The NTUA Microgrid Laboratory

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Introduction

The main activities of NTUA 's Microgrid Laboratory focus in research, testing and technology development in the area of Smart Grids. Smart Grids have been defined by the Smart Grids European Technology Platform as electricity networks that can intelligently integrate the actions of all users connected to them, generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies [1]. According to this definition, the main activities deal with planning and operation of modern power systems characterized by high penetration of renewable energy sources, distributed generation and flexible loads. For the efficient solution of related problems advanced control and ICT technologies are employed.

The Laboratory

Multi-Microgrid Cluster:

- ✓ Two single-phase microgrids
- ✓ One three phase microgrid

Consists of: PV generators, a small Wind Turbine(fully constructed in NTUA Lab), battery energy storage systems, controllable loads and controlled interconnection to the local LV grid

The laboratory SCADA:

- Based on a PLC (Programmable Logic Controller) system with Labview-CoDeSys software.
- Measurements on the AC and DC side of the inverters
- Environmental measurements (irradiation, wind speed etc.)
- Control of the DGs
- Load profile programming

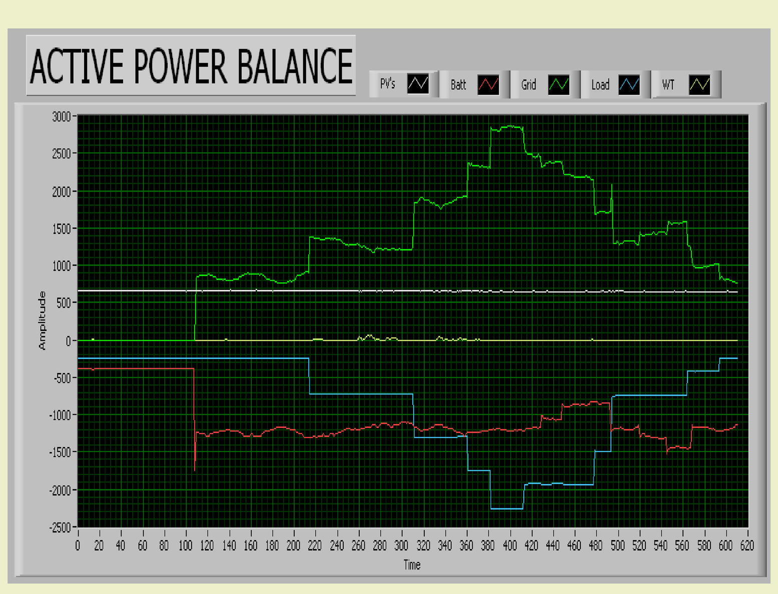

Figure 2. Grid connected mode active power balance

Multi-Agent System for Microgrid Operation:

- Java based platform called Jade and communicates with the DER/DGs via industrial communication protocols such as OPC.
- 10 load controllers that can be used to test algorithms for distributed control of Microgrids and DG/RES.

