Advanced Laboratory Testing Methods – SIRFN Project Activity

Georg Lauss;

AIT Austrian Institute of Technology,
EES, Energy Department,
Vienna, Austria;

SIRFN meeting, Paris 2015, France, *“Advanced Laboratory Testing Methods*“

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

Workshop Outline (SIRFN, March 19th, 2015)

Moderators: Georg Lauss (AIT), Blake Lundstrom (NREL), Oliver Gehrke (DTU);

- Possible classification of methods and related use cases
  - PHIL, CHIL, CoSimulation
- Laboratory equipment and related use cases
  - AC/DC amplifiers,
  - Lab' power rating/ grid level,
  - Real-time systems available,
  - Interoperability (technical/communication/interference)
  - existing know-how of the applied methods
- Use cases (reports)
  - RLC – Anti Islanding Testing (PHIL, CHIL) – (lead: NREL)
  - LVRT – Ride Through Testing (PHIL, CHIL) – (lead: AIT)
  - ICT – Communication emulation (CoSim, CHIL) – (lead / participant: DTU)

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- Advanced Laboratory Testing
  - Methods, Lab. Equipment, Expertise
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  - RLC – Anti Islanding Testing (PHIL) – (Blake, NREL)
  - LVRT – Ride Through Testing (PHIL) – (Georg, AIT)
  - ICT – Communication emulation (CoSim, CHIL) – (Oliver, DTU)
- Next Steps & New members

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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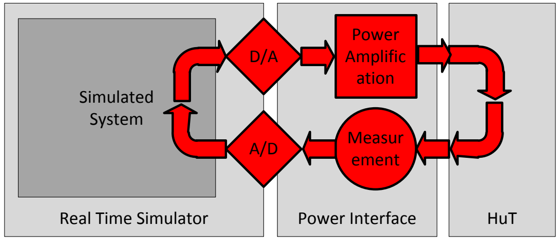
- Next Steps & New members

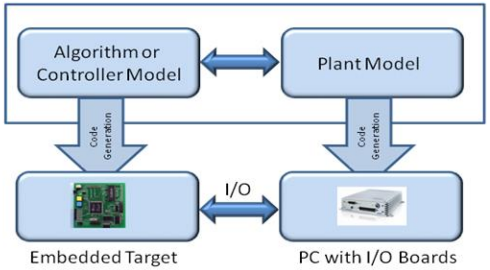
Proposed methods for advanced lab' testing

- 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)



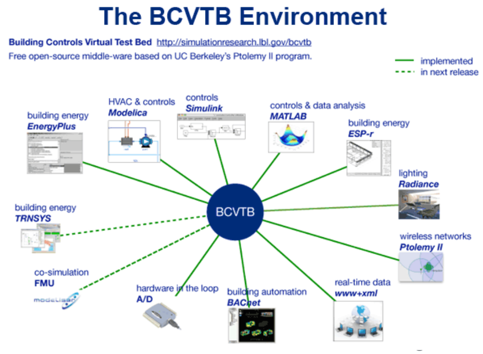
Source: AIT – Austrian Inst. Of Techn. Laboratory

- 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



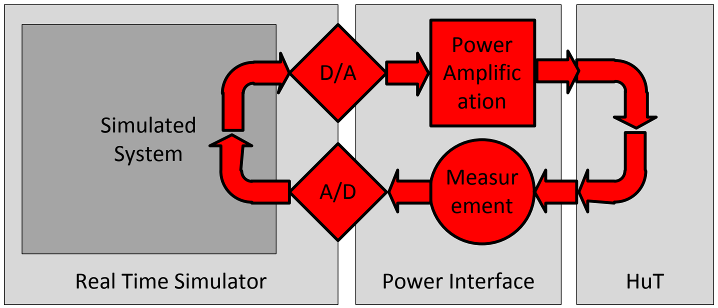
Source: autonomie.net

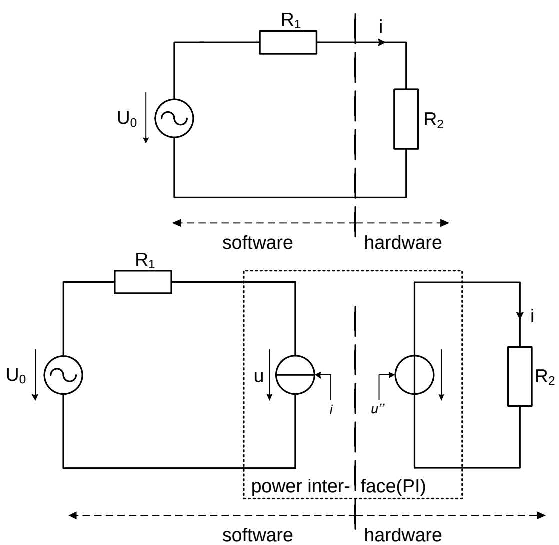
- Multi-Domain Simulation / Co-Simulation (MD/Co-Sim):
  - Suitable for investigations of various other control / communication circuitry integrated into the test system
  - High degree of flexibility, possibility of integrating various control loops into CHIL / PHIL environment



