Optimal Tariff Recommendation Module By Mixed-Integer Linear Programming

Furkan Koçak
Dept. of Electrical and Electronics Engineering
Bursa Uludag University
Bursa, Turkey
032111580@ogr.uludag.edu.tr

Derin Karadal
Eraslan Okulu
Izmir, Turkey
derinkaradal07@gmail.com

Abstract — As seen in every period of history, human always seeks the most optimal answer. Generally maximum efficiency with minimum power is desired. In this paper, a system that finds the most suitable tariff for the user according to the results obtained by using the user's previous billing information is presented. The tariff suggestion programme is a suggestion application which allows its participants to access to their current and optimal tariff systems. This programme can facilitate people's daily lives by aiming for maximum efficiency and low billing fees due to reasons such as increasing inflationary pressure and climate change. The infrastructure used is the Python programming language. Plugins are pip like PyQt5, pandas, SQLite. The design was made with a program called QT Designer. The static interface was converted to a dynamic interface with a converter. And the process starts.

Index Terms— Time-of-Use, EPDK, Residential, Commercial, Industry, Lightning, Agricultural Irrigation, QtDesigner, PyQt5, Python, Tariff,Optimization , Mixed-Integer Linear Programming

I. INTRODUCTION

A. Motivation

Due to high electricity prices, it turns out to be very important for the consumers to choose the tariff that suits them. This is the main thing we aim for this program where we choose the tariff suitable for each of the consumer.

B. Literature Review

Time-of-Use (TOU) pricing is a rate of prices depending on time, which having high electricity tariff at peak demand period and lower tariff at off-peak period. Simple TOU pricing is applied on industrial and commercial customers where they pay lower tariff for the electricity used during nighttime and higher tariff for daytime usage. In Malaysia, a flat tariff is applied on residential customer disregard the time of use. The result shows a significant price difference between the peak and off-peak hours are required to ensure the effectiveness of such pricing. Shown with examples in [1]. Adjusting electricity consumption according to times such as TOU is implemented in many countries such as France [2], USA [3] [5] [6] [7] [11], Canada [4], Britain [8].

C. Contributions

The contributions of this study to the literature are listed below.

- The application is able to serve all types of consumers defined by EPDK such as residential, commercial, industry, lightning, agricultural irrigation, business.
- This study selects the most suitable tariff for the consumer according to the tariff systems in Turkey.
- It also gives information about the tariffs that the consumer does not use.
- The interface of the application is useful, so the consumer can easily access it.

II. METHODOLOGY

A. Optimization Model

A.1.Objective Function

The objective function targets to minimize bill, it selects optimal situation from current tariff and alternative tariff.

$$\min \{\mathrm{OneTimeTariffBill} \,.\, u_1 + \mathrm{ThreeTimeTariffBill} \,.\, u_2 \}$$

A.2.Sets of Parameters and variables

The sets of parameters and variables used throughout the study are stated in this part. Prices approved by EPDK (The Energy Market Regulatory Authority "EMRA") and applied for February 1, 2022 are given in Table 1. Prices determined by EPDK has been listed in Table 1.

TABLE I.

EPDK (THE ENERGY MARKET REGULATORY AUTHORİTY) TARIFFS [9]

Consumer Type by EPDK	Consumption Fee (kr/kWh)
residental_7kWh_low	112,4105
residental_7kWh_high	167,8312
commercial_low	191,7712
business_low	222,7065
agricultural_watering_low	167,5809
lightning_low	206,4765
residental_day	169,999
residental_peak	248,9372
residental_night	106,8724
commercial_day	193,7409
commercial_peak	287,9227
commercial_night	117,7270
business_day	224,5286
business_peak	328,9164
business_night	141,4713
agricultural_watering_night	171,2557

