UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO

utad

INESCTEC

# Energy Flows Optimization in a Renewable Energy Community with Storage Systems Integrations


I. Araújo,[1] A. Cerveira[2,3] and José Baptista[1,4]

Maria.ines.araujo@energiasimples.pt, cerveira@utad.pt, baptista@utad.pt

1 Department of Engineering

2 Department of Mathematics

3 Artificial Intelligence and Decision Support INESCTEC UTAD Pole

4 Center for Power and Energy Systems INESCTEC UTAD Pole

UTAD - University of Trás-os-Montes and Alto Douro, School of Sciences and Technology, Engineering Department, 5001-801 Vila Real, Portugal


## Introduction

Currently, there is increasing implementation of renewable energy communities, where consumers and producers come together to form energy cooperatives. This growing trend has been accompanied by several studies aiming to optimize energy exchanges and sharing inside the community, always taking into account the most favorable tariff regimes for community members. This paper presents an analysis that, based on applying a linear programming model, optimizes energy transactions in a renewable energy community with the integration of storage systems. The results show the developed model's effectiveness, presenting substantial profits for the community.

## Methodology

The goal of this research is to maximize the REC profit, considering the use of production units for self-consumption and ESS. It is intended to determine when and how much energy to buy/sell to the grid and charge/discharge the battery, based on the demand, the production, the adopted tariff prices, and the energy selling price, considering the costs associated with the integration and maintenance of the ESS's.

$$PF_{ij} + x_{ij} + \sum_{b\in B} bs_{ijb} = D_{ij} + \sum_{b\in B} bi_{ijb} + y_{ij}\,, \quad i \in H, j \in M \quad (1)$$

## Optimization model

The objective function intends to maximize the REC profit, L, which is given by the difference between the revenue from the sale of energy to the grid and the cost of purchasing energy, including the cost of acquiring and maintaining the batteries, considering ten years (lifetime of a stored system considering its technical specifications):

$$\max L = 305 \sum_{i\in H} \sum_{j\in M} (y_{ij} \cdot co_{ij} - x_{ij} \cdot ce_i) - \sum_{i\in B} w_i \cdot (cabt_i + cmbt_i)$$

Where $x_{ij}$, amount of energy purchased from the grid (kWh), in hour *i* of month *j*; $y_{ij}$ is the amount of energy sold to the grid, in hour *i* of month *j*;

## Constraints

The system constraint that guarantees that the energy demand by self-consumers is satisfied is represented by Eq. (1). It ensures that the amount of energy produced by PV system plus the energy bought to the grid (RESP) and the energy discharged by the battery is equal to the demand plus the amount of energy injected into the battery and the energy sold to the grid (RESP).

- $H = \{1, \cdots, nh\}$, set of hour periods per day, where $nh = 24$;
- $M = \{1, \cdots, nm\}$, set of months per year, where $nm = 12$;
- $B = \{1, \cdots, nbt\}$, set of available batteries, were $nbt = \sum_{i\in TB} ni$ and $ni = 3$ is the number of available modules of type $i$, $i \in TB$;
- $cmbt_i$, maintenance cost of battery $i$, $i \in B$, over 10 years;
- $cabt_i$, cost of battery $i$, $i \in B$;
- $co_{ij}$, selling price of energy on the market (OMIE) to the RESP (€/kWh), in period $i$ of month $j$, $i \in H, j \in M$;
- $ce_i$, price for the purchase of energy from the RESP (€/kWh), in period $i$, $i \in H$;
- $PF_{ij}$, photovoltaic production, kWh, in period $i$ of month $j$, $i \in H, j \in M$;

## Case Study and Results

The REC under analysis is located in southern Portugal, has 7 self-consumers, and the data corresponds to 2021. This REC has a total contracted power of 182.8 kVA, where all members present the daily cycle and the bi-hourly tariff. REC's annual aggregate consumption is 221 MWh. About 70% of the energy is consumed during peak hours, and only 30% is consumed during off-peak hours. Figure 1 shows the aggregate consumption of the community for one working day of each month.

