ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

Virtual Simulation Experiment Teaching about Electricity Market Course

Dong Han[a], Yaoshang Liu

College of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai, China
[a]han_dong@usst.edu.cn

Abstract: *The virtual simulation experiment teaching platform of electricity market serves the teaching of electricity market theory. In this paper, the actual transaction scenarios of typical provinces in China are selected as the research object, and multiple experimental links such as medium and long-term market transactions and spot market transactions are set up to simulate all subjects, the overall market environment, all rules and the whole process of the power industry chain. In this teaching experiment project, students participate in the market as a power generation enterprise or electricity sales company, complete the transaction process such as market transaction declaration and clearing, and systematically conduct settlement rankings to truly present the whole process of electricity market transactions. Theoretical teaching is combined with simulation, and can be popularized and applied in the field of electricity market.*

Keywords: *Electricity Market, Virtual Simulation, Medium and Long-term Market Transactions, Spot Market, Transaction Declaration, Market Clearance*

1. Introduction

As one of the industries with the highest proportion of carbon emissions, the power industry is an important part of the green and low-carbon energy transition. In the face of many contradictions and challenges such as demand growth and energy shortage, energy utilization and environmental protection, it is necessary not only to innovate power technology such as new energy power generation and demand response, but also to pay attention to the construction of the power market and give play to the guiding role of the market. Therefore, in addition to cultivating traditional power technology talents, it is more necessary to cultivate power technology and economic compound talents with energy security concepts and international visions.

Electricity Economics and Electricity Market is an interdisciplinary course that applies economic principles to explore the workings and management of the electricity market. As a professional course that closely combines theory and practice in the discipline of electrical engineering, students not only need to master the basic disciplines such as advanced mathematics, power system optimization and operation analysis, and economics, but also put forward higher requirements for teachers' teaching. However, due to the breadth and complexity of the curriculum, it is difficult for students to understand how economic theory and the operation of the power system interact with each other based on textbook knowledge alone. In view of this, in order to keep up with the pace of power market construction and cultivate compound talents to meet market demand, it is particularly urgent to explore the teaching methods of power economy and power market courses[1].

In teaching, power trading involves multiple links such as power generation, transmission, power consumption, and dispatching, and the participating market entities are diverse, the trading varieties are rich, and the trading modes are different, covering a large number of power, energy, economics, and management knowledge points, and it is difficult for students to learn. The traditional electric power economics courses only have theoretical teaching, and the teaching mode is relatively boring, the teaching effect is not good, and the students' enthusiasm for learning is not high. In addition, power generation enterprises, electricity sales companies, etc. declare the electricity energy and price, and execute the transaction results through the dispatching center, and the operation is irreversible. There is a lack of practical basis for arranging students to participate in the internship of electricity market trading during the teaching plan, and there is a lack of relevant ways for students to combine theory and practice. Therefore, this paper changes the abstract and boring phenomenon of pure theoretical teaching in the

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

electricity market through the combination of theoretical teaching and simulation experiments. By participating in typical operation scenarios and transaction operation simulations, students can intuitively understand the whole process of electricity market transactions, so that the knowledge can be effectively internalized. Simulation experiments can not only consolidate students' theoretical knowledge, but also improve students' judgment, decision-making and innovation ability, so as to quickly achieve the teaching goals[2].

2. The rationality of the teaching design of virtual simulation of the electricity market

2.1. Holistic and orderly instructional design

Based on classroom theory teaching, this experiment planned four stages, including experiment preparation, hands-on practice,in-depth reflection and summary, and experiment effectiveness evaluation, and constructed a complete and closed-loop systematic experimental teaching framework with knowledge as the medium and process-oriented.

2.2. Student-centered, self-directed inquiry-based learning

In the teaching process, the experimental preparation, practical operation, and reflection and summary stages are all carried out entirely with students as the main body. In the process of experimentation, students need to use their own parameters, pre-order transaction results, power grid topology and other information to make independent decisions and declare quantity and price information to participate in market competition. The experimental evaluation adopts the subjective and objective fusion mechanism, and comprehensively evaluates the whole process and operation of students' participation in virtual simulation. The teaching design can fully mobilize students' initiative and exploration in learning, and is conducive to the cultivation of talent ability.