Source: Lawrence Berkley National Laboratories

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



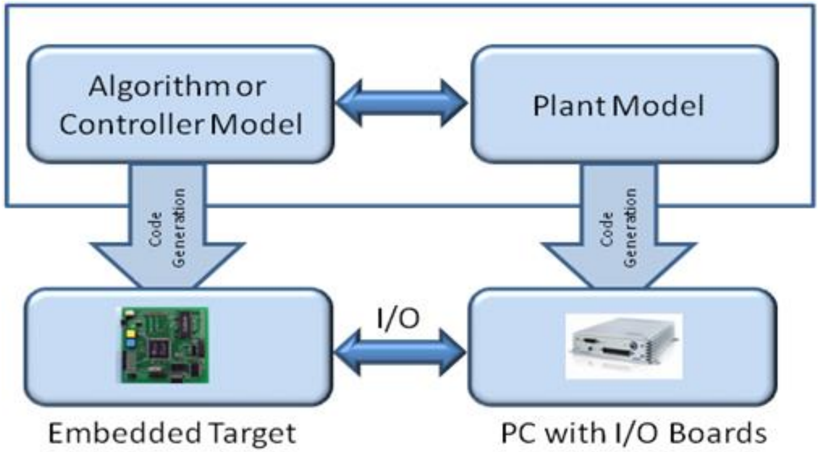


Simple test setup for a PHIL simulation – including dedicated Power interface (PI)

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

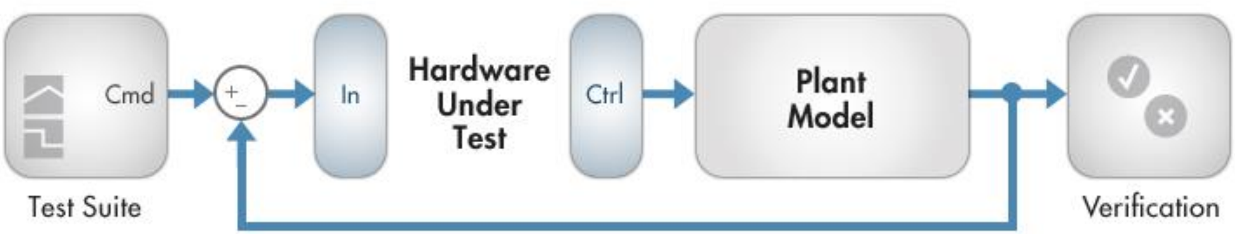
Controller Hardware-in-the-Loop (CHIL) Simulation



Source: autonomie.net

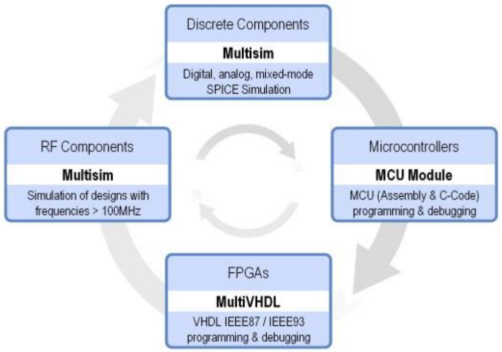
Controller Hardware-in-the-Loop (CHIL):

- 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.)



