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ADItech

MULTI SERVICES PROVIDED BY THE COORDINATION CONTROL OF DIFFERENT STORAGE AND FACTS DEVICES

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POWER SYSTEM ISSUES

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VIRTUAL & ON-SITE!

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Agenda

1. Introduction
2. OSMOSE project and Spanish demonstration
3. CENER facilities
4. Master control
5. Case study and results
6. Conclusions and future work

INTRODUCTION

Introduction About us

RESEARCH AREAS

- WIND ENERGY
- PHOTOVOLTAIC SOLAR ENERGY
- SOLAR THERMAL & THERMAL ENERGY STORAGE
- BIOMASS
- ENERGY IN BUILDINGS
- RENEWABLE ENERGY GRID INTEGRATION

INTEGRACIÓN EN RED DE ENERGÍAS RENOVABLES

RENEWABLE ENERGY GRID INTEGRATION

CENER

OSMOSE

PROJECT AND SPANISH DEMONSTRATION

OSMOSE project

OPTIMAL SYSTEM-MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY

OSMOSE addresses flexibility for the integration of high-shares of non-dispatchable renewable energy sources, through a holistic approach in order to capture synergies across FLEXIBILITY NEEDS and FLEXIBILITY SOURCES.

FLEXIBILITY SOURCES

Flexibility of RES Generation	Demand-Response	Grid Flexibility	New Storage

?

The challenge of the organising of the deployment of flexibility for the integration of renewable energy sources

- (A) Balance offer-demand at hourly or half-hourly timeframes
- (B) Existing and future system services
- (C) Dynamic control of grid flows

FLEXIBILITY NEEDS

Technologies and services deployed

Technologies for consumers
- ✓ Demand response

Grid technologies
- ✓ Network management, monitoring and control tools

Large-scale storage technologies
- ✓ Hydro storage

Distributed storage technologies
- ✓ Batteries
- ✓ Flywheel

Generation technologies
- ✓ Wind power
- ✓ PV

Market
- ✓ Electricity market
- ✓ Ancillary services

- ❑ OSMOSE proposes **four TSO-driven demonstrations (RTE, REE, TERNA and ELES)** aiming at increasing the techno-economic potential of a wide range of **flexibility solutions** and covering several applications, to foster the cost-efficient roll-out of flexibility solutions required for energy markets, for existing and future system services and for the dynamic control of grid flows.

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773406 https://www.osmose-h2020.eu/

OSMOSE Spanish demonstration

Multi-services by different storage and FACTS devices (WP4)

Development and demonstration of a hybrid solution, called Multi-Component Flexibility Solution (MCFS) aims to provide different flexibility services:

Target Services:

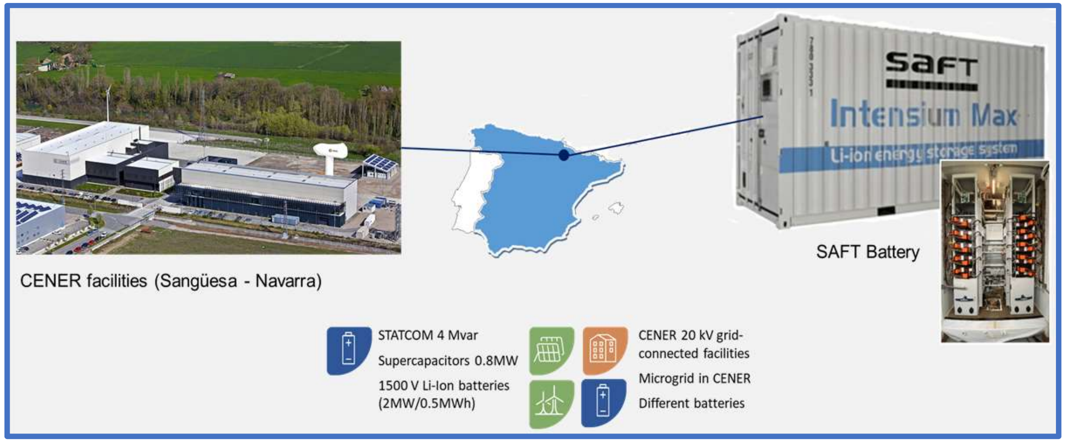
- Emulation of inertia, Fast Fault Current Injection, Power oscillation Damping
- Frequency regulation
- Setpoint tracking, Management of renewable energy variability, program management
- Congestion Management, Voltage Control

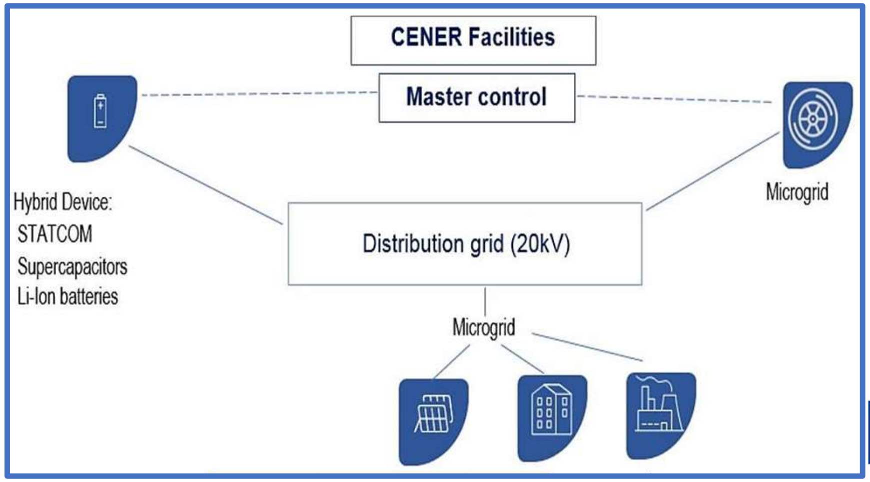
Innovation objectives:

1- A **Master Control** System (**MC**) to integrate the different flexibility technologies, coordinate their operation and define new control strategies.

