EPRI
Applied R&D for a Shared, Integrated Grid

Vienna, Austria March 14-16, 2023

2023 EPRI EUROPEAN WORKSHOP WEEK

Centro Nacional del Hidrógeno

Centro Nacional del Hidrógeno

National Hydrogen Center Capabilities and Applications

Javier Tobajas Blanco | Simulation, Control and End-Use Unit
Javier.tobajas@cnh2.es | Viena, March 14 2023

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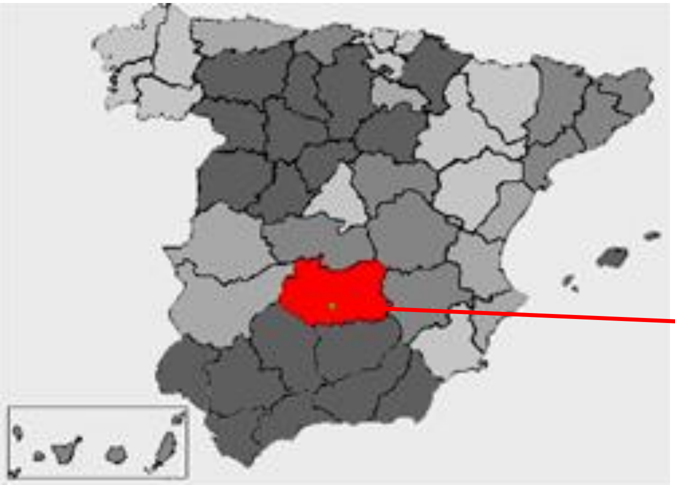
National Hydrogen Center

- **Public Research Center** created through a Consortium between the Ministry of Science and Innovation and the Junta de Comunidades de Castilla-La Mancha, 50% each.



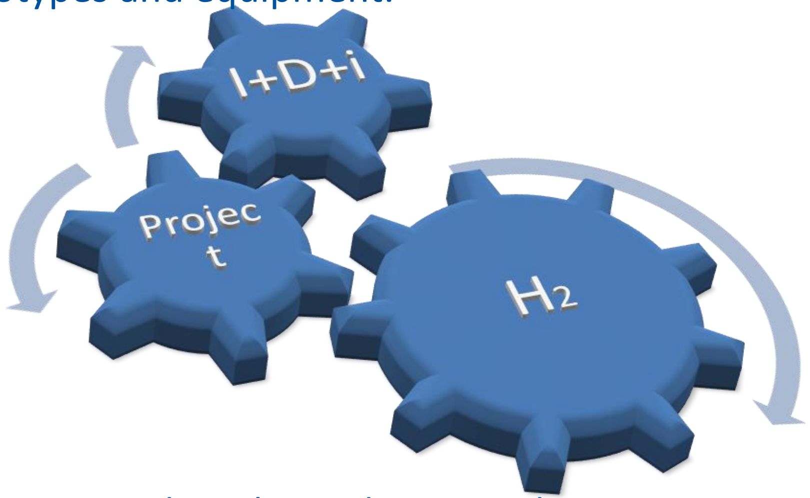
CNH2 Headquarters in Puertollano

National Hydrogen Center

Public organization focused on the ***development of H2 technologies*** and fuel cells (laboratories, test benches, experimental stations, batteries, storage systems, engineering, safety, regulations, among others).

Main Objectives

- **Promote and encourage H2 and fuel cell technologies** at national and international level by means of social perception studies, training and dissemination of their use and applications.
- Perform **research, experimentation and validation** of prototypes and equipment.
- **Develop and scale processes.**
- **Implement R&D&I projects:**
  - ✓ **Under contract** (through companies with public or private funding) public or private funds)
  - ✓ **In collaboration** (international, national or regional with public funding)
  - ✓ **Strategic** (financed with own resources).



- **Services to third parties** (consulting, training, characterization and analysis, design and construction of test benches, safety and regulatory studies, etc.).

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National Hydrogen Center

The main lines are:

- Hydrogen production
- Use of Hydrogen
- Hydrogen distribution, transport and storage
- Horizontal activities (safety, control, simulation...)

HYDROGEN PRODUCTION

ALKALINE ELECTROLYSIS

PEM ELECTROLYSIS

SOLID OXIDE ELECTROLYSIS

BIOTECHNOLOGIES FOR HYDROGEN PRODUCTION

USE OF HYDROGEN

FUEL CELL

H2 INTEGRATION IN SMART GRIDS

USE OF H2 IN TRANSPORT

USE OF H2 IN INDUSTRY

USE OF H2 IN BUILDINGS

HYDROGEN DISTRIBUTION, TRANSPORT AND STORAGE

MATERIALS IN CONTACT WITH H2

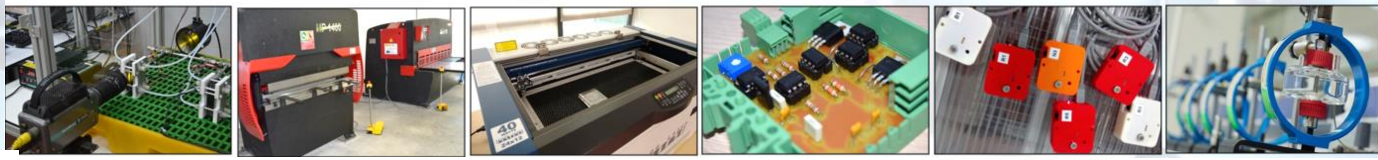
H2 INJECTION INTO THE NATURAL GAS NETWORK

HYDROGEN PURIFICATION

HYDROGEN STORAGE

POWER TO X (INCLUDING OTHER ENERGY SOURCES)

HORIZONTAL ACTIVITIES



SIMULATION

PROTOTYPING

MANUFACTURING SUPPORT

ELECTRONIC AND CONTROL

SECURITY

MATERIAL CHARACTERIZATION

GENERAL CONSIDERATIONS

Following installations are part of:

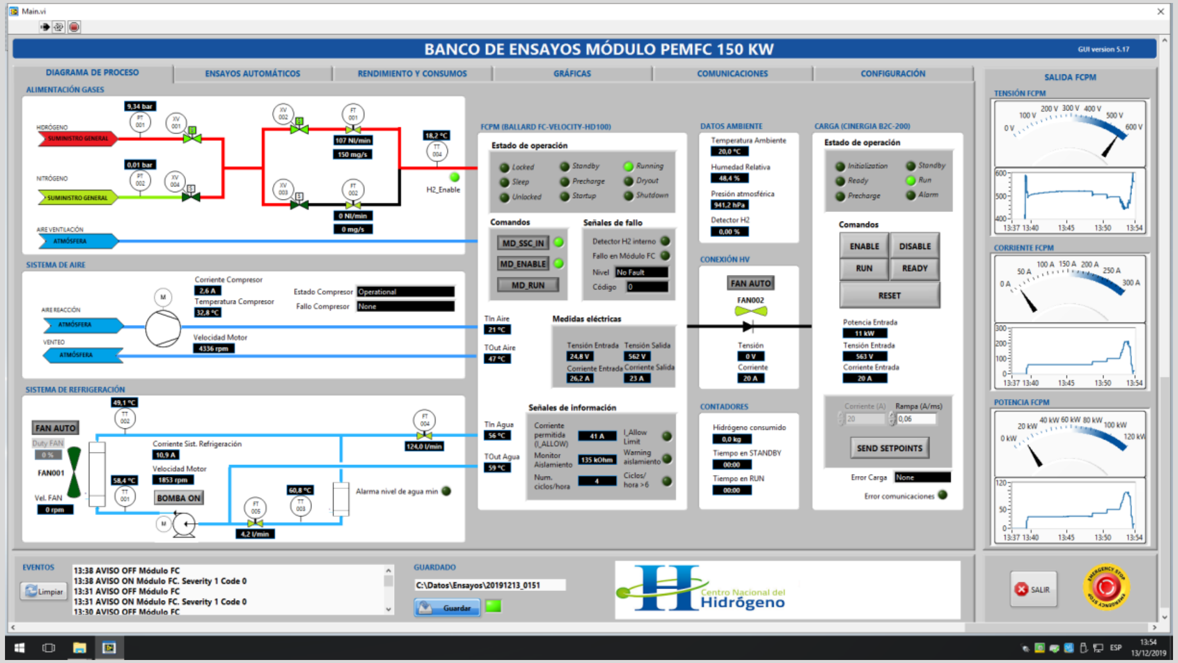
- ✓ National and European Collaboration R&D+i Projects
- ✓ Services provided to both National and International companies
- ✓ Internal Projects and Testbenches at CNH2 Laboratories

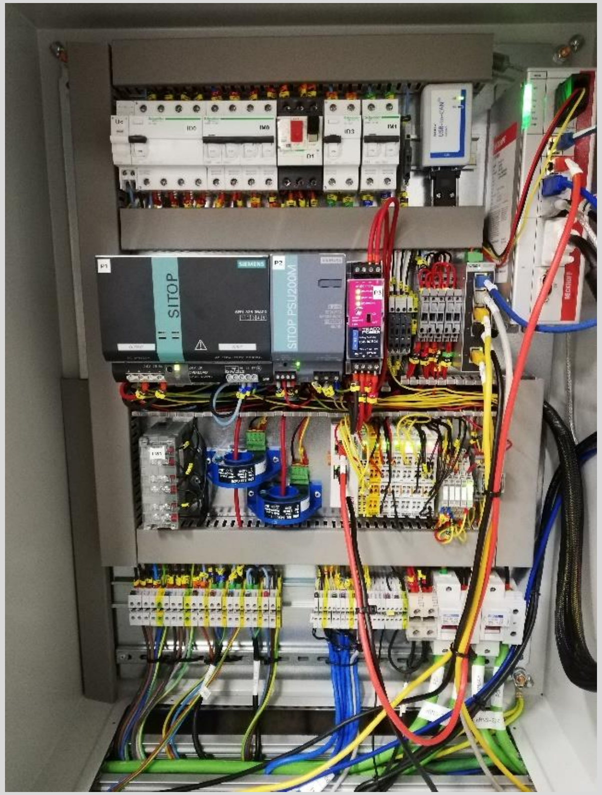
All the mechanical, electrical and control works presented are made by CNH2 own resources:

- ✓ Electrical design calculations, drawings and cabinet layouts
- ✓ Mechanical design of structures, installation and integration of subsystems in laboratory, container or final product
- ✓ Cabling, connections and electrical installation
- ✓ Data acquisition and signal processing
- ✓ PLC programming and Human-Machine Interfaces
- ✓ Remote access / Web Servers / Mobile Apps

PEMFC Heavy Duty Modules Test Bench 150 kW (1/2)

- ✓ Characterization of PEMFC Systems for Railways, Buses or Garbage trucks
- ✓ Integration of required subsystems: Cooling DI water / Air compressor / H2 Supply
- ✓ Regenerative programable Load/Source (High voltage battery BUS emulation)
- ✓ Multiple industrial communications including vehicle CAN Diagnosis





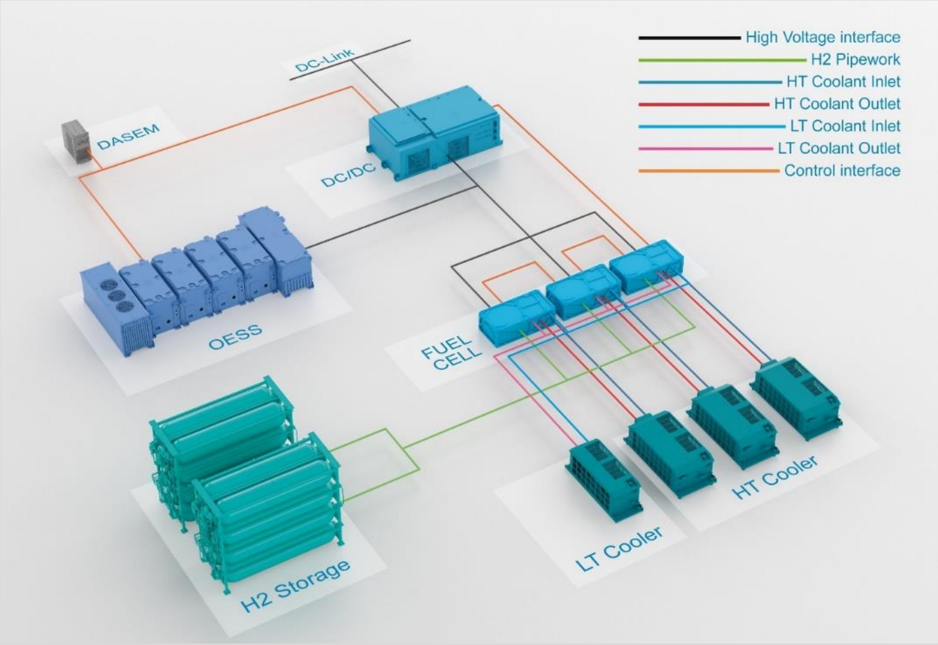
PEMFC Heavy Duty Modules Test Bench 150 kW (2/2)

