IE 48B Time Series Analytics
Project

Imbalance prediction for electricity markets

In this project, you are going to deal with the imbalance prediction for Turkish electricity market (the same problem as in your midterm) with some additional information. Note that the project will be covered in two phases. In the first phase you are expected to develop your methods and the second phase will involve making predictions with live data.

Background information regarding this task is made available again in this document.

Background (covered in midterm):
Electricity markets garner attention with their unique property of balancing requirements in both short and long term. Energy grids consist of heterogeneous interconnected systems, of an increasing number of small-scale and of dispersed energy generation and consumption devices. In these grids, electricity consumption and production should be at par at all times to prevent infrastructure damage. Therefore, over or under forecasting compared to actual consumption and production is severely penalized by the balancing market. Figure 1 illustrates the structure of the electricity markets.

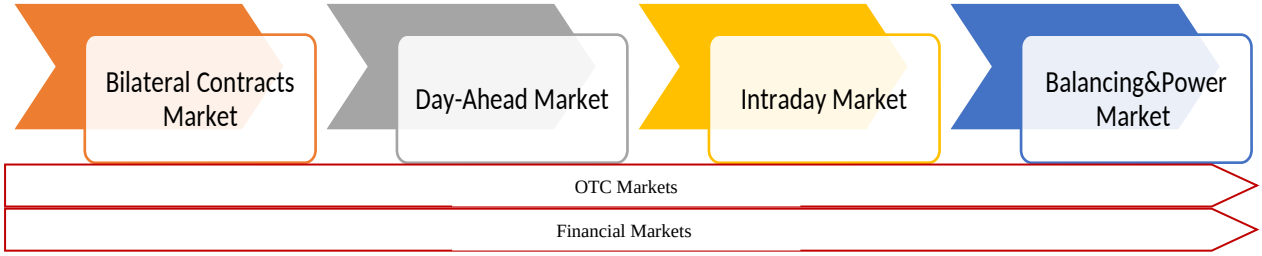

Figure 1. Structure of electricity market (PWC Turkish Electricity Market Report, 2021)

Ideally, if a distributor/supplier knows about their customer base's demand consistently with high accuracy, they might position themselves on the over the counter (OTC) (i.e. bilateral) markets via long term contracts and day-ahead market orders for fine tuning. Properly forecasting of the electricity load is the main pain point for all market participants. Increasing share of renewable energy sources (i.e. wind, solar, hydropower, geothermal) that are harder to forecast is major problem in terms of the foreseeability. Therefore, trading in the Day-Ahead Market is necessary.

In Turkey, every day until 12PM, market participants should place bid/ask orders for each of the 24 hours of the next-day according to their electricity needs or production. A bid/ask order roughly consists of price and amount papers for a particular hour. For example demand side asks for 100 MWh (megawatts per hour) electricity for a price of 1000 TRY per MWh for the 00:00-01:00 of next day. Similarly, supply side (i.e. an electricity generation company) asks for 1010 TRY per MWh for the same interval. Each player in the day-ahead market is required to provide their ask/bid orders and Enerji Piyasaları İşletme A.Ş. (EPİAŞ) is responsible for operating this market (similar to Borsa İstanbul's operating İstanbul Stock Market). After 12 PM each day, EPİAŞ solves an optimization problem to match the bids so that utility of all players in the market is maximized. This optimization

model can be reached from their paper [2]. Note that you are not expected to read their paper for the midterm task. This is provided for information purposes.

The result of this is a set of 24 market clearing prices (MCP, Piyasa Takas Fiyati-PTF in Turkish) per hour. An example for December 5th prices is illustrated in Figure 2. Every player is responsible for their ask/bid amounts. In other words, if a player on the demand side placed an order of 1000 MWh, it is responsible for purchasing this amount with the determined MCP (i.e. solution of the optimization problem) for that hour.