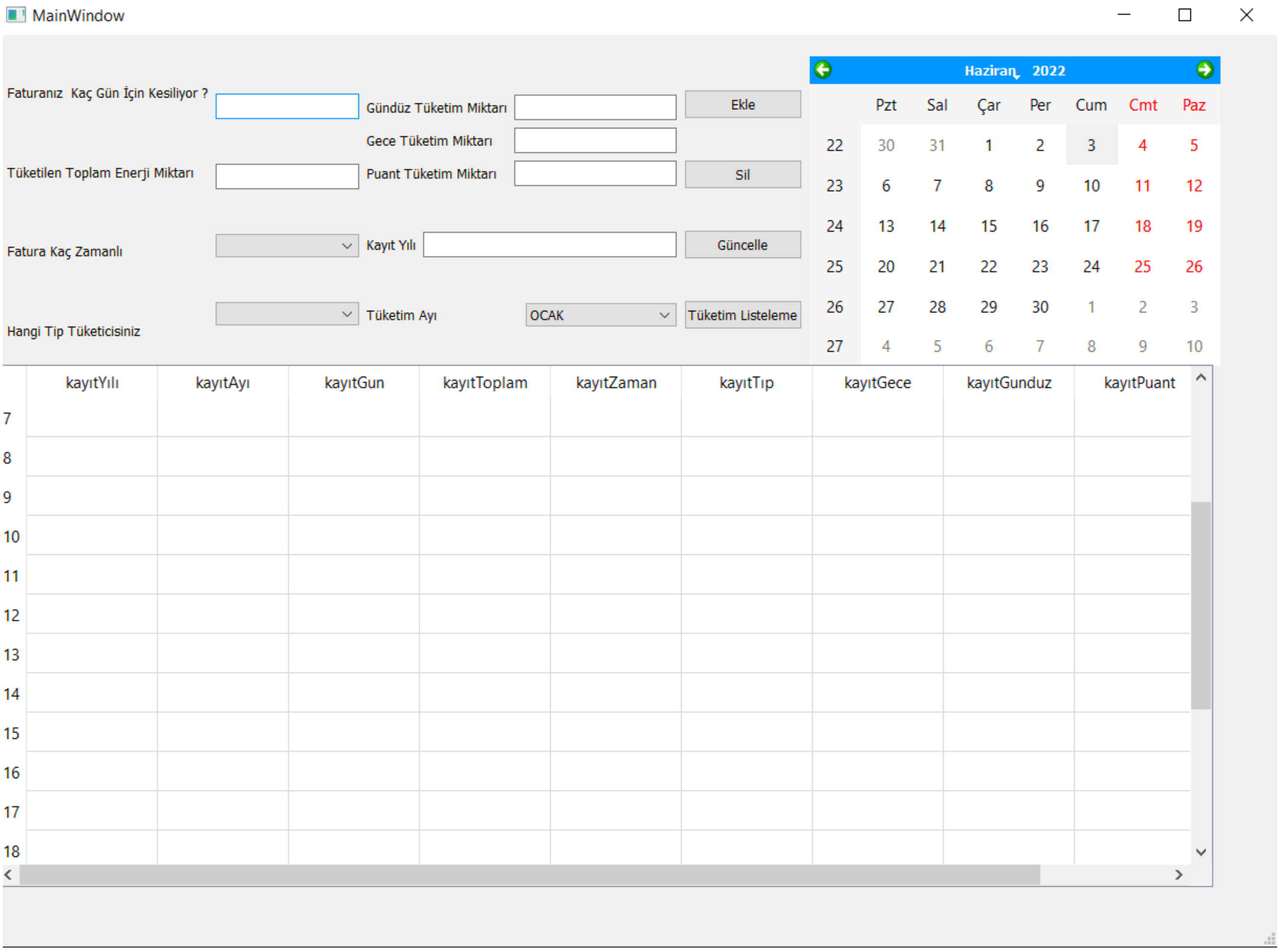

Fig. 1. Desktop Interface View-1

TABLE II. PARAMETERS TABLE

Bill Time	Bill Time presents daily period of bill.
Total Energy	It is the amount of energy consumed by user during the period.
Limit Energy	Represents the amount that should not be exceed by the consumer.
Daytime	represents the amount of energy consumed during the day
Peak Time	represents the amount of energy consumed during the peak.
Nighttime	represents the amount of energy consumed during the night.
Tariff Time	represents the time in the user's current tariff.
Consumer Type	represents the type of consumer.

Bill parameters asked to users are shown in Table 2. These parameters are used in the optimization problem. Explanation of the values is given in Table 2.

A.2.Contrains

Here the equations are provided since one of u1 and u2 will take the value 0 and the other 1.

$$\sum_{i} u_1 + u_2 = 1$$

$$LimitEnergy = BillTime\,.\,7$$

According to the statement made by EPDK, 7 kWh of energy per day should not be exceeded. If the consumer exceeds this amount, the portion worn is calculated at the higher price.

$$OneTimeTariffBill = OneTimeTariff\,.\,TotalConsumption$$

$$ThreeTimeTariffBill = PeakTariff\,.\,PeakConsumption + DaytimeTariff\,.\,DayConsumption + NightTariff\,.\,NightConsumption$$

Because of the prices announced by EPDK different according to the user, they are only specified as '-Tariff. The actual bill fee is calculated with the prices above.

