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Games Strategy Study of Power Generation and Carbon Emission Rights Trading

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ABSTRACT

It is of great significance to reduce carbon emissions from electric power generation for green development. In addition to technical measures, two trading mechanisms are built to optimize China's electric power generation: generation rights trading, and carbon emission rights trading. However, as the carbon emission rights trading are initiated, the issues of how to choose the right trading mechanism, and determining the appropriate strategy under the corresponding trading mechanism continue to confuse generation enterprises. In order to clarify these issues, the game theory was used to identify the proper trading strategies for generation enterprises under the two highly similar trade mechanisms. Results show that the two trading mechanisms are complementary to each other to some extent, and the generation enterprises should choose a proper trade strategy according to the endowment of generation prices, the technical abilities, the grid-loss price and the ratio of carbon-electricity conversion. The equilibrium solutions of trading scales and prices for the two trading mechanisms are mostly related to the endowments of generation prices. Generally, the buyers with higher endowments of generation prices should choose the carbon emission rights trading, and the buyers with lower endowments of generation prices can only benefit in generation rights trading. The bigger gaps between the endowments of generation prices of buyers and sellers are, the more likely the trade can be made and further result in a better environmental consequence. The conclusions provide suggestions to the government that, the grid-loss pricing and the ratio of carbon-electricity conversion could be used as key tools to regulate the market for both of the trade mechanisms.

INTRODUCTION

Global climate warming is a hot topic. From the "Kyoto Protocol" in 1997 to the 2016 Paris Agreement, and then to the Katowice Global Climate Conference in Poland in December 2018, countries have finally reached a consensus to take strong measures to reduce carbon emissions. In 2017, the national strategy of implementing green development with low carbon emissions was initiated by the Chinese government. However, the issue of a large quantity of carbon emissions, especially the large quantity of carbon emitted from power generation, is serious: According to a report released by the Global Carbon Project (GCP) at the Katowice Global Climate Conference, about 10.5 billion tons of carbon dioxide was emitted in 2018 by China, which ranked first in the world, and accounted for 27% of the global carbon emissions. In addition, according to China's National Energy Administration, the carbon emitted by power generation was about 4.1 billion tons in 2018, which accounted for 39% of China's carbon emissions. Therefore, it is of great significance to reduce carbon emissions from power generation in China.

In this context, the Chinese government began to restrict thermal power production, which led to a number of thermal generation enterprises producing much less than their designed capabilities. In this case, two trade mechanisms have been developed to optimize the electric power generation and to improve power generation efficiency: power generation rights trading, and carbon emission rights trading. Power generation rights trading was launched in 2007 (Zhang et al. 2014), while carbon emission rights trading was launched for the power generation industry in December 2017 (Du 2018).

The mechanisms of power generation and carbon emission rights trading are similar: Firstly, the commodities traded in the two mechanisms are the generation capability, which is the difference in the value between the initially endowed generation (or carbon emission) plans and the restricted generation (or carbon emission) plans. Secondly, in the two mechanisms, the generation (or carbon emission) plans are only allowed to be traded from the less efficient generators to the more efficient generators. Therefore, the two trade mechanisms can contribute to optimize power generation and reduce carbon emissions from power generation in China.

However, these two similar trade mechanisms have confused generation enterprises in recent years: Clarity around the issues of the choice of trade mechanism and proper trade strategy, is needed. This study focuses on these issues and provides strategy suggestions for power generation enterprises.

PAST STUDIES

Power generation rights trading is a unique trading type in China. Since it was launched in 2007, a number of studies have been undertaken by Chinese scholars: Shang (2009) proposed that, in the evaluation of power generation rights trading, the effect of carbon emission reduction should be included. Zhang et al. (2014) and Hu et al. (2017) summarized the achievements made by power generation rights trading in improving power generation efficiency and reducing carbon emitted by power generation. They found the achievements are remarkable.

With the development of power generation rights trading, scholars have also been concerned about the different detailed problems in the trade mechanism. For example, Zhang et al. (2013) discussed the mechanism of transaction prices, and the consequent cost changes. Zhou et al. (2017) focused on the transaction settlement and proposed the development of an information system to support the process from transaction to settlement. Wang et al. (2014) used the Aumann-Shapley method to study the problem of grid loss in the settlement of power generation rights trading.

