The Risk Identification, Analysis and Assessment of China’s Power System Under the Electricity Reform Environment

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Abstract. The new round of electricity reform in China will fundamentally change the current pattern of the power industry in terms of production, management and operation. During the process of power system reform, the security of the power system will face more risk challenges than ever before. This paper will first identify new risks of the power system in China under the new situation of electricity reform, and then analyses and evaluate these new risks. The major new risks are also specifically emphasized.

Keywords: Risk Analysis, Risk Assessment, Electricity Reform.

1. Introduction
On March 16, 2015, the State Council of China issued the "Several Opinions on Further Deepening the Reform of the Electric Power System" (referred to as Zhongfa No. 9), marking the start of a new round of power system reform that has attracted attention from the public. With the implementation of the power system reform, the power system in China will face new problems and new challenges, such as the increase of risk resources, the diversification of security subjects, the adjustment of security interfaces and responsibilities. The security risks will not be limited to security and operational risks of the physical system and power supply quality risks, the operational risks of electricity market will also be added into the power system.

In the past, the power industry in China has formed a relatively stable order and penetrated into all aspects of the national economy. This round of market-oriented reform in power industry will re-adjust the interest pattern of market entities, and inevitably affect the safety of all links of power production. How to identify and evaluate the new security risks that may arise after market-oriented reforms, and how to manage and avoid potential security risks is related to the operational efficiency and order of the market, and even determines the effectiveness of the reform to a large extent.

The process of risk quantitative analysis generally includes risk identification, risk analysis, and risk assessment. Therefore, the research idea of this paper is to identify, analyze and evaluate the new risks of the power system under the electricity reform according to the general process of risk quantitative analysis.

1) Risk Identification
According to the new requirements of the new round reform, this paper will sort out various specific power reform tasks, systematically classify potential and existing power system new risks, and identify the factors, nature and consequences of the risks.
2) Risk analysis

This paper will analyze and investigate the various risk events and possible causes of new risk sources in the power system based on the perception of risks, and also examine the status of potential risks. In this way, a systematic investigation and understanding of the risks, including nature, type, and possible consequences and losses of the risks, can be achieved, so as to enable decision makers to enhance the perception and recognition of risks.

3) Risk assessment

In the risk assessment stage, this paper will estimate and measure the probability of the existence and occurrence of new risks in the power system, and the scope and extent of losses in the reform transition period and the mature period. The risk proof method is adopted in the risk assessment method. According to the results of the risk assessment, it is determined that the new power system risk points need to be paid attention to in the process of power system reform.

2. The Identification and Analysis of New Risks in Power Industry

Based on the relevant documents and reform progress of the new round electricity reform, the new risks of power system security are identified from the main aspects of the reform such as transmission and distribution tariff, wholesale and retail power market construction.

2.1. New Security Risks arise from Transmission and Distribution Tariff

With the advancement and deepening of electricity reform, China will establish an independent electricity transmission and distribution tariff system with clear rules, reasonable level, and effective supervision. At the same time, the restriction and incentive mechanism for power grid enterprises will be improved to promote power grid enterprises to improve management, reduce costs and improve efficiency. According to the policy and trend of China's electricity transmission and distribution tariff reform, the main new risks of power system security may be faced with are as follows:

1) The risk of grid security cost recovery. Due to strict Electricity transmission and distribution prices are subject to strict supervision, and some safety costs may not be recovered through electricity prices.

2) The risk of insufficient investment for power grid. The low pricing of transmission and distribution tariff lead to insufficient investment in the power grid and slow construction in local areas.

3) The risk of reducing investment for power system reserve. After the power system reserve is included in tariff supervision, it may lead to reduction of reserve investment and affect the safety of power system.

2.2. New Security Risks arise from Wholesale Market Construction

With the construction of wholesale electricity market, power trading mechanism and the opening of power generation and utilization plan, the power system has changed from the traditional planning mode to the market-oriented mode, and the security of power system is facing the following new risks. In terms of power market design:

1) The risk of insufficient generation capacity adequacy. Due to the huge investment and long construction period of power plants, the adequacy of generation capacity may be insufficient in the power market environment, which may threaten the security of power grid in emergency.

