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Game Model Analysis on Government and Power Enterprise Collaboration in Power Security Work

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Abstract: Electric power energy is a kind of basic energy. Its security problem is of great importance. Power energy security work should be accomplished by both government and power enterprises. The paper first analyses the necessity for government and power enterprises collaboration on power energy security work. Then introduces game theory to establish a cooperative game model for government and electric power enterprises. Some in-depth analysis on the cooperative game model is developed. Based on the game model, the paper further discusses the strategies that government and electric power enterprises should adopt in the power energy security work, and the condition to achieve game equilibrium. It provides theoretical references for power system risk security work between government and electric power enterprises in the future.

Keywords: power energy security; game theory; risk assessment; government regulation

1 Introduction

To ensure power system security is a very complex system engineering project. It not only need advanced simulation as well as accurate analysis and calculation, but also need powerful law and regulation, proper management mechanism, scientific technical standard and appropriate structured power grid.

For a long time, researchers had concentrated on traditional stability analysis and technology a lot. Recently the probabilistic analysis model and algorithm were also introduced as a complementary method to ensure system security. However, the occurrence of various global catastrophe caused power system blackout accidents indicated that previous system security analysis method which only stayed at the technical level was not enough. In addition to continue with the existing analytical methods, we also have to establish a kind of power system risk assessment mechanism. The new risk assessment mechanism should be participated by governments, electric power enterprises and users. In the mean time it should be placed under the corresponding policy constraints to ensure its effects [1,2].

This paper carried out a detailed analysis of power system risk assessment work cooperated by government and electric power enterprises using game theory. Some conclusions and suggestions to improve China's power system security risk assessment work were given in the end, which can provide important reference for future electric power system security risk assessment work.

2 Necessity for Government and Electric Power Enterprise Cooperation in Power System Security Work

Power system security risk assessment work was generally carried out by electric power enterprises alone to ensure the enterprises' safety production in the past. However the power system accidents happened frequently around the world has shown that the existing power system stability analysis and the newly developed probabilistic risk assessment method was still not enough. Facts indicate that even if the system fully satisfied the requirements of traditional stability analysis (such as N-X principle); the system is still unable to avoid the occurrence of blackout [3]. To rely on traditional power system protective equipment and adjusting operation mode as the system defence line is not the fundamental way to solve the problem of large area blackout. At this new historical stage, new ideas and methods must be introduced to solve the problem. Therefore, the paper proposes a new power system security risk assessment system that should be cooperated by government and electric power enterprise. The new risk assessment system is built from practical point of view to prevent power system large area blackout. And it can assess and supervise the potential risks in the power industry.

Power system security risk assessment work must be cooperated by government, electric power enterprises and users. This is because:

1) Power industry itself is a public utility. As a kind of basic recourse, the security problem requires the government and society-wide consensus and cooperation [2,3].

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2) The purpose of the government-led power system security risk assessment system is quite different with the power enterprise self-led risk assessment system. For electric power enterprises, they generally focused on technical points to ensure system stability and maintain the company image. For government, the major concern is to protect the people's livelihood and social welfare to the greatest extent and prevent large area blackout.

3) Government-led power security risk assessment system is not simply guiding the enterprise's own electric power safety production, but rather analyses, assesses and supervises the power supply risks and treats it as the basic issue of energy security problem.

In whole, the government-led power system security risk assessment mechanism is not simply a technical work, but rather a series of security supervision and assessment action plan. That is to say, the government-led risk assessment system would not concentrated on the technical details within the enterprise to ensure the system stability (such as adjusting the power grid operation mode or protective relay equipment configuration), but rather develop and propose a security risk management and control requirements for electric power enterprises from the large area blackout prevention point of view.

3 Introduction of Game Theory in Cooperation between the Government and Power Enterprises

Game Theory was first founded by Von Neumann (1903-1957), although the research on the game theory related problem can be traced back to the 19th century or even earlier. Game theory studies the general principles that explain how people and organizations act in strategic situations. There are two main branches of game theory: cooperative and noncooperative game theory. Generally speaking, the basic elements of game theory are listed as follows [4–7].

