Assignment 1: Use appliances intelligently at your home

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Abstract

Over the past couple of decades smart home automation appliances has become a more popular tool for both suppliers and their customers. This request is growing accordingly to consumers needing better energy-saving and more efficient appliances. To answer whether using appliances intelligently at your home will minimize the energy cost, we should build a strategy to find a pricing curve for the householder. We break the evaluation process down to main intelligence pricing schemes; Time-of-Use and Real-Time-Pricing. Furthermore, we use those schemes to intelligent appliances to gain different results and evaluate the different output in the pricing curve. We apply analysis and design methods to the pricing curves to minimize the energy cost for each householder.

Introduction

The main aim of this report has been calculating how to minimize the energy cost in a neighbourhood using a strategy and solve as a mathematical problem. In households without any form for intelligent scheduling, the power demand is often low during night, light to moderate during the mornings and higher during the evenings. The content of this assignment concentrates on how to calculate the minimal energy consumption and develop a strategy to solve the linear programming problem. In this report we will also discuss the figure to illustrate pricing curve and further explain how the problem is solved with the main algorithms. We will also give a short analysis of the two different pricing schemes Time of Use (ToU) and the Real-Time Pricing (RTP).

Materials and methodology

We determined to use the programming language Python, as it was the language best suited to solve the linear problem in our situation. Python was used to minimize the cost of energy, and for our data collection technique we chose the program tool R to analyse the data from the neighbours. The study conducted was divided into two parts. The first part was to program the optimization problem in python and calculating the minimal energy consumption. The second part, we use the content of the analysis and draw the flowchart to illustrate the main pricing curve for the neighbours in R. The pricing curves that were illustrated in R considers both the non-shiftable appliances and the all the shiftable appliances. Each household has many variations of appliances, and the daily consumption is divided into a 24-slot-time-frame where each slot is equivalent to an hour period. These involve a set of representative non-shiftable appliances and shiftable appliances to provide a range of the possible time slots for the operating program. The price curving from the data collection provided us with a deeper understanding on how to practise intelligent appliance to minimize the energy cost.

Program Files

The solution of the assignment consists of 3 files:

1. solutions.py
2. household.py
3. appliance.py

The main file is solutions.py can be run in terminal by: *python solutions.py*. Solutions.py has 3 parts corresponding to the three assignment parts. Each part of the solution begins with "# Assignment 1_1", "# Assignment 1_2", "# Assignment 1_3" respectively. To differentiate appliances we have used the following naming convention:

1. appliance name begins with "~" is a shiftable appliance
2. appliance name begins with "*" is a random appliance.

After running the program the following files are generated.

Part 1 of the assignment:

-Reports/A simple household.png

-Reports/A simple household.xlsx

Part 2 of the assignment:

-Reports/A household.png

-Reports/A household.xlsx

Part 3 of the assignment:

-Reports/neighborhood/Household [xx].png (30 files named "Household0.png" to "Household29.png")

-Reports/neighborhood/neighborhood.xlsx (it's an excel file with 30 sheets- each sheet for one household in the neighborhood)

The file solutions.py contains solution for all the sections of the assignment. For the first two questions, the flow charts shown later in the report show that the program stops after getting solutions but this is drawn this way for the purpose of illustration. The program stops after finding solutions to the third questions.