2) The risk of insufficient transmission capacity adequacy. Great changes have taken place in the operation mode of power system in the market environment, which puts forward higher requirements for the transmission capacity of lines and power grid and easily leads to insufficient transmission capacity and affects the security of power grid.

3) The risk of peak regulation and lack of auxiliary services. In the future, organizing peak regulation and auxiliary service market according to market rules will increase the complexity of power grid operation and control and increase the security risk of power system.

In terms of system operation:
(1) The risk of aggravating structure contradictions in power grid. The large-scale market-oriented electricity trading will lead to the uncertainty of power flow and aggravate the structure contradiction of power grid.

(2) The risk of uncoordinated generation-network operation. Under the environment of power market, the coordinated operation of power generation and grid needs market means. Thus, the difficulty of coordination and the security risk of the power system are both increased.

(3) The security risk of market manipulation. Some power generation enterprises may form market monopoly, leading to the collapse of the power market, and eventually lead to power system safety accidents.

(4) The risk of power grid dispatch and operation. The increase of power trading will increase the uncertainty of power flow, which may lead to transmission congestion, voltage collapse and instability, and there are risks in the regulation and operation of power grid.

(5) The risk of independent operation of power trading exchange. The boundary between the power trading exchange and the dispatching unit is not clear, and there are risks in the coordinated operation.

(6) The risk of rigid implementation of maintenance plan. The arrangement of maintenance plan needs to be adjusted, and the implementation of the plan has the risk of uncertainty.

(7) The risk of information security. The diversity of market entities and the integration of various terminals to the power grid information system increase the information security risk.

In terms of large-scale development of new energy and grid integration:

(1) The risk of uncoordinated new energy and power grid planning. The lack of unity of new energy planning and power grid planning will affect the system security from the grid structure.

(2) The security and stability risk of large-scale new energy integration. The output of new energy generation has volatility and uncertainty, large-scale grid integration may cause the safety and stable problem of power system.

2.3. New Security Risks arise from Retail Market Construction

The construction of retail market includes incremental distribution system and deregulation of retail market, which is one of the core contents of this round electricity reform. From the overall requirements of Zhongfa No.9 document and supporting documents, the deregulation of the retail market will change the traditional marketing mode of power grid enterprises, and introduce the competition of multiple power retail entities, while the liberalization of incremental distribution investment encourages social capital to invest in distribution business. The main new risks of power system security are as follows:

(1) The structural risk of uncoordinated distribution and transmission network. The difficulty for overall planning of distribution network is increasing, which is easy to cause problems such as uncoordinated transmission and distribution, unreasonable construction timing and so on.

(2) The risk of repeated construction and cross feed of distribution network. Repeated construction and cross feed will disturb the normal power supply and consumption order and seriously affect the safe operation of power grid.

(3) The risk of safety responsibility interface and responsibility division of power distribution and retail. The relationships among power grid enterprises, power generation enterprises, power sales companies, power distribution companies, and market-oriented users and non-market users are not clear.

(4) The risk of unified dispatching of incremental distribution network. The independent distribution network dispatching will increase the coordination cost with the main network, reduce the dispatching efficiency to a certain extent, and affect the security of the power grid.

(5) The risk of faulty equipment in distribution network. Some distribution network operators may not update or build equipment on time for the purpose of pursuing interests, which seriously affects the system security.

(6) The risk of safety management for electricity users. Due to the absence of safety management of users, it is difficult to implement the responsibility for safe use of electricity.
(7) The risk of rapid development of distributed energy. Due to the power flow reversal, the risk for
distribution network security has been increased.

(8) The risk of power generation enterprises provides special distribution network for users. The
construction of special network in power plants directly supplies power to nearby users, which
disturbs the normal power supply and consumption order and poses a threat to the safe operation of the
power system.

