The design of multi-energy market trading systems considers the wholesale and retail markets

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Abstract. With the development of energy internet construction, the transactions of multi-energy sources in the energy trading market are getting closer and closer. In a single energy market transaction, each energy market only considers the transaction situation of this market, which brings potential losses to energy efficiency. It is urgent to study a market trading system of multi-energy coupling. First of all, this article sorts out the current status of the transaction development of domestic and foreign natural gas, electricity and heat markets. Then, it looks forward to the market trading model of multi-energy sources. Finally, we propose a multi-energy trading system considering the wholesale and retail markets. The energy trading system constructed in this paper can provide a direction for the development of a variety of energy trading in China.

1. Introduction

In traditional single energy market transactions, each energy market only considers the trading situation in this market, but it lacks the overall consideration of multi-energy sources, which causes potential losses in energy efficiency. Therefore, it is especially necessary to study the market trading system of multi-energy coupling to provide guidance for multi-energy trading.

At present, scholars have generally realized the importance of the integrated energy market, and exploratory research has also been carried out in the field of market construction and mechanism design. But there are few reports on comprehensive energy trading market systems that take into account the comprehensive energy transmission and coupling characteristics of electricity, heat, and gas. Literature [1] pointed out that the combined cycle gas turbine has the advantages of high power generation efficiency and low carbon emission rate, and will become an important element to promote the consumption of new energy. Literature [2] studied methods to evaluate the market power of natural gas suppliers. Literature [3] provided an overview of the EU electricity and natural gas market, and took Spain as an example to analyze the impact of combined cycle gas turbines as a key component connecting the electricity and gas markets on the operation and planning of the integrated energy market. Literature [4]-[6] summarized the coupling model of electricity and gas markets, and put forward a comprehensive energy market optimization model considering mutual influence.
2. Current situation of domestic and foreign natural gas market transactions

2.1 Foreign natural gas market trading mechanism
At present, there are three major natural gas markets: North America, Europe and Asia-Pacific. Among them, North America and Europe have formed a trading market based on natural gas trading centers. Almost all natural gas consumption in the United States and more than 60% of the United Kingdom is purchased through the natural gas trading market. The American Henry Hub and the British Natural Gas Trading Center (NBP) are the two most well-known natural gas market trading centers in the world. According to different trading mechanisms, natural gas market transactions can be divided into three categories: long-term contract transactions, over-the-counter transactions and exchange transactions.

2.2 Domestic natural gas market trading mechanism
Compared with the international market, China's natural gas trading has a lower degree of marketization and a single form of transaction. In addition, natural gas trading contracts and gas supply and supply conditions lack flexibility, and the price is fixed by the state. It belongs to an oligopoly market. In order to explore the natural gas market-oriented trading mechanism, the Shanghai Petroleum and Natural Gas Trading Center started trial operation on July 1, 2015. Trading varieties include PNG (pipeline natural gas) and LNG (liquefied natural gas), and the trading time is the same as that of A shares. The transaction mode includes three types: listing (negotiation), competition and bidding. The trading gas source mainly includes the direct gas supply for users and the incremental gas supply. And the market price of liquefied natural gas, coal gas, coal bed methane, shale gas.

3. Current situation of domestic and foreign power market transactions

3.1 Foreign power market trading mechanism
Because the natural monopoly attribute of the transmission and distribution links, power reforms in various countries basically adopt the "control the middle, let go of both ends" model, and introduce market competition on the electricity sales and generation sides. According to the different ways of market organization, foreign power markets can be roughly divided into two categories: decentralized mode and centralized mode.

3.2 Domestic electricity market trading mechanism
Since the No. 9 document was issued in 2015, the construction process of China's power market has continued to accelerate, and more than 30 power trading centers have been established in Guizhou, Beijing, and Guangzhou. At present, the scale of market-oriented transactions and the awareness of market subjects are constantly increasing, and the pattern of diversified market subjects in China is taking shape. In terms of market structure, China's electricity trading is mainly based on monthly bids in various provinces and mid- to long-term transactions negotiated bilaterally, with eight provincial spot trading pilots selected. On August 31 this year, the start-up meeting for the trial operation of the southern (starting with Guangdong) power spot market was held in Guangzhou. The Guangdong spot market is the first power spot market in the country to be put into trial operation, which marks the basic completion of the Guangdong power market system. It will provide important pilot demonstration and experience reference for the construction of a complete market system of China's "mid- to long-term + spot market".
4. Current situation of domestic and foreign thermal market transactions

4.1 Foreign thermal market trading mechanism
The products traded in foreign thermal markets mainly include steam and hot water, and the businesses include the supply and sales of steam and hot water and the maintenance and management of heating facilities. At present, there is no foreign trading center to carry out heat trading. The heating charge for home heating is generally measured and settled in the form of “unit price · square meter” per month / heating season, and the heat company directly charges the property or user. With the different development levels of various countries, as well as the differences in geographical location, climate environment, technological level, etc., the choice of heating methods and charging methods varies from country to country.

