Advanced Laboratory Testing Methods – SIRFN Project Activity

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Vienna, Austria;

SIRFN meeting, Kyoto 2014, Japan, “Advanced Laboratory Testing Methods“
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- **Introduction**
- **Advanced Laboratory Testing**
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  - Expertise
- **Use Cases Proposal (SIRFN Project Activity)**
  - RLC – Anti Islanding Testing (PHIL)
  - LVRT – Ride Through Testing (PHIL)
  - ICT – Communication emulation (CoSim, CHIL)
- **Next Steps & Invitation**
Utilizing novel ideas and novel methods for advanced laboratory testing

- **Motivation:**
  - Utilizing and exchanging the sophisticated know-how of international experts
  - Different methods and various approaches already exist on a global basis

- **State-of-the-Art:**
  - Test/simulation approaches are expanded and optimized due to the latest technologies (real time systems, power electronics, analogous/digital measurement devices..)
  - Novel simulation techniques get increasing importance in research and for manufacturers and for international standardisation groups

- **Intentions and Aim for Cooperation:**
  - Know-How exchange on an international level
  - Manifestation of effectuated methods for the solution of different problems
  - Creation of a work basis for future contributions to
    - Rapid prototyping and manufacturing
    - Standardized testing procedures (writing and testing)
    - Novel research areas in the electrical domain
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Proposed methods for advanced lab’ testing

- **Power Hardware-in-the-Loop (PHIL):**
  - Suitable for investigations on HuTs with feedback of the true power signals
  - Dynamic behaviour of the PA, Choice of interface algorithm (IA), measurement equipment
  - Stability considerations (Nyquist, Popov, Ljapunow criterion)
  - Measurement equipment used (I/O, transducers)

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

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

The implementation of PHIL tests environment enforces the use of a dedicated power amplification units (PA).

- **Inherent ‘closed-loop originality’ of PHIL simulation characterised by:**
  - Time delay introduced by real-time system (RTS)
  - Dynamic behaviour of the PA
  - Choice of interface algorithm (IA)
  - Measurement equipment used (I/O, transducers)

- **Consequences:**
  - Stability considerations (Nyquist, Popov, Ljapunow criterion)
  - Choice of PI / IA (accuracy, stability, …)

- **Power Interfaces (PIs) have to chosen according to the application in PHIL**
Controller Hardware-in-the-Loop (CHIL) Simulation

Controller Hardware-in-the-Loop (CHIL):
- Suitable for investigations of control boards only (pre-standardisation, communication test procedures, etc.)
- High degree of automated test sequences, no risk of high power flows
- Well-defined real time capable operating systems and integrated libraries (SimPower Systems, propr. Libraries, etc.)

Source: autonomie.net

Source: The Mathworks
Multi Domain Simulation / CoSimulation

- Multi-Domain Simulation / Co-Simulation (MD/CoSim):
  - 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: www.ni.at

Source: Lawrence Berkley National Laboratories

Source: www.v2v2.at
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Equipment PHIL / CHIL

Components and machinery used / required for PHIL / CHIL / Co Simulations for electrical circuits:

- **Power Amplification Unit**
  - Switched mode amplifiers (lower BW)
  - Linear amplifiers (higher BW)

- **Real Time Computing System**
  - Standard real-time capable machines

- **Measurement devices**
  - (current/voltage)

- **Component Modelling Libraries**
  - Passive (R, L, C, grid impedances, nonlinear devices)
  - Active (PV inverters, converters, motor drives)
Equipment PHIL / (CHIL) - Test Setup

Test stand equipped for PHIL simulation:

- AC / DC measurements (U, I, P, Q, S, f, …)
- Linear sources (AC; DC)
- Grid impedances (free programmable)
- 4-wire power measurement (MIMO)
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Expertise

Encouragement: Machinery & Know-How both are very suitable upgrade of the laboratory setup (advanced Testing methods).