PEMFC Stacks and Modules Test Benches 1-10 & 10-30 kW

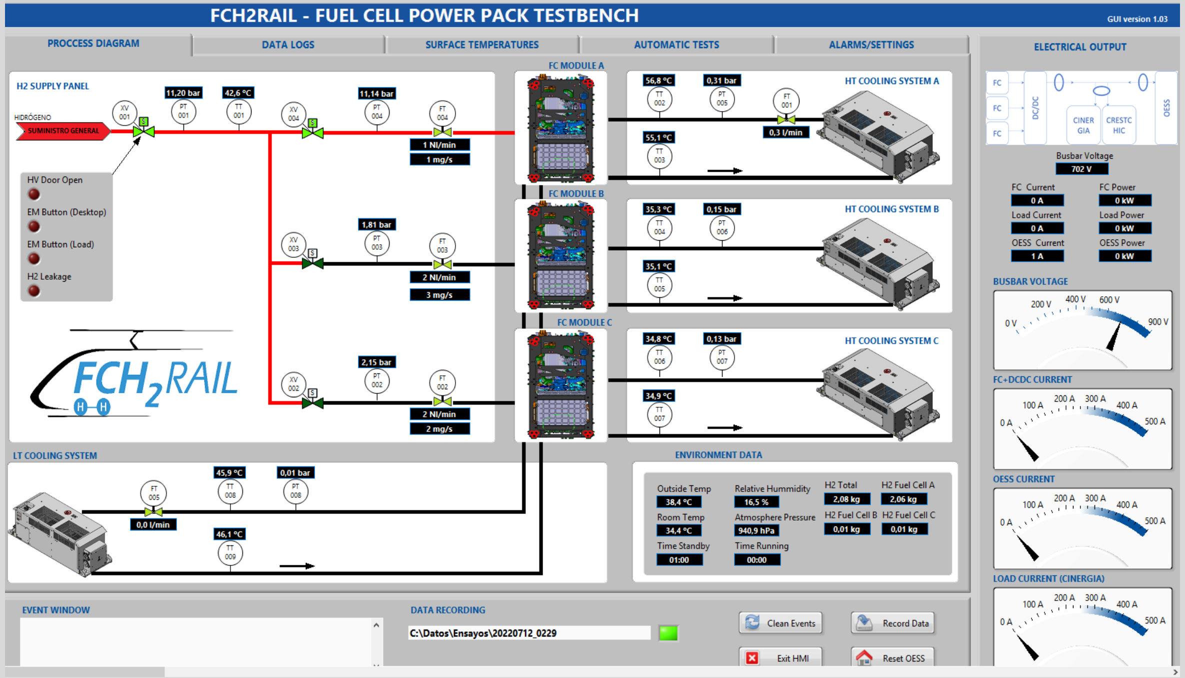
- ✓ Adaptable to many PEMFC Stacks and Modules
- ✓ Gasses conditioning and precise flow measurements
- ✓ Alarms and hydrogen detection
- ✓ Climatic chamber for long-time and accelerated life tests

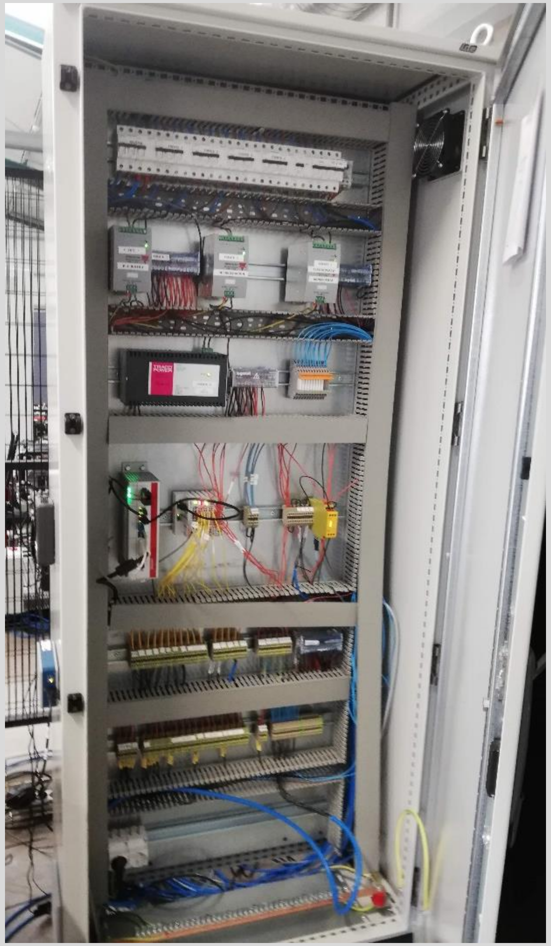
Project FCH2RAIL - PEMFC + OESS Test Bench 210 kW (1/2)

- ✓ Testbench fully dedicated to the integration a Fuel Cell PowerPack
- ✓ Hybridation FC+Batteries tested versus a real train track profile emulation
- ✓ A complete validation has been made in terms of interfaces, performance and safe operation before the installation of the PowerPack in the Train



Project FCH2RAIL - PEMFC + OESS Test Bench 210 kW (2/2)





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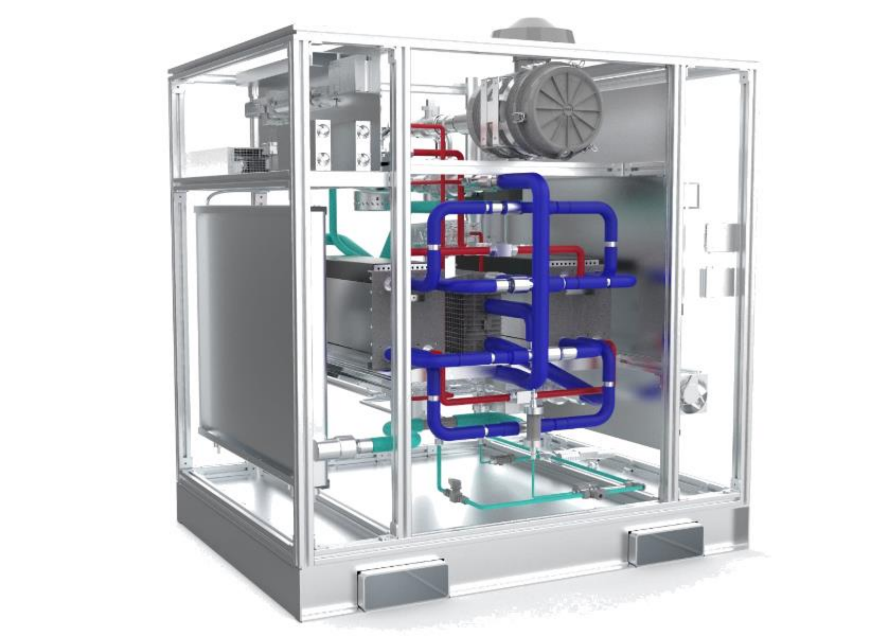
PEMFC Genset Prototypes 20 kW VAC & VDC (1/2)

- ✓ Prototypes of zero-emission alternative to diesel combustion gensets
- ✓ Fully developed at CNH2 for Nedstack Fuel Cells
- ✓ Absolute mechanical robustness and electrical safety design due to outdoor requirements of the off-grid market (events, festivals, construction sites…)



PEMFC Genset Prototypes 20 kW VAC & VDC (2/2)

Project - TOGETHER

- ✓ Micro-CHP used in cogeneration of electricity and heat for residential uses.
- ✓ Development of a small H2 Refuelling Point at 200 bar

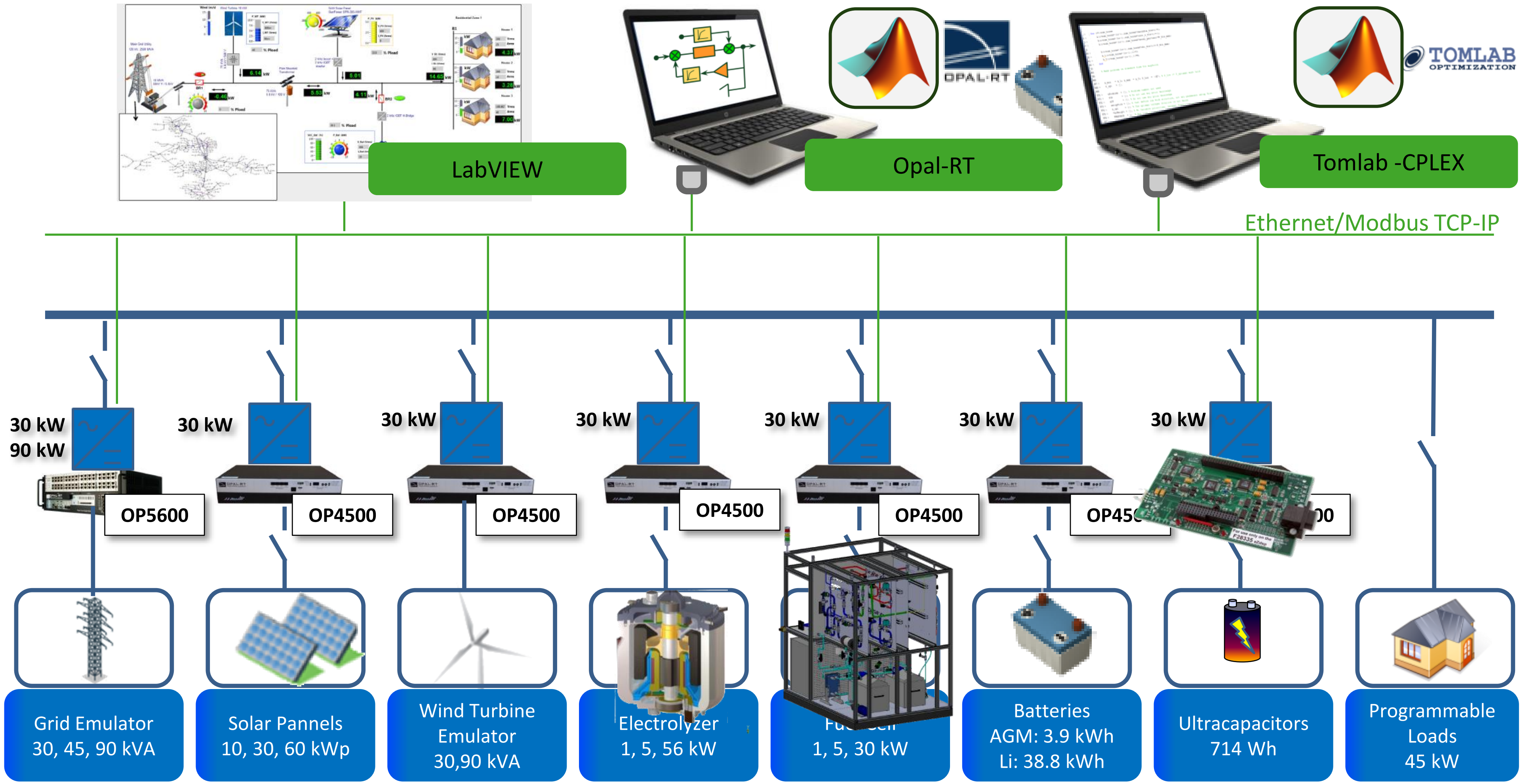
Project – H2LOGIN

- ✓ Retrofitting of Electric Forklift with Fuel Cell PowerPack
- ✓ Development of a H2 range exteneder for a Diesel Delivery Van
- ✓ Communication interfaces and IoT for logistics applications

Microgrids Laboratory

- ❑ Development of Hybrid Energy Storage Systems in Microgrids Applications
- ❑ New components for Microgrids Testing and Validation
- ❑ Development of Model Predictive Control Algorithms for Energy Management System including Mixed Logic and Integer Variables (MILP, MIQP, MINLP)
- ❑ New control algorithms for Power Electronics developing and validation
- ❑ Testing and Validation Services of Control Algorithms for Microgrids.

Microgrids Laboratory



Interreg Sudoe

IMPROVEMENT

IMPROVEMENT Project

INTEGRATION OF COMBINED COOLING, HEATING AND POWER MICROGRIDS IN ZERO-ENERGY PUBLIC BUILDINGS UNDER HIGH POWER QUALITY AND CONTINUITY REQUIREMENTS

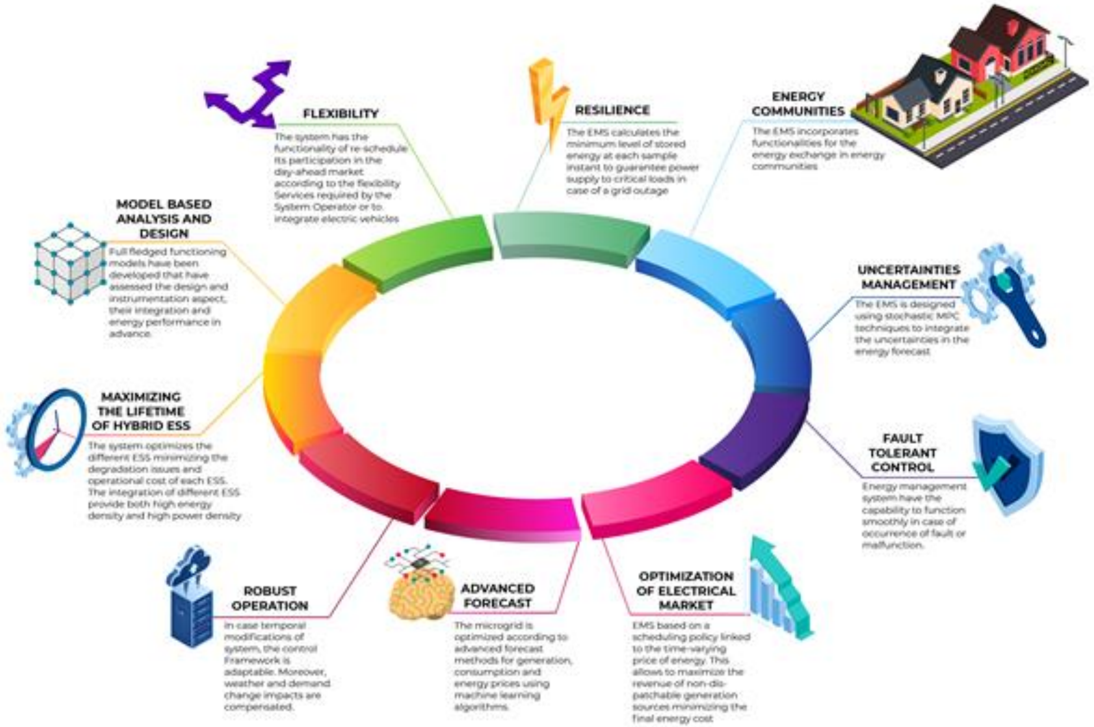
Centro Nacional del Hidrógeno · UCLM Universidad de Castilla-La Mancha · ISAE ENSMA · TÉCNICO LISBOA · LNEG · Junta de Andalucía · Universidad de Córdoba · Junta de Andalucía Consejería de la Presidencia, Administración Pública e Interior Consejería de Hacienda y Financiación Europea · Agencia Andaluza de la Energía · Université Perpignan Via Domitia

- Introduction
- Objectives
- Pilot Plants
- Electrical Microgrid Management System
- Thermal System

Introduction

In recent years, numerous projects have been developed to reduce energy consumption in buildings, both from the point of view of energy efficiency and integration with renewable energies.