3. The sophistication of the virtual simulation system for the electricity market

3.1. Reasonable anti-emotion mechanism

Transaction information, according to their own income and experimental rankings to achieve feedback on the experimental operation, prompting students to continuously summarize experience, and constantly improve their own quotation strategies in follow-up transactions.

3.2. Comprehensive transaction process

This experimental platform includes the whole process of monthly centralized bidding transactions, monthly rolling service transactions, multi-day time-based transactions, day-ahead spot transactions, real-time spot transactions, and multi-time scale power transactions.

3.3. Perfect evaluation system

After the end of the whole process of trading, the experimental platform calculates the income of each student according to the results, and ranks them in order according to the high and low, which is used as a reference for students' experimental scoring and improves the objectivity of experimental teaching scoring. At the end of the experiment, the teacher comprehensively considered the students' experimental rankings and the experimental reports submitted by the students to conduct subjective and objective evaluations.

Figure 1 shows a flowchart of students participating in a virtual simulation experiment. In this model, students can choose to become a power generation company or a sales company, a process that can be chosen by the student or randomly assigned by the administrator. Subsequently, students analyze the data parameters of power generation companies and electricity sales companies, and participate in a number of typical operational scenarios, which cover challenges such as balancing power supply and demand and difficulties in absorbing new energy sources. Through multiple rounds of virtual simulation experiments, students will make trading decisions, quote prices, and analyze transaction results in a simulated electricity market. Eventually, they need to complete the task of generating earnings and a ranking of the experiment's performance to test their learning in the virtual simulation.

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

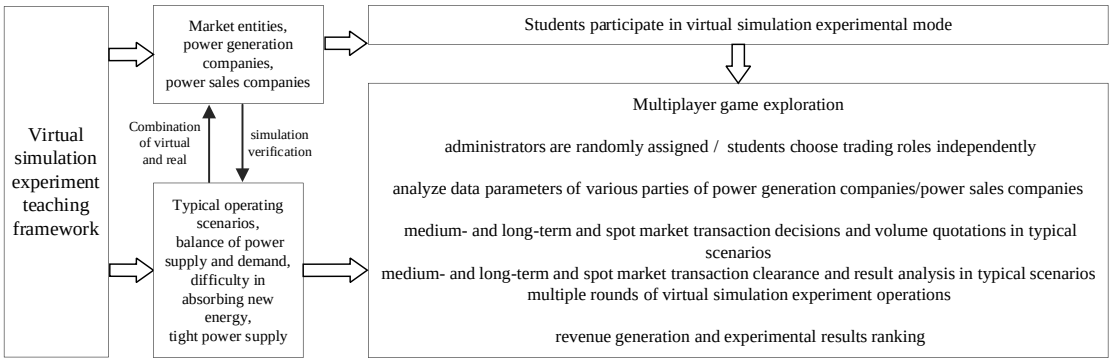

Figure 1: Teaching framework for virtual simulation experiments in the electricity market

4. An introduction to virtual simulation experiments in the electricity market

4.1. Electricity Market Definition

The electricity market, in a broad sense, is the sum of the relationships between the production, transmission, use and sale of electricity; The electricity market in the narrow sense usually refers to the medium- and long-term electricity market and the spot market, that is, the mechanism by which electric energy producers and users trade electric energy and its related products through negotiation and bidding, and determine the price and quantity through market competition[3].

4.2. Major members of the electricity market

Participants and stakeholders in the electricity market, including market players, market operators and system operators.

1) Market entities: Enterprises that comply with the rules for access to the electricity market and act as bidding entities participating in the competition and operation of the electricity market, including power generation enterprises, electricity sales companies, power users and power grid enterprises.

2) Market operation institutions: institutions that establish a fair trading mechanism in accordance with the articles of association and rules approved by the government, provide fair and high-quality trading services for various market entities, ensure information openness and transparency, and promote the perfection of trading rules and market fairness, also known as power trading institutions or power trading centers[4].

3) Power system operation organization: an institution that implements the market trading plan, is responsible for the operation and scheduling of the power system and the real-time balance of the power system, and ensures the safe, stable, high-quality and economic operation of the power system, also known as the power system dispatching agency.

4.3. The type of electricity market transaction

4.3.1. Centralized bidding

Adopt the method of declaring the price, and a plurality of market parties quote together (according to the unified power package format) to form a declaration curve between the buyer and seller, and the buyer and seller can make a transaction before the intersection of the declaration curve.

