Paper ID- 2023112032

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

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Introduction

Renewable Energy Sources:

- Renewable energy sources (RESs), such as solar and wind, offer a sustainable and environmentally friendly alternative to traditional fossil fuel-based energy generation.
- They are abundant and widely distributed, making them an attractive option for decentralized energy production.

Distributed Energy Sources:

- Distributed energy sources (DERs) refer to smaller-scale power generation systems that are located closer to the point of consumption, often integrated into the local grid.
- They provide the advantage of localized power generation, reducing transmission losses and increasing energy efficiency.
- They can be easily integrated with energy storage systems such as battery banks, supercapacitor arrays or electric vehicles to mitigate the intermittent nature of renewable energy production.

Power electronics devices:

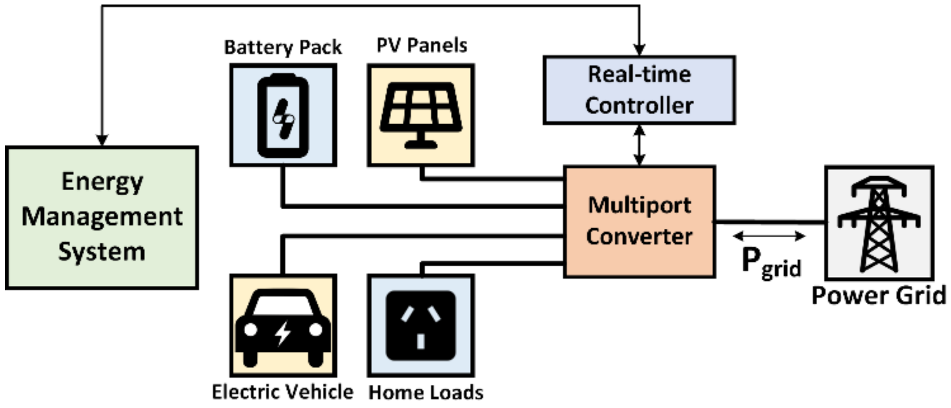
- Enable the seamless integration of renewable energy sources with the energy storage devices and grid or standalone systems.

Multi-port Converters

Multi-port converters (MPCs) are power electronic devices that enable the efficient management and control of energy flow between multiple sources and loads in a system. They main difference over the conventional converters is that they integrate multiple power converters into a single unit.

MPCs advantages over the conventional architecture:

- Less passive and active components
- Compact Design
- Higher efficiency
- Simplified structure
- Less power stages
- Lower cost
- Reduced size and volume

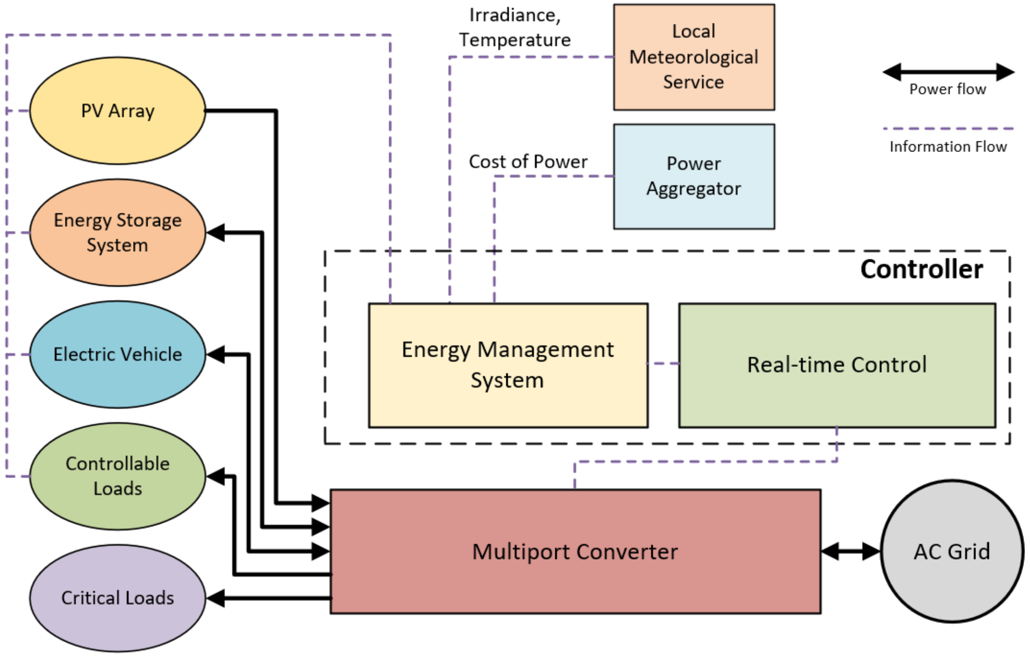


Proposed System Description

Optimization techniques play a key role to the design and operation of MPCs, allowing for the efficient interconnection of input sources by maximizing system effectiveness and optimizing energy utilization.

Proposed MPC energy management system capabilities:

- •Optimal charging-discharging of interconnected energy storage arrays.
- •Power exchange adjustment with the electrical network based on load, cost, and local energy demand.
- •Command signal communication with network operators and collective load representation.
- •Communication with electric mobility service providers, transactions providers, and energy providers for EV connection.
- •Utilization of a software interface (GUI) for operation monitoring and parameterization via a user-selected computer.



