Risk Assessment of Regulatory Business Under New Regulatory Relationship: A Case Study of Power Grid Enterprises

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Abstract—As the power system reforms continue to deepen, the power grid enterprises (PGEs) are facing new regulatory relationships, followed by more and more regulatory risks (RRs) under the new situation. In this context, studying the regulatory risks faced by the regulatory business can help PGEs correctly recognize the internal and external risks and put forward countermeasures. A comprehensive RRs evaluation model for the PGEs is conducted in this paper based on the Bayesian best-worst method and matter-element extension model. Based on the risk assessment results, power grid enterprises can identify the key risk points. Meanwhile, power grid enterprises can strengthen their internal control, propose risk management measures, and further enhance the awareness and ability of risk prevention in the business operation.

Keywords- risk assessment; regulatory business; Bayseian best-worst method; matter-element extension method

1 Introduction

With the reform of the power system entering the "deep water zone", the relationship between regulators and power grid enterprises (PGEs) is much more subtle. In this context, the regulatory risks (RRs) of PGEs are increasing, not only within the enterprise, but also including new risks brought by external environment and policy changes. Wu et al. [1] analyzed China's power grid investment supervision policy and constructed a compatible incentive and constraint mechanism of power grid investment supervision. Duan et al. [2] studied the supervision mode of PGEs in Britain and America, then constructed a policy framework of price supervision for PGEs in China. Wang et al. [3] studied the problem of different information feedback results caused by inconsistent cost collection caliber between cost supervision and cost accounting under transmission and distribution cost supervision mode. Most of the existing literatures

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analyze the single aspect of electricity price or investment in power grid regulation, there is a lack of research on the RRs of regulation business for PGEs.

This paper evaluates the RRs of regulatory business of PGEs under the new regulatory relationship. First, the risk index system covering four links of license, investment, transmission distribution price and operation is constructed. Then, we established a comprehensive risk evaluation model based on the Bayesian best-worst model (BBWM) and matter-element extension method (MEEM). Finally, we evaluated the RRs of a provincial PGE, which can prove the effectiveness of the proposed model.

2 Regulatory risk analysis of regulatory business in pges

For the PGEs, the regulatory business mainly represents the power transmission and distribution business. So, we divided it into four aspects: license, investment, transmission and distribution price, and operation.

1) License regulation. In order to ensure the legalization of PGEs engaged in power business, it is necessary to review the conditions, scope and business situation of power business license, and supervise and manage the situation of PGEs obtaining license.

2) Power grid investment regulation. The regulation of investment is helpful to ensure the scientificity and efficiency of power grid investment. There are certain regulatory risks in the effectiveness and implementation of investment.

3) Transmission and distribution price regulation. In order to realize the market-oriented transactions and the premise for opening up competitive business, it is necessary to avoid the risks brought by transmission and distribution prices. It is important to restore the attributes of power commodities. The risks of price fluctuation and price execution should be considered comprehensively.

4) Power grid operation regulation. To ensure the healthy development of PGEs, it is of great significance to consider the risks of operation safety, service quality and quota implementation.

The RRs evaluation index system of the regulatory business in PGEs is shown in Figure 1, as below:

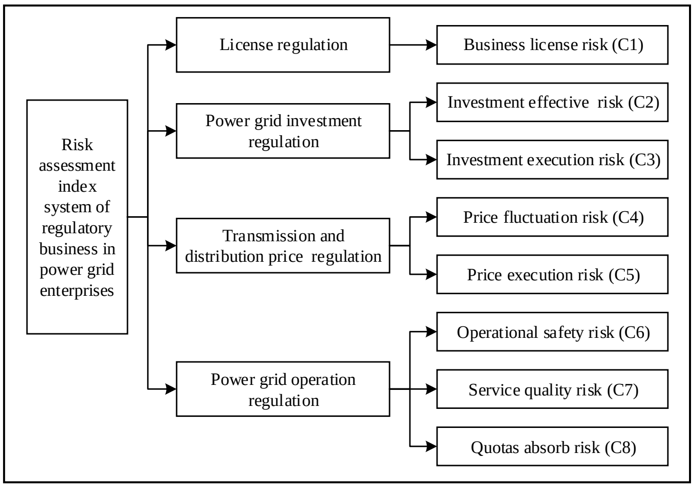

Figure 1. The RRs evaluation index system of regulatory business in PGEs.

