Electricity Case

OVERVIEW

The Electricity Trading Case provides the opportunity for participants to work in a role-based team environment to engage in an electricity trading market controlled by a strict regulatory policy. Participants are required to forecast the supply and demand of electricity, and execute strategies accordingly while reacting to prevailing market events. Each team will participate in a closed supply and demand market for electricity by producing it using power plant assets and distributing it to customers, and will also have access to a forward market. Through the full cycle of electricity markets, participants will need to dynamically formulate their role-based strategies and optimally perform trade executions.

KEY OBJECTIVES

- Design a model to calculate the effect of news releases on the supply and demand for electricity. Use this information to make a decision on the optimal level of production of electricity (for Producers' role), the optimal quantity to be delivered to customers (for Distributors' role) and the optimal trader activity to fill the tender offers from factories (for Traders' role).
- Maximize profits as a team of Producers, Distributors, and Traders by communicating and sharing private news information with each other.

DESCRIPTION

The Electricity Trading Case will comprise 7 independent heats with 4 team members competing together. Each heat will be 15 minutes long and represent 5 trading days of calendar time. Order submission using the RIT API will be disabled. Data retrieval via the RIT API will be enabled.

- Number of trading heats: 7
- Number of sub-heats: 5 period per heat
- Trading time per heat: 900 seconds minutes (15 minutes)
- Calendar time per heat: 5 trading days during the first week of August

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TEAM ROLES

In this case, each team member will have 1 of 3 specific roles and the team will determine the role of each member:

- ABCD-1: Role of Producer
- ABCD-2: Role of Distributor
- ABCD-3: Role of Trader #1
- ABCD-4: Role of Trader #2

Electricity Case: Each team member is required to trade in a specific role for this Case.

Producers

The Producers own a solar power plant and a natural gas power plant. Each day, Producers will decide how much electricity to produce the next day. For example, day 3 starts at minute 6:01 (6 minutes and 1 second in the simulation); Producers have to decide by the end of day 3 (by minute 9:00 in the simulation) how much electricity to produce over day 4 (which starts at minute 9:01 in the simulation). The decision is made on day 3 and electricity will be produced and delivered the day after (day 4).

Producers will have access to the electricity forward and spot markets. There is one security traded on each market, ELEC-F on the forward market and ELEC-dayX on the spot market. ELEC-F is a forward contract written on the commodity ELEC-dayX with a contract size of 500 MWh [1] and delivery over the next day (day X). For example, if a Producer sells 1 contract of ELEC-F today (day 1), the Producer will have to deliver 500 MWh of electricity (ELEC-day2) to the counterparty the next day (day 2). ELEC-dayX is the electricity spot, where "X" is the day in the simulation. For example, ELEC-day2 is electricity spot on day 2, ELEC-day3 is electricity spot on day 3, etc. ELEC-dayX can be traded on the spot market on each respective day; 1 contract of ELEC-dayX is equal to 100 MWh.

Since electricity cannot be stored, and it has to be disposed [2] in case it is not delivered, Producers should sell the electricity by the end of the day it is produced, either with a forward contract from sale of the previous day, or on the spot market during the day it is produced. For example, if on day 1 the Producers decide to produce 2,000 MWh of ELEC-day2, they will have to deliver 2,000 MWh of electricity on day 2. They can sell 3 contracts of electricity on the forward market on day 1 so that, on day 2, they will deliver 1,500 MWh of ELEC-day2 (recall that each ELEC-F contract size is 500 MWh). On day 2, Producers can also sell 500 MWh of ELEC-day2 spot (which is 5 contracts of ELEC-day2). Combining the 1,500 MWh delivered through the forward contract with the 500 MWh traded spot, the Producers ensured they did not have any excess MWh of electricity that they had to dispose. If they are able to sell only 1,500 MWh of electricity on the forward market and they did not make any trades on the spot market, Producers will have produced 500 MWh more than they sold and they will have to dispose the excess electricity spot on Day 2 (ELEC-day2) of 500MWh.