2- New hybrid and modular storage solution with the capability to offer multiple system services, formed of supercapacitors, lithium-ion battery storage, STATCOM and power electronics, called **Hybrid Flexibility Device (HFD).**

3- HV Energy Storage: a Li-ion battery connected at high voltage level in DC (>1kV) to improve the integration of batteries in the high voltage grid.

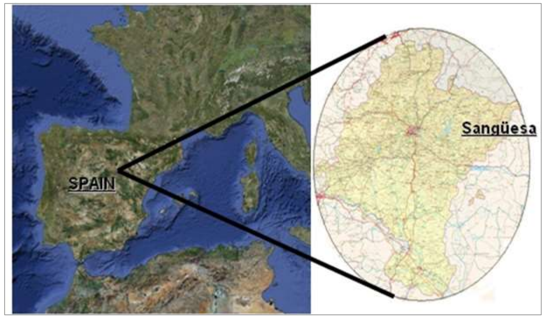




CENER FACILITIES

- ATENEA MICROGRID
- SIMULATION CAPABILITIES

CENER facilities: Atenea Microgrid

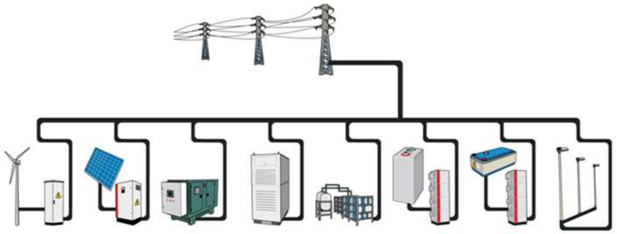


Reconfigurable AC Microgrid

Multiple Technologies

On-Grid / Off-Grid

Internal network voltage in Testing Laboratory is 20kV.



GENERATION

PV system, 25 kWp

Wind turbine, 20 kW

Diesel generator, 55 kVA

Gas microturbine, 30 kW

STORAGE

Flow battery, 50 kW, 4 hours

VRLA batteries, 50 kW, 2 hours

Li-ion battery, 50 kW, ½ hour

Supercapacitors, 30 kW, 45 s

LOADS

Programmable loads 120 kVA

Industrial area lighting

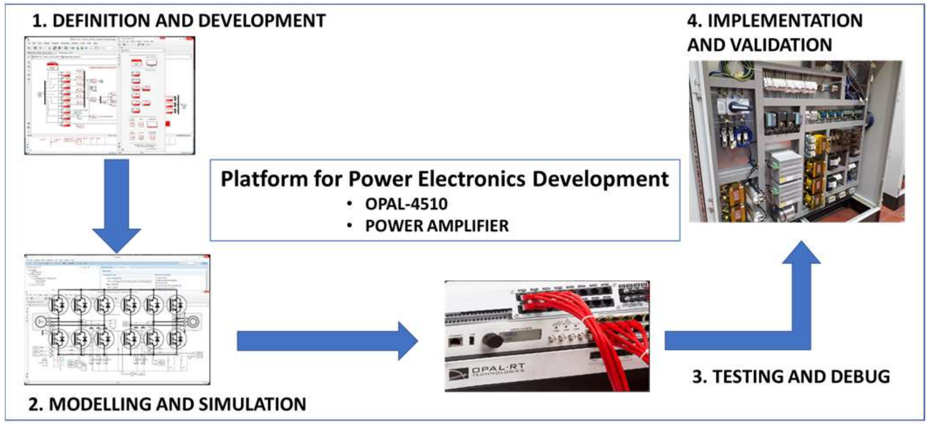
Electric vehicle

CENER facilities: ENERGY Storage System Testing

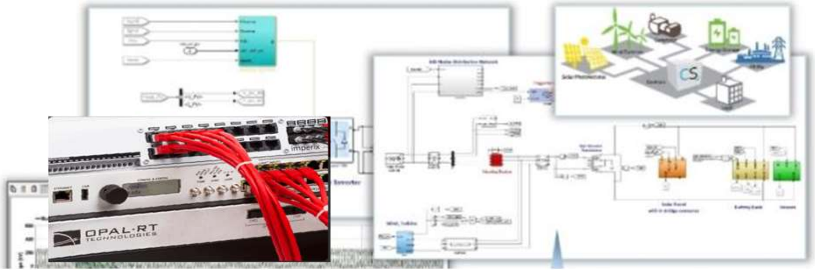
- A high-performance laboratory for electrical storage tests of different capacity and voltage range
- 500 kW AC/DC Grid Emulator
  - ✓ 3-phase/1-phase/split phase / Multichannel Grids
  - ✓ Independent phase configuration
    - ✓ voltage rms
    - ✓ phase angle
    - ✓ frequency and harmonics
  - ✓ Generation of disturbances
    - ✓ Harmonics, Interharmonics, Subharmonics
    - ✓ Voltage Dips
    - ✓ Frequency variation
    - ✓ Flicker
  - ✓ IEC, LVRT,SEMI-F47,CBEMA test Standards

Ion Lithium Battery 1 MW, 500 kWh.

CENER facilities: P-HIL laboratory



- **Power Electronics Development**
- **Smart-Grid Control Development**
- **Energy Management System (EMS) Development**

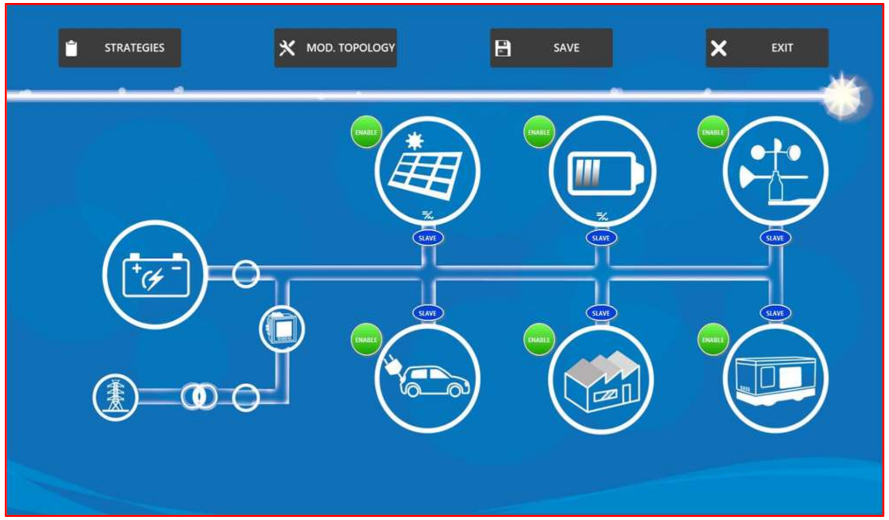


Platform for Smart-Grids Control and EMS Development

- **OPAL-4510**
- **POWER AMPLIFIER**

MODBUS

Anl. Dig. I/O



Energy Management System (EMS)

EMS based on a **configurable HMI** for multi-technological Power Plants and Microgrids.