3 Measurement model of regulatory risk for regulatory business in power grid enterprises

3.1 Bayesian best-worst method

The traditional best-worst method (BWM) is firstly adopted in 2015 [4], which can reduce the number of weight determination and improve the efficacy comparing with the analytic hierarchy process approach. Different from BWM, the BBWM used in this paper further introduces the probability of inputs and outputs, and regards the weight as the possibility of each event [5]. When the input and output are determined, the polynomial probability distribution is added. This process can be expressed as follows:

$$P\left(A_W \mid w\right)=\frac{\left(\sum_{j=1}^{n} a_{jW}\right)!}{\Pi_{j=1}^{n} a_{jW}!}\prod_{j=1}^{n} w_j^{a_{jW}} \tag{1}$$

where w means probability distribution of the worst indicator.

Then, we can calculate the probability of event j, as shown in (2):

$$w_j \propto \frac{a_{jW}}{\sum_{j=1}^{n} a_{jW}} \tag{2}$$

Therefore, the probability of occurrence for the worst indicator c_W can be expressed as:

$$w_W \propto \frac{a_{WW}}{\sum_{j=1}^{n} a_{jW}} = \frac{1}{\sum_{j=1}^{n} a_{jW}} \qquad (3)$$

Based on the above formulas, we can obtain (4):

$$\frac{w_j}{w_W} \propto a_{jW} \qquad (4)$$

So far, the traditional weighting steps are converted into event probability calculations, and the hierarchical Bayesian model is used to solve this problem.

Assuming that the decision group is composed of K experts, then we can construct the best comparison vector of indicators A_B^k and the worst comparison vector of indicators A_W^k. Then, the weight of each indicator determined by the decision makers can be expressed as w^k. Hence, we can calculate the final weights w^{agg} determined by all of the experts.

3.2 Matter element extension method

The MEEM is constructed based on the traditional matter-element principle and the extended set model. The core principle is to analyze the relationship between the matter-element to be evaluated and each evaluation grade through the measured data, which can further evaluate the grade of evaluation object [6].

Assuming that P has several characteristics C, and the value of the characteristics can be expressed as V, P,C,V can be also named as the basic element of R.

Supposing there are n features of P, which can be expressed as $\{c_1, c_2, \ldots\ldots, c_n\}$ and $\{v_1, v_2, \ldots\ldots, v_n\}$. In addition, R can be also regarded as a n-dimensional matter-element.

$$R = (P,C,V) = \left[R_1, R_2, \ldots R_n\right]^T = \begin{bmatrix} P & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \qquad (7)$$

The specific steps of MEEM are as follows:

1) Construct the classical domain, node domain and matter-element to be assessed.

$$R_j = \left(P_j, C_i, V_{ij}\right) = \begin{bmatrix} P_j & c_1 & v_{1j} \\ & c_2 & v_{2j} \\ & \vdots & \vdots \\ & c_n & v_{nj} \end{bmatrix} = \begin{bmatrix} P_j & c_1 & < a_{1j}, b_{1j} > \\ & c_2 & < a_{2j}, b_{2j} > \\ & \vdots & \vdots \\ & c_n & < a_{nj}, b_{nj} > \end{bmatrix} \qquad (8)$$

where $\{c_1, c_2, \ldots\ldots, c_n\}$ means the characteristics C of P_j, $\{v_1, v_2, \ldots\ldots, v_n\}$ represents the value of P_j, and P_j represents the j evaluation level. $< a_{ij}, b_{ij} >$ represents the upper and lower bounds of v_{ij}.