The solar power plant generates electricity every day depending on how many hours of sunshine there will be during the day. That is, it is possible to produce more electricity using the solar power plant when there are no clouds. The following equation shows the amount of electricity produced by the solar power plant in relation to the number of hours of sunshine:

$$ELEC_{solar} = 7 \times H_{day}$$

where:

$ELEC_{solar}$ is the number of contracts of electricity produced by the solar power plant over the day;
H_{day} is the number of hours of sunshine over the day.

There is no cost for producing electricity using the solar power plant.

Producers cannot shut down the solar power plant but they will be provided with weather forecasts of how many hours of sunshine are expected the following day. Hence, they will be able to forecast how much electricity will be produced by the solar power plant. The weather forecasts received on day 1 will provide information about the weather on day 2. There will be an initial report at the beginning of each day followed by an update at 12:00pm each day (1 minute and 30 seconds after the start of the day in the simulation) and then there will be the final update in the evening (30 seconds before the end of the day in the simulation). The final update will provide Producers with the correct estimates of the number of hours of sunshine the next day. In other words, in the evening, Producers will know exactly how many hours of sunshine there will be the next day.

Producers will have to decide whether to utilize the natural gas power plant based on the expected solar output and the expected demand for electricity. Indeed, if there is strong demand for electricity, Producers can make additional profits by utilizing the natural gas power plant and selling the electricity on the ELEC-F or ELEC-dayX spot market.

In order to produce electricity using the natural gas power plant, Producers have to buy natural gas spot (NG) and then use the natural gas power plant to transform it into electricity. Each NG contract is for 100MMBtu (million British Thermal Unit). The natural gas power plant is able to convert 800 MMBtu into 100 MWh (that is 8 contracts of NG into 1 contract of ELEC-dayX, where X is the following day). For example, Producers can buy 8 contracts (800 MMBtu) of NG on day 1 and then lease and use the natural gas power plant on day 1. On day 2, they will receive 1 contract (100MWh) of ELEC-day2. There is no cost for the Producers to operate this facility. Producers will decide to operate the natural gas power plant today but the electricity will be delivered the day after since it takes time to convert natural gas into electricity.

In addition, the Ministry of the Environment and Climate Change (MECC) has developed policies that discourage Producers from producing more than they are able to sell. Indeed, for each contract of electricity (ELEC-dayX) that is not delivered by the end of day X and needs to be disposed, the MECC will charge a fee of $24,000. The fee will be collected by MECC at the end of each day. For example, if on day 1 a Producer has decided to produce 20 contracts (2,000 MWh) of ELEC-day2 (by combining the solar and natural gas power plants production) but only 3 contracts (1,500 MWh) of ELEC-F were sold on day 1 and no ELEC-day2 spot was sold over day 2, there is an excess of 5 contracts (500 MWh) of ELEC-day2 and MECC will charge $100,000 (=5 contracts x $24,000/contract) over day 2.

Distributors

Distributors carry the electricity from the Producers to their customers (individual consumers and families). Distributors are able to sell electricity for $70/MWh to the customers, but they have to buy the electricity from either the forward or the spot market.

Distributors have seen that, historically, the demand for electricity from customers during the month of August is strongly correlated with the temperature. When the temperature is high, the consumption of electricity is also high because air conditioning systems tend to be turned on for longer periods of time due to the higher/longer demand for AC. Similarly, when temperatures are lower than average, the consumption of electricity is also lower than average.

Distributors have developed the following model to forecast the consumption of electricity by customers based on the average temperature over the day:

$ELEC_{customers} = 200\text{-}15 \times AT + 0.8 \times AT^2 - 0.01 \times AT^3$

where:

$ELEC_{customer}$ is the number of contracts of electricity demanded by the Distributors' customers;
AT is the average temperature (in degrees Celsius) expected next day;
AT^2 is AT to the power of 2 and AT^3 is AT to the power of 3.