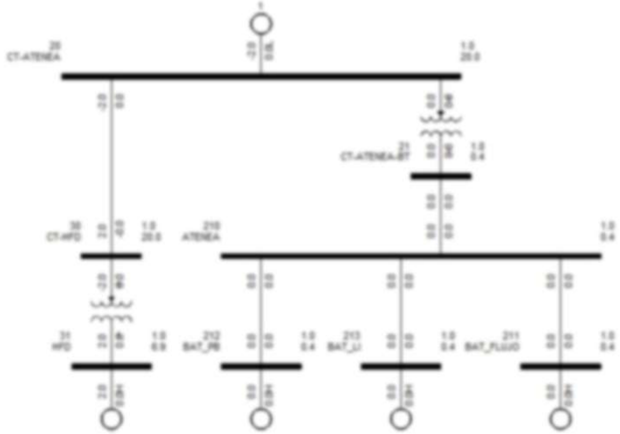
Strategies, Control and SCADA are embedded into the same **HW and SW Platform:**

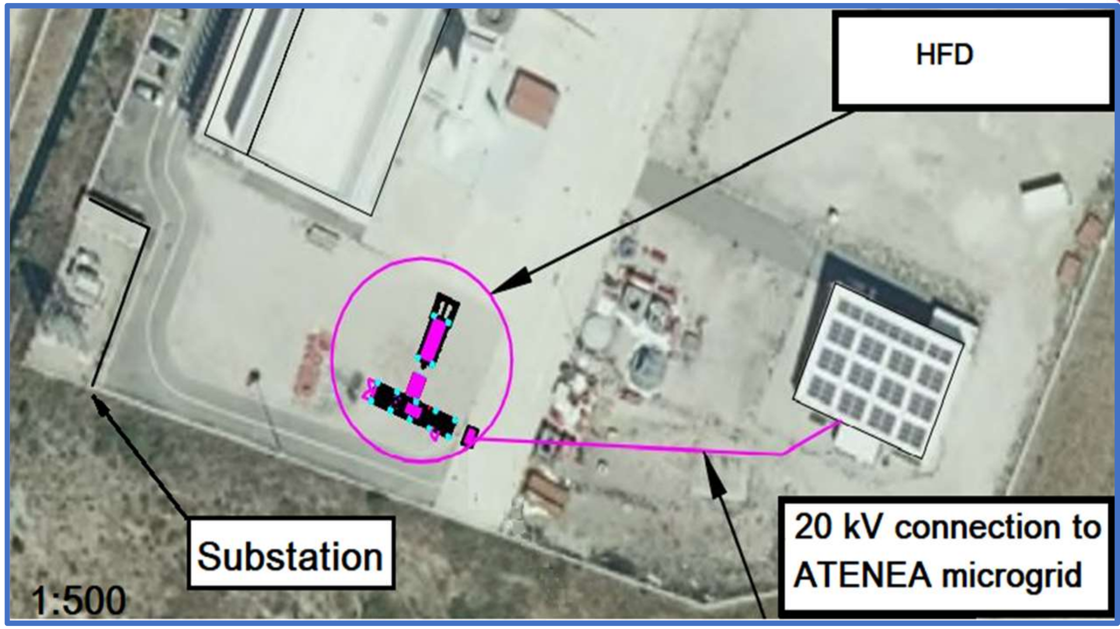
- ✓ Integrates Standardize industrial communication protocols.
- ✓ Integrates Advanced Smart Strategies for power plant energy optimization including optimal storage management considering **storage degradation.**
- ✓ Energy market and weather forecast access for strategies
- ✓ Integrates power plants elements control.

CENER facilities: OSMOSE Spanish demo

RED ELÉCTRICA DE ESPAÑA

Multi-services by different storage and FACTS devices (WP4)





- **Master control/HMI**
  - ✓ SCADA
- **HFD**
  - ✓ STATCOM
  - ✓ Li-ion battery 1MW, ½ hour
  - ✓ SC

- **Atenea Microgrid**
  - ✓ Li-Ion battery 50 kW, ½ hour
  - ✓ Redox-Flow battery 50 kW, 4 hours
  - ✓ Lead acid storage devices, 50 kW, 2 hours
  - ✓ PV plant
- **Transformer: 20/0.69 kV - 8MVA.**
- **20kV Medium Voltage Cells with Sepam S80 protection**