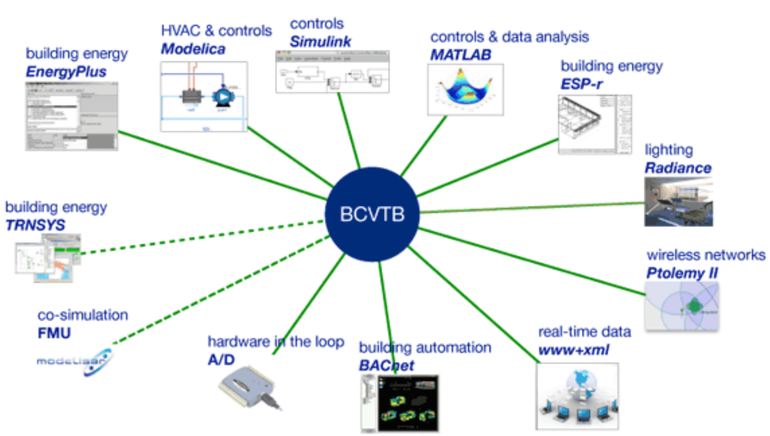
Source: The Mathworks

Multi Domain Simulation / CoSimulation

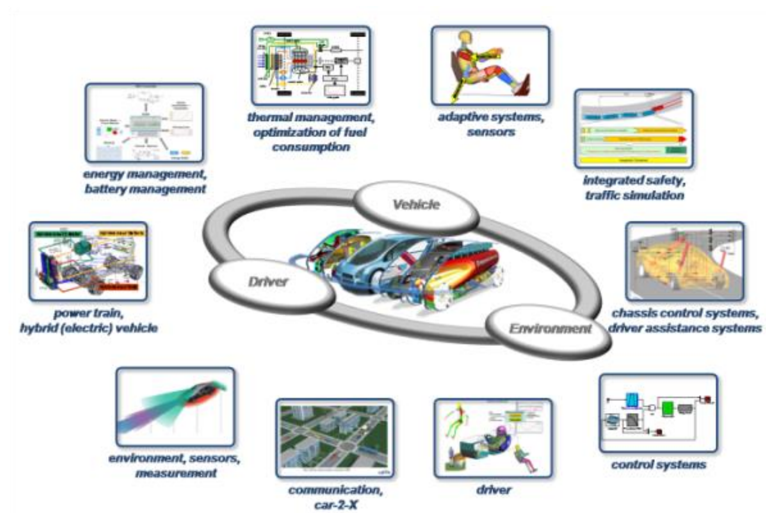


Source: www.ni.at

- 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: Lawrence Berkley National Laboratories

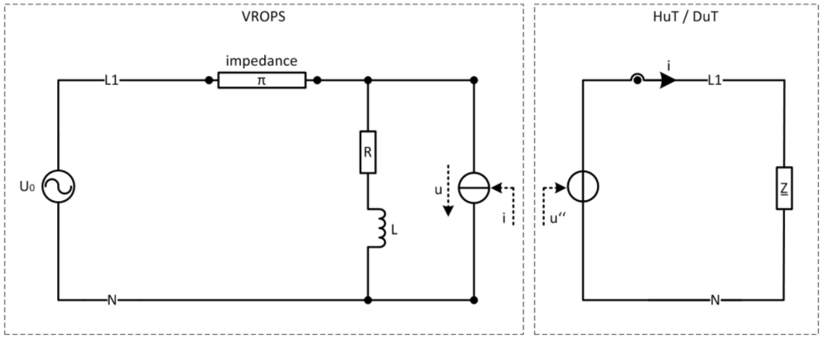


Source: www.v2v2.at

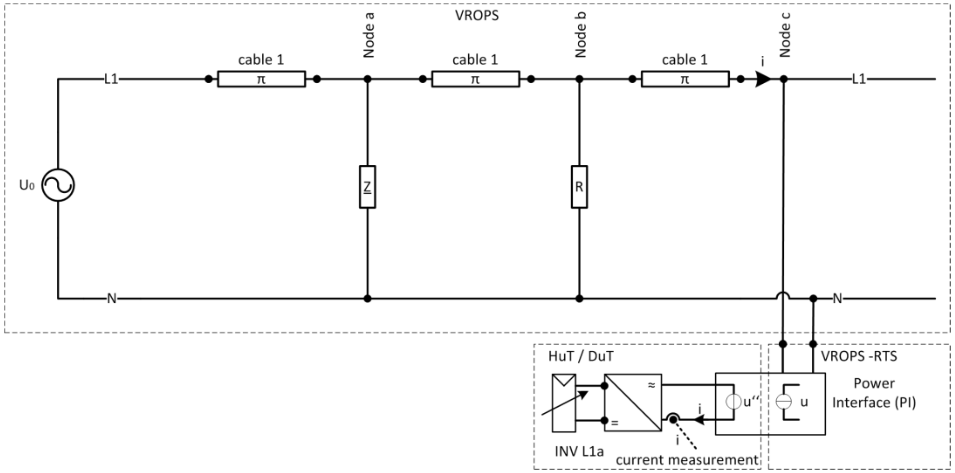
Equipment PHIL / CHIL

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)



Electrical circuit for a PHIL simulation – including various impedances Z.

