BUCHAREST 2018 SYMPOSIUM ON MICROGRIDS
University Politehnica of Bucharest, Romania
2-6 Sept. 2018

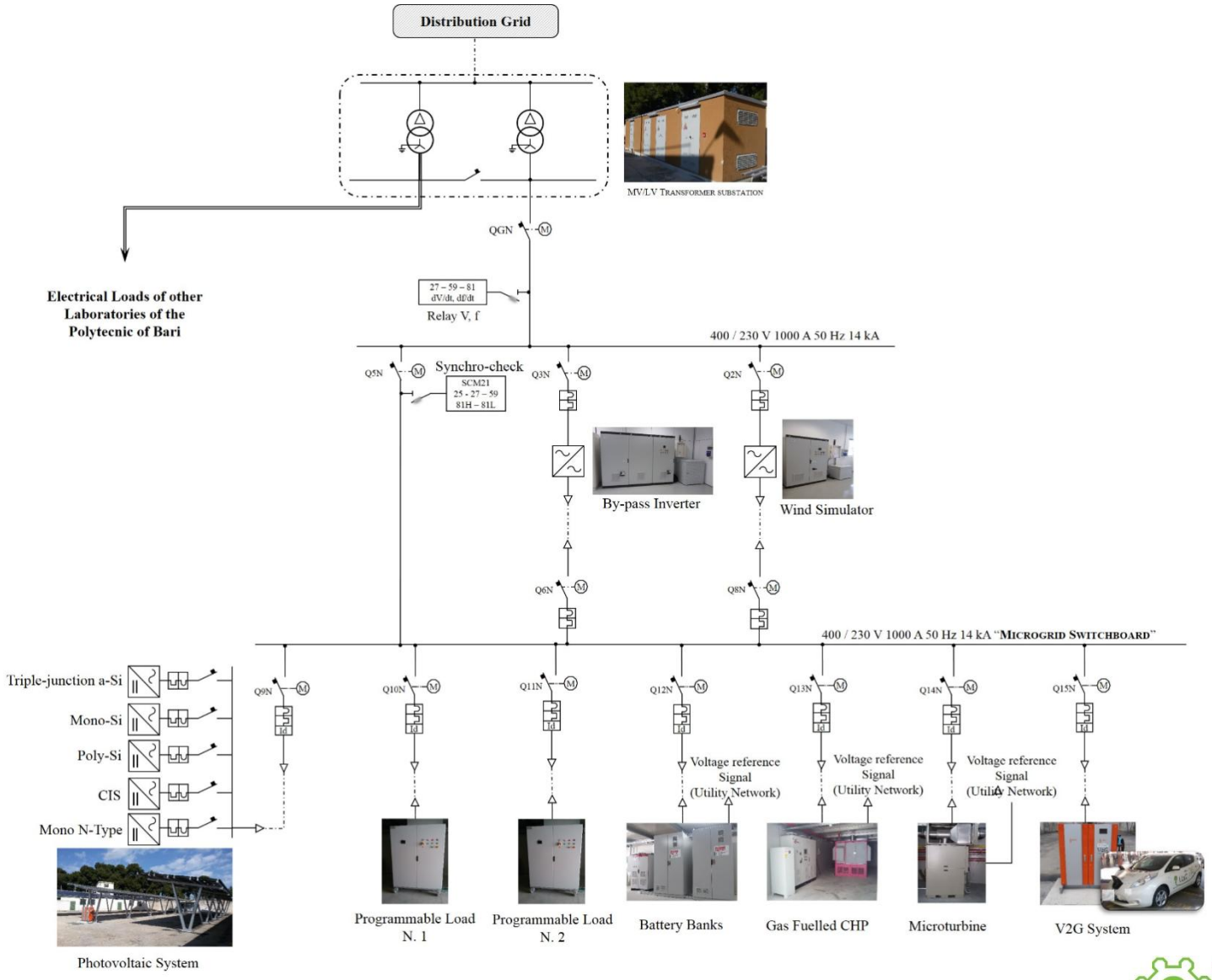
The Prince Lab microgrid test bed

Enrico De Tuglie
enricoelio.detuglie@poliba.it

DEI
DEPARTMENT OF
ELECTRICAL AND
INFORMATION ENGINEERING

PrInCE
POLITECNICO DI BARI

The experimental μG



PrINCE
POLITECNICO DI BARI

The μG switchboard

PrINCE
POLITECNICO DI BARI

The by-pass inverter

Four-quadrant 200 kVA three-phase AC/AC converter

Main functions of the inverter:

- Decoupling the μG from the distribution grid;
- Direct control of the power exchanged with the distribution grid;
- Regenerative loads;
- Emulation of additional generation;
- Bumpless transition.