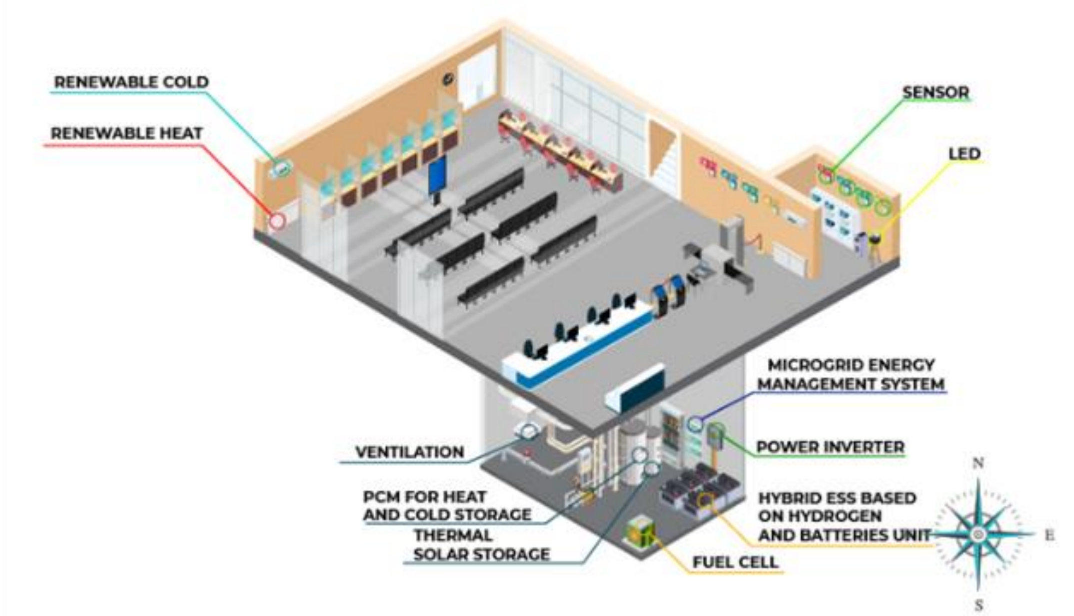
However, the specific problem of integrating this type of energy systems in facilities, is that the reliability of the electricity supply has to be considered as a fundamental aspect.



Introduction

There are some places where power outages can mean more than economic losses:

- For health reasons in hospitals
- Scientific considerations in technology centers and universities
- Defense conditions either in military installations
- Security and surveillance in transport stations and airports



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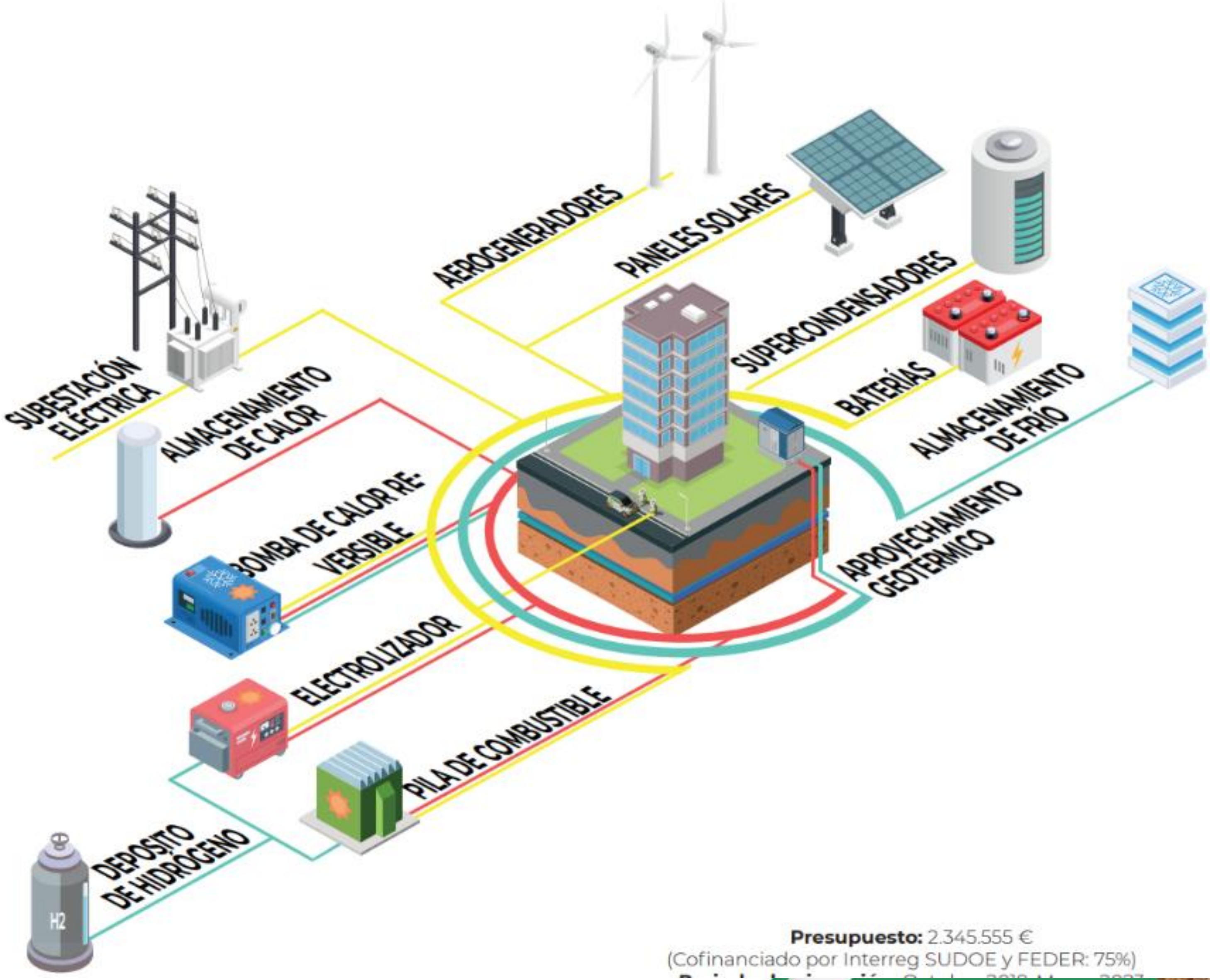
Objectives

The main objective of the IMRPOVEMENT project

To convert **public buildings** into **zero energy buildings** by integrating renewable **energy microgrids with combined heat, cooling and power generation** with inverters with active neutral control using **hybrid energy storage systems (Hydrogen, batteries, ultracapacitor)** that will ensure power quality and continuity of service to equipment sensitive to power quality disturbances (high-tech equipment) while increasing energy efficiency in this type of buildings.



Objectives

Specific Objectives

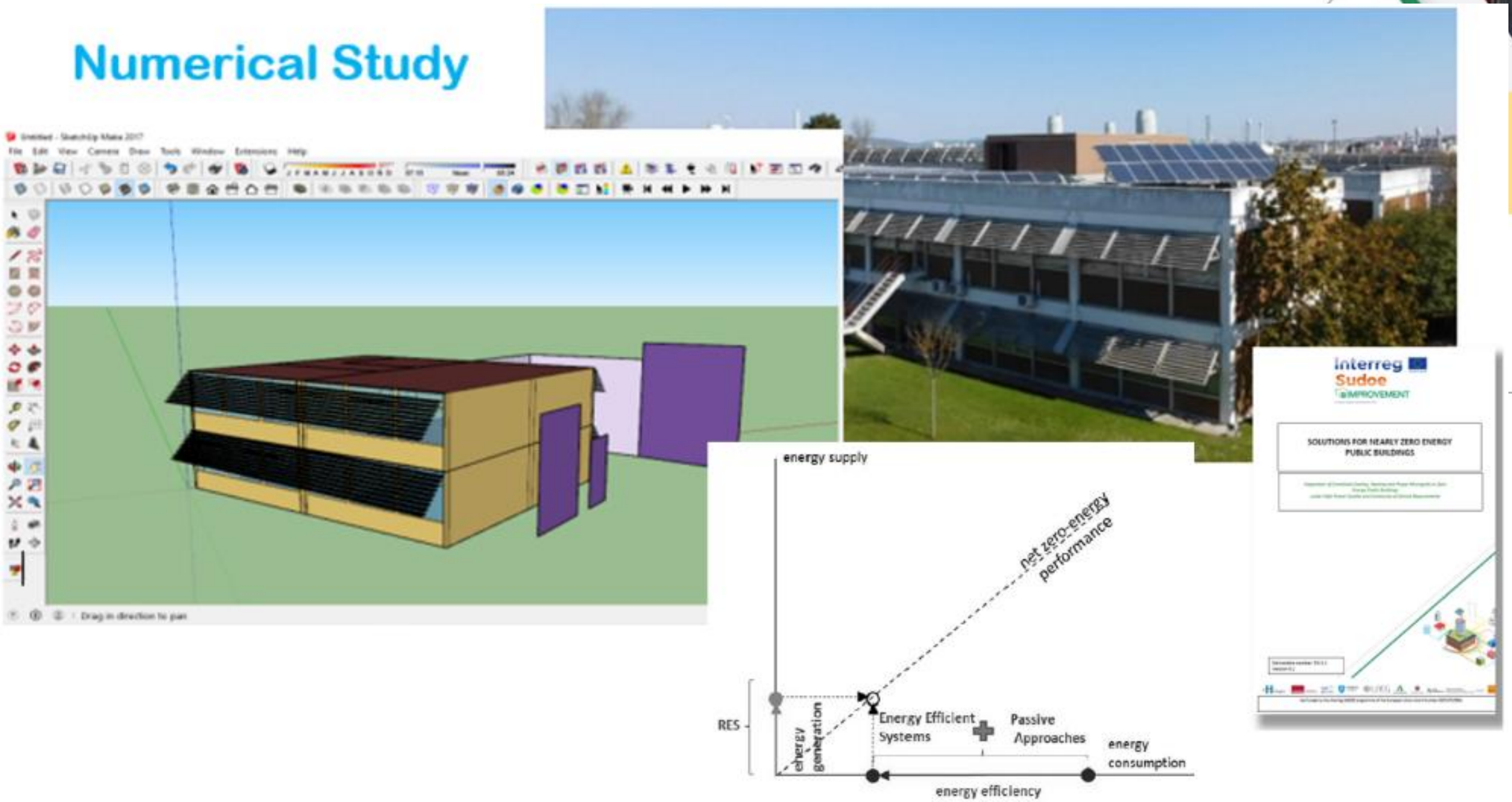
- Development of a system to improve energy efficiency in public buildings through a solar heating and cooling generation system and the incorporation of active/passive techniques for buildings with zero energy consumption.

- Development of a fault resistant power control system for microgrids under high quality design criteria and continuity of supply.

- Development of an energy management system for renewable generation microgrids with a hybrid energy storage system under criteria of minimum degradation, maximum efficiency and priority in the use of renewable energies

LNEG Pilot Plant

The main objective is to achieve and offer a thermal comfort situation in the facilities.