In 2015, carbon emission trading was piloted in China, and some Chinese scholars studied the impact of carbon emission trading on power generation rights trading. For example, Huang et al. (2017) used game theory to analyse the generation enterprises' operation strategies under the generation rights trade mechanism with carbon emission constraints. Zhang et al. (2017) used the game theory to discuss the impacts of carbon constraints and found that generation prices are the key factors in the trade. Wei et al. (2015) argued that power generation rights trading can contribute to abating the imbalanced allocation of initial carbon emission rights. Moreover, in transaction strategy making, the generation enterprises need to take their own costs into account. Zhao et al. (2016) initially envisaged a combined trade model for generation rights and carbon emission rights. They found that, by using the carbon tax as a tool, transaction prices will tend to be reasonable.

Compared to China, the theory of carbon emission trading was proposed and studied earlier by international scholars, and these international studies mainly focus on the aspects of initial carbon emission rights allocation, the price mechanism and the economic benefit. For example, Hammoudeh et al. (2014) found that the prices in carbon emission trading are mostly affected by the prices of energy commodities. Specifically, the impact of the electricity price on the carbon price is positive, while the impact of the coal price on the carbon price is negative. Further, Menezes et al. (2015) found that coal prices would fall faster than carbon prices over the short term, and the impacts of electricity prices and coal prices on carbon prices are symmetrical. From the perspective of price policy, the study made by Li et al. (2014) showed that, for carbon abatement, a carbon tax is needed in the short term, while rigid electricity prices are also needed for the long term.

The economic benefits of carbon emissions trading are also reflected in the impact on generation enterprises' investments. According to the study made by Du et al. (2015), as the cost of carbon reduction is part of an enterprise's operation cost, the minimum social cost of carbon reduction would be achieved as all the enterprises seek minimum operation costs and maximum economic benefits. Some scholars also found that the price of carbon emission trading can be used to adjust investment in clean energy power generation for the purpose of stimulating investment into the renewable energy (Gujba et al. 2012, Wu et al. 2013).

The studies above not only show how the mechanisms of power generation and carbon emission rights trading are implemented in China but also show that the two mechanisms are effective in reducing carbon emitted by China's power generation. However, there are limited studies of the appropriate choice of trade mechanism or the proper trade strategy for generation enterprises. Based on the existing studies, this study uses game theory to describe how generation enterprises bid under the two trade mechanisms. By analysing the game equilibrium conditions under the two trading mechanisms, trade strategy advice for generation enterprises can be obtained.

METHODOLOGY

To some extent, the mechanisms of power generation and carbon emission rights enable generation enterprises in different regions to decide the scale and prices of trading. By using the information platforms for trades, buyers and the sellers can find or provide their trade needs dynamically. It can be assumed that the sellers provide their trade bids first, in which the quantities of commodities and the corresponding prices are included. Then the buyers search for the trade bids, and they only take the bids which can maximize their profits. If not, the buyers can also provide their trade needs online, and the sellers will decide whether to adjust their initial bids to fit the buyers' needs. The processes above are allowed to be repeated within limited times, and in this case, the sellers and buyers are negotiating though the trade information platforms. Thus, strategy study in the two trade mechanisms is transformed into study of the negotiation.

Game theory can be used to study negotiation problems in trading. In the negotiation game, participants negotiate for acceptable means to distribute profits. The game will continue until the negotiation is complete, or the time limit is reached. In the process, the participants are aware of the necessary information for the trades. Therefore, the negotiation game in the two trade mechanisms can be treated as a finite game with perfect information (Rowe 1985).

Hypothetically, A is the set of sellers, B is the set of buyers, and the deal is made by A_k and B_j (k and j are natural numbers indicating the serial number of the two sets). Before the trades, it is already acknowledged that the generation prices of A_k and B_j are P_{ak} and P_{bj}, respectively. The commodity quantity of A_k is X_{ak}. If A_k chooses the mechanism of generation rights trading, it will publish the bid as X_{ak} and P_{ck}, in which P_{ck} indicates the bid price. If A_k chooses carbon emission rights trading, the commodity quantity should be transferred as T_{ak}, and the bid published on the second information platform will be T_{ak} and P_{ek}, in which P_{ek} indicates the bid price.