Generation facilities - CHP system

- The gas-fuelled CHP has a rated power of 120 kW.

- The system is equipped with a multi-inverter machine combined with a variable-speed thermo-electric generation unit including two separate engines, able to keep its maximum global efficiency in the range from 15% to 100% of its rated power.

Electric characteristics		
Rated electric power	[kWe]	104
Rated thermal power	[kW]	185
Electric power efficiency	[%]	31,5
Thermal efficiency	[%]	56
Engine RPM	[rpm]	Variable from 900 to 2,500
Reactive power		Adjustable from capacity to induttive

PrInCE POLITECNICO DI BARI

Generation facilities - Microturbine

- The Capstone C30 turbine has a rated power of 30 kW.

- The gas microturbine consists of a tiny turbo-charger rotor that spins at up to 96,000 rpm with a direct coupled permanent magnet generator.

- The micro-turbine is equipped with an heat exchanger, that could be combined with the gas-fuelled engine and other systems installed in the laboratory and used for cogeneration applications.

Electric characteristics		
Rated electric power	[kW]	30
Fuel consumption	[MJ/h]	457
Exhaust gas mass flow rate	[kg/s]	0,31
Electrical efficiency	[%]	26

PrInCE POLITECNICO DI BARI

Generation facilities - PV system

- The PV generator is installed on the roof of the parking lots of the lab.

- It is made up by 242 PV modules with five different technologies, for a total power of about 50 kW.
- These modules are organized into five sub-arrays with different technologies and a rated power of about 10 kW each.
- Each of the five sub-arrays is connected to the AC microgrid through an inverter able to comply with any reactive control signal coming from the network operator.

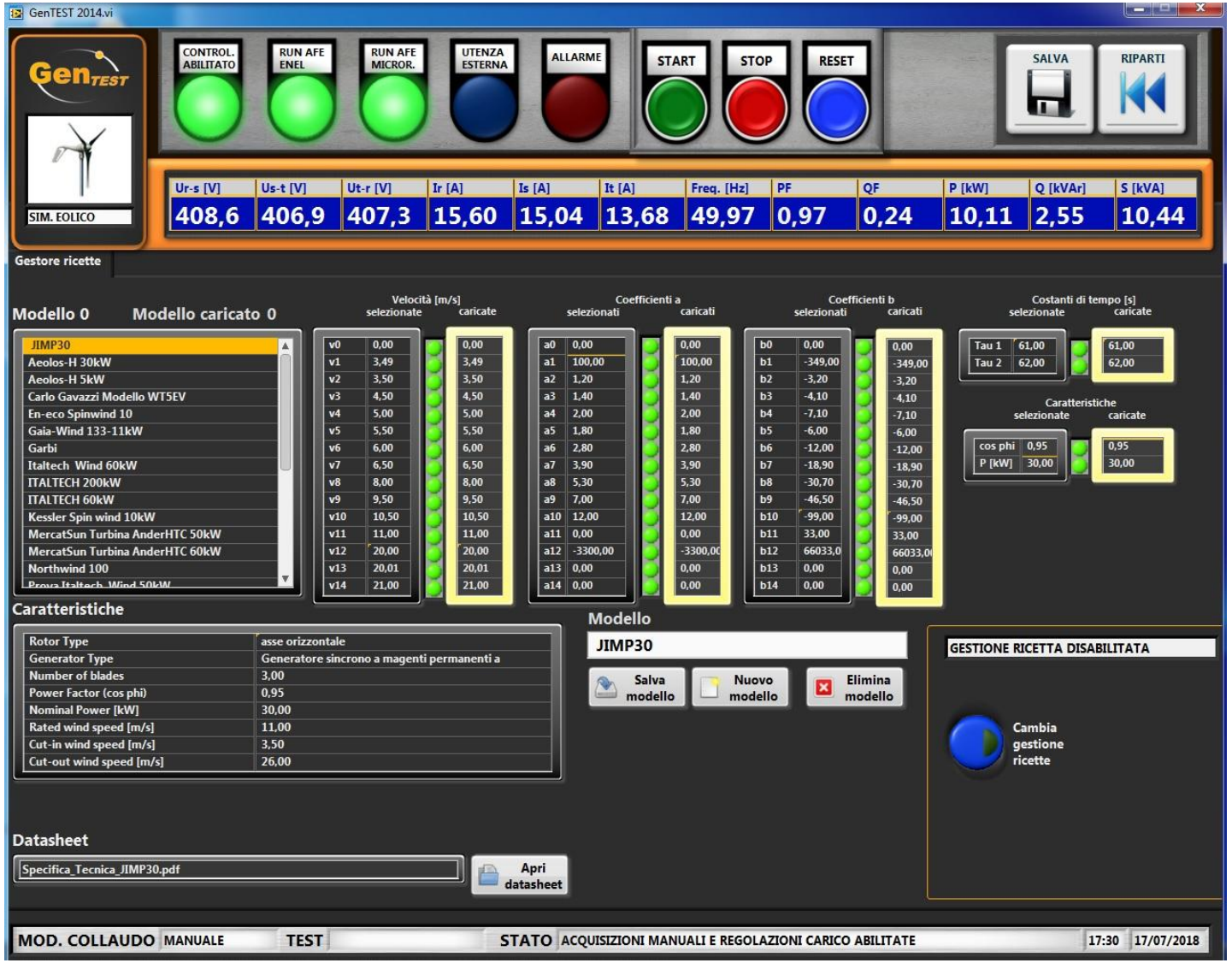
Sub-arrays	Electric characteristics				
	Maximum output power rating [kWp]	Type of modules	N. of strings	N. of modules per string	Total modules
GFV1	9.216	triple-junction a-Si	4	16	64
GFV2	10.53	Mono-Si	2	19+20	39
GFV3	10.5	Poly-Si	2	21	42
GFV4	9.6	CIS	8	8	64
GFV5	9.9	Mono N-Type	2	17 + 16	33

