LAAS Days
Research & Technology

Hybrid electrical network for Building integrated Photovoltaic (BIPV)

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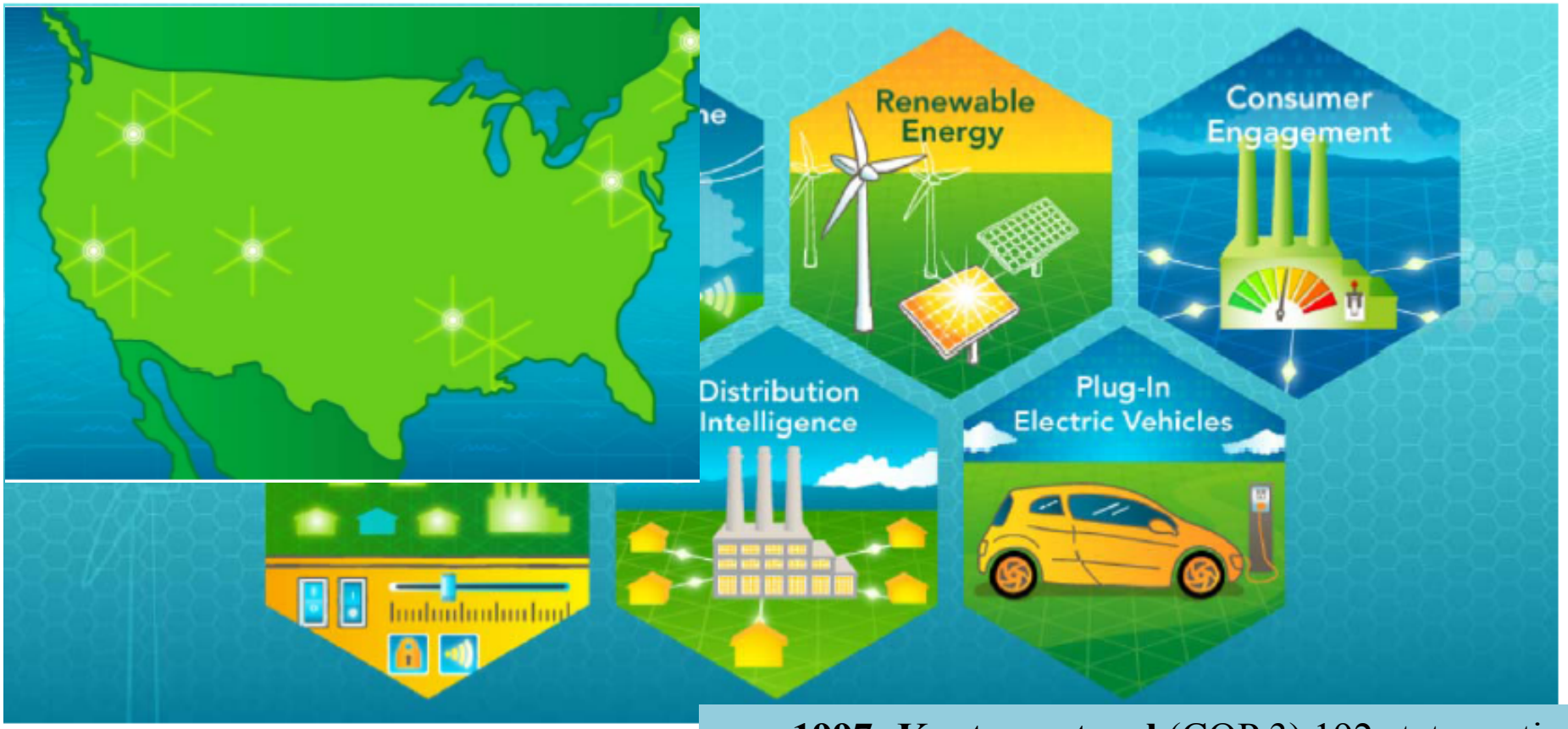
Concepts of smart-grids and smart-homes were developed during the sixties in United states



https://www.smartgrid.gov/the_smart_grid/smart_home.html

1997: Kyoto protocol (COP 3) 192 state parties, -5% of GHG emissions below 1990 levels.

2015 : COP21 in Paris more than 190 countries were engaged to limit increase of temperatures less than 2°C !

What is a energetical microgrid (MG) ?

A microgrid is an energy/power supply network built around local power and heat generation facilities. It is designed to operate autonomously or in synchronization with a national grid within a clearly defined area.

A electrical MG is typically made up of

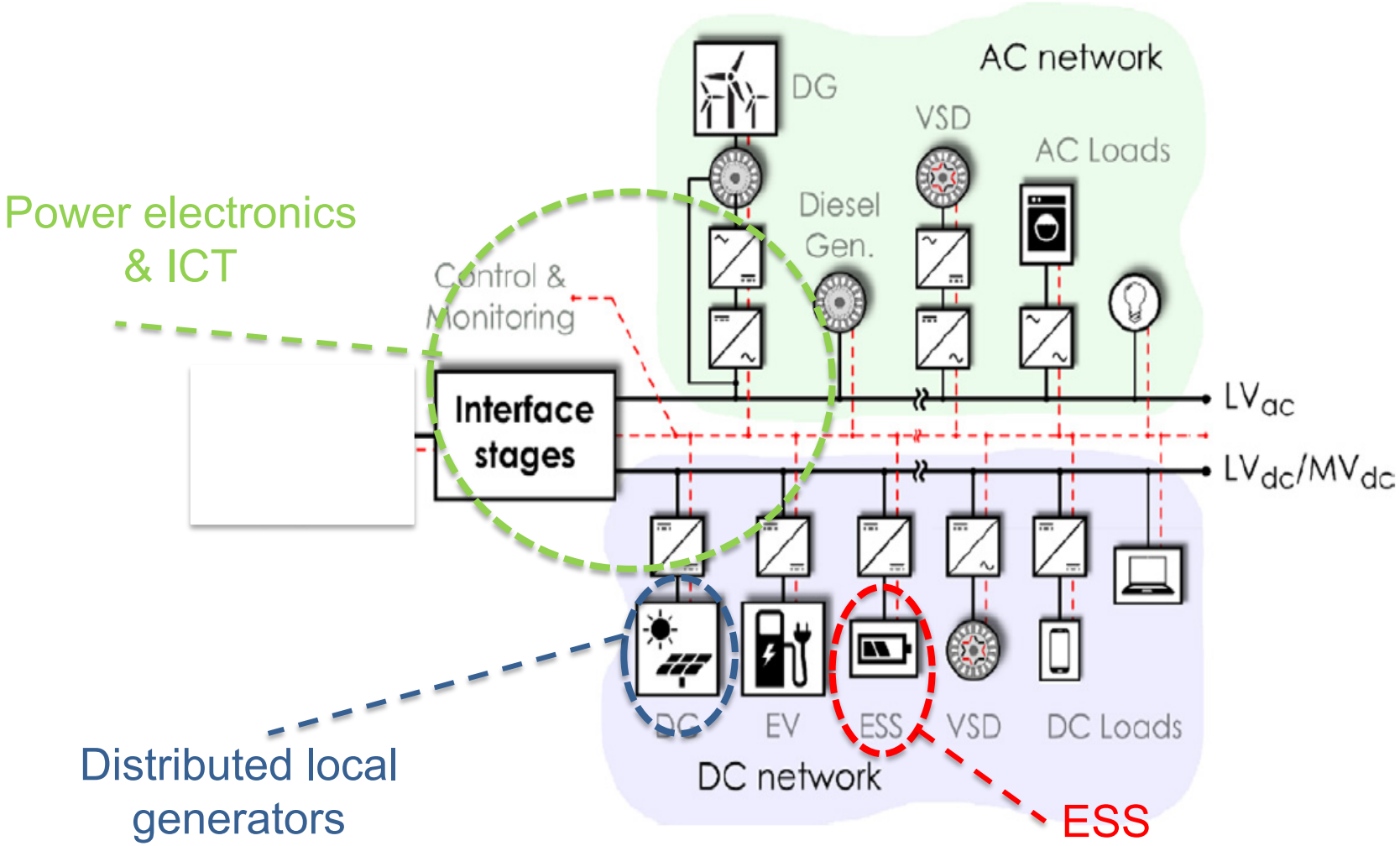
- **Renewable energy sources (solar, wind, hydrolic, biomass)**
- **Fossil fuel energy sources to ensure grid stability**
- **Energy storage solutions (batteries, hydrogen storage, mechanical storage, etc.)**
- **A low-voltage supply grid regulated by a smart control system**

