Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

ePOWER:
Smart power electronic converter for the provision of integrated services to electric grids and consumers

Co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH–CREATE-INNOVATE (project code: T2ΕΔΚ-01775)

Existing technology (I)

- **High number of Distributed Generation systems with Renewable Energy Sources interconnected with the low-voltage electrical grid (e.g. PVs on buildings) :**
  - stochastic electric energy generation by RES
  - limited controllability
  - difficult short-term forecasting of their operating status etc.
- **Problems:**
  - difficult to control the conventional energy-production plants and regulate the electrical grid frequency → **rejection of RES-generated energy**
- **Solution:** electric energy storage systems

Existing technology (II)

- Additional **advantages of the electric energy storage systems**:
  - support of “valley filling” / “peak-shaving” operations
  - improvement of the electric system response during fast fluctuations of the electric energy production and demand
- **Contribution of distributed storage:** voltage support at the Point of Common Coupling, minimization of the local grid losses etc.
- **Cost of electric energy storage systems:** reduction by >60% till 2030.
- Distributed storage in **future power systems: batteries of electric vehicles**

Existing technology (III)

- Alternative types of electric energy storage units:
  - **batteries:** high energy density
  - **supercapacitors:** high power density
  - **hybrid configurations:** combination of advantages

- Device for the interconnection of RES and energy storage with the electrical grid:

power electronic converters DC/AC (inverters)

Existing technology (IV)

Existing industrial and scientific solutions:

- PV inverters for Volt/VAR support at the distribution network: **without energy storage capability**
- Hybrid energy storage in PV systems: implemented by combining separate DC/DC converters for each energy storage unit → **high complexity and cost**
- Commercially available hybrid PV inverters: **feature only battery storage** and **without functionality of supporting the electrical grid**
- Commercially available inverters for electrical grid support: **only with batteries for energy storage**

The solution developed in this project (I)

ePOWER:

Smart power electronic converter DC/AC:

constitutes the interface of small-scale energy storage units and PV arrays with the low-voltage electrical grid

The solution developed in this project (II)

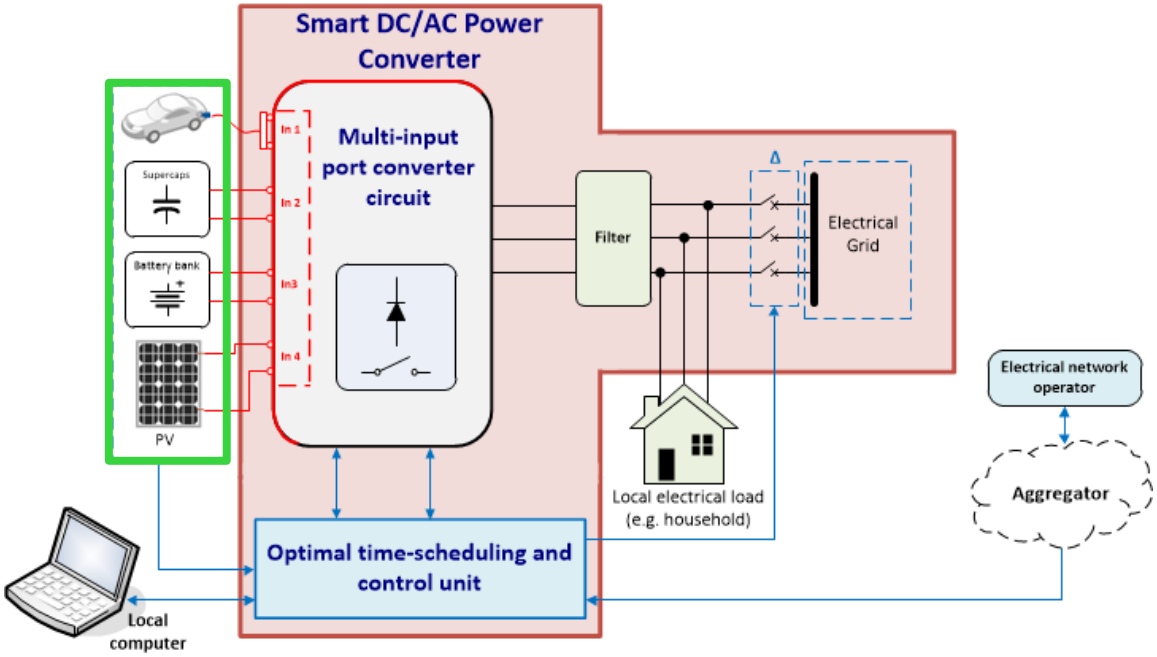
ePOWER:

Smart power electronic converter DC/AC that offers:

- **ancillary services to the electrical grid** (frequency regulation, voltage support at the PCC during high voltage drops)
- **uninterruptible operation of the local hosting system** (e.g. residential electrical system) **during prolonged disturbances of the electrical grid** (e.g. short-circuits, blackouts etc.)