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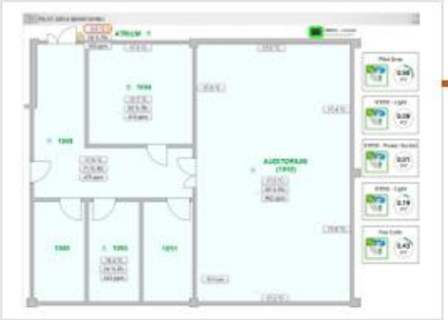
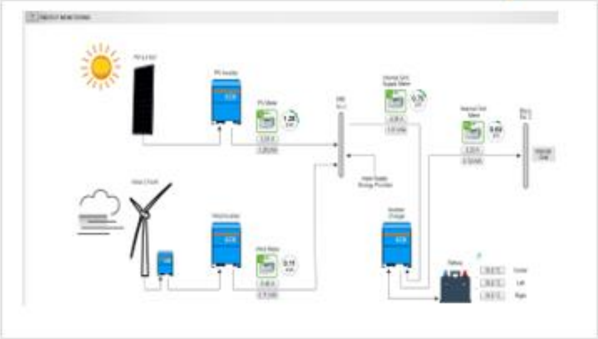
LNEG – Thermal EMS Pilot Plant

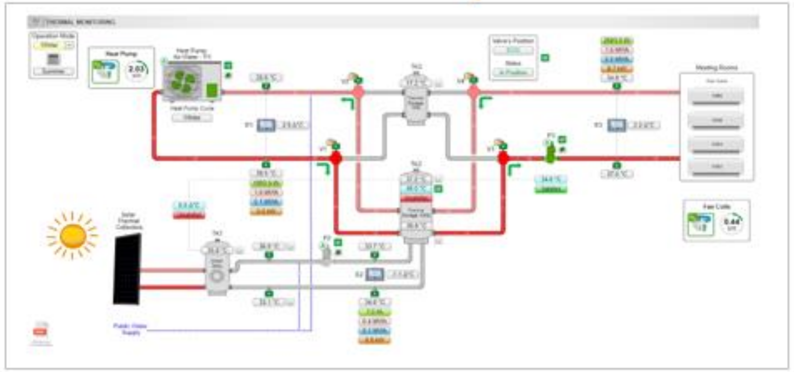
Pilot Plant



Electrical Production System



Thermal EMS System plant



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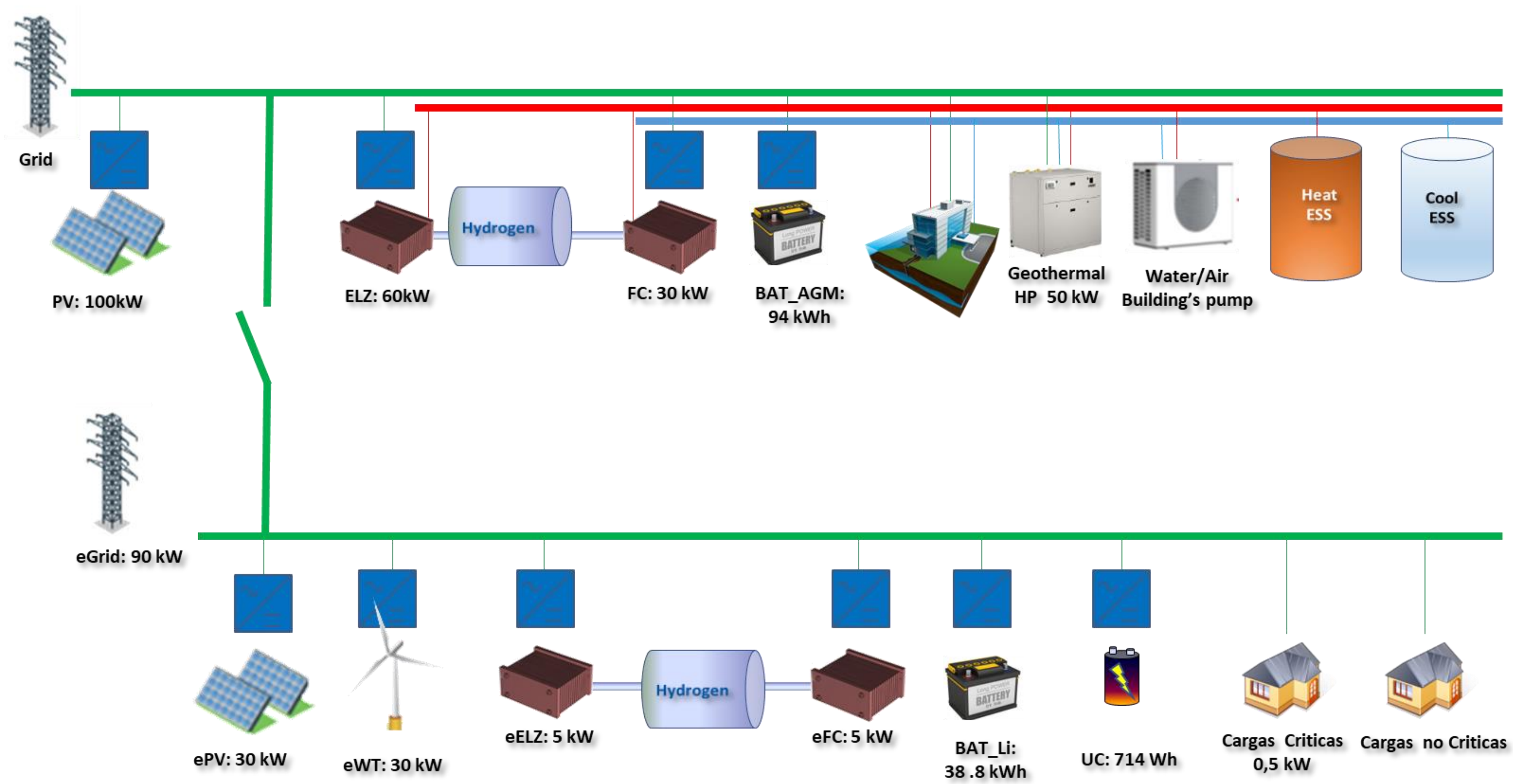
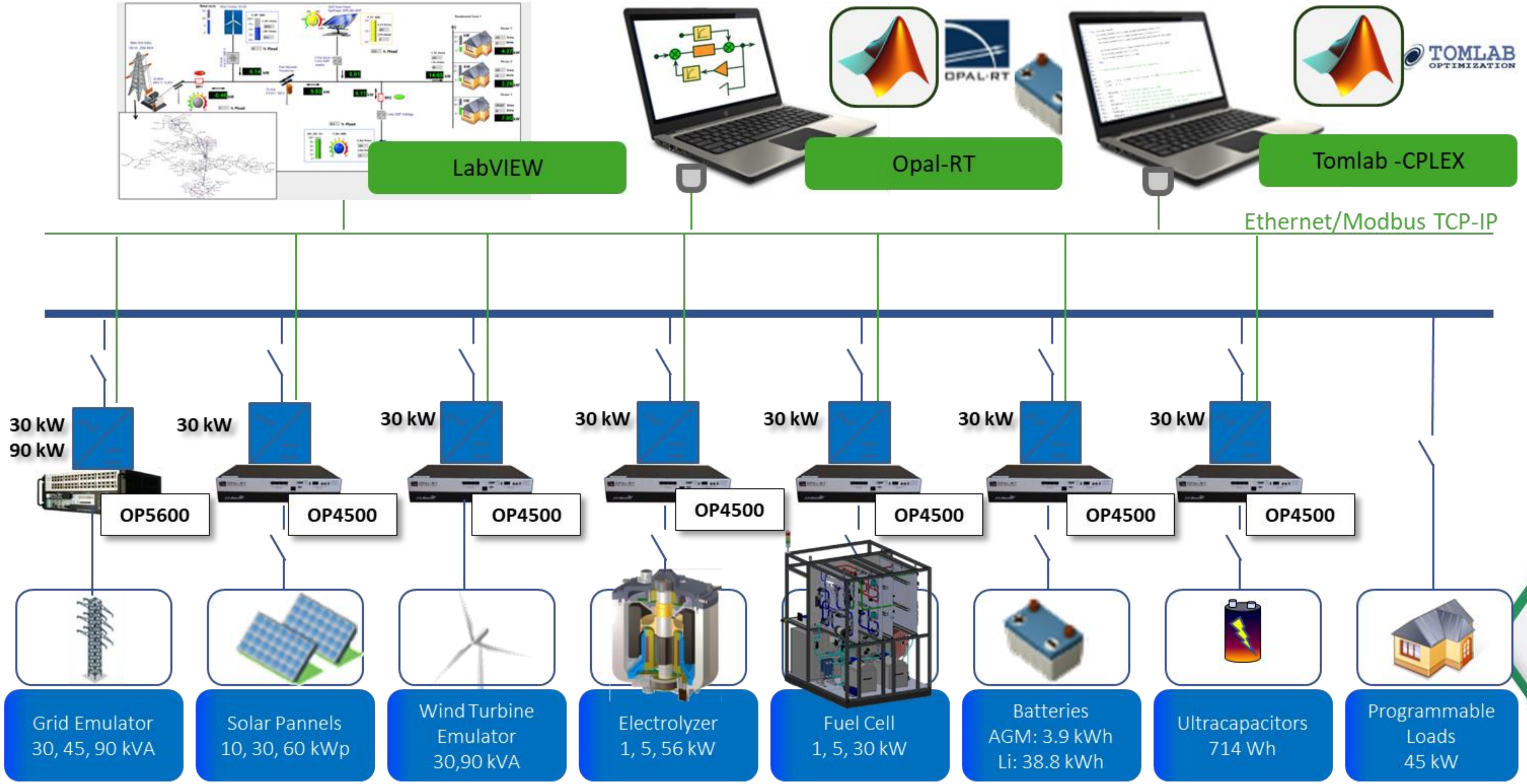
CNH2 Pilot Plant

CNH2 Pilot Plant



1. Electrical Microgrid



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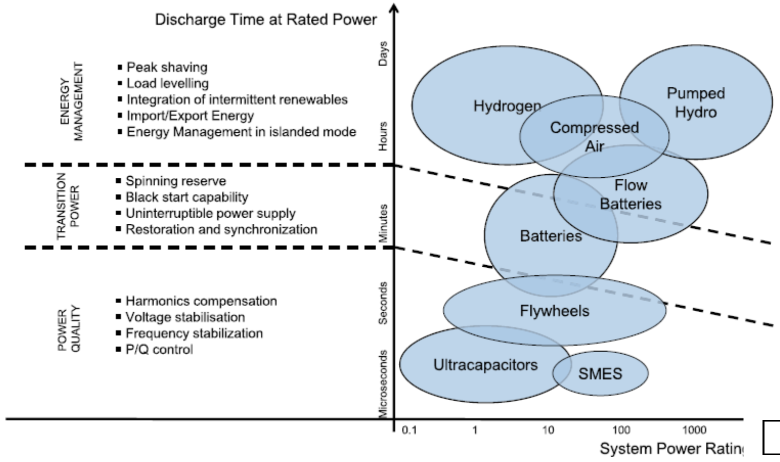
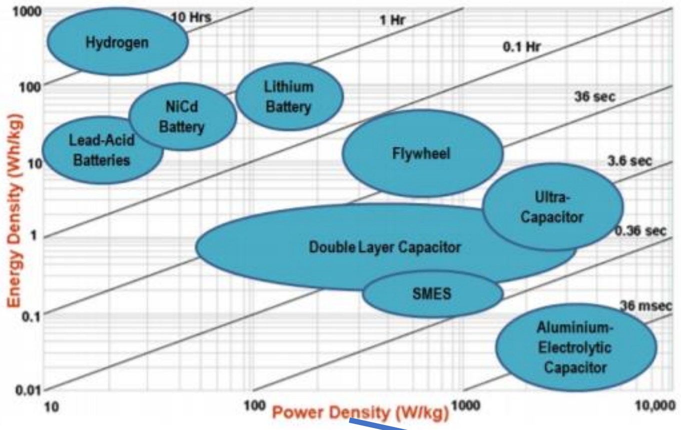
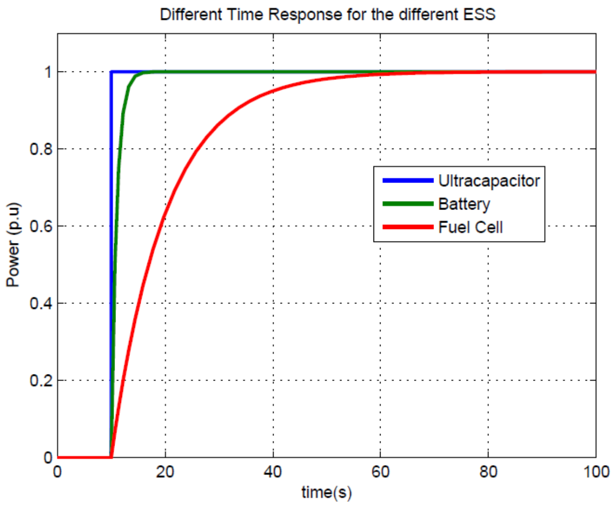
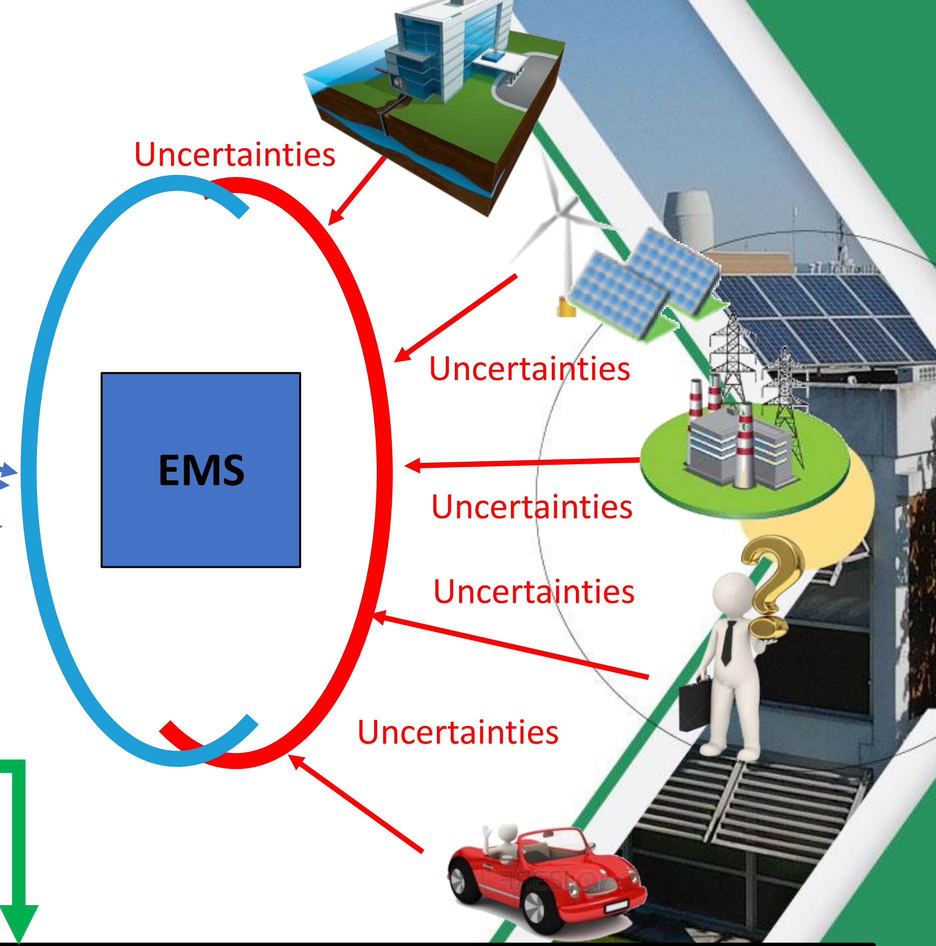