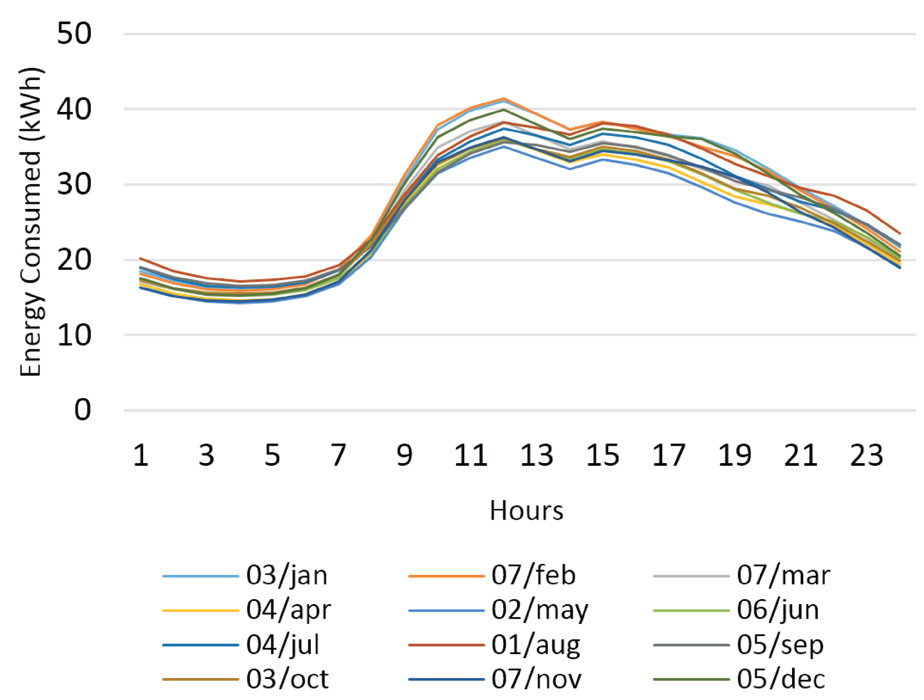


**Fig.1** Aggregate consumption of the 7 self-consumers corresponding to one working day of each month

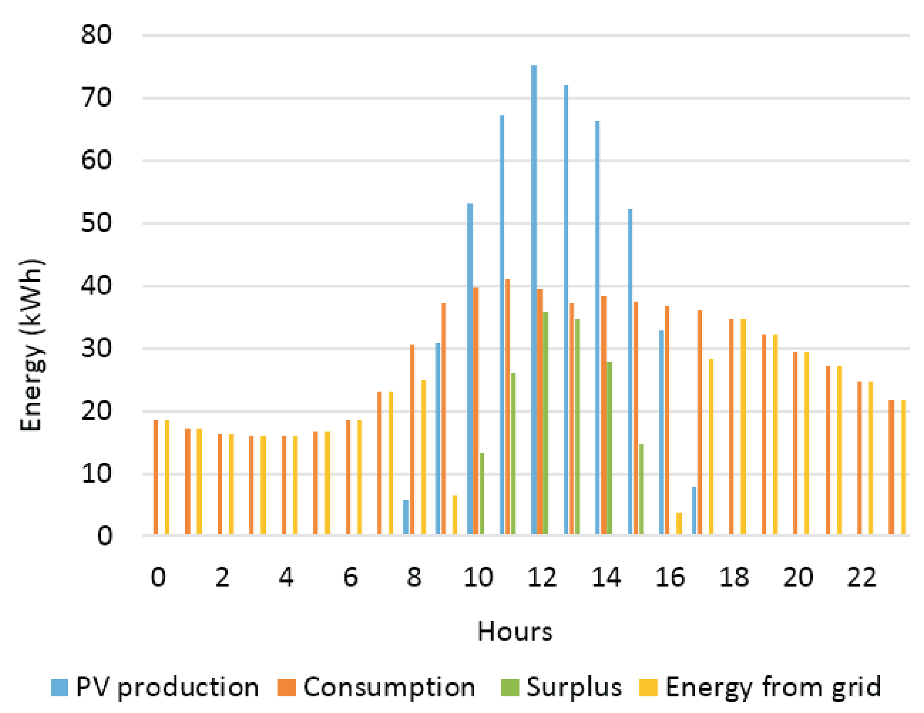


**Fig.2** Production data, consumption, surplus energy and energy purchased from the grid on a day in July, analysis without optimization

