Genetic Algorithm for Load Scheduling

Introduction

The use of electricity generation systems powered by photovoltaic (PV) sources, connected to the grid is well-developed. Nonetheless, the main drawback of these systems is the dependence of the electricity generation with respect to the environmental conditions. Different approaches can be used to mitigate this problem, such as the use of energy storage systems like lithium-ion batteries. However, to add such devices into the system, a considerable increase in the initial investment is necessary, which from the point of view of small users is not always possible. Another solution consists of leveraging the possibility to organize the turn-on times of programmable electricity appliances such as washing machines, dryers and air conditioning systems. In this case, the cost of the hardware necessary to implement this solution is reduced, compared to the use of an energy storage system.

In this work, a genetic algorithm is used to select the best turn-on times for four different appliances during one day. A residential environment supported by a PV generation system is considered. Two different objectives were studied, the cost minimization (reducing the electricity bill), and energy exchange minimization, i.e., reducing the energy that is exported or imported from the grid. The generation and consumption powers are shown in Fig. 1(a) and Fig. 1(b), respectively. Furthermore, it is assumed that the forecasts of electricity generation and consumption are available for the algorithm.

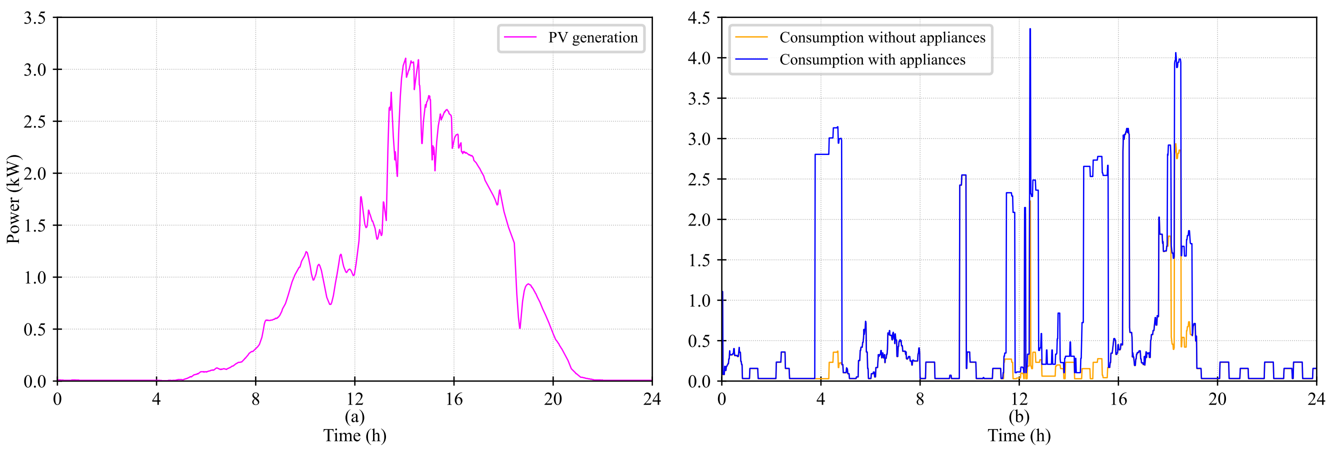

Figure 1: Power profiles (a) PV generation. (b) Load with and without appliances.

The following programmable appliances are considered to be available in the system: Dishwasher, tumble dryer, washing machine and washer dryer. Regardless of the appliances used for this case, what is more important is to characterize the power profiles of each appliance, as shown in Fig .2. This is considered as the initial case where no optimization has been performed.

Tools and methods

In this work, the genetic algorithm is used to select the start-up time for each appliance during the day, and the global optimization toolbox of MATLAB is used to solve the optimization problem. Two different cost functions are evaluated, first the energy exchange minimization is studied to reduce the total energy that is imported or exported to the grid during the day. The second objective corresponds to the minimization of the electricity cost. In an optimization problem, the cost function which is intended to be minimized and the constraints of the problem have to be formulated. The resolution considered for the power profiles is of 1 minute.