4.3.2. Listed for trading

The trading entity is listed in the market, and the quotation demand includes quotation and transaction volume; The buyer lists the demand, the seller lists the amount of electricity sold and the price of electricity, and if the other party can accept the bid, it can be delisted. If there is a simultaneous competitive relationship, you can bid again, and the best bidder wins.

4.3.3. Bilateral consultations

The two sides of the power supply and demand independently negotiate the transaction amount (electricity) and price, form a bilateral negotiation transaction intention, declare and confirm through the

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

power trading platform, and form the transaction result and sign the transaction contract after being checked by the power trading center.

4.3.4. Spot quotes

In the day-ahead market, that is, the day before the planned execution date (D-1), market participants submit the trading declaration information for each period of the coming day according to the market information and operating parameters released before the day, and the resource portfolio status and day-ahead trading volume price will be generated after the declaration is completed.

4.4. The electricity market is cleared

4.4.1. Centralized bidding and unified clearing algorithm

When the price difference and time are the same, the multiple declared quantities are temporarily combined, so as to form a list of buyers declaring electricity with monotonously decreasing price differences and sellers declaring electricity queues with monotonously increasing price differences[5].

4.4.2. Centralized bidding high-low matching algorithm

Similar to the centralized and unified clearing algorithm, the same matching amount and price difference are formed, and after the end of the clearing after the security check, the transaction amount of the market entity is equal to the sum of the matching electricity that has passed the security check, and the transaction price difference of the matching electricity is equal to the matching price difference, that is, the price difference of different matching amounts is different.

5. Virtual simulation experiment steps for power market

The experimental platform supports students to independently choose two types of market entities for power generation companies or power sales companies to participate in the bidding simulation of the medium and long-term (monthly concentrated transactions, monthly rolling matchmaking, multi-day time-division trading), and spot (spot and real-time trading). As shown in Figure 2, in medium- and long-term trading, students participate in monthly centralized trading, monthly rolling matchmaking, and multi-day time-division trading. On the basis of checking market trading conditions, current position status and other information, they make independent decisions to make a volume quotation, and the system clears it in real time; then enter the spot market to carry out date and real-time transactions. Under the view of the supply and demand situation of the power grid, price trends, bidding space, unit information, etc., different transaction declaration plans are formulated based on boundary conditions and their medium- and long-term position status, and based on simulation clearing method, the predicted clearing price is deduced, and the expected returns are calculated. By comparing and viewing the expected winning bids and returns of multiple transaction declaration plans, select the best-in-class declaration plan.

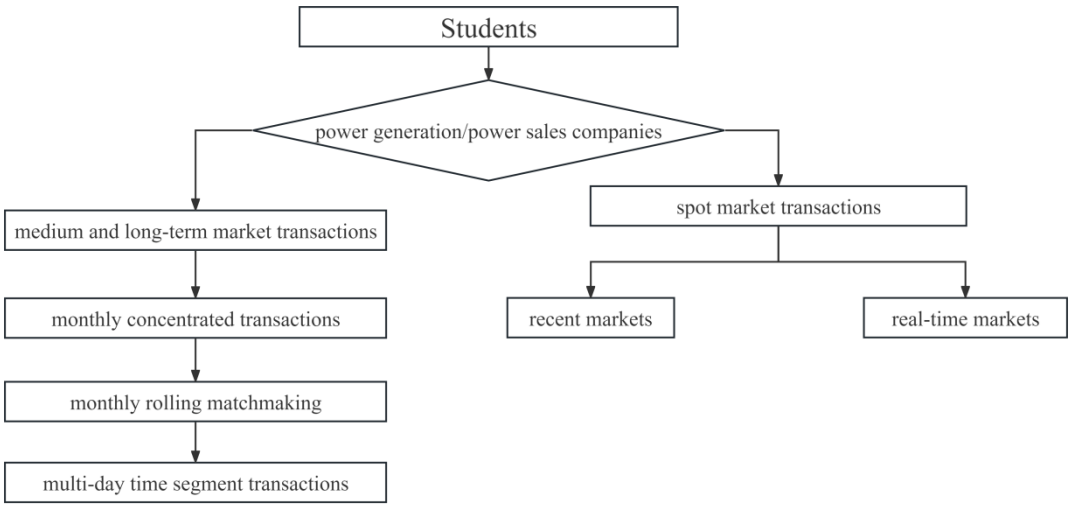

Figure 2: Virtual simulation process of power market

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

Step1: Students log in to the experimental platform by themselves, view and analyze relevant information of power generation companies and power sales companies, and freely choose the role of power generation companies or power sales companies;