Proposed MPC Optimization Algorithm

An optimal operating schedule for the connected units is generated, based on the particle swarm optimization algorithm (PSO). It interconnects an EV, a battery bank, local electrical loads, residential cooling-heating system, as well as its thermal model and a PV array.

The optimization problem is solved every 24 hours based on the cost of power and the meteorological data of the day ahead.

The goal of the optimization is to minimize the operating cost of the local system interconnected by the MPC and at the same time satisfy all technical and operational constraints.

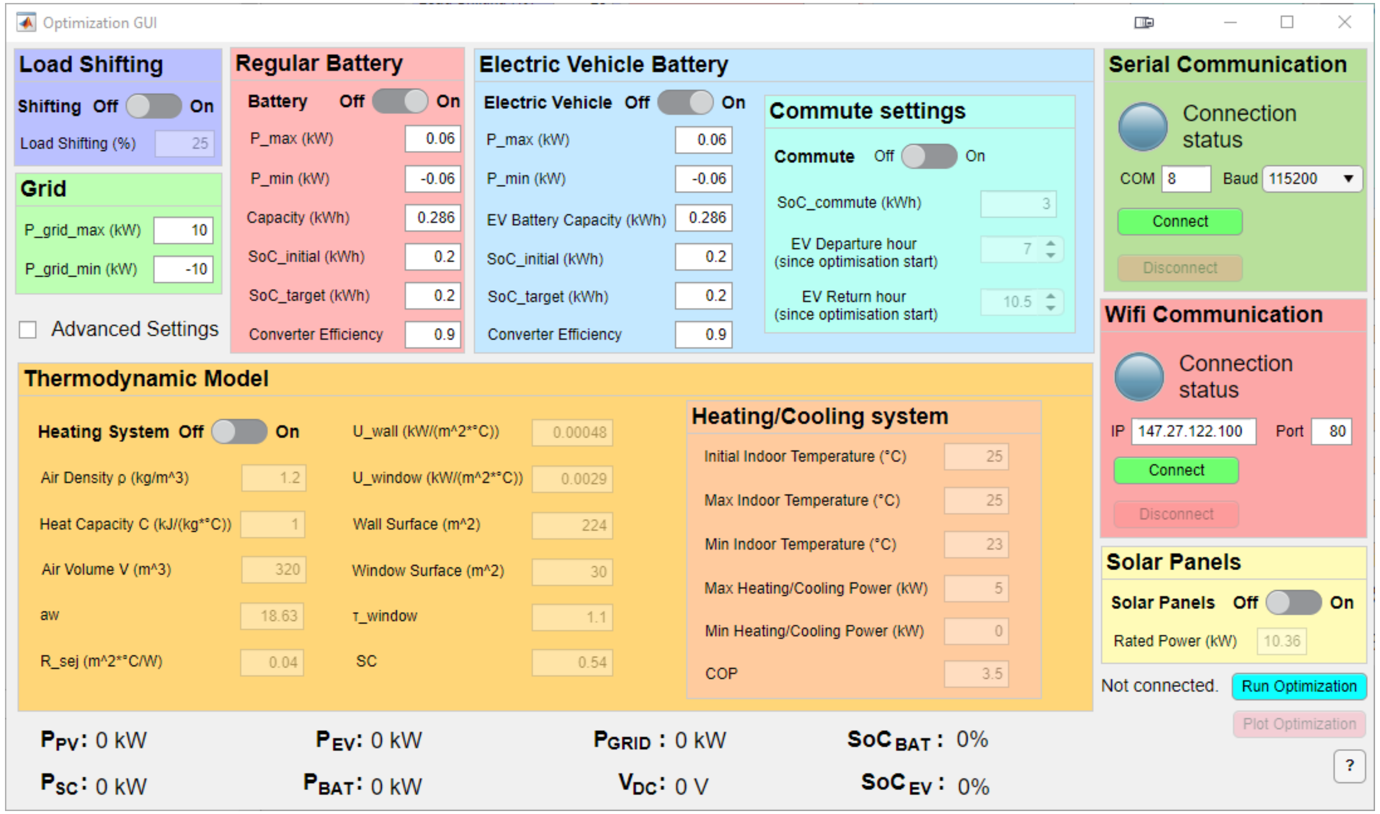
The optimal charging-discharging trajectories of the electric vehicle and the battery bank generated by the optimization algorithm are given as set-points to the real-time control algorithm of the MPC.

$$\min_{\substack{P_{EV},P_B,\\ P_{EC},P_{L,sh}}} \left\{ \sum_t \left[\left(P_{EV}(t) + P_B(t) + P_{EC}(t) + P_{L,sh}(t) \right) \cdot \widehat{EP}(t) - P_{PV}(t) \cdot EP_{PV}(t) \right] \cdot dt \right\}$$