B. End-User Interface

The interface Fig. 1. and Fig.2. was created with QtDesigner. Mathematical operations were modelled with Python Software language Visual Studio Code editor supported by the PyQt5 library. The user first types of the number of days for which the electricity bill has been issued (Usually between 28-32 days). The total amount of energy consumed is written in kWh, which is the total monthly consumption. The next step is to type how many times the tariff meets. Among the sub-options, it can be 1 or 3 times. The user selects the consumer type such as residential, commercial, agricultural irrigation, lighting, industry. If it's 3- times tariff, the consumer will type the daytime, night, and peak consumptions. After the user has entered the bill data's periodically, the program will process the entered data into the DB Browser (SQLite) Database with add button. The Delete Button: Deletes the data from the database. The Update Button: Allows us to re-write in database. The List Button: Clicked this button shows the entered data in the table windows.

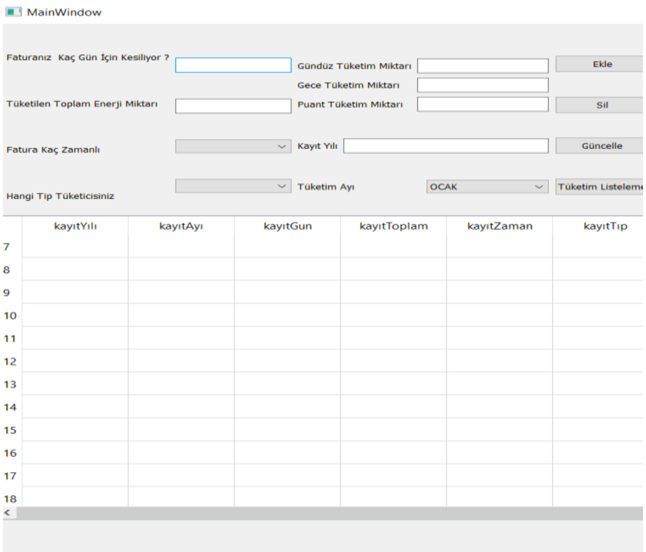

Fig. 2. Desktop Interface View-2

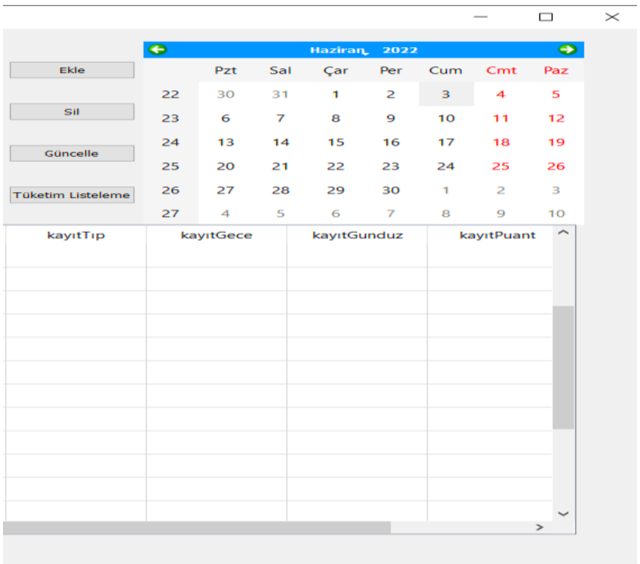

Fig. 3. Desktop Interface View-1

The given Calendar Fig. 3. allows the day range to be calculated. Minimize the window, make it full screen, or close the program buttons are shown with icons in the upper right.

III. Test&Results

A. Inputs

Bill data were collected from domestic consumers and manually created samples suitable for commercial and non-commercial 1-time and 3-time tariff systems.

In the measurements, residential and commercial data, which people may encounter more, were taken. Day, night, and peak tariffs are written in kr/kWh. The actual value of the sample bill is stated in the tables. If the tariff is correct, profit is recorded in the table, and if it is incorrect, loss is recorded.

B. Use-Cases

B.1. Residential

Consumption in the tables Table 3 kr/kWh calculated over. It seems more accurate for users with high peak consumption to choose 1-Time. Therefore, it seems more profitable for this residential user to choose 1- time.