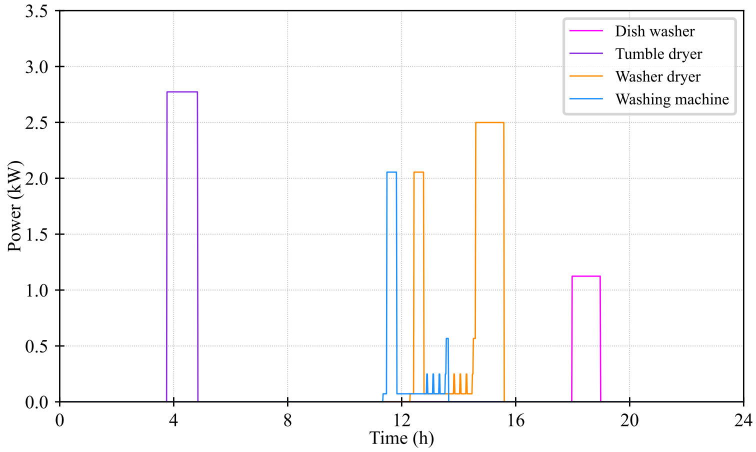

Figure 2: Power profiles of programmable appliances.

Constraints

For this problem, the constraints correspond to the minimum and maximum starting times for each appliance. All the appliances have to start at a time $t > 0$. However, the maximum starting time depends on the length of the cycle of each appliance. For example, the dish washer cycle lasts 1 hour, therefore the maximum starting time is at $t = 23$ h.

Cost function

The total energy exchange, depends on the difference on power, considering that the PV power is $P_{PV}(t)$ and the load power is $P_L(t)$. The resulting grid power $P_G(t)$, neglecting losses, is calculated as:

$$P_G(t) = P_{PV}(t) - P_L(t) \tag{1}$$

To reduce the total energy exchange with the grid, it is necessary that the grid power is always zero. Therefore, the cost function for energy minimization is described as:

$$E_E = \sum_{t=0}^{t=1440} |P_G(t)| \tag{2}$$

For the cost minimization it is considered that there are two tariffs during the day, and if some energy is sent to the grid it is sold at a fixed rate. The cost function for cost minimization can be described as:

$$C_E = \sum_{t=0}^{t=1440} K(P_G, t) \cdot P_G(t) \tag{3}$$

where the coefficient $K(P_G, t)$, represents the price of energy at different times, as shown in Fig. 3.

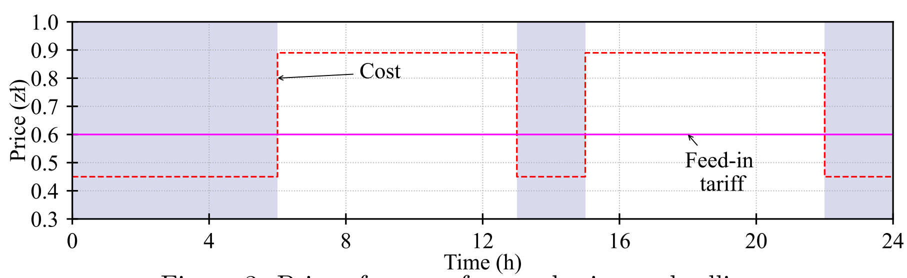

Figure 3: Price of energy for purchasing and selling.

Results

Results regarding the minimization of energy exchange are shown in Fig. 4. It can be noted that the power profiles of the appliances are grouped trying to match the generation profile of the PV system. The power profiles after cost minimization of are shown in Fig. 5. The appliances profiles are grouped at the beginning of the day, when the electricity price is cheaper.