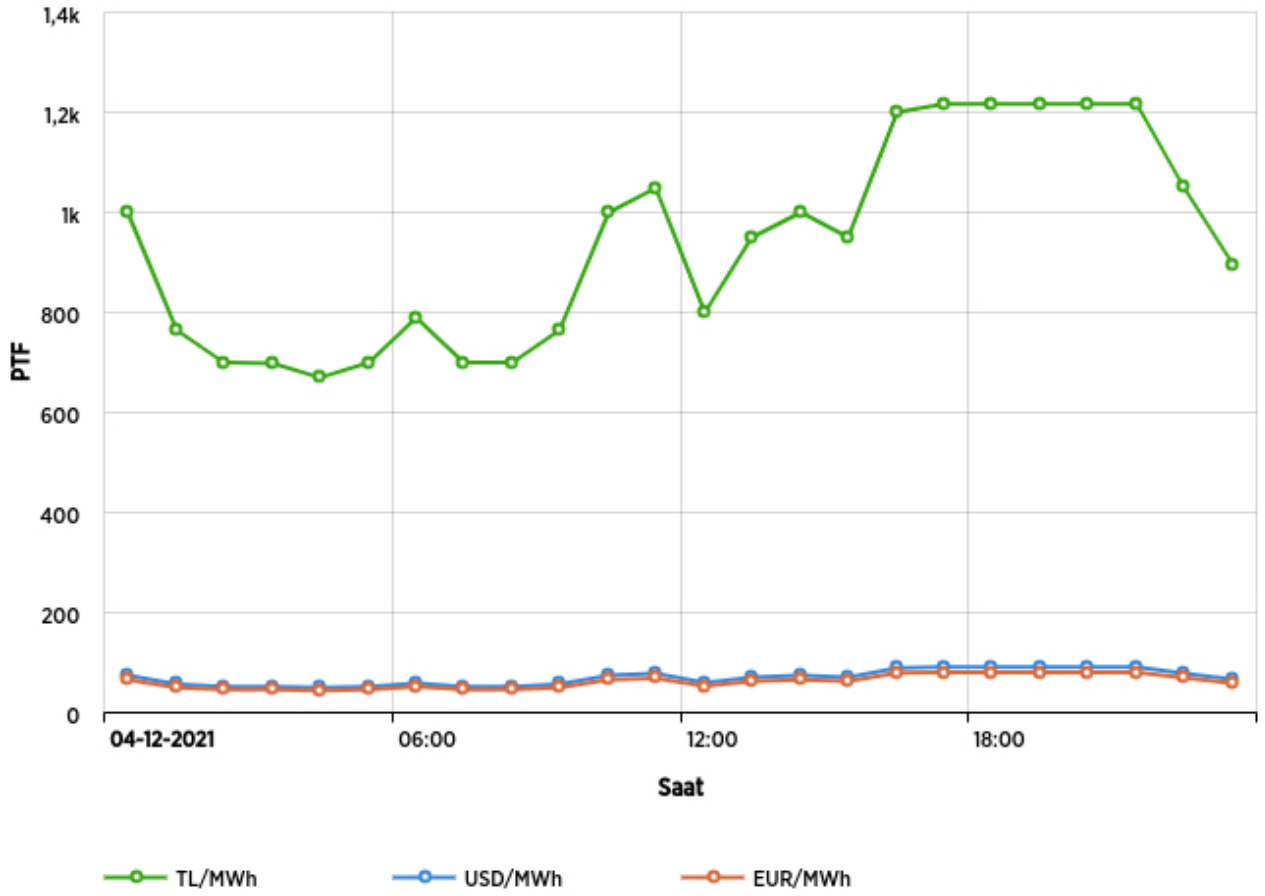

Figure 2. Market clearing prices for December 5th,2021. The prices have gone up significantly due to exchange rate increases and the increase in the natural gas prices for the generators with natural gas.

Players determine their ask/bid amount based on their forecasts and determine the price to ask/bid based on their costs in general. Note that forecasts are mainly driven by the weather conditions or special events such as national or religious holidays.

Today after pricing decisions are made, a player has the information of the amount of electricity they should buy or sell (i.e. consume or produce). However, forecasts are generally far from perfect. This is mainly due to unexpected events such as weather conditions' change drastically (and weather forecasts are usually inaccurate) or the team responsible for forecasting these quantities may have problems with developing good forecasting models.