https://www.engie.com/en/businesses/microgrids-decentralized-energy

- **A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode**

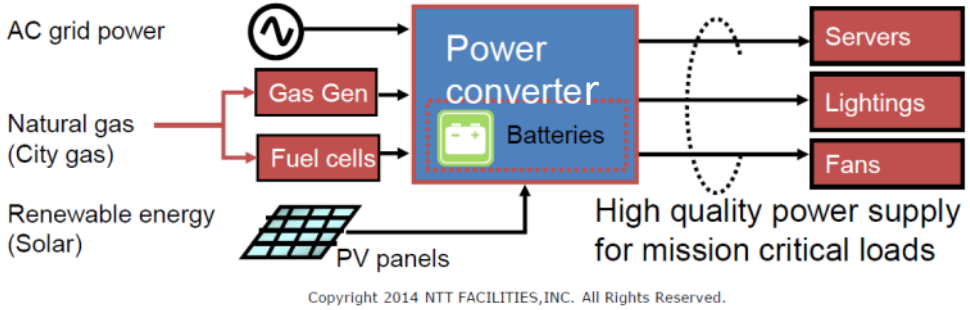
https://building-microgrid.lbl.gov/microgrid-definitions

Example of an hybrid Microgrid structure

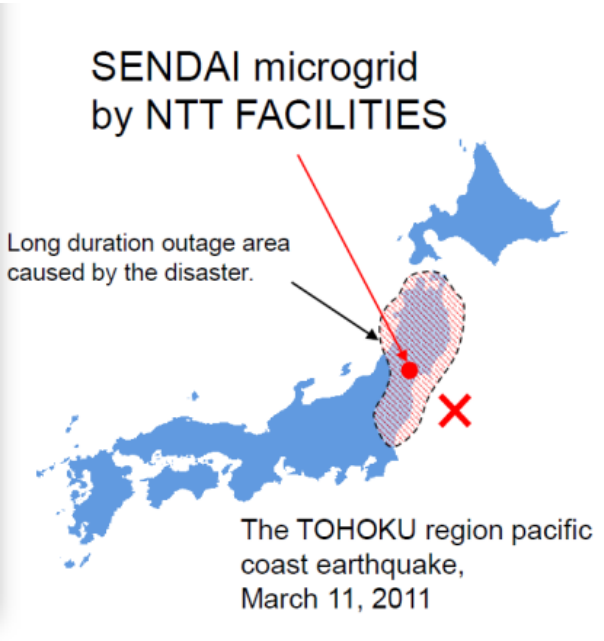


Eneko Unamuno and Jon Andoni Barrena, '**Hybrid ac/dc microgrids—Part I: Review and classification of topologies**', *Renewable and Sustainable Energy Reviews*, vol. 52, pp. 1251–1259, Dec. 2015.

Example of high level of robustness microgrid : 1 MW inside the Sendai university campus



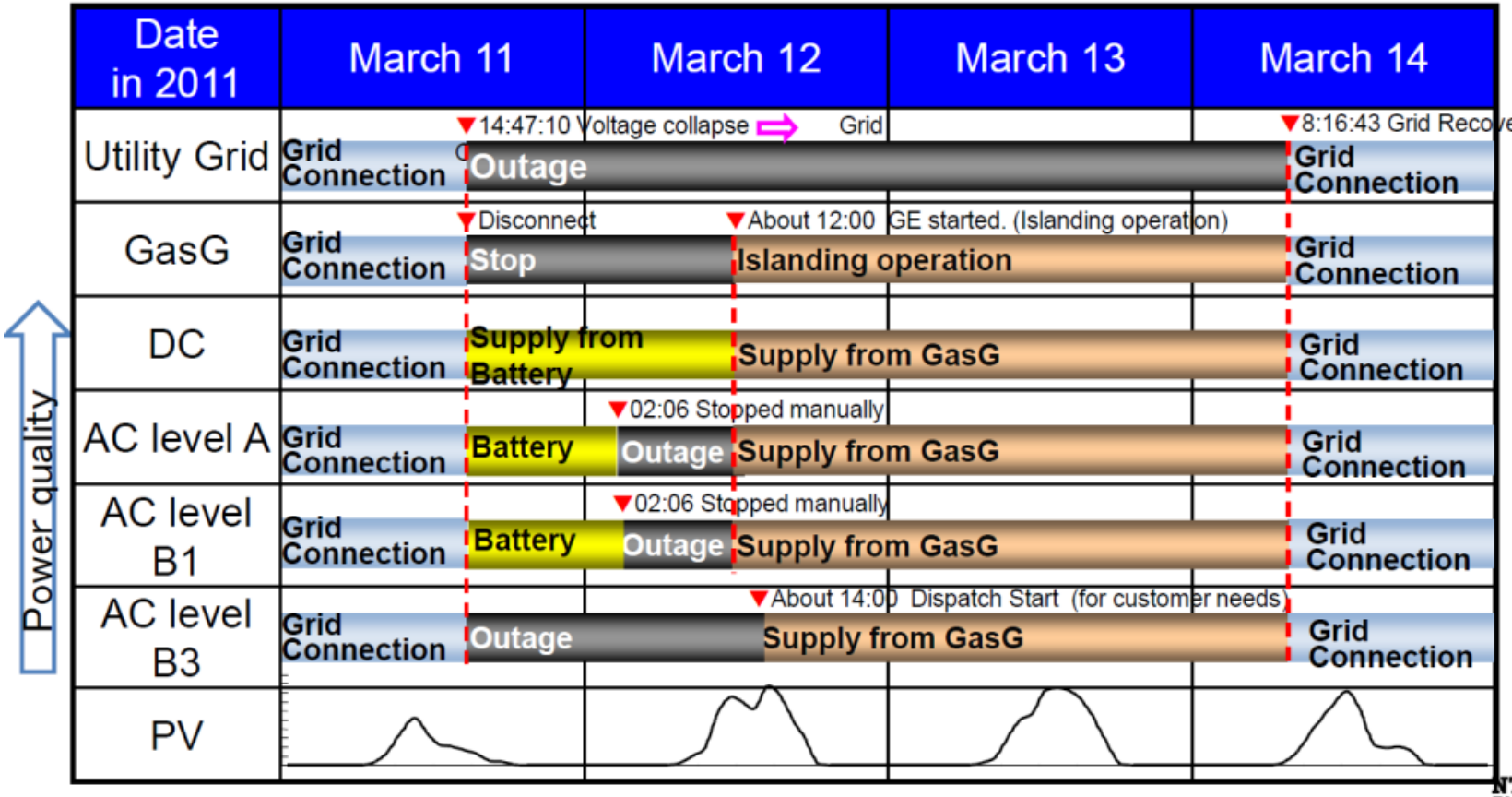
https://building-microgrid.lbl.gov/projects/der-cam



http://microgrid-symposiums.org/wp-content/uploads/2014/12/tianjin_keiichi-hirose.pdf

Condition of Supplying Power during March 11

- The system continued to supply DC, A, B1without any interruptions for batteries and PV generation system.
- GasG supplied power for 43 hours during outage.