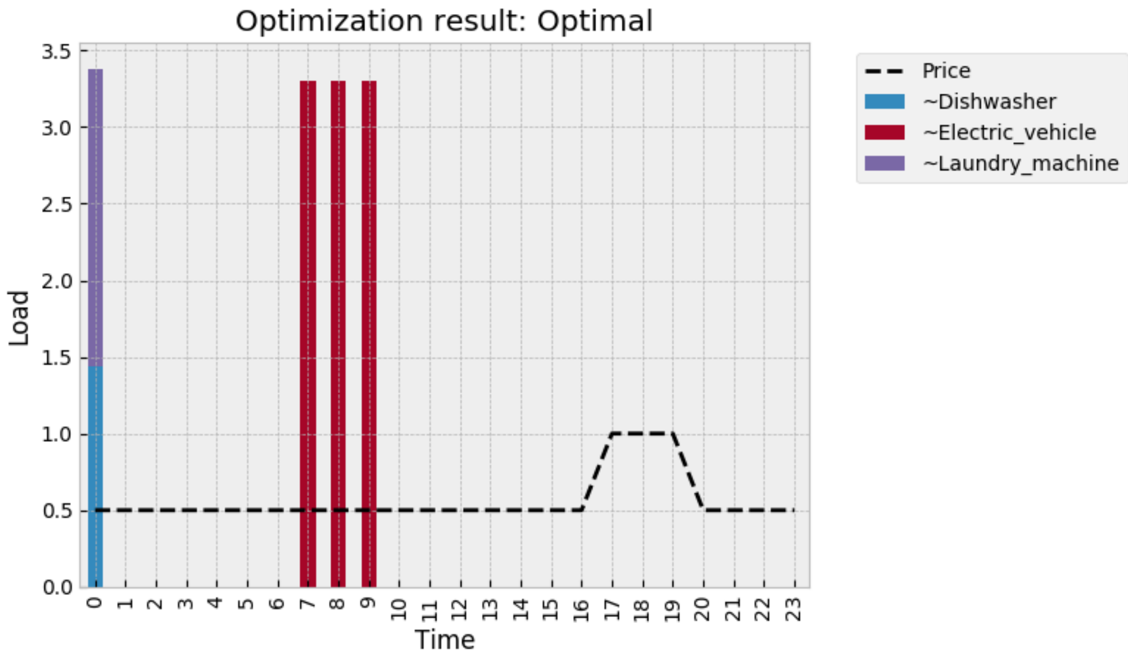
Results and analysis

In this section we present a brief analysis of the Time-of Use and Real-Time pricing schemes and outlines the strategy for different appliances to analyse the data we collected.

Hogan (2014) argues that Time-of-Use (TOU) refers to the prices set as an advantage to customers, but then the price is changeable over the day to capture the impacts in the shifting of the electricity conditions. The prices are often set well in advance of the period, and does not always reflect the actual conditions. By conditions, Real-time pricing reflect the current conditions and will provide the best available signal to minimize value of power for example in this case a simple household or a small neighbourhood. TOU measure consumption at specific times and keeps the cumulative totals for the certain periods of the day rather than the individual totals for each measured period for the day. TOU is a lesser amount of correct and slightly less fair than RTP.

In this report we provide an analysis of the TOU and RTP schemes by designing the strategy for a simple household to minimize the energy cost. The process of analysing data was to develop a strategy to use the appliances intelligently to minimize energy cost for the first part a simple household with only three appliances. We used the time-of-use pricing scheme and the peak hours was in the range of 5:00pm-8:00pm, while other timeslots were off-peak hours. The second part we designed a strategy for a household with all non-shiftable, all shiftable appliances and random combination of appliances. In this part we choose a random combination of appliances and used Real-time pricing scheme. The third part we consider a small neighbourhood with 30 household and every households has the same alignment as the second part. The only different alignment in this part is that only a fraction of the households owns an Electric vehicle.