As a summary, a player on demand side agrees on purchasing amount of d_t for an hour t (similarly producer agrees on producing amount p_t). Due to the stochasticity mentioned earlier, actual demand/production may not be consistent with the demand/production forecast. In other words, the demand/production can be larger or smaller in real life. This is so called "imbalance" problem in the system. If actual demand happens to be larger/smaller for a player on the demand side, it should purchase/sell electricity during the day (i.e. if actual demand happened to be smaller than agreed, excess demand should be sold), this is done in intra-day market (IDM) on an hourly basis. The operations are the same as day-ahead market. If a player on demand side has excess demand, it places a sell order in the market as an amount, price pair for the particular hour. If the same player is short in demand, it places an ask order as an amount, price pair for the particular hour. Operations are done in a similar way for the producer side. If a player on supply side has excess production, it places a sell order in the market as an amount, price pair for the particular hour. If the same player is short in production, it places an ask order as an amount, price pair for the particular hour. In other words, there is a requirement to supply the deficit. This market operations result in a new set of prices which is so called "IDM Weighted Average Price (WAP)".

Even, the operations in the intra-day market may not help companies to solve their "imbalance" problems. They may not find a player for the excess demand/production. If this happens, EPİAŞ penalizes the imbalance amount with maximum of MCP and WAP for the corresponding hour multiplied by 1.03. The imbalance information is released by EPİAŞ on the following link. Note that there is a release delay for this information. Imbalance amounts on 01.01.2021 is shown in Figure 3.

Date	Hour	Pozitive Imbalance Quantity (MWh)	Negative Imbalance Quantity (MWh)
01/10/2021	00:00	310.78	-918.06
01/10/2021	01:00	195.19	-698.85
01/10/2021	02:00	129.07	-614.45
01/10/2021	03:00	380.61	-426.55
01/10/2021	04:00	550.63	-230.69
01/10/2021	05:00	604.28	-366.81
01/10/2021	06:00	255.74	-506.92
01/10/2021	07:00	180.48	-546.20
01/10/2021	08:00	613.60	-921.82
01/10/2021	09:00	152.17	-1,229.38
01/10/2021	10:00	551.41	-975.72
01/10/2021	11:00	245.28	-918.70
01/10/2021	12:00	1,543.87	-739.35
01/10/2021	13:00	1,112.98	-785.83
01/10/2021	14:00	402.64	-927.50
01/10/2021	15:00	251.19	-857.13
01/10/2021	16:00	666.21	-836.28
01/10/2021	17:00	599.53	-814.09
01/10/2021	18:00	337.49	-911.02
01/10/2021	19:00	242.25	-730.76
01/10/2021	20:00	548.79	-705.19
01/10/2021	21:00	615.92	-601.90
01/10/2021	22:00	882.07	-844.02
01/10/2021	23:00	779.20	-718.38

Figure 3. Imbalance amounts on 01.01.2021 (taken from the transparency platform of EPİAŞ)

The meaning of imbalance with respect to the type of the player is summarized in Table 1.

	Consumer	**Producer**
Positive imbalance	Less consumption	More production
Negative imbalance	More consumption	Less production

Table 1. Meaning of positive and negative imbalance with respect to the player types in the market

You are provided the summary of the market operations and information relevant to Midterm in the previous paragraphs. Based on the given information, there is one particular classification problem which is of utmost importance to market players. This is to predict the system imbalance sign for a particular hour three hours before the imbalance occurs. The sign of the system imbalance is determined by the net imbalance which is the sum of positive and negative imbalances shown in Figure 3. In other words, players are interested in overall system imbalance in order to make their trading decisions. For example for hour 23:00 of 01.01.2021 in Figure 3, the net imbalance is 779.20 – 718.38 = 60.82 which is positive. Positive imbalance generally occurs if consumers' demand is less than the agreed amount in the day-ahead market or producers' production is larger than the agreed amount in the day-ahead market as summarized in Table 1.

The main reason of the interest in the sign of the system imbalance is due to the relation between the price and the demand/supply. If the system imbalance is positive, intra-day price (namely WAP) is generally smaller since supply is larger than required amount. It is generally the opposite for the negative imbalance case. Correct classification of the system imbalance for a particular hour helps decision makers to make their pricing decisions in an effective way.