TABLE III. Resindential Bill Analysis

Residential	Daytime	Nighttime	Peaktime	Bill	Tariff
1-times	41.723	36.810	37.923	130,94 TL	True (+35,89 TL)
1-times	44.63	49.86	48.74	178,13 TL	True (+72,38 TL)
3-times	50,73	12,71	65,71	263,42 TL	False (-118,51 TL)
3-times	56.23	32.4	44.86	241,91 TL	False (-91.83TL)

B.2. Commercial

Consumption in the tables Table-4. kr/kWh calculated over. In 3-time tariffs, the higher the night consumption and the lower the peak consumption, the more profit the consumer will make. It is seen that commercial consumer makes a profit in 1-Time Tariff with this consumption.

TABLE IV. COMMERCIAL BILL ANALYSIS

Commercial	Daytime	Nighttime	Peaktime	Bill	Tariff
1-times	90.534	4.154	29,611	118,00 TL	True (+167,57 TL)
1-times	1852.64	95.01	525.07	3588,98 TL	True (+2434,75 TL)
3-times	859.13	635.05	588.172	4762,23 TL	False (-123,73 TL)
3-times	335,72	171,93	15,51	508,94 TL	True (+284,45)

IV. Conclusion

Today, while energy consumption is increasing, our resources are running out. Supply does not meet demand. For this reason, each consumer must have high efficiency and low energy consumption. The contribution of switching to the right tariff to the consumer is the decrease in bill fees of 20% on average. A large body of literature demonstrates that consumers will alter their consumption patterns in response to a range of TOU tariffs, with an average reduction in peak time energy consumption of around 15% depending on the tariff design. Detailed profits and losses are shown in the Test and Results section. Electricity bills are a serious expense item in Turkey, as there is more inflationary pressure than the rest of the world. Although many consumers do not have detailed information on this subject, many of them face high bills because there are wrong tariffs. Our program will contribute to Turkey with the idea of the right tariff, lower bills. There are different tariff applications in the world and studies have been done on the benefits of being on the right tariff in the literature. We have developed such an application for end-user usage to choose the right tariff in Turkey.

Dynamic pricing also finds its place in the world with different applications. Approximately 10 % of the customers are on this tariff (as of over 3.4 million metering points, about 340.000 customers. It is being studied how algorithms can be developed so that customers can buy electricity at the best price. Improvements are being made on it.

In future studies it is planned to work on applications that facilitate tariff selection for consumers with monomial and polynomial power levels. The desktop application has been developed, but it is planned to reach a lot of people by developing a phone application with the same functions. A program that is being worked on and planned to be developed in the future, it will be possible to reach more people in Turkey in the future.

ACKNOWLEDGMENT

We would like to thank Electrical Engineer M.Sc. Semanur Sancar, who informed us about the conference and helped us organize the paper.

REFERENCES

[1] Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia(2016), Kuala Lumpur, Malaysia, INSPEC Accession Number: 15918728

[2] Crossley, D. (2009). Task 15–case study–tempo electricity tariff–france. IEA DSM. Disponível em.

[3] Kiguchi, Y. (2021). Residential Demand Response using Electricity Smart Meter Data (Doctoral thesis).

[4] National Research Council Canada, Institute for Research in Construction Building M24, 1200 Montreal Road, Ottawa, Ontario, Canada K1A 0R6

[5] CSW Communications, 2600 Via Fortuna Suite 500, Austin, TX 78746, USA

[6] Energy and Environmental Economics, Inc. (E3), Suite 1700, 353 Sacramento Street, San Francisco, CA 94111, US

[7] Kenneth E. Train, Daniel L. McFadden and Andrew A. Goett The Review of Economics and Statistics Vol. 69, No. 3 (Aug., 1987), pp. 383-391 (9 pages) Published By: The MIT Press

[8] Frederiks, Elisha R., Karen Stenner, and Elizabeth V. Hobman. "Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour." Renewable and Sustainable Energy Reviews 41 (2015): 1385-1394.

[9] https://www.epdk.gov.tr/Detay/Icerik/3-1327/elektrik-faturalarina-esas-tarife-tablolari

[10] Griffiths, Benjamin, Algorithmically Developing Efficient Time-of-Use Electricity Rates (November 18, 2020).

[11] Renewable and Sustainable Energy Reviews Volume 97, December 2018, Pages 276-289 Received 10 September 2017, Revised 22 August 2018, Accepted 23 August 2018, Available online 5 September 2018, Version of Record 5 September 2018