# Design of the Trans-provincial New Energy Spot Transaction Mode and Analysis of the Mode's Effects on New Energy Consumption

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**Abstract.** Trans-provincial new energy transactions consist of medium- and long-term transactions and spot transactions. Trans-provincial spot transactions have been mainly executed in areas where there is some difficulty with new energy consumption. To further improve the system's capability to accommodate new energy, this paper designs a replacement transaction mechanism for electricity delivered through the same channel according to the status quo of trans-provincial new energy spot transactions and the reality of China's electric power market. A production simulation-based decision analysis model for trans-provincial new energy consumption is established so as to analyse quantitatively the effects of the proposed transaction mode on new energy consumption. A typical case is selected out from a certain province as the delivery end, and the testing results show that the trans-provincial spot transaction mode and the quantitative analysis model proposed in the paper can improve the new energy consumption and utilization rate of the delivery end significantly.

## 1 Introduction

In China, new energy is being developed in a centralized and large-scale way, causing an over-high new energy installation capacity in some areas so that new energy cannot be fully accommodated in those areas, so trans-provincial new energy consumption will be an important measure for addressing the problem of China's new energy consumption. The lack of a market mechanism, in particular, a spot market mechanism that accommodates to the uncertainty and fluctuation of new energy output, is one of major problems impacting China's trans-provincial new energy consumption, so a reasonable market mechanism will become a critical means to address the problem of new energy consumption in China.

Viewed globally, trans-provincial new energy consumption has proved to be successful in foreign countries and regions as they were trying to achieve a high-proportion new energy consumption [1-3]. Yet, more efforts are still to be made so as to explore a trans-regional market mechanism as no mature pattern in this aspect is available for China currently.

Relevant studies by domestic and foreign scholars have been in progress. Based on the traditional clearing mode in which the negative externality of the thermal power generation environment is ignored, a carbon transaction mechanism has been introduced in literatures [4-7] to internalize the carbon emission costs, thus aiming to improve trans-provincial new energy consumption by putting into implementation a low-carbon incentive mechanism to facilitate the transactions of thermal power and new energy generation rights. The method is not engaged sufficiently in the existing trans-provincial transaction mode. A market mode featured by the involvement of power sales companies in trans-provincial transactions has been proposed and the risks possibly caused have been analysed, thus aiming to enhance the participation of power sales companies in trans-provincial transactions by establishing a united regional market featured with its regionalized balance in literature [8-11]. Nevertheless, no study has been conducted on the roles played by the delivery channel in improving new energy consumption in literatures. Some suggestions on how to establish a sound trans-provincial transaction mechanism from the perspective of power transaction have been proposed in literatures [12, 13], aiming to improve the trans-provincial new energy consumption capability. A mechanism has been proposed for trans-provincial clean energy accommodation and compensation based on power generation right transactions in the literature [14], but the mechanism is just limited to clean energy plants at the delivery end and thermal power units in the place where clean energy is accommodated. A plan on how to implement a trans-provincial continuous transaction mechanism has been proposed in the literature [15], and the construction of state and provincial-level power markets was designed in details. In the literature [16], a trans-provincial power transaction framework under the renewable portfolio standard has been put forward and

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optimal decision models have been established for different transaction subjects. In summary, no spot transaction market mechanism aimed to optimize the existing trans-provincial power transmission plan has been proposed in current studies. Nor has any quantitative decision analysis model to be used in studies concerning the effects of a trans-provincial spot transaction mechanism on new energy consumption been proposed.

Based on the above analysis, a trans-provincial replacement transaction mechanism has been designed for electricity delivered in the paper. A production simulation-based decision analysis model to be used in studies on the trans-provincial new energy consumption is established, and the role that the proposed transaction mode played in improving new energy consumption is quantitatively analysed on the basis of a typical case.

## 2 Replacement Transaction Mechanism

Medium- and long-term physical contracts and trans-provincial surplus electricity spot transactions are two existing basic trans-provincial new energy transaction modes in China [17]. However, the current spot transactions of surplus new energy power are mainly conducted through trans-regional channels, As a result, the total volume of electricity to be transacted is limited due to the limited scope of transactions.