The Smart DC/AC Inverter developed in the ePOWER project

Subsystems:

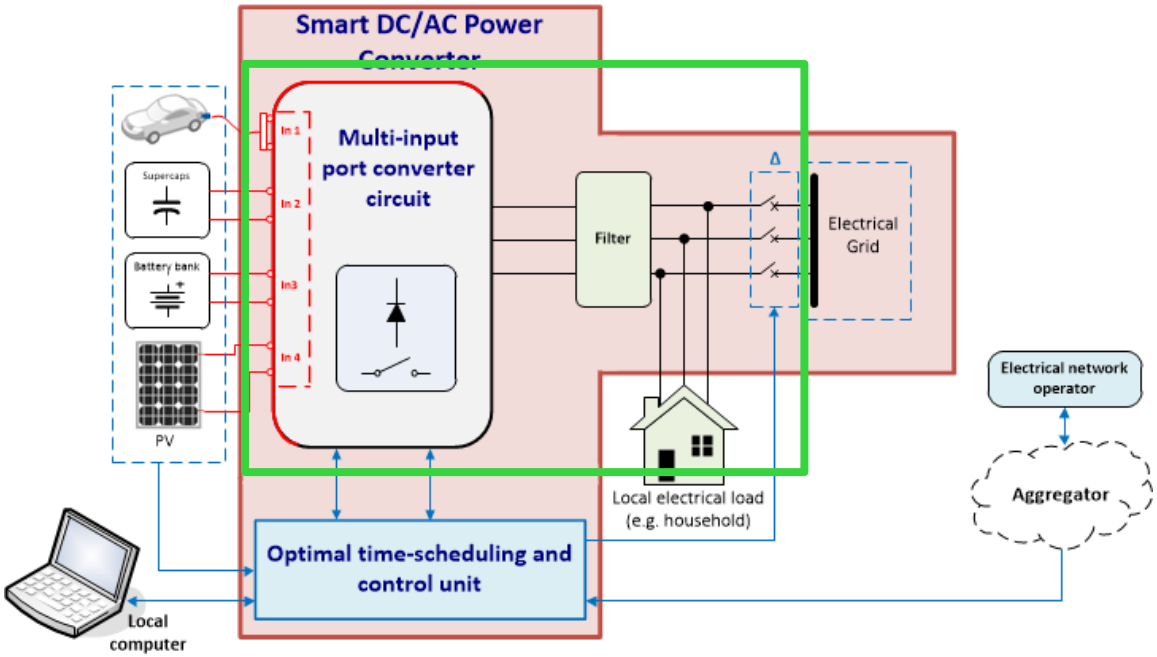


4 DC inputs for connection of:

- electric vehicle, supercapacitor bank, battery bank (either Li-ion, or lead-acid type) and a PV array

The Smart DC/AC Inverter developed in the ePOWER project

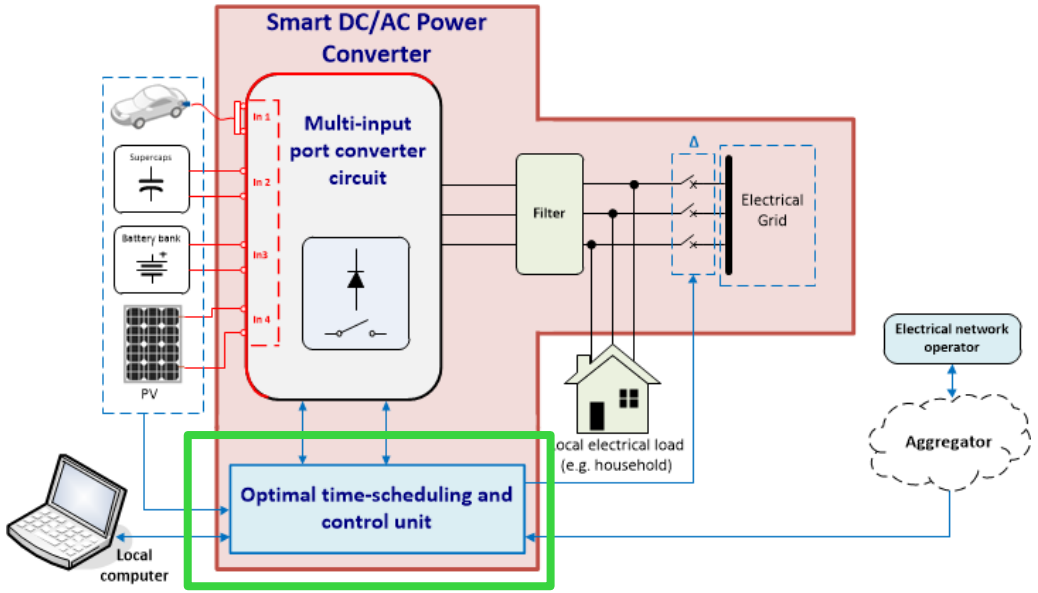
Subsystems:



Power circuit & filters:

- Multi-Port Converter (MPC) topology
- 3-phase AC outputs

The Smart DC/AC Inverter developed in the ePOWER project



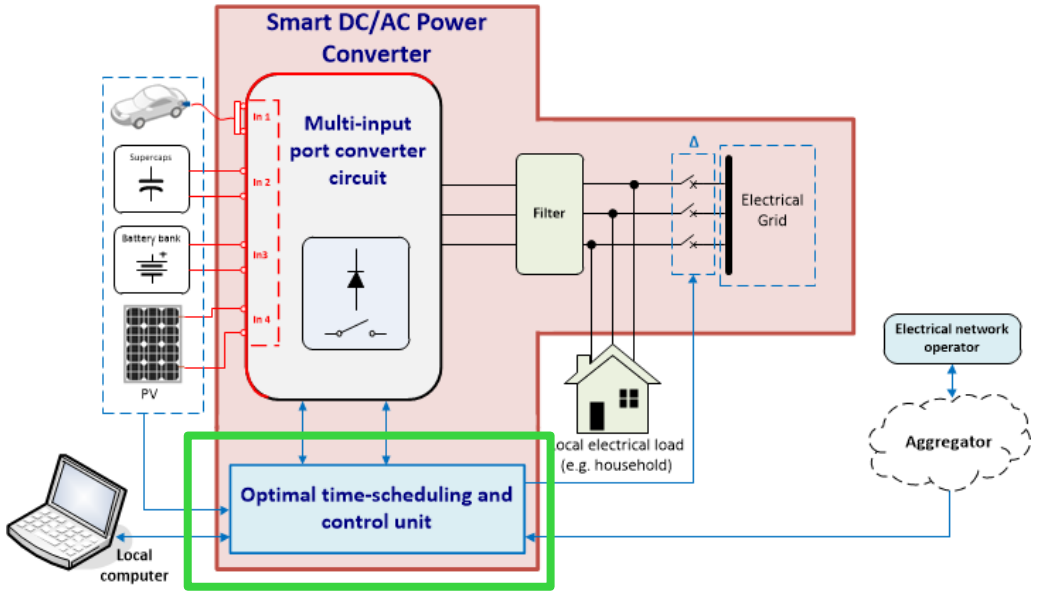
Real-time control unit:

- **Calculation of the optimal charge/discharge trajectories of the electric vehicle and the battery bank** according to:

  1) forecasts (electric energy cost, power system load, PV energy production)

  2) preferences of the electric vehicle user (duration of charging, recharging level during disconnection etc.)