1) Players. This refers to the individual who make decisions. The goal of each player is to maximize their own utility by selecting a variety of actions.

2) Action. It refers to the decision variables of a player at a time point in the game.

3) Information. In game model, it was generally expressed by information set. It refers to the collection set that the players think the game may have reached the point.

4) Strategies. It refers to a complete set of procedures with regard to players' behavior. It tells the player how to act under every foreseeable circumstance.

5) Payoffs. It refers to the measured profits or losses of the players after they have taken some action.

6) Outcome. It means after the game, the model constructor would select a collection of elements in action, payoffs and other elements the modeller is interested in.

7) Equilibrium. It refers to the strategy that the players choose to maximize their own payoffs.

A description of a game includes: players, strategies, payoffs, actions, information, *et al*. Among these, players, action and outcome are together called Rules of the Game. The modeller's purpose is to determine the equilibrium by the use of game rules.

From the game point of view, government and the electric power enterprises meet all the basic elements required by game [6,7]. Therefore we establish the game model between government and electric enterprises as follows.

The players of the model are supposed to be the "government" who represents the maximized social welfare and "electric power enterprise" that provides power supply service. Government, as the representative of the social welfare, would inspect and supervise the electric power enterprises.

This model abstracts the relationship between government and electric power enterprises as regulation and being regulated. It eliminated the need for principal-agent relationships within the government. In the model, assume the action set of power enterprises is A1= {implement risk management satisfying government expectation, not implement risk management satisfying government expectation}. The action set of government is assumed to be A2={effective supervision, not effective supervision}. In addition, the information in the model is assumed as complete information. That is to say each player knows exactly what action would the other player take.

It should be clear that government and electric power enterprise have different angles in power system risk assessment. Although electric power enterprise would also take some kind of security risk management measures to maintain the system stability as well as its own image, but the power enterprise would generally conduct these risk management measures giving priority to system stability. On the other hand the government would give priority to ensuring users' power supply. Because of this fundamental difference, although power enterprises have taken some kind of security risk management measures, the key lies in whether the enterprise have taken the risk management measures that meet the government requirement. This is why the paper makes the power enterprise action set A1 to be "satisfy" or "not satisfy" the government expectation. Figure 1 shows the game model between government and electric power enterprise.

The payoff of government supervision is assumed as follows. The cost for government supervise enterprise is C. The profit that the government would enjoy from enterprise safety production is P. If the government supervise the enterprise carefully, the profit that the government get would be $P-C$. If blackout accident happened in power enterprise, the image damage to government would be D.

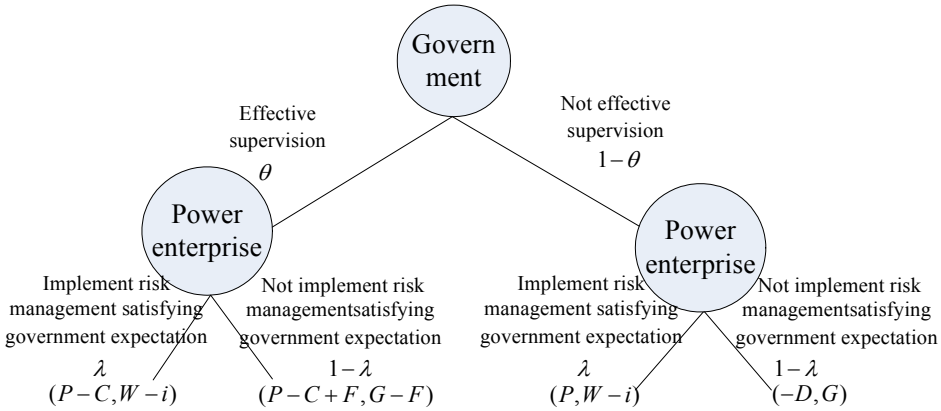

Figure 1. Game model between government and electric power enterprise

The payoff of electric power enterprise is assumed as follows. The input that the power enterprise expands for safety production is i. The income of power enterprise when it takes risk management measures satisfying government expectation is W. The income of power enterprise when it doesn't take risk management measures that satisfies government expectation is G. Generally $G > W$ as the enterprise must arrange some capital investment if it takes the risk management measures that satisfies government expectation. Once the enterprise is found that it doesn't take the risk management measures at government expectation, a fine would be charged to the power enterprise represented as F.