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MASTER CONTROL

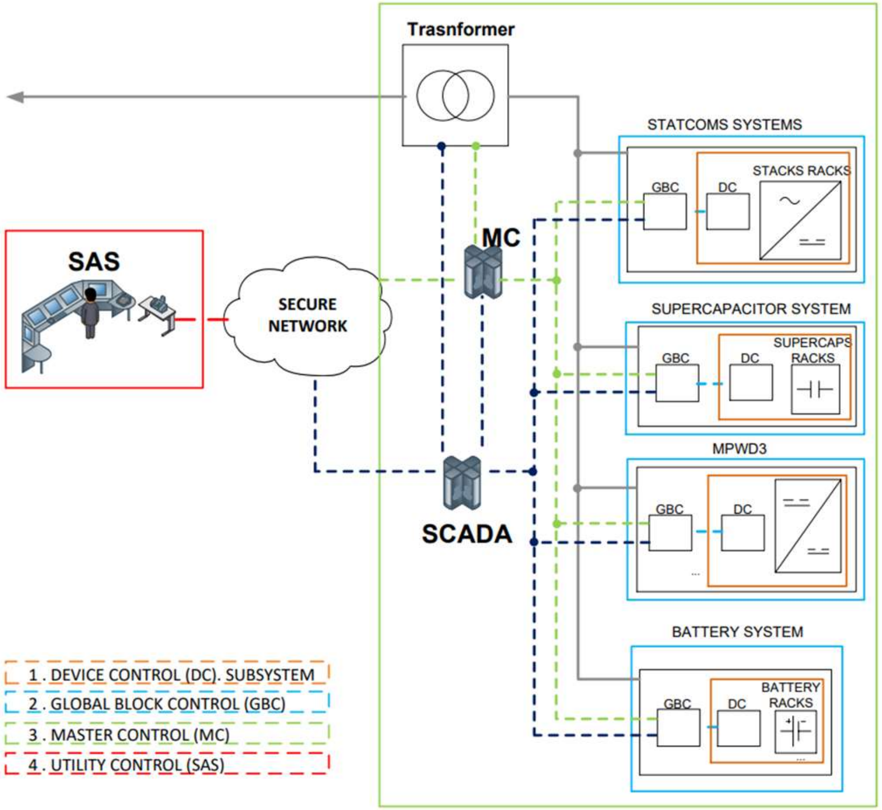
Master Control: Objectives

DEVELOPMENT OBJECTIVES

- **Integrate the MCFS in a coordinate operation and under new control strategies that minimize BESS degradation.**
- **Provide in real time to the TSO the necessary configuration capacity to program a combined response from the managed devices according to the appropriate operating needs of the transmission network .**
- Enable the **global/local control operation system.**
- For that reason, the system developed is:
  - ✓ **A global central control system.**
  - ✓ A comprehensive **storage management system independent of the underlying technology.**
  - ✓ **Highly configurable** with the characteristics, capabilities and limitations of the physical devices and the PCC.
  - ✓ **Interoperable based on communication protocols** with the devices to enable their control and to update in real time their status and relevant information from the grid.

MCFS CONTROL

Layer 3 MC: Global control operations of the equipment and SCADA of the installation.

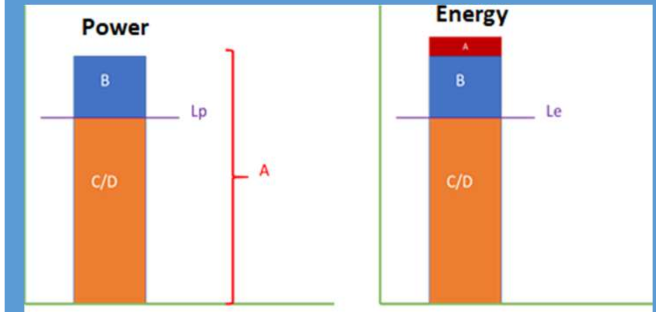


Master Control: Services

FLEXIBILITY SERVICES

	1st LEVEL	2nd LEVEL	3rd LEVEL
Objective of the controls at each level	To provide grid stability support services	To provide voltage and frequency control services once grid stability has been guaranteed	To optimize the management of the flexibility devices, taking into account the nature and characteristics of the devices it manages.
Operated by MC	No	Yes	Yes
Services and Functionalities	• Inertia emulation (A) • Fast Fault Current Injection (A) • POD (A) • P-f regulation (trapezoidal response) (A) • P-f regulation (primary frequency regulation on disturbed condition) (A)	• P-f regulation (continuous primary frequency regulation) (B) • Voltage control (D) • Q setpoint control (D)	• Setpoint tracking (C) • Program management (C) • Congestion management (D)

Distribution of the power/energy based on the functionality

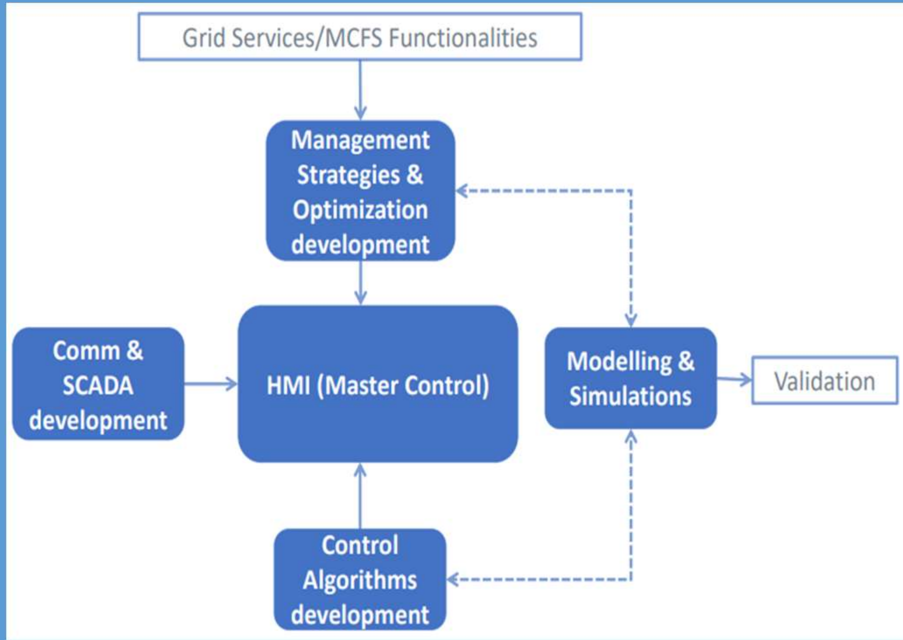


Lp [0%-100%]   Le [0-100]·(%(E_{NC} - E_{tA}))

Master Control: Control Modules

- **Control module**: to establish the operation of the MC for the calculation of the setpoint power attending to prerequisites of the TSO, P and Q of a global set of storage systems, to correct the power measured at PCC, responding correctly to the power requirements at PCC.
- **Energy optimization**: to establish the setpoints to the equipment, depending on the grid events, services and equipment status, so that the plant responds taking into account both the test plans as services to be provided foreseen in the project.
- **SCADA**: enable the global/local control operation system and update in real time their status and the grid.