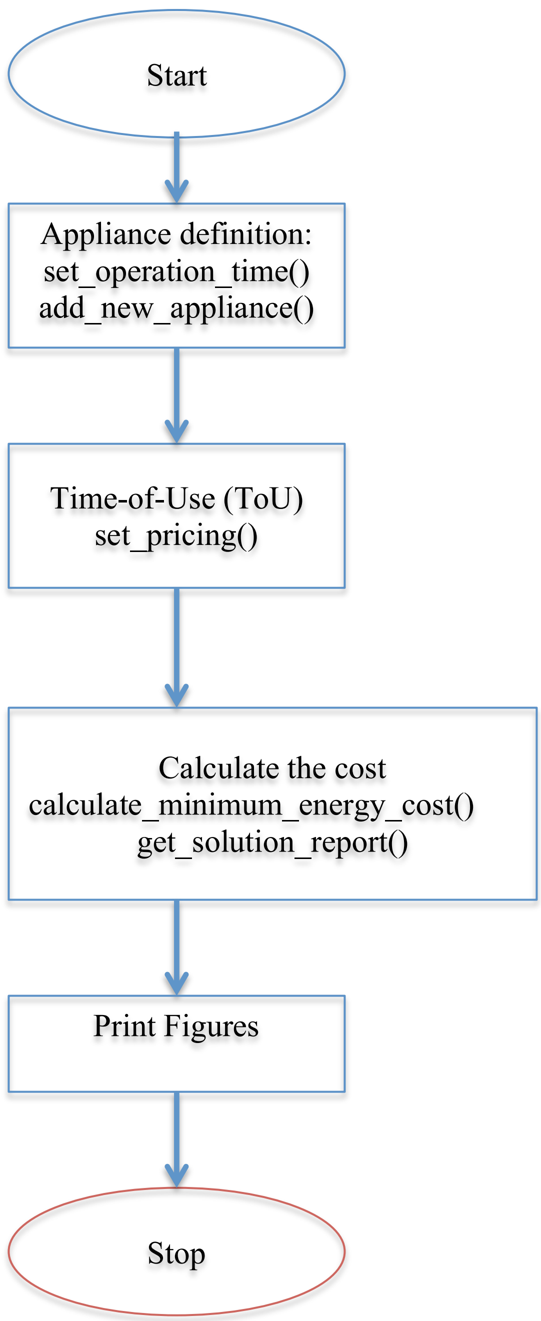
First part



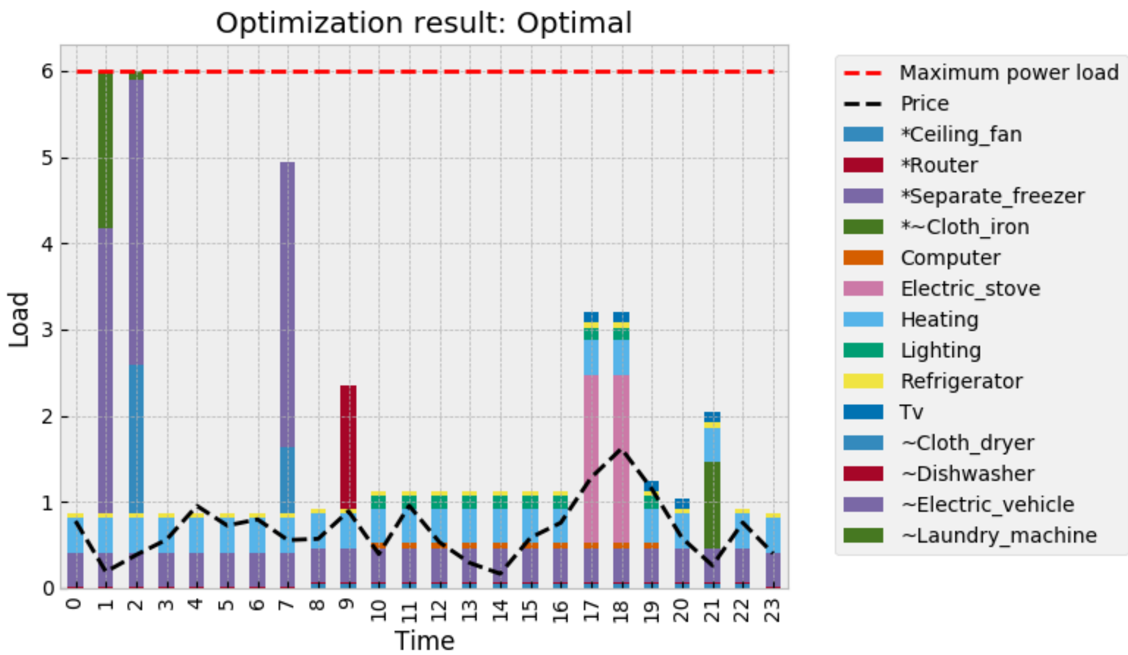
This pricing curve has only three appliances and the time-of use was used as a pricing scheme. The colour blue is demonstrated for dishwasher, colour red for the electric vehicle and the colour purple is for the laundry. The optimization result from this simple household illustrated that the range of the peak hours are from 5:00pm to 8:00pm. The price for this household is 1NOK/KWh for the peak hours and 0.5 NOK/KWh for off-peak hours. The pricing curve showed that the price is show as the colour black and started on 0.5 NOK/KWH. The pricing curve shows that the dishwasher and the laundry machine was turned on 00:00 am and the dishwasher had a load on 1.44 kWh and the laundry machine had a load on 1.94 kWh. The electric vehicle was loaded from 07:00 -09:00 pm and the daily usage was 9.9 kWh.