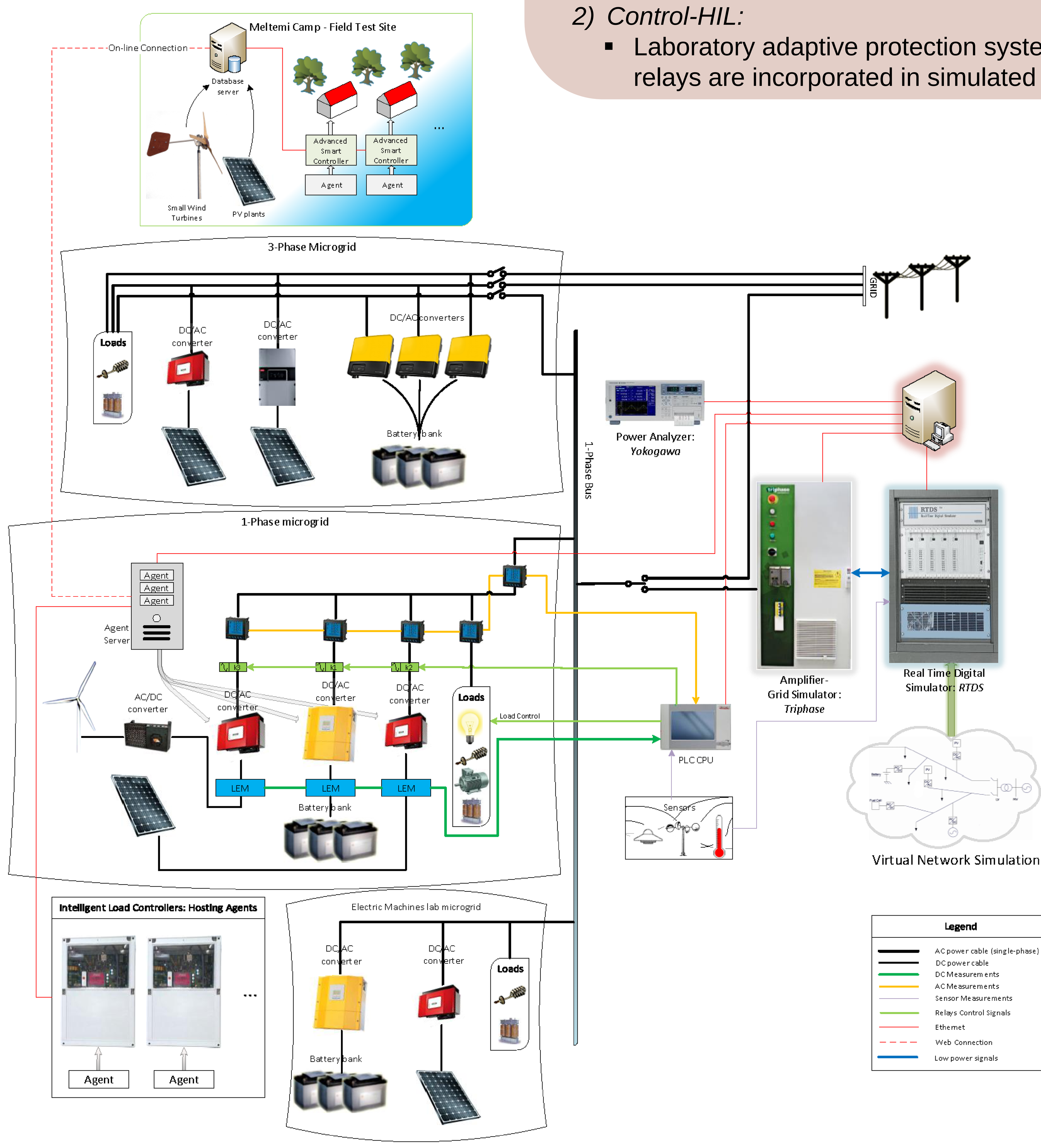

Figure 1. NTUA Microgrid Laboratory structure

Hardware-in-the-Loop (HIL) simulation environment:

1) *Power-HIL:*
   - Power devices (e.g PV inverters, etc) are connected to fully simulated systems in a closed loop environment [3], [4].
   - Real Time Simulator (RTDS) [5]
     - Typical time-step of 50 usec
     - In dedicated software, electric power networks with various components such as generators, protection devices, distributed generation etc, are simulated
     - Analogue and Digital inputs/outputs
   - Switched-Mode Amplifier (AC/DC/AC converter) as a power interface in the PHIL

2) *Control-HIL:*
   - Laboratory adaptive protection system is being developed at NTUA. Hardware relays are incorporated in simulated power systems