PrINCE POLITECNICO DI BARI

Generation facilities - Wind Turbine Emulator

- The wind turbine emulator has a rated power of 60 kW.
- It consists of a four-quadrant three-phase AC/AC converter equipped with a microcontroller and a Personal Computer (PC).
- Several mathematical models have been implemented into the microcontroller to emulate the behavior of static and dynamic models of wind generators.
- In order to test several wind turbine models under time-varying wind speeds, an anemometer installed on the roof of the laboratory feeds the wind turbine emulator.
- The software is also able to accept as an input the wind speed profile defined by recorded data.

Generation facilities - Wind Turbine Emulator



PrInCE
POLITECNICO DI BARI

Storage devices - Battery Energy Storage System

- This device is composed of two Sodium-Nichel battery banks for a total storage capacity of 180 kWh and a maximum charge/discharge power of 60 kW.

- It is connected to the μG through a bi-directional converter which allows active and reactive flows in both directions.

- The system is supported by a master controller able to monitor in real-time the state of charge and to follow the control signal coming from the SCADA system.

Storage devices - Vehicle-to-Grid (V2G)

- The V2G system is composed by a charging station for fast (DC) charging and discharging of electrical vehicles.

- DC charging station is connected to the μG through a four-quadrant converter which allows electrical vehicles to supply energy and ancillary services to the μG.

- The charging/discharging schedules will be generated by the μG controller (the SCADA) through specific control strategies.