Energy Storage System	Degradation Issues
Ultracapacitors	Overcharge, Undercharge
Batteries **Lifetime:** Cycles	Overcharge, Undercharge High stress current ratio AC Current Ripple
Electrolyzer **Lifetime:** Hours	Fluctuations of current Start/Stop Cycles
Fuel Cell **Lifetime:** Hours	Fluctuations of current Start/Stop Cycles



The use of storage systems is not free to meet service life costs. If the degradation criteria are not met, this useful life may be lower and detract from economic competitiveness. Battery-hydrogen degradation has complementary behavior

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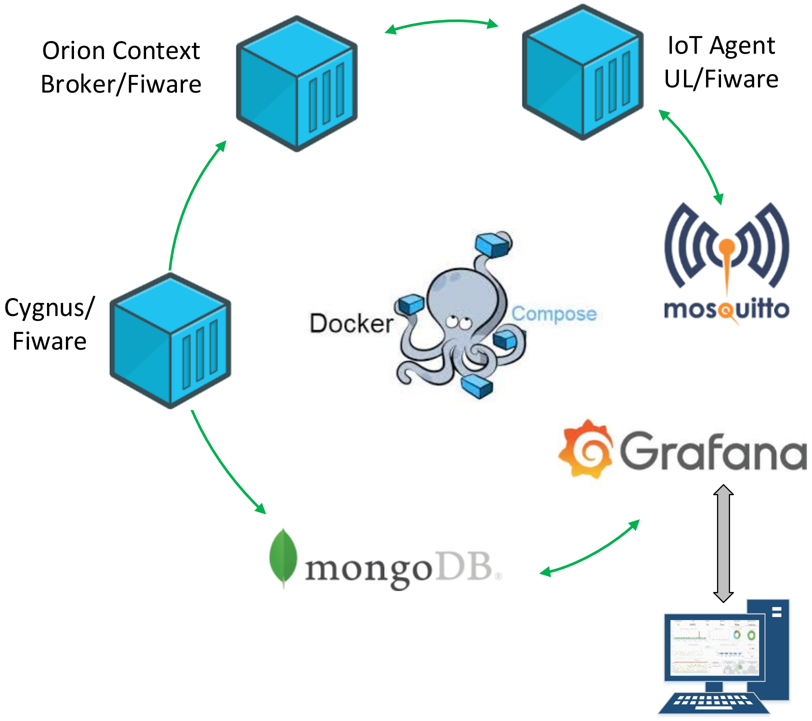
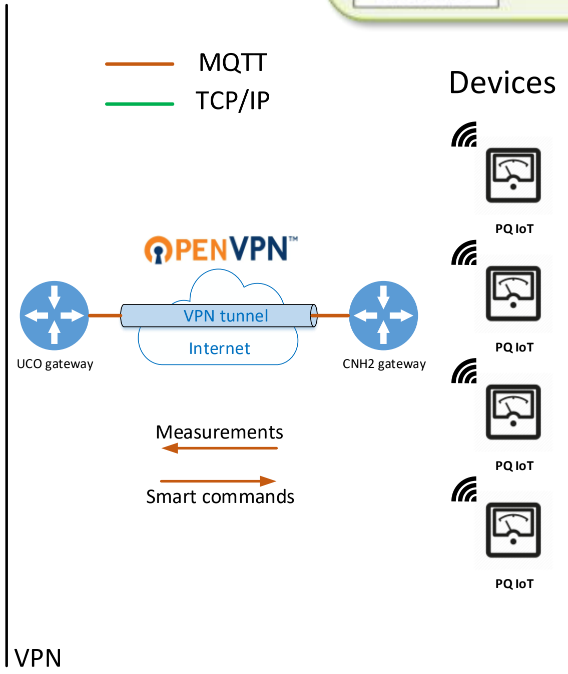
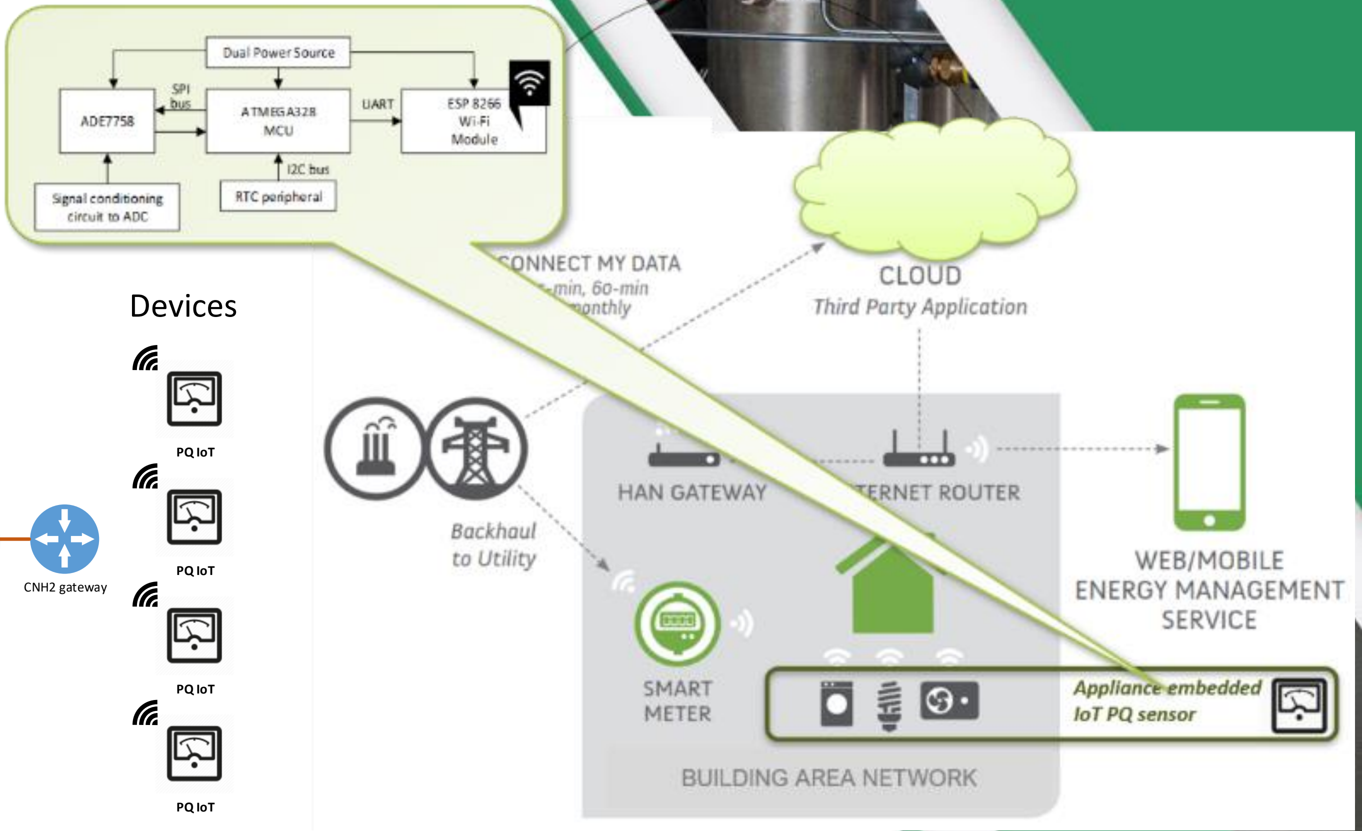
Power Management System

The inclusion of **IoT sensors** in the infrastructure for advanced power quality measurement.







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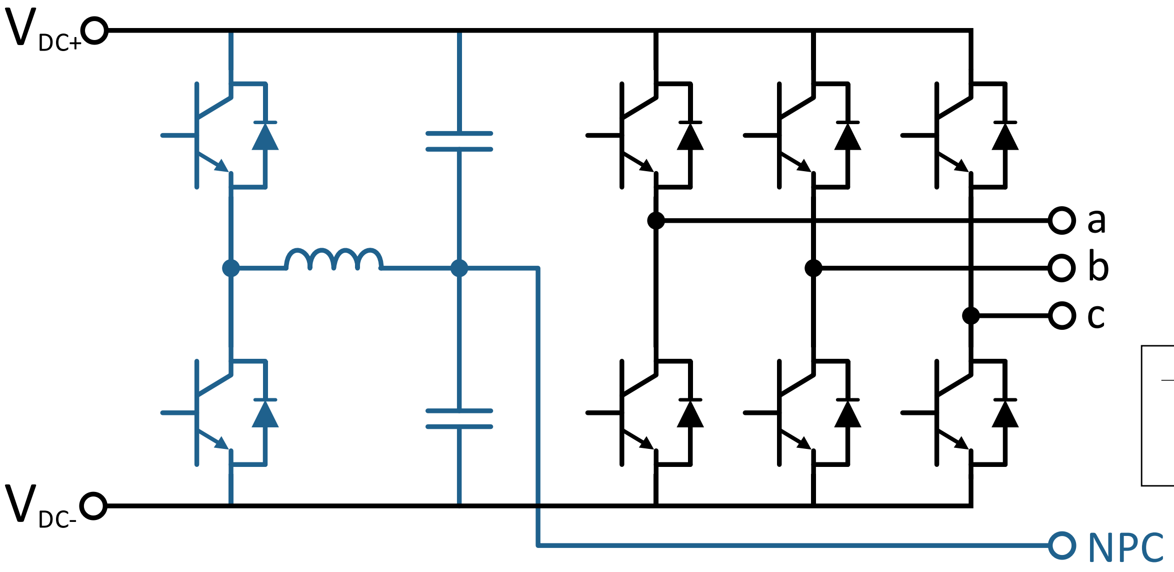
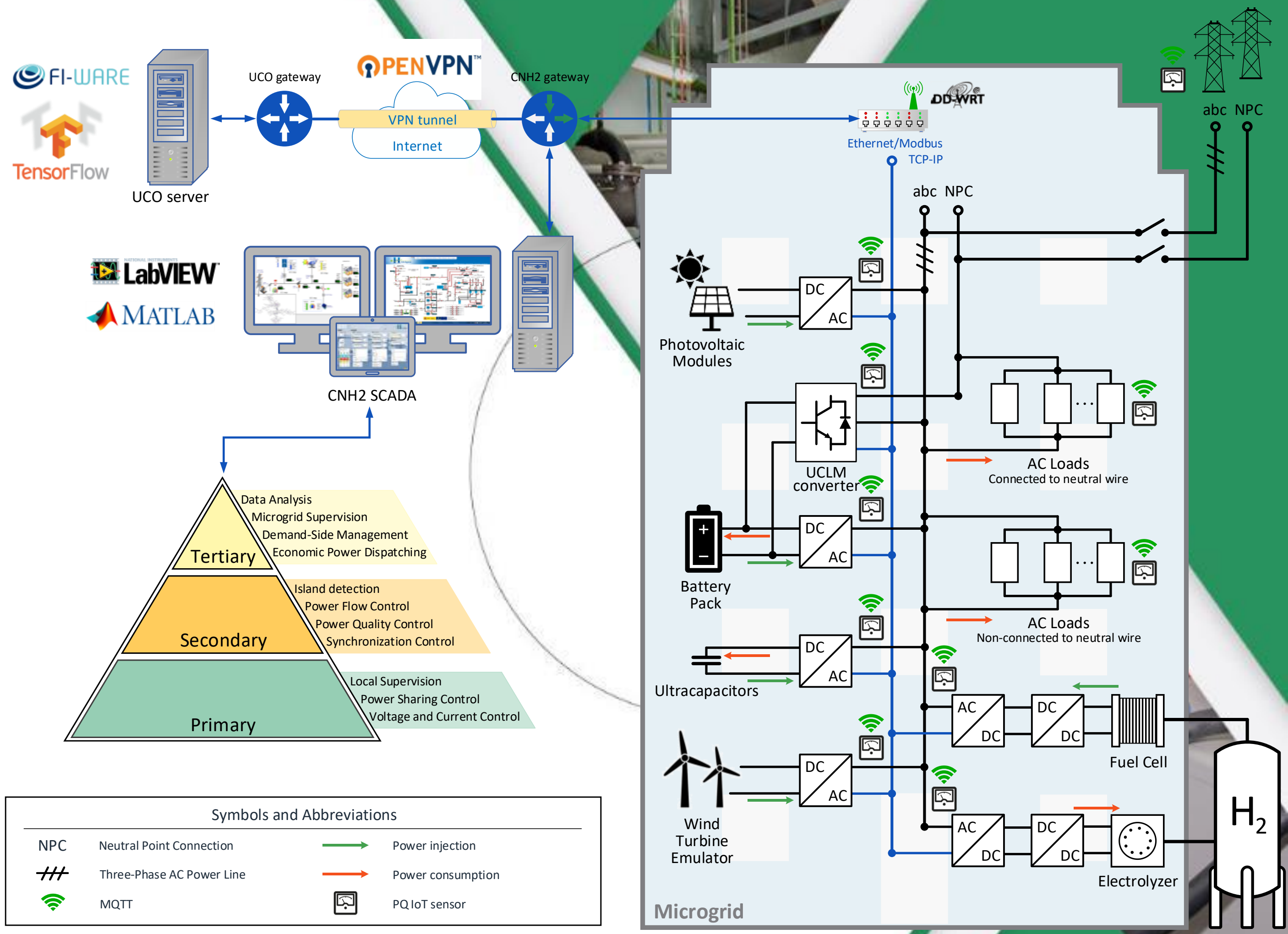
Power Management System

The development of a **four-wire inverter with active neutral control** to improve the power quality of the complete system.





