Department of Electrical Technology

TET 4565 -Kraftmarkeder og energisystemplanlegging

Project

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Date

Table of Contents

List of Figures

List of Tables

1 Introduction

2 Problem formulation

2.1 Motivation

Today, the power production becomes more reliant on renewable power. This means that the price may vary greatly throughout the day, depending on the supply and demand in the given hour. This offers an incentive for the consumers to use electricity when demand is low and reduce their load when demand is high. The new grid tariff, introduced in 2022, encourages consumers to even out their electricity use throughout the day, by imposing an extra fee based on the highest electricity demand within an hour. With the increasing number of electric home devices allowing for flexible usage, new opportunities opens for scheduling the electricity use. It will enable consumers to plan their use throughout the day, taking advantage of price variations.

During this project, we will look at how a household can optimise their electrical vehicle charging over a two-day period. The EV is modelled with charging-restrictions to avoid too much wear and tear on the battery. This means that the battery cannot fully charge within one hour, but need to be spread out throughout the day. There is also a restriction on how much the total load of the household can be within one hour, and it is assumed that the overall spending in the rest of the house is not affected by the electricity price.

As the electricity demand for the next day is not know, the optimisation problem has a component of uncertainty. The next day demand becomes clear at midnight, and the system has the possibility to adjust the schedule for EV-charging for day two. This vary from a scenario with perfect information, where one is able to schedule optimally from the first hour.

During this project, the electricity use of a household will be investigated. The uncertainty is the electricity demand the following day.

The questions that will be answered during the course of the project is:

1. How much can a household smooth their peaks and bottoms by optimising its EV-charging?
2. How will the uncertainty affect the optimisation problem?

3 Mathematical formulation

Mathematically, the problem can be formulated as an optimizing problem to minimize the difference between the consumption peaks and bottoms.
Sets:

$$T = \{1, 2, \ldots, 48\} \qquad \text{Set of time periods, total of 48 hours}$$

Parameters:

$$\begin{aligned} P_{\mathrm{EV}}^{\max} &: \text{Maximum power rate of the EV charger} \\ E_{\mathrm{EV}}^{\mathrm{required}} &: \text{Total energy required by the EV before the end of the total period} \\ P_{\mathrm{house}}(t) &: \text{Household's power consumption at time } t \\ P_{\mathrm{limit}} &: \text{Maximum household and EV power consumption combined} \end{aligned}$$

Variables:

$$\begin{aligned} P_{\text{EV}}(t) &: \text{Power used by the EV charger at time } t \\ z_{\max} &: \text{Maximum total power consumption by EV and household} \\ z_{\min} &: \text{Minimum total power consumption by EV and household} \end{aligned}$$

Objective Function:

$$\min(z_{\max} - z_{\min}) \tag{1}$$

Subject to:

Constraints to define the auxiliary variables:

$$z_{\max} \geq P_{\text{household}}(t) + P_{\text{EV}}(t) \quad \forall t \in T \tag{2}$$

$$z_{\min} \leq P_{\text{household}}(t) + P_{\text{EV}}(t) \quad \forall t \in T \tag{3}$$

Energy requirement constraint:

$$\sum_{t \in T} P_{\text{EV}}(t) = E_{\text{EV}}^{\text{required}} \tag{4}$$

EV charger power limit:

$$0 \leq P_{\text{EV}}(t) \leq P_{\text{EV}}^{\max} \quad \forall t \in T \tag{5}$$

Combined household and EV power limit:

$$P_{\text{house}}(t) + P_{\text{EV}}(t) \leq P_{\text{limit}} \quad \forall t \in T \tag{6}$$

4 Data Analysis

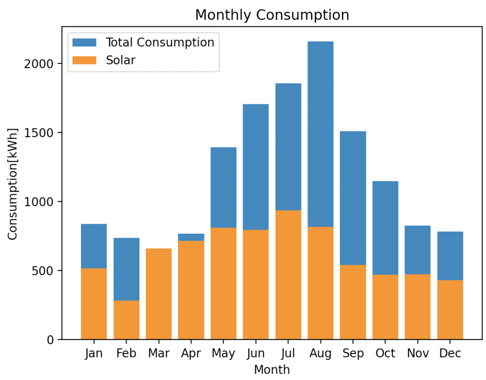
When analyzing the Austin household dataset, we created a new column called Total consumption, which is the sum of power from solar and the grid. By aggregating the consumption of solar and total consumption for each month for house nr. 10, we get the Monthly Consumption plot in figure 1a. From the bar graph, there is clearly a seasonal trend in the power consumption. The consumption increases drastically in the summer months which might be because of an increase in air-conditioning used to cool down households in the Texan summer.

