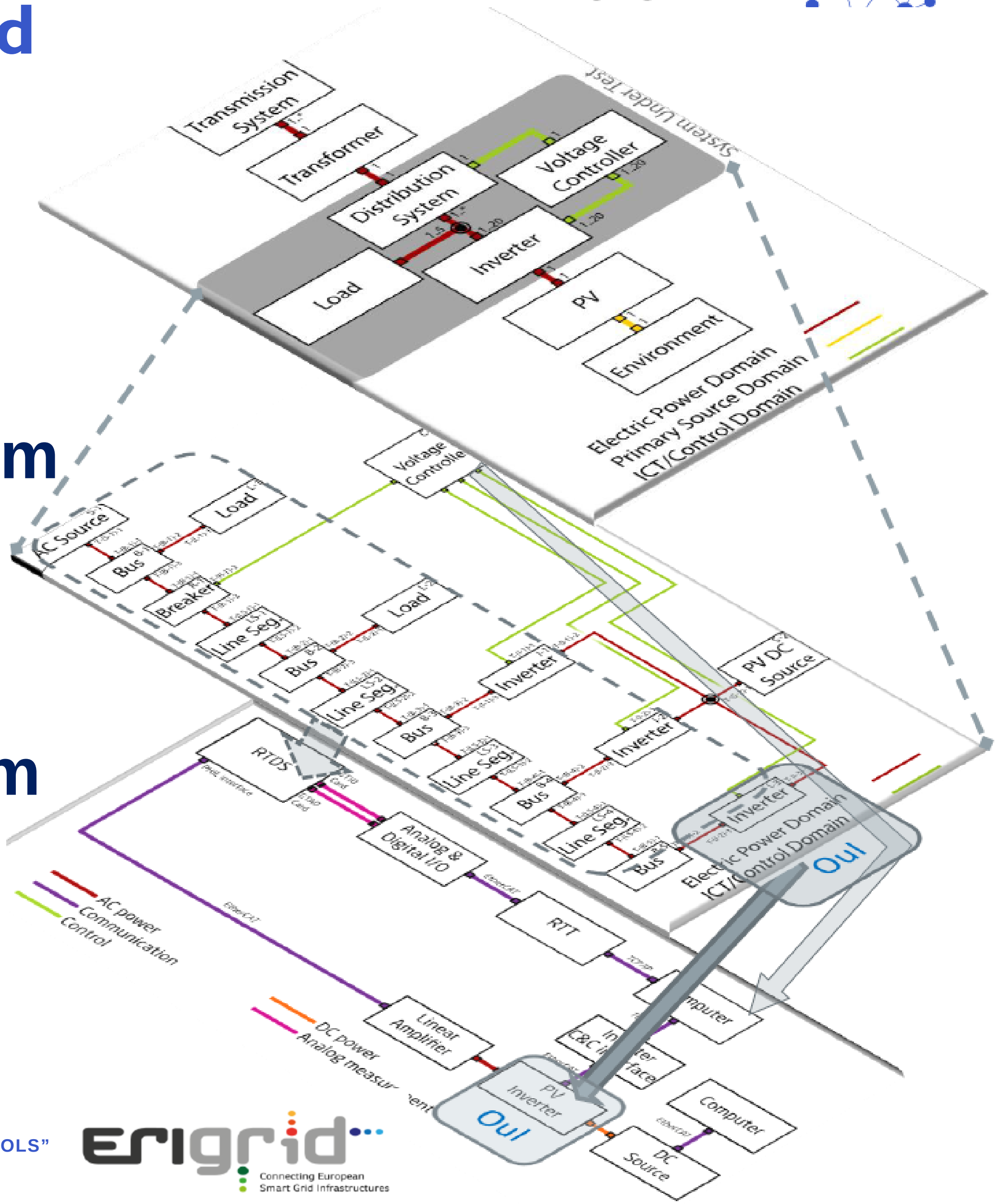
> *“Validation (testing) is done in order to de-risk a component, **system** or technology for its intended purpose in a ‘risk-free’ environment […]”*
>
> **- Peter Vaessen, DNV-GL**

