Examining The New Challenges In Coordinated Control And Communications For Microgrid Technologies

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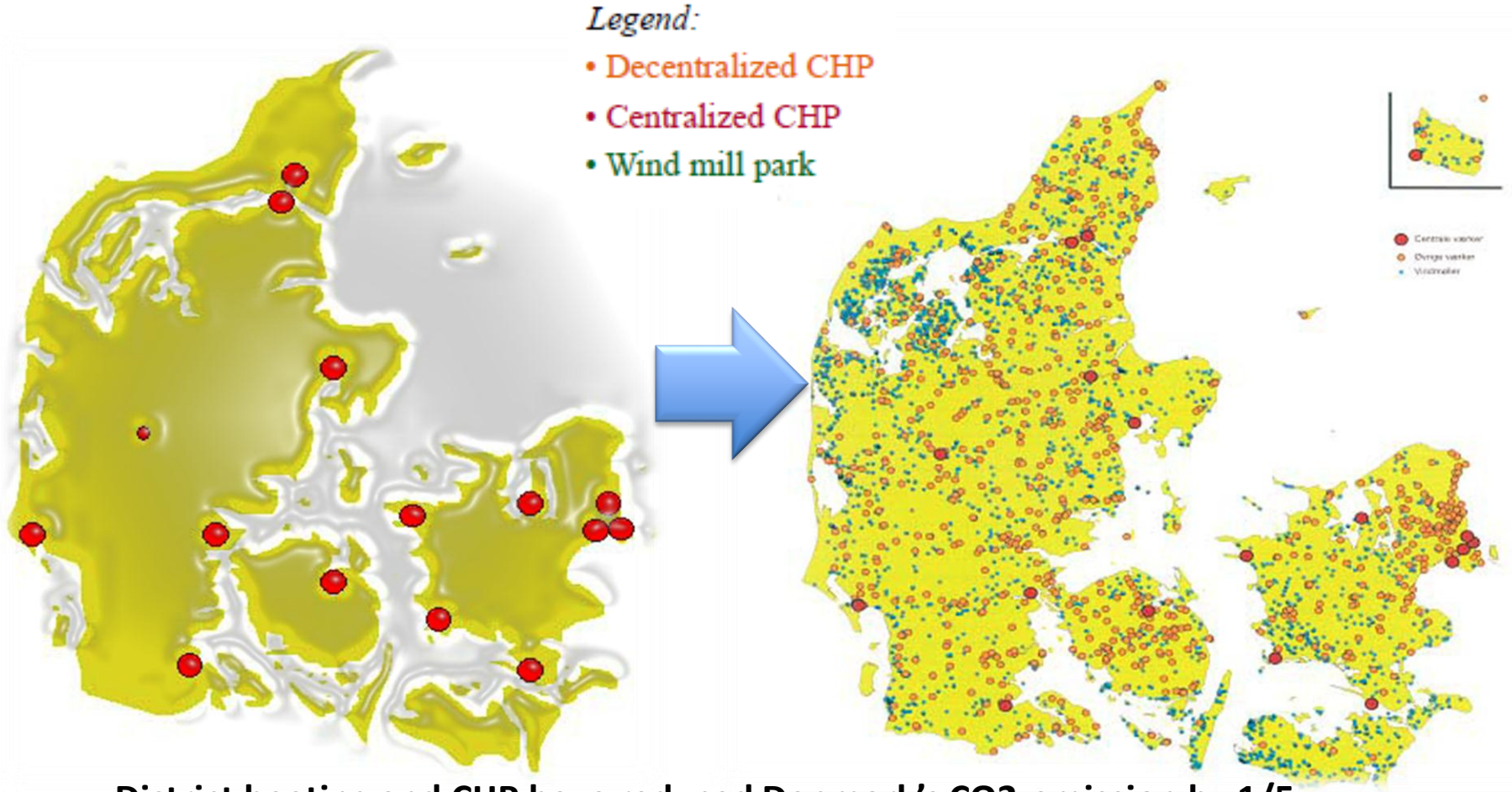
Denmark, Grønland, and Faroe Islands

Area	
Denmark	43,094 km^2
Greenland	2,166,086 km^2
Faroe Islands	1,399 km^2
Population	5,543,453
Greenland	57,695
Faroe Islands	49,483

Denmark energy

Centralized production in the mid 80's ***Decentralized production of today***



District heating and CHP have reduced Denmark's CO2-emission by 1/5.

IEEE

Aalborg University

Aalborg University was created through a merger of a number of well-established institutions, combined with the establishment of a number of new faculties in 1974.

Aalborg University was characterised by its well-reputed education form of **problem based project (PBL) work** – also known as the ***Aalborg model.*** The number of students is around 15,000.

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Organisation – Department of Energy Techonolgy

- Electric Power Systems
- Power Electronic Systems
- Electrical Machines
- Fluid Power Mechatronic Systems
- Mechanics and Combustion
- Thermal Energy Systems

Multi-disciplinary Research Programmes

- Wind Turbine Systems
- Fluid Power in Wind and Wave Energy
- Biomass
- **Microgrids**
- Photovoltaic Systems
- Modern Power Transmission Systems
- Smart Grids and Active Networks
- Fuel Cell and Battery Systems
- Automotive and Industrial Drives

- ***Approximately 40 faculty members***
- ***Approximately 70 PhD students***
- ***Approximately 20 TAPs (technical administrative employees)***
- ***Approximately 250 students***
- ***Approximately 50% of the turnover comes from external projects***

Microgrid research group

Program Coordinators

Josep M. Guerrero

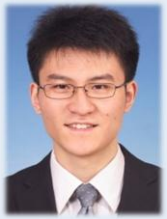
Juan C. Vasquez

Post Docs / A. Prof.

Tomislav Dragicevic
DC MGs

Fen Tang
Windpowered MGs

PhDs



Lexuan Meng
Tertiary Control
EMS Optimization

Qobad Shafiee
Secondary Control

Yajuan Guan
AC/DC Microgrid Modeling

Wu Dan
Primary Control

Nelson Diaz
Energy storage for MicroGrids

Chendan Li
MGs Agents

Outline

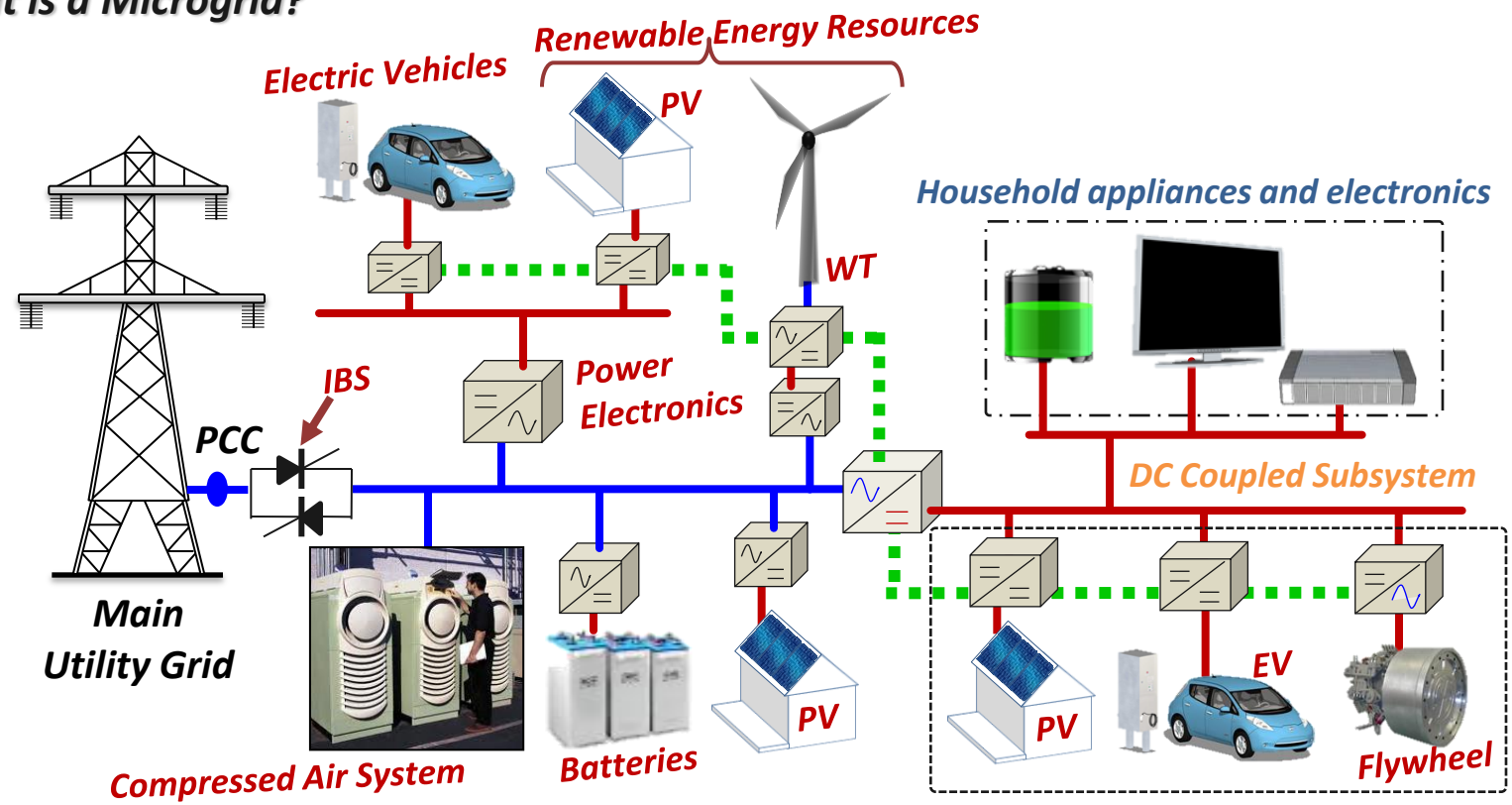
- Microgrid Definition and Operation
- Microgrid Research Programme in AAU
- Microgrid Research Activities and Laboratories

CIGRÉ C6.22 Working Group Definition:

Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded.

Hybrid AC/DC Microgrids

What is a Microgrid?