Under the above assumptions, the game matrix can be set up as shown in Table 1.

Table 1. Game matrix between government and electric power enterprises

Enterprises / Government	Implement risk management satisfying government expectation(λ)	Not implement risk management satisfying government expectation($1-\lambda$)
Effective supervision(θ)	$P-C,W-i$	$P-C+F,G-F$
Not effective supervision($1-\theta$)	$P,W-i$	$-D,G$

4 Analysis and Discussion on the Game Model between Government and Power Enterprise

It is generally recognized that power enterprises gives priority to the system stability. Although sometimes they also take action to ensure users' profit but the default priority is system. That means as long as there is any opportunity, the enterprise would tend to ensure system stability rather than taking risk management measures satisfying government expectation to ensure users' power supply. This constitutes a strict game relationship.

In Table 1, we use θ to represents the probability that government take effective supervision on power enterprises while $1-\theta$ means the probability that government doesn't take effective supervision. Similarly, λ refers to the probability that power enterprise implements risk management satisfying government expectation while $1-\lambda$ means the enterprise doesn't implements the risk management satisfying government. Solve the game's mixed strategy is to seek the Nash equilibrium of the game.

Given λ, the expected utility of effective supervision or not effective supervision is the same for the government, as in

$$\lambda(P-C)+(1-\lambda)(P-C+F)=\lambda P+(1-\lambda)(-D) \quad (1)$$

$$\lambda=1-\frac{C}{P+F+D} \quad (2)$$

Given θ, the expected utility of risk management satisfying government expectation or not satisfying government expectation is the same for electric power enterprises, as in

$$\theta(W-i)+(1-\theta)(W-i)=\theta(G-F)+(1-\theta)G \quad (3)$$

$$\theta=\frac{G-W+i}{F} \quad (4)$$

Therefore, the mixed strategy of Nash equilibrium is:

$$\lambda=1-\frac{C}{P+F+D} \quad (5)$$

$$\theta=\frac{G-W+i}{F} \quad (6)$$

We use geometric figures to explain the above mixed strategy of Nash equilibrium as follows. Figure 2 explains the strategies chosen by government and Figure 3 shows the power enterprise strategic choices. In Figure 2, the longitudinal axis means expected utility that the enterprise doesn't implement the risk management satisfying government expectation. And the lateral axis

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means the probability of the government supervision. Suppose the expected utility of the enterprise not implement the risk management satisfying government expectation is V, then

$$V = \theta(G-F)+(1-\theta)G = G-\theta F \quad (7)$$

From Figure 2 we can see that during the process that point M moves to point N, if the probability of government supervision is greater than θ_1, and then the expected utility of the enterprise would decrease. Thus the power enterprise would choose the strategy of "implement risk management satisfying government expectation". When increasing the penalty to punish the enterprise not implementing risk management satisfying government expectation, the enterprise' expected utility would decrease. Thus the government would decrease the supervision probability. In the long run, the government's less supervision would lead to the power enterprise tend to not implement risk management satisfying government expectation, and this would finally pull the government supervision probability back to θ_1.

In Figure 3, the longitudinal axis represents the expected utility that government carry out supervision and the lateral axis means the probability that the power enterprise choose to implement the risk management satisfying government expectation. During the process of point K moves to point L, the probability of power enterprise choose to implement the risk management satisfying government expectation increase thus the expected utility of government decreases. Then the government would tend to choose not to supervise. In the long run, the decrease of government supervision would make the power enterprise tend to choose not implement risk management satisfying government expectation. This would finally pull the probability of enterprise implementing risk management satisfying government expectation back to λ_1.

Through analysis of the game model, some conclusions can be drawn as follows.