- We consider **system tests** where the power system is *in-the-loop;*
  - Optional: *communication in-the-loop*
- The test system & testbed enables relevant **interaction phenomena** which arise from N≥2 components under test
- Examples:
  - small signal stability phenomena
  - cascading disturbance or blackstart
- Validation & Security assessment problems

Test Case

Test System

Lab System (Testbed)



“Advanced Laboratory Testing Methods”

Presenter:

Efren Guillo-Sansano

University of Strathclyde – Glasgow

Task Leader, SIRFN – Advanced Laboratory Testing Methods

“Advanced Laboratory Testing Methods”

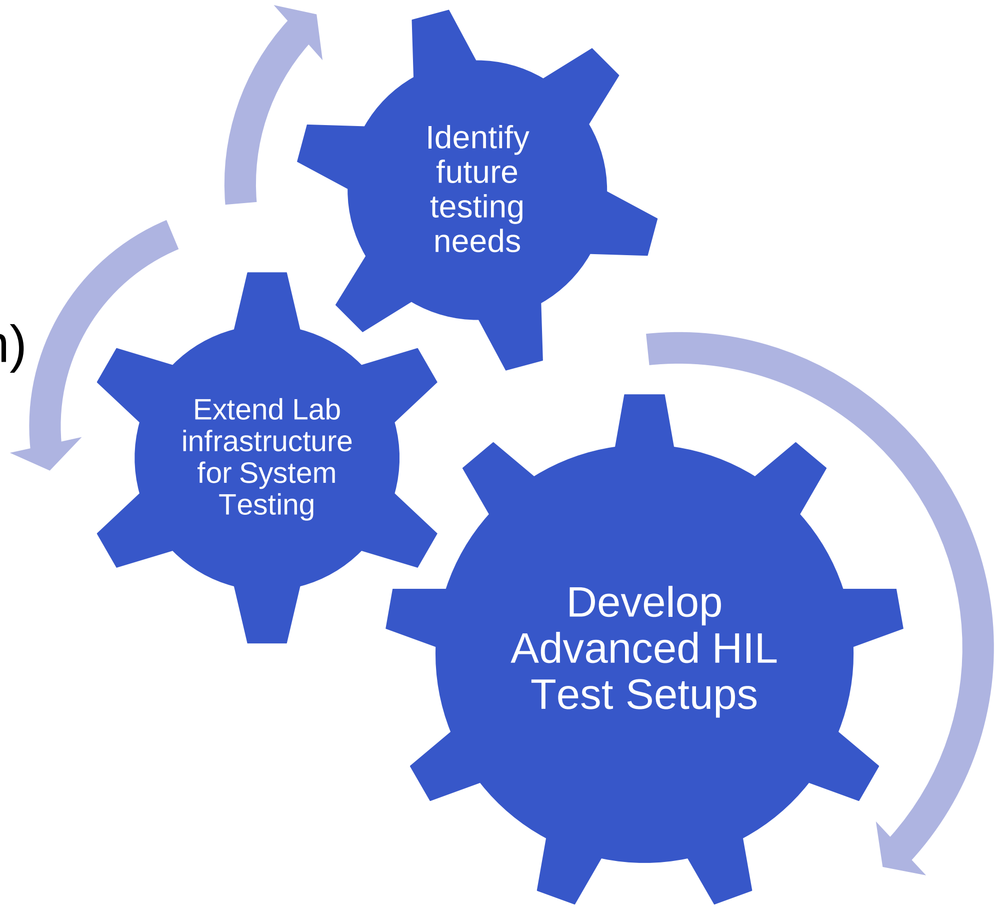
Scope and Objectives

Scope:

- Enhancement of current testing methods in different lab-environments
- Integration of new testing methods (e.g. C-/P-HIL, Co-Sim) to evaluate and demonstrate new power system components and control.