$$R_p = \left(P, C_i, V_{ij}\right) = \begin{bmatrix} P & c_1 & V_{1p} \\ & c_2 & V_{2p} \\ & \vdots & \vdots \\ & c_n & V_{np} \end{bmatrix} = \begin{bmatrix} P & c_1 & < a_{1p}, b_{1p} > \\ & c_2 & < a_{2p}, b_{2p} > \\ & \vdots & \vdots \\ & c_n & < a_{np}, b_{np} > \end{bmatrix} \tag{9}$$

where $\left\{v_{1p}, v_{2p}, \ldots\ldots, v_{np}\right\}$ is the range of P corresponding to $\left\{c_1, c_2, \ldots\ldots, c_n\right\}$, and P represents the evaluation level.

$$R_0 = \left(P_0, C_i, V_i\right) = \begin{bmatrix} P_0 & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \tag{10}$$

where R_0 represents the matter-element to be assessed, and $\left\{v_1, v_2, \ldots\ldots, v_n\right\}$ represents the basic indicator data of P_0 to $\left\{c_1, c_2, \ldots\ldots, c_n\right\}$.

2) Determine the index weight.

The weights of all the RRs are calculated by the BBWM model introduced above.

3) Closeness function establishment.

We can estimate the relationship between the matter-element to be assessed and the domain normalized through (11):

$$D(v') = \left| v' - \frac{a'_{ij} + b'_{ij}}{2} \right| - \frac{b'_{ij} - a'_{ij}}{2} \tag{11}$$

where a and b are respectively the left and right endpoint of the normalized nodal domain.

The closeness function is further calculated by (12):

$$N = 1 - \frac{1}{n(n+1)} \sum_{i=1}^{n} D w_i \tag{12}$$

where N can be regarded as the closeness, D means the distance and w_i is the weight of each indicator.

Combining (11) and (12), the closeness can be obtained by:

$$N_j(p_0) = 1 - \frac{1}{n(n+1)} \sum_{i=1}^{n} D_j\left(v_i\right) w_i(X) \tag{13}$$

where $N_j(p_0)$ can be regarded as the closeness between the matter-element to be assessed and each grade, $D_j\left(v_i\right)$ means the distance between the object element to be assessed and the domain normalized, $w_i(X)$ is the indicator weights calculated by BBWM, and n represents number of evaluation indicators.

4) Evaluation level determination.

$N_{j'}(p_0) = max\left\{N_j(p_0)\right\}, (j = 1, 2, 3, ..., m)$ can be regarded as R_0 is closer to level j'.

4 Case Study

In this paper, a typical provincial PGE is selected to be the research item, which can also help to verify the effectiveness of the constructed RRs evaluation model. The risk grade is set to five levels: 1 means very low risk, 2 means low risk, 3 means medium risk, 4 means high risk, and 5 means very high risk.

4.1 Establishment and normalization of classical domain, segment domain and matter-element to be assessed

The qualitative indicators are based on consultation with relevant experts, and a ten-point scoring rule is adopted.

1) Set the classical domain.

$$R_1 = \begin{bmatrix} P_1 & C1 & \langle 0,2 \rangle \\ & C2 & \langle 0,2 \rangle \\ & C3 & \langle 0,2 \rangle \\ & C4 & \langle 0,2 \rangle \\ & C5 & \langle 0,2 \rangle \\ & C6 & \langle 0,2 \rangle \\ & C7 & \langle 0,2 \rangle \\ & C8 & \langle 0,2 \rangle \end{bmatrix} \quad R_2 = \begin{bmatrix} P_2 & C1 & \langle 2,4 \rangle \\ & C2 & \langle 2,4 \rangle \\ & C3 & \langle 2,4 \rangle \\ & C4 & \langle 2,4 \rangle \\ & C5 & \langle 2,4 \rangle \\ & C6 & \langle 2,4 \rangle \\ & C7 & \langle 2,4 \rangle \\ & C8 & \langle 2,4 \rangle \end{bmatrix}$$