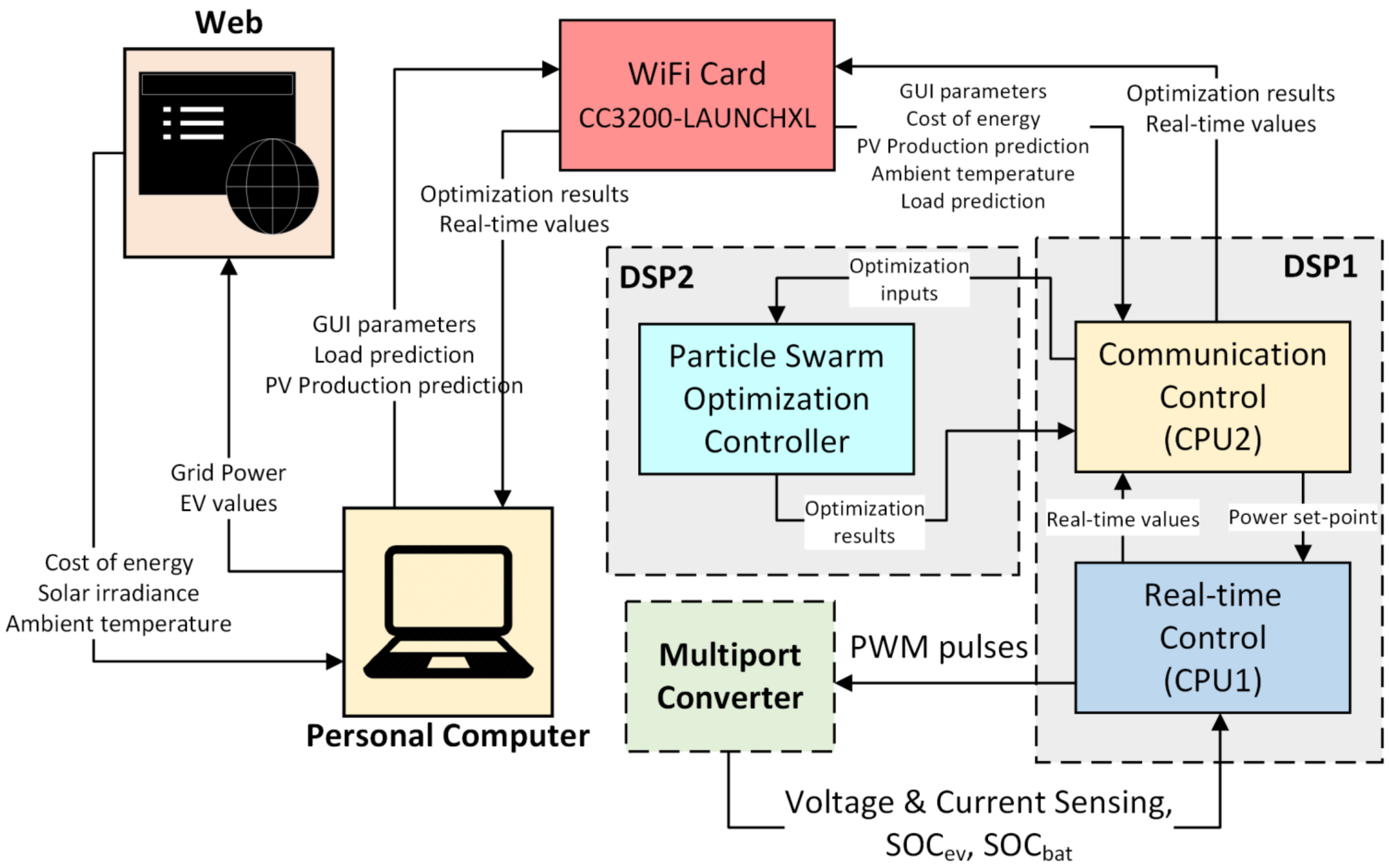
Graphical User Interface

The user interface is designed to:

- Enable or disable individual energy subsystems,
- Configure basic systems' parameters,
- Interact with the software operational and PSO parameters
- Determine the availability of the electric vehicle.
- Enable forecasting of both household energy consumption and PV energy production.