NTT FACILITIES

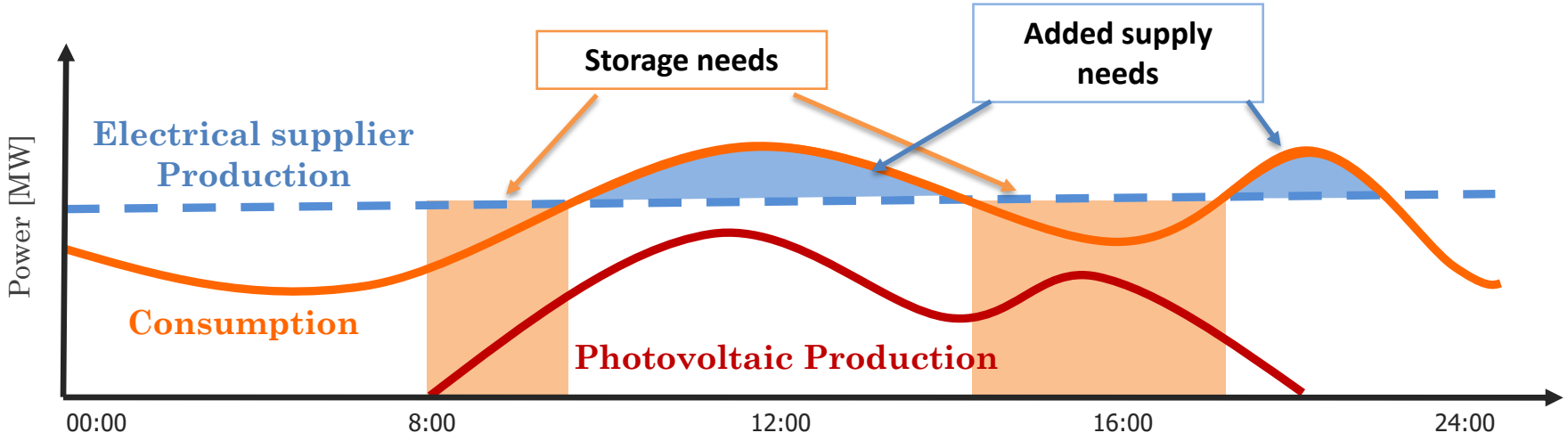
Two 350 kW natural gas fired gensets, 50 kW of PV, modest battery storage

Specifications of a typical distributed grid with Renewable Energy Production

Renewable Energies are intermittent

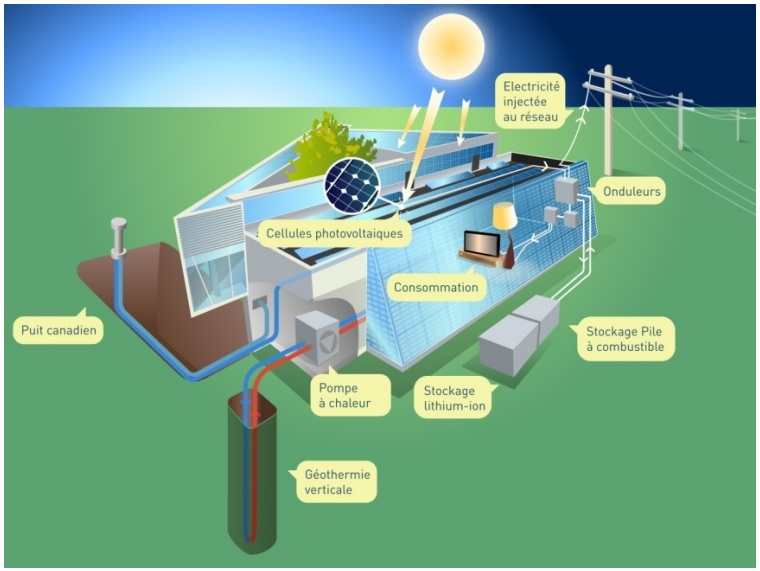
Storage system for electric network is one solution at high rate of Renewable Energy (RE)

- Making interactive grids (smart grids)
- Maximize the productivity of renewable energies
- Smooth peak consumption / production
- Making buildings more energy producers see autonomous
- Reduce the cost of electricity by reducing losses



ADREAM, «Energy» positive building
One structure dedicated to research in new passive and BIPV building, micro-grids and Smart Grids

From design 2008 to reality … 2012



www.laas.fr/ADREAM

Energy storage systems for BIPV ?

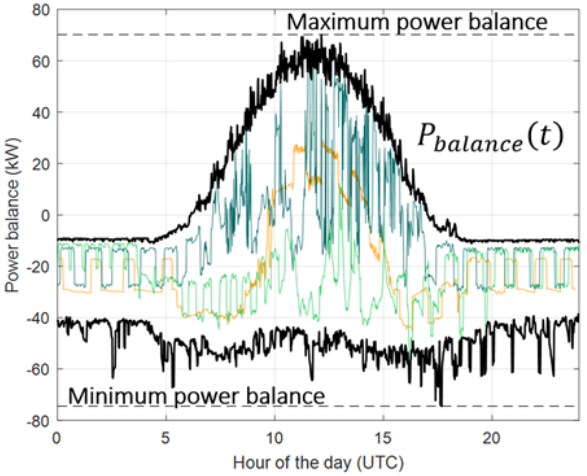
Storage battery pack optimal sizing : first step analyze real data