Objectives

- To identify laboratory limitations and future needs
- To develop system level testing techniques
- To propose/recommend advanced test procedures
- Cost/Benefit studies for lab infrastructure enhancements



Motivation for "Advanced Laboratory Testing Methods"

Need to ensure a smooth transition to a more distributed grid:

- Grid codes do not provide testing procedures reflecting the impact of units on the grid behaviour

✓New procedures and methods for testing and validation

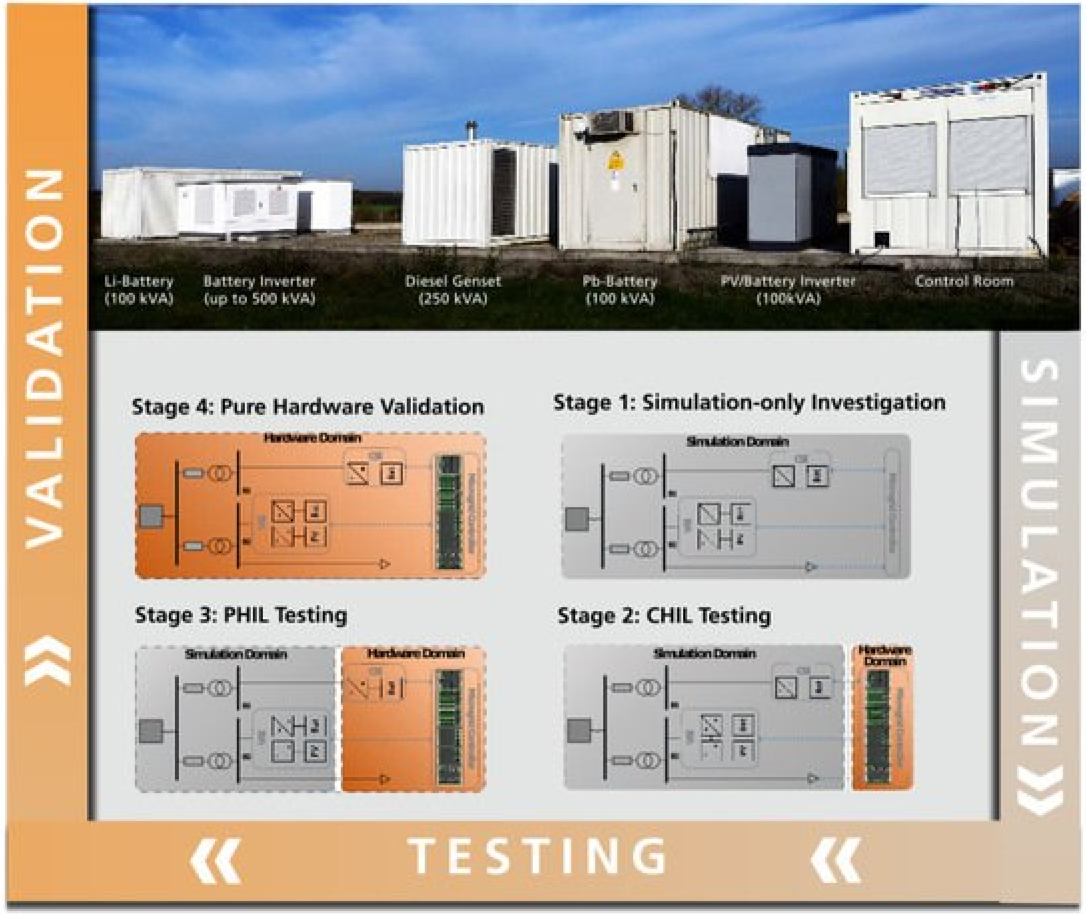
- Availability of testing equipment might be a limiting factor for pure lab testing

✓Advanced laboratory evaluation methods based on real-time simulation (RTS) and Hardware-in-the-Loop (HIL)

✓Physical equipment or controllers can interact with RTS

Challenges for laboratory-based system testing

- Extension and development of new testing methods are going in line with developments of novel power system components
- Overcoming gaps of missing lab-components and conditions
  - Increasing flexibility of laboratories
  - Cost saving solution independent of testing realism loss
- Standardization and certification with advanced methods.