Approach followed to develop the MC/HMI



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Master Control: Energy Management Strategy

- **Minimising**:
  1. **Unnecessary use of equipment,**
  2. **Deviation of their SoC from the recommended levels according to their technology,**
  3. **Operations in aggressive power ranges and/or far from those that minimise degradation.**
- The **objective function** of the optimisation problem is described as follows:

$$min\left|\sum_{bat=1}^{n}(Kb_{bat}\cdot S_{bat}+Ksoc_{bat}\cdot|VarSOC_{bat}|+Kp_{bat}\cdot|VarP_{bat}|)+K_{pns}\cdot pns\right|$$

- Optimization problem **restrictions:**
  1. **Minimum and maximum limits of SOC and Power restricted (manufacturer, electrical, etc).**
  2. **Lp and Le limits.**
  3. **2nd and 3rd level functionalities set-point required by the grid operator must be met.**

Parameters	Description
bat:	Each of the ESS available.
Kb_{bat}:	Weight of the idle consumption.
S_{bat}:	Battery status (on/off).
$Ksoc_{bat}$:	Weight of battery degradation due to state of charge variation by technology.
$VarSOC_{bat}$:	Absolute value of the variation of the state of charge with respect to its ideal state of Charge according to technology and design.
Kp_{bat}:	Weight of battery degradation per power usage value according to technology.
$VarP_{bat}$:	Absolute value of the variation of the absolute power with respect to its ideal power according to the technology and its design.
K_{pns}:	Weight of power not supplied due to ESS technical restriction.
pns:	Power not supplied due to ESS technical restriction.

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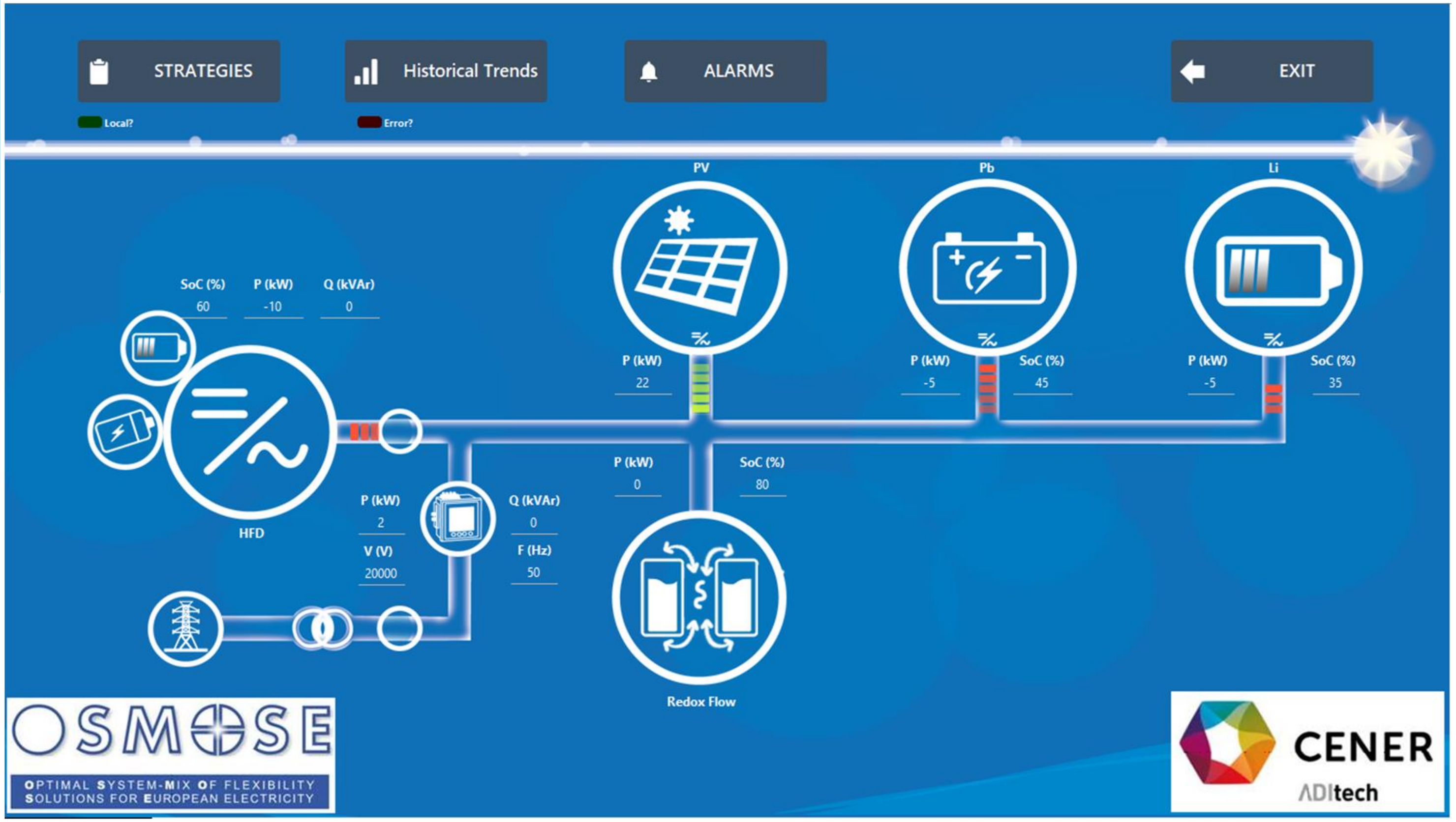
Master Control: SCADA