1) There is a strict game relationship between government and electric power enterprise. Through selecting different strategy, the government and enterprise can achieve equilibrium.

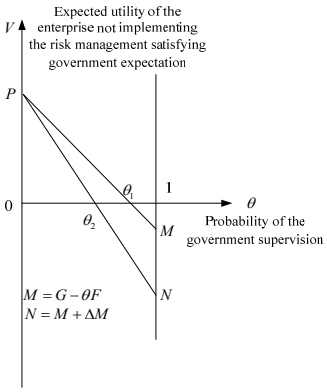

Figure 2. Strategy selection of government supervision

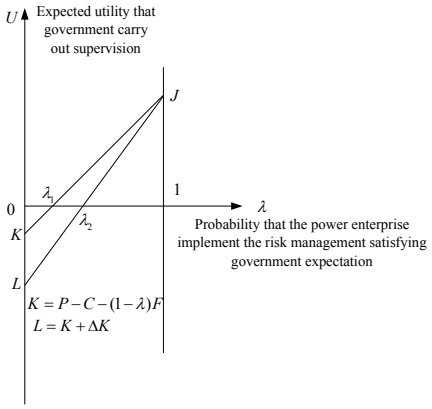

Figure 3. Strategy selection of power enterprise

2) To increase the punishment intensity to power enterprises not implementing risk management satisfying government expectation can decrease the necessity of government supervision. In the mean time the probability of enterprise implementing the risk management satisfying government expectation would increase.

3) When government utility increase, or the damage from power industry accidents increase, then the probability of the power enterprise implementing risk management satisfying government expectation would increase.

4) When the profit difference between enterprise not implementing risk management satisfying government expectation and enterprise implementing risk management satisfying government expectation increase, the government supervision to enterprise should increase.

5 Conclusion and Suggestions

In conclusion, the power security problem is a complex system project and of great importance. Based on the game model, the authors would give the following suggestions to improve the power system security risk assessment work in China in the future.

1) As a kind of basic recourse, electric power system security work is very complex and requires the government and society-wide consensus and cooperation.

2) The game equilibrium between government and power enterprise can be achieved by selecting different strategies. The strategy selection can be specified by power system risk assessment terms.

3) Improve the risk management system and strengthen the security risk supervision intensity is necessary. As an important lifeline of national economy, power industry has a great impact on the national security. Therefore government should intensify the supervision intensity to power enterprises. Increase the punishment intensity to enterprise which doesn't implement the risk management satisfying government expectation would guide the power enterprise correct their strategy and improve the risk management process. In the mean time this can also make power enterprise increase the probability to implement the risk management satisfying government expectation and

decrease the cost and probability of government supervision.

4) Government supervision cost money. Therefore the government should take all kinds of incentives and guidance measures to increase the power enterprise self investment on risk assessment management measures and decrease government supervision cost.

References

[1] U. S. Department of Energy Office of Energy Assurance. Vulnerability assessment methodology electric power infrustructure, 2002.

[2] H. Hou, "Coping with Catastrophe Power Security Risk Assessment and Emergency Disposal System," Ph. D. dissertation, College of Electrical and Electronic Engineering, Huazhong Univ. of Sci. & Tech., Wuhan, China, 2009.

[3] Wenyuan Li. Risk assessment Of Power Systems: Models, Methods, and Applications, New York: Wiley-interscience, 2004.

[4] Drew Fudenberg, Jean Tirole. *Game theory,* Cambridge: The MIT press, 1991.

[5] Martin J. Osborne, Ariel Rubinstein. A course in game theory. Cambridge: The MIT press, 1994.

[6] Ferrero, R. W., Shahidehpour, S. M., Ramesh, V. C. Transaction analysis in deregulated power systems using game theory. IEEE Transactions on Power Systems, Vol. 12, No. 3, pp. 1340-1347, Aug 1997.

[7] Singh, H. Introduction to game theory and its application in electric power markets., IEEE Trans. on Computer Applications in Power, Vol. 12, No. 4, pp. 18-20, Oct 1999.

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