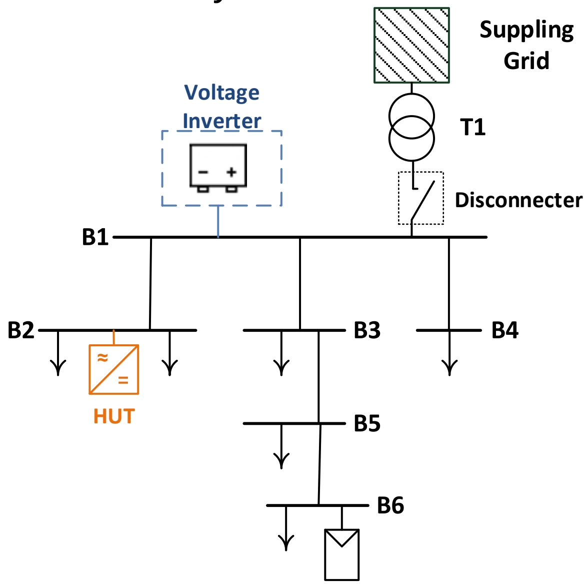


From: Montoya, J. et al, "Advanced laboratory testing methods using real-time simulation and hardware-in-the-loop techniques: a survey of smart grid international research facility network activities", Energies 2020.

Previous Activities for "Advanced Laboratory Testing Methods"

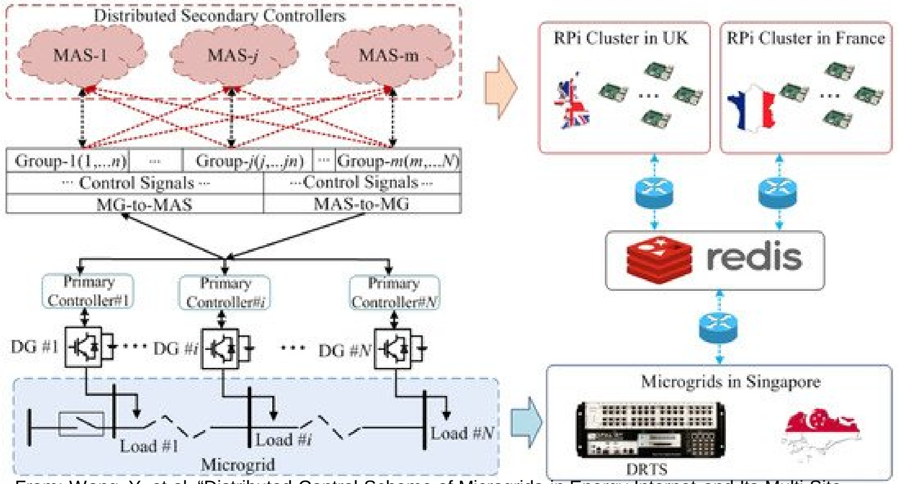
1) HIL for Grid Code Enhancement

- Detection and review essential parts of compliance testing
- Identifying current obstacles of Grid Code testing for improvements
- Recommendations for the regulatory framework
- HIL-based testing procedures (e.g. round-robin HIL tests)
- Test case/model library



2) Review of methods, test procedures, studies, and experiences employing advanced lab techniques

- Interfacing methods of PHIL, CHIL, and PSIL simulation
- HIL testing of power system protection and control
- HIL testing of smart grid/microgrid controllers, energy management systems, and power electronic converters
- Co-simulation and RTS integration (multi-domain)
- Geographically distributed HIL and RTS
- Industrial experiences and HIL in standardized testing.