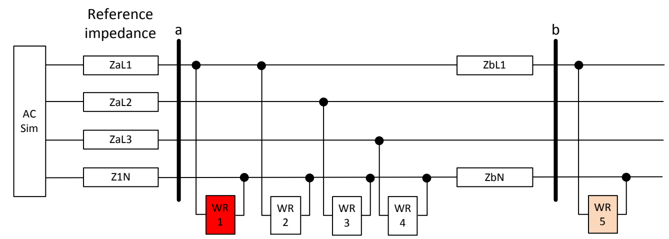


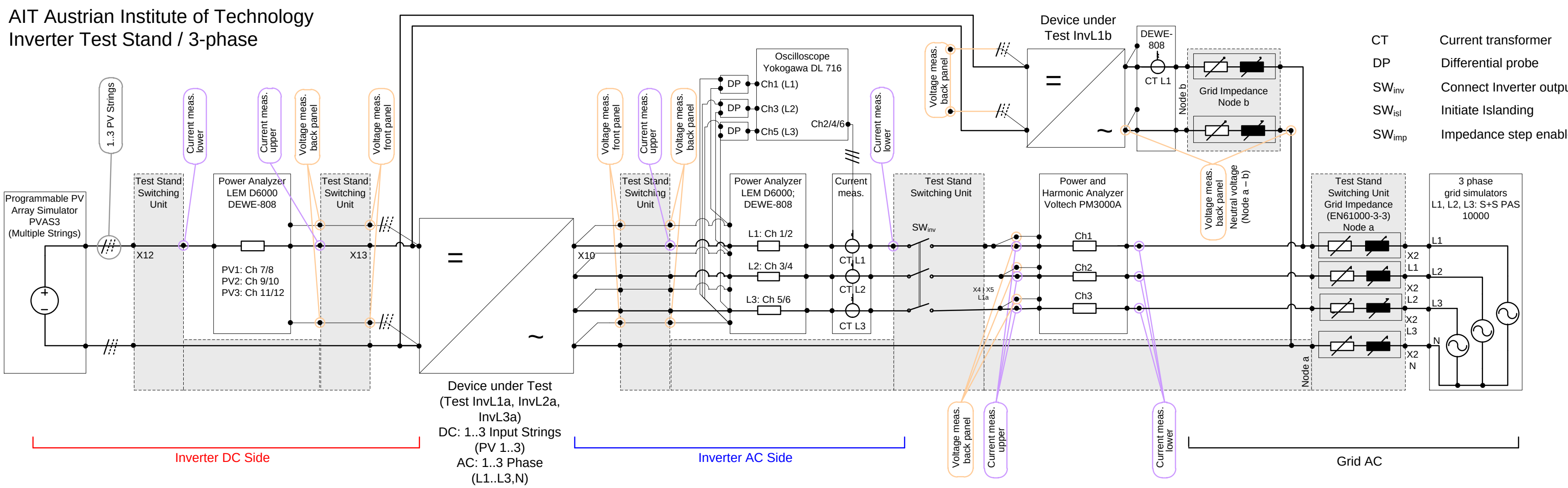
Electrical circuit for a PHIL simulation – including an active component (PV inverter)

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)





Test stand equipped for PHIL simulations.

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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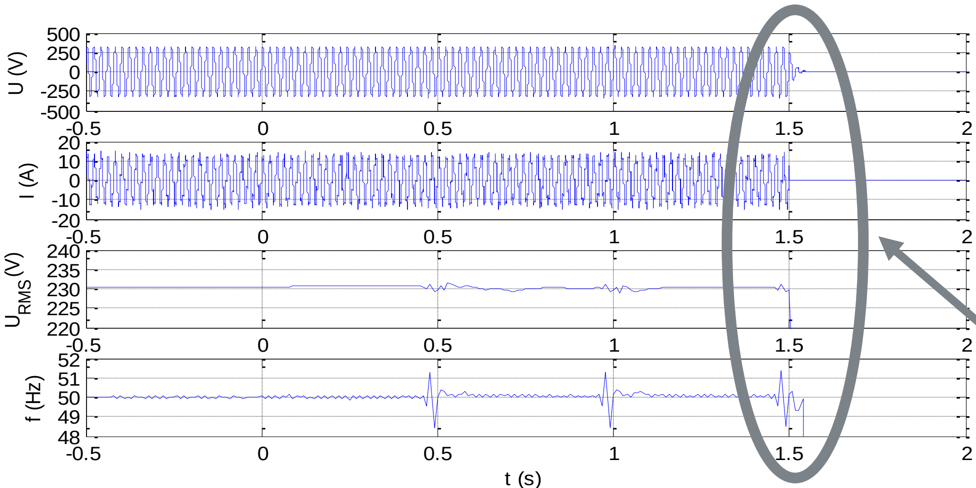
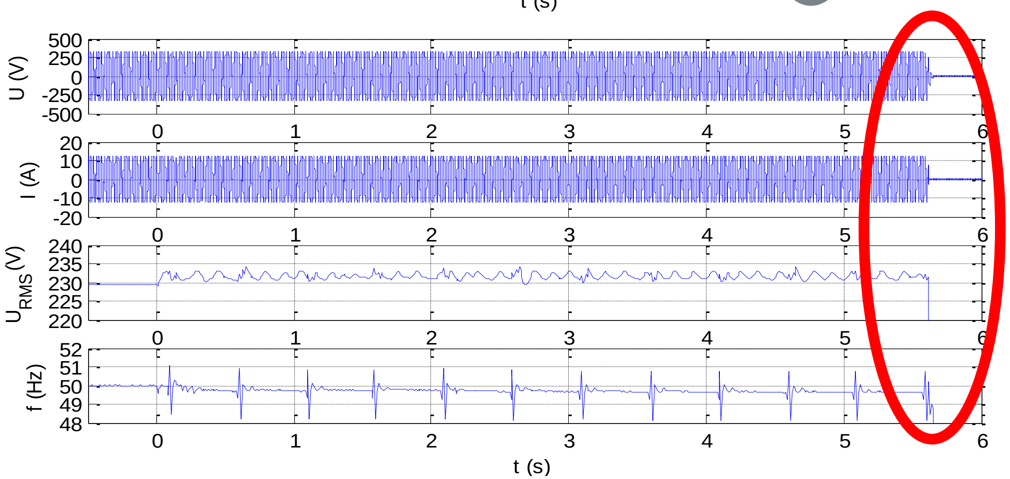
Use Case 1: RLC – Anti Islanding Testing (PHIL)