In figure 2a of Total Consumption above, we can see how the data points in the total consumption column and the solar columns are spread. The orange line is the median value, the part in the box above the orange line is the third quartile, and the part of the box below the orange line is the second quartile. In the box is the middle 50% of the data. The black dots are the outliers, and what is between the box and the lines are the 1st and the 4th quartile. The total consumption box plot shows that the data has a few outliers and the solar box shows a very low median value, but still has a few high values.

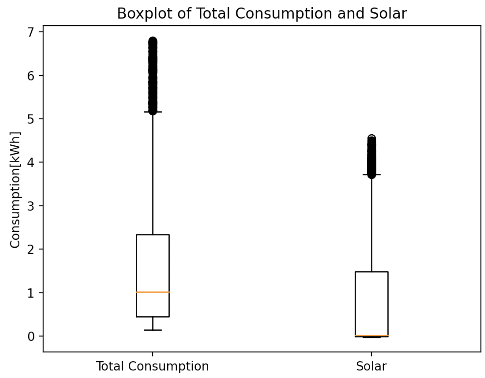
Figure 2a and 2b shows that there normally is a low consumption and even more low solar production, which makes sense because the total consumption is made up of solar. For solar, very high values are as common medium high values. The occurrence of specific consumption values gradually decrease as the consumption increases.

Figure 3 shows the total consumption grouped by the day of the week. The consumption is higher on Wednesday, Friday and Saturday, and lowest on Monday and Tuesday.

5 Conclusion

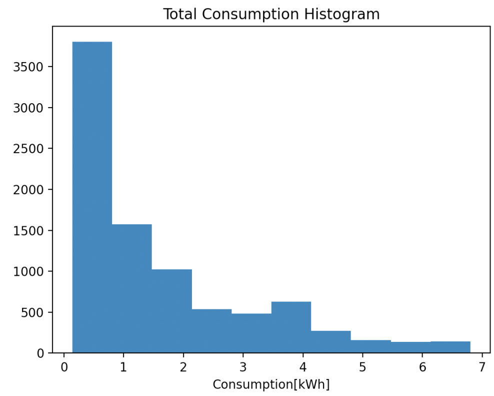


(a) Monthly Consumption

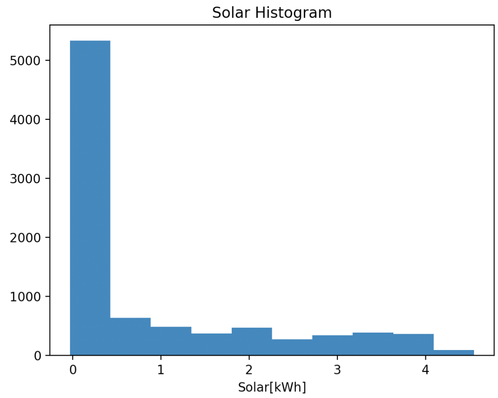


(b) Boxplot of consumption and solar

Figure 1: Solar and Total Consumption Comparison



(a) Histogram Consumption



(b) Histogram Solar

Figure 2: Histogram of Solar and Consumption

Appendix

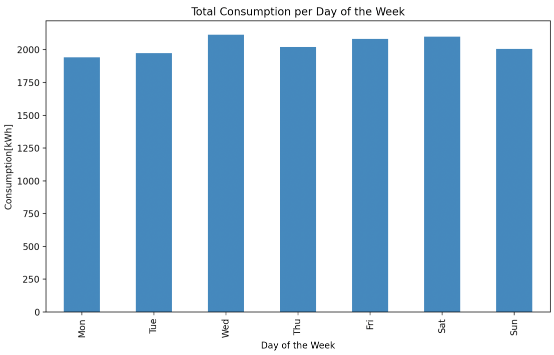


Figure 3: Total Consumption Grouped by Day of the Week