The relationship between T_{ak} and X_{ak} is given by Equation (1):

$$T_{ak} = \eta_k \cdot X_{ak} \qquad ...(1)$$

Where, η_k indicates the "carbon-electricity" conversion coefficient, and is related to the generator capacity of A_k.

As there are some differences in the settlements of the two trade mechanisms, the different benefit functions will directly affect game strategies. According to the practices in China, the benefit functions are shown in Table 1.

In Table 1, U_{1ak} and U_{1bj} indicate the benefits A_k and B_j can receive from the generation rights trade, and U_{2ak} and U_{2bj} indicate the benefits A_k and B_j can receive from the carbon emission rights trade. N_{1kj} and N_{2kj} indicate the marginal cost of B_j if the deal was made. R_{kj} indicates the grid loss fee paid to the grid company, and r indicates the price of grid loss. In addition, X_{bj} ($X_{bj} \cdot \eta_j \le T_{ak}$) indicates the actual generation quantity of B_j and P_f indicates the price of the remaining carbon emission rights to be sold in the future. Usually, r and η_k will be set by the government as published information before trading.

According to some studies, the marginal cost of B_j can be described as

$$N_{1kj} = e_{xj} - q_{xj} \cdot X_{ak} + h_{xj} \cdot X_{ak}^2 \qquad ...(2)$$

Where, e_{xj}, q_{xj} and h_{xj} are the generator's technical indicators. As the marginal cost should not be negative, based on the extremum theory, the necessary conditions below should be fulfilled:

$$\begin{cases} e_{xj} > 0 \\ q_{xj} > 0 \\ h_{xj} > 0 \\ q_{xj}^2 \le 4 \cdot h_{xj} \cdot e_{xj} \end{cases} \qquad ...(3)$$

The grid company does not participate in the trade negotiations, and whether a deal can be reached depends on the expectations of buyers' and sellers' benefits. The following three assumptions are also required:

Assumption 1: It is necessary for a deal to be made such that the buyer and seller can both benefit from one of the trade mechanisms. This means that $U_{1ak} \ge 0$ while $U_{1bj} \ge 0$, or $U_{2ak} \ge 0$ while $U_{2bj} \ge 0$.

Assumption 2: If U_{1ak} < or $U_{1bj} < 0$, the generation rights trade will not be made, and similarly, if U_{2ak} < or $U_{2bj} < 0$, the carbon emission rights trade will not be made.

Assumption 3: If it is expected that $U_{1ak} > U_{2ak}$, A_k will only

Table 1: The benefit functions under the two trading mechanisms.

	Trading Mechanisms	
	Power generation rights trading	Carbon emission rights trading
A_k	$U_{1ak} = P_{ck} \cdot X_{ak}$	$U_{2ak} = P_{ek} \cdot T_{ak}$ $= P_{ek} \cdot X_{ak} \cdot \eta_k$
B_j	$U_{1bj} = (P_{ak} - P_{ck}) \cdot X_{ak}$ $- R_{kj} - N_{1kj}$	$U_{2bj} = P_{bj} \cdot X_{bj} - P_{ek} \cdot T_{ak}$ $+ (T_{ak} - X_{bj} \cdot \eta_j) \cdot P_f - N_{2kj}$
The power grid company	$R_{kj} = r \cdot X_{ak}$	0

choose the mechanism of generation rights trading, and B_j can only find the bid of A_k on the generation rights trading platform. If it is expected that $U_{1ak} < U_{2ak}$, then A_k will only choose the mechanism of carbon emission rights trading, and B_j can only find the bid of A_k on the carbon emission rights trading platform. If it is expected that $U_{1ak} = U_{2ak}$, the strategy to choose the trade mechanism is only dependent on the preference of A_k.

EQUILIBRIUM SOLUTIONS AND STRATEGY ANALYSIS

Based on the negotiation models built in Section 3, the trade strategies can be obtained by seeking the equilibrium solutions. The model solving method is backward induction.