ADREAM
PV building
LAAS-CNRS
100 kWp

A

Three-year data set
Power Analysis

$P_{PV}(t), P_{Load}(t)$

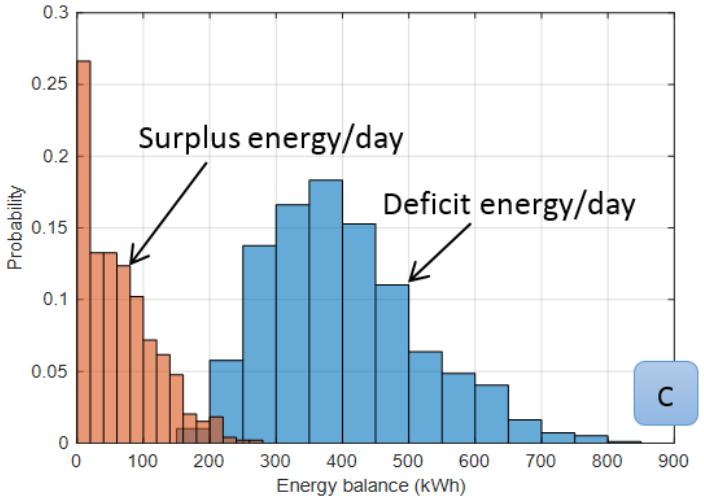


B

1min resolution PV building power balance

More than 3-year data set

Probabilistic analysis of surplus and deficit **energy/day**



C

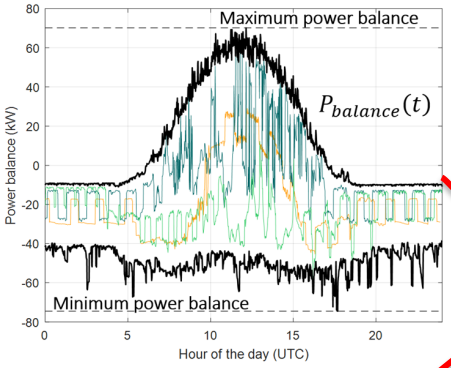
Probabilistic analysis of surplus and deficit energy per day

Jérémy Dulout, PhD 2017

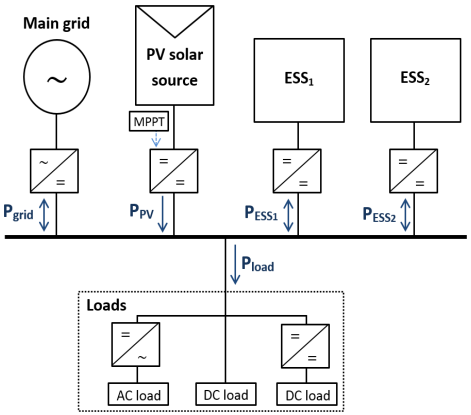
Jérémy Dulout et *al.*, '**Optimal Sizing of a Lithium Battery Energy Storage System (BESS) for Grid-Connected Photovoltaic Systems** ', ICDCM 2017.

Optimal sizing of energy storage systems

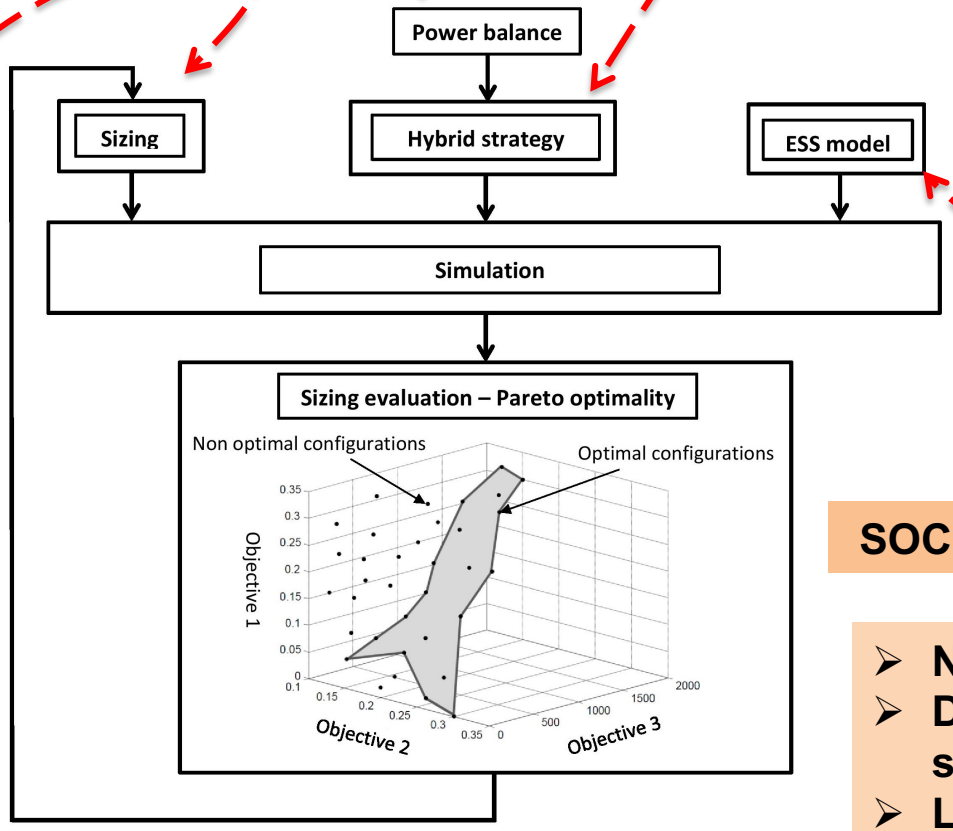
Hybrid Energy Storage System optimal sizing



