Research on grid supervision index system based on AHP and Multi-level Matter-element Analysis Model in China

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Abstract. In the context of the new situation of electricity reform, the Chinese government has strengthened the supervision of power grid enterprises. By sorting out the power grid supervision documents issued by the government in recent years, it classifies and analyzes its specific requirements for power grid enterprises; classifies and summarizes government regulatory requirements; designs a regulatory model to build a hierarchical model. Using the combination of statistical principle and Delphi method, the index weight of the index system is designed based on AHP; the multi-level matter-element analysis model is used to evaluate the implementation of policies in recent years.

Keywords: multi-level matter-element; analysis model; policy research; AHP; grid supervision index system

1. Introduction
In 2015, the "Several Opinions of the Central Committee of the Communist Party of China and the State Council on Further Deepening the Reform of the Electric Power System" ([2015] No. 9) issued a document marking the official launch of the government's new requirements for strengthening the power grid supervision, followed by a series of supporting departments. As the most important change since the power system reform in 2002, the above series of policy documents put forward new requirements for the government to strengthen the power grid supervision, and will guide the development plan of the power grid company. At present, China's power grid is shifting from safety to "safety and efficiency". At the same time, the government changed the profit model of the power grid, separated the purchase and distribution of the power grid, redefined the pricing methods for power transmission and distribution, audited effective assets, opened up market competition, and formulated new market trading mechanisms to fundamentally change the operation of China's power grid. Compared with before the power reform, the number of policy documents related to price regulation and market supervision has increased year by year after the start of power reform. At present, many programmatic policy documents are still in the trial stage, and the government's supervision status on the power grid is gradually being compared with the power grid. Adaptation, it
can be seen that the government's policy documents on the regulation of prices and markets will increase in the future, until the final government regulation is compatible with the development of the power grid, in line with China's future development goals.

2. Literature review
At present, there are many researches on the new power reform policy, which are mainly divided into the discussion of policy mechanisms, the evaluation of policies, and the research aspects of power grid development based on policy background.

Yang et al. constructed an investment management optimization system for power grid companies, based on the realization of the new round of economic situation and the implementation of a new round of power system reform [1]. Zhou et al. studied the impact of effective FIT policy on PV-MG investment and applied the model to an actual microgrid in Shenzhen to verify its effectiveness, based on the current PV-MG's feed-in tariff (FIT) policy [2]. Li et al. used the method of fitting, game theory and empirical analysis to evaluate the policy from the perspective of overall planning, support policy and policy implementation, and combined international experience to propose improvements to China's wind power policy from seven aspects [3]. Luo et al. proposed that the construction policy of distributed generation can be considered from three aspects: distributed power generation access policy, power grid construction cost policy and government incentive policy. The government should adjust its policies to influence the development direction of distributed generation, and achieved good results in practice [4]. Zhang et al. discussed the factors driving the growth of wind power installed capacity in China's provinces, especially the provincial wind energy policy. The results show that the adoption of provincial wind energy policies and general energy plans has had a positive impact on the growth of wind power installed capacity in various provinces in China [5]. Lin et al. analyzed the principles of China's differential electricity pricing policy, the externalities of energy and the revised Ramsey pricing rules, and pointed out the policy implications of China's differential electricity pricing policy. The results show that the main role of differential electricity pricing policy is that enterprises are expected to be higher. When the price of electricity is reduced, the total cost is reduced in advance to increase production efficiency [6]. Hou et al. discussed the impact of renewable energy policies on large-scale power generation systems and constructed a system dynamics (SD) energy generation model to simulate the results of wind power policies based on complex systems [7]. Zhang et al. systematically collected and combed the policies of China's biomass power generation policy from 2006 to 2012, and analyzed the policy issues according to the effect of policy implementation, based on the actual demand of biomass power generation projects [8]. Xu et al. proposed a dynamic integrated resource strategic planning (DIRSP) model based on semi-Markov decision process, and discussed the impact of different policy combinations and input intensity on the low carbon transition time and scale in the power planning process [9].

3. Design of grid supervision indicators based on policy text research
Considering the power reform No. 9 document is the implementation of the spirit of “making the market play a decisive role in resource allocation and better playing the role of the government” proposed at the Third Plenary Session of the 18th Central Committee held in November 2013, combined with the delivery time of the project task. The subject of the project will be released from January 1, 2014 to December 31, 2017.

From the perspective of the collection of policy documents, the new requirements for government policy supervision of this topic mainly come from the regulatory documents issued by relevant government departments, including the National Development and Reform Commission, the National Energy Administration and other relevant national ministries.