Hybrid AC/DC Microgrids

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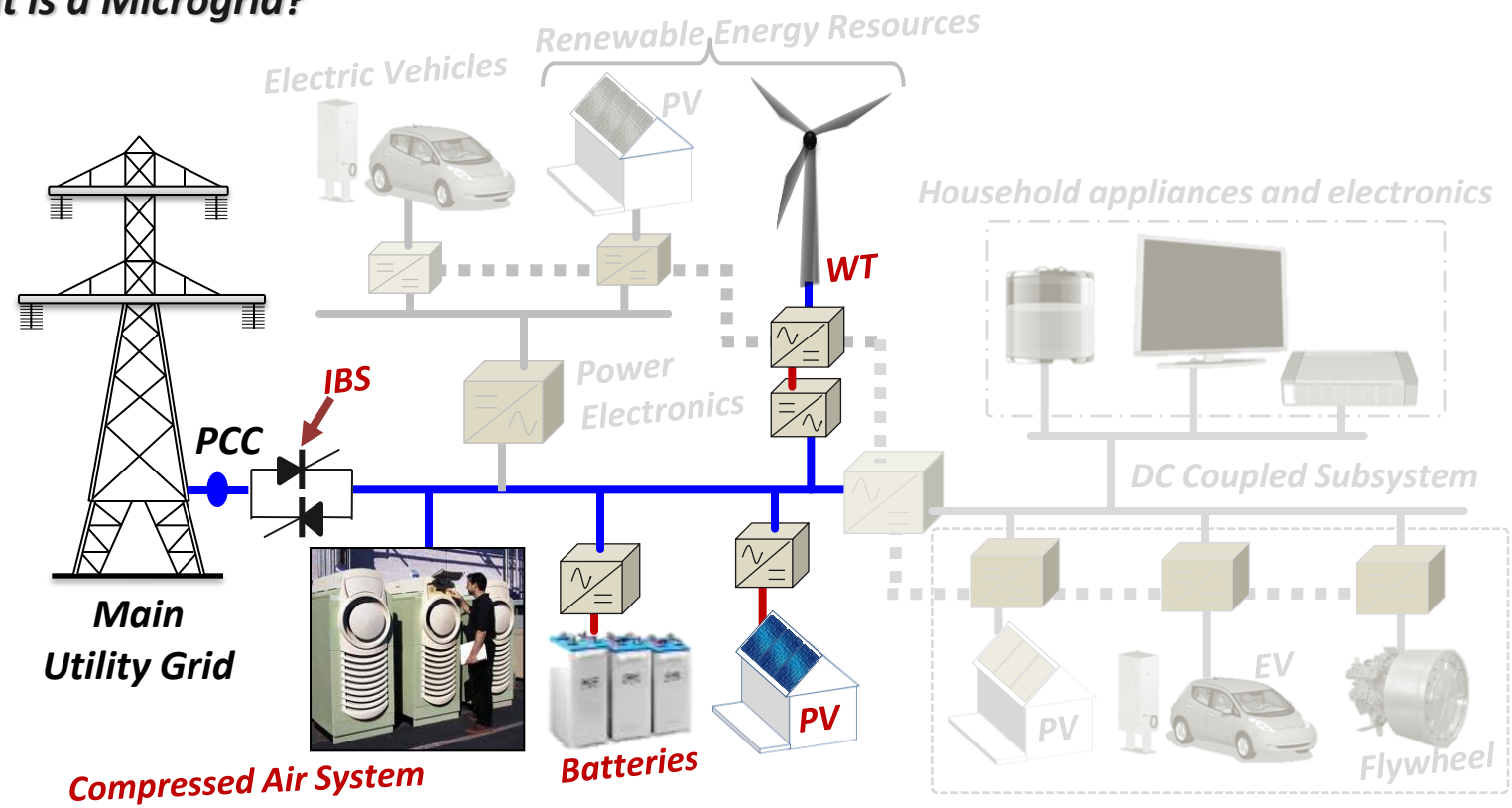
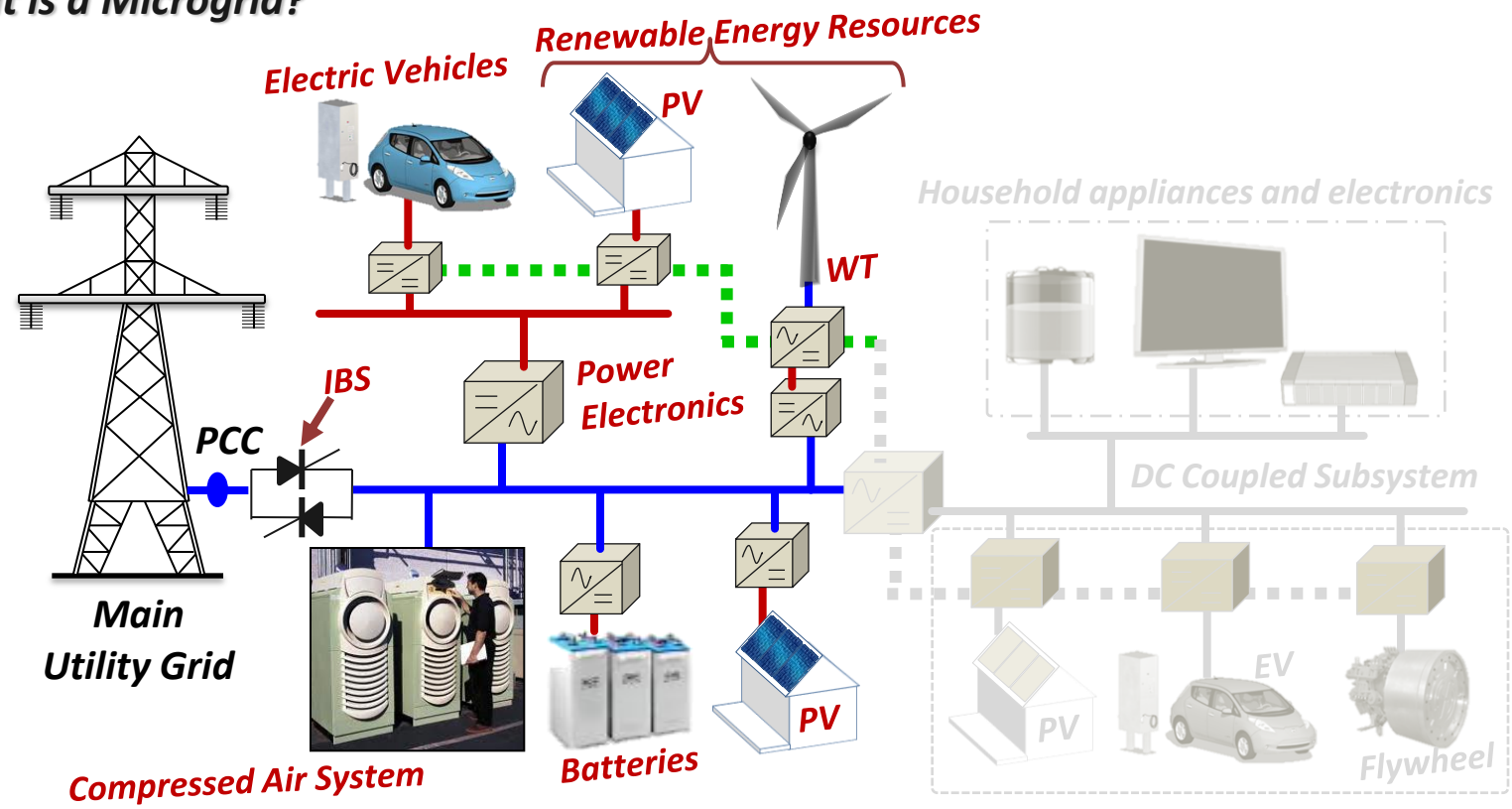


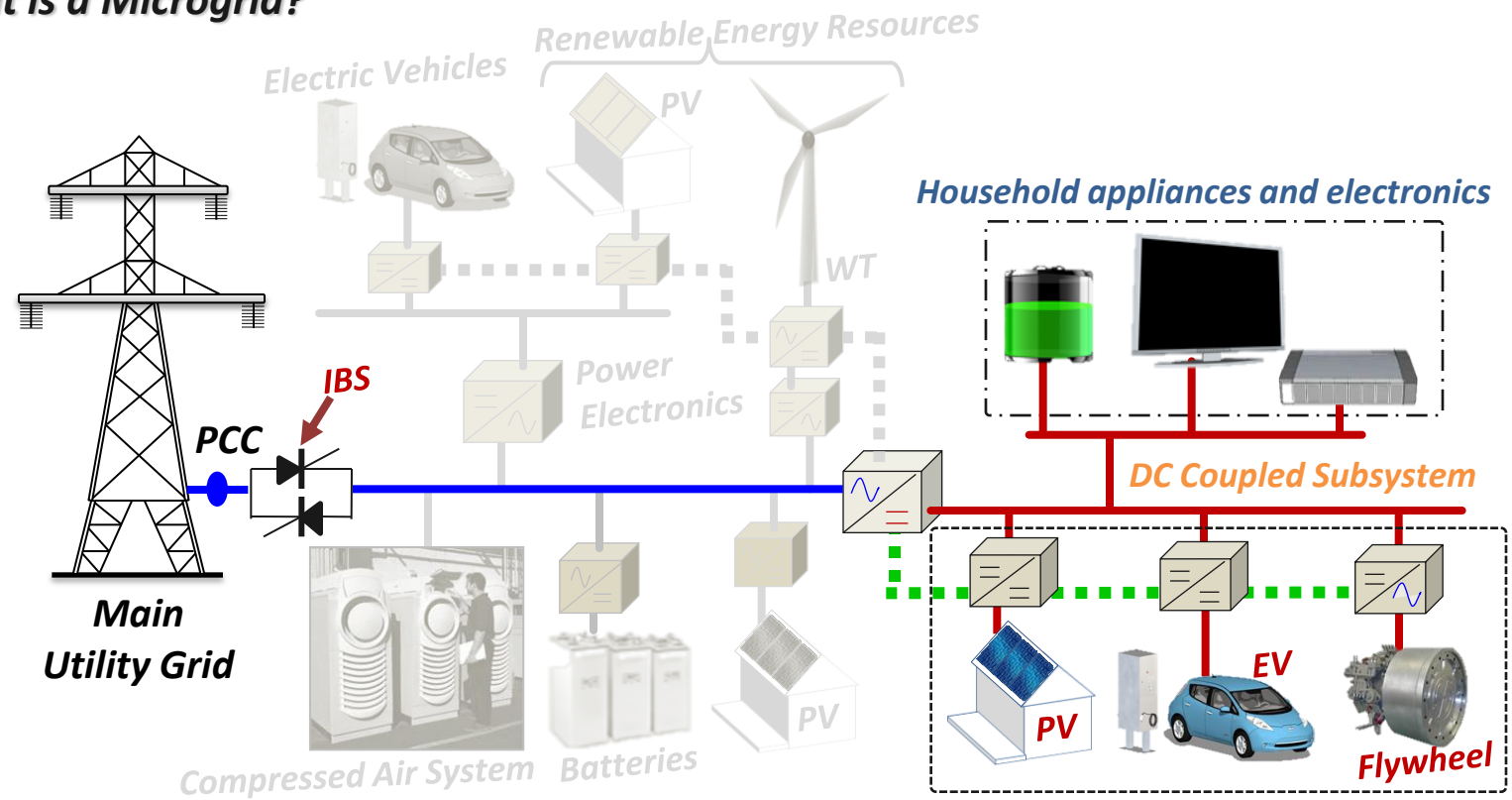
Hybrid AC/DC Microgrids

What is a Microgrid?



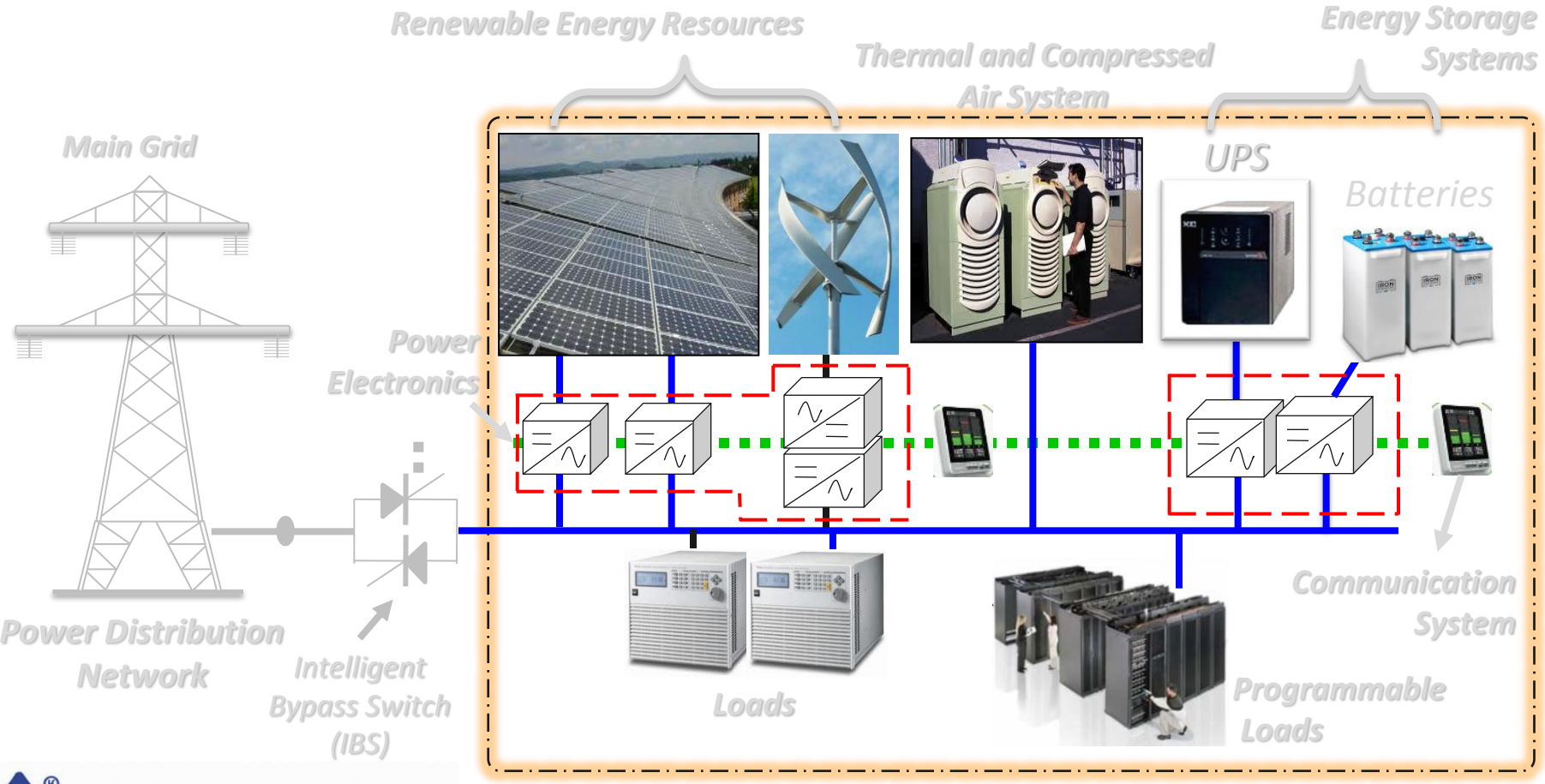
DC Coupled subsystem

What is a Microgrid?