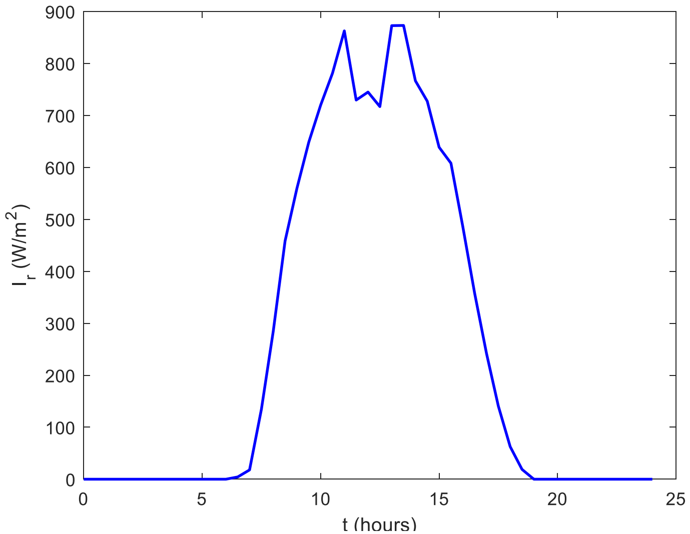


Communication Diagram of the System

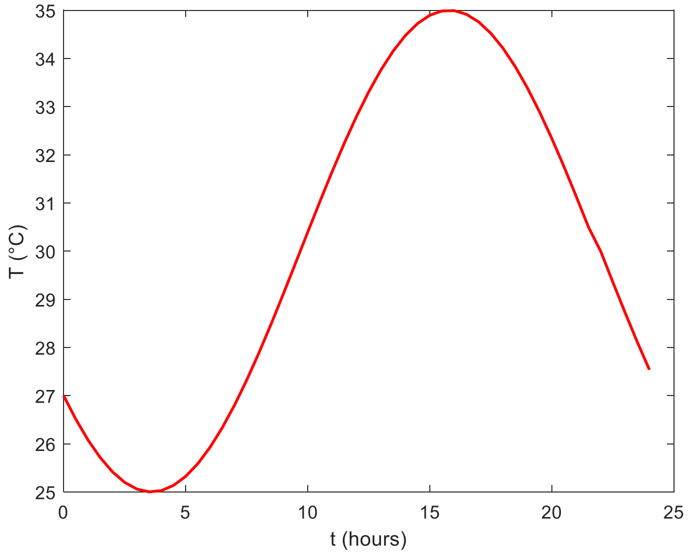


Optimization Algorithm Input Example