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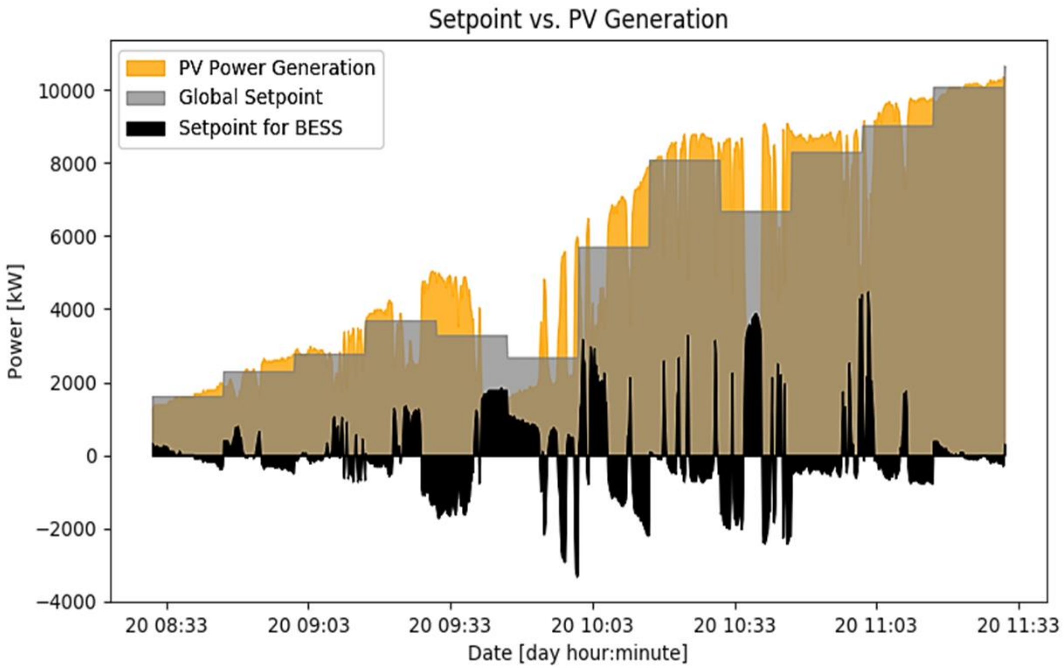
CASE STUDY AND RESULTS

CASE STUDY AND RESULTS

I- Congestion Management:

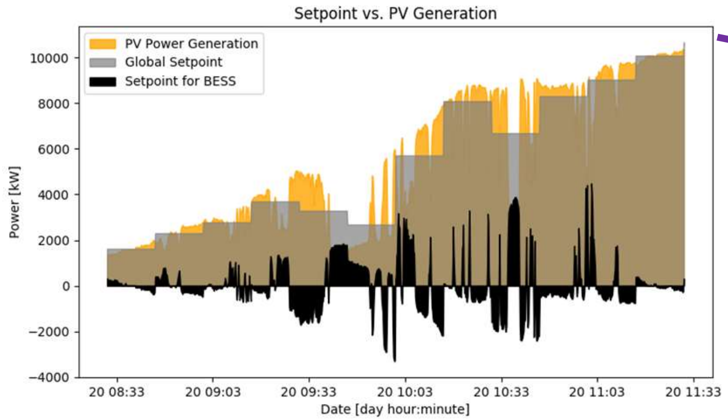
- **Objective** of studies:
    - MC capability management of different technologies, allowing power exchange of the different devices with the grid.
    - Functionality: Power flow congestion management in the interconnection node with PV integration.
- **Scenario**:
    - The set of BESS try to compensate for the deviation between PV generation and the PV prediction.
    - Lp: 30%
    - Le: 40%

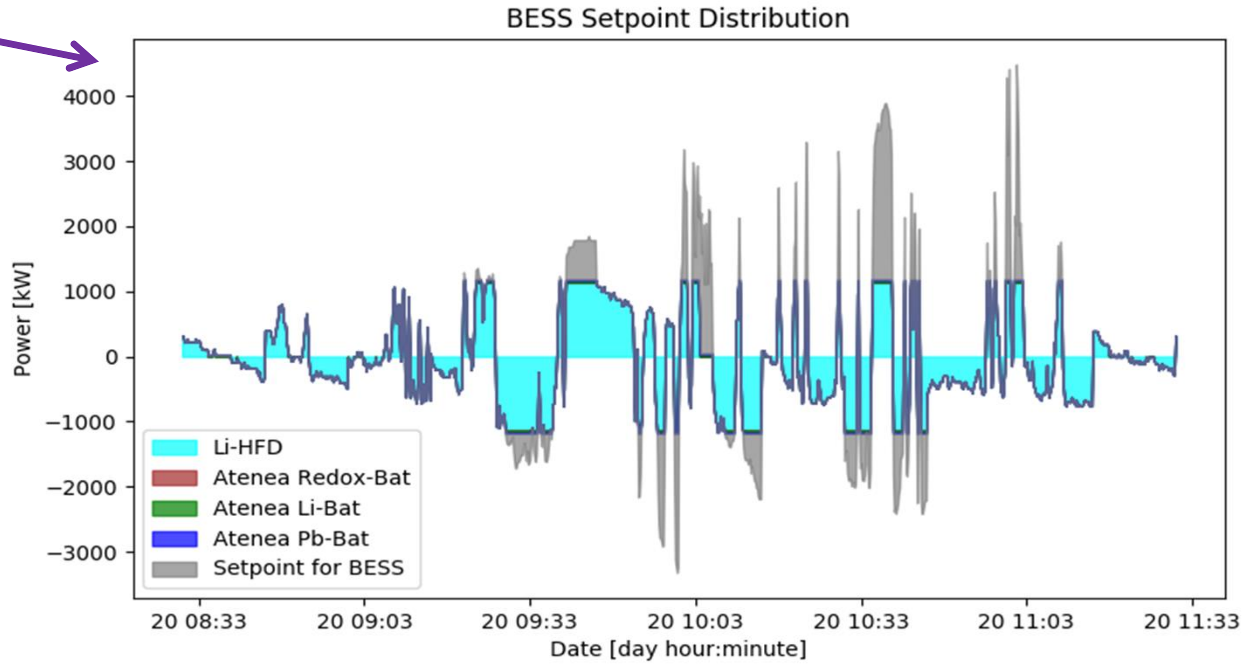
Parameters	Li-HFD	Atenea Redox	Atenea Lithium	Atenea Pb-Bat
Technology	Lithium	Redox Flow	Lithium	Pb
Capacity (kWh)	500.0	200.0	43.2	35.0
Nominal Power (kW)	1600.0	45.0	30.0	15.0
Minimum SOC	0.20	0.10	0.25	0.40
Maximum SOC	0.90	0.95	0.90	0.85
Initial SOC	0.70	0.70	0.70	0.70
Off-load consumption (kW)	16.0	5.0	1.3	3.7
2nd Level func.	✓	✓		
3rd Level Func.	✓		✓	✓