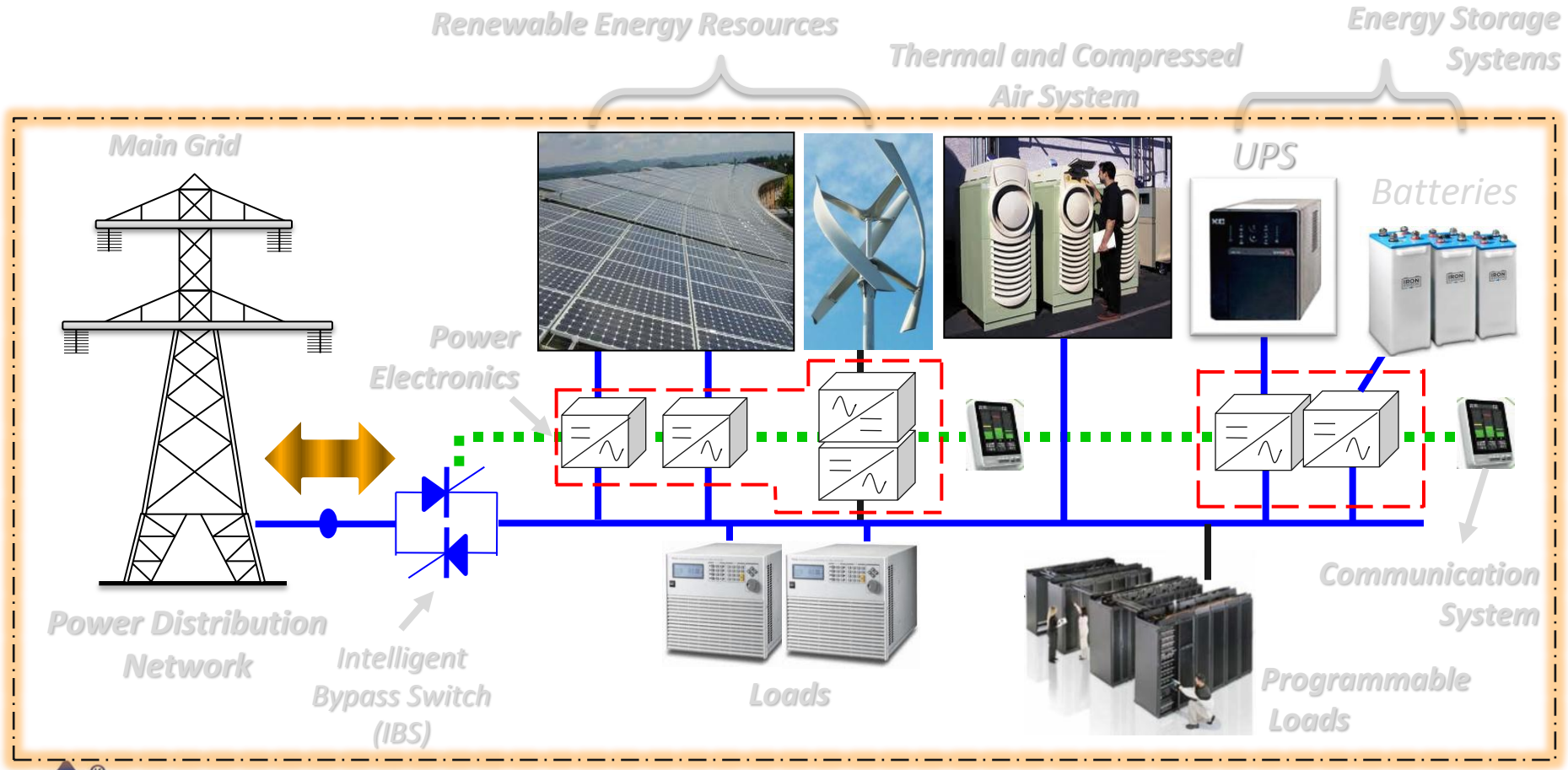
General aspects of a Microgrid: "Definition and Operation"

Modes of Operation: ISLANDED



General aspects of a MicroGrid: "Definition and Operation"

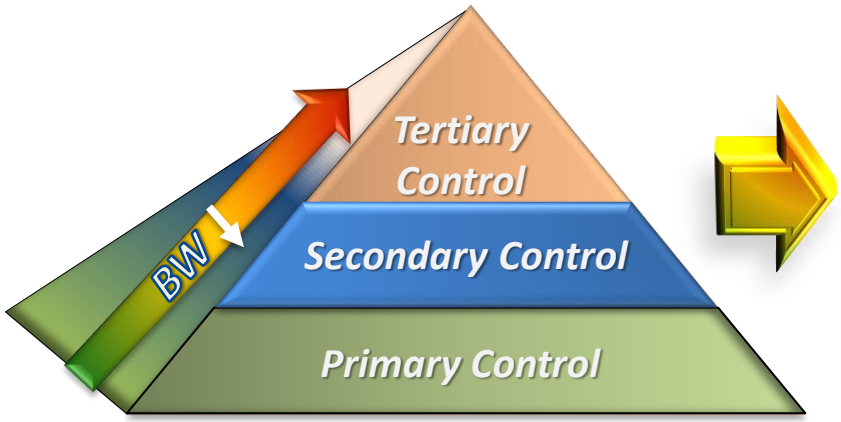
Modes of Operation: GRID CONNECTED

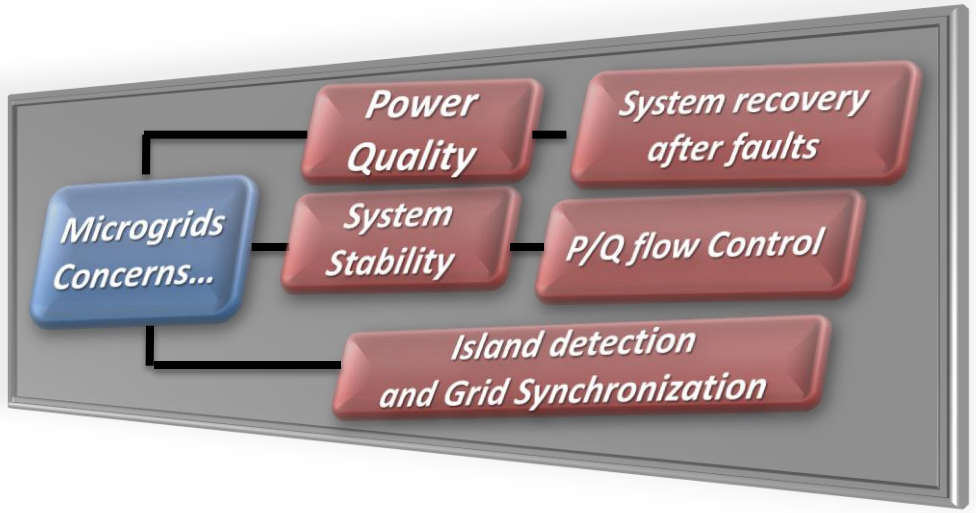


General aspects of a MicroGrid: "Definition and Operation"

Hierarchical Control for MicroGrids

- ***Primary Control*: Modeling + Inner loops + droop Control (P/Q Sharing).**
- ***Secondary Control*:**
  - ***f/V Restoration (Island) :*** *Set-points assignation from MGCC to the DGs .*
  - ***Synchronization (Island to grid Connected mode)***
- ***Tertiary Control*: Power Import/export from/to the grid.**





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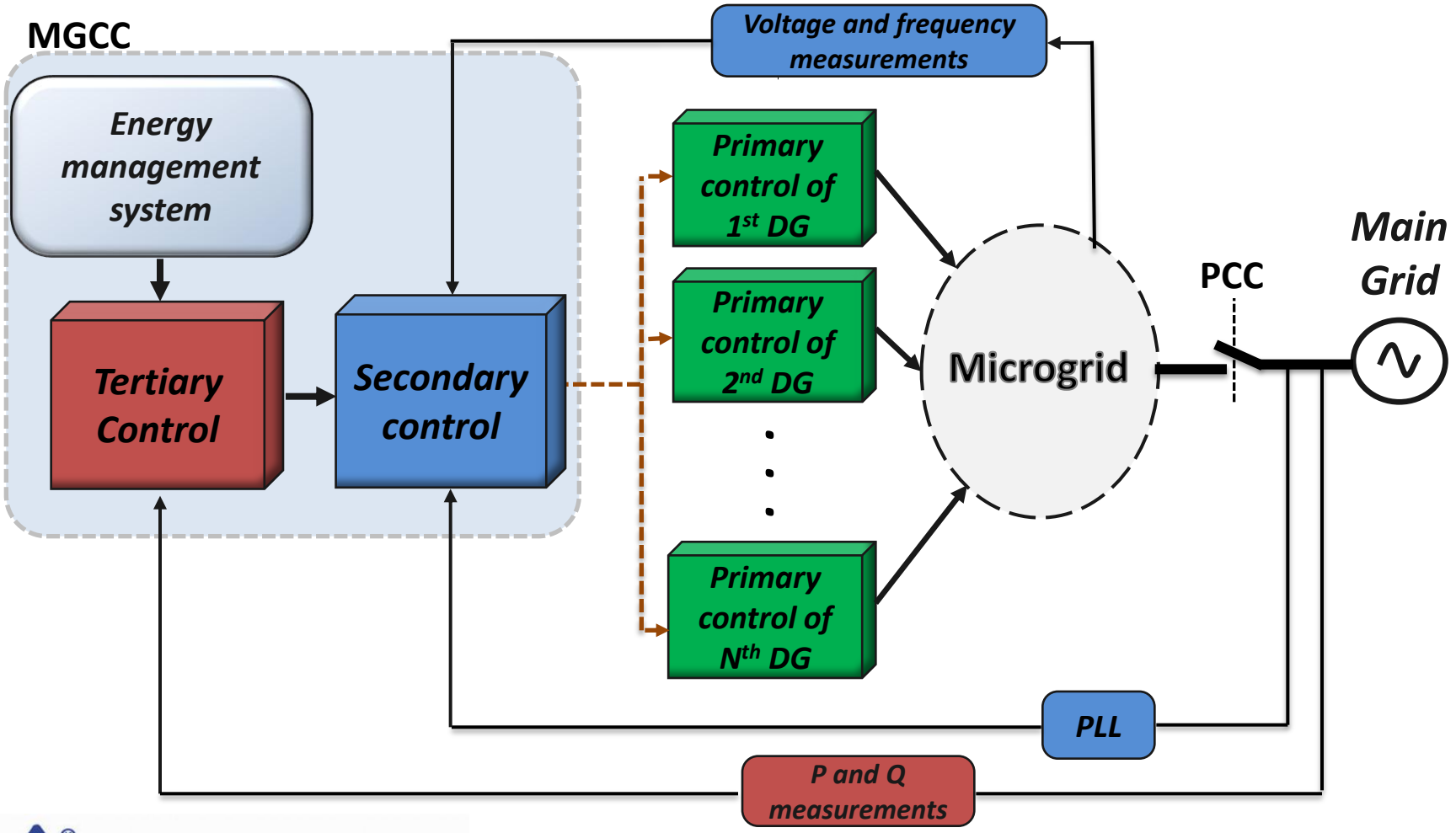
Hierarchical control of Microgrids



Microgrids research challenges

- Modelling, Control & Operation
- Distributed Control
- Integration of Energy Storage
- Standard-based ICT
- EMS Optimization
- Protection Schemes
- Power Quality