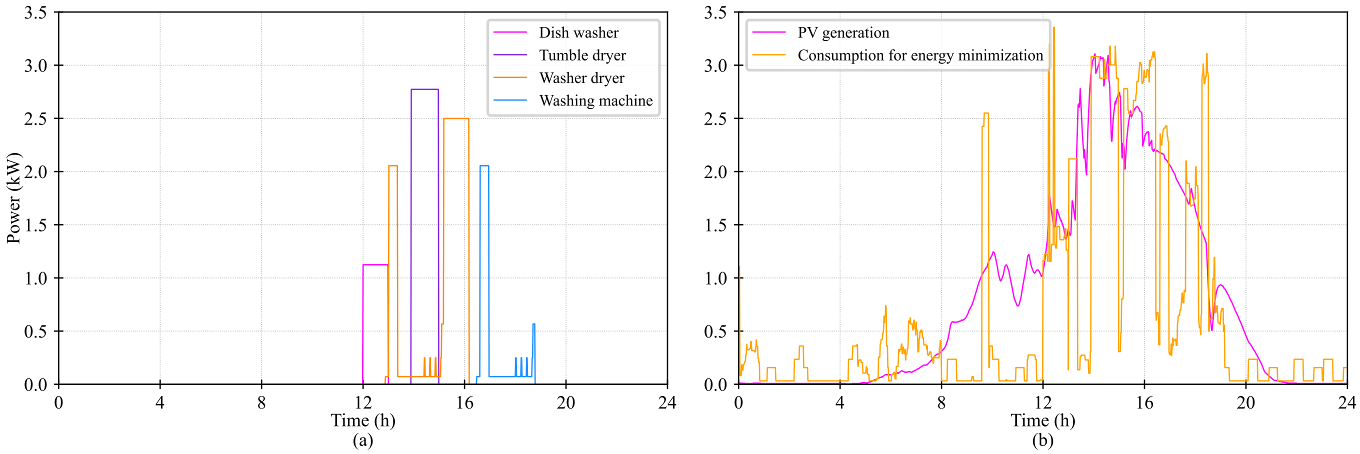

Figure 4: Power profiles after energy exchange minimization. (a)Individual appliances. (b)PV generation and aggregated load profile.

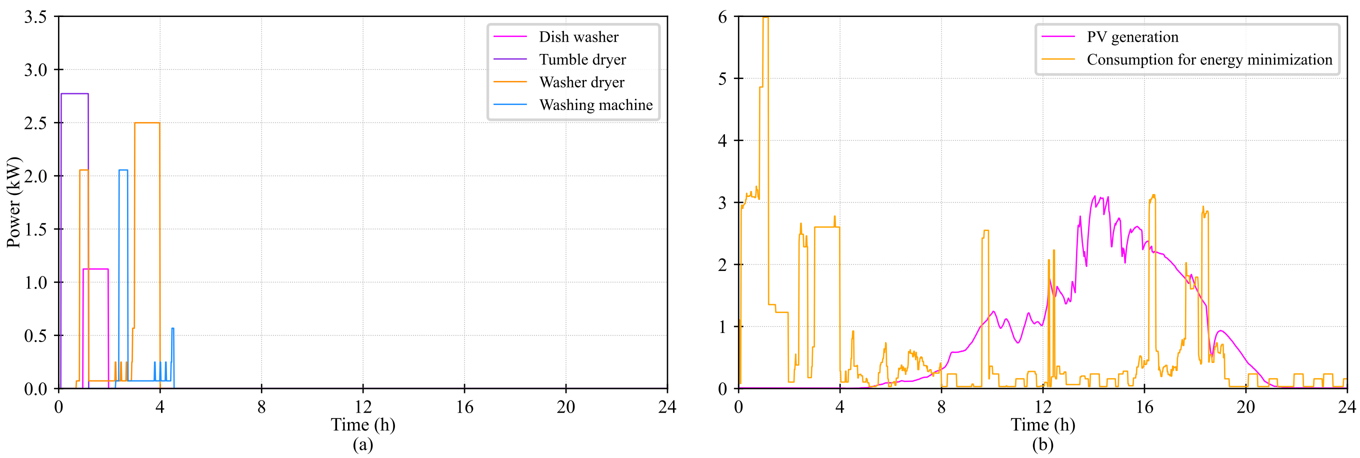

Figure 5: Power profiles after cost minimization. (a)Individual appliances. (b)PV generation and aggregated load profile.

Comparison

The results for the initial case, and considering different objective functions are summarized in Table 1. Negative values of the cost indicate that the user receives profit for selling energy to the grid. The profit using the cost minimization approach is almost doubled compared to the energy minimization. However, this is at the expense of demanding and importing large amounts of power from the grid.

Table 1: Summary of results for different cases

Strategy	**Cost (zł)**	**EE (kWh)**	$P_{G,max}$ **(kW)**	$P_{G,min}$ **(kW)**
Original	-1.51	18.01	2.97	-3.14
Cost	-2.85	25.25	3.05	-6.1
Energy	-1.45	10.27	2.7	-1.98