Required background for the project:
Detailed information about the system imbalance is provided by the transparency platform of EPİAŞ. This is under balancing power market (BPM) under markets category ("Dengeleme Güç Piyasası (DGP)" under "Elektrik Piyasaları"). You will observe four pieces of information:

- SMP (System Marginal Price) – SMF (Sistem Marjinal Fiyatı): This the set of prices settled after intra-day operations.
- Link: https://seffaflik.epias.com.tr/transparency/piyasalar/dgp/smf.xhtml
- System's Direction – Sistem Yönü: This is the direction of the imbalance. It is "energy deficit" or "energy surplus".
  Link: https://seffaflik.epias.com.tr/transparency/piyasalar/dgp/sistem-yonu.xhtml
- Up Regulation Instructions – YAL Talimat Miktarı: This provides the aggregate volume of the transactions regarding the energy deficit (YAL means "yük alma") with some categories (represented by separate columns). Some of the columns represent the volume of the energy deficit.
  Link: https://seffaflik.epias.com.tr/transparency/piyasalar/dgp/yal-talimat-miktarlari.xhtml
- Down Regulation Instructions – YAT Talimat Miktarı: This provides the aggregate volume of the transactions regarding the energy surplus (YAT means "yük atma") with some categories

(represented by separate columns). Some of the columns represent the volume of the energy surplus.
Link: https://seffaflik.epias.com.tr/transparency/piyasalar/dgp/yat-talimat-miktarlari.xhtml

A sample data for 09.12.2021 is provided in Figure 4 (sorry about the resolution, you may want to zoom into the document):

Date	Hour	System's Direction	MCP (TL/MWh)	SMP (TL/MWh)	Up Regulation 0 Coded (MWh)	Up Regulation 1 Coded (MWh)	Up Regulation 2 Coded (MWh)	Down Regulation 0 Coded (MWh)	Down Regulation 1 Coded (MWh)	Down Regulation 2 Coded (MWh)
09/12/2021	00:00	↑ Energy Surplus	989.00	769.00	122.43	0.00	0.00	89.67	0.00	0.00
09/12/2021	01:00	↓ Energy Deficit	905.89	905.89	94.35	0.00	0.00	222.92	0.00	0.00
09/12/2021	02:00	↑ Energy Surplus	898.98	770.00	0.00	0.00	0.00	22.50	0.00	0.00
09/12/2021	03:00	↔ Balanced	845.97	845.97	0.00	0.00	0.00	0.00	100.00	0.00
09/12/2021	04:00	↔ Balanced	845.97	845.97	0.00	0.00	0.00	0.00	100.00	0.00
09/12/2021	05:00	↔ Balanced	800.00	800.00	0.00	0.00	0.00	87.00	100.00	0.00
09/12/2021	06:00	↑ Energy Surplus	813.30	770.00	0.00	0.00	0.00	1.00	100.00	0.00
09/12/2021	07:00	↓ Energy Deficit	898.99	898.99	55.00	0.00	0.00	1,171.13	100.00	0.00
09/12/2021	08:00	↓ Energy Deficit	1,204.86	1,217.00	1,298.80	0.00	0.00	1,165.45	0.00	0.00
09/12/2021	09:00	↓ Energy Deficit	1,205.57	1,217.00	2,053.25	0.00	0.00	0.00	0.00	0.00
09/12/2021	10:00	↓ Energy Deficit	1,201.02	1,217.00	1,026.00	0.00	0.00	0.00	0.00	0.00
09/12/2021	11:00	↓ Energy Deficit	1,200.59	1,217.00	1,436.67	0.00	0.00	0.00	0.00	0.00
09/12/2021	12:00	↓ Energy Deficit	898.98	898.98	653.33	0.00	0.00	0.00	0.00	0.00
09/12/2021	13:00	↓ Energy Deficit	887.57	887.57	749.20	0.00	0.00	0.00	0.00	0.00
09/12/2021	14:00	↓ Energy Deficit	899.99	945.01	1,321.48	0.00	0.00	0.00	0.00	0.00
09/12/2021	15:00	↑ Energy Surplus	924.99	770.00	107.07	0.00	0.00	0.00	0.00	0.00
09/12/2021	16:00	↑ Energy Surplus	1,188.99	1,138.99	377.17	0.00	0.00	0.00	0.00	0.00
09/12/2021	17:00	↓ Energy Deficit	1,208.26	1,217.00	877.00	0.00	0.00	0.00	0.00	0.00
09/12/2021	18:00	↓ Energy Deficit	1,201.86	1,217.00	1,143.67	0.00	0.00	0.00	0.00	0.00
09/12/2021	19:00	↓ Energy Deficit	931.05	975.00	1,088.00	0.00	0.00	0.00	0.00	0.00
09/12/2021	20:00	↓ Energy Deficit	900.00	945.00	987.00	0.00	0.00	0.00	0.00	0.00
09/12/2021	21:00	↓ Energy Deficit	898.98	945.00	1,216.43	0.00	0.00	0.00	0.00	0.00
09/12/2021	22:00	↓ Energy Deficit	868.45	990.00	1,886.90	0.00	0.00	0.00	0.00	0.00
09/12/2021	23:00	↓ Energy Deficit	813.31	848.31	921.77	0.00	0.00	0.00	0.00	0.00