Distributors will receive news during the case. This news contains the weather forecasts and will provide information about the expected average temperature for the next day. The weather forecasts received on day 1 will provide information about the weather on day 2. There will be an initial report at the beginning of each day followed by an update at 12:00pm each day (1 minute and 30 seconds after the start of the day in the simulation) and then there will be the final update in the evening (30 seconds before the end of the day in the simulation). The final update will provide Distributors with the correct estimates of the average temperature for the next day. In other words, in the evening Distributors will know exactly what the average temperature will be the next day.

Distributors will have to buy electricity in the ELEC-F or ELEC-dayX markets in order to provide it to their customers. Distributors are strongly encouraged not to buy more electricity than what is needed to satisfy their consumers; otherwise, for each contract of electricity in excess that has to be disposed, they will be charged by the Ministry of the Environment and Climate Change (MECC) the same fee that is applied to the Producers.

In addition, the contractual agreement between the Distributors and their customers includes a clause that will charge a penalty to the Distributors in case they do not meet the demand for electricity from the customers. For example, if the total electricity demanded by the customers is 3,000 MWh (30 contracts) and the Distributors are only able to buy 2,500 MWh (25 contracts) from the ELEC-F and ELEC-dayX markets, there will be 500 MWh (5 contracts) of excess demand for which they will be charged a penalty. The penalty will be calculated according to the following formula at the end of each day:

$penalty = \$24{,}000 * ED = \$24{,}000 * 5 = \$120{,}000$

where:

ED is the excess demand (expressed in number of contracts) which is the difference between demand for electricity from customers and the electricity that the Distributors bought in the ELEC-F and ELEC-dayX markets.