CASE STUDY AND RESULTS

I- Congestion Management: Setpoints Distribution



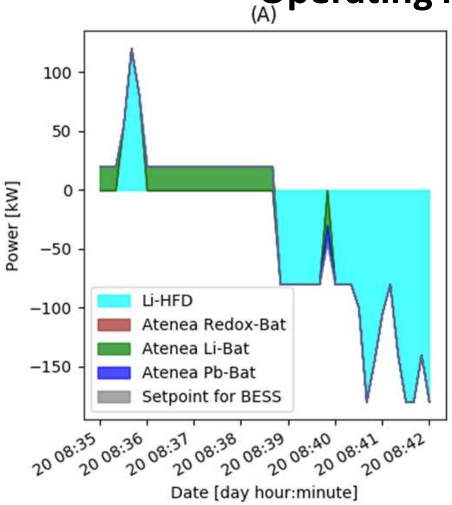


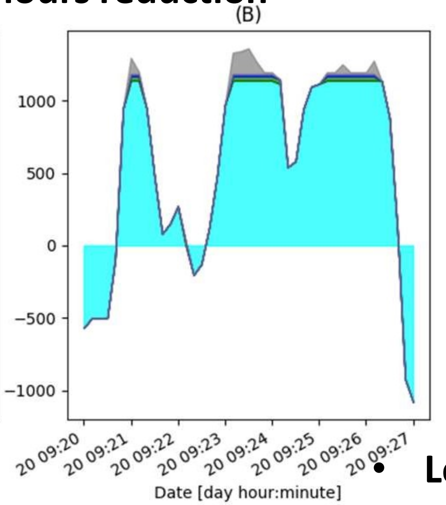
Optimization Parameters	Li-HFD	Atenea Redox	Atenea Lithium	Atenea Pb-Bat
K_B	12.3	3.8	1.0	2.8
Optimal SOC level	0.6	0.5	0.6	0.8
K_{SOC}	0.5	0.1	0.5	1.0
Optimal Power level (kW)	500.0	40.0	21.6	3.5
K_{POT}	0.4	0.1	0.4	1.0
2nd Level func.	✓	✓		
3er Level Func.	✓		✓	✓

CASE STUDY AND RESULTS

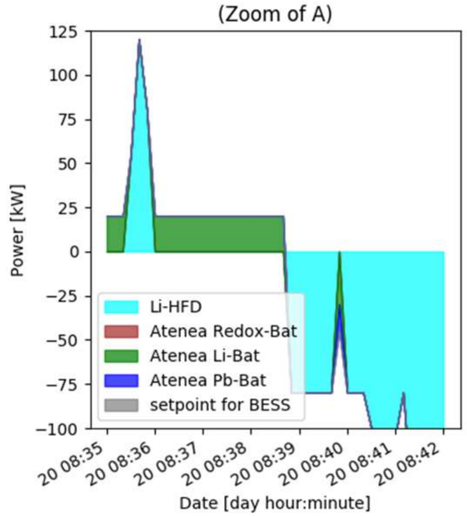
I- Congestion Management: Restrictions

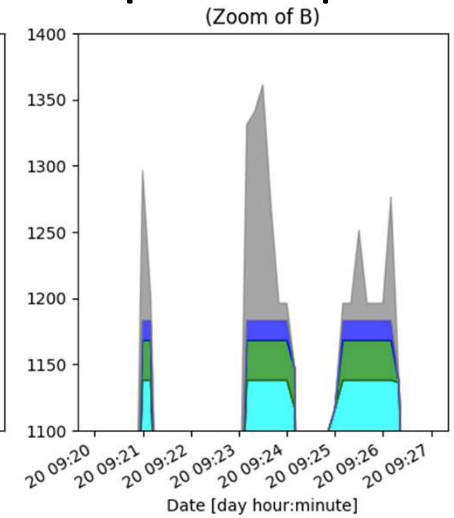
- **Operating hours reduction**



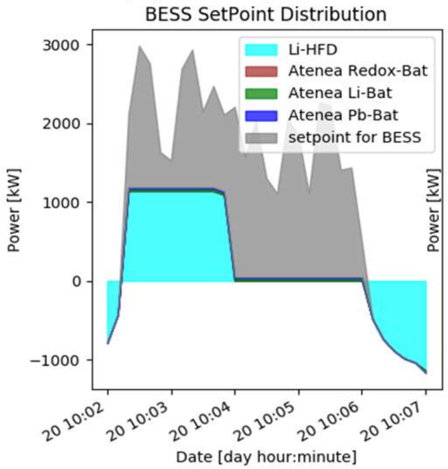


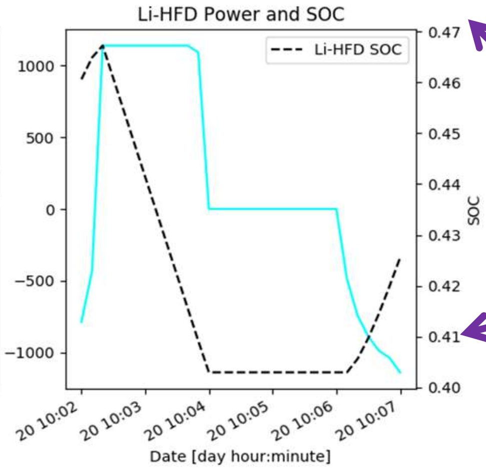
- **Technical restrictions and Lp limit compliance**