Running appliances at the same time in this case 2:00am which has the low energy prices, the household would save money. To run all the three appliances at the same time when there are lowest energy prices, will not be reasonable. The dishwashers should not be left unattended during the night because of the risk of fire break out during the night. The risk will be greater because you have less time to react and escape. Therefore, it is important to turn off the electrical products that are used in the household before the night. But then again if we simply run your dishwasher at night we will save on the electricity cost because of the off-peak hours. Nevertheless, it will not be reasonable to run all three appliances when the lowest energy prices because the off-peak hours cost 0.5NOK/KWh and all the loading that comes within an hour will increase significantly. This will only bring a higher energy bill for the household. A solution for this linear problem is maybe to power load the electric vehicle 2:00 - 4:00am, and turn on the dishwasher and the laundry from 7:00-8:00am.

Simple flowchart of the algorithm:

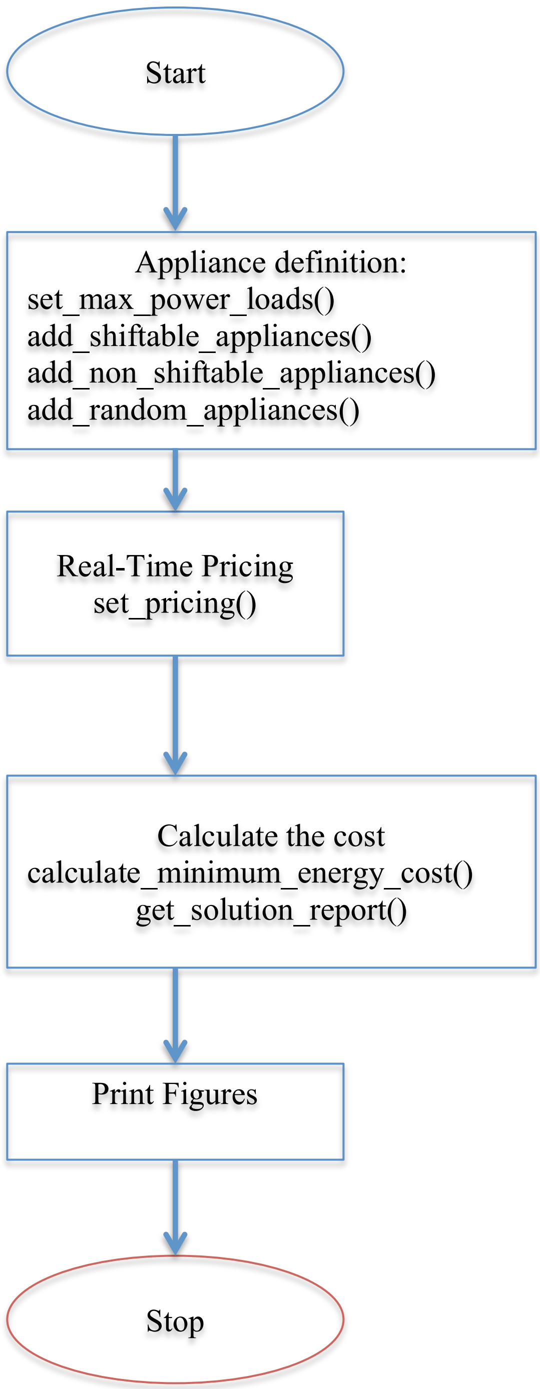


Second part



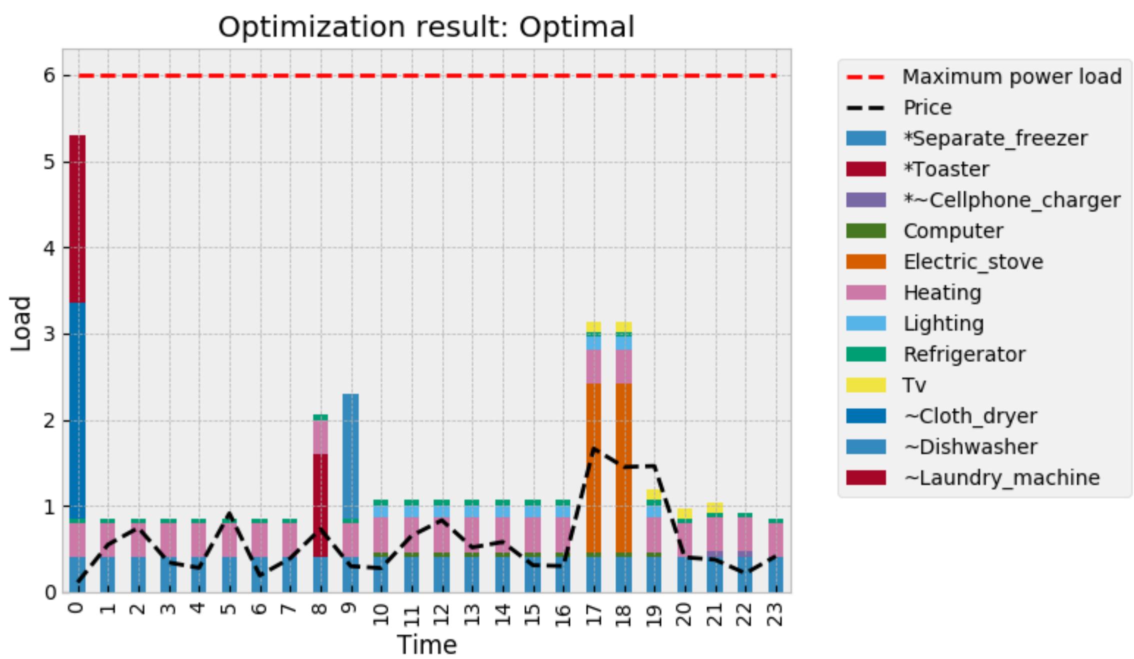
In this part of the report we have a household with both the all non-shiftable and all shiftable appliances. We selected numbers of random combination of appliances with distinct colours and marked with a star (*). The Real-time pricing is using a random function to generate the pricing curve during a day. The maximum power load is estimated to 6 kWh and is illustrated with a red horizontal line.