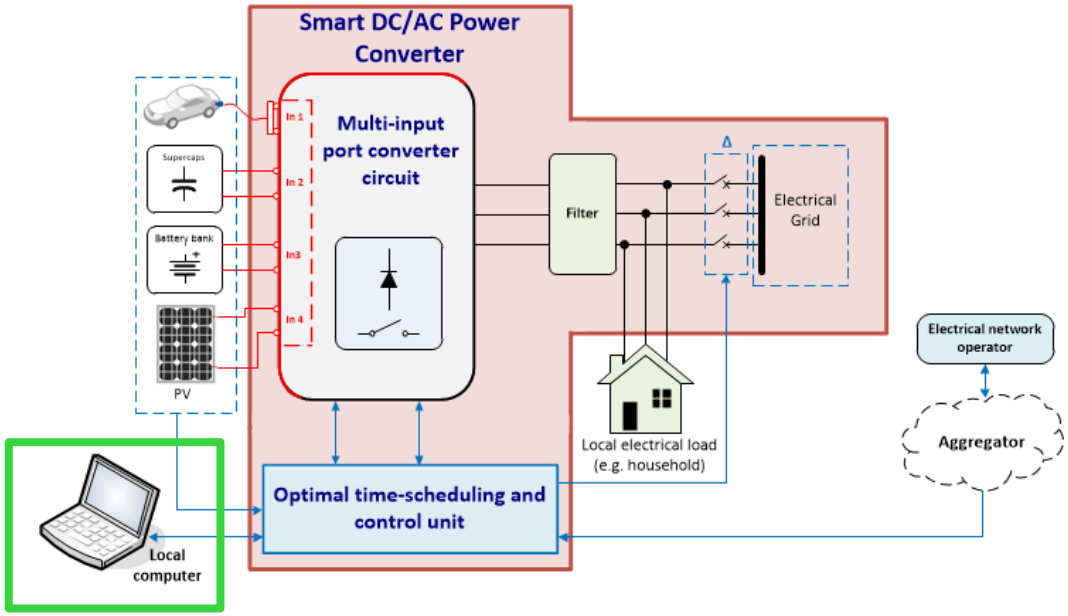
The Smart DC/AC Inverter developed in the ePOWER project



Real-time control unit:

- Support of the electrical grid voltage & frequency
- PV array Maximum Power Point Tracking (MPPT) even under partial shading
- Power supply to the local load during prolonged undervoltage of the electrical grid
- Reactive power support to the electrical grid during short-term undervoltage conditions of the electrical grid

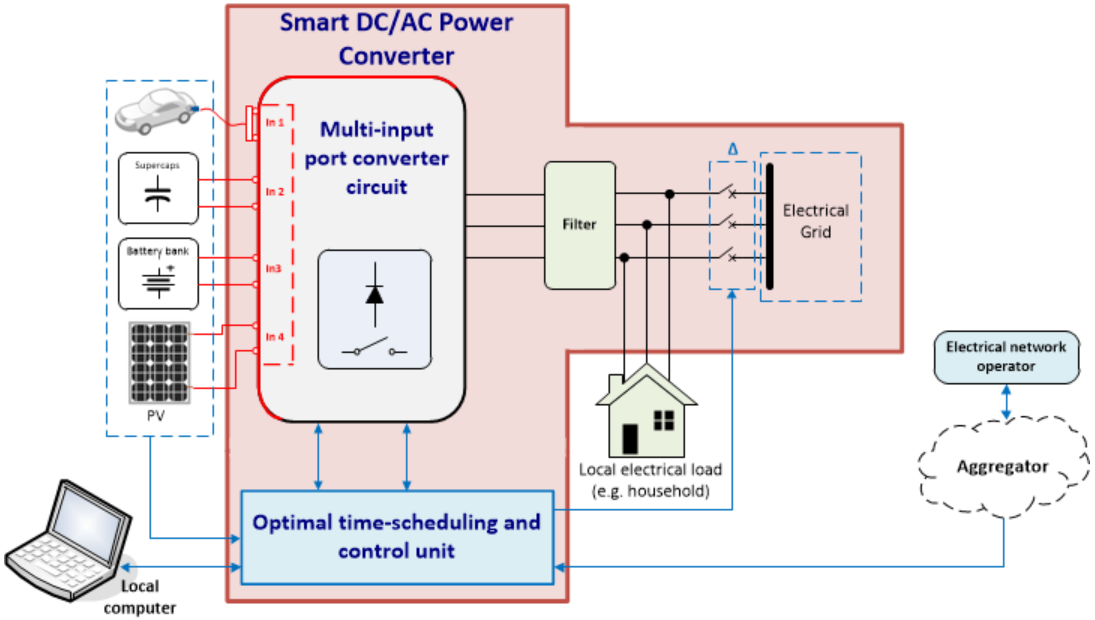
The Smart DC/AC Inverter developed in the ePOWER project



Communication interface with a local computer for definition by the user of:

- size of the energy storage units
- maximum power exchange with the electrical grid
- power quality specifications and
- monitoring of the DC/AC inverter operation