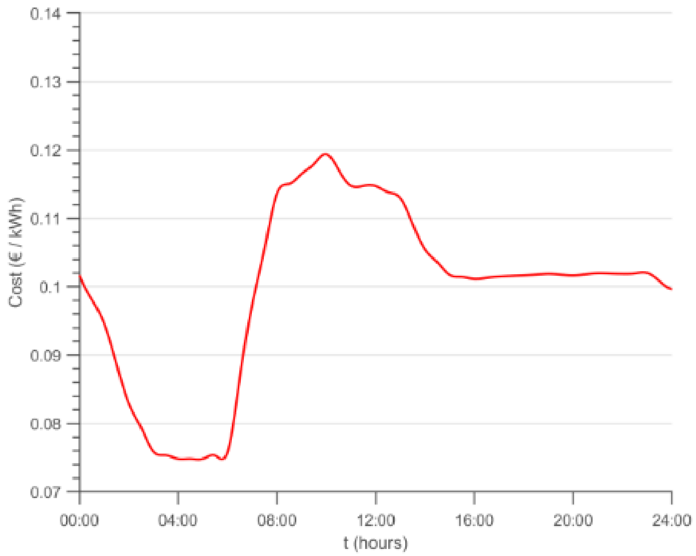
Solar Radiation



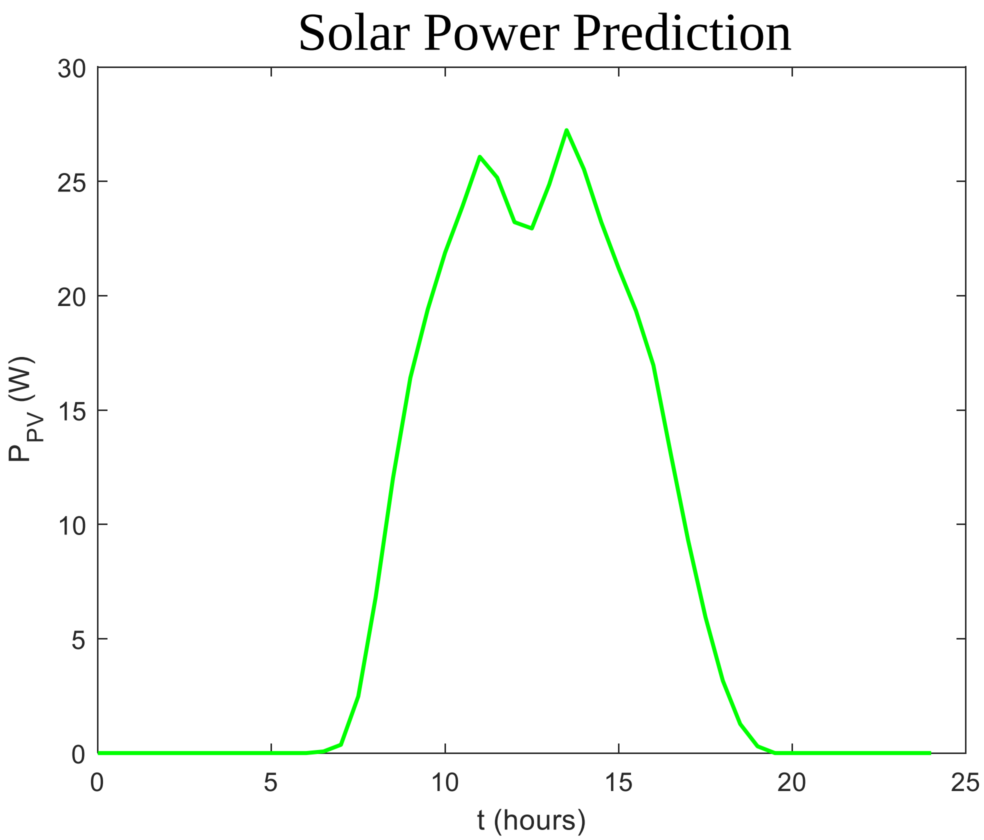
Temperature

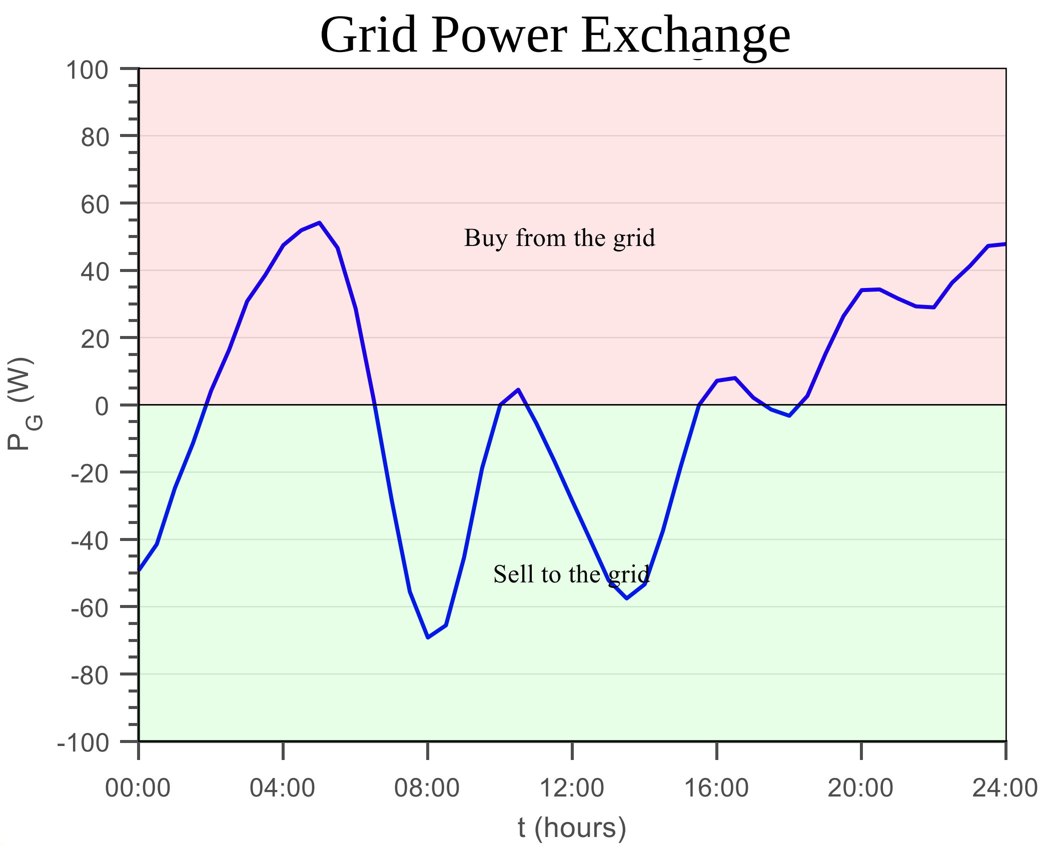