(9) The risk for distribution network and load coordination operation. The entities in the retail
market has been diversified, and the coordination for the distribution network and load is more
difficult.

3. The Assessment of New Risks in Power Industry
Risk assessment is to estimate and measure the probability of risk occurrence, the scope and degree of
loss. On the basis of the identification and analysis of the new risks in the power system, this section
will analyze the possibility, impact degree and impact time of the new risks in the power system, and
provide the basis for proposing countermeasures for the subsequent risks.

There are a large number of technical methods and tools for risk assessment. The risk assessment
techniques based on expert knowledge have wide application scenarios, low requirements for
operators' mathematical analysis, and most of the operation processes are simple and fast. In the risk
assessment technology based on expert knowledge, the method of risk matrix has the characteristics of
simple operation, strong practicability and wide application. Therefore, the risk matrix method is used
to quantitatively evaluate the new risks of power system under the new situation.

The process of risk matrix assessment is divided into three steps. One is to determine the criteria
for risk assessment. Second, each expert independently evaluates the risk probability and risk
consequence. The third is to average value of risk probability and risk consequence of each risk by
statistical experts, and the experts discuss and reach an agreement. Finally, the risk matrix is formed
after the experts discuss and agree.

(1) Determination of Risk Assessment Criteria
This paper made the following hierarchical definitions of risk probability and risk consequence
according to the definition of risk matrix by Australian National Standards Association.

The probability of risk occurrence: 1 means rare, 2 is unlikely, 3 is possible, 4 is likely, and 5 is
almost certain.

The degree of risk consequence: 1 indicates insignificant, 2 indicates minor, 3 indicates moderate,
4 indicates major, and 5 indicates catastrophic.

At the same time, the power system reform is a dynamic process. In different stages of reform, the
risk probability and risk consequence of various risks may also change. Therefore, the evaluation of
risk probability can be divided into two stages: the transition period and the mature stage.

The transitional period of reform: the power market is still in the process of establishment, with
the coexistence of market and plan, and relatively imperfect market mechanism.

The mature period of reform: the power market is relatively mature and the market mechanism is
basically established.

(2) Expert Evaluation
We have invited several experts to independently evaluate the risk probability and risk
consequences in the transition period and mature stage of reform. After statistics and calculation, the
risk assessment results are shown in the table below.
Table 1 Assessment Table for New Risks in Power System under the Electricity Reform