Equilibrium Solution for Generation Rights Trade Mechanism

If the buyers and sellers do not cooperate: According to Equations (2) and (3), under the power generation trading mechanism, the income function of B_j can be expressed as Equation (4):

$$U_{1bj} = (P_{ak} - P_{ck} - r)\cdot X_{ak} - (e_{xj} - q_{xj}\cdot X_{ak} + h_{xj}\cdot X_{ak}^{2}) \quad ...(4)$$

The derivation of equilibrium solutions follows from the extreme condition, $\frac{\partial U_{1bj}}{\partial X_{ak}} = 0$, so that it can be found that:

$$P_{ck} = P_{ak} + q_{xj} - r - 2\cdot X_{ak}\cdot h_{xj} \quad ...(5)$$

Equation (5) provides the guidance of the proper bid for B_j in the generation rights trade, and A_k will publish its bid as Equation (5), as X_{ak} is already acknowledged by A_k.

If the ideal bid of X_{ak} and P_{ck} is taken by B_j, the benefit to B_j is given by Equation (6):

$$U_{1bj} = h_{xj}\cdot X_{ak}^{2} - e_{xj} \quad ...(6)$$

As $P_{ck} \geq 0$ and $U_{1bj} \geq 0$, it can be known that:

$$\sqrt{\frac{e_{xj}}{h_{xj}}} \leq X_{ak} \leq (\frac{P_{ak} + q_{xj} - r}{2\cdot h_{xj}}) \quad ...(7)$$

Equation (7) provides the guidance to A_k of the proper commodity quantity for a single bid. According to the assumptions in Equation (3) ($q_{xj}^{2} \leq 4\cdot h_{xj}\cdot e_{xj}$), the proper P_{ck} in the bid should be:

$$0 \leq P_{ck} \leq P_{ak} - r \quad ...(8)$$

In Equation (8), it is necessary that $P_{ak} \geq r$.

In summary, in the generation rights trade mechanism, if the buyers and sellers do not cooperate, and if Equations (5), (7) and (8) hold simultaneously, the negotiation can be made, and both the buyers and sellers can obtain the maximum benefits.

In addition, for rational strategy making, according to Equations (5), (7) and (8), the benefits of A_k are given by

$$U_{1ak} = P_{ck}\cdot X_{ak} = (P_{ak} + q_{xj} - r - 2\cdot X_{ak}\cdot h_{xj})\cdot X_{ak} \quad ...(9)$$

In addition, if $\max(U_{1ak})$ can be obtained when $\frac{\partial U_{1ak}}{\partial X_{ak}} = 0$, then the equilibrium solutions for the bid are

$$X_{ak}^{*} = \frac{P_{ak} + q_{xj} - r}{4\cdot h_{xj}}, P_{ck}^{*} = \frac{P_{ak} + q_{xj} - r}{2} \quad ...(10)$$

If the buyers and sellers cooperate: The cooperation relationship means that the buyers and sellers will not bargain for the trade price and scale, but the basis of the cooperation lies in the conditions for the maximum total return of both parties. The total benefit is given by Equation (11):

$$U_{1ak} + U_{1bj} = (P_{ak} - r)\cdot X_{ak} - (e_{xj} - q_{xj}\cdot X_{ak} + h_{xj}\cdot X_{ak}^{2}) \quad ...(11)$$

The equilibrium solution of Equation (11) can be obtained when $\frac{\partial (U_{1ak} + U_{1bj})}{\partial X_{ak}} = 0$:

$$X_{ak} = \frac{P_{ak} + q_{xj} - r}{2\cdot h_{xj}} \quad ...(12)$$

Equation (12) shows that in order to maximize the benefits of buyers and sellers, the transaction scale needs to match the technical parameters of the buyers.

Equilibrium Solution for Carbon Emission Rights Trade Mechanism

If the buyers and sellers do not cooperate: According to Equation (2), the benefit of B_j in the carbon emission rights trade mechanism is given by

$$U_{2bj} = P_{bj}\cdot\frac{T_{ak}}{\eta_j} - P_{ek}\cdot T_{ak} - (e_{xj} - q_{xj}\cdot\frac{T_{ak}}{\eta_j} + h_{xj}\cdot\frac{T_{ak}^{2}}{\eta_j^{2}}) \quad ...(13)$$

The equilibrium solution for Equation (13) is obtained when $\frac{\partial U_{2bj}}{\partial T_{ak}} = 0$, and the solution is given by

$$P_{ek} = \frac{P_{bj}}{\eta_j} + \frac{q_{xj}}{\eta_j} - \frac{2\cdot h_{xj}\cdot T_{ak}}{\eta_j^{2}} \quad ...(14)$$

