Design of renewable energy consumption market system based on the interactive transaction of source-grid-load-storage

Dunnan Liu¹, Tingting Zhang¹*, Hua Li¹, Mingguang Liu¹ and Heping Jia¹

¹ School of economics and management, North China Electric Power University, Beijing, 102206, China
*Corresponding author’s e-mail: 120192206117@ncepu.edu.cn

Abstract. Renewable energy has the characteristics of clean, safe and low variable cost. High proportion of renewable energy access is of great significance for improving energy structure and improving power economy. However, with the continuous increase of renewable energy access ratio, in the case of full guaranteed acquisition, the peak load regulation capacity of power generation side will be insufficient, which can’t meet the requirements of full purchase of renewable energy, resulting in the phenomenon of power abandonment. It is urgent to stimulate the interactive ability of all users to participate in the consumption of renewable energy. Based on this, this paper puts forward a renewable energy consumption market system which includes medium and long-term, day ahead and real-time trading mode to promote the interaction between source network and load storage. Through the design of the mechanism, we can give full play to the regulatory potential of the user side and let the more efficient renewable energy units obtain more auxiliary service resources.

1. Introduction
Renewable energy power generation has dual value of electric energy and green, and its green value is reflected by quota market[1]. China's current quota system only considers that users must complete a certain amount of renewable energy quota[2-4], and does not consider the difference of users' participation in consumption, and does not consider the friendliness of different users for renewable energy power generation and consumption, but only allocates them to power consumers in the form of quota indicators[5]. Due to the lack of flexibility in China's domestic power supply structure[6], it is urgent to stimulate the interactive ability of all users to participate in the consumption of renewable energy[7]. The market mechanism should consider the user's friendliness to the consumption of renewable energy, accurately measure the user's contribution to renewable energy consumption; the market mechanism should encourage capable users to consume more renewable energy; it should reflect the value of users' flexible regulation and control ability.

For the traditional thermal power enterprises, its electric energy has power value and flexibility value[8-9]. In the power system with high proportion of renewable energy access and full guarantee purchase of renewable energy, the flexible regulation and control ability of thermal power enterprises is particularly important. The existing compensation mechanism of auxiliary service requires the generating units with regulation ability to undertake the obligation of providing physical auxiliary services, and most generating units should bear the economic responsibility of auxiliary services[10]. However, it is not clear how to quantify the efficiency of power dispatching agencies to use auxiliary services, including whether the cost of using auxiliary services can be less than the dividend brought by consuming unstable power sources, and the compensation price of auxiliary services has always been
controversial. The market mechanism should be able to reflect the real value of auxiliary services, and more efficient renewable energy units can obtain more auxiliary service resources through the design of the mechanism.

This paper proposes a market system framework of renewable energy consumption with the interaction of source network, load and storage, which is divided into medium and long-term market, day ahead market and real-time balance mechanism from time dimension. The details are shown in the following figure:

![Figure 1. Market system framework of renewable energy consumption based on the interactive transaction of source-grid-load-storage](image1)

### 2. Medium and long term market trading mode

#### 2.1. Time sharing trading model with source following load

Based on the basic attribute of medium and long-term power transaction as physical transaction, in the renewable energy consumption market system of source grid load storage interaction, the traditional generation plan formulated by the government is transformed into the government authorization contract. Thermal power enterprises and users conduct electricity wholesale transactions for many years, years, seasons, months and weeks through bilateral negotiation. Annual - weekly transactions are divided into peak valley level three trading. Maintain the planning and scheduling mode basically unchanged, and ensure that the decomposition power of various contracts is basically balanced in the implementation of peak valley level on a weekly basis. The scheduling of all government authorized contracts for non-renewable energy is decomposed into peak valley level in the weekly dimension, and renewable energy shall declare the weekly peak valley allocation amount (which needs to be checked and passed by the dispatching). With the improvement of market maturity, the transaction mode of peak valley level three sections can be further promoted to "24 points" decomposition, promote "48 points" and other segmented electricity trading, so as to achieve better docking with the spot market.