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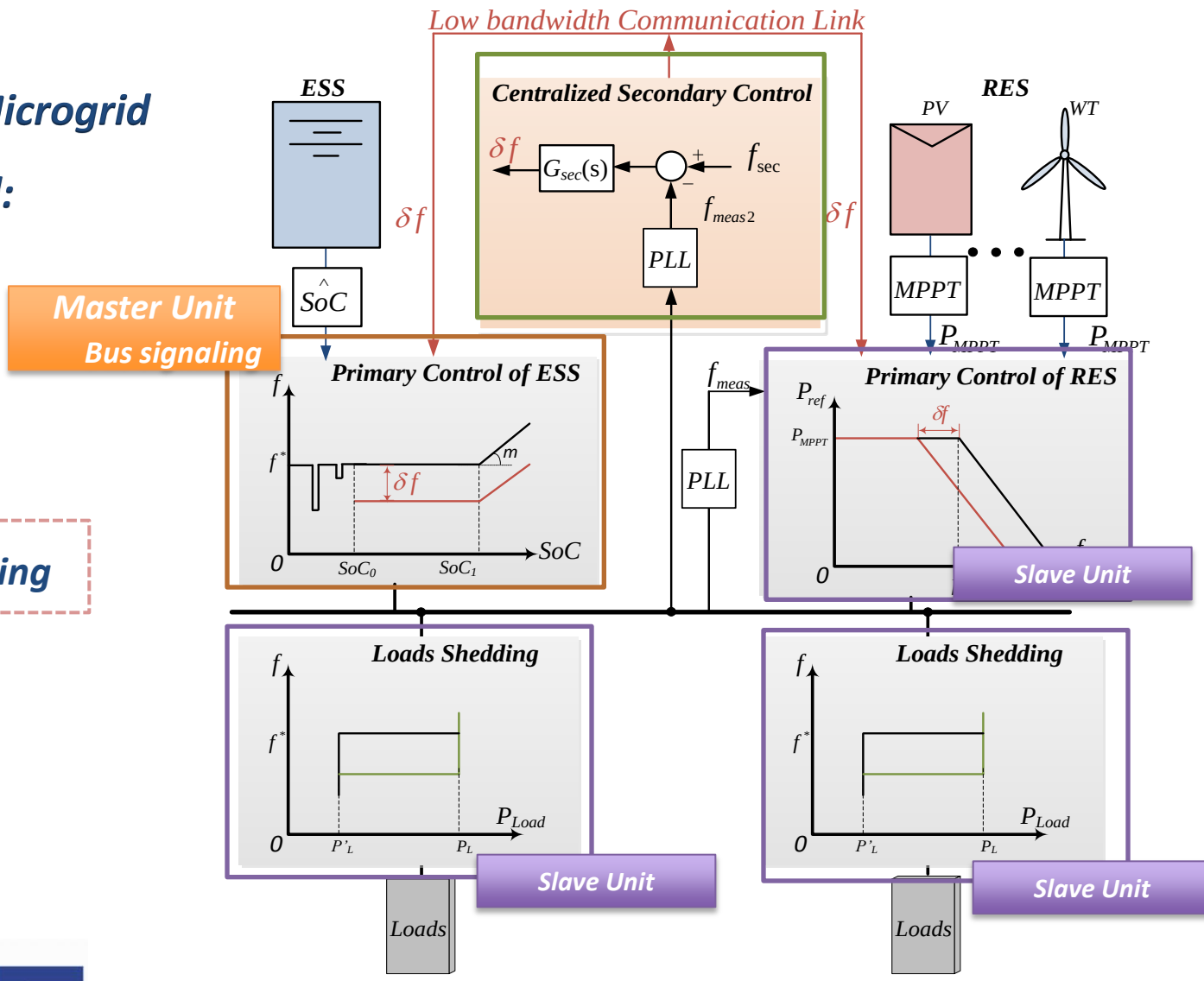
Microgrids research – primary control

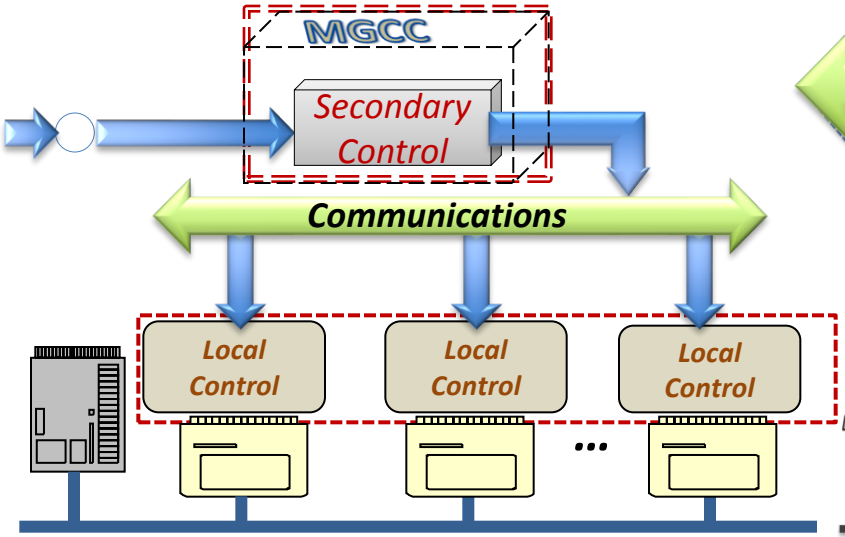
AC Low voltage Microgrid coordinated control:

Bus frequency signaling

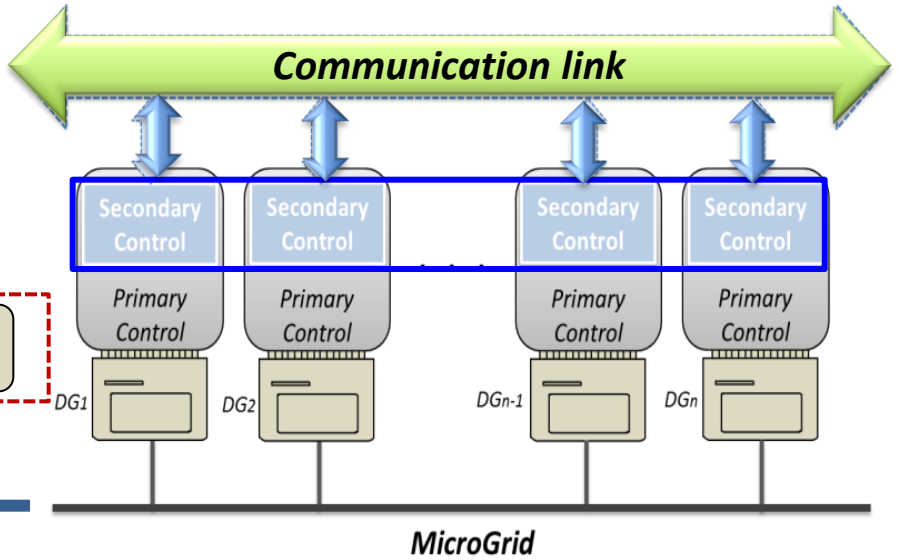


Microgrids research – secondary control

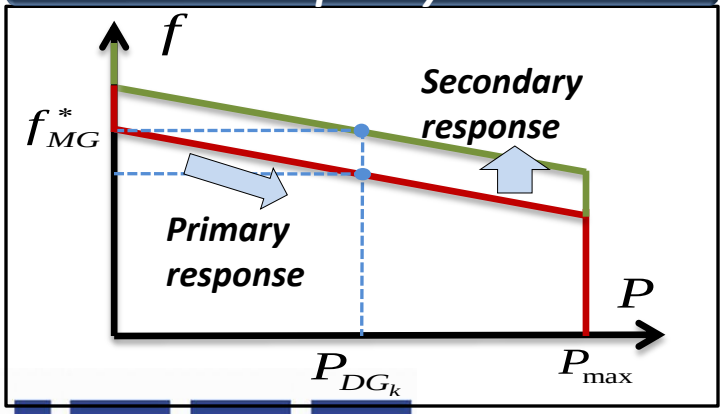
Centralized



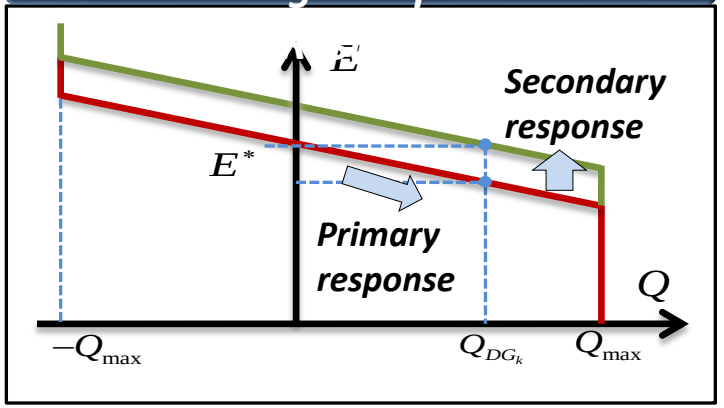
Distributed



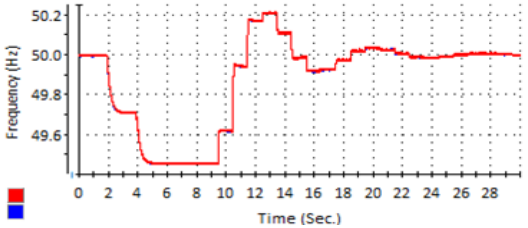
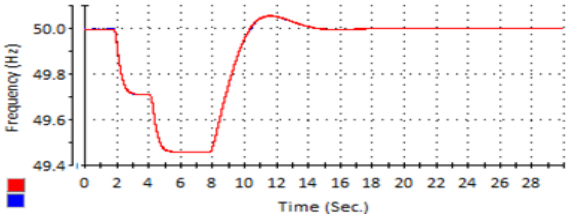
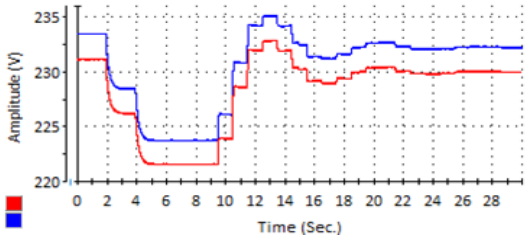
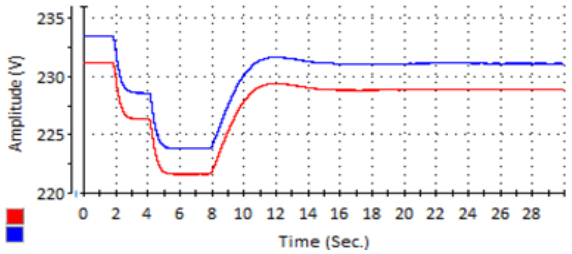
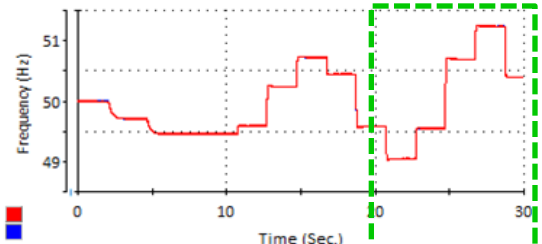
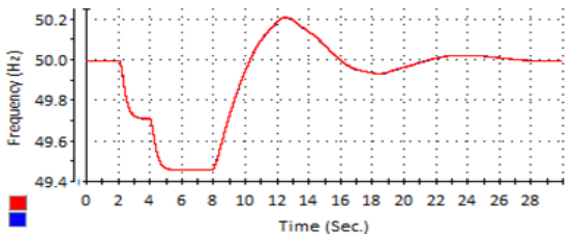
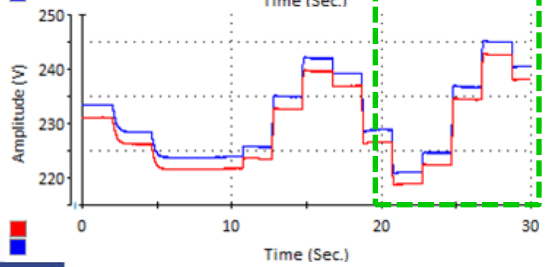
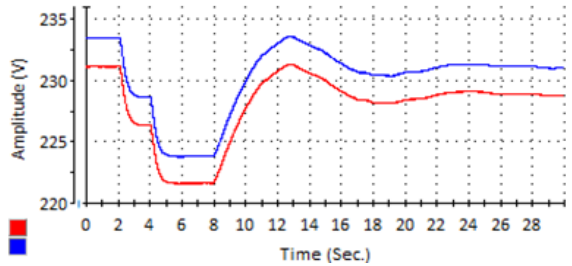
Frequency