PRINCE
POLITECNICO DI BARI

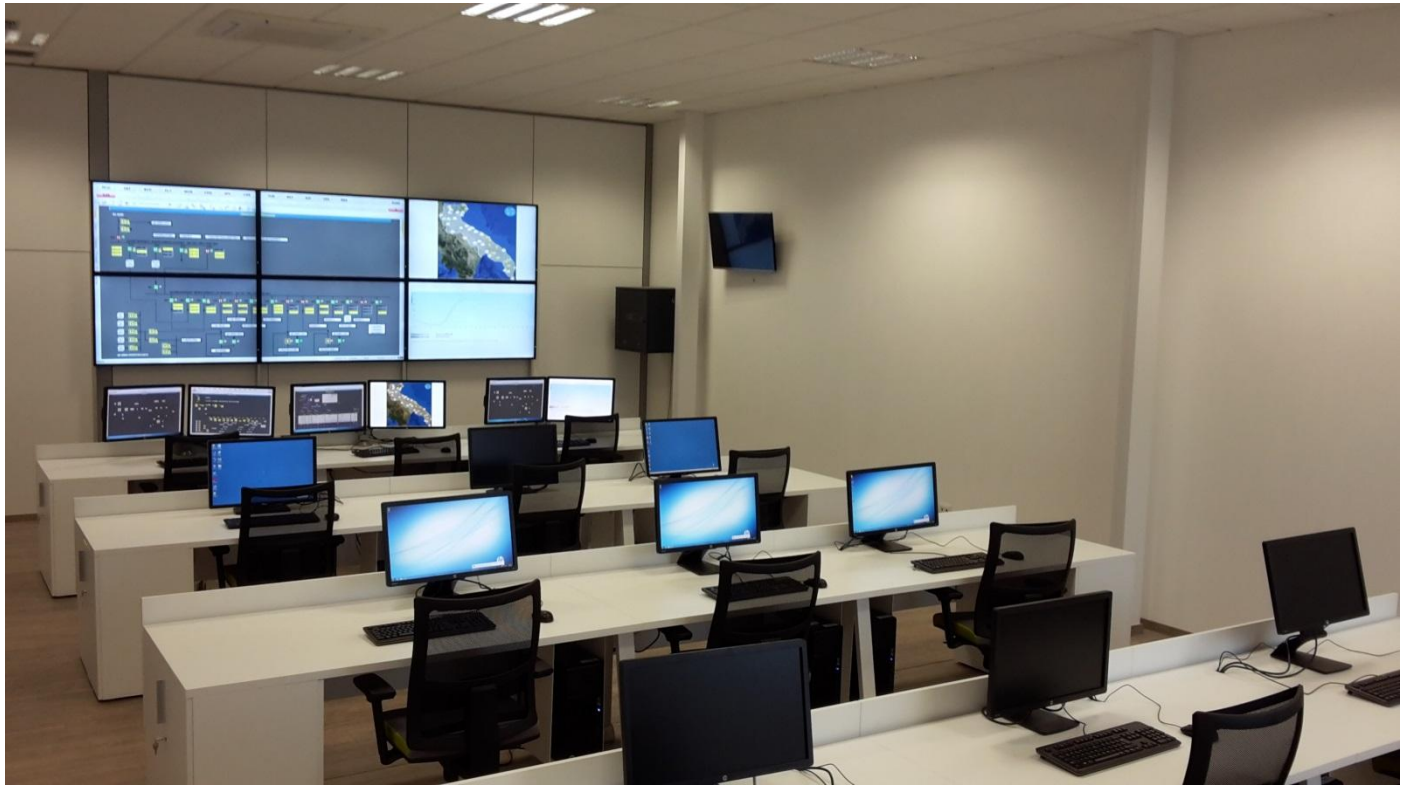
Loads - Programmable Loads

The two programmable loads have a rated power equal to 150 kVA each.

They are equipped with an inverter connected to a set of resistances loading the system up to 120 kW. The same converter can provide an inductive or capacitive load.