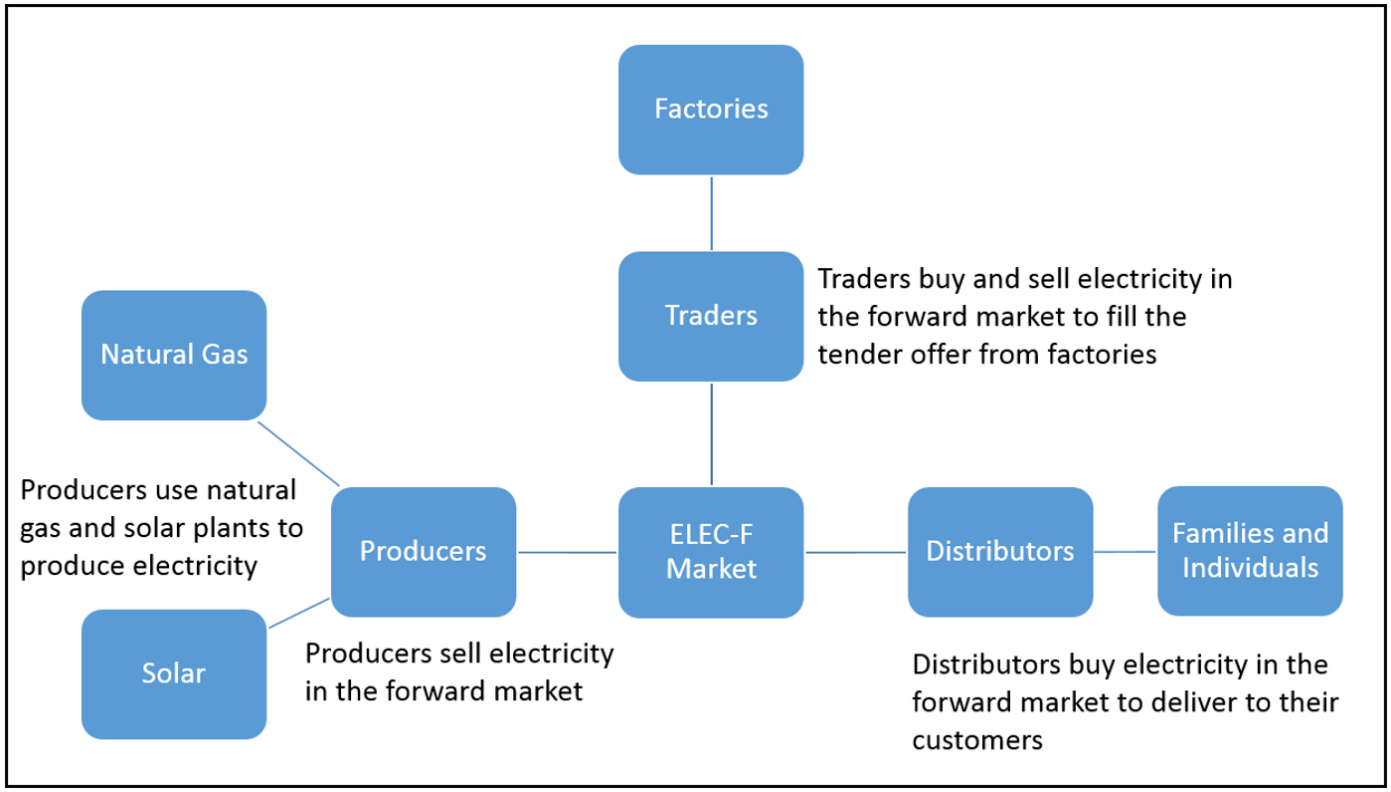
Trader

During the trading period, Traders will receive institutional orders from some clients who wish to buy or sell large quantities of electricity for the following day. These clients are large factories that intensively use electricity and find it more convenient to buy from the Traders rather than the Distributors. Traders act as the "shock absorber" for the market. They balance the supply and demand and help markets achieve equilibrium. Traders have access to the ELEC-F and ELEC-dayX markets.

Traders will receive "The Factory Tender Report" which describes the expected institutional orders activity via News.

The interaction between different market participants, including their profit maximization objectives and teamwork, is what will largely influence the overall profits of each team. Thus, participants have to optimize the dynamics of each role.

The chart below will summarize the three roles that we have described above.



[1] MWh (megawatt per hour) is the unit of measure of electricity.
[2] Disposing of electricity means that Producers will be forced to dump the electricity and will not be able to carry it over to the next day. It's equivalent to selling the electricity for $0.

MARKET DYNAMICS

Producers, Distributors, and Traders will be able to trade the securities according to the table below:

Security: ELEC-dayX
Description: Electricity spot on day "X"
Contract Size: 100 MWh
Accessibility: Producers, Distributors, Traders
Shortable: Yes

Security: ELEC-F
Description: Forward for delivery of electricity the day after
Contract Size: 500 MWh
Accessibility: Producers, Distributors, Traders
Shortable: Yes

Security: NG
Description: Natural Gas spot
Contract Size: 100 MMBtu
Accessibility: Producers
Shortable: No

Producers will be able to utilize the following assets:

Asset: NG_POWER_PLANT
Description: Power plant for the production of electricity using natural gas
Ratio: From 800 MMBtu to 100 MWh
Conversion Period: End of day

Asset: SOLAR_POWER_PLANT [3]
Description: Solar Panels for the production of electricity
Ratio: $6 \times H_{day}$
Conversion Period: End of day

[3] Please note that the solar power plant will produce electricity every day, which will be distributed as endowment to the Producers in RIT Client. The solar power plant cannot be controlled by Producers and it will not be available in the RIT Client under the module "Assets".

Producers will be limited to using 10 natural gas power plants at a time. The natural gas power plant can convert, at a maximum, 80 contracts of NG to 10 contracts of ELEC-dayX. Producers can decide to convert less than 80 NG contracts into ELEC-dayX.

The electricity spot market

The electricity spot market is a market where the prices are controlled by the Regulatory Authority for Electricity (RAE). RAE is an independent entity that regulates, controls and monitors the electricity market. Since electricity cannot be stored and has to be delivered immediately, RAE sets the electricity prices and all market participants will be forced to trade at those prices imposed by the authority.