Voltage Amplitude



Microgrids research – secondary control

Time Delay	Centralized Secondary Control	Distributed Secondary Control
1 sec.	Frequency Restoration		
	Voltage Restoration		
2 sec.	Frequency Restoration		
	Voltage Restoration		

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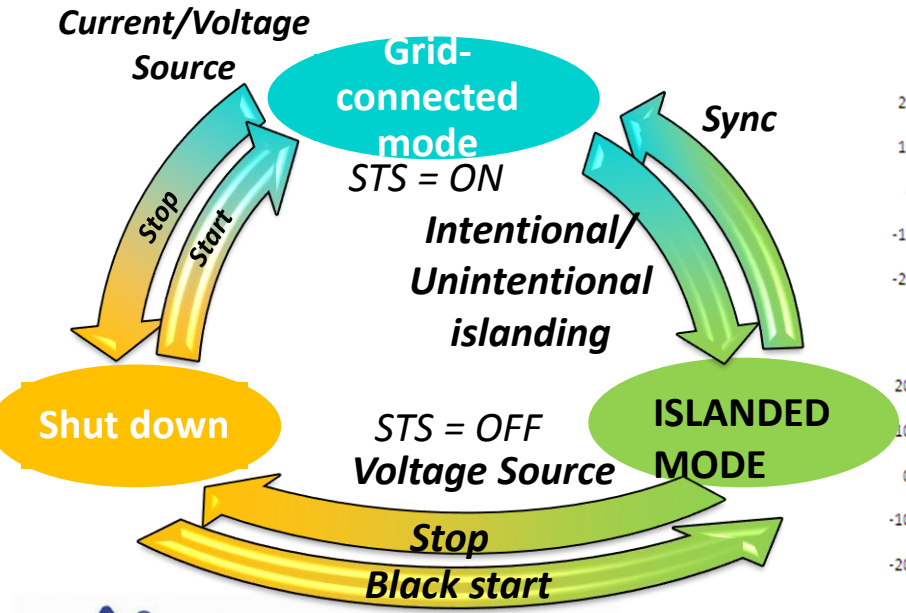
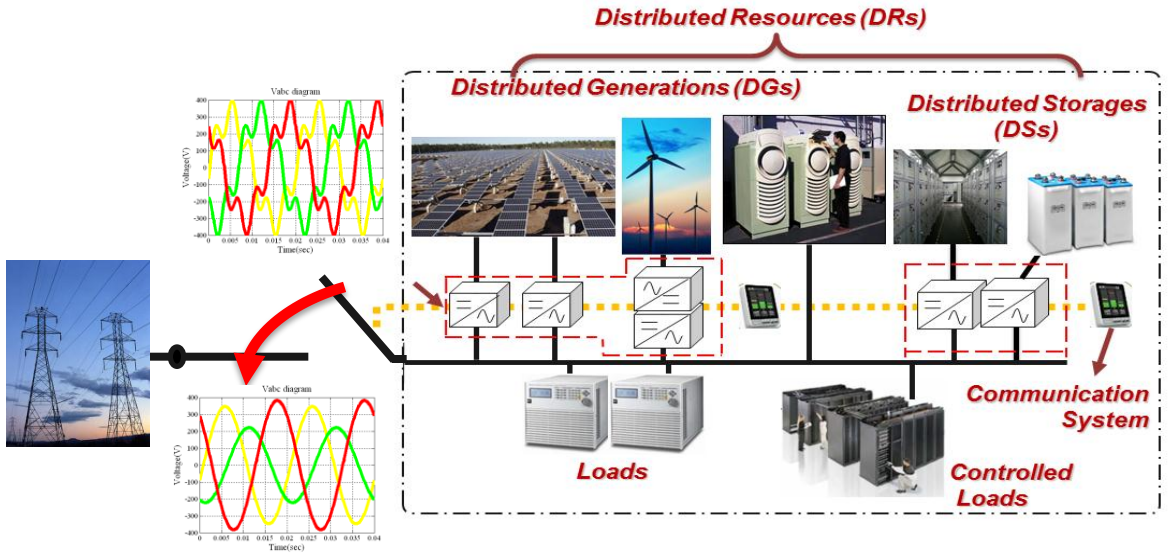
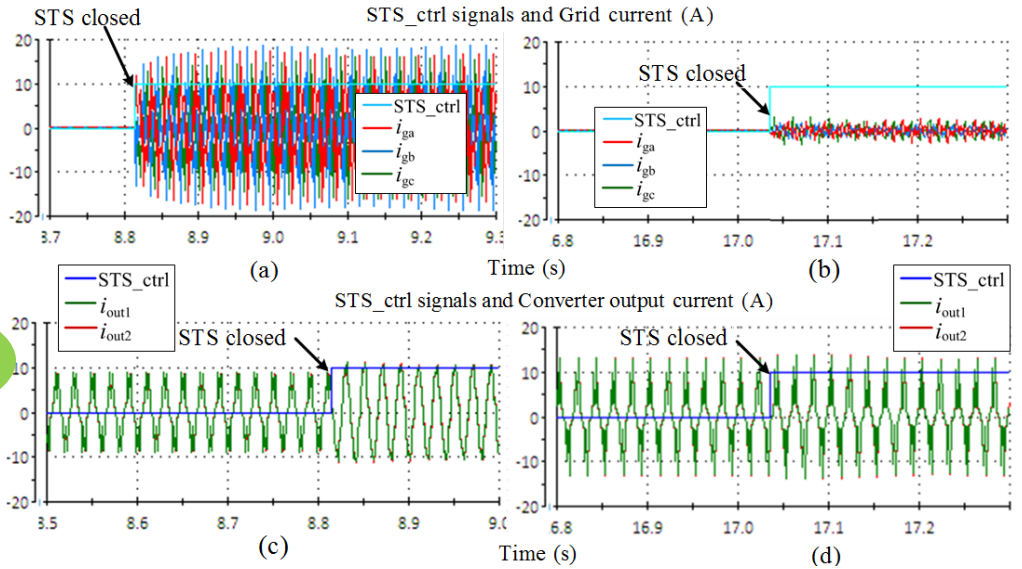
Microgrids research - synchronization

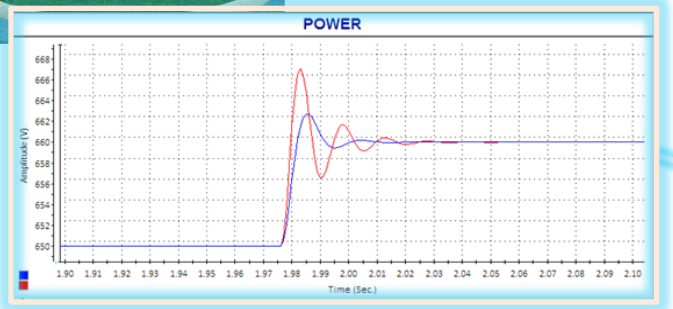
Distributed Active Synchronization for Microgrid under Unbalance and Harmonic Distortions