The replacement transaction mechanism for electricity delivered through the same channel is a kind of power generation right transaction mechanism in nature. Its basic idea is shown in Fig. 1. Most of the existing power generation right transactions are on either a yearly or monthly basis, so new energy power generation enterprises may execute power generation right transactions with conventional power generation enterprises by way of bilateral negotiations or open tenderings when they estimate an accommodation challenge in front. The volume of electricity to be transacted needs to be ascertained ahead of schedule, and the peak, valley and horizontal curves of transactions may be required in the future, so it is not necessary for the existing power generation right transactions to vacate channels/space for the transmissions of new energy power though it vacates space for new energy power generation.

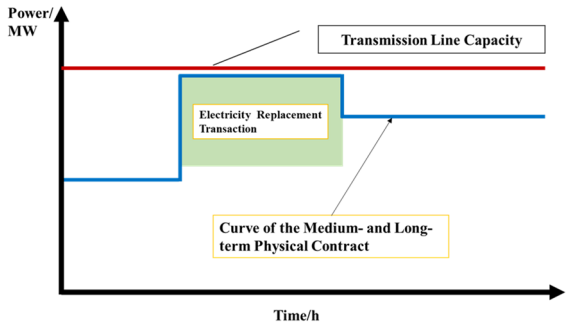


**Fig.1** Replacement transactions within the same channel.

New energy power generation enterprises may conduct power generation right transactions with conventional power generation enterprises by way of bilateral negotiation or open tendering when the curtailment may occur. The replacement transactions of electricity delivered through the same channel can achieve this goal.

### 2.1 Transaction subjects

The transaction subjects include new energy power generation enterprises and conventional energy power generation enterprises in the same region. And conventional energy power generation enterprises are required to own trans-provincial electricity transaction contracts to deliver electricity.

### 2.2 Transaction mode

Transactions can be executed by way of bilateral negotiation, centralized matching or open tendering, etc. By bilateral negotiation, it means that a new energy enterprise may agree with an enterprise that generates power by using the conventional energy on the electricity delivery channel to be transferred, the maximum electricity delivery space to be transferred and the transfer price. By centralized matching and open rendering, it means that a new energy enterprise may submit its declaration information, including the alternative power generation curves and price information that they would like to buy, monthly or several days ahead of schedule; a conventional energy power generation enterprise may declare to transfer its electricity delivery space, its trans-provincial delivery channel and required price compensation, and the electricity transaction agency may make a matching or achieve an open rendering transaction according to the details declared. A formal transaction result will occur after the transaction result is submitted to the dispatch organ for a safety check.

### 2.3 Execution of transactions

As the channel is fully occupied and there are also demands for new energy delivery before or on the day when a transaction is being executed, the transaction replacement result shows that the replaced part of electricity delivered through the same channel shall be subtracted from the medium- and long-term electricity delivery transaction plan for the conventional power supply, the replaced part of electricity delivered through the same channel shall be added to the medium- and long-term delivery transaction plans for new energy and the new energy power enterprise shall pay the replacement costs to the conventional energy power generation enterprise. If there is no demand for new energy delivery, the transaction replacement result will not be executed.

## 3 Decision Analysis Model

### 3.1 Decision analysis

The decision analysis for trans-provincial new energy consumption consists of the following several steps:

Step 1: Enter the provincial-level grid data, including conventional power supply data, load data, and new energy station data;

Step 2: Enter the curve data of the medium- and long-term physical contract on the tie line between provinces, and the safe transmission capacity of the tie line;

Step 3: Establish an annual optimization dispatch model based on the specific trans-provincial new energy transaction mode;

Step 4: Solve the model to get the yearly power generation plans and the power-generating capacity of conventional power supplies and new energy stations. Based on a power curtailment curve as well as the volume curve of the conventional power supply in the province in the medium- and long-term physical contracts, we can get the electricity replacement transactions.

### 3.2 Optimization model

In order to get the new energy power abandonment curve, a production stipulation-based method needs to be used to solve the new energy consumption analysis model [18-20]. The objective function is to maximum the consumption of new energy as follows.

$$\max J = \sum_{t=1}^{T}\sum_{n=1}^{N}\left(p_w^{t,n} + p_{pv}^{t,n}\right) \quad (1)$$

Where T is the number of dispatch periods. N is the number of divisions of the system. $p_w^{t,n}$ is the generation power of wind power units in area n at time period t. $p_{pv}^{t,n}$ is the generation power of PV units in area n at time period t.