The indicators obtained by sorting are shown in Table 1.
Table 1. Grid regulatory indicators Table

| Target Layer                          | Criteria Layer                        | Indicator Layer                      |
|--------------------------------------|---------------------------------------|--------------------------------------|
| Grid Regulatory Indicators           |                                       | Market Order B₁₁                      |
|                                      |                                       | Renewable Energy Consumption B₁₂      |
|                                      |                                       | Electricity Trading B₁₃               |
|                                      |                                       | Market Access B₁₄                     |
|                                      |                                       | Grid Operation Safety B₂₁             |
|                                      |                                       | Safe Production B₂₂                   |
|                                      |                                       | Safety and Operations Supervision B₂  |
|                                      |                                       | Information Security B₂₃              |
|                                      |                                       | Power Dispatch B₂₄                    |
|                                      |                                       | Power Grid Planning B₂₅               |
|                                      |                                       | Transmission and Distribution Price B₃₁|
|                                      |                                       | Cross Subsidy B₃₂                     |
|                                      |                                       | Price and Service Supervision B₃      |
|                                      |                                       | Renewable Energy Tariff Subsidy B₃₃   |
|                                      |                                       | Universal Service B₃₄                  |
|                                      |                                       | Metering And Charging Service B₃₅     |

4. Evaluation Model of Supervision Indicators based on AHP

Compared with the 9-level scale obtained by the traditionally used expert method, this paper improves the weight determination method, starting from the data itself and based on the frequency statistics (see Table 2). The policy mentioned frequency is replaced by the expert method and corresponds to the 9-level scale design weight. Firstly, using Matlab to conduct a one-sample non-parametric test on the number of index relationships under different policy mentioned frequencies, determine the characteristics of its distribution, and then classify the index weights according to its distribution, and combine the nine-level gradient method to make different levels. The frequency is referred to in response to different policies to determine the final weight. This method refers to the specific frequency distribution characteristics of relevant policy indicators through the policy, ensures the weight to determine the objectivity, avoids the subjectivity of the expert method, and combines the nine-level gradient method to reduce the inconsistent of final weight due to the large data difference.

Table 2. Indicator relationship frequency distribution table

| Frequency of policy reference to relationship between indicators | The number of indicator relationships at this frequency | Scaling |
|-----------------------------------------------------------------|--------------------------------------------------------|---------|
| 1                                                               | 64                                                     | 2       |
| 2                                                               | 55                                                     | 2       |
| 3                                                               | 17                                                     | 3       |
| 4                                                               | 18                                                     | 3       |
| 5                                                               | 9                                                      | 4       |
| 6                                                               | 12                                                     | 5       |
| 7                                                               | 5                                                      | 6       |
| 8                                                               | 3                                                      | 6       |
| 9                                                               | 6                                                      | 7       |
| 10                                                              | 4                                                      | 7       |
| 12                                                              | 2                                                      | 8       |
| 17                                                              | 2                                                      | 8       |
| 20                                                              | 1                                                      | 8       |
| 24                                                              | 7                                                      | 8       |
| 25                                                              | 4                                                      | 9       |
| 26                                                              | 1                                                      | 9       |
| 34                                                              | 1                                                      | 9       |
| 48                                                              | 1                                                      | 9       |
Compared with the traditional Delphi method to determine the weight, this paper improves the weight determination method. By referring to the specific frequency of relevant policy indicators and combining the Delphi method, the importance degree between each index is compared, and the nine-level gradient method is used. A judgment matrix is constructed by comparing the importance value of one index with another. Through calculation, the weights of each index of the grid supervision index evaluation system are obtained, and the final weights are shown in Table 3.

Table 3. Grid Supervision Index Weight Table

| Criteria layer | Weights | Indicator layer |
|----------------|---------|-----------------|
| B1             | 0.1283  | B11 0.4213      |
|                |         | B12 0.3344      |
|                |         | B13 0.0656      |
|                |         | B14 0.1788      |
|                |         | B21 0.2636      |
|                |         | B22 0.4758      |
| B2             | 0.2764  | B23 0.0538      |
|                |         | B24 0.0981      |
|                |         | B25 0.1087      |
|                |         | B23 0.4005      |
|                |         | B32 0.3261      |
| B3             | 0.5954  | B33 0.1674      |
|                |         | B34 0.0699      |
|                |         | B35 0.0361      |

5. Policy evaluation based on Multi-Level Matter-Element Analysis Model

5.1. Multi-Level Matter-Element Analysis model

The matter element is also called the elementary element and is represented by the ordered triplet \( R = (N, c, v) \), where \( N \) is the name of the given thing, \( c \) is the characteristic of the thing, and \( v \) is the magnitude of the feature of the thing. If a thing has \( n \) features \( c_1, c_2, \ldots, c_n \) and corresponding feature magnitudes \( v_1, v_2, \ldots, v_n \), then the matter-element model can be described as:

\[
R = (N, c, v) = \begin{pmatrix}
N & c_1 & v_1 \\
& c_2 & v_2 \\
& \vdots & \vdots \\
& c_n & v_n
\end{pmatrix}
\]  

The multi-level matter evaluation model constructed in this paper is based on the traditional matter-element evaluation model. The evaluation of the bottom-level single-element in the indicator system is completed first, and then the similar steps are used to recursively from the bottom of the evaluation system to the top layer.