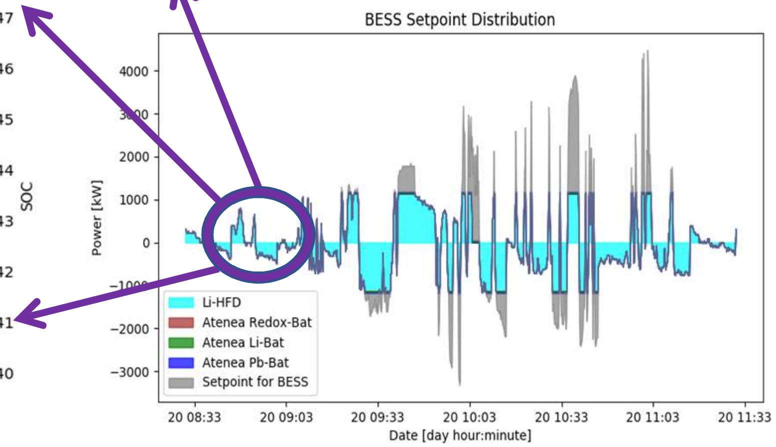




- **Le limit compliance**



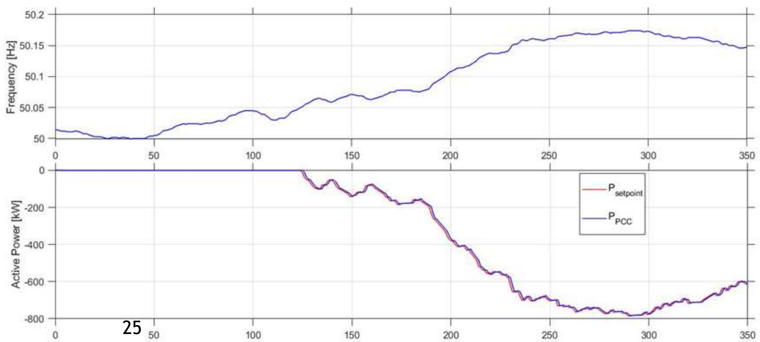


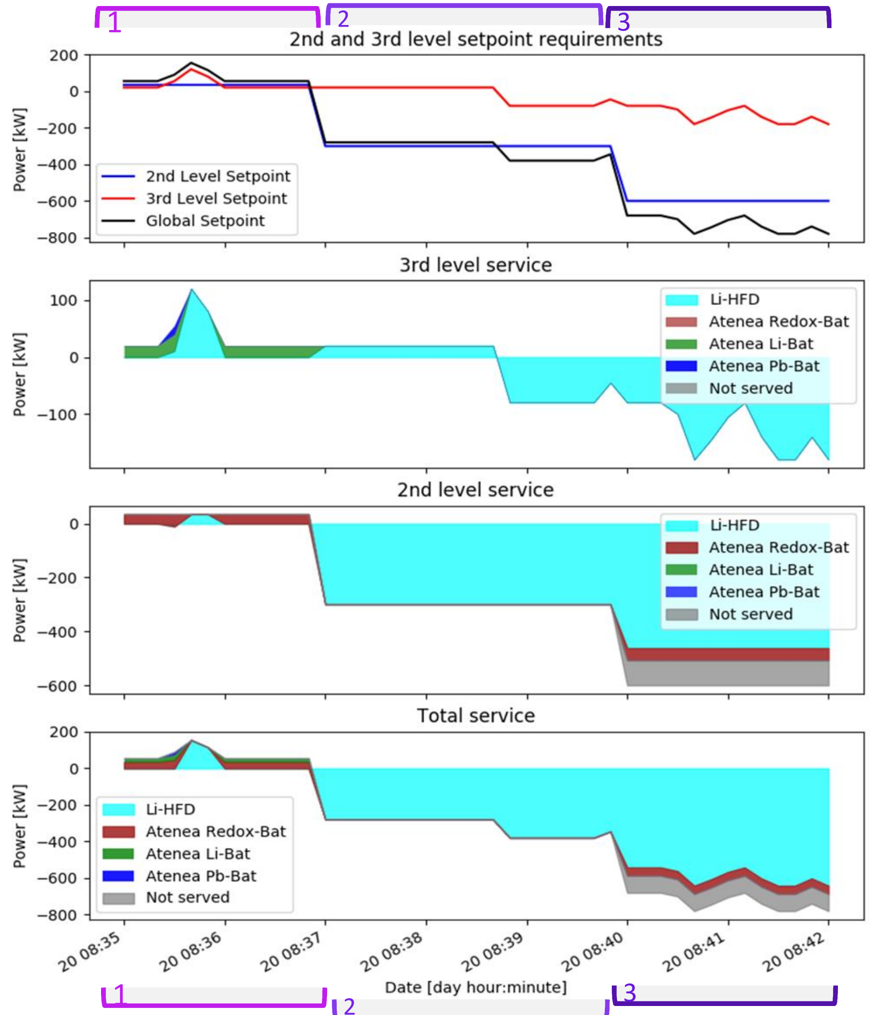


CASE STUDY AND RESULTS

II- Congestion Management + P-f:

- **Scenario**: the set of BESS try to compensate both:
  - A challenge congestion situation may cause a **frequency variation** if the event is important to be considered or in case the grid is weak.
  - To keep the **reliability of the grid**, besides of congestion management, **P-f regulation** functionality may participate to support the grid.
- **Flexibility of the solution proven;** the MCFS provides both services at the same time:
  - → Providing power to prevent congestion on the node
  - → to restore the nominal frequency of the grid.





CONCLUSIONS AND FUTURE WORK

CONCLUSIONS AND FUTURE WORK

- ✓ **OSMOSE Spanish demonstration addresses flexibility for the integration of RES by a MCFS to provide flexibility services.**
- ✓ **ATENEA microgrid enables hybridization and performance testing of HFD working as a MCFS.**
- ✓ **Master Control** development implies a **supervisory control based on modularity: plant control, energy management strategies and SCADA** for HFD and to provide flexibility services stablished by the TSO.
- ✓ **The energy strategy** developed minimize degradation in terms of:
  - **Unnecessary operating hours**, deviation of their **recommended SOC** and **preventing aggressive power ranges operations.**
  - **Respecting the technical limits** stablished by the manufacturer and the grid connection.
- ✓ **A case study** recalls the maximisation of **PV integration** in a **congestion management service** based on flexibility storage solution **through Le and Lp parameters.**
- ✓ Evidence of **flexibility** is presented in terms of **multiple services provided by the MCFS.**

→ **Future work**

Thank You Very Much!

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