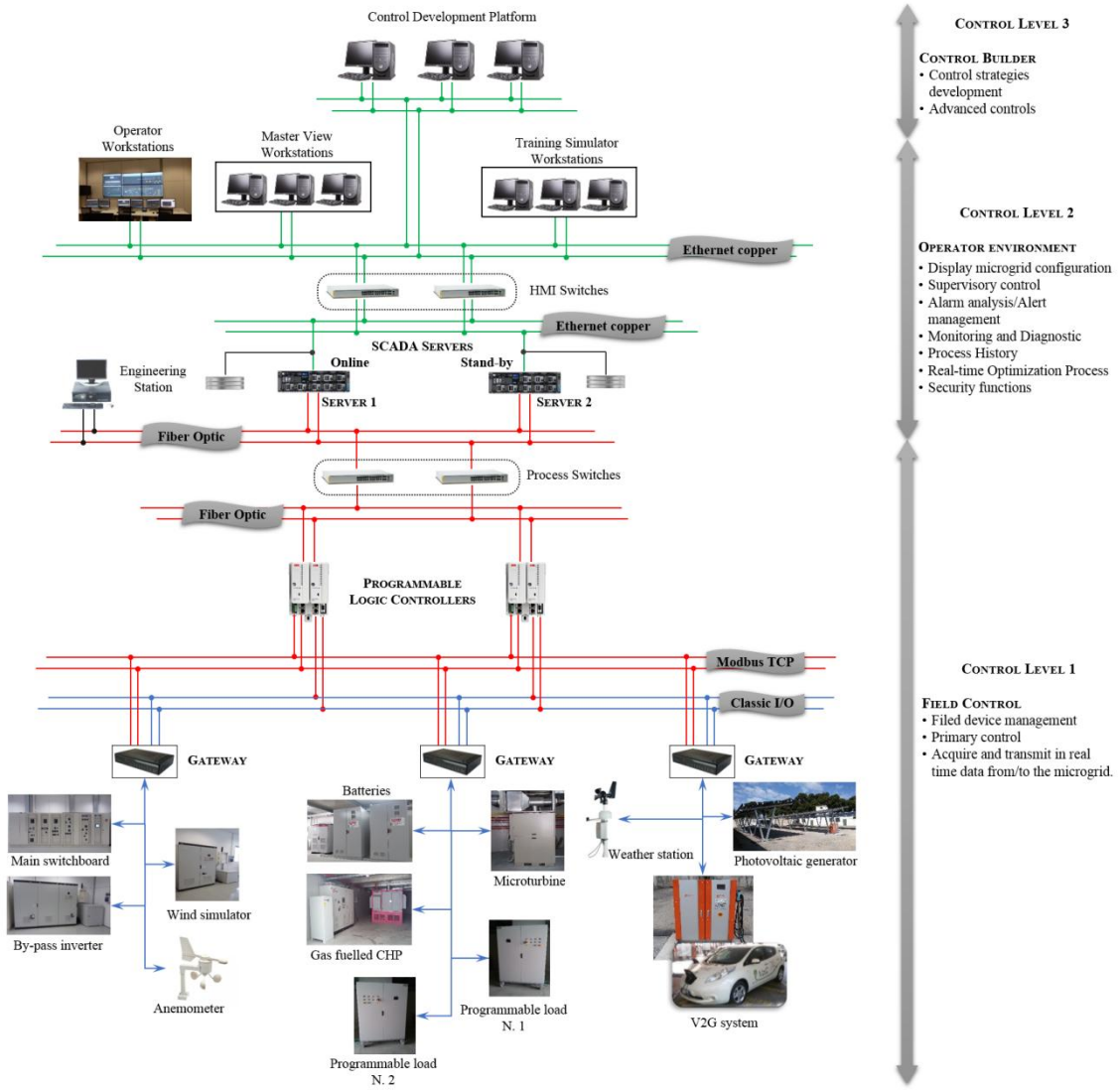
- The local controller is equipped with an ad-hoc software tool allowing to implement load curves.