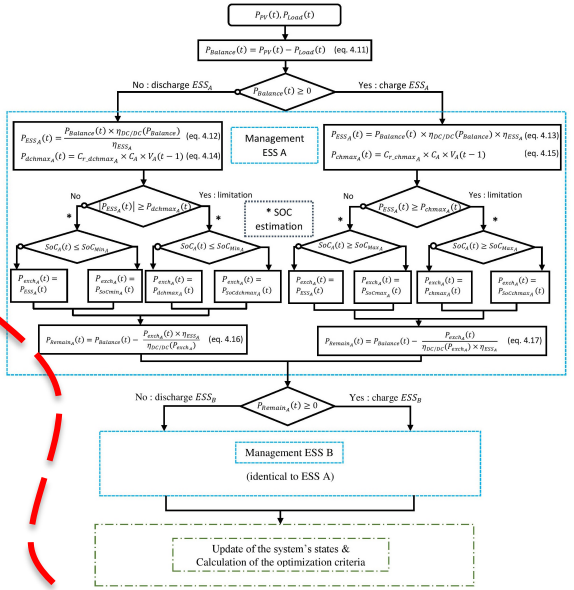
Real data



A specific MG



A specific algoritm

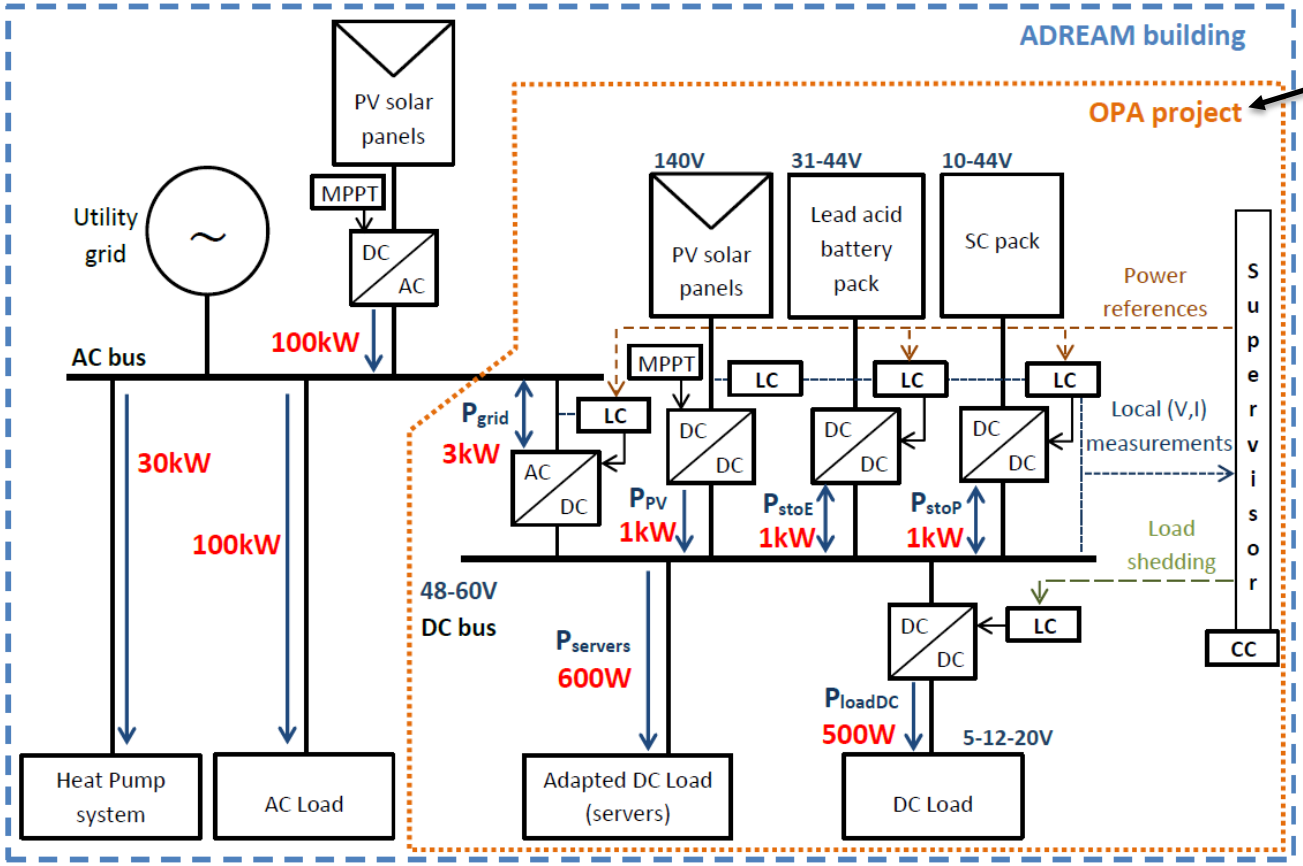


SOC, SOH, efficiency

- No clear trend
- Difficult to analyze with sensitivity analysis
- Lot of parameters …

OPA an Open Platform Project and an experimental Microgrid controlled by DC bus signaling

Decentralized control based on the bus voltage



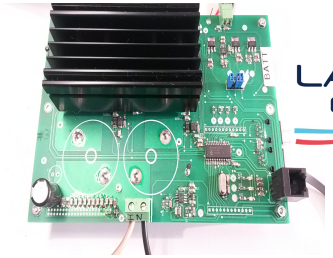
LVDC microgrid

Multidisciplinary research platform:

- **IoT (sensors network),**
- **planning optimization,**
- **power electronics,**
- **etc.**

Jérémy Dulout, Corinne Alonso, Lionel Séguier, Bruno Jammes, '**Development of a photovoltaic low voltage dc microgrid for buildings with energy storage systems**', ELECTRIMACS, Toulouse, 4-6 July 2017, pp. 1-6.

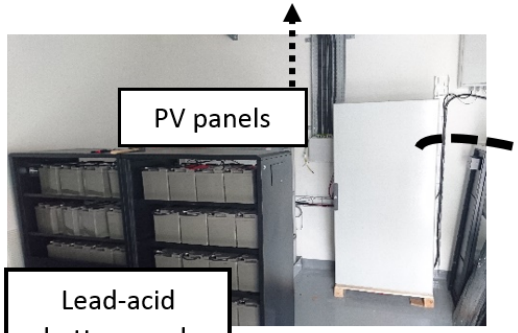
LVDC grid dedicated for Zero Energy Building