![Figure 2. Time sharing trading model](image2)

#### 2.2. Source-source interactive transaction of renewable energy and thermal power

Under the framework of this paper, in addition to the renewable energy part of the government authorized contract, the rest will be fully listed in the market; the traditional transaction between renewable energy and users can’t be carried out in the medium and long-term market, and the part that can’t be absorbed by the market will be purchased by the power grid at a lower purchase price. On this basis, the market transaction mode of interaction between renewable energy and thermal power sources is designed to carry out the power generation right transfer market from long-term and D-2 time scales. Renewable energy enterprises can purchase power generation rights from thermal power enterprises by means of market-oriented means through bilateral negotiation or continuous listing; It is allowed to trade generation rights between thermal power enterprises in order to avoid deviation assessment. Therefore,
renewable energy enterprises and thermal power enterprises form a strategic market win-win alliance to carry out market replacement transactions. Thermal power plants will replace part of the power generation space to new energy enterprises (wind farms, photovoltaic power stations) on the premise of maximizing revenue. At the same time, after the renewable energy power generation enterprise obtains the power generation space, because of its lower marginal cost level, the profit will be higher than that of thermal power. Through the price of power generation right transfer contract, the thermal power enterprise will be compensated to realize the price discovery of auxiliary service resources by sharing the alliance interests.

Figure 3. Source-source interactive transaction of renewable energy and thermal power

3. Day ahead time scale market trading model

3.1. Load follows source (renewable energy and large users with regulatory capability)

With the continuous increase of renewable energy access ratio, in the case of full guaranteed acquisition, the peak load regulation capacity of power generation side will be insufficient, which can’t meet the requirements of full purchase of renewable energy, resulting in power abandonment. Due to the influence of new energy output and load fluctuation, the single generation side control method can’t meet the needs of power grid operation. Therefore, the introduction of demand side flexible load to participate in the transaction of "load following source" through market trading mechanism is helpful to promote the consumption of renewable energy and relieve the pressure of peak load regulation.

Under the framework of renewable energy consumption market system with source grid load storage interaction, power users and new energy enterprises are organized to carry out D-1 medium and long-term trade with curve. Power users can realize load curve tracking of new energy output curve by means of energy storage, regenerative electric heating and process optimization.

The transaction object of this trading mode is the predicted renewable energy output curve, and the whole transaction process is as follows:

Preparation before transaction: before the transaction, the power dispatching department will release the predicted output curve of renewable energy and the historical load curve of users of the whole network. Users can submit the load forecast curve of trading day according to their own historical load curve and production plan.

In the first stage, the power users and the new energy stations are listed at the same time, the new energy stations report the predicted output curve and electricity price, and the users report the electricity consumption and electricity price. Both parties grab the buyer or the seller at the same time, and the time is priority; the transaction power is the smaller value of the remaining electricity of both parties, and the electricity price is the price of the listing party.

Figure 4. The first stage: double hanging and double picking
The second stage of centralized matching: new energy and users have not been transacted, and the curve and electricity price will be applied for the second time, and the centralized matching transaction is carried out. According to the price order, the clearing price takes the user's quotation.

![Figure 5. The second stage: centralized matchmaking](image)

At the execution date of the transaction, users adjust their own electricity load according to the new energy output curve, so as to realize the flexible resource transfer on the user side, and reflect the value of the difference of user load friendliness through market-oriented transaction.

### 3.2. Source following load (unilateral bidding of thermal power)

Usually in the day ahead market mode, thermal power units need to declare their minimum economic output. The schedulable space of the unit in the day ahead market is the range from its minimum output to its maximum output; for the thermal power unit with physical contract, it is necessary to declare its physical contract curve of the second day, and the schedulable space of the unit in the day ahead market is the range from its physical contract output to its maximum output. Under the framework of the market system in which the source network can absorb renewable energy, the space for thermal power units to participate in the day ahead market is constrained by the physical contracts concluded in the medium and long-term market. As for the quantity of the maximum output space, since the medium and long-term contracts are concluded by peak-valley-flat three sections, the unilateral quotation of the thermal power units in the day ahead is also the quotation of the third period of peak valley level.

In view of this, in the afternoon before yesterday, the organization of unilateral quotation of thermal power units. Due to the organization of "load following source dynamic" user tracking the transaction of energy generation curve in the morning of the day ago, the user side flexibly adjusts resources and optimizes the generation output curve of available energy. Due to the strong volatility and randomness of the generation output of renewable energy, it can be considered that it does not have the ability of day ahead regulation. Therefore, thermal power units can combine the constraints of their own contracts and the maximum output limit to organize unilateral quotation of thermal power units for the remaining electricity of the day ahead. For units with strong regulation and control ability, curves with strong fluctuation and units with weak regulation ability can choose relatively stable curves, thus reflecting the value of thermal power units' regulation and control ability differentiation.

### 4. Real-time electricity trading market

According to the principle of "day ahead bidding and real-time call", after the day ahead generation plan is determined, the order of real-time up regulation unit call (ranking from low to high according to the additional issue price) and descending unit dispatching order (ranking from high to low according to the price of reduced generation) are determined by pre listing. In the process of real-time operation, when the actual power demand of the system deviates from the day ahead generation plan of the system, the corresponding units are called according to the principle of price priority to increase or reduce the power generation to ensure the real-time balance of the system. The other units will generate electricity according to the power generation plan curve formulated a few days ago. Among them, the pre listed units are mainly thermal power units with regulation capacity. The system deviation mainly comes from the load forecast deviation, the new energy output forecast deviation and the output deviation caused by the generator itself. In terms of settlement, according to the deviation between the actual on grid
electricity and the monthly priority generation and base electricity, the fees for providing up-regulation or down-regulation services are settled according to the pre listing price.