The Smart DC/AC Inverter developed in the ePOWER project

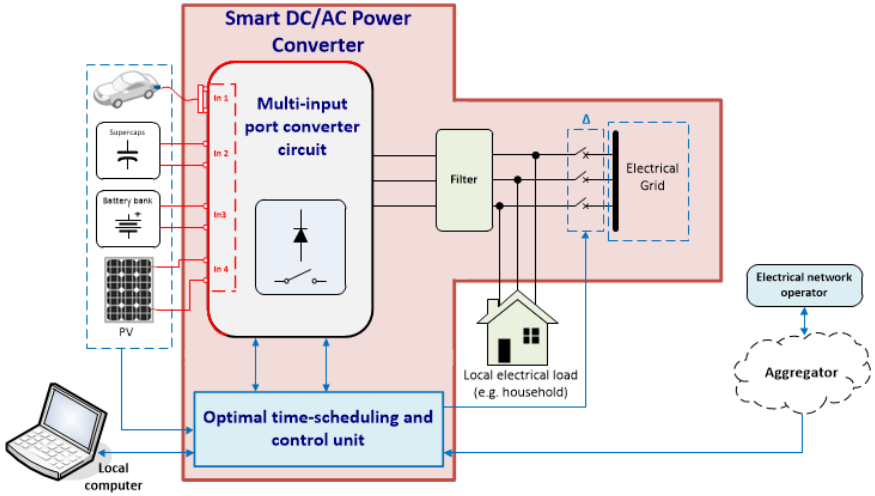


Proper design of the overall Smart DC/AC Inverter for:

- **parameterization** of the desired operational characteristics by the user, without requiring modification of its hardware
- **maximum efficiency** and **minimum size and cost**

Novelty of ePOWER:

- comprises an integrated system for **optimal management of multiple energy production and storage units**
- combines the multiple components of an energy conversion and storage system into an optimally-designed and cost-effective device
- it is able to perform both energy management and voltage/frequency support at the low-voltage electric grid level, as well as to improve the quality of the generated power
- **it is also applicable in local Microgrids**



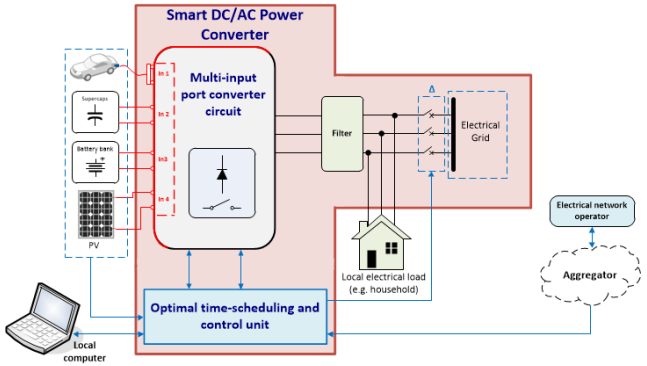
ePOWER project goals

1. **Develop a fully-functional experimental prototype system**

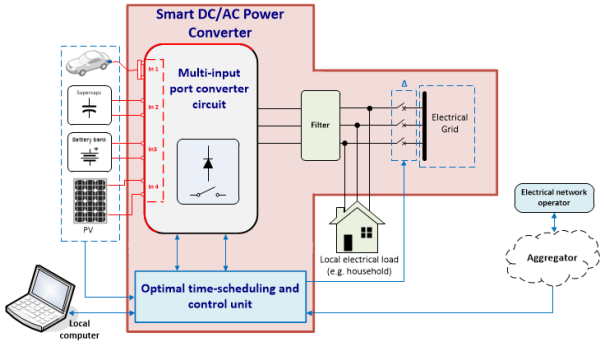
2. **Produce novel research results:**

   - power electronics, control for interconnection with Smart Grids / Microgrids, energy storage/management systems, embedded systems etc.