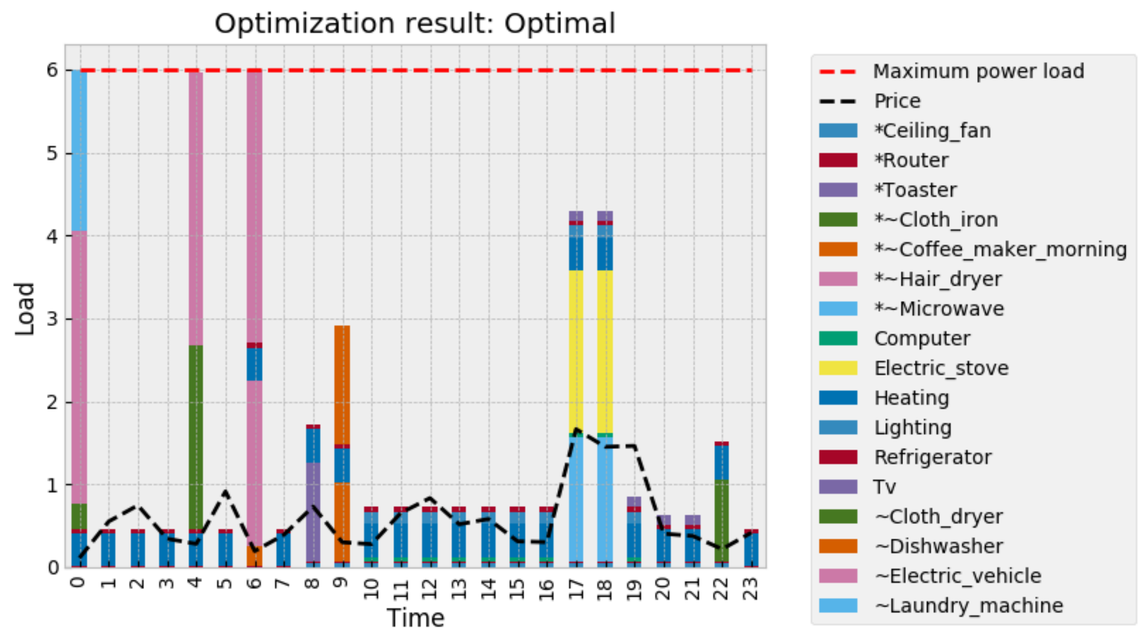
The price has the same colour as the first price curve, but the pricing curve consider higher price in the peak-hours and lower price in the off-peak hours. The pricing curve illustrates that non-shiftable appliances that are active great parts of the time-period. This is because these non-shiftable appliances are dependent on constant energy replenishment, for example the refrigerator. As the pricing curve demonstrates, the non-shiftable appliances will require less energy for longer period, rather than compared to shiftable appliances that requires greater energy for shorter runtime. There will be reasonable to consider the shiftable appliance to the off-peak hours to have a lower energy price. The pricing curve has off-peak from 12:00-01:00 am and from 02:00-04:00 am, therefore would the electric vehicle be load in this timeline. For the reason the maximum power load is estimated to 6 kWh, we should share the time load the electric vehicle in two periods. The pricing curve has a rising pricing cost from 07:00-09:00 am and vary from low energy cost to high energy cost to 04:00pm. The pricing curve has off-peak and the energy cost is on the lowest point at 04:00 pm. After the lowest point we see that the occur a peak-hour and price energy increases from 0.2-0.3 Kwh to 1.6 Kwh at 05:00 pm. The pricing curve diminishes a little before we reach another peak hour at 07:00 pm with the load at 2 kWh. A logical explanation for these increases is because people are often finished at work or school and are going to make dinner or other daily tasks before the bedtime.