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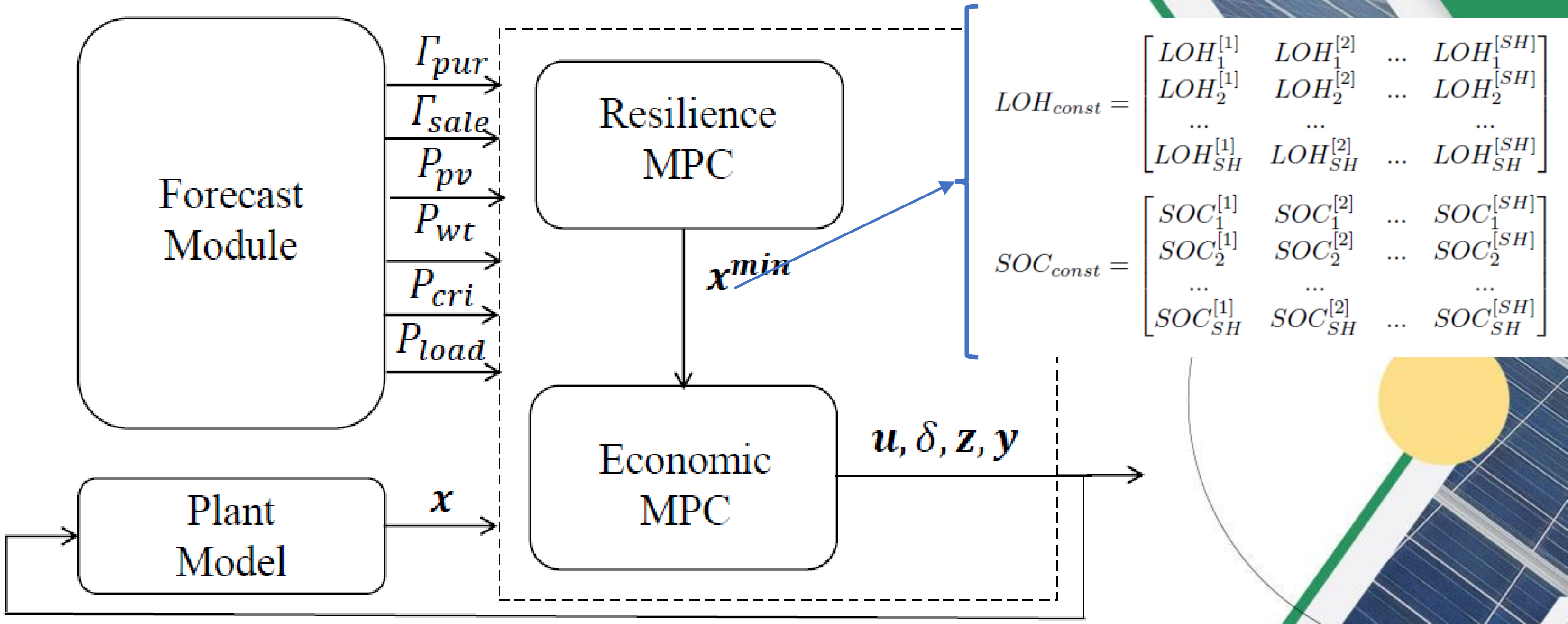
1. Electrical Microgrid

- Economic Criteria
- Resilience Criteria
  - Survival Criterion
  - Criticality Criterion
- Renewable Energy Criterion
- Minimum equipment degradation criterion



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1. Electrical Microgrid

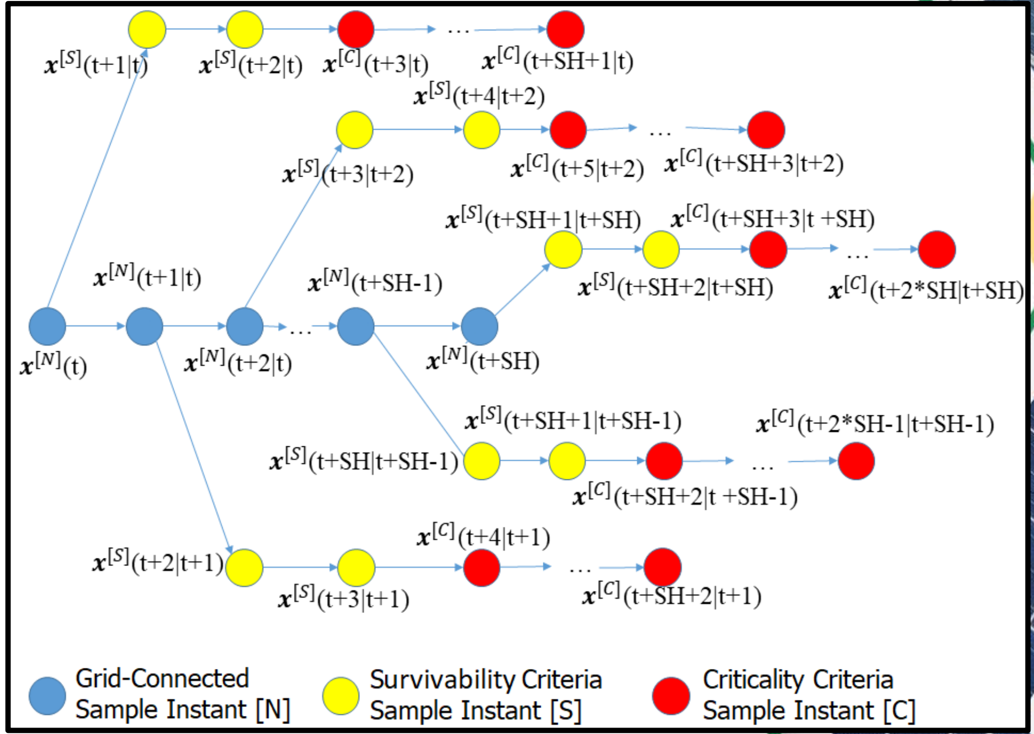
Resilience-Oriented Schedule of Microgrids Algorithm:

A two-stage optimization is proposed:
The minimum storage in each energy storage system is calculated considering economic cost aspects of the energy storage systems according to the forecast of critical loads. Two levels of resilience are established:

1) **Survivability** (Supply of the greatest number of loads during a certain time 2 hours from the event of loss of the main grid)

2) **Criticality:** Supply of critical loads during a horizon of 24 hours from the event loss of main network. This is done considering the loss of the main network at each optimization instant.

Day ahead Market is optimized by following minimum storage restrictions



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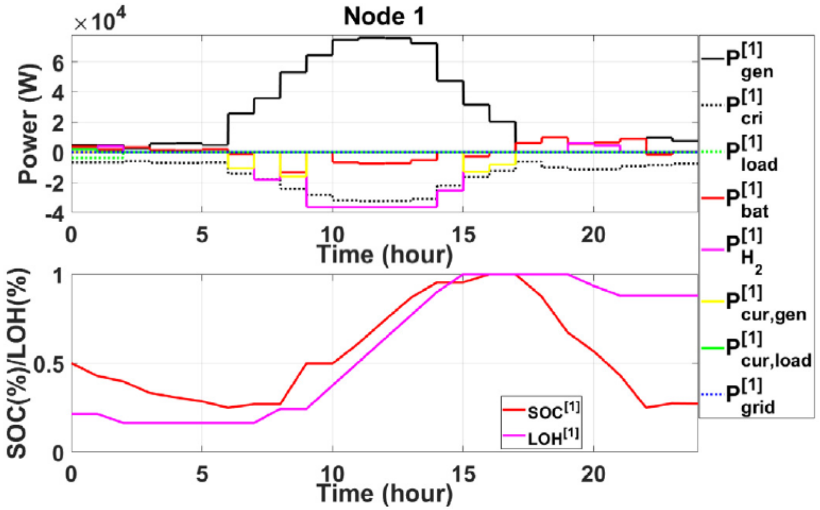
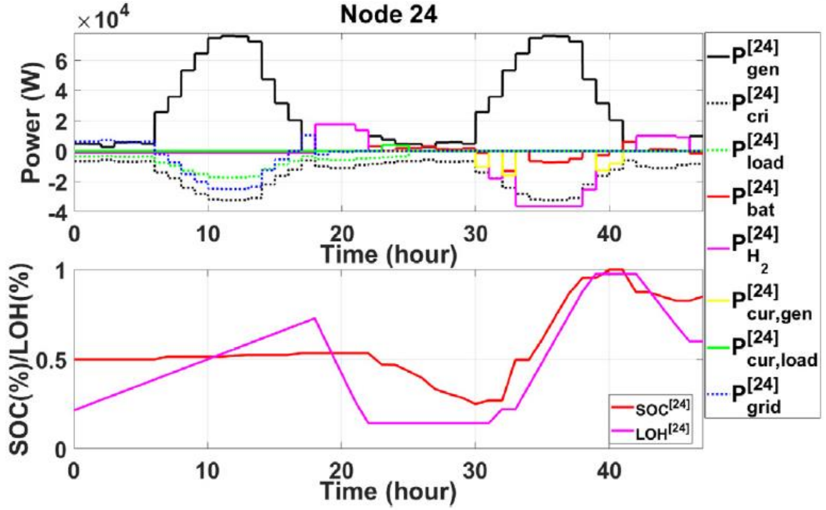
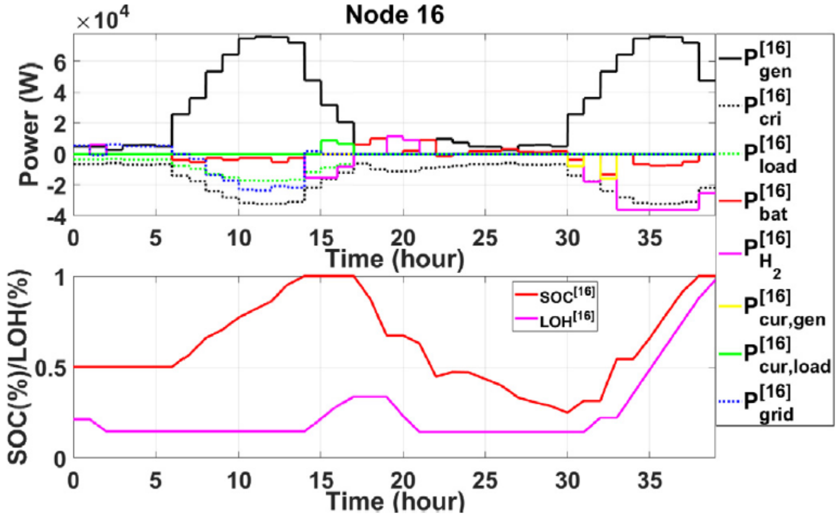
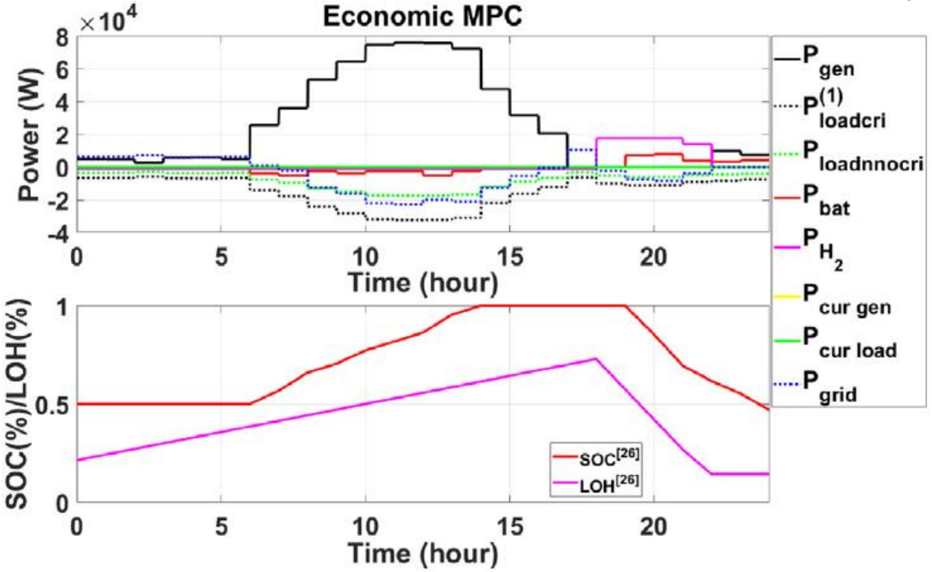
1. Electrical Microgrid