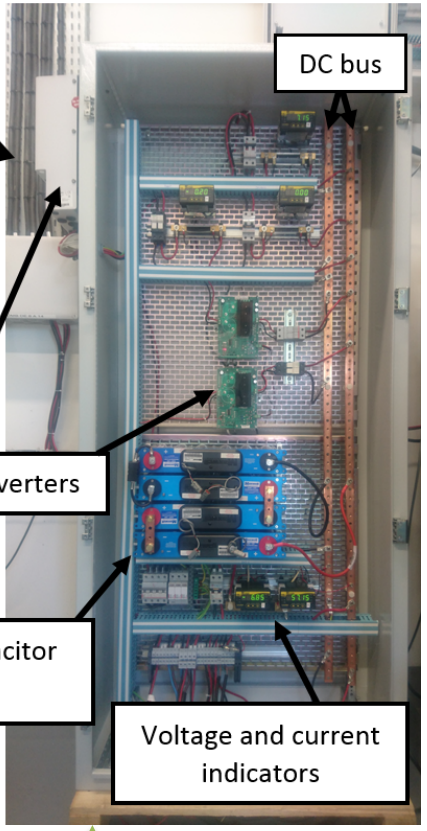


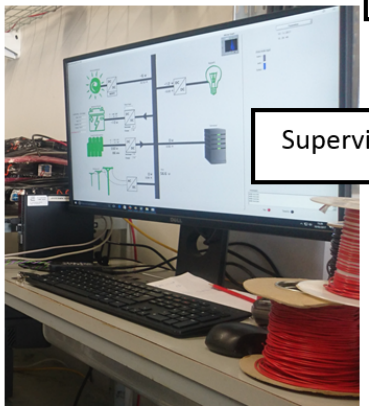
1kW bidirectional DC/DC converter

Control and communication board

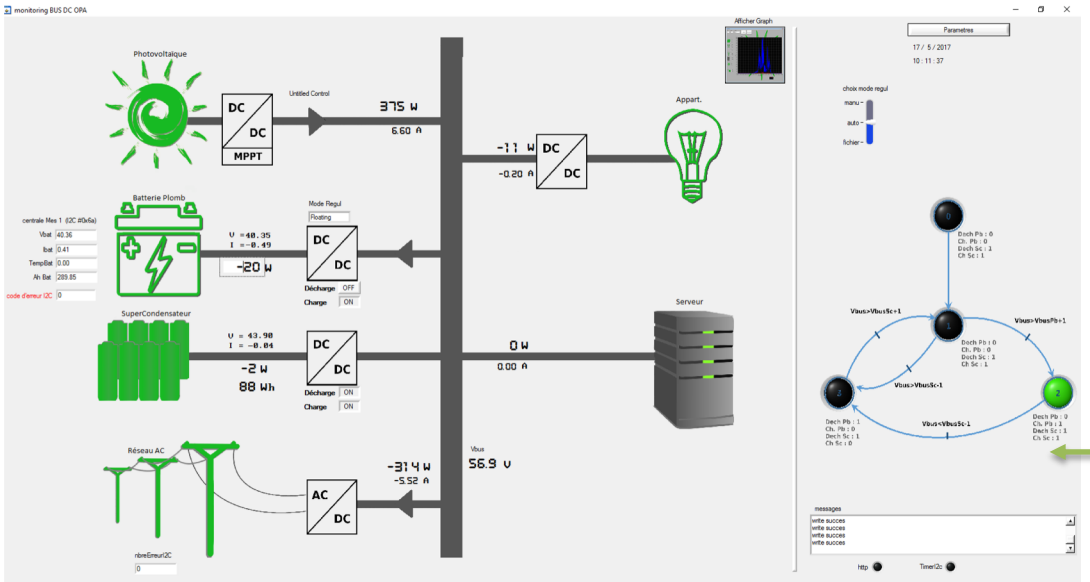
LAAS designed and realized converters





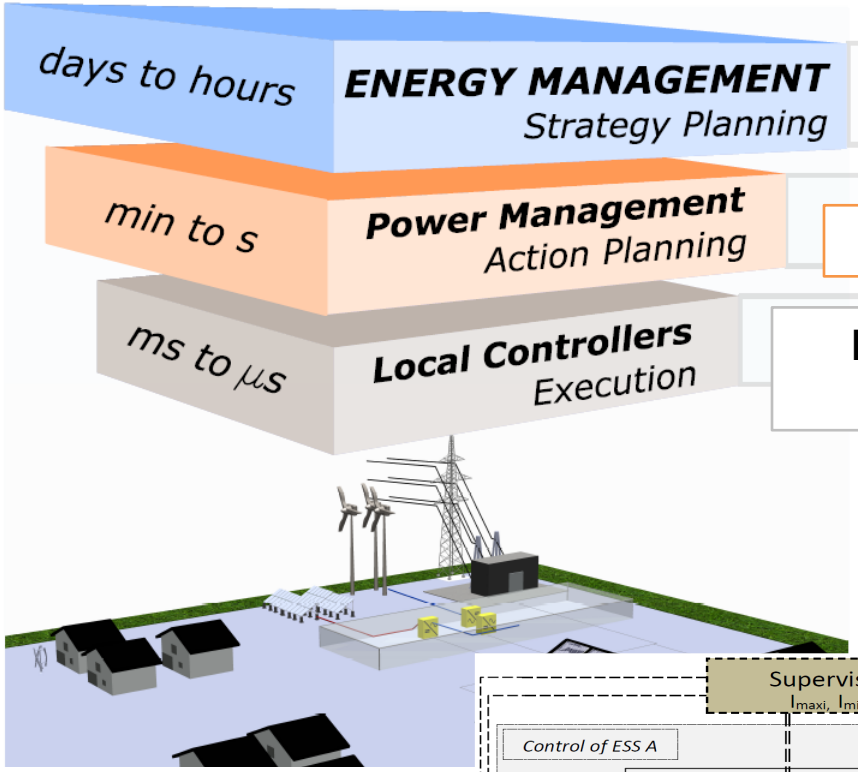


DC microgrid



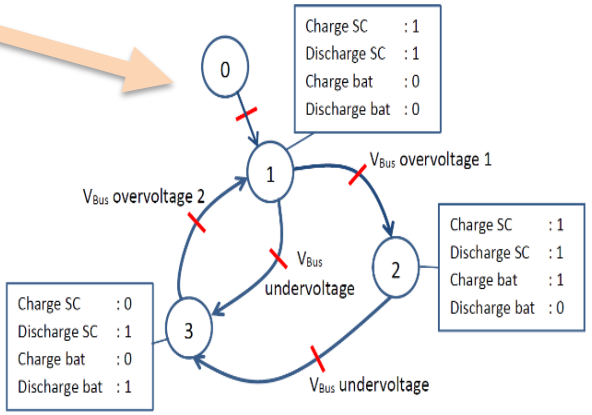
User interface (LabWindows / CVI)

Control of a Microgrid: a Multi-level (hierarchical) control

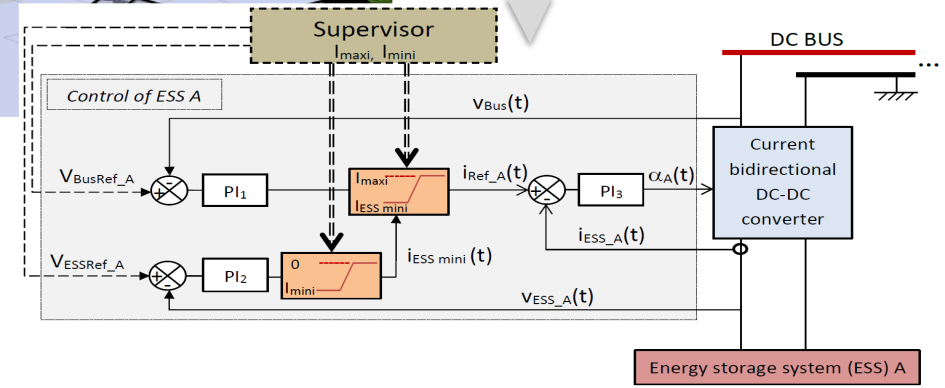


High level Control : self-comsumption, low environmental impact, low cost, isolated MG, networks of MG, smart-grids, eco-districts, planification, forecasting …