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)

relative power	match	reactive power (inductive)	reactive power (capacitive)	active pwoer	Q factor	trip time limit (max)		no P, Q controls active		P(f) and Q(U) - with Hyst.	P(f) and P(U) - with Hyst.	P(f), P(U) and Q(U) - with Hyst.	P(f) and Q(U) - no Hyst.	P(f) and P(U) - no Hyst.	P(f), P(U) and Q(U) - no Hyst.
P	Q_L / $Q_{L,res}$	Q_L	Q_C	P	Q_R	t_{max}		t_{max}		t_{off}	t_{off}	t_{off}	t_{off}	t_{off}	t_{off}
(%)	(%)	(kVAr)	(kVAr)	(kW)	-1	(s)		(s)		(s)	(s)	(s)	(s)	(s)	(s)
50%	100%	4.43	4.46	2	2.222	5		0.16		0.12	0.17	0.22	0.21	0.18	0.16
	101%	4.47	4.46	2.00	2.234	5		0.20		0.16	0.17	0.20	0.21	0.21	0.16
	102%	4.52	4.46	2.00	2.245	5		0.20		-	-	-	-	-	-
	103%	4.56	4.46	2.00	2.256	5		0.16		-	-	-	-	-	-
	104%	4.61	4.46	2.00	2.267	5		0.13		-	-	-	-	-	-
	105%	4.65	4.46	2.00	2.277	5		0.13		0.12	0.14	0.12	0.13	0.14	0.14
	99%	4.39	4.46	2.00	2.211	5		0.12		0.12	0.14	0.14	0.11		0.14
	98%	4.34	4.46	2.00	2.2	5		0.13		-	-	-	-	-	-
	97%	4.30	4.46	2.00	2.189	5		0.13		-	-	-	-	-	-
	96%	4.25	4.46	2.00	2.178	5		0.14		0.17	0.14	0.14	0.13	0.13	0.17
	95%	4.21	4.46	2.00	2.166	5		0.14		0.33	0.14	0.14	0.14	0.13	0.14

operation point 2

$P_{WR,AC}$ =	2000	W
U_{AC} =	230.0	V
I_{AC} =	11.0	A
U_{DC} =	450.0	V

P/Q controls activated

No P/Q controls activated

Ad 1) “AI Testing via PHIL – Initial Results” (NREL)

>>> Presentation Blake (NREL)

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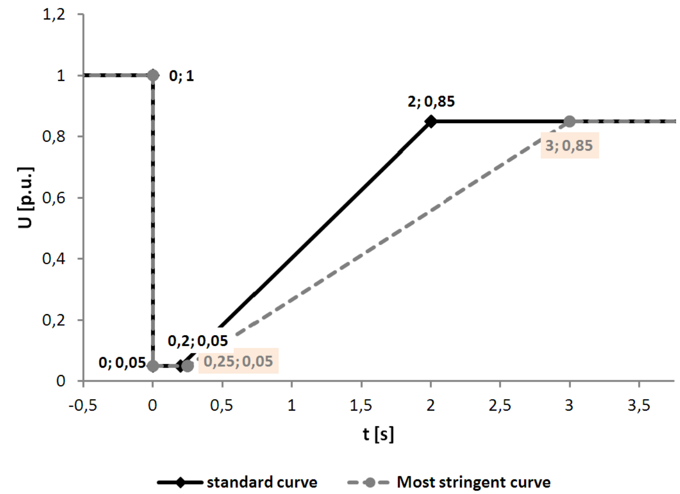
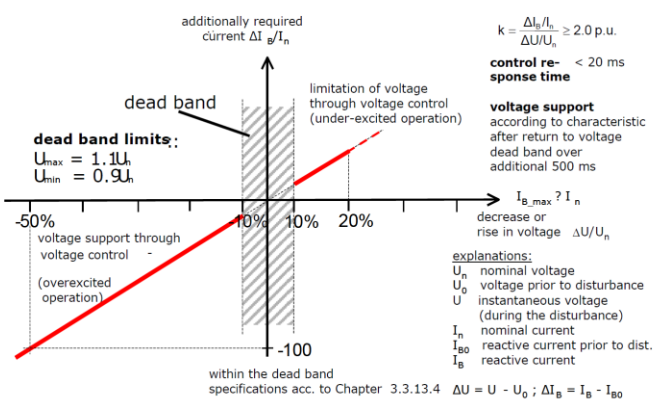
Use Case 2: LVRT – Ride Through Testing (PHIL/CHIL)

