Quantitative Evaluation Model of Energy Saving and Emission Reduction Effect of Generation Right Transaction

Junhong Guo, Xiaohong Xue, Ling Li, Lu Xue* and Yongli Wang

1 State Grid Jibei Electric Power Company Limited, Beijing, 100053, China
2 North China Electric Power University, Beijing, 102200, China
*Corresponding author’s e-mail: xl1124213797@163.com

Abstract. The basic form and the process of power generation trading was introduced, also with the intention declaration model of power generation transaction and the transaction matching model were constructed. Then, a quantitative evaluation model of energy saving and the effect of emission reduction of power generation trading were built. Finally, through the example data of the power generation rights transaction declaration in Anhui province, the validity check results of the power generation rights transaction were analyzed, and the energy conservation and emission reduction effects of power generation rights trading were quantitatively evaluated. The results showed that power generation rights trading had significant energy saving and emission reduction effects, and had certain economic value and environmental protection value.

1. Overview of Power Generation Trading
Power generation trading mainly refers to the purchase or sale of generating capacity between generating sets. The object of power generation rights transaction is a right and indicator, different with the power generation plan in the traditional sense.

1.1 Process of Power Generation Transaction
Power generation trading is mainly carried out among thermal power units. The main flow of power generation rights trading is shown in figure 1.
Figure 1. Generation Rights Trading Process

2. Model Building

2.1 Model of Intention Declaration
For power generation right trading, the first thing to declare is the intended power and intended price. What the replaced party \( i \) declares is the reduced online power consumption \( Q_i \), so its power generation quantity \( q_i \) can be converted through its auxiliary power consumption factor \( r_i \). The substitute party \( j \) declares the increased on-grid electricity quantity \( Q_j \), so its power generation quantity \( q_j \) can be converted by its power consumption rate \( r_j \).

\[
q_i = \frac{Q_i}{(1 - r_i)} \quad (1)
\]

\[
q_j = \frac{Q_j}{(1 - r_j)} \quad (2)
\]

The declared price of the replaced party \( i \) is the intent price \( P_i \); the declared price of the substitute party \( j \) is the intended price \( P_j \). Let the transaction power between the replaced party \( i \) and the substitute party \( j \) be \( Q_{ij} \), and the corresponding transaction price is \( P_{ij} \). Therefore, the social utility of the transaction is shown in equation (3).

\[
U_{ij} = (P_i - P_j)Q_{ij} + (P_j - P_i)Q_{ij} = (P_i - P_j)Q_{ij} \quad (3)
\]

\[
P_{ij} = \frac{(p_i + p_j)}{2} \quad (4)
\]

2.2 Evaluation Model
According to the unit coal consumption data \( c_k \) and the power generation amount \( q_k \) of the replaced party \( i \) and the substitute party \( j \), the standard coal \( SC_k \) required to be used to generate the transaction power can be calculated in the \( k \)-th transaction, the expressions are: as follows.
According to the desulfurization efficiency $\eta$ of the unit and the sulfur content $s$ of the coal, the sulfur dioxide emission $E_{SO2}$ are: as follows.

$$E_{SO2,k} = SC_i \times s_i \times c \times (1 - \eta_k)$$  

(7)

$$E_{SO2,j} = SC_j \times s_j \times c \times (1 - \eta_j)$$  

(8)

$c$ represents the conversion coefficient of sulfur dioxide.

Then for the kth transaction pairing, the replaced party $i$ and the substitute party $j$ will issue the carbon dioxide emissions $E_{CO2}$ generated by the standard coal consumption, the expressions are: as follows.

$$E_{CO2,i} = 2.6SC_i$$  

(9)

$$E_{CO2,j} = 2.6SC_j$$  

(10)

2.3 Pairing Model

In order to ensure the maximum benefit of power generation trading, an improved social utility optimal model is proposed in this paper. The objective function of the model is

$$\max \sum_{i=1}^{n} \sum_{j=1}^{m} U_{ij}$$  

(11)

$n$ and $m$ represent the number of the replaced party and the substitute party. The constraints are: as follows.

$$SC_i > SC_j$$  

(12)

$$E_{SO2,i} > E_{jSO2}$$  

(13)

$$E_{CO2,i} > E_{jCO2}$$  

(14)

After forming a pairing result, the power trading institution is required to check the validity of the result. The verification process of the validity of power generation right trading is shown in figure 2.

3. Case Study

The actual data of power trading were taken as an example to verify and analyze the energy-saving and emission reduction effects of power generation right trading.
Table 1. The Replaced Power Plant Foundation and Declaration Data

| Basic Data | Number of Power Plant | Aqwj | Lheq | Lhyq | Tlsh | Gdtl | Hdlia |
|------------|-----------------------|------|------|------|------|------|-------|
|           | auxiliary power rate (%) | 5.11 | 6.95 | 6.82 | 7.74 | 4.75 | 8.82  |
|           | coal consumption (g/kwh) | 318.44 | 315.42 | 307.87 | 317.07 | 292.73 | 337.46  |
|           | desulfurization rate (%) | 96.75 | 94.99 | 95.85 | 95.36 | 90.23 | 90    |
|           | sulfur content (%) | 0.45 | 0.54 | 0.43 | 0.45 | 0.29 | 0.7   |
| Declared Data | declaration for electricity (mwh) | 20000 | 66000 | 75000 | 75000 | 75000 | 37000 |
|           | declared price (yuan/mwh) | 253 | 251 | 250 | 245 | 245 | 244   |

As a result, the deal produces the matching of power and the average price, the result as shown.