Medium level Control

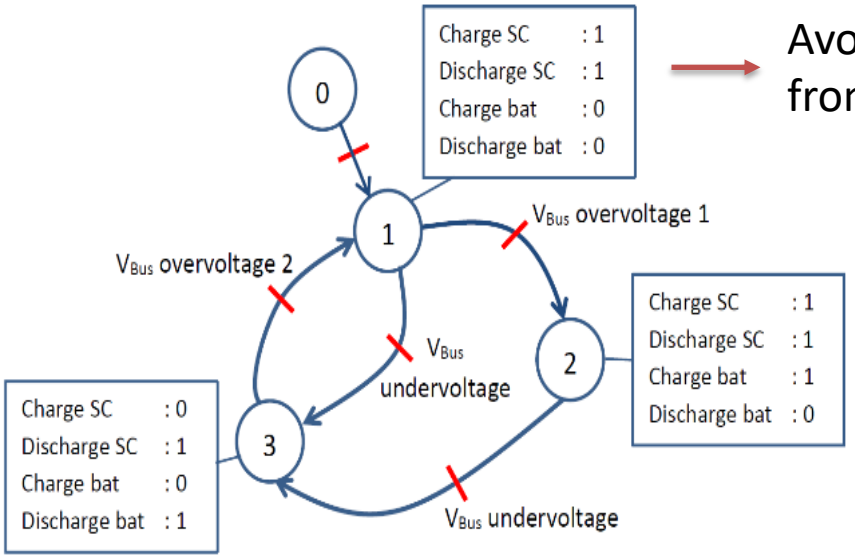


Low level Control of ESSs



Medium level : a DC bus signaling for OPA microgrid

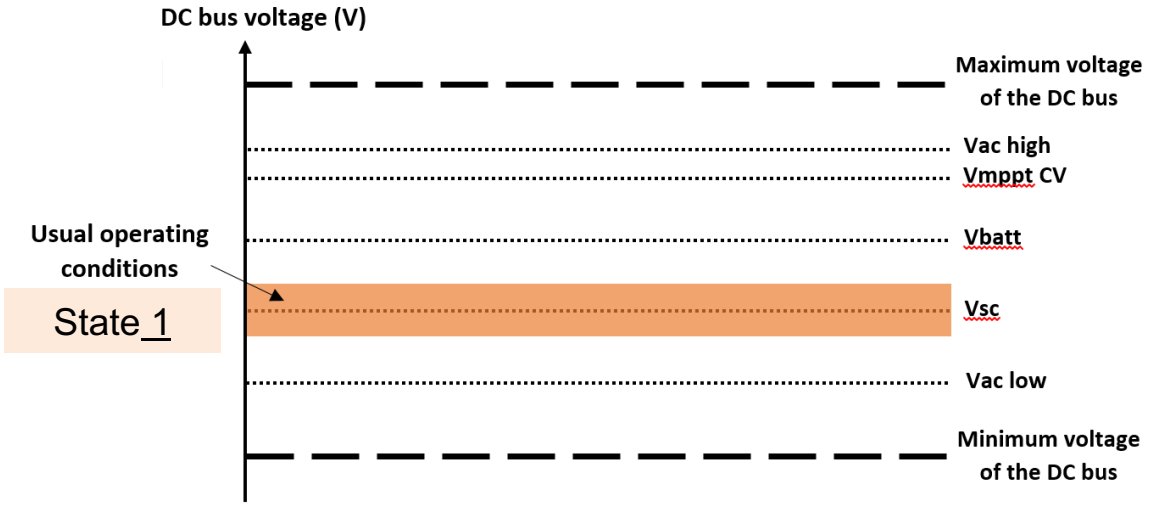
State machine for hybrid ESS management



Avoids µ-cycles from the battery

Bus voltage reflects Pbalance

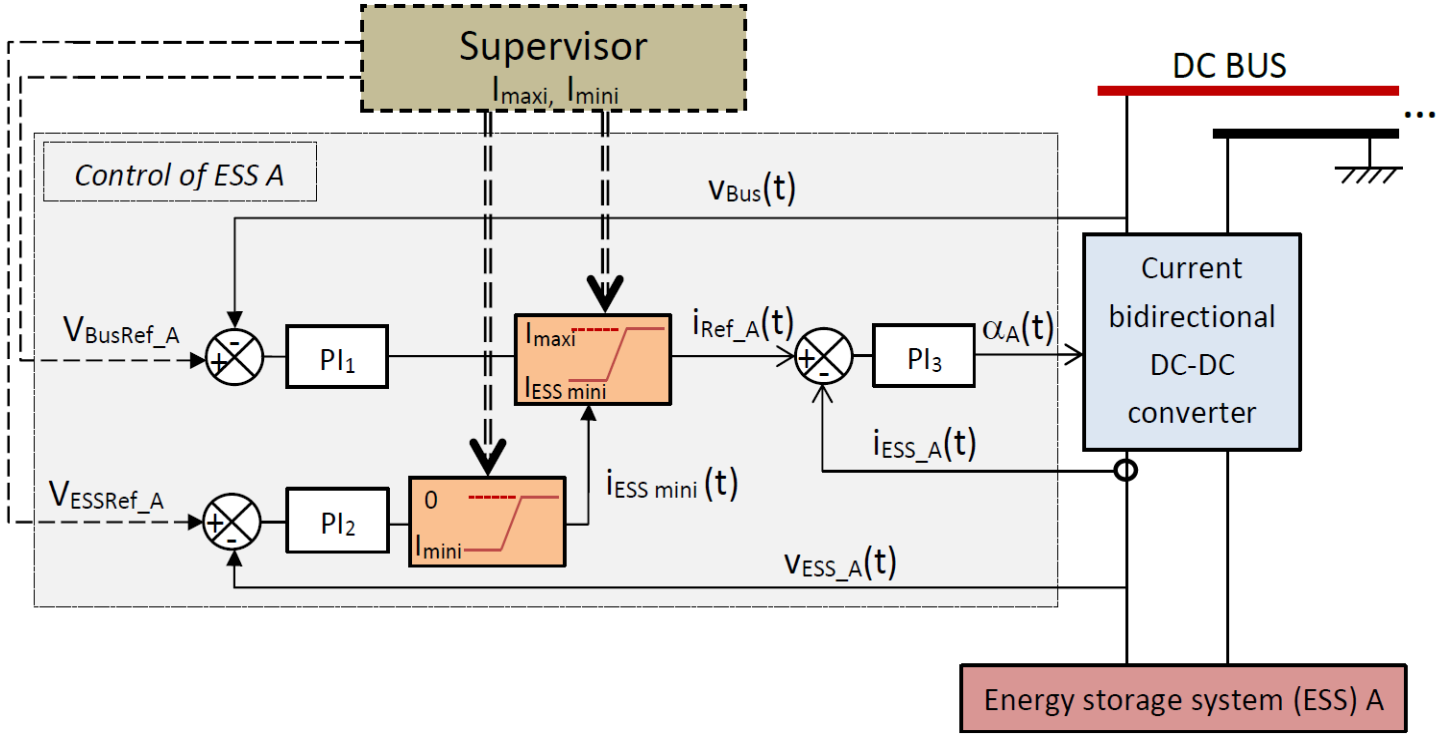
Vbus ↗ when Pbalance>0
Vbus ↘ when Pbalance<0



Simple and robust DC Voltage bus (48 - 60 V)

Low Level Control of a Microgrid

Control of ESSs



Cascade regulation (two voltage references, single inner current loop):

- **Strategy of storage (Vref bus),**
- **Voltage of ESS & C-rate limitations linked to SoC, SoH, T°, costs …**