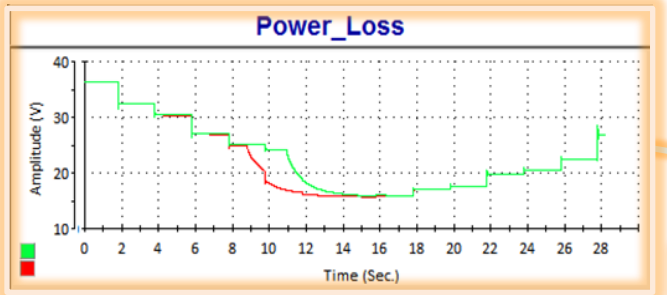


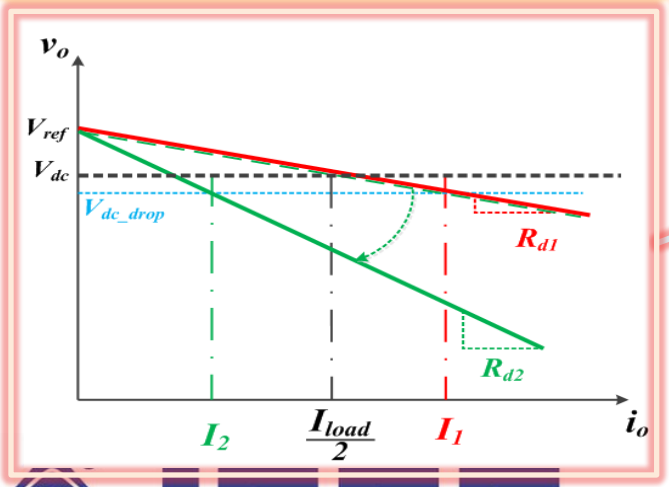


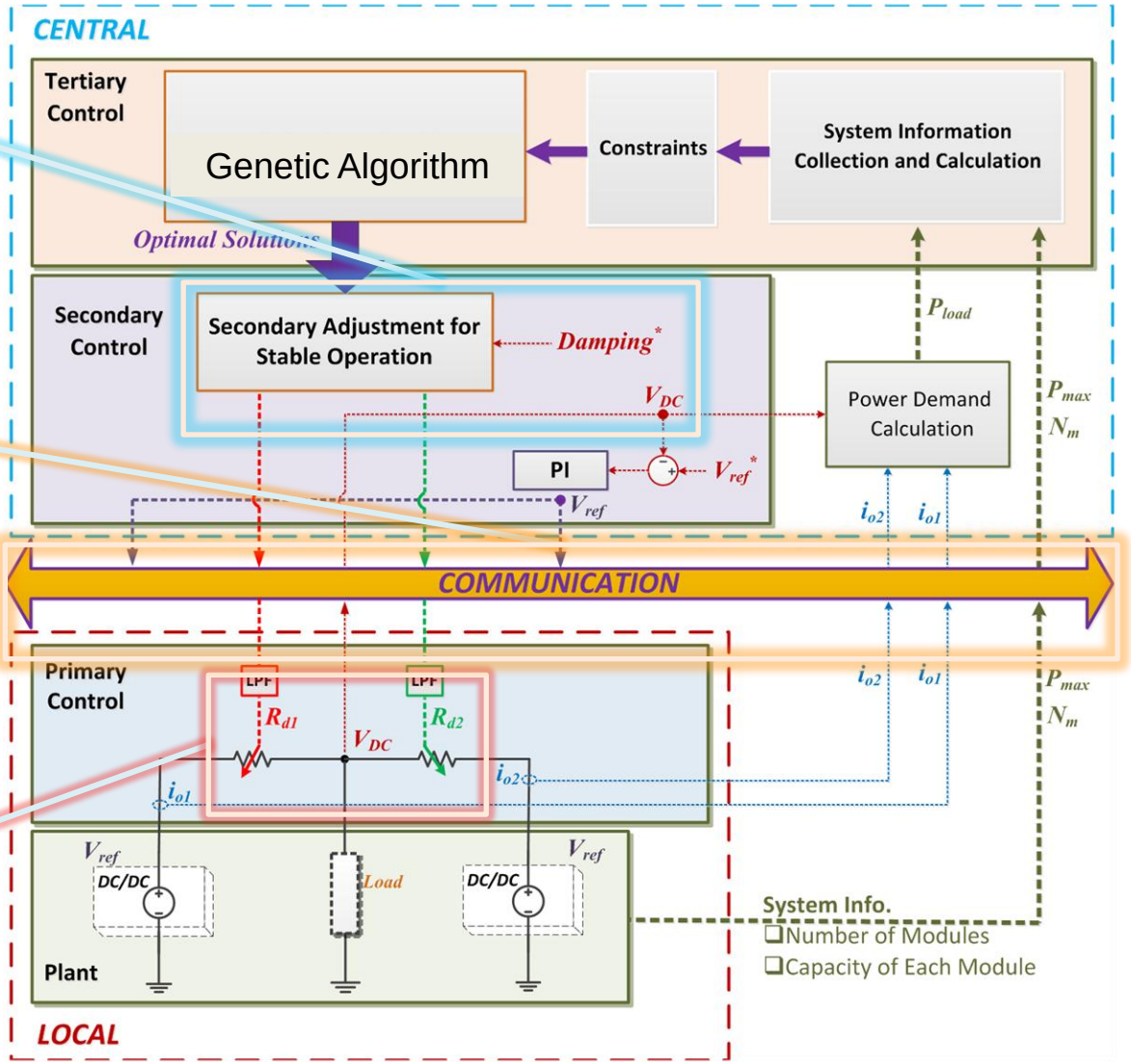


Microgrids research – tertiary control





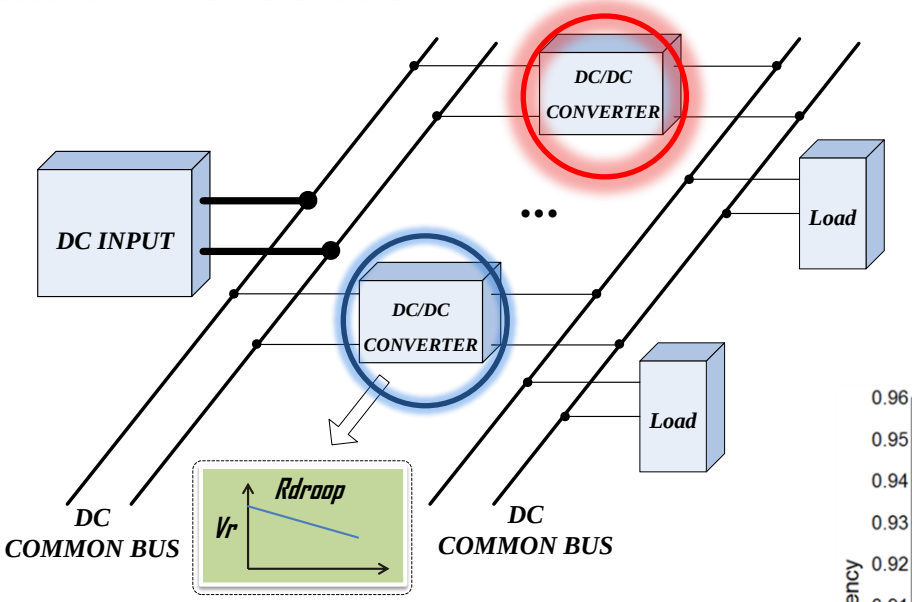




Microgrids research – tertiary control

Tertiary Control and Energy Management System in Microgrids

➢ *DC System Optimization ---- Local Generation Control*

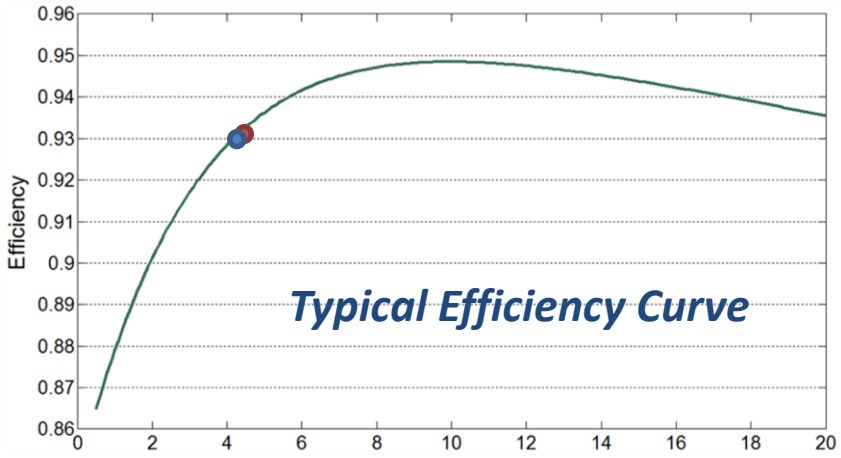


Objective

- *System Overall Efficiency*

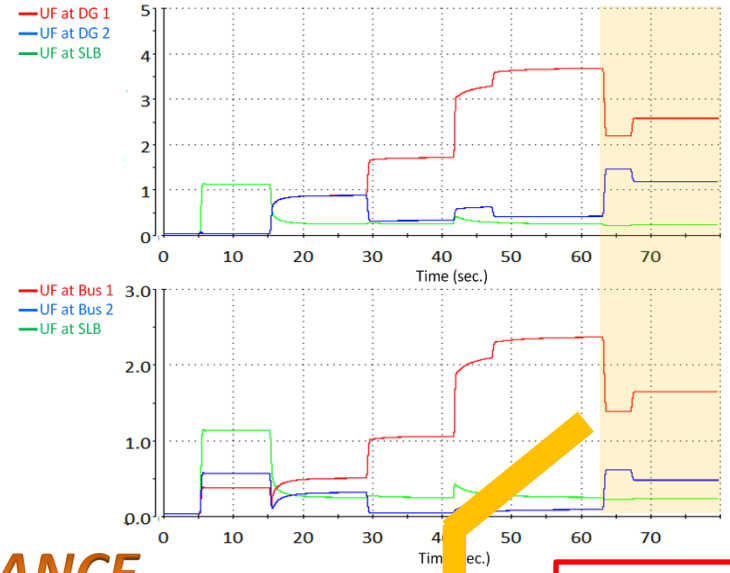
Constraints

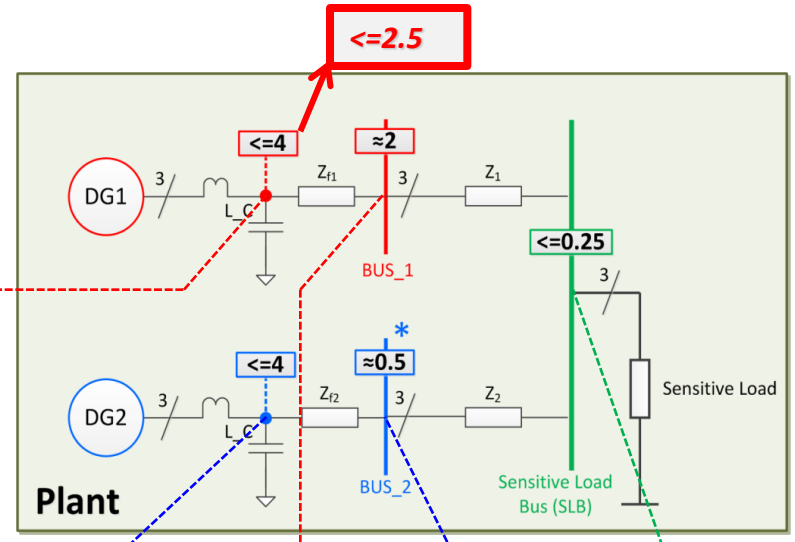
- *Capacity*
- *DC Bus Voltage*
- *System Dynamics*

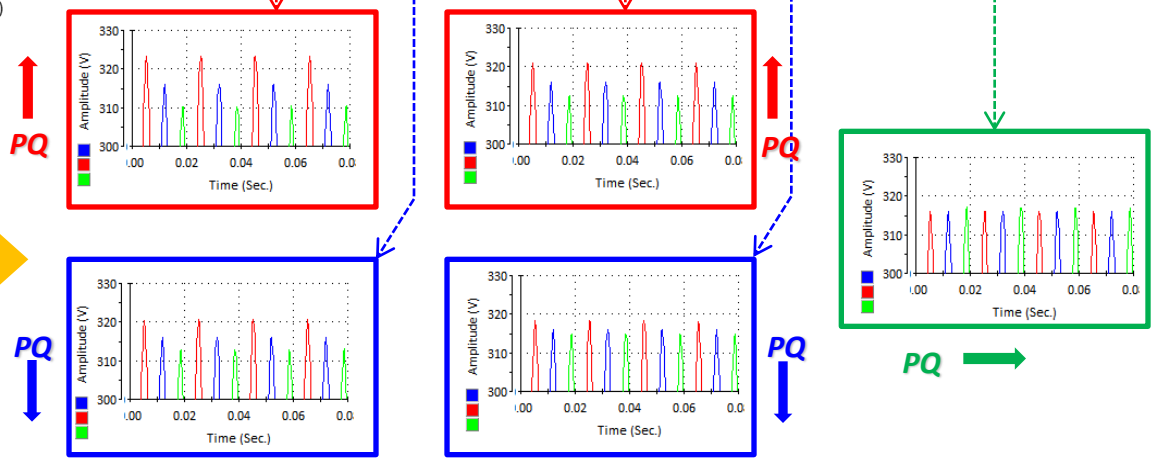


Problem Formulation

Microgrids research – tertiary control







UNBALANCE COMPENSATION OPTIMIZATION

TERTIARY CONTROL AND ENERGY MANAGEMENT SYSTEM IN MICROGRIDS

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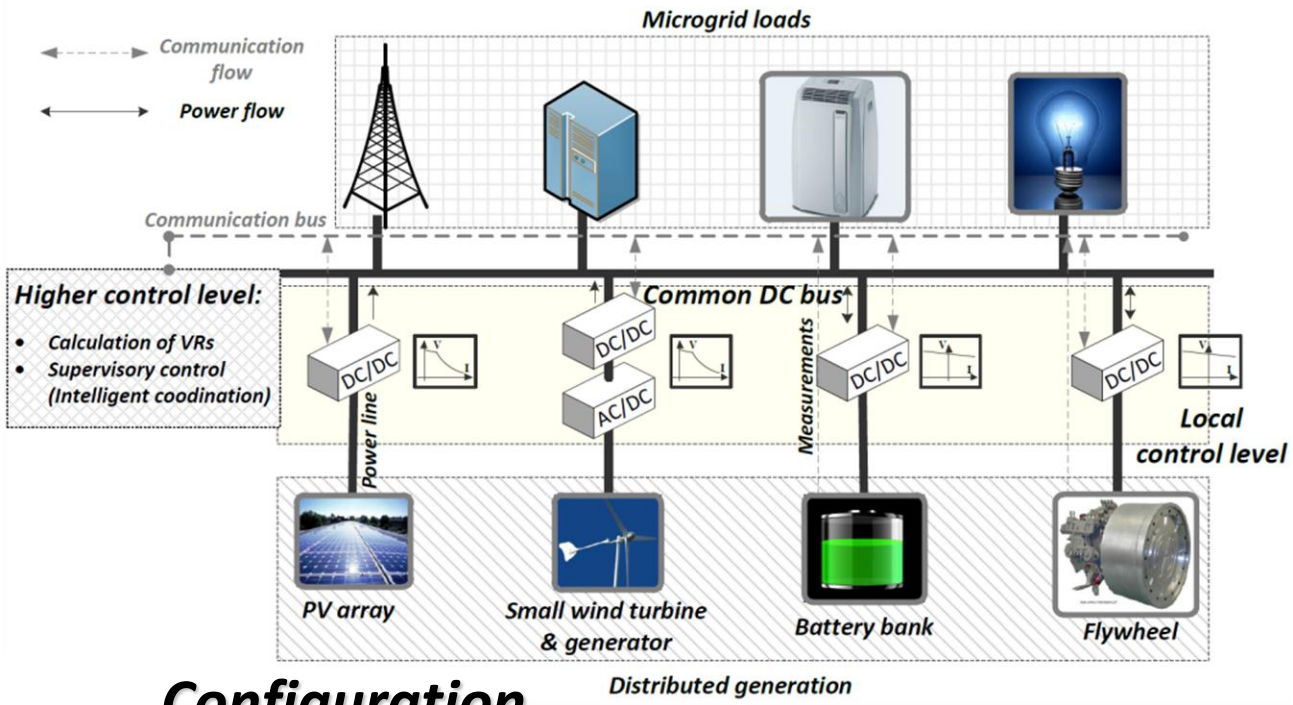
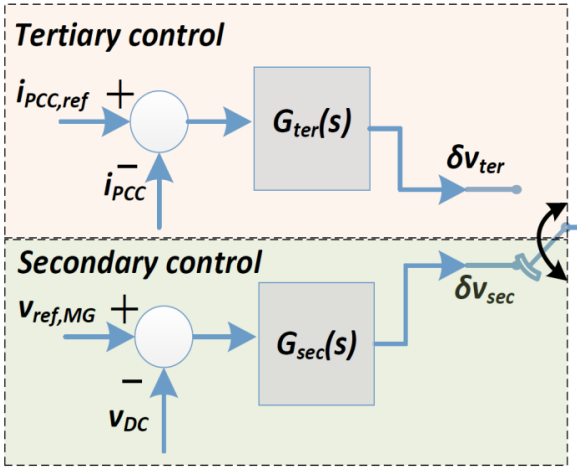
Microgrids research – dc coupled systems