- 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



Source: FprTS 50549-1



Source: TC2007 German Transmission Code

Use Case 2: LVRT – Ride Through Testing (PHIL/CHIL)

FRT Fault Ride Through Tests:

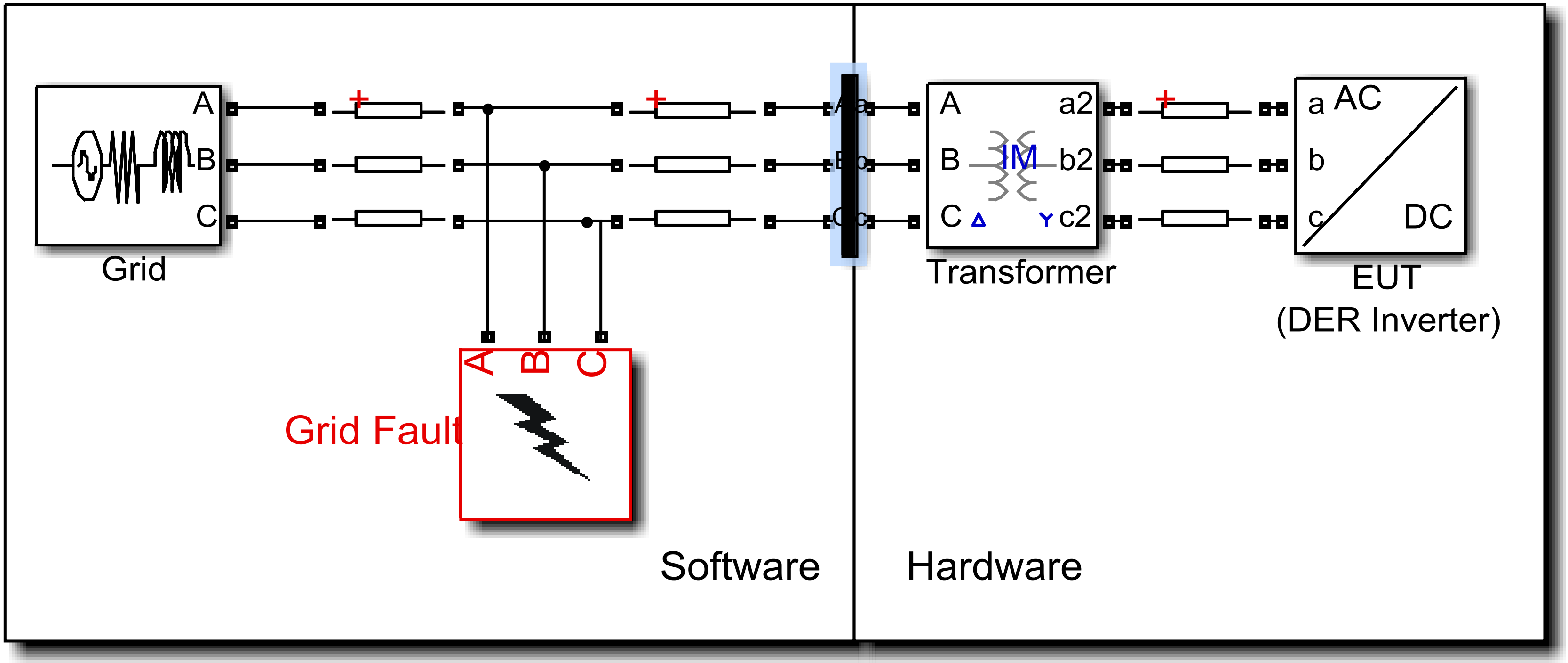
- Implementation of impedance network in real time (identical to true FRT test setup according to current standards)
  - Switched mode amplifiers (lower BW)
  - Linear amplifiers (higher BW)

- 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:



Ad 2) “LVRT and TIE paper - PHIL Simulation” (NTUA / AIT)

>>> Presentation Panos (NTUA)

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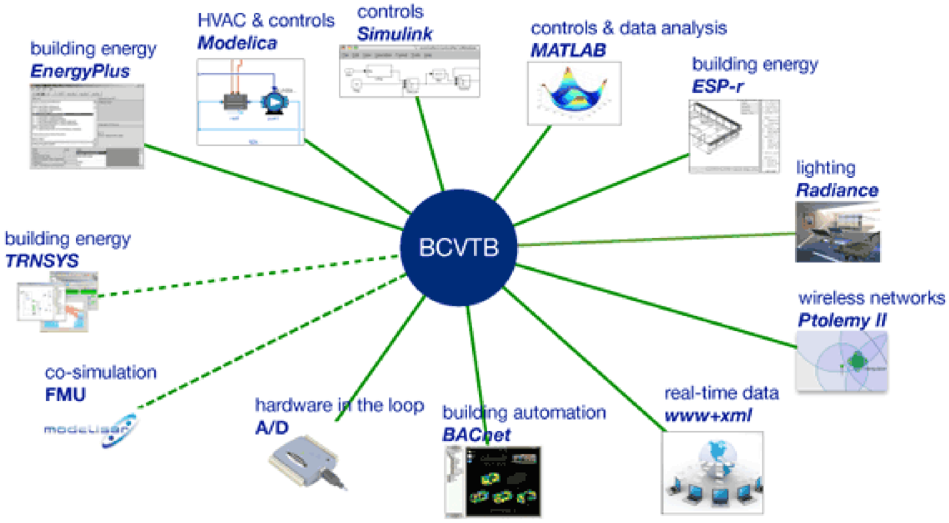
Use Case 3: ICT – Communication emulation (CoSim, CHIL)