5.2. Case Analysis

Firstly, the experts in the field use the scoring method to divide the implementation level of each evaluation index in the supervision index system mentioned in this paper into \( m \) grades, assuming \( m = 4 \), that is, excellent, good, medium, and poor, respectively. Level 1, Level 2, Level 3, Level 4, according to the "Classification Principle of Grades" in the inspection standard, combined with the experience of experts, determine the safety level evaluation criteria for each indicator.
Table 4. Grid supervision evaluation index level standard

| Criteria layer | Indicator layer | excellent | good | medium | poor |
|----------------|-----------------|-----------|------|--------|------|
| B1             | B11             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B12             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B13             | 80~100    | 70~80| 60~70  | 0~60 |
|                | B14             | 85~100    | 75~85| 60~75  | 0~60 |
|                | B15             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B22             | 90~100    | 75~90| 60~75  | 0~60 |
| B2             | B21             | 80~100    | 70~80| 60~70  | 0~60 |
|                | B22             | 85~100    | 75~85| 60~75  | 0~60 |
|                | B23             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B24             | 85~100    | 75~85| 60~75  | 0~60 |
|                | B25             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B22             | 80~100    | 70~80| 60~70  | 0~60 |
| B3             | B31             | 80~100    | 70~80| 60~70  | 0~60 |
|                | B32             | 85~100    | 75~85| 60~75  | 0~60 |
|                | B33             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B34             | 90~100    | 75~90| 60~75  | 0~60 |
|                | B35             | 90~100    | 75~90| 60~75  | 0~60 |

Then, 14 indicators were inspected, and the results of the scoring were shown in Table 5.

Table 5. results of the scoring

| indicators | score | B11 | B12 | B13 | B14 | B21 | B22 | B23 |
|------------|-------|-----|-----|-----|-----|-----|-----|-----|
| B24        | 76    | 76  | 70  | 79  | 77  | 81  | 78  |
| B25        | 76    | 76  | 70  | 79  | 77  | 81  | 78  |
| B31        | 77    | 77  | 70  | 79  | 77  | 81  | 78  |
| B32        | 77    | 77  | 70  | 79  | 77  | 81  | 78  |
| B33        | 77    | 77  | 70  | 79  | 77  | 81  | 78  |
| B34        | 77    | 77  | 70  | 79  | 77  | 81  | 78  |
| B35        | 77    | 77  | 70  | 79  | 77  | 81  | 78  |

5.3. Result

The secondary indicators belong to each level as follows:

Table 6. The secondary indicators belong to the relevance of each evaluation set

| Indicator layer | K1i | K2i | K3i | K4i | Level |
|-----------------|-----|-----|-----|-----|-------|
| B11             | -0.273 | 0.6 | -0.36 | -0.6 | 2     |
| B12             | -0.333 | 0.333 | -0.2 | -0.5 | 2     |
| B13             | -0.115 | 0.7 | -0.233 | -0.425 | 2   |
| B14             | -0.317 | -0.097 | 0.8 | -0.3 | 3     |
| B21             | -0.386 | -0.069 | 0.867 | -0.325 | 3   |
| B22             | -0.353 | 0.2 | -0.12 | -0.45 | 2     |
| B23             | -0.3 | -0.125 | 0.5 | -0.125 | 3     |
| B24             | -0.273 | 0.1 | -0.04 | -0.4 | 2     |
| B25             | -0.419 | -0.234 | 0.267 | -0.1 | 3     |
| B31             | -0.4 | -0.143 | 0.667 | -0.25 | 3     |
| B32             | -0.344 | 0.9 | -0.3 | -0.475 | 2   |
| B33             | -0.258 | 0.2 | -0.08 | -0.425 | 2   |
| B34             | -0.321 | 0.4 | -0.24 | -0.525 | 2   |
| B35             | -0.353 | 0.533 | -0.12 | -0.45 | 2   |

The correlation between the primary indicator and the general indicator regarding the grade p, the results are as follows:
Table 7. The primary and secondary indicators belong to the relevance of each evaluation set

| Criteria layer                          | K1i   | K2i   | K3i   | K4i   | Level |
|----------------------------------------|-------|-------|-------|-------|-------|
| Market and Sustainable Supervision B₁  | -0.2906 | 0.3927 | -0.0908 | -0.5015 | 2     |
| Safety and Operations Supervision B₂   | -0.3582 | 0.0546 | 0.2234 | -0.3566 | 3     |
| Price and Service Supervision B₃       | -0.3508 | 0.3169 | 0.1348 | -0.3791 | 2     |
| Grid Regulatory Indicators A          | -0.3170 | 0.2896 | 0.0250 | -0.4458 | 2     |

6. Conclusion
After statistical analysis, it was found that through the comprehensive evaluation and analysis of the grid supervision indicators, it is concluded that although the overall policy implementation level is “good”, at the specific level, the policy implementation level is not ideal:

For the first-level indicators, the safety level is “good” in terms of Market and Sustainable Supervision, and Price and Service Supervision; however, the Safety and Operations Supervision level is “medium”.

In terms of secondary indicators, the five aspects of the Market Access, Grid Operation Safety, Information Security, Power Grid Planning, and Transmission and Distribution Price are “medium”, indicating that the current implementation of these aspects needs to be improved.

Acknowledgments
This research was financially supported by the Science and Technology Project of State Grid Corporation Headquarters, and the project name is Research on Evaluation System and Development Strategy Optimizing of Power Grid Development under New Background of Government Supervision (52170018000X)

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