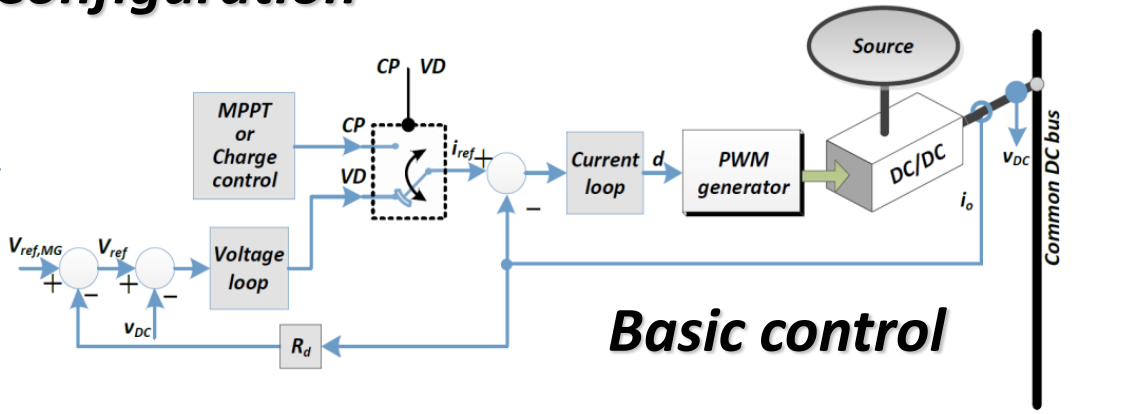
DC Microgrids Operation and Control

- Remote **telecom** applications
- **Coupled** renewable systems
- DC **powered homes**
- Fast **HEV** charging stations



Configuration





Basic control

Intelligent Microgrid Lab - iMGlab

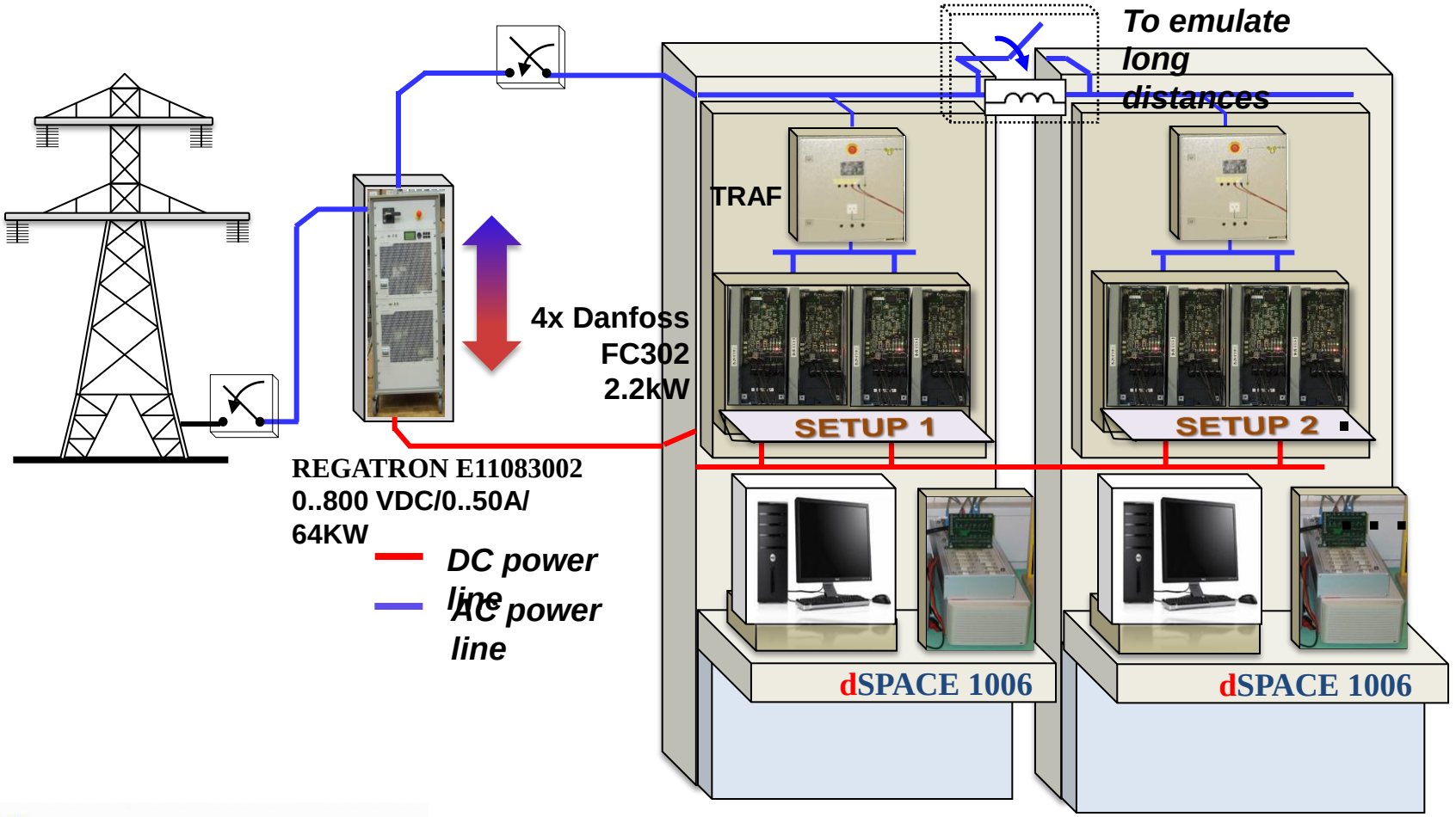
The Intelligent Microgrid Laboratory (iMGLab) is a powerful platform designated for research and education on AC, DC and hybrid Microgrid technologies.

The laboratory is based on 6 workstations,
Every SETUP:

- 4 DC-AC power electronics converters,
- LCL-filters,
- Motorized change-over switches
- Smart-meters.

Every setup is able to emulate a multi-converter low-voltage Microgrid,
local and energy management control programmed in dSPACE real-time control platforms.

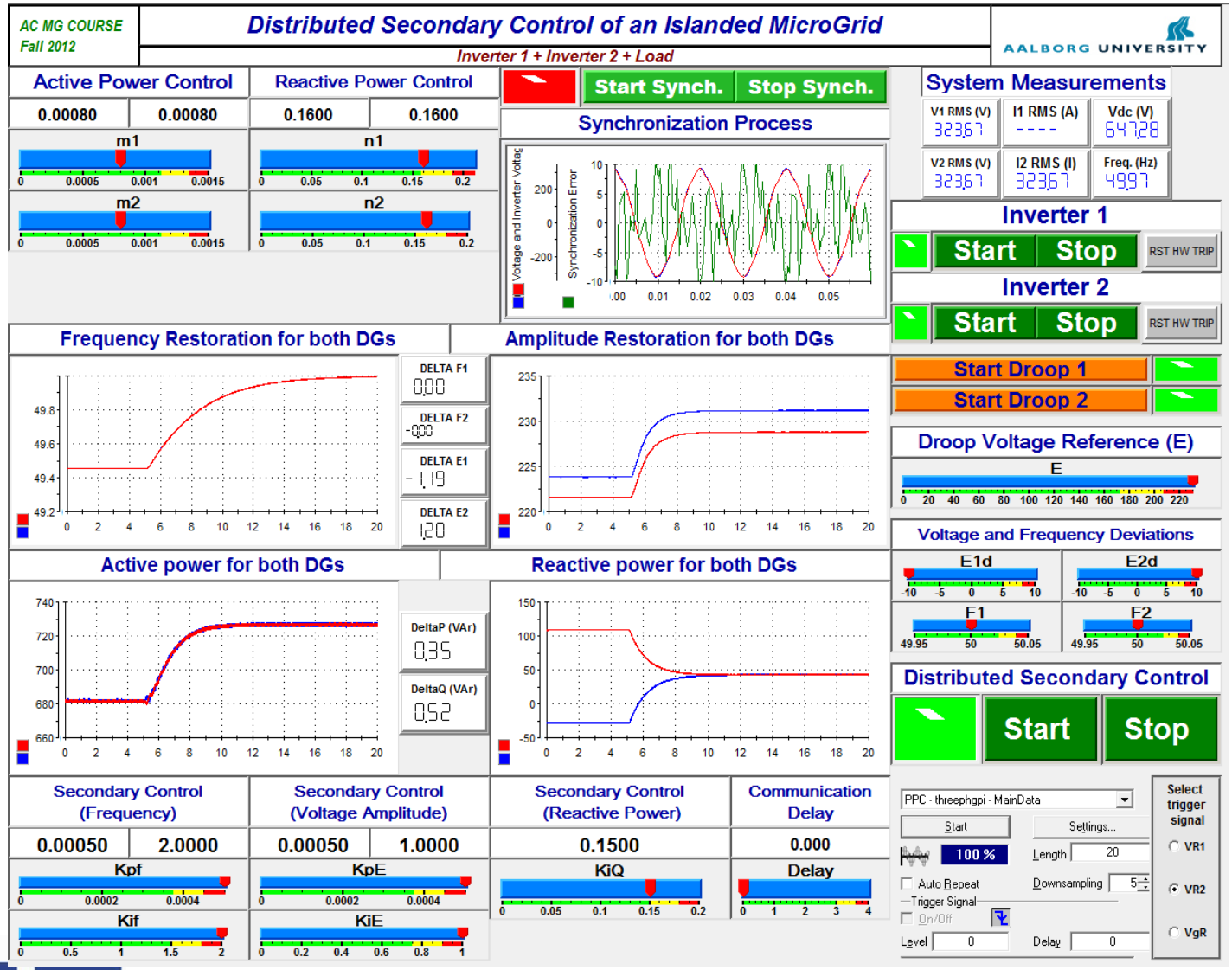
Intelligent Microgrid Lab - iMGlab



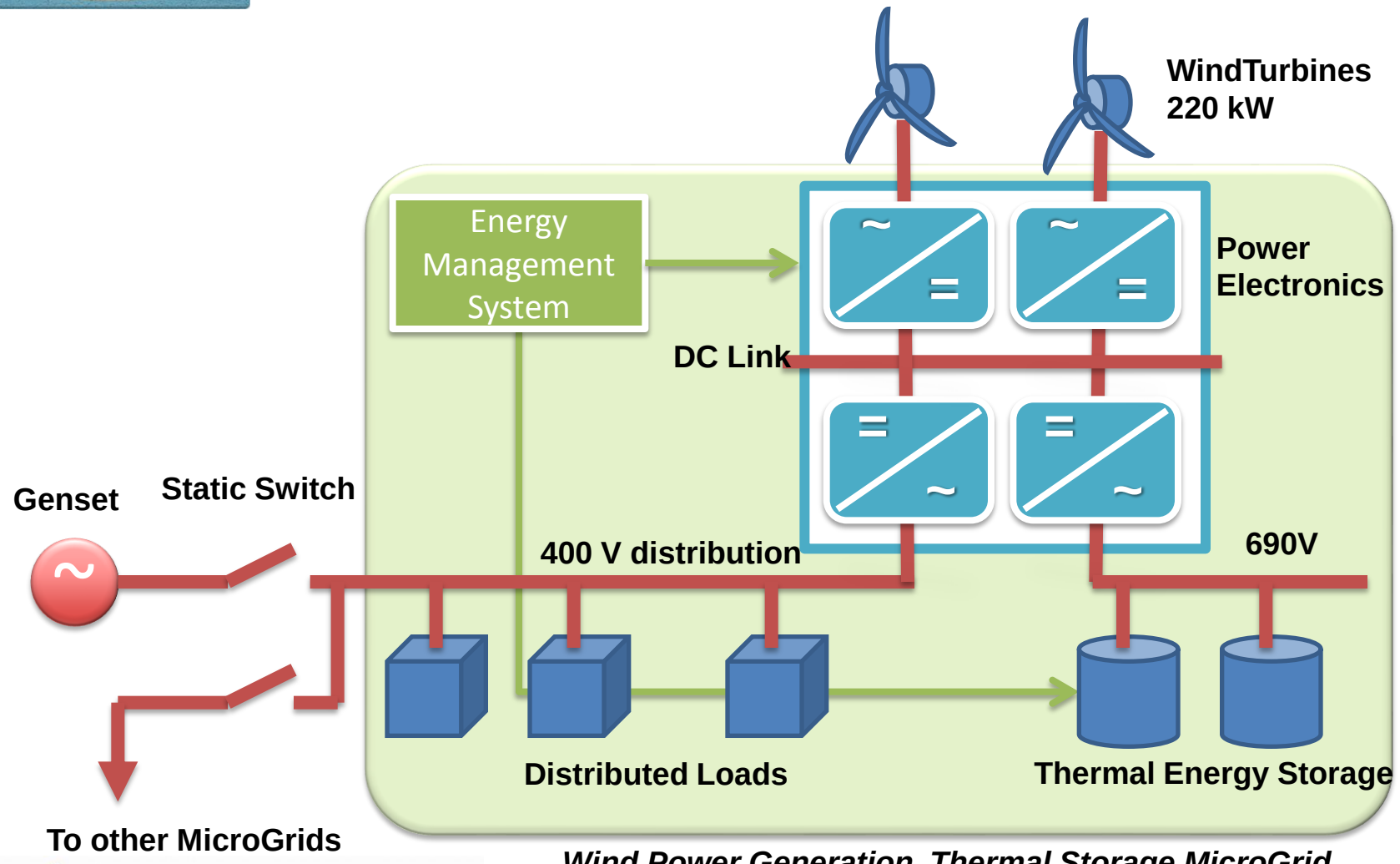
Experimental tests - DSPACE 1006

Real-time control and monitoring platform through *Control-Desk*

Electrical schemes from Matlab SimPowerSystems library are directly compiled into C code and downloaded to the dSPACE