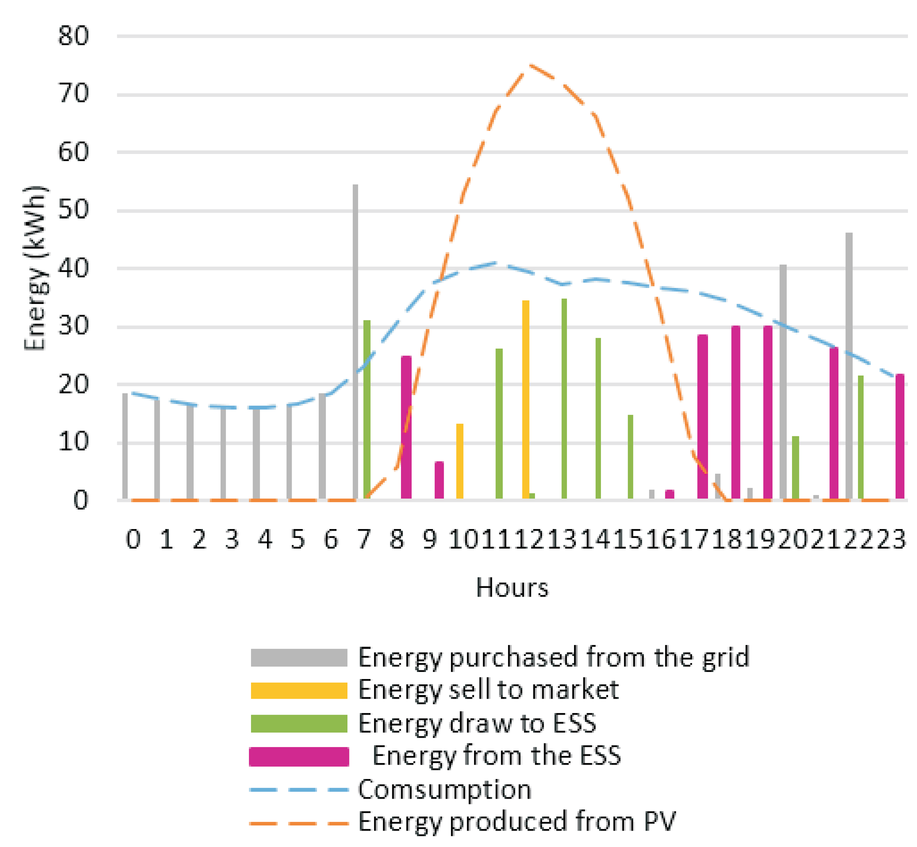


**Fig.3** Energy data with ESS, for a working day in January

## Conclusions

This paper aims to create a tool using linear programming capable of optimizing the energy flows of a REC. Two scenarios were considered. Scenario A1 considers the REC with the integration of energy production systems. Scenario A2 also considers the integration of ESS, and the proposed optimization model is applied to maximize the REC's profit. The goal was to determine when and how much energy to buy/sell to the grid and charge/discharge the battery based on the demand, the production, the adopted tariff, and the energy selling price, considering the costs associated with the integration and maintenance of the ESSs. Concerning scenario A1, it was concluded that of the total energy purchased from the grid in January, about 49.7% of the energy fell in the off-peak periods. This value decreases by 17.7% if a summer month is analyzed. This means that considering only the integration of photovoltaics, the import of energy from the grid in the winter months is quite high, which makes the system not very autonomous.

In scenario A2, ESS with a total capacity of 105 kWh is used. Through data analysis, it is concluded that it is possible to reduce about 67% of energy imports in peak hours compared to scenario A1. On the other hand, there is an increase in net consumption during off-peak periods when energy prices are significantly lower. Thus, when the energy sale price is competitive, the batteries discharge by injecting the energy into the grid. Conversely, battery charging can occur before peak periods when energy purchase prices are lower, maximizing community profits.


21th International Conference on Renewable Energies and Power Quality (ICREPQ'23)

Madrid (Spain), 24th to 26th May 2023