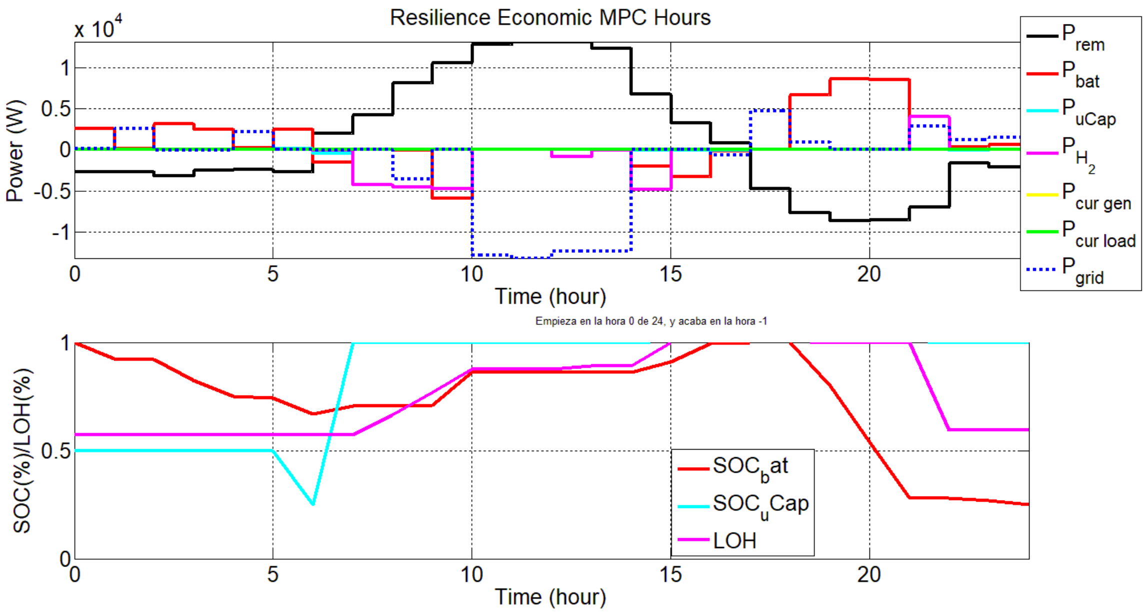


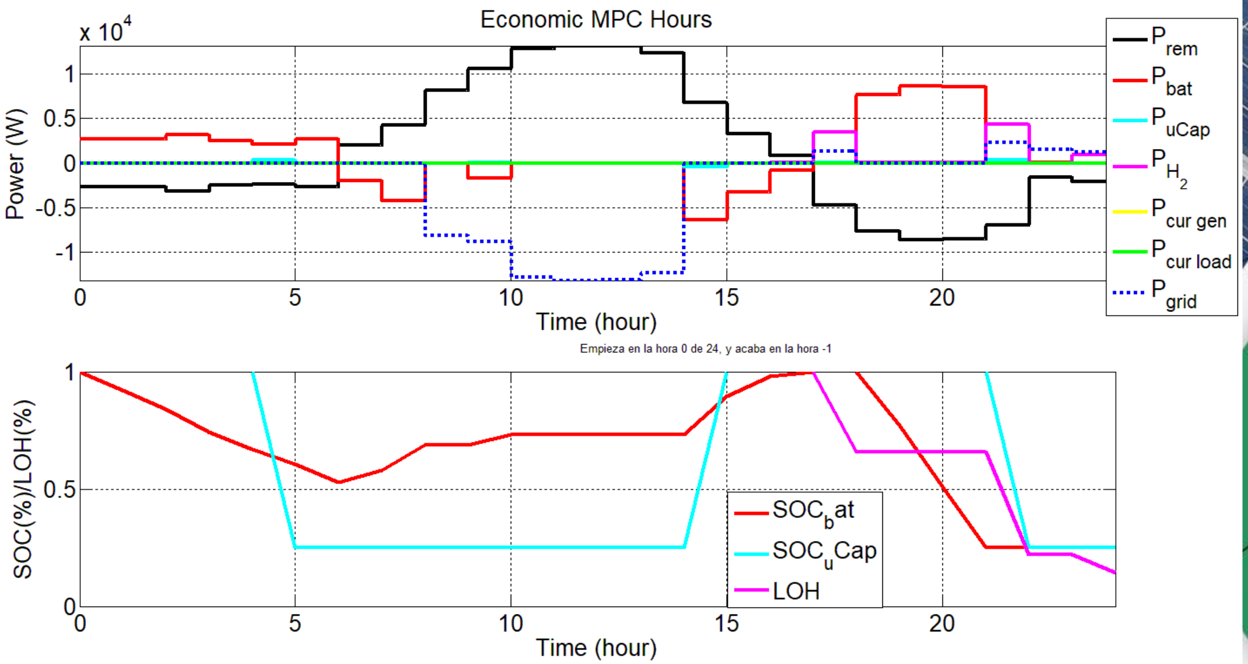




1. Electrical Microgrid

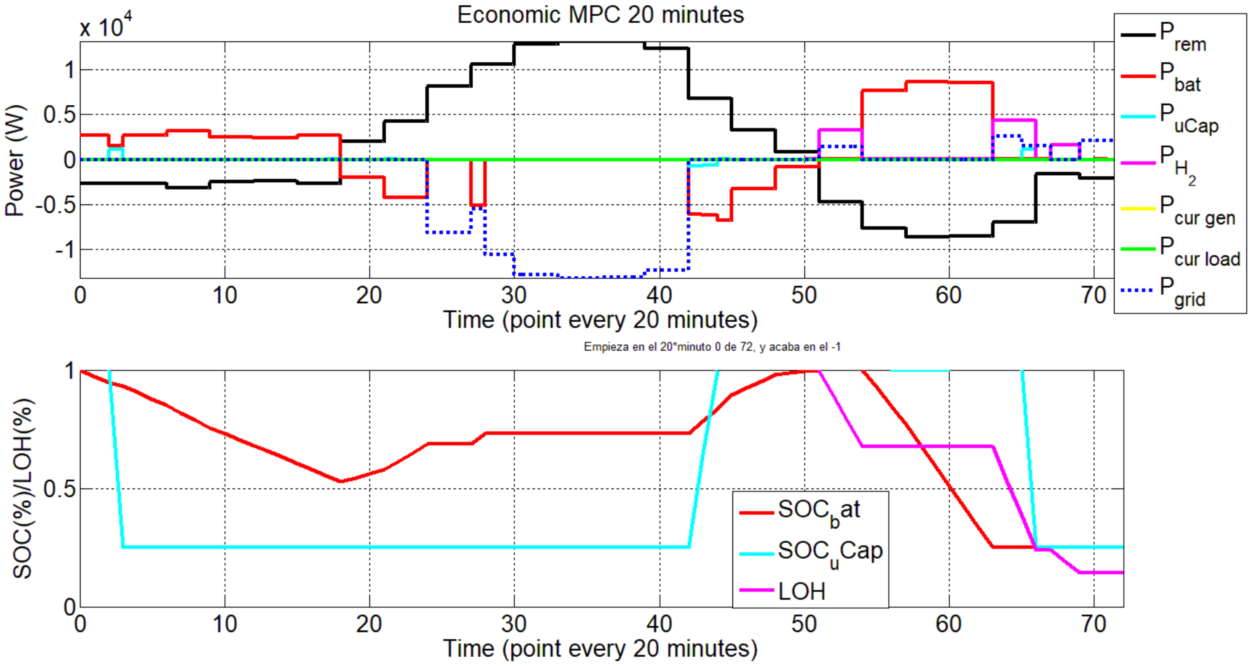
- Once the Resilience criterion has been calculated and stablished, the algorithm focused in the Economic criteria is launched.

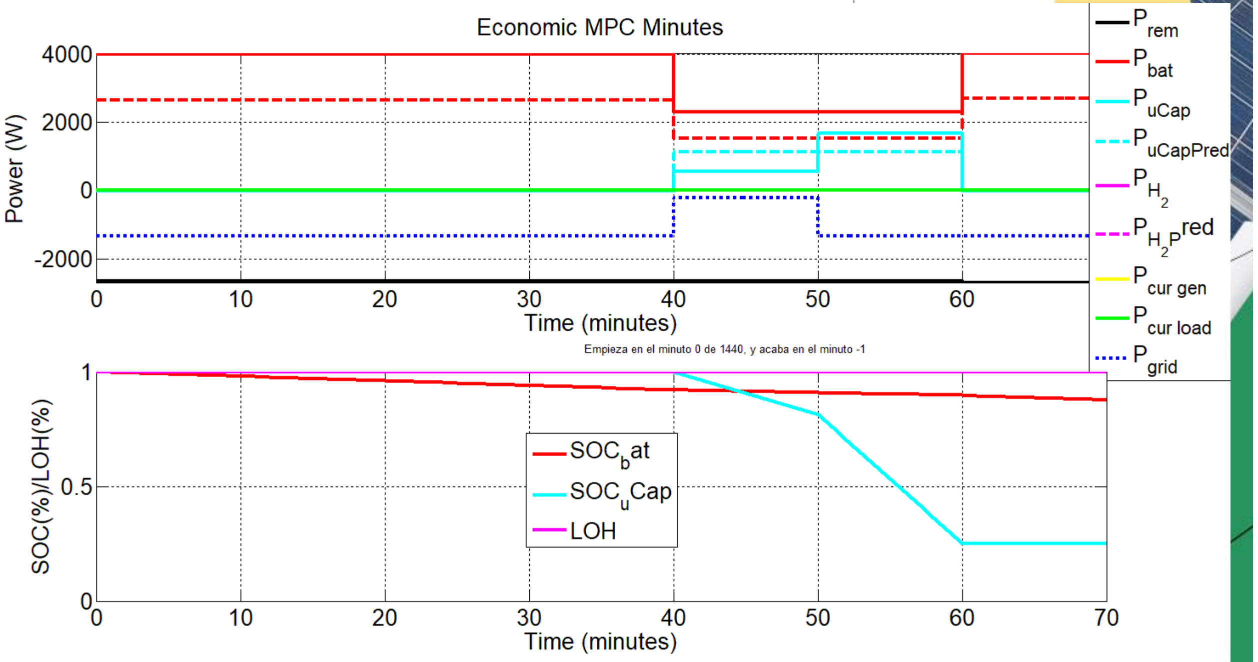




1. Electrical Microgrid

Once calculated the Economic prediction by next 24 hours, we discretize it to control the system every minute





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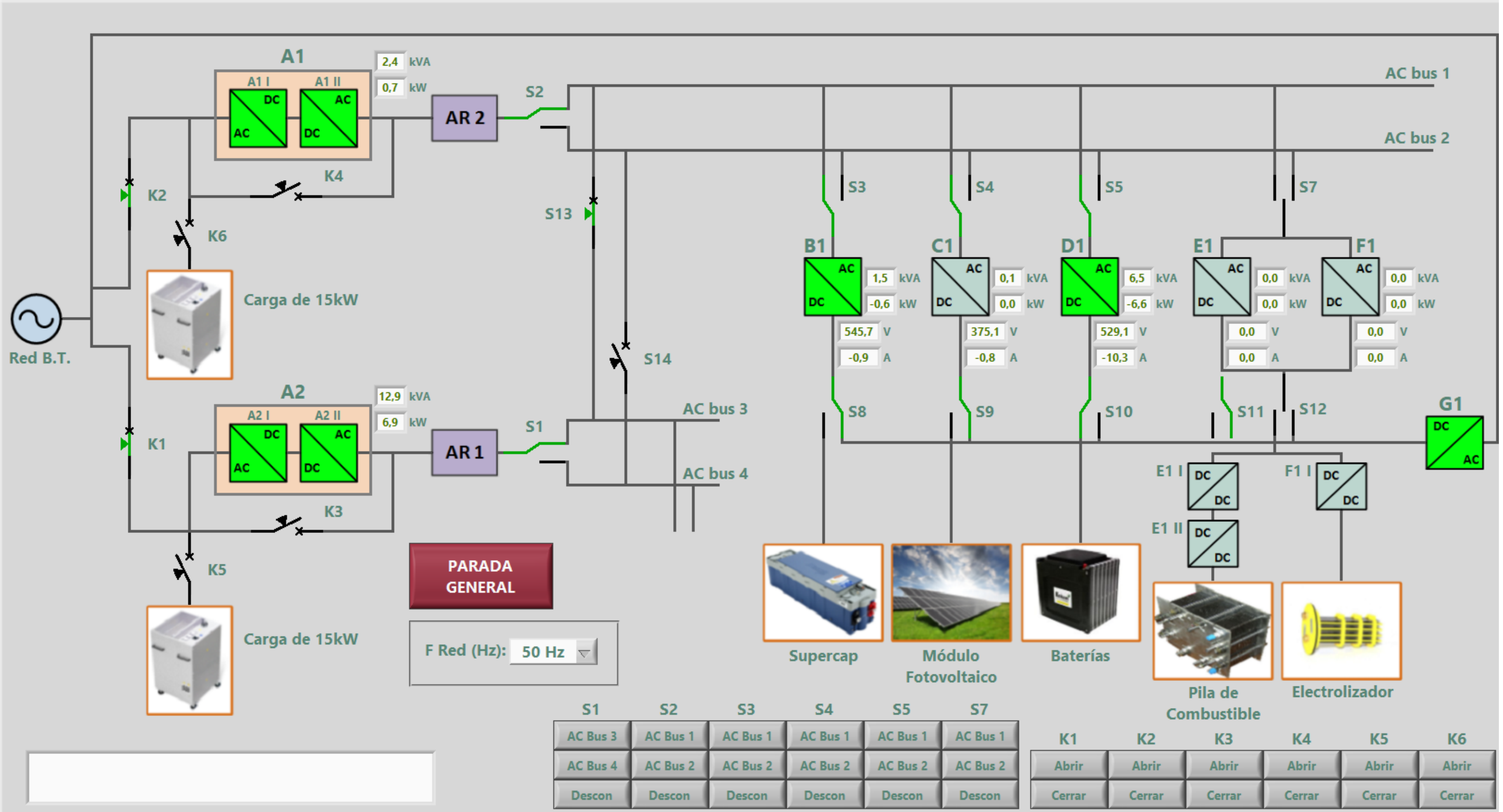