Step2: Enter the monthly centralized bidding transaction, and students who play the role of power generation companies will make independent decisions on peak, flat and valley periods based on typical daily supply and demand situations, fuel price trends and other information; students who play the role of power sales companies will make independent decisions on peak, flat and valley periods based on typical daily supply and demand situations, weather conditions, agent retail users' electricity capacity and other information;

Step3: The centralized bidding trading market is cleared, and students check the transaction profile of both buyers and sellers, analyze their winning electricity price results and the electricity declaration status of the next trading link;

Step4: Enter the rolling matchmaking transaction, and the power generation company will independently decide on the purchase or sell electricity and price of peak, flat and valley periods based on the centralized bidding transaction situation; the power sales company will independently decide on the purchase or sell electricity and price of peak, flat and valley periods based on the centralized bidding transaction situation;

Step5: The rolling matchmaking trading market is cleared, and students check the transaction profile of buyers and sellers, analyze their winning electricity price results and the electricity that can be declared in the next trading stage;

Step6: Enter multi-day time-divided trading, and the power generation company checks the trading market within the target date in the trading window, and independently decides to declare the electricity and price for 24 periods of the day based on the position information. Only one set of quantity and price is declared in each period, and the power sales company operates the same as the power generation company;

Step7: The time-divided trading market is cleared, and students view the transaction overview of the entire market on the page, analyze their winning electricity price and position;

Step8: Enter the spot market to trade, and the power generation company analyzes the position volume and price curve after medium and long-term trading under the current spot target date, system supply and demand profile, node electricity price trend and other information, and its own unit constraint information; the power sales company analyzes the position volume and price curve after medium and long-term trading under the current spot target date, system supply and demand profile, node electricity price trend and other information, and its own agent retail users' recent electricity usage forecast curve;

Step9: Simulated declaration of spot market. Power generation companies make independent decisions on electricity energy and prices in order of non-decreasing output and price based on system supply and demand profiles, their own unit output plan, and the electricity price trends of nodes at different times. Power sales companies can declare electricity demand for a maximum of 10 segments based on system supply and demand profiles, their own agent retail users' recent electricity usage forecast curves, and the electricity price trends of nodes at different times;

Step 10: Power generation companies and power sales companies use simulation liquidation methods to calculate the expected winning bid output and profit situation based on the simulated declaration plan formulated. Correction and declaration plan based on the pre-expected clearance results, students can optimize quotation strategies and master the operation rules of the power system in the market operation environment during continuous correction;

Step11: Power generation companies and power sales companies submit formal spot volume quotations information based on the results of the simulated declaration plan, and use the day-to-day volume quotations information in real time in the market;

Step 12: The spot market is cleared, and students check the transaction volume of the entire network and analyze the node electricity prices and branch conditions at different moments;

Step13: Students view single-day or multi-day settlement data details and earning rankings on the settlement page;

Step14: Students exchange subject identities and repeat steps 2 to 13.

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

6. Experimental results

After the transaction is over, students will obtain different returns based on their own quotation decisions, and then obtain their respective rankings. in:

6.1. Medium-and long-term trading(centralized bidding transaction, rolling matchmaking transaction, multi-day time-sharing transaction)

When the market clears, the buyer's declarations are sorted from low to high, the seller's declarations are sorted from high to low, and then paired in turn to form a trading pair. Transaction consideration spread = buyer declared price - seller declared price. When the transaction price difference is negative, the transaction cannot be completed, and the transaction price difference is positive or equal to zero, and the transaction pair with a large price difference is preferred; when the transaction price difference is the same, the transaction with an earlier declaration time is preferred, and the arithmetic average of the buyer's declaration price of the last transaction pair and the seller's declaration price are used as the unified transaction electricity price.

1). The quotation of the power generation company is lower than the quotation of the power sales company, and the clearance is small and the clearance price is low.

The transaction consideration spread is positive or equal to zero. The declared electricity volume of each market entity is low and the declared price is low, resulting in a low unified transaction electricity price, and the winning electricity volume of each market entity is low and the returns are low.