Control Room



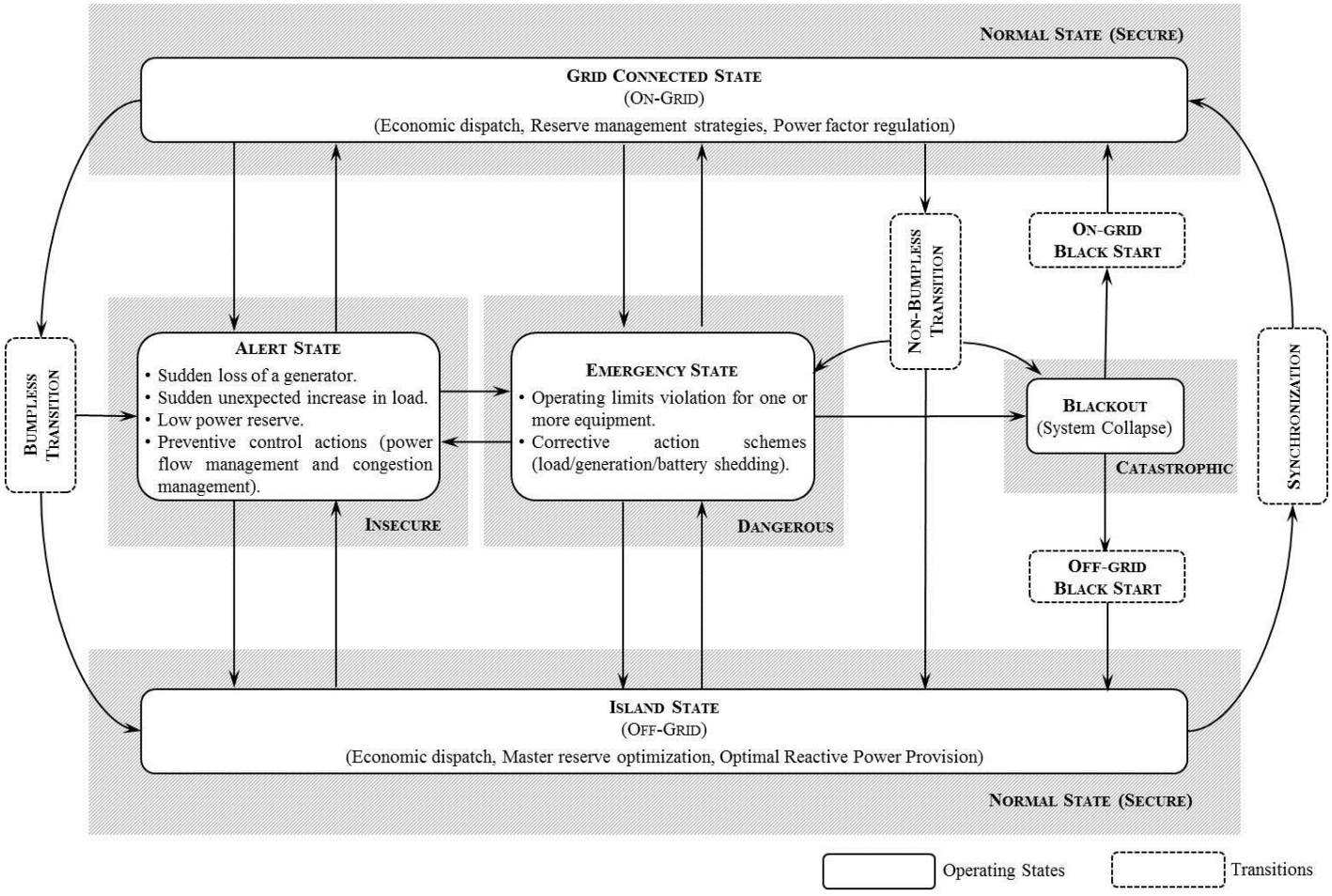
- In a control room hosting 6 client PCs, the operator can control and monitor the overall AC microgrid.