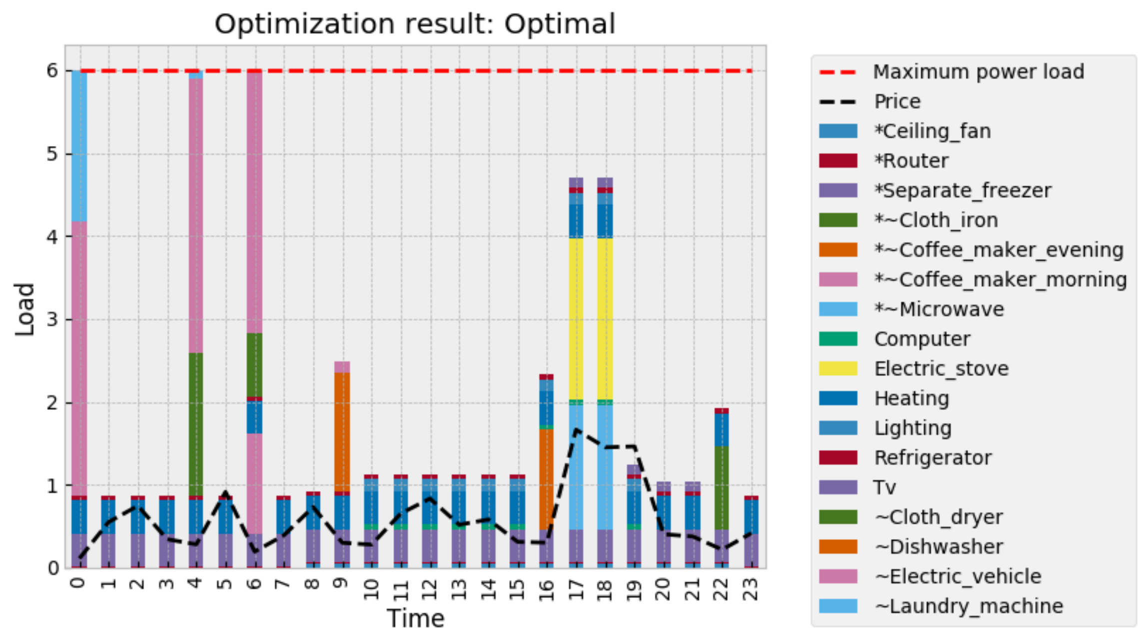


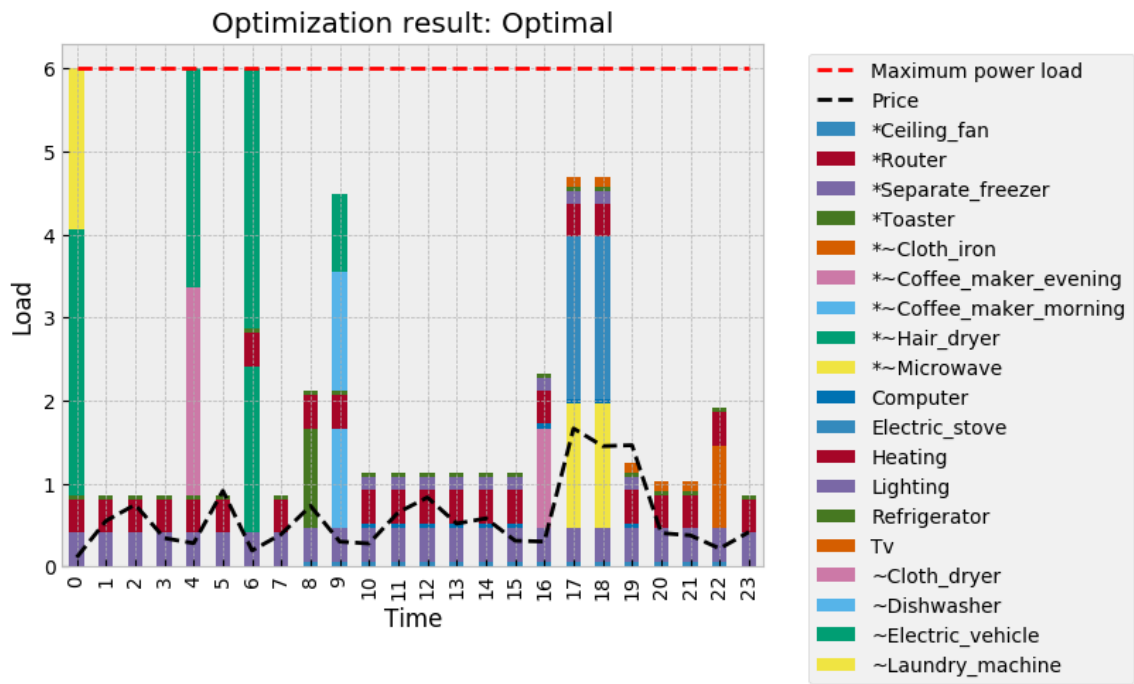
Third part

The last part of the analysis we consider a small neighbourhood with 30 households and the settings for the households is the same as the second part. The table above provides an illustration of the 30 households with different output since we used a random generator. We included Real-Time-Time pricing scheme to generate the pricing curve in a day with consuming of the random function. Pricing each household has non-shiftable and shiftable appliances and several random combinations of appliances. In this part we will assume that only a few of the households owns an electric vehicle. Curved pricing for the 30 households consider higher price in the peak-hours and lower price in the off-peak hours.




Optimization result: Optimal
Load
Time
Maximum power load
Price
*Ceiling_fan
*Router
*Toaster
*~Cloth_iron
*~Coffee_maker_morning
*~Hair_dryer
*~Microwave
Computer
Electric_stove
Heating
Lighting
Refrigerator
Tv
~Cloth_dryer
~Dishwasher
~Electric_vehicle
~Laundry_machine