2. **Exploit the industrial potential of the ePOWER Smart DC/AC inverter**



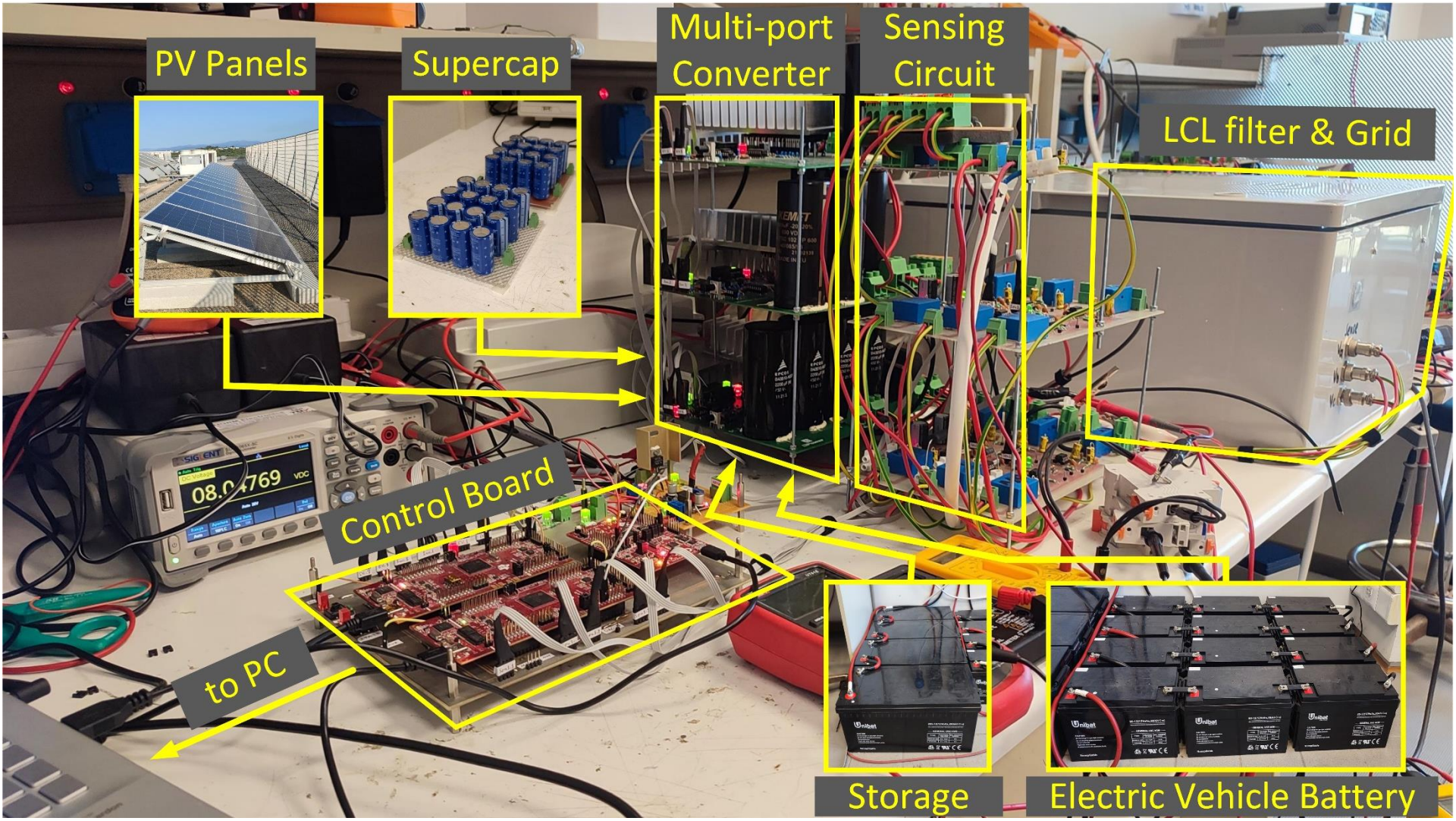
ePOWER project implementation



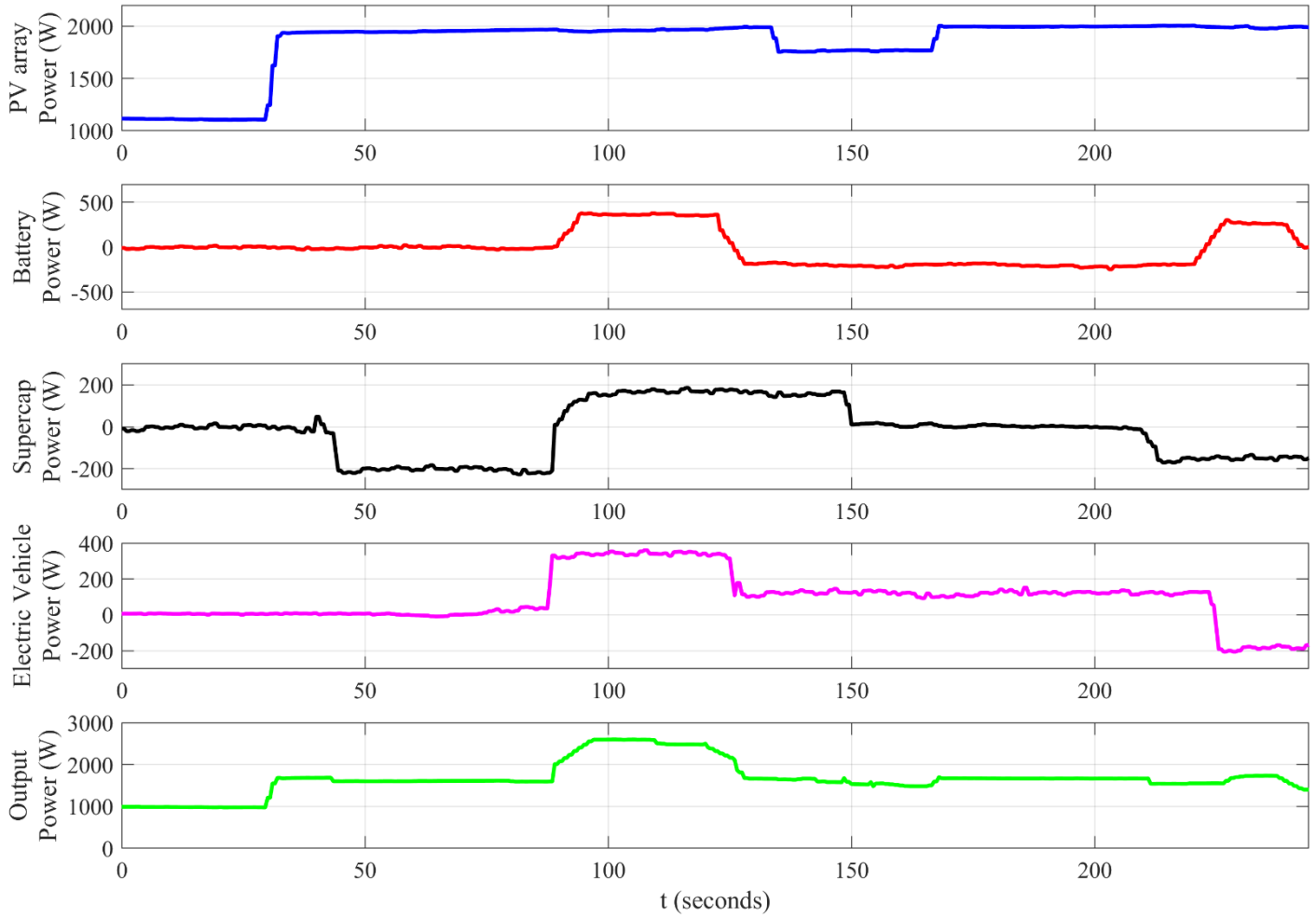
- Starting date: **12/5/2020**
- Duration: **38 months**

  (after extension due to COVID-19 protection measures)
- Total budget: **460789.63 €**
- Partners (Greek research institute and companies):
  - **Telecommunication Systems Research Institute / Technical University of Crete (coordinator)**
  - **SUN ENERGY SOLUTION**
  - **PROJECTON**