SCADA System – Logical and physical structure

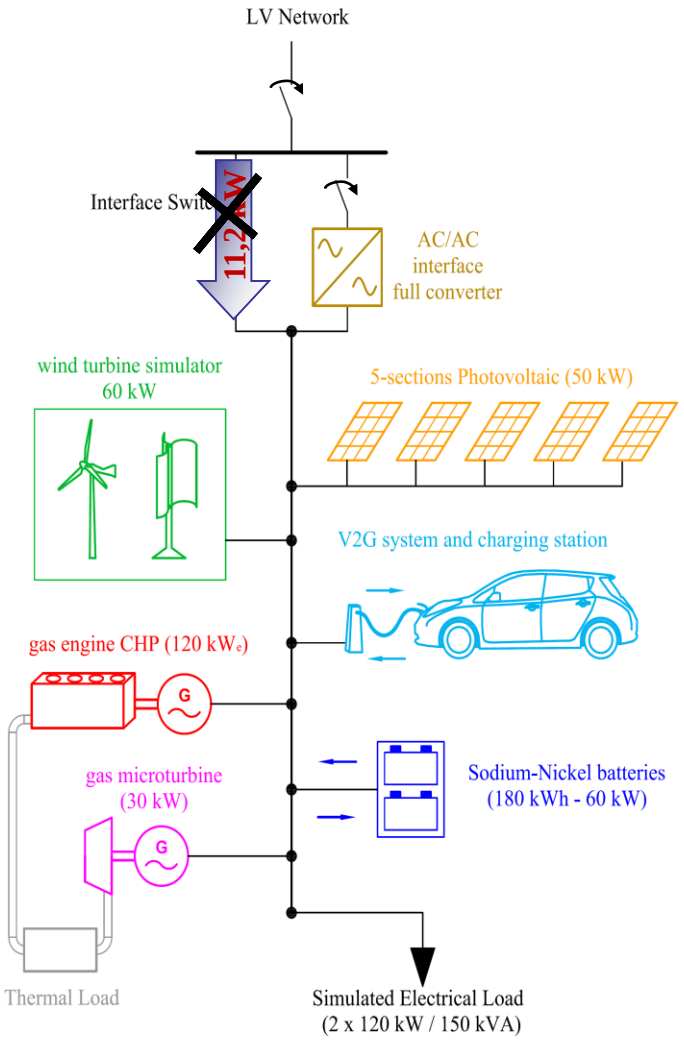


PrInCE
POLITECNICO DI BARI

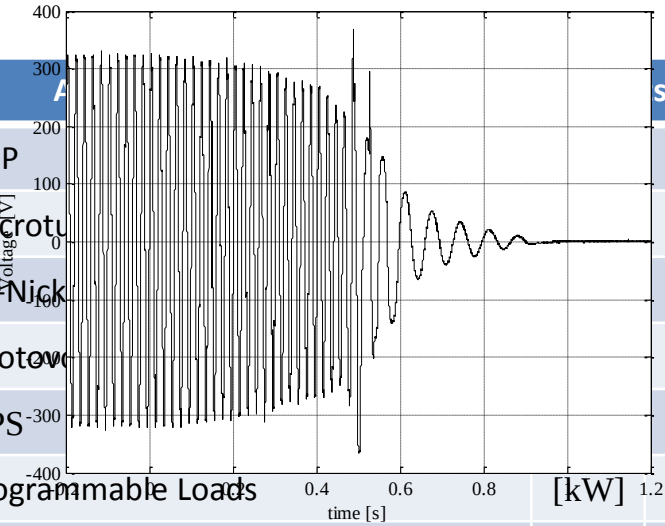
Energy Management System - Control Strategies

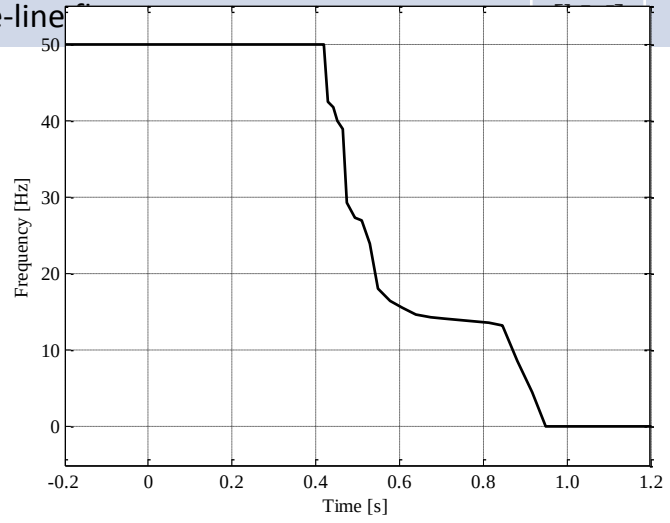


Test Case I – Blackout



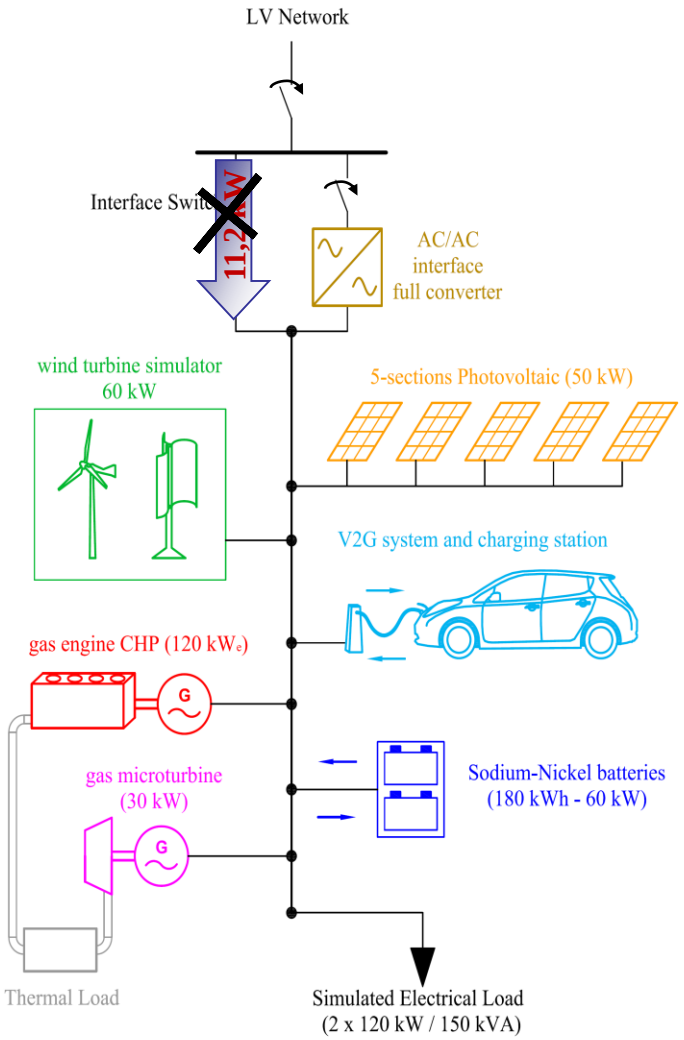
A	s
CHP	27,2
Microtu	1,7
So-Nick	4
Photov	19,3
UPS	-9,4
Programmable Loads [kW]	-54
Tie-line	11,2