The RAE will issue a "Price and Volume Bulletin" every day with the forecasted prices for the next day that have been calculated using the expected state of the electricity system, the Producers' offers, and the Distributors' and Traders' demand. The RAE will also have information on the volume of electricity that will be available the next day and will provide this information to the participants. An example "Price and Volume Bulletin" is provided below:

"Given the expected supply and demand in the market, the Regulatory Authority for Electricity board expects that the price for tomorrow will be between $10.00 and $25.00.

There will be 200 contracts available in the entire ELEC market, 100 contracts for buying and 100 contracts for selling. There is a total of 28 Producers, 28 Distributors and 56 Traders in the market.

Please note that the RAE will charge a bid-ask spread of 1 cent."

The RAE issues 2 bulletins per day. The second one will be more accurate than the former since the RAE will have more information to evaluate the supply and demand at noon.

Note that, in the example above, there are only 100 contracts available for buying and 100 contracts available for selling on the spot market. Once participants have bought/sold all the contracts available in the ELEC-dayX market, they will not be able to change their ELEC-dayX position. Participants will be penalized for any open position of ELEC-dayX according to the fines explained above and in the section "POSITION CLOSE OUT" below.

Participants are encouraged to buy/sell electricity on the forward market by trading the security ELEC-F. Waiting until the next day to trade ELEC-dayX on the spot market is much riskier because the volume available to buy/sell will be limited. If participants have any excess electricity in their accounts by the end of the day, they will have to dispose of it.

Please also note that there will be an ELEC-dayX spot market for days 2 through 5 only, as no electricity is produced for delivery on day 1. On day 5, it is possible to produce electricity for day 6 and it is also possible to buy ELEC-F for delivery of electricity on day 6; the settlement of any outstanding position of ELEC-day6 is discussed in the section "POSITION CLOSE OUT" below.

The following is a simplified example of the case:

Assume that on day 1 Producers knew that they would produce 1,500MWh (15 contracts) of electricity for day 2 using the solar power plant (there is no cost for producing electricity using the solar power plant) and also decided to produce 2000 MWh (20 contracts) of electricity using the natural gas power plant at a cost of $14.875/MWh.

The average cost for the 3,500 MWh (35 contracts) of electricity produced is $8.5/MWh [=(1,500MWh x $0 + 2,000MWh x $14.875)/(1,500MWh + 2,000MWh)].

On day 1:

Distributors have bought 2 contracts (1,000 MWh) of ELEC-F from the Producers and 5 contracts (2,500 MWh) of ELEC-F from the Traders at a price of $40/MWh. Traders initially bought 5 contracts (2,500 MWh) of ELEC-F from the Producers for $25/MWh.

Profit generated by each member (per MWh).

Producers:

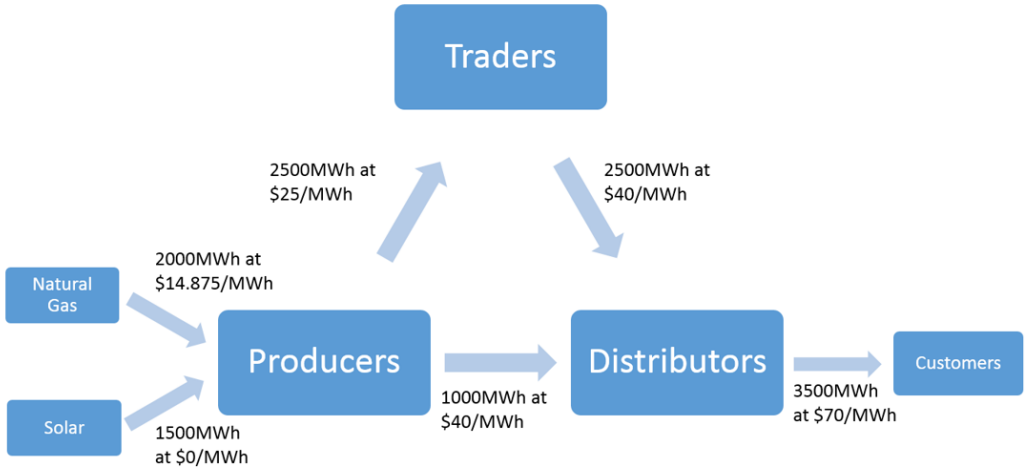
Average Selling Price per MWh = (1000MWh x $40 + 2500MWh x $25) / 3500 MWh equals ~ $29.286
Profit = Average Selling Price per MWh – average cost per MWh = $29.286 – $8.50 = $20.786