Faroe Island project



Wind Power Generation, Thermal Storage MicroGrid

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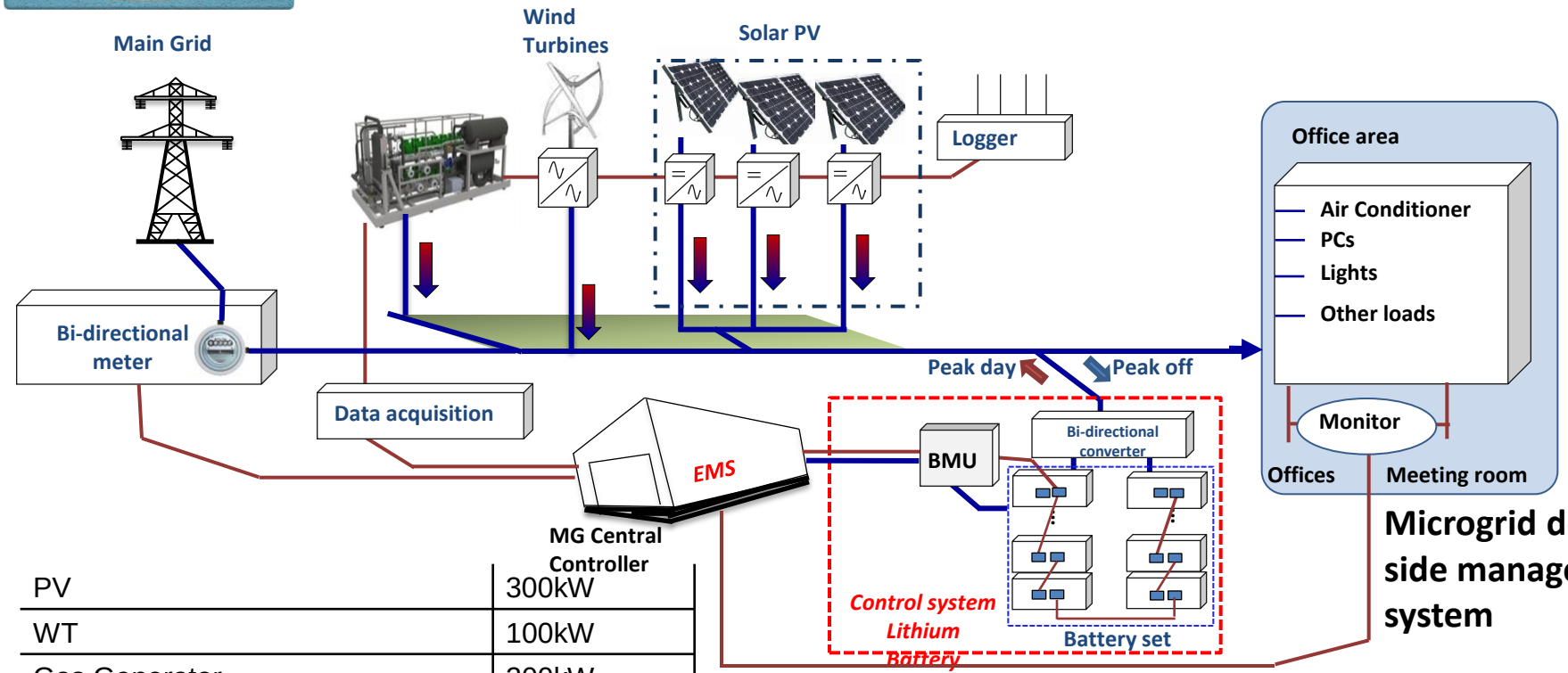
Shanghai PV MicroGrid Project



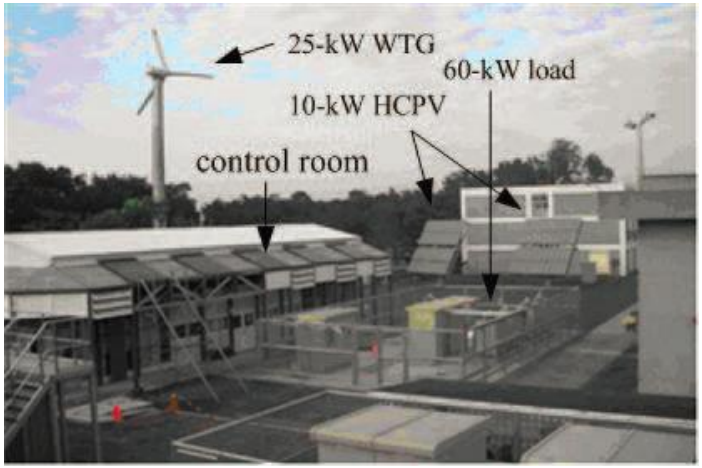
Microgrid demand side management system

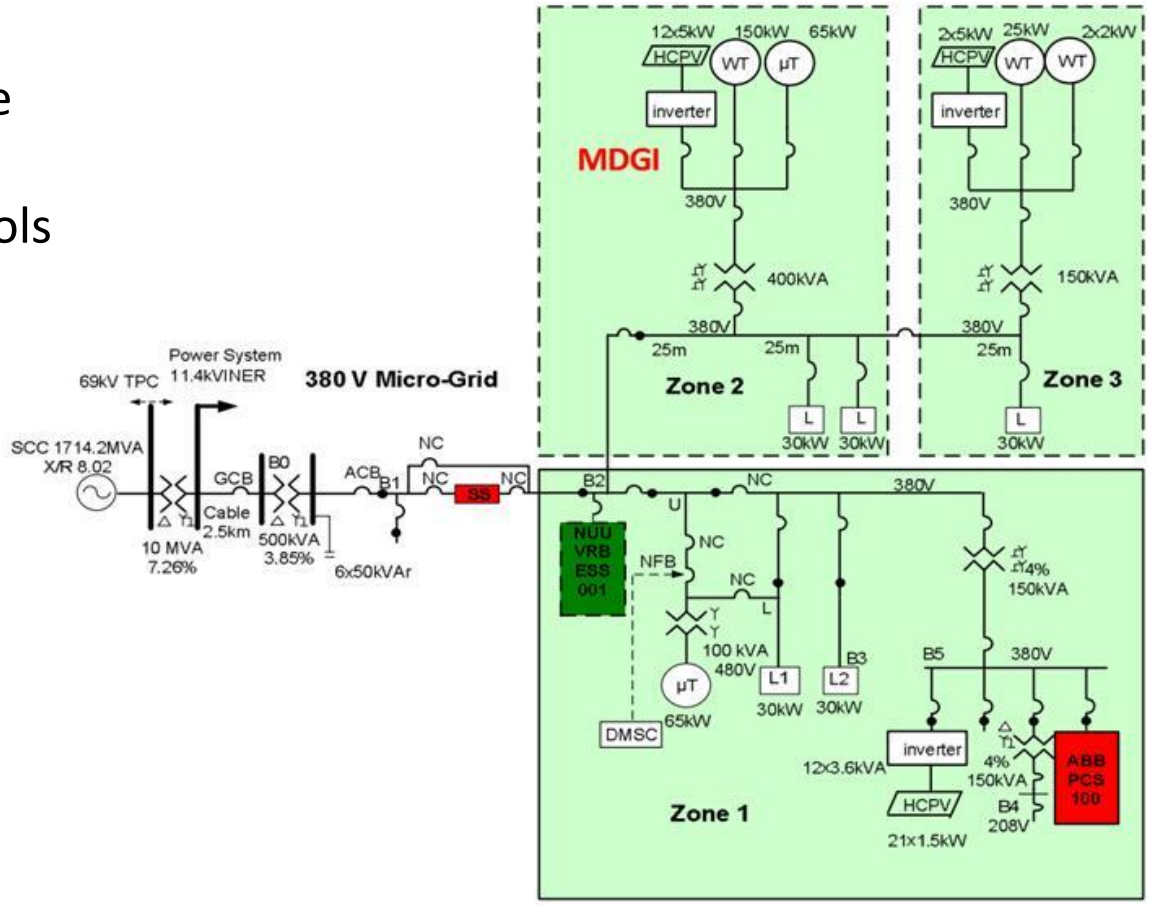
PV	300kW
WT	100kW
Gas Generator	200kW
Storage Batteries	300kWh
Unidirectional PV on-grid Inverter	300kW
Unidirectional Wind on-grid Inverter	100kW
Bidirectional converter	200kW
AC/DC Distribution System	500kW

- 500 kWp MicroGrid
- Tertiary Control
- Energy Management System
- Communications

Taiwan INER MicroGrid Project

- 150 kW Microgrid
- Islanding operation multizone
- Fault tolerant
- Primary and secondary controls





MicroGrids Courses

AC Microgrids

Industrial/PhD course on
AC Microgrids
in Theory and Practice

Industrial/Ph.D. Course in

AC MicroGrids

– in theory and practice

Oct. 14 – Oct. 15
2013

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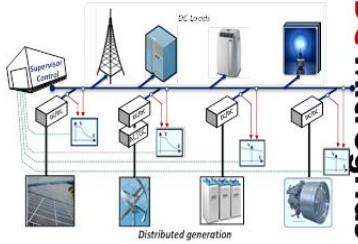

DC Microgrids

Industrial/Ph.D. Course in

DC Microgrids

– in Theory and Practice

Nov. 26 – Nov. 27
2013

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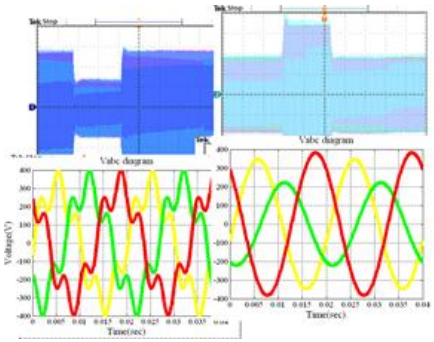
Department of Energy Technology
Aalborg, Denmark



Industrial/Ph.D. Course

Power Quality in Microgrids

in Theory and Practice

Oct. 16 – Oct. 17
2013

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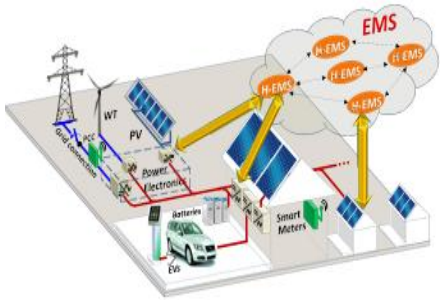
Aalborg - Denmark



Industrial/PhD course on
EMS and Optimization in Microgrids - In Theory and Practice

Oct. 28 – Oct. 30
2013

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Aalborg - Denmark

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Thank you for your attention!

For cooperation or further information, please contact us:

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http://www.et.aau.dk/research-programmes/MicroGrids/Lab.+Facilities/