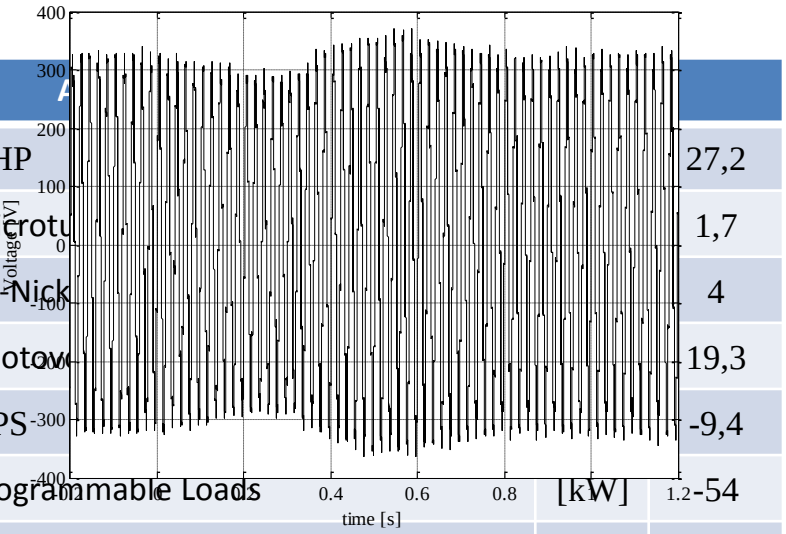


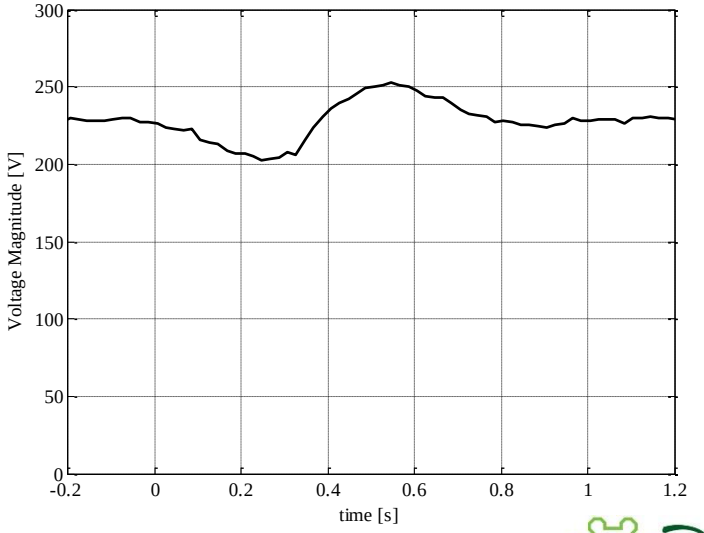
PRINCE
POLITECNICO DI BARI

Test Case II – Emergency islanding



CHP		27,2
Microtu		1,7
So-Nick		4
Photov		19,3
UPS		-9,4
Programmable Loads	[kW]	-54
Tie-line flow	[kW]	11,2





PRINCE
POLITECNICO DI BARI

Work Done

- Parallel/Island operation
- Reserve management
- Dynamic model of the overall system for Dynamic Security Assessment & Control
- Day-ahead Economic Dispatch
- On-line Economic Dispatch

Work to do

- Influence evaluation on distribution systems (technical end economic aspects)
- Load following
- Improving the robustness of the emergency islanding
- Testing other functions for the optimal operation
- Integration of other devices (flywheels, supercapacitors, fuel cells)
- Integration of droop controlled devices
- Open Source platform for exchanging data with the scientific community.
- … Other Ideas? We are available for cooperations with you.

Thank You

Enrico De Tuglie
enricoelio.detuglie@poliba.it

PrInCE
POLITECNICO DI BARI