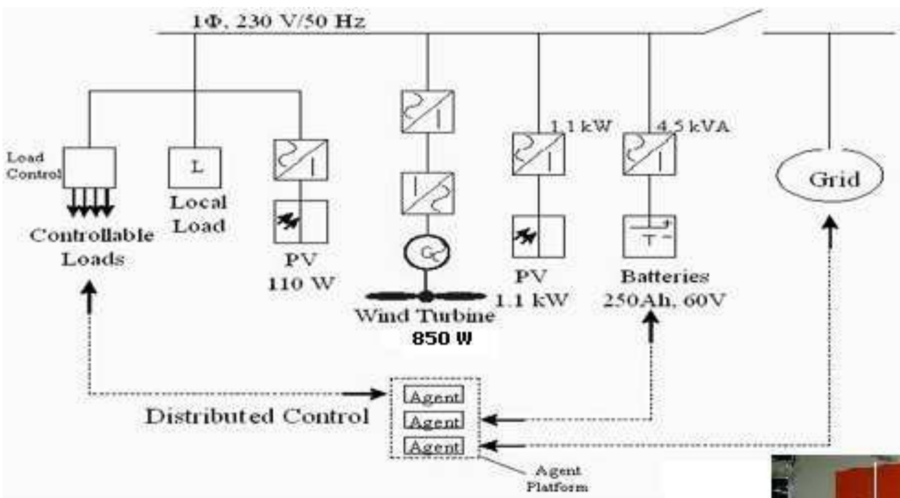
The Electric Energy Systems Laboratory of ICCS-NTUA

LV Microgrid:

A main component of the Laboratory is a microgrid that comprises two PV generators, a small Wind Turbine, battery energy storage, controllable loads and a controlled interconnection to the local LV grid. The battery unit, the PV generators and the Wind Turbine are connected to the AC grid via fast-acting DC/AC power converters. The converters are suitably controlled to permit the operation of the system either interconnected to the LV network (grid-tied), or in stand-alone (island) mode, with a seamless transfer from the one mode to the other. A schematic diagram of the microgrid system is depicted in the figure below, along with a photo of the actual installation.



The central component of the microgrid system is the battery inverter, which regulates the voltage and frequency when the system operates in island mode, taking over the control of active and reactive power. The battery unit power electronics interface, consists of a Cuk DC/DC converter and a voltage source PWM inverter, both bi-directional, permitting thus charging and discharging of the batteries. The DC/DC converter provides the constant 380 V DC voltage to the DC/AC converter input. The HF transformer, operating at 16.6 kHz, provides electrical isolation between the battery bank and the grid. The four-quadrant DC/AC converter comprises a single phase IGBT bridge, output filters and a grid-connection inductor.

In more details, the microgrid features:

· PV generator 1: Modules : 10 series connected - Single crystal Si, 110W, 12 V per module.
Inverter: SMA/Sunny Boy/1100 W
· PV generator 2: Modules : 1 - Single crystal Si, 110W, 24 V.
Inverter: Soladin grid connected solar inverter 120 W
· Small Wind Turbine: Generator: 3 phase axial flux PMSG, 850W.
Inverter: SMA/Windy Boy/ 1700W. The Wind Turbine was constructed by students of ICCS-NTUA.
· Batteries: Cells: Lead-acid, vented type, 30 cells, 2 V, 250/370 Ah.
Inverter: SMA/Sunny Island/4.5 kVA, bi-directional, suitable for grid-connected and islanded operation.

· Grid: Connection to local building distribution (lab switchboard). MCB for protection – Contactor for control
· Loads: Controllable resistive-inductive load, switchable capacitive. Lighting (incandescent, CFL).Small motor and other available appliances

MultiAgent System for Microgrid Operation:
The use of MAS technology can solve a number of specific operational problems:
· The small DG (Distributed Generation) units have different owners, so centralized control is difficult. Several decisions should be taken locally.
· Lack of dedicated communication facilities.
· Microgrids will operate in a liberalized market, so the decisions of the controller of each unit concerning the market should have a certain degree of «intelligence».

The local DG units besides selling power to the network have also other tasks: producing heat for local installations, keeping the voltage locally at a certain level or providing a backup system for local critical loads in case of a failure of the main system. Prediction of photovoltaic generation is provided based on real meteorological data and serves as an input to the controllers.
These tasks reveal the importance of the distributed control and autonomous operation.

Real Time Digital Simulator (RTDS) and Switched-Mode Amplifier:
· A rack of the commercially available Real Time Digital Simulator RTDS® is operated. The rack contains several processing cards that work in parallel, an interface card as well as various analog, digital inputs and outputs. In dedicated software (RSCAD) electric power networks with various components such as generators, transformers, protection devices, loads etc are simulated with a typical time-step of 50 μsec

· A Switched-Mode Amplifier provided by Triphase is used as a Power Interface between the RTDS and physical equipment to perform Power Hardware in the Loop (PHIL) simulation. The power electronic converter platform allows the user to design a Matlab-Simulink control model, upload it to the Target PC (converter's powerful control unit) and connect the user's PC to the Target PC to allow real-time control of and interaction with the inverter cabinet. In addition, several inputs and outputs equipped with A/D and D/A converters are available for receiving and sending signals to the external world.

Small Wind Turbines:
Studies on small Wind Turbines are performed focusing on rural electrification applications. A test site for testing small Wind Turbines has been developed on the roof of the Electrical Engineers building in NTUA where Power curve measurement, as well as testing of controllers (e.g. DC/DC converter) for small Wind Turbines is possible.

PV outdoor tests:
A facility to perform long term photovoltaic module outdoor tests according to the DERlab standard has been developed in the laboratory. The main objective of the long term measurements is the continuous recording of meteorological and electrical data for at least one year.

Laboratory SCADA:
The laboratory SCADA is implemented using a PLC system with Labview-CoDeSys software. The following features are available:

- Measurements on the AC and DC side of the inverters
- Environmental measurements
- Control of the DGs
- Load profile programming