Example of results with Hybrid storage system

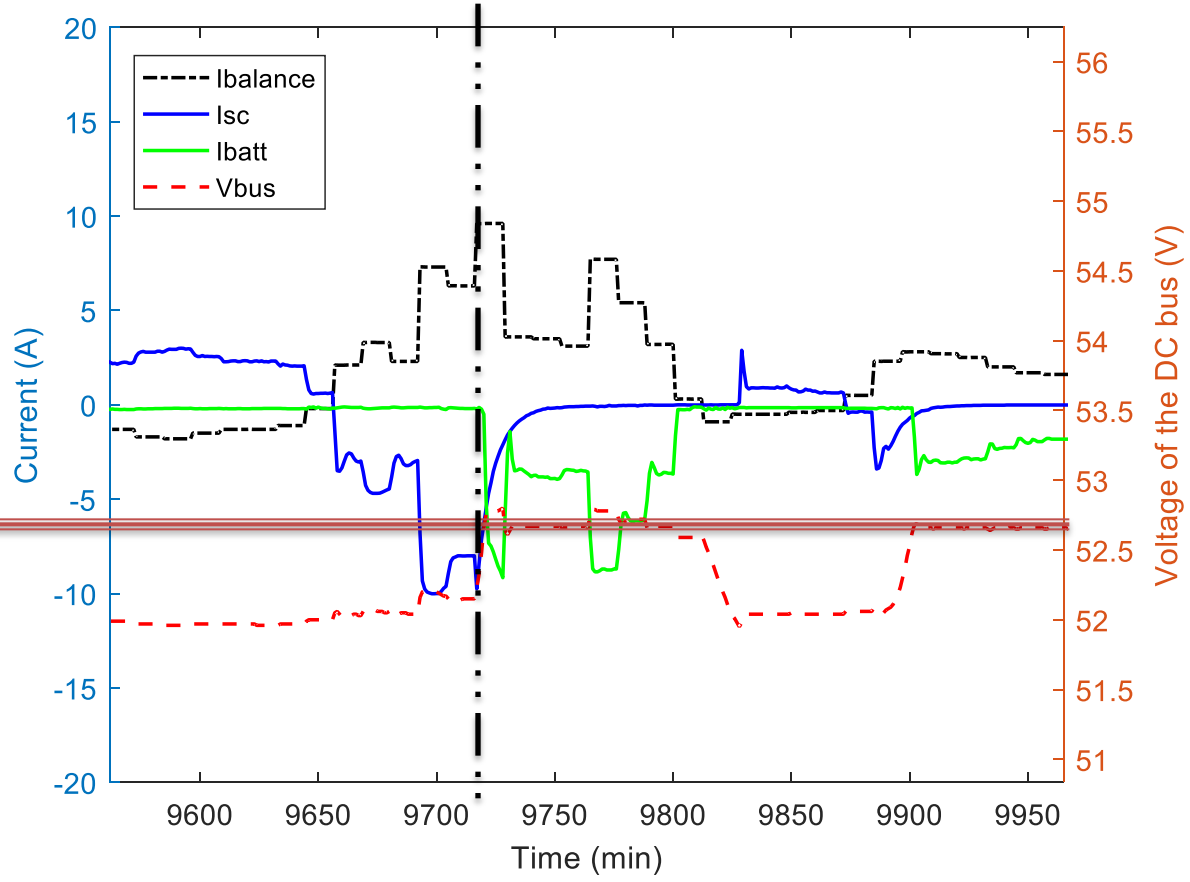
Experimental results

SC
charge & discharge

State 1

State 2

SC : charge & discharge
Batteries: charge



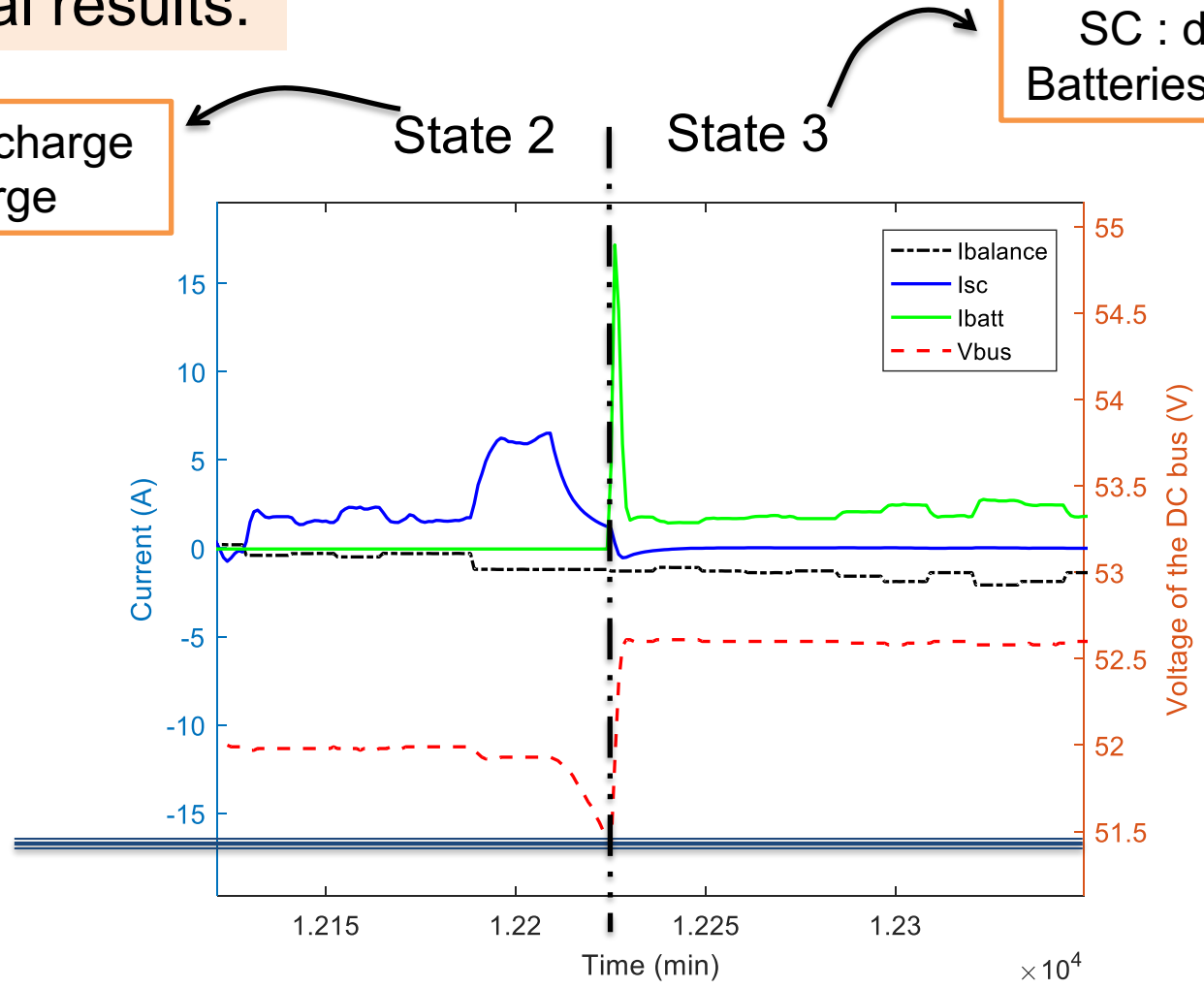
Over-voltage 1

Other example of results with Hybrid storage system

Experimental results:

SC : charge & discharge
Batteries: charge

SC : discharge
Batteries: discharge

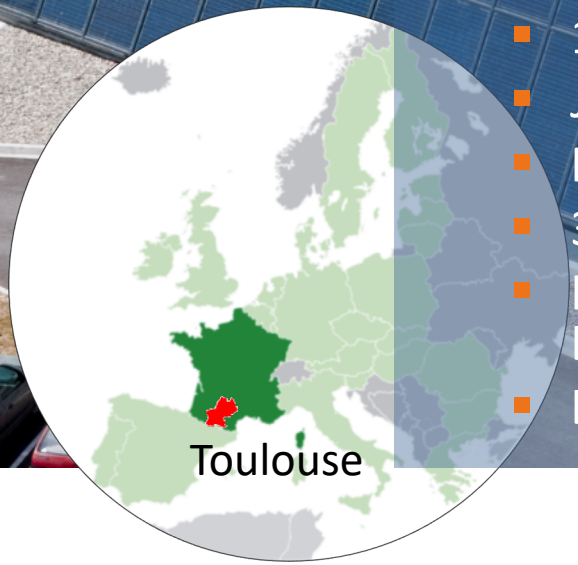


Under-voltage

LAAS People involved in PV and MG area

Thanks to Energy axis

- Corinne Alonso Bruno Jammes Bruno Estibals
- Post-docs : H. Valderrama, R. Leyva, C.Cabal, S. Petibon, C. Carrejo, Y. El Basri, M. Bressan, A. Sferlazza
- High links with technical staff of the lab I2C & IDEA Lionel Séguier, Christelle Ecrepond …
- 16 Thesis since 2002 with 13 in PV and RE systems
- Jeremy Dulout, First PhD in MG
- PhD students L. Garcia, I. Papas, K. Neuhaus, M. Gaetani
- 3 to 5 L3, M1, M2 and final engineer student stages per year
- Invited Professors (Luis Martinez-Salamero, Fernando Jimenez, C. Lefrou, C. Darras)
- Links between ISGE, ESE, MAC, ROC, DISCO, SARA



Thank for your attention