Energy Cost

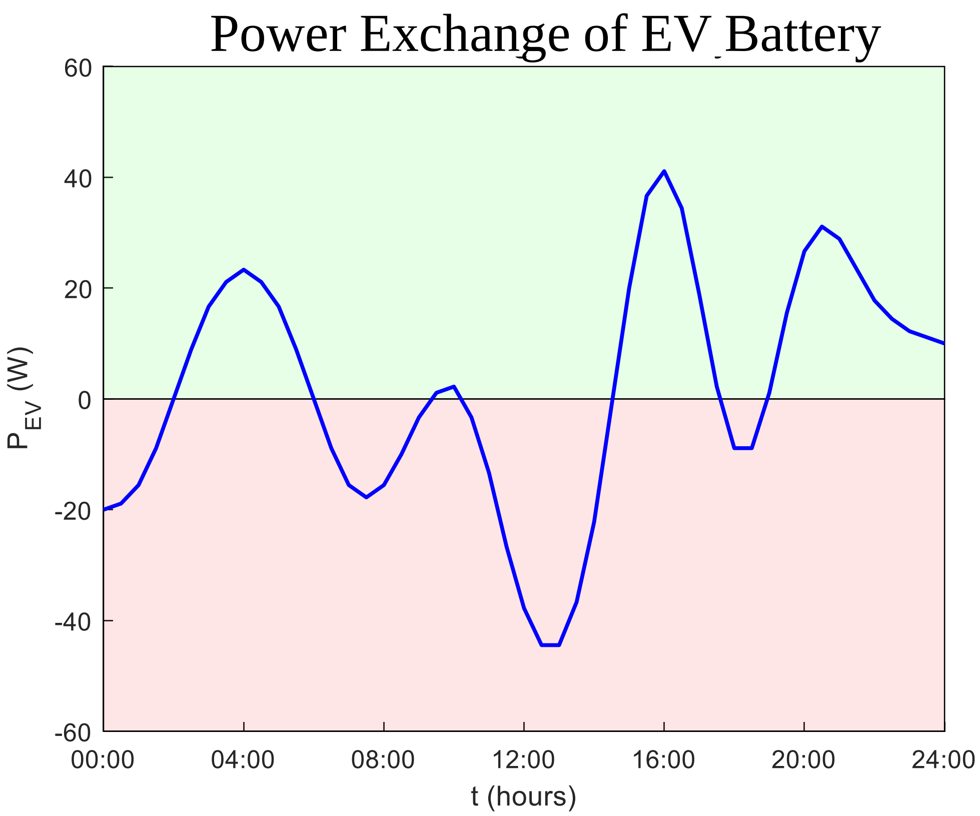


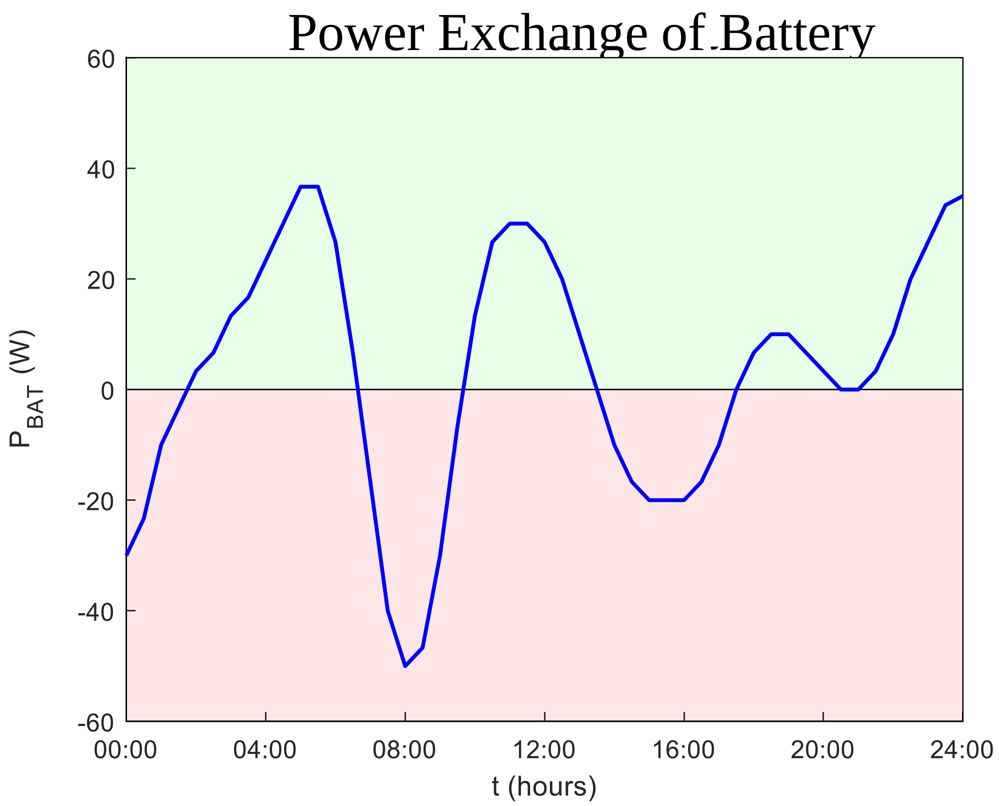
Solar Prediction and Output Power Trajectory