The constraint conditions include regional load demand balance constraint, spinning reserve constraint, the generation power boundary constraint for thermal power units, the minimum on/off time constraint for thermal power units, the ramp rate constraint for thermal power units, new energy generation power constraint, transmission line capacity constraint, etc. For more information, it could be found in [18-20].

## 4 Case Testing

### 4.1 Case introduction

In the typical provincial-level grid, the total installation capacity of thermal power units is 20.86 million kW, the total installation capacity of hydropower is 9.9 billion kW, the total installation capacity of wind power is 13.17 million kW, and the total installation capacity of PV is 8.64 million kW. In the trans-provincial DC channel, the volume of electricity delivered according to the medium and long-term physical contract is 18 billion kWh.

### 4.2 Analysis of the new energy consumption effect

Table 1 shows changes in annual new energy consumption by such a typical provincial-level grid before and after the execution of electricity replacement transactions within the same channel.

**Table1.** Changes in new energy consumption before and after the execution of electricity replacement transactions.

| | Before | After |
|---|---|---|
| New energy curtailment ratio (%) | 11.62 | 7.45 |
| New energy consumption (100 million kWh) | 356.45 | 373.24 |
| Net volume of electricity transmitted through tie line (100 million kWh) | 180 | 180 |

Based on the above results, we can obtain the following conclusions.

(1) The execution of electricity replacement transactions within the same channel can improve significantly the consumption and utilization level of new energy in such a typical provincial-level grid. Before the execution of electricity replacement transactions, the new energy power curtailment ratio is 11.62%. But the ratio declines to 7.45% after the execution of electricity replacement transactions, registering a drop of 4 percentage points.

(2) The execution of electricity replacement transactions within the same channel increases the volume of new energy power in that typical provincial-level grid; meanwhile, the total volume of electricity delivered remains unchanged. After the execution of electricity replacement transactions within the same channel, the volume of new energy power in such a typical provincial-level grid increased by 1.679 billion kWh but the total net volume of electricity transmitted through the delivery channel remains unchanged at 18 billion kWh.

Fig. 2 shows the operation status of the delivery channel after the execution of electricity replacement transactions within the same channel.

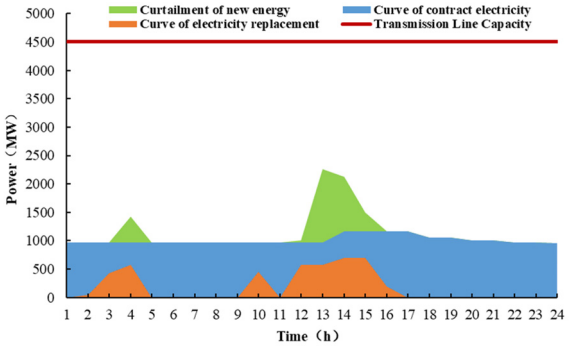


**Fig.2** Changes in transmission power after the execution of electricity replacement transactions.

As can be seen from the above figure, electricity replacement transactions between new energy and the conventional power supplies can reduce the volume of new energy power curtailment at certain periods of time. However, not all the new energy power curtailment can be consumped because the space used for electricity replacement is under the volume restriction specified in the medium- and long-term physical contracts. Considering that electricity replacement transactions do not change the total volume of electricity delivered and the delivery curve, we can carry out incremental spot

transactions between provinces to further improve the utilization rate of new energy by taking advantage of the surplus capacity of the channel between provinces.

## 5 Conclusions

As the scale of new energy power generation continues to expand, new energy power generation can be effectively allocated in a wider range through the construction of a large power grid. At present, China's trans-provincial transaction mechanism is still imperfect. Under the condition that the electricity composition of medium and long term physical contracts is determined, incremental spot transactions only will limit the further improvement of new energy absorption capacity. The electricity replacement transaction mechanism of the same channel designed in this paper can further increase the proportion of new energy electricity in the outgoing channel and improve the consumption and utilization level of new energy.

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