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

→ <u>Outlook</u>:

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

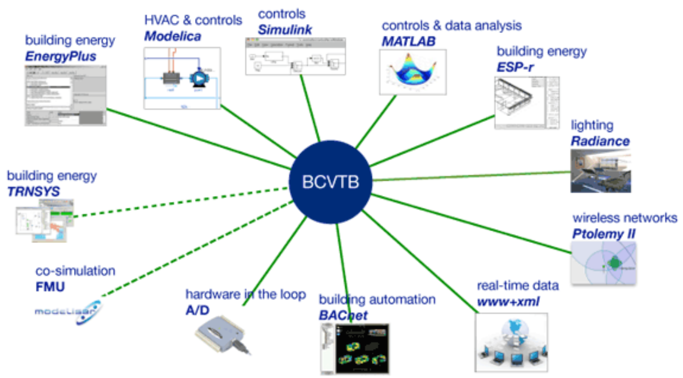


Source: Lawrence Berkley National Laboratories

Use Case 3: ICT – Communication emulation (CoSim, CHIL)

- Slides from DTU (Ol. Gehrke)
- -> sorry, he’s not here and couldn’t make it

- … on the agenda for the next meeting!!



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Invitation for (new) SIRFN participants

Member list: (Asia / Europe / America):

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

- Interest (new participents):
  - NTUA (Greece - Dimeas, Kotsampopoulos)
  - DTU (Denmark – Gehrke, Bindner)
  - …

Given Name	Company / Organization	Country
Kazuo	YOSHINO Consultant Co.	Japan
de Jong	DNV GL - R&I	Netherlands
Lundstrom	Integrated Alternate Solution	United States
Yuka	NEDO	Japan
Johnson	Sandia National Labs	United States
Hamilton	Brookhaven National Lab	United States
Conklin	U.S. Department of Energy	United States
Calin	European Distributed Energy Resources Laboratories e.V.	Germany
HIROSHI	Mitsubishi Research Institute	Japan
Heckmann	Fraunhofer IWES	Germany
Lauss	AIT Austrian Institute of Technology	Austria
Tadao	sogoport service co.,ltd	Japan
Ota	The University of Tokyo	Japan
Shah	Integrated Alternate Solution	Pakistan
SOLANGE	CITYTELL UNITETED ARAB EMIRATES	United Arab Emirates
Kari	VTT	Finland
MONJU	DELUXE HAIR TRADING LLC, UNITETED ARAB EMIRATES	United Arab Emirates
HEILSCHER	Ulm University of Applied Sciences	Germany
Crolla	University of Strathclyde	United Kingdom
Luna	Mardon Advance Trading Inc.	Philippines
Jun	AIST	Japan
LEE	EDF	Korea
Gehrke	DTU	Denmark

Next Steps: Use Cases!

Project Tasks - To be done:

- Use Case 1: Anti Islanding Test (PHIL)
  - Implementation in PHIL simulation
  - Verification with conventional testing ($f_{resonance}$, voltage/current waveforms, etc…)
- Use Case 2: Fault Ride Through FRT (P/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

Given Name	Company / Organization	Country
Kazuo	YOSHINO Consultant Co.	Japan
de Jong	DNV GL - R&l	Netherlands
Lundstrom	Integrated Alternate Solution	United States
Yuka	NEDO	Japan
Johnson	Sandia National Labs	United States
Hamilton	Brookhaven National Lab	United States
Conklin	U.S. Department of Energy	United States
Calin	European Distributed Energy Resources Laboratories e.V.	Germany
HIROSHI	Mitsubishi Research Institute	Japan
Heckmann	Fraunhofer IWES	Germany
Lauss	AIT Austrian Institute of Technology	Austria
Tadao	sogoport service co.,ltd	Japan
Ota	The University of Tokyo	Japan
Shah	Integrated Alternate Solution	Pakistan
SOLANGE	CITYTELL UNITETED ARAB EMIRATES	United Arab Emirates
Kari	VTT	Finland
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Luna	Mardon Advance Trading Inc.	Philippines
Jun	AIST	Japan
LEE	EDF	Korea
Gehrke	DTU	Denmark