4.2 Domestic thermal market trading mechanism
Most of China's central heating is realized by cogeneration of heat and electricity. A small number of communities, schools or public institutions use small gas boilers and coal-fired boilers for heating. Under the planned economy system, China's heating market is a regional oligopoly market mechanism. The construction of thermal power plants is subject to the approval of the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development, etc., to determine the heating area, and the heating price is determined by the government.

5. Wholesale-retail two-level multiple functional trading system

5.1 Design of multi-energy market trading system

5.1.1 The division of multi-energy flow market trading system. As shown in Figure 1, according to the trading objects, the multi-energy flow market system is divided into electricity, natural gas, cold demand, heat demand, financial derivatives, etc.; According to time, the multi-energy flow market system is divided into medium and long-term markets (including more than one year market, annual market, quarterly market, monthly market and weekly market, etc.), pre-market and real-time market; According to the nature of the market, it is divided into a physical market and a financial market.

Among them, the electricity market includes electricity market, power generation rights trading market, auxiliary service market, carbon trading market, green card market and many other market types related to electricity trading.

![Figure 1. Multi-energy flow market trading system.](image)

5.1.2 Wholesale-retail two-level multi-functional trading system. Wholesale side: The core of energy suppliers participating in the wholesale side transaction of multi-energy flow is the price of...
multi-energy sources.

Wholesale price model: coal-fired price, node electricity price and node gas price. The electricity market uses node electricity prices, and the natural gas market uses node electricity prices to design node gas prices, which are used to fully reflect the price signals of the natural gas market. The node gas price will fully consider the rapidly fluctuating gas demand of the electricity market, which helps to change the lack of real-time response and congestion management in the natural gas market.

Primary energy market transactions:
① Joint transaction between the natural gas market and the electricity market. Coupling equipment represented by gas-fired units and gas-electricity coupling equipment (P2G) makes the power and natural gas infrastructure closely related to the economics and reliability of their respective markets.
② Considering that coal can be converted into natural gas and electricity, energy suppliers should also participate in the coal market transaction, and formulate a trading strategy with comprehensive consideration of revenue.

Secondary energy market transactions:
Energy suppliers can participate in financial markets to avoid risks in the energy market; At the same time, energy suppliers can also represent their users through the market incentive mechanism to participate in the auxiliary service market and demand response.

Retail side:
At the retail side of the current multi-energy flow market, users and energy suppliers mainly use contract agency methods for transactions. And the regional multi-energy flow market is mostly monopolized, which is generally provided by an energy supplier. The main contents of the current transaction are as follows:
① Multi-function package. It provides customers with the best energy supply combination plan covering electricity, gas, heating, etc., and provides an optimized combination of various electricity price plans and electrical equipment plans.
② Contract energy management. The energy-saving service companies and the energy-using units agree on the energy-saving target of the energy-saving project in the form of a contract. Energy-saving service companies provide necessary services to energy-using units to achieve energy-saving goals, and energy-consuming units pay the investment and reasonable profits of energy-saving service companies with energy-saving benefits.
③ Operation and maintenance services for energy equipment. It provides a full range of services for improving the reliability of enterprise electricity consumption and energy operation and maintenance management. Services include architectural design, construction, and maintenance. Among them, the building design includes renewable energy power generation, communication, heating, and water supply.
④ Integrated customized service. When carrying out comprehensive energy services, considering the large number of subjects, different users have different interests, and their goals for participating in interaction are also different. Therefore, the service mode can be divided into standardized user service mode and VIP user service mode according to different characteristics of the service.
6. Conclusion
This paper first analyzes the development status of domestic and foreign natural gas market, electric power market and thermal power market. Subsequently, a two-level trading system considering the wholesale market and the retail market was designed and proposed, which provides a reference for energy market transactions under the construction of China's energy internet.

Acknowledgements
Science and Technology Project of SGCC, Research and Demonstration of Integrated Energy Management and Optimal Control Technology for Multi-energy Flow.

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