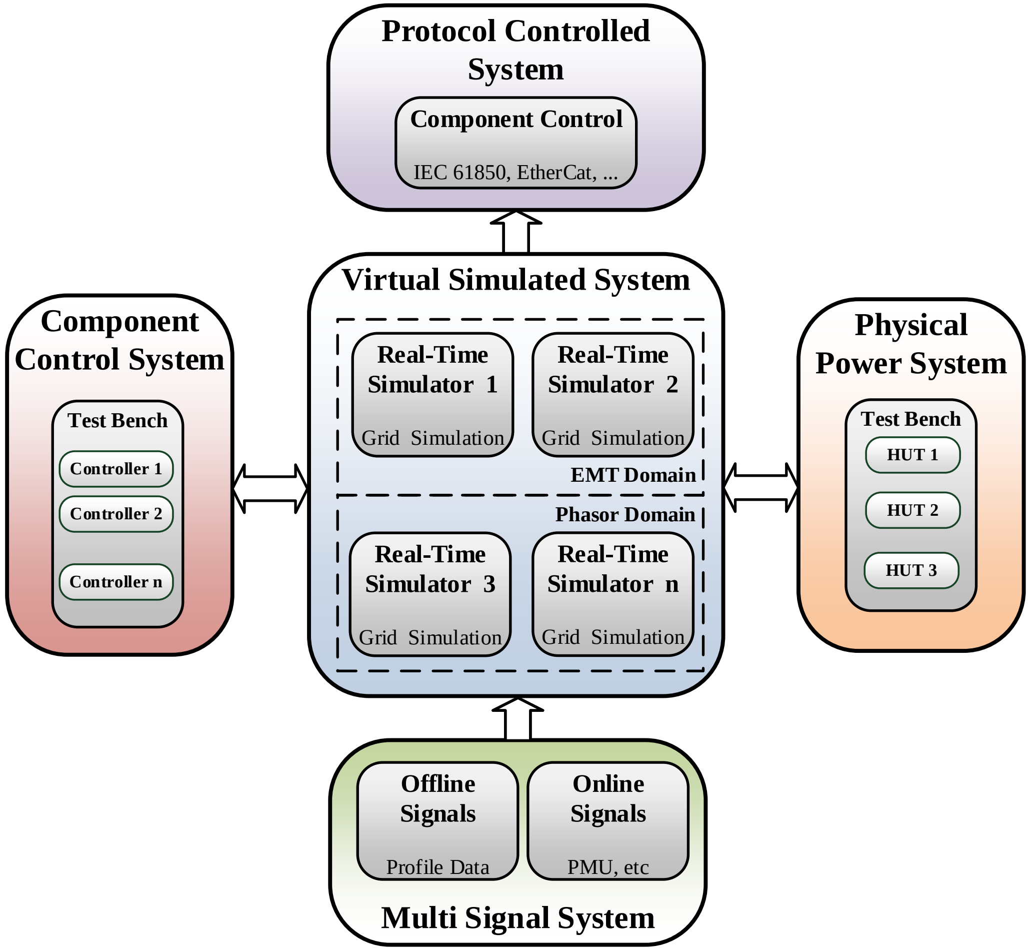


From: Wang, Y. et al, "Distributed Control Scheme of Microgrids in Energy Internet and Its Multi-Site Implementation", EEE Trans. Ind. Inform. 2020.

Summary for “Advanced Laboratory Testing Methods”

This task deals with following topics to **<u>enhance the testing of Smart Grid infrastructures and their functionalities</u>**:

- Identify and review state-of-the-art testing procedures
- Identify needs to further develop flexible testing methods
- Develop recommendations on future testing techniques
- Collaborative activities among test infrastructures
- Application of advanced methodologies within the network
- Perspective on the quickly evolving landscape of novel simulation techniques such as RTS, PHIL, CHIL, PSIL, etc.



From: Brandl, R. et al, “Power System-in-the-Loop Testing Concept for Holistic System Investigations”, IEEE IESES 2018.

General Discussion

Presenter:

Ron Brandl

DERlab e.V. / Fraunhofer IEE

Operating Agent, ISGAN Annex 5: SIRFN

Thank you

How to contact us:

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