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Next Steps: Notes (Use Cases)

Project Tasks - To be done:

- Use Case 1: Anti Islanding Test (PHIL)
  - Lead: NREL (Blake)
  - Participants: AIT, IWES, (Lodz), Sofia, …,
- Use Case 2: Fault Ride Through FRT (P/CHIL)
  - Lead: AIT (Georg)
  - Participants: SANDIA, NREL, KEMA, IWES, (Lodz)…,
- Use Case 3: Communication Control Testing (CoSim, P/CHIL)
  - Lead: DTU (Oliver)
  - Participants: FREA, Strathclyde, VTT, IWES, …SANDIA, NREL, Sofia,

Given Name	Company / Organization	Country
Kazuo	YOSHINO Consultant Co.	Japan
de Jong	DNV GL - R&l	Netherlands
Lundstrom	Integrated Alternate Solution	United States
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Conklin	U.S. Department of Energy	United States
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Heckmann	Fraunhofer IWES	Germany
Lauss	AIT Austrian Institute of Technology	Austria
Tadao	sogoport service co.,ltd	Japan
Ota	The University of Tokyo	Japan
Shah	Integrated Alternate Solution	Pakistan
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Kari	VTT	Finland
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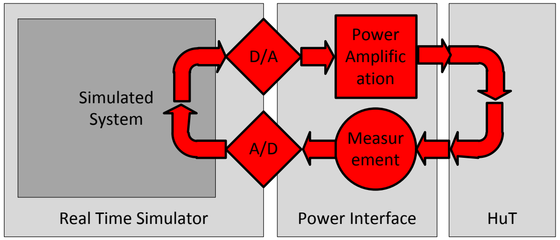
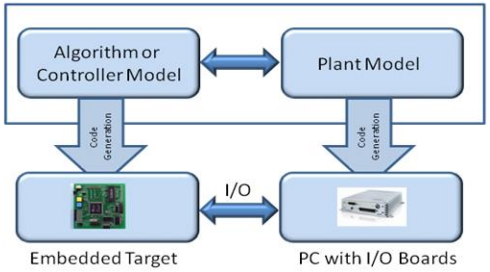
Crolla	University of Strathclyde	United Kingdom
Luna	Mardon Advance Trading Inc.	Philippines
Jun	AIST	Japan
LEE	EDF	Korea
Gehrke	DTU	Denmark

Notes:

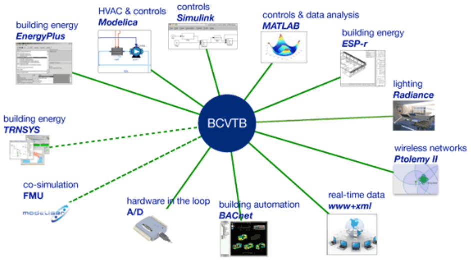
- Laboratory equipment
  - AC/DC Simulators
  - Measurement systems
  - Digital Real-time simulator (DRTS)



- Methods (Know-How)
  - PHIL
  - CHIL
  - CoSimulation



- Use Cases (Experiences)
  - Mentioned use cases
  - others



Next Steps: Notes (Use Cases)

Project Tasks - To be done:

- Use Case 1: Anti Islanding Test (PHIL)
  - Lead: NREL (Blake)
  - Participants: AIT, IWES, VTT, …,
- Use Case 2: Fault Ride Through FRT (P/CHIL)
  - Lead: AIT (Georg)
  - Participants: SANDIA, NREL, KEMA, …,
- Use Case 3: Communication Control Testing (CoSim, P/CHIL)
  - Lead: DTU (Oliver)
  - Participants: FREA, Strathclyde, IWES, …SANDIA, NREL,

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de Jong	DNV GL - R&l	Netherlands
Lundstrom	Integrated Alternate Solution	United States
Yuka	NEDO	Japan
Johnson	Sandia National Labs	United States
Hamilton	Brookhaven National Lab	United States
Conklin	U.S. Department of Energy	United States
Calin	European Distributed Energy Resources Laboratories e.V.	Germany
HIROSHI	Mitsubishi Research Institute	Japan
Heckmann	Fraunhofer IWES	Germany
Lauss	AIT Austrian Institute of Technology	Austria
Tadao	sogoport service co.,ltd	Japan
Ota	The University of Tokyo	Japan
Shah	Integrated Alternate Solution	Pakistan
SOLANGE	CITYTELL UNITETED ARAB EMIRATES	United Arab Emirates
Kari	VTT	Finland
MONJU	DELUXE HAIR TRADING LLC, UNITETED ARAB EMIRATES	United Arab Emirates
HEILSCHER	Ulm University of Applied Sciences	Germany
Crolla	University of Strathclyde	United Kingdom
Luna	Mardon Advance Trading Inc.	Philippines
Jun	AIST	Japan
LEE	EDF	Korea
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Thank you!

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