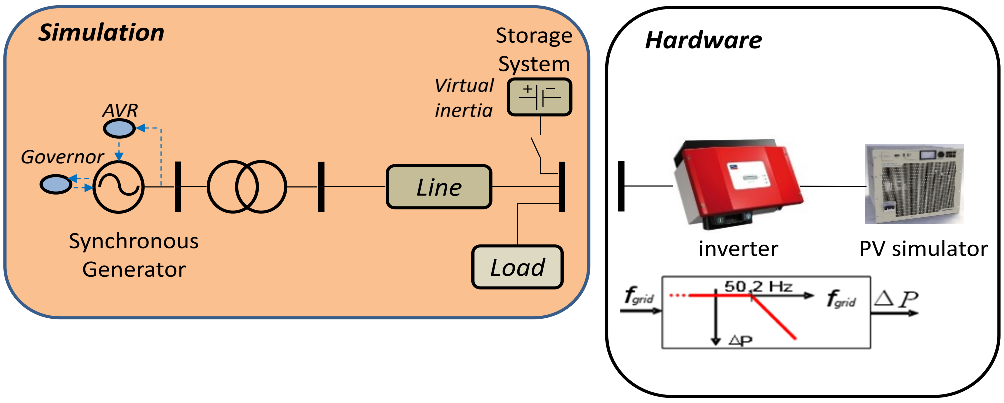
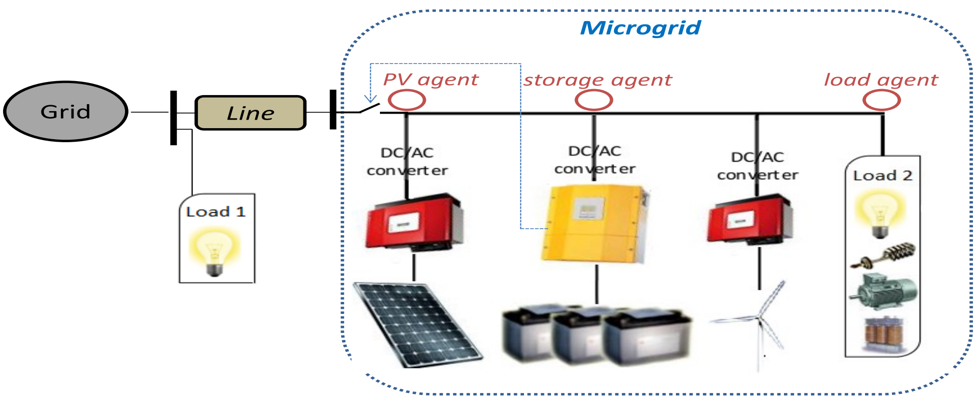
National Technical University of Athens

2nd Laboratory Exercise: "Parallel operation of synchronous generators and distributed generation – monitoring and control of laboratory Microgrid"

1st experiment: In this laboratory experiment, the power sharing between synchronous generators and distributed generation units (DG), as well as primary frequency regulation, are examined. A hardware photovoltaic (PV) inverter, which is fed by a PV simulator (controllable DC power supply) is connected to a real-time simulated network, which consists of a synchronous generator and a controllable load. After a reduction of the load, the frequency of the network is measured with and without the use of the *P(f)* droop control of the hardware PV inverter. In addition, the possibility of DG and storage inverters to provide virtual inertia is examined.



2nd experiment: The laboratory microgrid consists of PV panels, a small wind turbine, batteries and controllable loads. The batteries, the PV panels and the wind turbine are connected to the AC grid through DC/AC power inverters. The inverters are appropriately controlled so that both grid-connected and islanded operation (with seamless transition from one mode to the other) is possible. The main component of the microgrid is the battery inverter, which regulates the voltage and frequency of the system in islanded operation. Moreover, control of the microgrid using a multi-agent system is implemented.



Queries:

1a) Two synchronous generators, with nominal power 10 MW each and droop coefficients R_1=1% and R_2=5% respectively, supply a 20 MW load with their nominal power at nominal frequency (50 Hz). Calculate the power generation of each generator and the frequency of the system if the load is reduced to 15 MW.

1b) A synchronous generator, with nominal power 10 MW and droop coefficient $R_1=1\%$, and a distributed generation unit, with nominal power 3 MW and *P(f)* droop characteristic with gradient 40% of the available power per Hz (with no "dead-band"), supply a load of 10 MW, providing 7 MW and 3 MW respectively at nominal frequency (50 Hz). Calculate the power generation of each unit and the frequency of the system if the load is reduced to 8 MW.

2a) The microgrid operates in grid-connected mode. The DSO requests 2 kW active power generation from the microgrid as a whole. The power generation of the PV inverter is 1 kW, the wind-turbine inverter 0.5 kW and the load consumption 2 kW. What is the required power of the battery inverter? (ignore line losses).

2b) The microgrid operates in islanded mode and the battery inverter is connected only to a load.

- The power of the load is set to 0.5 kW and the microgrid's frequency is measured at 49.8 Hz.
- The power of the load is set to 2 kW and the microgrid's frequency is measured at 49.6 Hz.

i. Calculate and draw the f-P droop characteristic of the battery inverter.

ii. If the power generation of the PV inverter is 1 kW, the wind-turbine inverter 0.5 kW and the load consumption 0.8 kW, what is the power of the battery inverter? Do the batteries absorb or provide power? (ignore the line losses).

iii. At the above power equilibrium, calculate the new frequency of the microgrid using the f-P droop that was calculated in i.