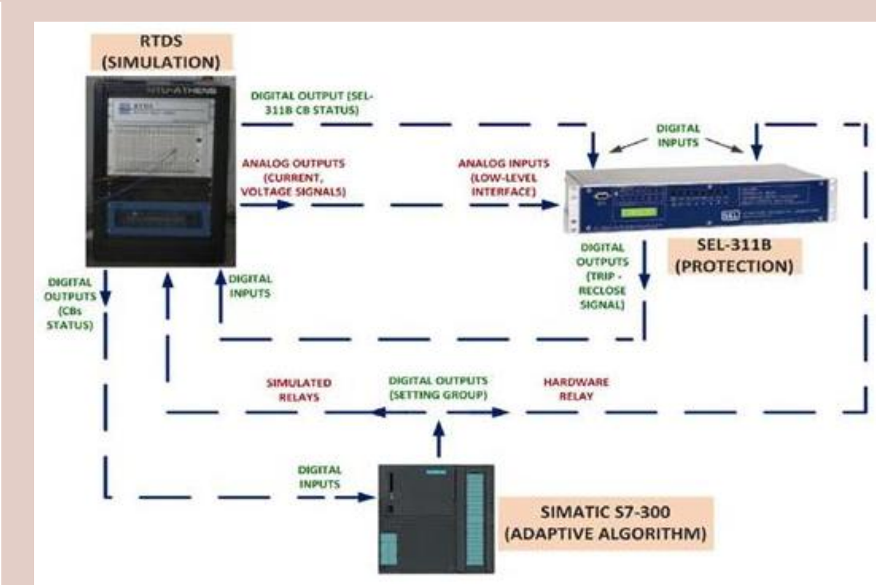

Figure 3. Configuration for Adaptive Protection Scheme

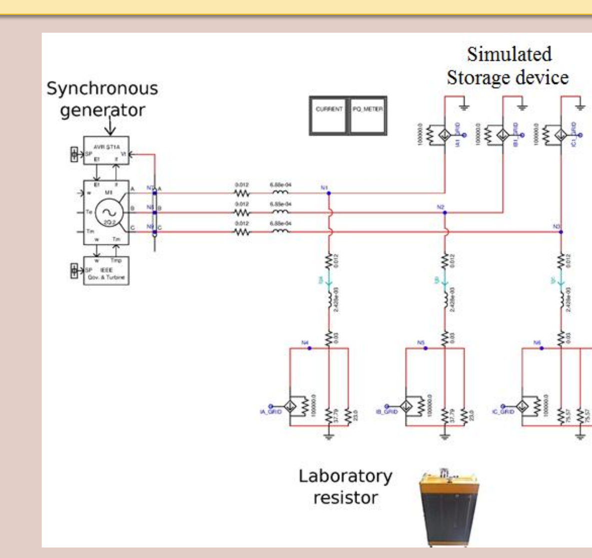

Figure 4. PHIL experimental test

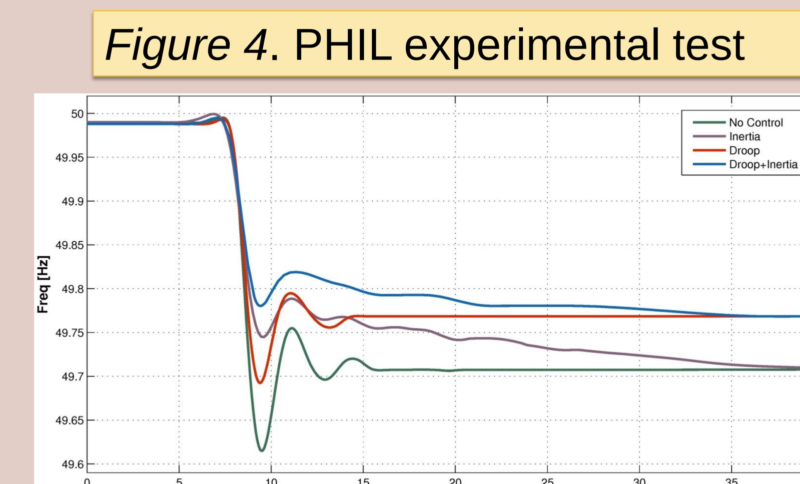

Figure 5. Frequency response obtained in a PHIL test for different control algorithms

A Future Smart Micro-Grid Infrastructure:

The new setup will integrate the three microgrids and will provide the opportunity to operate them as a single microgrid or as a virtual power plant (VPP). Local controllers will be installed for each microgrid component. The local controllers will acquire measurements and control microgrid inverters and relays and will communicate with each other by means of standardized protocols, connected to an Ethernet switch. The proposed setup can be used to implement both centralized and decentralized microgrid control schemes [2].

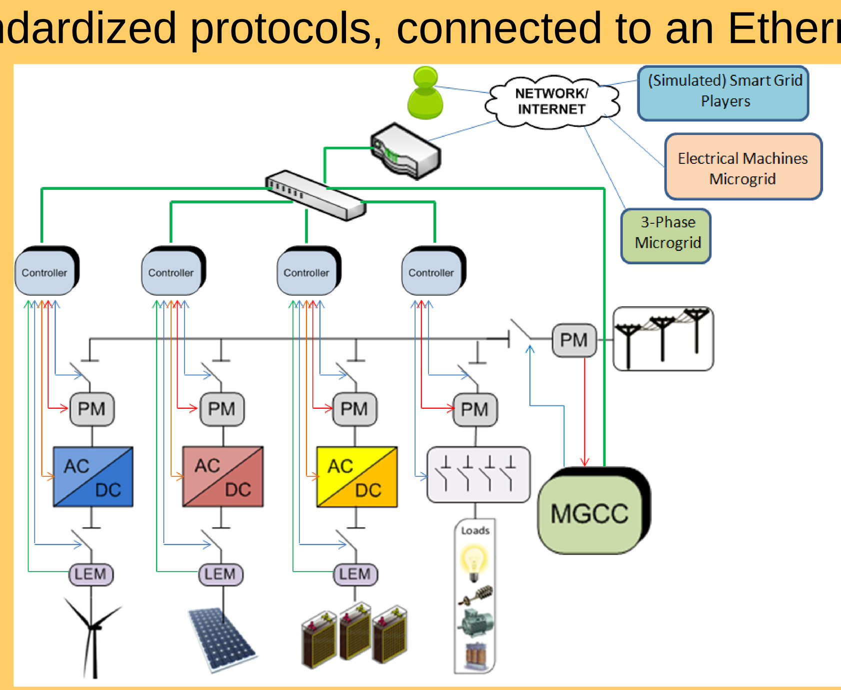

Figure 6. Future structure of single-phase laboratory microgrid

References

[1] Smart Grids European Technology Platform: http://www.smartgrids.eu
[2] Hatziargyriou, "Microgrids: Architectures and Control", Wiley-IEEE Press, January 2014
[3] P. Kotsampopoulos, A. Kapetanaki, G. Messinis, V. Kleftakis, N. Hatziargyriou,"A PHIL facility for Microgrids", International Journal of Distributed Energy Resources, Vol. 9, No. 1,pp. 71-86, January-March 2013
[4] V. Kleftakis, A. Rigas, A. Vassilakis, P. Kotsampopoulos, N. Hatziargyriou, "Power-Hardware-in-the-loop simulation of a D-STATCOM equipped MV network interfaced to an actual PV inverter", IEEE PES, Innovative Smart Grid Technologies ISGT Europe 2013, Copenhagen, October 2013
[5] RTDS Technologies: http://www.rtds.com