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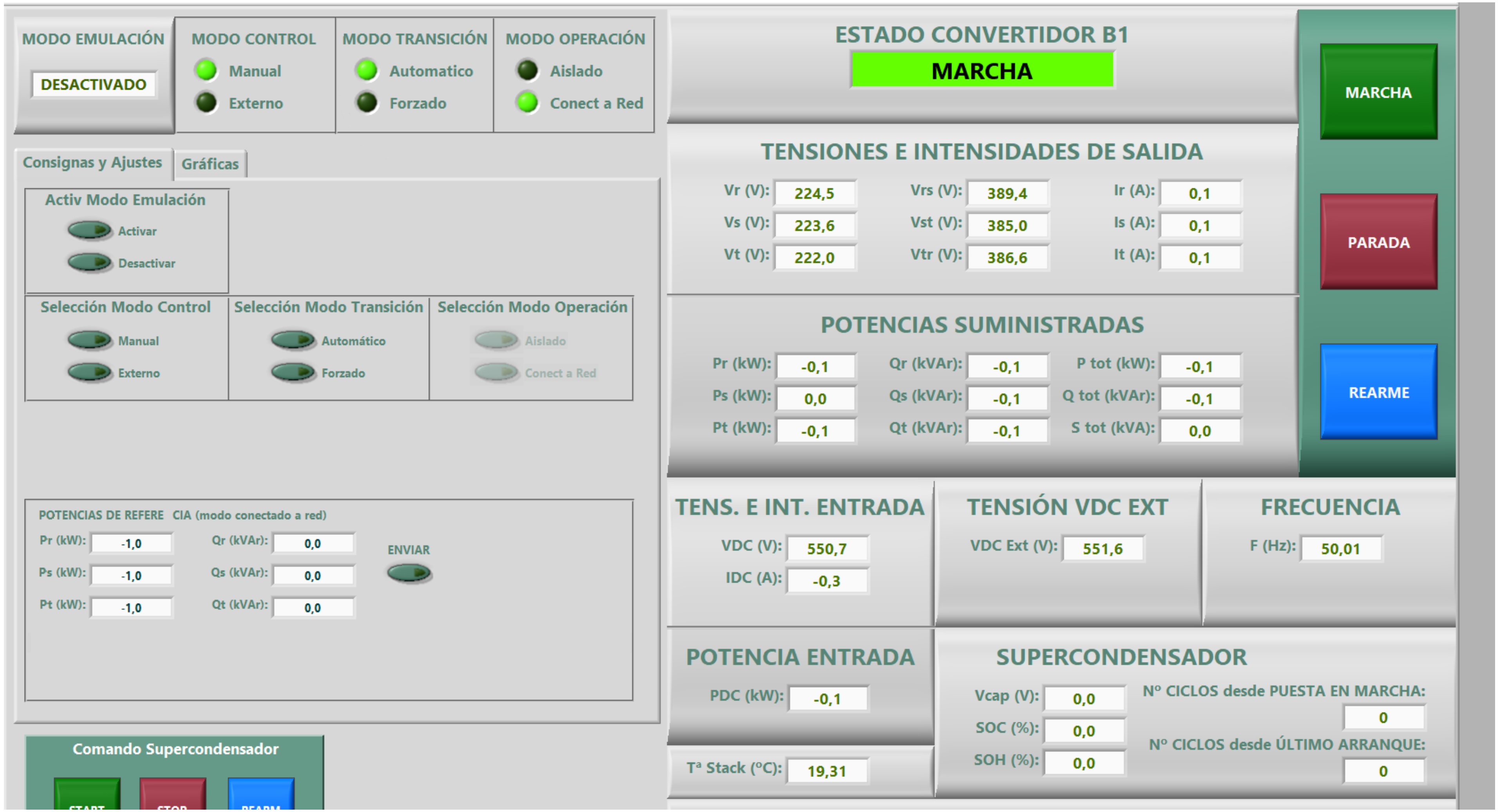


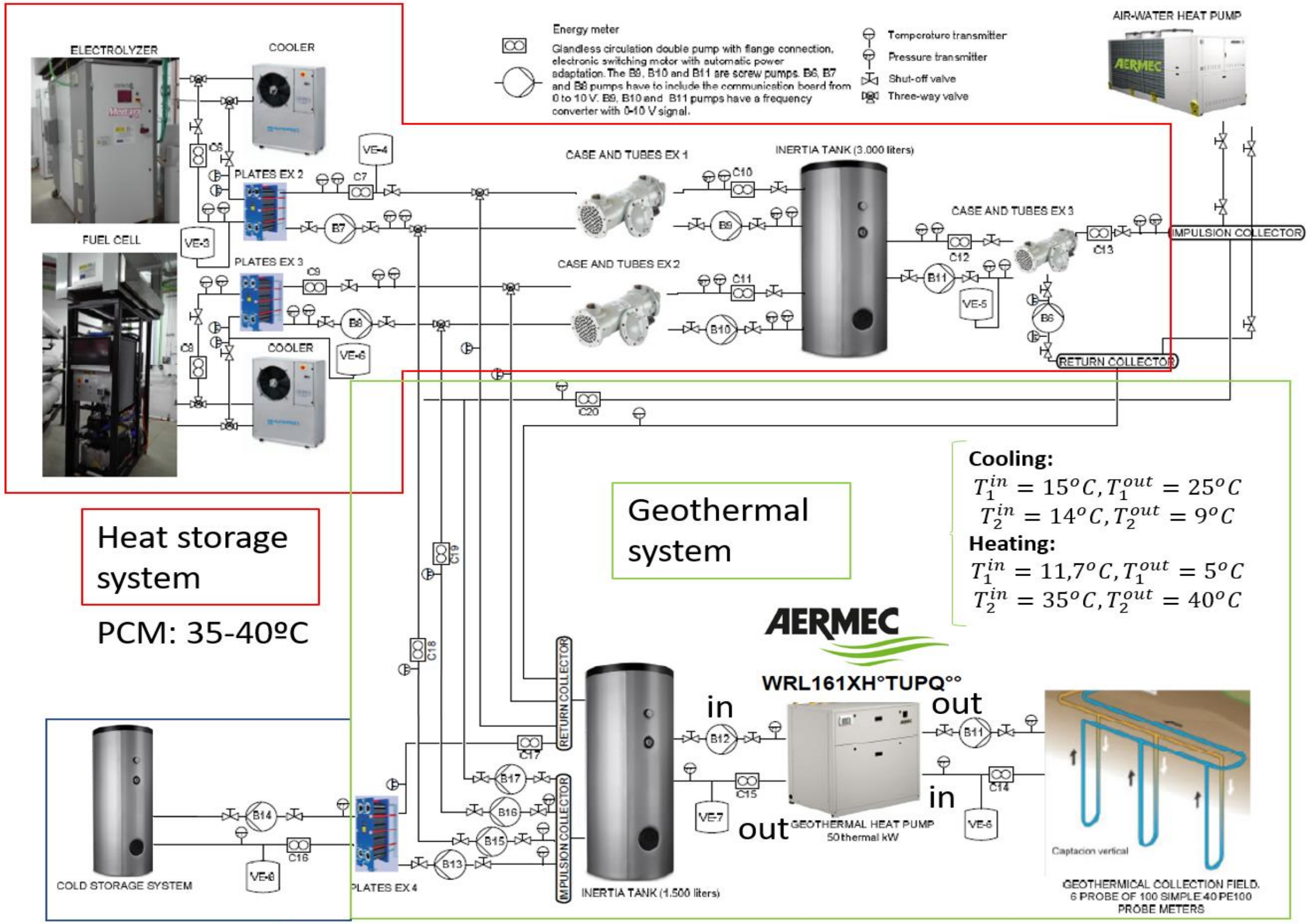
2. Thermal Recovery System (CNH2)

3 main parts:

- CESS
- HESS
- GRS

Capable of injecting recover heat to air conditioner system of the building

Reduce electrical consumption



Heat storage system

PCM: 35-40ºC

Geothermal system

Cooling:

$T_1^{in} = 15^o C, T_1^{out} = 25^o C$

$T_2^{in} = 14^o C, T_2^{out} = 9^o C$

Heating:

$T_1^{in} = 11{,}7^o C, T_1^{out} = 5^o C$

$T_2^{in} = 35^o C, T_2^{out} = 40^o C$

Cold storage system

PCM: 10-14ºC

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2.3. Heat Energy Storage System (HESS)

HEAT STORAGE SYSTEM

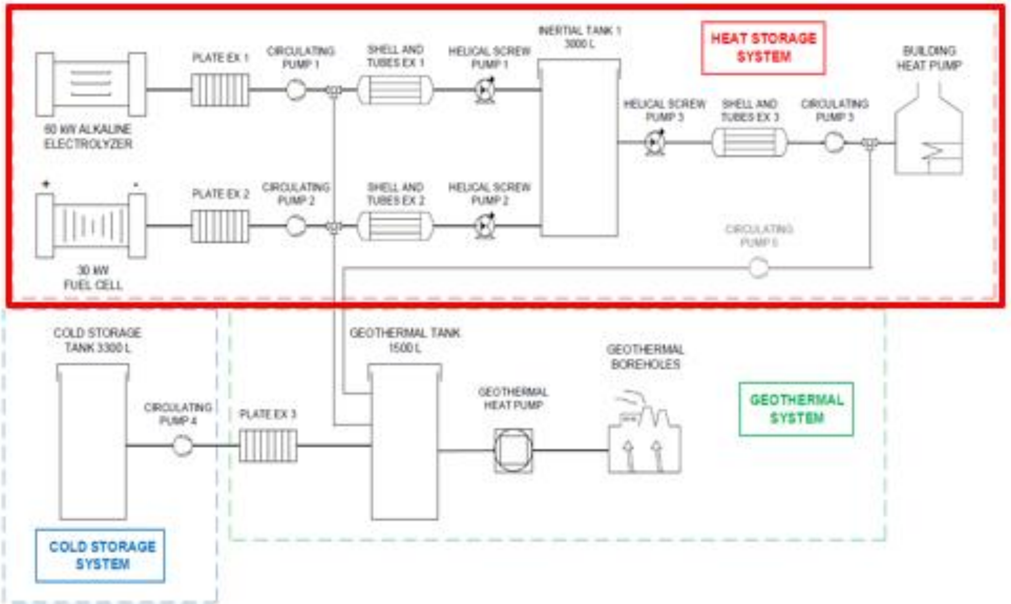
- **OBJECTIVE:** Take advantage of the **waste heat** generated from the **electrolyzer** and the **fuel cell** to **reduce the building's energy consumption**
  - **Waste heat** is recovered though different **heat exchangers**
  - The recovered heat is stored in **an inertial tank (3000 L)** which contains **100 kW slurry microencapsulated PCM**
  - The outlet of the inertial tank is injected in the general building air-conditioner

Alkaline electrolyzer

- Electric power: 60 kW
- Thermal power: 60 kW
- Operating temp: 60 – 75°C
- H_2 production: 10,66 Nm^3/h
- H_2 pressure: 10 bar

PEM Fuel Cell

- Electric power: 30 kW
- Thermal power: 30 kW
- H_2 consumption: ≤ 500 L/min
- Air consumption: ≤ 2500 L/min



2.3. Heat Energy Storage System (HESS)

Hydrogen Cycle

Heat

Alkaline Electrolyzer

H2 Storage Park (10 bar) and (200 bar)

Heat

PEM FC

¡¡Thank you very much!!

Javier Tobajas Blanco
Javier.tobajas@cnh2.es

Simulation, Control and End-Use Unit
Viena, March 14 2023