In low voltage grids commonly used components have to be integrated into the PHIL simulation:

- Power Amplification Unit
  - Switched mode amplifiers (lower BW)
  - Linear amplifiers (higher BW)

- Real Time Computing System (standard products)

- Component Modelling
  - Passive (R, L, C, grid impedances, nonlinear devices)
  - Active (PV inverters, converters, motor drives)

Know-How for P/CHIL and CoSim analysis takes time and effort!
→ Commitment of the management
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Use Case 1: RLC – Anti Islanding Testing (PHIL)

DuT - matched conditions:
- $f_{res} = 50.0$ Hz
- $P_{load} = 2.00$ kW
- $Q_L = 4.30$ kW
- $Q_C = 4.30$ kW
- $Q_f = 2.15$

trip time = 1.5 sec

DuT - mismatched conditions:
- $f_{res} = 49.6$ Hz
- $P_{load} = 2.00$ kW
- $Q_L = 4.27$ kW
- $Q_C = 4.30$ kW
- $Q_f = 2.14$

trip time > 5 sec
Use Case 1: RLC – Anti Islanding Testing (PHIL)

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<th>relative power</th>
<th>P</th>
<th>Q_L/Q_L_res</th>
<th>Q_L</th>
<th>Q_C</th>
<th>P</th>
<th>Q_R</th>
<th>t_max</th>
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<th>operation point 2</th>
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<td>U_{AC} = 230.0 V</td>
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<td>I_{AC} = 11.0 A</td>
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<td>U_{DC} = 450.0 V</td>
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<th>P(f) and P(U) - with Hyst.</th>
<th>P(f) and Q(U) - no Hyst.</th>
<th>P(f) and P(U) - no Hyst.</th>
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</table>

P/Q controls activated

No P/Q controls activated
Ad 1) “Anti-Islanding Testing via PHIL” (source: NREL)

• By modeling the distribution system point of common-coupling (PCC) complex impedance with a higher bandwidth than the PV inverter’s anti-islanding function, it is possible to evaluate the PV inverter’s performance as if it were installed on the distribution circuit.
Ad 1) “AI Testing via PHIL – Initial Results” (source: NREL)

- PHIL testing is able to emulate traditional AI lab testing – implications for future IEEE 1547.a standards development

- PHIL AI testing is capable of finely tuning load to generation – impact on AI performance evaluation is significant
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Use Case 2: LVRT – Ride Through Testing (PHIL/CHIL)

- **Application:**
  - Testing and validation of LV and HVRT capabilities of DER inverters
  - Testing and validation of FRR (dynamic grid support) capabilities

- **Features & benefits**
  - Allows flexible testing multiple fault locations and parameters
  - Easy variation of grid characteristics
  - Feedback from DER on fault will be taken into account
  - Possible to assess interaction of multiple DER

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Source: TC2007 German Transmission Code
Source: FprTS 50549-1
Use Case 2: LVRT – Ride Through Testing (PHIL/CHIL)

FRT Fault Ride Through Tests:

- Implementation of impedance network in real time (identical to true FRT test setup according to current standards)
  - Switched mode amplifiers (lower BW)
  - Linear amplifiers (higher BW)

- Advantage of real time simulation:
  - Introduction of measured grid fault scenarios in RTS
  - Physical effects (transf. saturation, etc. can be modelled in RT and run in PHIL simulation)
  - Automated test protocol for a series of voltage dips (suitable for PHIL and CHIL simulation)

- Verification with well-known FRT behaviour of existing components
Use Case 2: LVRT – Ride Through Testing (PHIL/CHIL)

Proposed Network to be implemented in RT:
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Use Case 3: ICT – Communication emulation (CoSim, CHIL)

Proposed Test Scenarios (ICT - Communication):

- Emulation of state-of-the-art communication test protocols (SIRFN Project ‘ Test Scenarios … ‘, etc.)

- Simulation of remote control and control interaction of different used test protocols

→ Outlook:
Integration of ICT Co Simulation into CHIL or even PHIL simulation scenarios

Source: Lawrence Berkley National Laboratories
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Invitation for the SIRFN participants

Member list: (Asia / Europe / America):

- **Asia**: 12 participants
- **America**: 4 participants
- **Europe**: 8 participants

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<tr>
<th>Given Name</th>
<th>Company / Organization</th>
<th>Country</th>
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<td>Kazuo</td>
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</table>
Next Steps: Use Cases!

Project Tasks - To be done:

- **Use Case 1: Anti Islanding Test (PHIL)**
  - Implementation in PHIL simulation
  - Verification with conventional testing ($f_{\text{resonance}}$, voltage/current waveforms, etc…)

- **Use Case 2: Fault Ride Through FRT (PHIL / CHIL)**
  - Implementation in PHIL simulation
  - Verification with conventional testing by means of
    - Impedance network
    - Grid simulator with normative grid impedance

- **Use Case 3: Communication Control Testing (CoSim, P/CHIL)**
  - Implementation in CoSim or P/CHIL simulation
  - Verification of the remote and control capability communication protocols integrated in DER networks
Join now for ‘Advanced Lab‘ Testing Methods‘

Thank you!

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