It can be foreseen that A_k will publish its bid according to Equation (15), as T_{ak} is already acknowledged by A_k. Then, the benefit of B_j can be described as in Equation (15), according to Equations (13) and (14):

$$U_{2bj} = \frac{h_{xj} \cdot T_{ak}^{\ 2}}{\eta_j^{\ 2}} - e_{xj} \quad ...(15)$$

As it is necessary that $P_{ek} \geq 0$ and $U_{2bj} \geq 0$, it can be found that

$$\sqrt{\frac{e_{xj} \cdot \eta_j^{\ 2}}{h_{xj}}} \leq T_{ak} \leq \frac{P_{bj} + q_{xj}}{2 \cdot h_{xj}} \cdot \eta_j \quad ...(16)$$

According to Equations (14) and (16), it can be found that

$$0 \leq P_{ek} \leq \frac{P_{bj}}{\eta_j} \quad ...(17)$$

According to the solutions obtained in Equations (16) and (17), the benefits of A_k can be described as

$$U_{2ak} = P_{ek} \cdot T_{ak} = P_{ek} \cdot X_{ak} \cdot \eta_k = \frac{P_{bj}}{\eta_j} \cdot T_{ak} + \frac{q_{xj}}{\eta_j} \cdot T_{ak} - \frac{2 \cdot h_{xj} \cdot T_{ak}^2}{\eta_j^{\ 2}} \quad ...(18)$$

As it is necessary for the $\max(U_{2ak})$ that $\frac{\partial U_{2ak}}{\partial T_{ak}} = 0$, the equilibrium solutions are

$$\begin{cases} T_{ak}^* = \dfrac{P_{bj} + q_{xj}}{4 \cdot h_{xj}} \cdot \eta_j \\ P_{ek}^* = \dfrac{P_{bj} + q_{xj}}{2 \cdot \eta_j} \end{cases} \quad ...(19)$$

If the buyers and sellers cooperate: The cooperation relationship means that the buyers and sellers will not bargain for the trade price and scale, but the basis of the cooperation lies in the conditions for the maximum total return of both parties. The total benefit is given by Equation (20):

$$U_{2ak} + U_{2bj} = P_{bj} \cdot X_{bj} - (e_{xj} - q_{xj} \cdot \frac{T_{ak}}{\eta_j} + h_{xj} \cdot \frac{T_{ak}^{\ 2}}{\eta_j^{\ 2}}) \quad ...(20)$$

The equilibrium solution is obtained when $\frac{\partial (U_{2ak} + U_{2bj})}{\partial T_{ak}} = 0$:

$$T_{ak} = \frac{P_{bj} + q_{xj}}{2 \cdot h_{xj}} \cdot \eta_j \quad ...(21)$$

Equation (21) shows that in order to maximize the benefits of both buyers and sellers, the transaction scale needs to match the technical parameters of the buyers.

Strategy analysis

According to the assumptions set in Section 3, and the equilibrium solutions obtained above, the issues of which trade mechanism should be chosen, and how to publish (or take) the bid in the corresponding trade mechanism are as following:

Firstly, if one of the Equations (5), (7), and (8) is not true, then B_j will not choose the generation rights trade. Further, A_k will also not choose the generation rights trade. The bid strategy for the carbon emission rights trade is as shown in Equations (14), (16), (17) and (19).

Secondly, if one of the Equations (14), (16), and (17) is not true, then B_j will not choose the carbon emission rights trade, Further, A_k will also not choose the carbon emission rights trade. The bid strategy for the generation rights trade is as shown in Equations (5), (7), (8) and (10).

Thirdly, if equations (5), (7), (8), (14), (16), and (17) are all true, the buyers and sellers are facing the issue of trade mechanism selection.

A_k will first chooses the trade mechanism by comparing benefit expectations, according to Equations (9) and (18), which is a comparison of the equilibrium conditions. It can be found that if $P_{ak} - r > P_{bj}$, both A_k and B_j will choose the generation rights trade. If $P_{ak} - r < P_{bj}$, both A_k and B_j will choose the carbon emission rights trade. If $P_{ak} - r = P_{bj}$, the strategy of trade mechanism selection is dependent on the buyer's or the seller's preference. When the trade mechanism is chosen, the trade strategy for the corresponding trade mechanism can be known from Equations (5), (7), (8) and (10), or Equations (14), (16), (17) and (19).