2). The quotation of the power generation company is lower than the quotation of the power sales company, and the power is cleared out and the price is high.

The transaction consideration spread is positive or equal to zero. The declaration volume of each market entity is high and the declaration price is high, resulting in a high unified transaction price, and the winning bids of each market entity is high and the returns are high.

3). The quotation of the power generation company is higher than the quotation of the power sales company and has not been cleared.

The transaction price difference is negative and the market cannot clear it. There is no electricity sold in each market entity, and the return is 0.

6.2. Spot trading (someday trading, real-time trading)

Table 1 shows that when the market clearance is released, the power generation companies are sorted from low to high according to the declared price, and the declared price of the last winning unit is used as the market clearance electricity price. For different types of units, when the quotations are the same, fresh energy will be given first and thermal power will be given; for the same type of units, when the quotations are the same, the winning power of the unit will be determined according to the proportion of the declared power corresponding to the quotations.

Table 1: Winning bids and profit comparison table of power generation companies under different quotation scenarios

scene	Quotation status of power generation companies	Winning bid situation	Cleaning capacity	Revenue situation
1	Low quotation	Priority wins bid	When the declared power is the same, the clearing power is high	Higher
2	High quotation	Not won the bid	0	0
3	Higher quotation	Win more electricity	/	Highest
4	Higher quotation	Win less electricity	/	Below scenario (3)

ISSN 2522-6398 Vol. 8, Issue 4: 150-156, DOI: 10.25236/FER.2025.080422

7. Conclusions

This experiment innovatively constructs a virtual simulation platform for the power market, which deeply integrates real physics principles, transaction rules and a situational economic and social environment. Two major market players, power generation companies and power sales companies, have been introduced. In addition, the platform also covers two major trading markets, medium and long-term and spot, as well as five trading types: monthly centralized trading, monthly rolling matchmaking, multi-day time-sharing trading, daily trading and real-time trading. During the experiment, students will play the role of power generation companies and power sales companies, and will personally participate in several links such as monthly centralized transactions, monthly rolling matchmaking, daily time-division trading, recent transactions and real-time transactions. They need to make decisions independently and simulate market entities' quotations, clearance and settlement behaviors. Through this personal experience, students can fully and deeply understand the entire process of power market transactions, thereby deepening their understanding and mastering of the theoretical knowledge of power transactions.

This virtual simulation experiment teaching is committed to placing students at the center of the course through the careful guidance of teachers and active practical operations of students, encouraging them to actively observe and analyze the experimental process and its results with scientific thinking, and conduct comprehensive summary, in-depth reflection and summary. We have implemented multi-situation and multiple rounds of experimental teaching strategies, allowing students to constantly summarize and adjust their strategies when facing the transaction results of each link, in order to maximize their benefits in the entire transaction process. This process greatly improves students' autonomy, promotes the effective internalization of knowledge, and transforms it into practical abilities, thereby enhancing students' judgment, decision-making and innovation abilities. In addition, an inquiry-based teaching method was adopted, and a series of inquiry-based experimental links were designed around students' needs to fully stimulate students' enthusiasm for active learning. Under this framework, students are given the power to make independent decisions, which not only greatly enhances their interest in learning, but also gradually cultivates their habit of independent inquiry-based learning. This teaching model of "learning by doing, doing by learning" truly makes students the masters of learning and effectively stimulates their motivation and initiative in learning.

References

[1] Ding Yi, Deng Hui. Special message from the column "Key Technologies for Power Market Operation and Simulation" [J]. Zhejiang Electric Power, 2022, 41(09):1-2.
[2] Hu Man, Liu Ningning, Yang Ming. Construction and application of the simulation experimental platform of the power spot market [J]. Journal of Shandong Electric Power College, 2021, 24(03): 53-56.
[3] Xu Lipeng. Research on government regulation of photovoltaic power generation prices in my country [D]. Northwest University, 2015.
[4] Xia Fan. Research on information disclosure mechanism and its effectiveness in my country's power market [D]. North China Electric Power University (Beijing), 2020.
[5] Ma Yuze, Li Tao. Research on the clearing mechanism of the electricity spot market integrating carbon trading recently [J]. Research on Science and Technology Management, 2024, 44(12): 193-201.