Mixed-integer linear programming

Guidelines

- Answers to go in **answers.docx**. The document should be submitted in a pdf format. Clearly and succinctly answer the questions.
- Python implementation to go in **answers.py**. In order to get full marks for the implementation parts, your code should be clear, well commented, sensibly structured and correct. As indicated per the question, marks may be deducted if the problems are not sensibly formulated.
- The results reported in **answers.docx**. must be verifiable in the code to get full marks. The results must be rounded to 1 decimal place.

Smart home scheduling problem

Your task is to use mixed-integer linear programming to schedule the operation of the smart home illustrated in Figure 1. The operation of the smart home must comply with the following rules:

- The homeowner aims to pay as less as possible for electricity;
- The operation of the smart home must be scheduled for 24 hours ([0, …,23] h);
- The homeowner can buy or sell electricity from the electricity network. The homeowner buys electricity when the house is consuming electricity from the network. On the other hand, the homeowner sells electricity when the house is injecting electricity into the network;
- The electricity exchanged with the network results from the electricity consumed by the electric vehicle and appliances, and electricity generated by the electric vehicle and rooftop solar system;
- The appliances are uncontrollable. The rooftop solar system and electric vehicle are controllable. Controllable devices can be scheduled;
- The electricity consumption of the appliances must always be satisfied;
- The generation of the rooftop solar system can vary between zero and its expected maximum output;
- The electric vehicle can charge (consume) and discharge (inject) electricity. However, it cannot charge and discharge at the same time[1]. The state-of-charge of the electric vehicle battery

[1] This must be ensured in the formulation of the problem by using mixed-integer linear constraints.

increases when it charges and decreases when it discharges. The state-of-charge evolves along with the time t, as described by:

$$SOC_{t+1} = SOC_t + (\eta P_t^+ - \frac{P_t^-}{\eta})\Delta t, \quad \forall\ t \in T \tag{1}$$

where SOC is the state-of-charge (in kWh), η is the efficiency, P_t^- is the discharging power (in kW), P_t^+ is the charging power (in kW), and Δt is the length of t (in hours, $\Delta t = 1h$). The efficiency is 0.9, the state-of-charge can vary between 0 and 39 kWh, the discharging and charging power can vary between 0 and 3.7 kW;

- The electric vehicle arrives at 10h and leaves the house at 20h. This means that it can charge and discharge in the following interval [10,20[h. The electric vehicle arrives at the house with a state-of-charge of 30 kWh. The owner requires that the state-of-charge of the electric vehicle is at least 33 kWh before leaving the house at 20h.

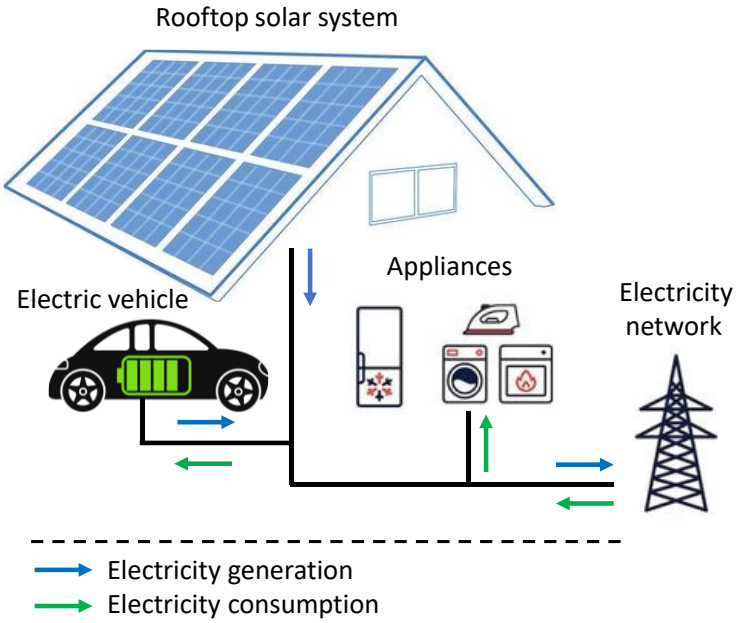

Figure 1. Smart home.

Data provided in the **answers.py**:

- Buying and selling prices for 24 hours;
- Electricity consumption of the appliances for 24 hours;
- Expected solar generation for 24 hours;
- Availability of the electric vehicle to charge and discharge;

Questions [100 marks]

1. Formulate and implement the mixed-integer linear problem. The mixed-integer linear problem should be formulated in **answers.docx [15 marks]** and implemented in **answers.py** (in **function_1**) **[15 marks].** Report in **answers.docx** the total electricity cost of the house, electricity bought and sold **[5 marks]**.

2. The homeowner bought a new controllable appliance. The new appliance operates once a day and consumes 1 kW during 3 consecutive hours (i.e., 1 kW/h). The operation of the appliance

cannot be stopped, after being started. Formulate and implement a new mixed-integer linear problem to schedule the operation of the smart home with the new appliance. The mixed-integer linear problem should be formulated in the **answers.docx [10 marks]** and implemented in the **answers.py** (in **function_2**) **[15 marks].** Report in **answers.docx** the total electricity cost of the house, and the scheduling of the new appliance **[5 marks]**;

3. The smart home also pays a daily fee for electricity network access. The daily fee is defined by the piecewise function (1). The piecewise function (1) defines a daily fee according to the maximum power consumed P_t^B and generated P_t^S by the smart home during the day. Formulate and implement a new mixed-integer linear problem to schedule the operation of the smart home considering the daily network fee. In this problem, the new appliance described in question 2 should not be considered. The mixed-integer linear problem should be formulated in **answers.docx [15 marks]** and implemented in **answers.py** (in **function_3**) **[15 marks].** Report in **answers.docx** the total electricity cost of the house and electricity network fee **[5 marks]**.

$$\lambda^{NF} = \begin{cases} \$0.5, & \max_t(P_t^B, P_t^S) \leq 4\ kW \\ \$1.0, & 4\ kW < \max_t(P_t^B, P_t^S) \leq 8\ kW \\ \$1.5, & \max_t(P_t^B, P_t^S) > 8\ kW \end{cases} \quad (1)$$

Further notes and tips:

- Follow the order of the questions to implement and run the mixed-integer linear problems. You cannot answer questions 2 or 3 without answering question 1;
- The **answers.py** provides commented code to help you structure the code. The areas to be coded by you are **<to be completed by the student>** and **<to be replaced by the student>**. In the main function, you only need to activate function_1, function_2 or function_3 to run the experiments. You do not need to code in the main function.