CONCLUSIONS

This study uses game theory to explore the issues of how to select the proper trade mechanism, and the choice of proper trade strategy in the corresponding trade mechanism. According to the equilibrium solutions and strategy analysis obtained in this study, power generation enterprises should choose the proper trade strategy according to the endowments of generation prices, the technical abilities, the grid-loss price and the ratio of carbon-electricity conversion. Moreover, grid-loss pricing and the ratio of carbon-electricity conversion could be used as the key tools to regulate the market for both of the trade mechanisms.

REFERENCES

Du, J.G. 2018. China's carbon emission rights trade market is launched. Ecological Economy, 34(3): 10-13.

Du, L., Hanley, A. and Wei, C. 2015. Marginal abatement costs of

carbon dioxide emissions in China: A parametric analysis. Environmental and Resource Economics, 61(2): 191-216.
Gujba, H., Thorne, S., Mulugetta, Y., Rai, K. and Sokona, Y. 2012. Financing low carbon energy access in Africa. Energy Policy, 47(supp-S1): 10-20.
Hammoudeh, S., Nguyen, D.K. and Sousa, R.M. 2014. Energy prices and CO_2 emission allowance prices: A quantile regression approach. Energy Policy, 70: 201-206.
Hu, W.D., Gu, Y.G., Xu, L. and Li, Z.B. 2017. 2016 Annual report on power trading. Electric Power, 50(4): 35-38.
Huang, S.J. and Yang, J. 2017. Game analysis of mitigation tournament considering generator heterogeneity in Duopoly electricity market. Chinese Journal of Management Science, 25(12): 68-77.
Li, J.F., Wang, X., Zhang, Y.X. and Kou, Q. 2014. The economic impact of carbon pricing with regulated electricity prices in China: An application of a computable general equilibrium approach. Energy Policy, 75: 46-56.
Menezes, L.M.D., Houllier, M.A. and Tamvakis, M. 2015. Time-varying convergence in European electricity spot markets and their association with carbon and fuel prices. Energy Policy, 88: 613-627.
Rowe, G.W. 1985. Mutations, mixed strategies and game theory. Journal of Theoretical Biology, 117(2): 291-302.
Shang, J.C. 2009. Generation Right. Exchange theory and its applications based on energy-saving and emission-reducing part one generation right exchange theory. Automation of Electric Power Systems, 33(12): 46-52.
Wang, Z., Liu, C.H., Wei, Z., Yuan, S.Q., Yuan, Z.C. and Wang, Y. 2014. Losses allocation resulting from generation rights trade based on superposition principle and Aumann-Shapley method. Power System Protection and Control, 2: 13-22.
Wei, Q., Zhang, Z.Y. and Wang, L.L. 2015. Experimental research on carbon emission trading of electricity industry and enterprises' strategy. Soft Science, 29(11): 115-118.
Wu, N., Parsons, J.E. and Polenske, K.R. 2013. Impact of future carbon prices on ccs investment for power generation in China. Energy Policy, 54(8): 160-172.
Zhang, J.H. and Li, W. 2013. Research on price strategies of power generation rights trade based on game theory. Technoeconomics & Management Research, 9: 9-13.
Zhang, X., Geng, J., Pang, B., Xue, B.K. and Li, Z. 2014. Application and analysis of generation right trade in energy-saving and emission reduction in China. Automation of Electric Power Systems, 17: 87-90.
Zhang, X.H., Lu, C.H. and Chen, Z.W. 2017. Analysis on carbon abatement investment strategy for thermal power generation-companies in carbon dispatching mode. Chinese Journal of Management Science, 25(11): 179-188
Zhao, W.H., Lin, M.X. and Gao, J.Q. 2016. Combined transaction model of generation right and carbon emission right under the power market mechanism with renewable energy considered. Advances of Power System & Hydroelectric Engineering, 32(11): 1-8.
Zhou, M., Yan, Y., Ding, Q., Wu, Z.Y., He, Y.H. and Long, S.Y. 2017. Transaction and settlement mechanism for foreign representative power markets and its enlightenment for Chinese power market. Automation of Electric Power Systems, 41(20): 7-14.