Figure 4. Data from Balancing Power Market. The direction has three categories (surplus, deficit and balanced). Day-ahead (MCP) and intra-day (SMP) prices are not the same all the time due to the imbalance in the market. SMP is generally smaller than MCP if there is an energy surplus in the market. This is due to the supply/demand relation.

Normally, if down instructions (i.e. "yük atma") is larger than up instructions in terms of the volume, that means there is an energy surplus in the system. However due to the data collection problems EPİAŞ may have or some other reasons, system's direction information may not be in accordance with this information. Therefore we will rely on the raw volume data of up and down instructions.

Project Task

In this project, we will be interested in the sign of the difference between the total volume of the down and up instructions. If total down volume is greater than up volume, the class is positive (energy surplus), it is negative otherwise. You are required to use this information as the primary information of system's imbalance instead of the system's imbalance on EPİAŞ to avoid confusion. Moreover, a threshold on the difference is needed to determine the balanced class. You can assign neutral/balanced as label for the cases where the difference between up and down instructions is between -50 and 50.

The volume of the "up and down instructions" information between January 1st, 2019 and December 10th, 2021 is provided as separate *.csv files. You will be receiving live updates on this information during the phase 2 of the project. The decision making task is introduced as follows: An analyst makes

trading decisions everyday until 12 pm for the rest of the day. In other words, as an analyst you are responsible for prediction of the system imbalance (defined in a custom way above for this project) for the hours 12, 13, 14, …, 22 and 23 of the same day before 12 pm.

Performance measure
Error rate: Your model will be scored based on your accuracy for each day. If all twelve hours are predicted to be correct, your score is one for the day. If you have 6 hours misclassified, it is 0.5 and etc.

Note that you will be compared to 2 baseline methods as a competitor. First one uses the previous day's same hour's system's direction. Similarly, second one uses the system's direction of the same hour of the same day (previous week). In the time series context, these are lag 24 and lag 168.

Prediction and Report
This project is organized as a competition (like in platforms such as www.kaggle.com) in which you are expected to make submission everyday. For this purpose, we have built a system so that you will be able to make submissions via Google Form and monitor your progress through Google Sheets. We will be informing you about the submission system once we finish our tests.

Note that 30% of your project grade will be determined by your final rank in this competition. First place will get full points (30 points) and this will decrease to a minimum of 15 points proportional to your deviation from the top performer (assuming that you did not miss any day during the second phase).

You are required to submit a written report with a brief description of your final method, how you evaluated your methods, and you choose the parameter settings. You are allowed to work as a group of at most 3 members.

Your report should have the following format:

1. Introduction: Problem description, summary of the proposed approach, descriptive analysis of the given data.
2. Related literature: Summarize relevant literature if there is any
3. Approach: Explain your approach to this problem.
4. Results: Provide your results and discussion.
5. Conclusions and Future Work: Summarize your findings and comments regarding your approach. What are possible extensions to have a better approach?
6. Code: Provide the Github link for your codes at the end of your report.

Timeline
Beginning from **December 20th, 2021**, you will be given your passwords and usernames for access to the system. We will have a trial period for the system. Use the trial period to ask your questions, play around with the system and build your prediction pipeline. It will also be a chance for us to fix any unforeseen issues. We will proceed with the evaluations as usual, however we will restart all of the scores on **December 27th, 2021**. Then, the live phase of the project will begin. The submission system will be closed after **January 10th, 2022**

References

[1] PWC Turkish Electricity Market Report (2021), available on **https://www.pwc.com.tr/tr/sektorler/enerji/turkiye-elektrik-piyasasina-genel-bakis-2021.pdf** accessed 04.12.2021.

[2] Derinkuyu, K., Tanrisever, F., Kurt, N., and Ceyhan, G. (2020). Optimizing day-ahead electricity market prices: Increasing the total surplus for energy exchange İstanbul. Manufacturing & Service Operations Management, 22(4):700–716.