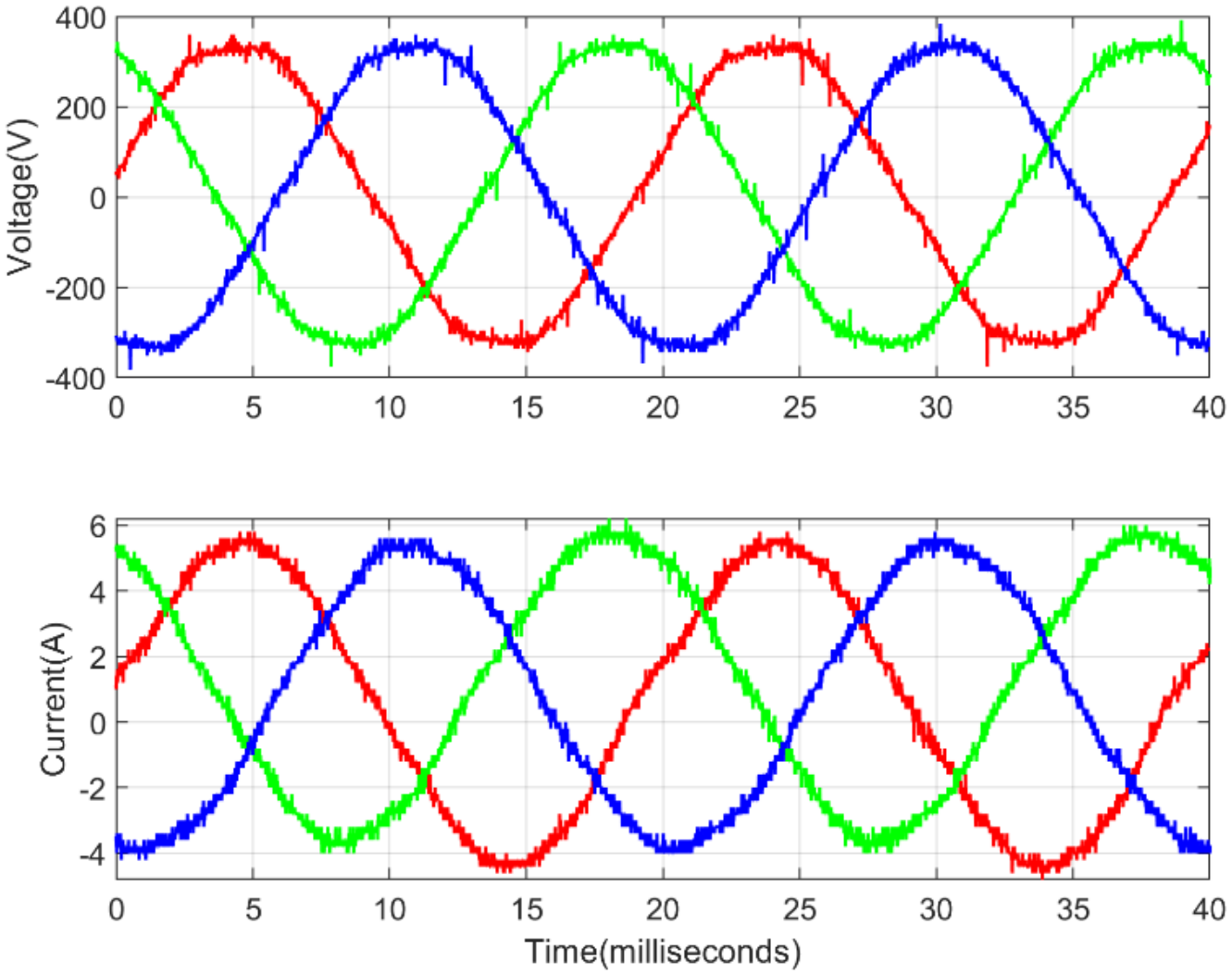
Experimental prototype of the ePOWER multi-port DC/AC inverter



Experimental waveforms depicting the various power flow options of the ePOWER multi-port DC/AC inverter



Example of the output voltages and currents at 3 kW



Publications

- ✓ I. Roditis, M. Dakanalis, E. Koutroulis and F. D. Kanellos, "Three-Phase Multiport DC–AC Inverter for Interfacing Photovoltaic and Energy Storage Systems to the Electric Grid," in *IEEE Journal of Emerging and Selected Topics in Industrial Electronics*, vol. 4, no. 3, pp. 982-994, July 2023.
- ✓ M. Dakanalis, I. Kalaitzakis, I. Roditis, E. Koutroulis, F. D. Kanellos, E. Sergaki, “Real-time Energy Management System for a Multiport DC/AC Inverter”, *2023 12th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, Athens, Greece, 2023, pp. 1-5.
- ✓ I. Roditis, M. Dakanalis, I. Mandourarakis, E. Koutroulis and F. Kanellos, "A New Multiport DC-AC Power Converter for Distributed Energy Applications," *2022 IEEE 1st Industrial Electronics Society Annual On-Line Conference (ONCON)*, Kharagpur, India, 2022, pp. 1-6.
- ✓ I. Kalaitzakis, M. Dakanalis and F. D. Kanellos, "Optimal Frequency Support by Residential Multi-Port Power Converters," *2022 11th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, Bremen, Germany, 2022, pp. 1-4.
- ✓ I. Kalaitzakis, M. Dakanalis and F. D. Kanellos, "Optimal Power Management for Residential PEV Chargers with Frequency Support Capability," *2021 10th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, Thessaloniki, Greece, 2021, pp. 1-4.

Awards

✓ **Best Student Paper award** on Electronics at the *2023 12th International Conference on Modern Circuits and Systems Technologies (MOCAST):*


12th International Conference on Modern Circuits and Systems Technologies

MOCAST

28-30 June 2023, Athens, Greece

Best Student Paper and Presentation on Electronics

Awarded to

Michail Dakanalis

together with

Iason Kalaitzakis, Ioannis Roditis, Eftichios Koutroulis, Fotios Kanellos and Eleftheria Sergaki

for

Real-time Energy Management System for a Multiport DC/AC Inverter

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