5. Conclusion

Under this framework, medium and long-term trading is more abundant in time scale, which provides an effective means to avoid deviation for market participants. The medium and long-term power contract avoids the spot risk for both parties, restores the value curve of electricity to a certain extent, and at the same time fits the curve change of power price and power value to the maximum extent. Among them, short-term trading can deal with the volatility and randomness of new energy generation, and can reduce rigidity and tap greater regulation capacity compared with spot trading. Medium and long-term trading with curve considering spot can promote new energy consumption and reflect the space-time value of rapid regulation ability.

The generation rights trading market, which combines forward trading with D-2 trading, can not only adapt to the current generation scheduling arrangement mode, but also meet the trading needs of power producers. On the one hand, it gives more trading flexibility to both sides of the transaction, so that the participants can obtain further profit opportunities under the favourable situation of the market. On the other hand, it gives full play to the role of power generation rights trading in energy saving and consumption reduction and avoiding market risks in the power market, which is conducive to the optimal allocation of power generation resources, maintaining the stability of the system and improving social benefits. On the one hand, the compensation mechanism of auxiliary services is replaced by the way of full transfer of power generation in energy and thermal power enterprises. The real value of auxiliary service resources can be found by means of market-oriented transaction. Through price signal, the investment behaviour of thermal power enterprises in flexible transformation can be guided, so as to better explore the flexible regulation and control ability of power generation side.

In the real-time electricity trading market, we believe that renewable energy power generation has no day regulation ability. After day ahead market transactions, users participate in tracking curve trading, and the user side regulation ability has been tapped; the flexible regulation ability of thermal power units has also been mined to a certain extent. Before the spot market is carried out, the real-time market up and down adjustment mechanism of thermal power enterprises' pre quotation is introduced.

Acknowledgments

Supported by the National Key Research and Development Project(2020YFF0305800)

References

[1] Yang L.B., Zhang T.H., Li Y.C., Li X.G., Wu M. and Yu B.B. (2020) Dynamic simulation of renewable energy power trading system based on quota system. Power system automation, 3 (05): 497-507.

[2] Chen Q.X., Liu X., Fang X.C., Guo H.Y. and Lin Q.B. (2020) Power market clearing mechanism considering renewable energy security consumption. Power system automation: 1-8 [2020-12-22] http://kns.cnki.net/kcms/detail/32.1180.TP.20201209.2001.002.html.

[3] He J.L., Xu S., MI C.X. and Yu T (2020) Mechanism improvement design of renewable energy quota system, green power certificate and carbon trading under the background of electricity spot. China foreign energy, 25 (10): 19-25.

[4] Cui Z.P. and Yang W., (2019) Discussion on renewable energy consumption quota accounting and performance trading mode. China electric power enterprise management, 34: 51-53.

[5] Wang M. (2019) China's renewable energy development is facing challenges. Social science journal, 2019-11-14(002).

[6] Gong S., Shi Q.G., Mao Y.C. and sun H.Z. (2017) Flexibility status and technology development of thermal power units in China. Applied energy technology, 05: 1-6.
[7] Liu M.C., Zheng H, Qin L.J., Liu S.W., Li T and Liang J. (2020) Research on resource coordination scheme of load storage integrated peak shaving based on source network. Electrical measurement and instrumentation: 1-10 [2020-12-22] http://kns.cnki.net/kcms/detail/23.1202.TH.20200617.1126.002.html.

[8] Zhang B, Wu Z. and Jin Y.F. (2020) Study on peak load regulation and energy saving management of thermal power transformation development. China electric power industry, 11: 102-103.

[9] Cui Y., Zhou H.J., Zhong W.Z., Zhao Y.T. and Cui C.W. (2020) Optimal dispatch of power system with energy storage considering thermal power peak shaving initiative and demand response. High voltage technology: 1-12 [2020-12-22] https://doi.org/10.13336/j.1003-6520.hve.20200440.

[10] Luo H.H., Wang H, Ge W.C., Liu C. and Wang Y.B. (2020) Design of bidding mechanism for dynamic peak shaving auxiliary service market considering quotation supervision. Journal of Electrotechnics: 1-14 [2020-12-22] https://doi.org/10.19595/j.cnki.1000-6753.tces.200264.