Table 2. The Substitute Power Plant Foundation and Declaration Data

| Basic Data | Number of Power Plant | Aqsq | Hsd | Hdw | Hdh | Aqsh | Gdbb |
|------------|-----------------------|------|-----|-----|-----|------|------|
|           | auxiliary power rate (%) | 4.2  | 5.35 | 4.67 | 4.73 | 4.2  | 4.63  |
|           | coal consumption(g/kwh) | 263  | 279.45 | 281.26 | 268.65 | 263  | 291.23  |
|           | desulfurization rate (%) | 99.78 | 96.88 | 95.3 | 98.8 | 99.78 | 97.56  |
|           | sulfur content (%) | 0.42 | 0.54 | 0.42 | 0.7 | 0.42 | 0.81  |
| Declared Data | declaration for electricity (mwh) | 140000 | 56000 | 75000 | 95000 | 105000 | 127000 |
|           | declared price (yuan/mwh) | 243 | 250 | 255 | 264 | 270 | 285   |

The results of energy conservation and emission reduction were obtained as shown in table 4.

Table 3. Transaction Matching Result

| Number | Number of Replaced Power Plant | Number of Substitute Power Plant | Volume of Electricity | Average Price of The Transaction |
|--------|--------------------------------|----------------------------------|-----------------------|----------------------------------|
| 1      | aqwj                           | aqsq                            | 20000                 | 248.00                           |
| 2      | lheq                           | aqsq                            | 66000                 | 247.00                           |
| 3      | lhyq                           | aqsq                            | 54000                 | 246.50                           |
| 4      | lhyq                           | hsdc                            | 21000                 | 250.00                           |
| 5      | tlsh                           | hsdc                            | 35000                 | 247.50                           |
| 6      | tlsh                           | hdwh                            | 40000                 | 250.00                           |
| 7      | gdtl                           | hdwh                            | 35000                 | 250.00                           |
| 8      | gdtl                           | hdwh                            | 40000                 | 254.50                           |
| 9      | hdlia                          | hdwh                            | 37000                 | 254.00                           |
| 10     | mece                           | hdwh                            | 18000                 | 253.50                           |
| 11     | mece                           | aqsh                            | 49500                 | 256.50                           |
| 12     | tlsh                           | aqsh                            | 55500                 | 255.50                           |
| 13     | tlsh                           | gdbb                            | 1500                  | 263.00                           |

The results of check trading reduction matching results obtained as shown in table 4.
To sum up, about 4.8 billion kwh of electricity generation rights trading was actually completed, 300,000 tons of standard coal was saved, 459 tons of sulfur dioxide emissions were reduced, and 790,000 tons of carbon dioxide emissions were reduced, resulting in remarkable results in energy conservation and emission reduction.

4. Conclusion
The paper expounds the process of power generation right trading in typical provincial market, and builds a quantitative evaluation model of energy saving and emission reduction effect of power generation right trading on this basis. With the power generation right example data, the paper verifies the validity of power generation right trading and the quantitative evaluation model of trading results. The example analysis results show that the power generation right trading model proposed in this paper has significant energy saving and emission reduction effects.

References
[1] Ling,C.Y., Wen,F.S., Meng,W.C, etal. (2016) Bilateral transaction negotiation model of power generation rights under two-part electricity price mechanism. J. Power construction. 37(3):90-98.
[2] Li,C.B., Kang,C.Q., Xia,Q., etal. (2003) Power Generation Trading and Its Mechanism Analysis.J. Automation of Electric Power Systems. 27(6):13-18.
[3] Chen,H. Research on Generation Rights Trading Model Considering Carbon Emission Constraints. D. Nanchang University, 2014.
[4] Shi,Q.S., Liu,K., Wen,M. (2017) Inter-provincial power generation transaction model based on blockchain technology. J. Power construction. 38(9):15-23.
[5] Tian,S. (2014) Generation Power Trading Model Based on Stakeholder Theory and Its Bidding Strategy. J. Power construction. 35(1):122-126.
[6] Zhang,X., Geng,J., Pang,B, etal. (2014) Application and Analysis of Power Li,X.P. Research on Compensation Mechanism of Desulfurization and Denitrification Electricity Price in Coal-fired Power Plants. D. North China Electric Power University, 2009.
[7] Generation Trading in China's Energy Saving and Emission Reduction. J. Automation of Electric Power Systems. 38(17):87-90.
[8] Yang,H.P., Peng,J.X., Wang,B.Y, etal. Multi-objective optimization of power generation rights trading based on performance energy saving and emission reduction. J. Hydropower Energy Science. 35(8):154.
[9] Chang,J.C. (2009) Theory and application of power generation trading based on energy saving and emission reduction. J. Automation of Electric Power Systems. 23(12):46-52.
[10] Wu,Y., Liu,J.Y., Gao,H.J., etal. (2016) Research on Wind Power Generation Trading Based on Risk Decision. J. Power grid technology. 40(3):833-839.