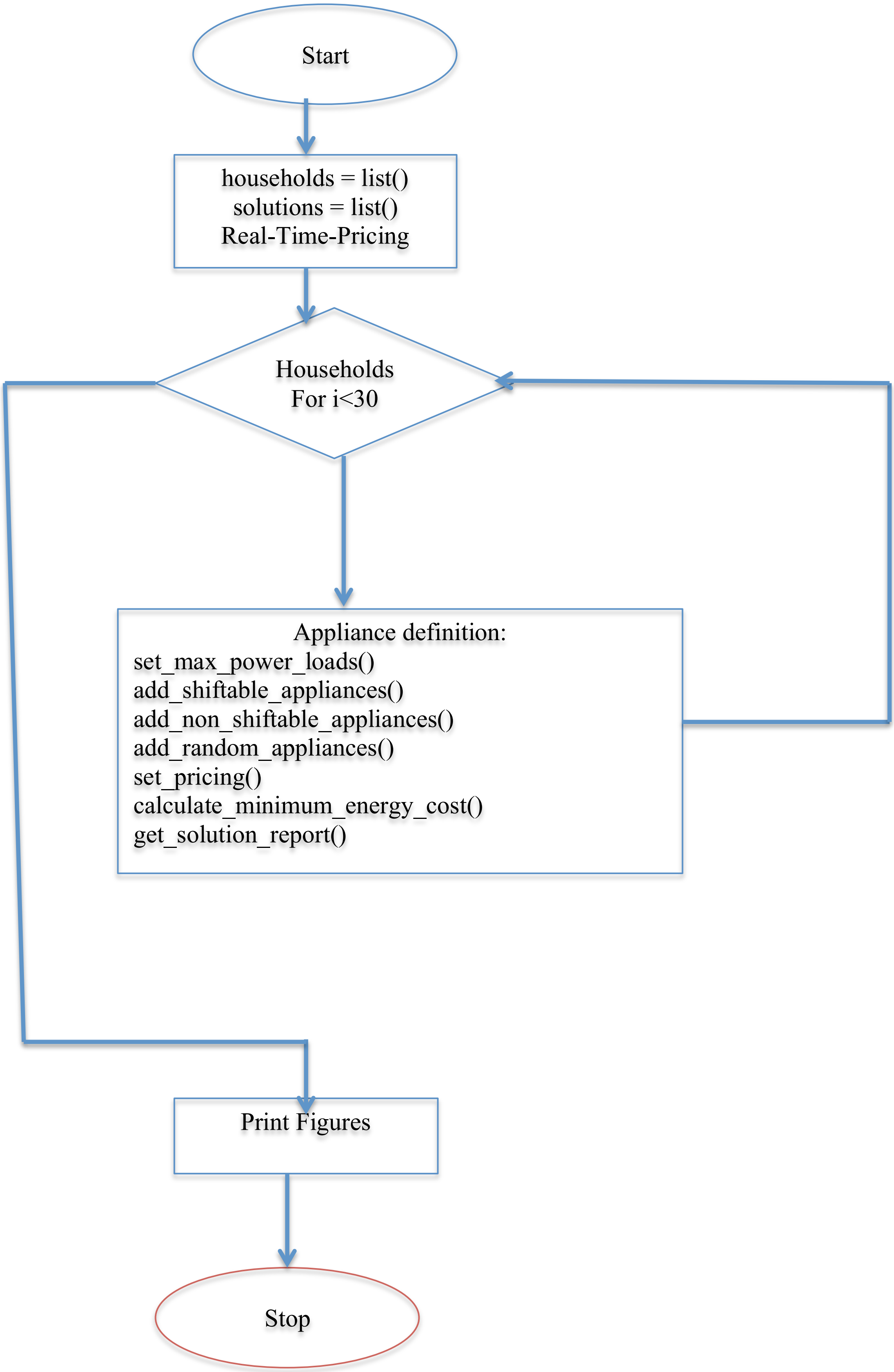

Optimization result: Optimal
Load
Time
Maximum power load
Price
*Ceiling_fan
*Router
*Separate_freezer
*~Cloth_iron
*~Coffee_maker_evening
*~Coffee_maker_morning
*~Microwave
Computer
Electric_stove
Heating
Lighting
Refrigerator
Tv
~Cloth_dryer
~Dishwasher
~Electric_vehicle
~Laundry_machine



Above we included four random households to give a deeper understanding and analysis of the table with all the 30 households. The first pricing curve is from household 1, second pricing curve is from household 10, the third pricing curve is from household 18 and the last pricing curve is from household 27.

The function for higher price in the peak-hours and lower price in the off-peak hours is the same in all the households. As the second part, we have the maximum power load at 6 kWh in every household. The off-peak at 2:00 pm on all the pricing curves has higher column at this timeline and this is because of the energy cost in this period. From the timeline 07:00-09:00 pm there are greater differences between the different householders how they use the energy. Similar as the pricing curve from second part we can conclude that we reach a peak-off time around 04:00 pm, but after the peak-off period the price rises drastically for all house owners. As we concluded earlier, it could be a sign that people come home from work or school and thus use energy to make dinner or other daily tasks.

Simple flow chart of the algorithm for part three



Conclusions

This report has shown that by using appliances intelligently in households, it will minimize the energy cost. As mentioned above, power demand will usually be low or moderate during morning, high during the evenings during the nights. The first part of the report we had a simple household with only three appliances and we used the time-of-used pricing scheme. The price is higher for the peak time and lower for off-peak time for every household independent by using Time-of-use or Real-time-Pricing. The second part we have a household with both non-shiftable and shiftable appliance and used Real-time-Pricing scheme. The pricing curve show it was best to load the shiftable appliance in off-peak times for lower energy cost. In the third part, we consider a small neighbourhood with 30 households and all setting with the non-shiftable and shiftable appliance is the same as the second part. Likewise, as second part we used a random function to generate the curving pricing for householders.

The pricing curves that were represented above showed that it is sparingly profitable to use appliances intelligently for the households. This report also presented that smart appliances at home will lead to smarter use of energy, which in turn leads to lower power energy usage. Furthermore, this will also have positive effect on the environment as the householder can use the energy when it is low-peak. This can lead to householder minimize the energy cost and distribute the power throughout the day.

References

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