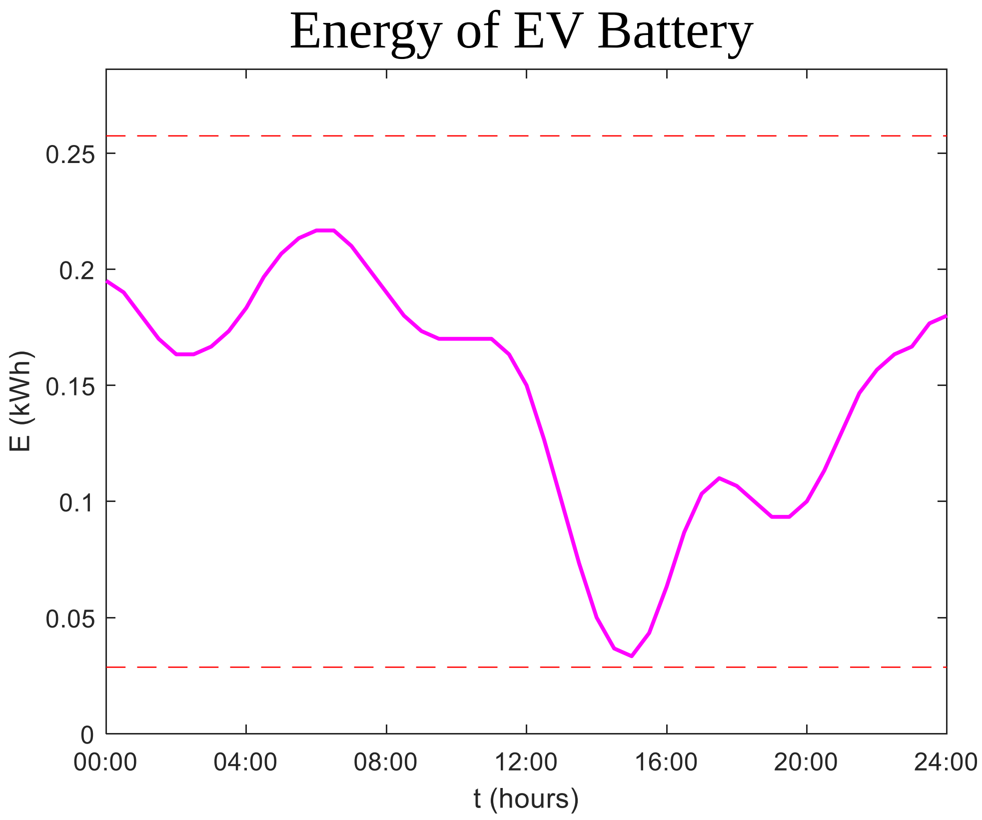


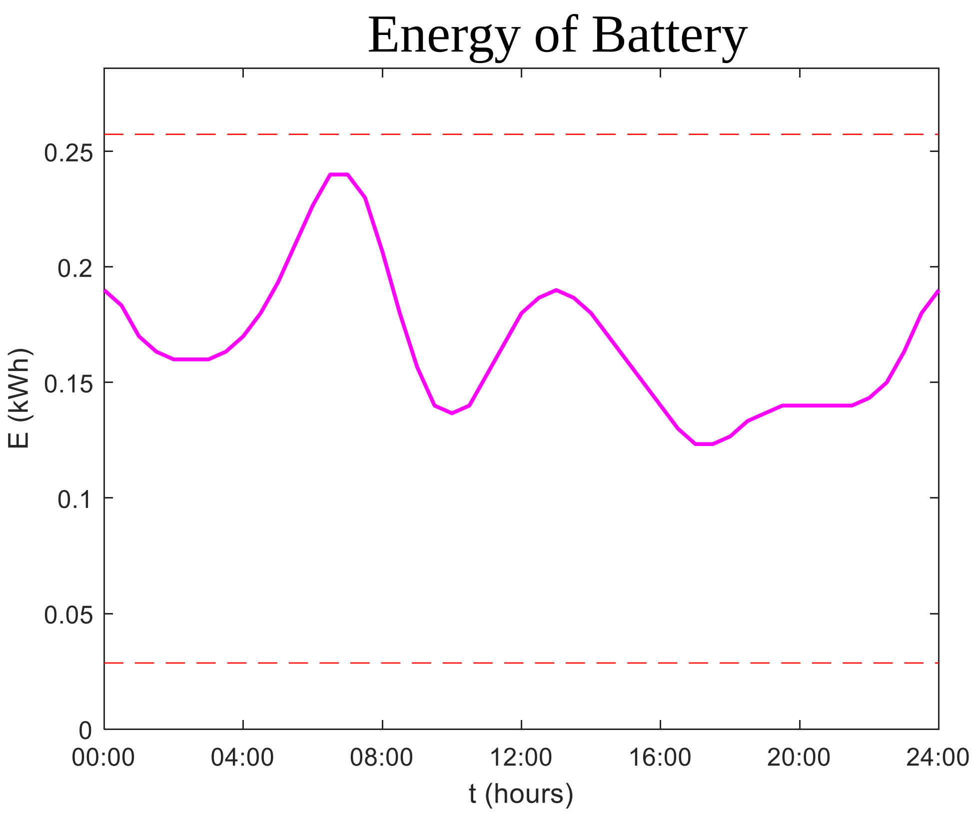
EV and Battery power trajectories



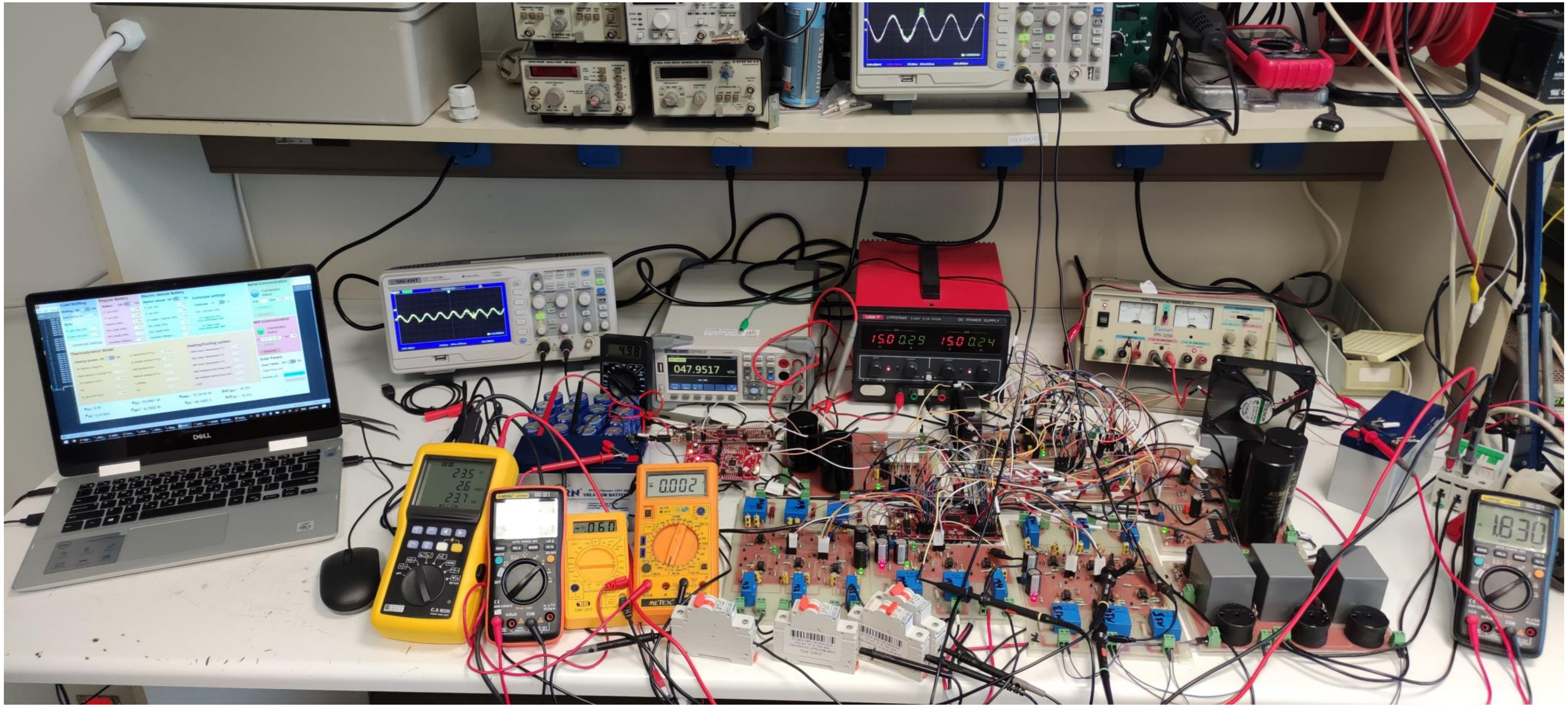


EV and Battery energy trajectories



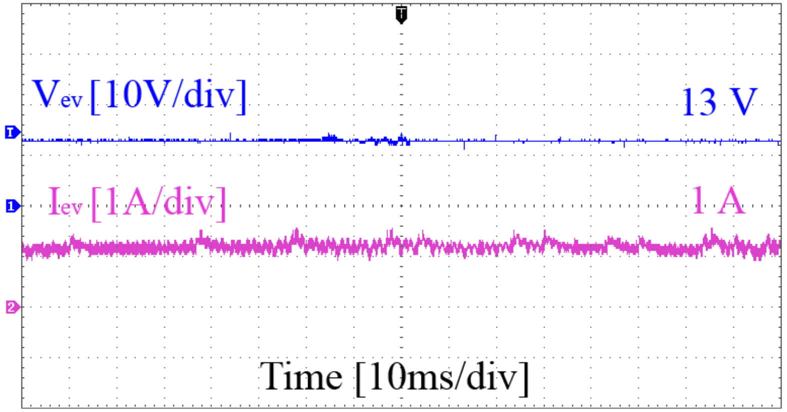


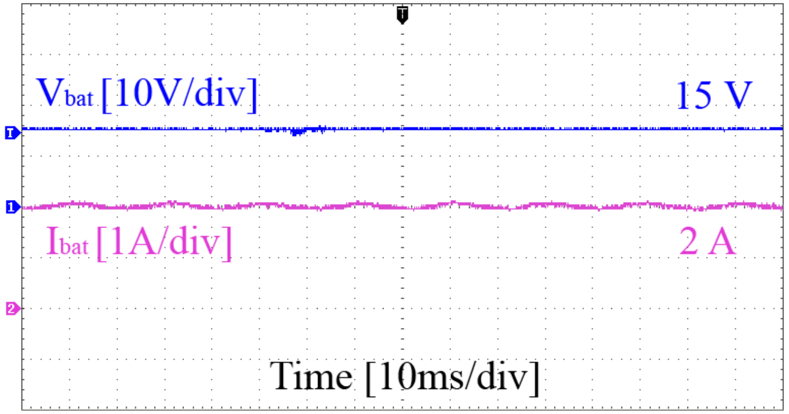
Experimental Setup



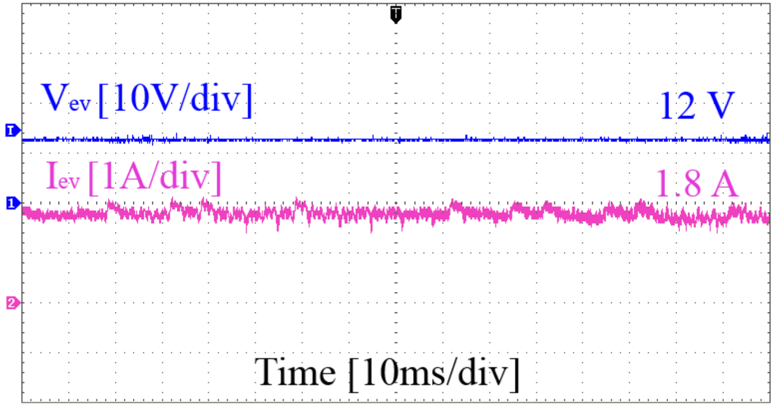
Experimental Results

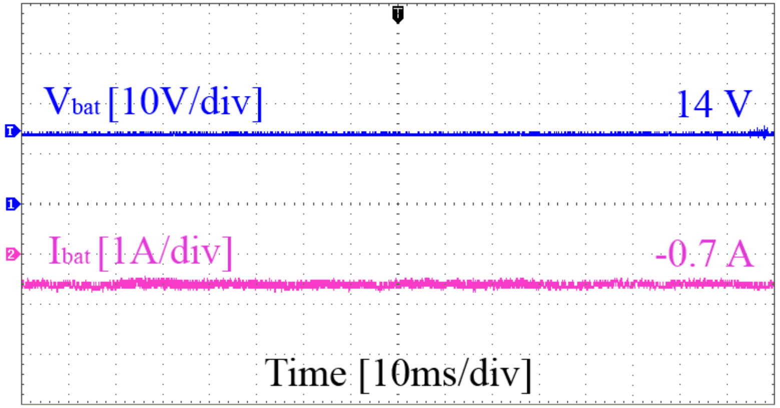
t_1 = 11:30: P_{ev} = 13 W, P_{bat} = 30 W





t_2 = 15:00: P_{ev} = 20 W, P_{bat} = -10 W





Conclusions

- A novel real-time optimization EMS was presented for the integration of a photovoltaic array, an energy storage system, and an electric vehicle using a multiport converter circuit.
- The operating schedule of the connected units was optimized using a DSP-based optimization process based on the Particle Swarm Optimization algorithm, resulting in improved energy management and reduced cost.
- Successful end-to-end operation of the proposed system was demonstrated in terms of energy management, power optimization, and real-time control.
- The integration of RES, energy storage units, and EVs using a multiport DC/AC inverter can provide a reliable and sustainable power source.
- EVs can further enhance the performance and flexibility of the energy management systems

Acknowledgement

This research has been 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: T2EDK-01775).

Thank you for your attention!