| No. | Name of Risk                                                      | Transitional Period | MATLAB Period |
|-----|------------------------------------------------------------------|---------------------|--------------|
|     |                                                                  | Probability | Consequences | Probability | Consequences |
| 1   | The risk of grid security cost recovery                          | 3.92        | 3.18         | 2.12        | 1.89         |
| 2   | The risk of insufficient investment for power grid               | 2.12        | 2.78         | 3.15        | 3.75         |
| 3   | The risk of reducing investment for power system reserve         | 2.76        | 2.33         | 2.87        | 3.56         |
| 4   | The risk of aggravating structure contradictions in power grid   | 3.82        | 3.78         | 1.25        | 3.85         |
| 5   | Risk of insufficient generation capacity adequacy                | 1.21        | 3.12         | 3.56        | 3.15         |
| 6   | The risk of insufficient transmission capacity adequacy          | 2.02        | 2.93         | 4.22        | 3.90         |
| 7   | The risk of peak regulation and lack of auxiliary services       | 3.83        | 3.02         | 1.03        | 3.79         |
| 8   | The risk of uncoordinated generation-network operation          | 3.06        | 3.59         | 1.21        | 3.51         |
| 9   | The security risk of market manipulation                         | 3.31        | 3.76         | 1.33        | 3.72         |
| 10  | The risk of power grid dispatch and operation                    | 3.45        | 3.81         | 2.51        | 3.79         |
| 11  | The risk of independent operation of power trading exchange      | 3.85        | 2.32         | 1.25        | 3.48         |
| 12  | The risk of rigid implementation of maintenance plan             | 4.12        | 3.25         | 1.12        | 3.15         |
| 13  | The risk of information security                                 | 1.05        | 3.89         | 3.28        | 3.90         |
| 14  | The risk of uncoordinated new energy and power grid planning     | 3.62        | 2.98         | 1.54        | 2.86         |
| 15  | The security and stability risk of large-scale new energy integration | 3.18   | 3.52         | 3.25        | 3.42         |
| 16  | The structural risk of uncoordinated distribution and transmission network | 2.89   | 3.72         | 1.43        | 3.78         |
| 17  | The risk of repeated construction and cross feed of distribution network | 3.75   | 3.28         | 1.32        | 3.68         |
| 18  | The risk of safety responsibility interface and responsibility division of power distribution and retail | 3.95   | 4.05         | 1.28        | 3.95         |
| 19  | The risk of unified dispatching of incremental distribution network | 1.59   | 2.72         | 1.30        | 2.71         |
| 20  | The risk of faulty equipment in distribution network             | 1.78        | 2.15         | 1.62        | 2.12         |
| 21  | The risk of safety management for electricity users              | 2.12        | 1.59         | 4.12        | 2.51         |
| 22  | The risk of power generation enterprises provides special distribution network for users | 2.12   | 2.18         | 2.32        | 2.32         |
| 23  | The risk of rapid development of distributed energy              | 2.51        | 2.09         | 4.85        | 2.15         |
| 24  | The risk for distribution network and load coordination operation | 1.93        | 2.13         | 4.23        | 3.85         |

(3) The Formation of Risk Matrix

According to the above experts' evaluation results, the new risk matrix of power system under the power reform is formed, including the matrix chart of transition period (Figure 1) and the matrix chart of mature period of reform (Figure 2). Among them, the risk in the brown area is extremely important,
and emergency measures must be taken; the risk in the red area is very important, which must be paid enough attention to and formulate the risk plan; the risk in the yellow area is of medium importance; the risk in the green area is of low importance.

![New risk matrix of power system in the transitional period of reform](image1)

**Fig. 1** New risk matrix of power system in the transitional period of reform

![New risk matrix of power system in mature period of reform](image2)

**Fig. 2** New risk matrix of power system in mature period of reform

4. Conclusions

According to the risk matrix of the transition period and maturity period of the reform, the new risk of the power system in the red area must be paid enough attention to.

In the transitional period of reform, due to the imperfect market system and mechanism, the coexistence of planning and market and other factors, there are many new risks in the power system, and the key risks are mainly in the planning and operation coordination of the development, transmission, distribution and retail links. It includes: 1) power generation: the risk of uncoordinated generation and network operation; 2) power transmission: the risk of grid security cost recovery, the risk of aggravating grid structure contradiction, the risk of peak regulation and lack of auxiliary services, the risk of power grid dispatch and operation, the risk of independent operation of power trading exchange, the risk of rigid implementation of maintenance plan, the risk of uncoordinated new energy and power grid planning, the security and stability risk of large-scale new energy integration; 3) power distribution: the structural risk of uncoordinated distribution and transmission network, the risk of repeated construction and cross feed of distribution network, the risk of safety responsibility interface and responsibility division of power distribution and retail, etc.

In the mature period of reform, the market system and mechanism are relatively perfect, and the key risks still exist in the transitional period of reform, but the probability and influence degree of occurrence are weakened in varying degrees. However, under the market environment, the power
system itself is prone to medium and long-term security risks, such as the risk of insufficient investment in power grid, the risk of reducing grid reserve investment, the risk of generating capacity adequacy, and the risk of grid transmission capacity adequacy. At the same time, with the development and maturity of the electricity sales market, the interaction between the user side and the system is more frequent, and the risks of the load side and information security of the power system increase, such as the risk of information security, the risk of safety management for electricity users, the risk of rapid development of distributed energy, and the risk for distribution network and load coordination operation.

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