Distributors:

Profit = Selling price to customers – cost of buying electricity = $70 – $40 = $30

Traders:

Profit = Selling price to Distributors – cost of buying electricity = $40 – $25 = $15



On day 2:

at the beginning of day 2, they could trade ELEC-day2 spot in order to close their position. The price at which they could trade will be imposed by the Regulatory Authority for Electricity as explained above.

The following is an example with a spot transaction.

Assume that on day 1 Producers knew that they would produce 1,500 MWh (15 contracts) of electricity for day 2 using the solar power plant (there is no cost for producing electricity using the solar power plant) and also decided to produce 2,000MWh (20 contracts) of electricity using the natural gas power plant at a cost of $14.875/MWh.

The average cost for the 3,500 MWh of electricity produced is $8.5/MWh [=(1,500MWh x $0 + 2,000MWh x $14.875)/(1,500MWh + 2,000MWh)].

On day 1, Distributors bought 2 contracts of ELEC-F (each contract is for 500MWh so Distributors bought 1,000 MWh of electricity) from the Producers at a price of $40/MWh. Traders did not buy or sell any ELEC-F contract.

At the end of day 1, Producers will have 2,500MWh of unsold electricity (3,500 MWh produced – 1,000MWh sold to Distributors). At the beginning of day 2, the Regulatory Authority for Electricity declares that the price for ELEC-day2 for the day will be $20/MWh. To avoid penalties, the Producers will sell the remaining 2500MWh of ELEC-day2 at the spot price of $20/MWh.

Profit generated by each member (per MWh).

Producers:

Average Selling Price per MWh = (1000MWh x $40 + 2500MWh x $20) / 3500 MWh equals ~ $25.71
Profit = Average Selling Price per MWh – average cost per MWh = $25.71 – $8.50 = $17.21

Distributors:

Profit = Selling price to customers – cost of buying electricity = $70 – $40 = $30

Traders:

Traders' profits are zero because they did not trade.

TRADING/POSITION LIMITS AND TRANSACTION COSTS

The maximum trade size will be 10 contracts for the security ELEC-F and 80 contracts for the security NG. Producers, Distributors and Traders will be allowed to have at maximum a net position of 300 contracts of ELEC-dayX. Producers will be allowed to have at maximum a net position of 80 contracts of NG. Producers, Distributors and Traders will be allowed to have at maximum a net position of 60 contracts of ELEC-F..

There are no transaction costs to trade ELEC-F and NG. The ELEC-F market will allow participants to submit only rounded integer quotes.

POSITION CLOSE OUT

Each outstanding position 0f ELEC-day2 through ELEC-day5 will be closed out at a distressed price of $0 at the end of days 2 through 5 respectively. The fee of $20,000/contract from the Ministry of the Environment and Climate Change will be applied to all long positions of ELEC-day2 through ELEC-day5 at the end of days 2 through 5 respectively. A penalty of $20,000/contract will also be applied to all short positions of ELEC-day2 through ELEC-day5 at the end of days 2 through 5 respectively.

At the end of the case (end of day 5), any outstanding positions in ELEC-day6 will be closed at the final RAE price announced during day 5. No fines will be applied to long or short positions of ELEC-day6.

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Location and operating hours

Lab operating hours
Monday to Friday, from 9:00 AM to 5:00 PM

Lab location
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Graduate Rotman students access
24/7 access using the fob

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Monday to Friday, from 9:00 AM to 5:00 PM

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