$$R_3 = \begin{bmatrix} P_3 & C1 & \langle 4,6 \rangle \\ & C2 & \langle 4,6 \rangle \\ & C3 & \langle 4,6 \rangle \\ & C4 & \langle 4,6 \rangle \\ & C5 & \langle 4,6 \rangle \\ & C6 & \langle 4,6 \rangle \\ & C7 & \langle 4,6 \rangle \\ & C8 & \langle 4,6 \rangle \end{bmatrix} \quad R_4 = \begin{bmatrix} P_4 & C1 & \langle 6,8 \rangle \\ & C2 & \langle 6,8 \rangle \\ & C3 & \langle 6,8 \rangle \\ & C4 & \langle 6,8 \rangle \\ & C5 & \langle 6,8 \rangle \\ & C6 & \langle 6,8 \rangle \\ & C7 & \langle 6,8 \rangle \\ & C8 & \langle 6,8 \rangle \end{bmatrix}$$

$$R_5 = \begin{bmatrix} P_5 & C1 & \langle 8,10 \rangle \\ & C2 & \langle 8,10 \rangle \\ & C3 & \langle 8,10 \rangle \\ & C4 & \langle 8,10 \rangle \\ & C5 & \langle 8,10 \rangle \\ & C6 & \langle 8,10 \rangle \\ & C7 & \langle 8,10 \rangle \\ & C8 & \langle 8,10 \rangle \end{bmatrix}$$

2) Set the nodal domain and matter-element to be assessed.

$$R_p = \begin{bmatrix} P & C1 & \langle 0,10 \rangle \\ & C2 & \langle 0,10 \rangle \\ & C3 & \langle 0,10 \rangle \\ & C4 & \langle 0,10 \rangle \\ & C5 & \langle 0,10 \rangle \\ & C6 & \langle 0,10 \rangle \\ & C7 & \langle 0,10 \rangle \\ & C8 & \langle 0,10 \rangle \end{bmatrix} R_0 = \begin{bmatrix} P_0 & 7.8 \\ & 2.3 \\ & 3.5 \\ & 8.2 \\ & 9.3 \\ & 8.9 \\ & 7.5 \\ & 4.6 \end{bmatrix}$$

4.2 Indicator weight determination

Based on the ideas and reports given by five experts, the best comparison vectors and worst comparison vectors are as follows:

$$A_B = \begin{pmatrix} 5 & 7 & 6 & 5 & 1 & 2 & 3 & 4 \\ 4 & 7 & 6 & 3 & 1 & 5 & 2 & 3 \\ 6 & 7 & 8 & 2 & 1 & 4 & 3 & 5 \\ 6 & 8 & 7 & 3 & 1 & 2 & 4 & 5 \\ 5 & 8 & 7 & 4 & 1 & 2 & 3 & 6 \end{pmatrix} A_W = \begin{pmatrix} 4 & 1 & 3 & 3 & 9 & 8 & 7 & 6 \\ 5 & 1 & 3 & 7 & 8 & 4 & 7 & 6 \\ 3 & 2 & 1 & 7 & 8 & 5 & 6 & 4 \\ 2 & 1 & 2 & 5 & 7 & 6 & 4 & 3 \\ 4 & 1 & 2 & 5 & 8 & 7 & 6 & 3 \end{pmatrix}$$

The comprehensive weights are obtained through the MATLAB software. Then, the calculation results of indicators can be shown in Table 1, as follows:

TABLE 1. Weights of eight indicators

Indicator	***C1***	***C2***	***C3***	***C4***
Weight	9.05%	5.51%	6.43%	13.74%
Indicator	**C5**	**C6**	**C7**	**C8**
Weight	23.64%	15.47%	15.57%	10.59%

4.3 Risk level determination

According to the formula mentioned above, the closeness of the risk level for the provincial power grid company is calculated as follows:

$$N_1(p_0) = 1 - \frac{1}{8*(8+1)} \sum_{i=1}^{8} D_j(v_i) w_i = 0.99345$$

$$N_2(p_0) = 1 - \frac{1}{8*(8+1)} \sum_{i=1}^{8} D_j(v_i) w_i = 0.99631$$

$$N_3(p_0) = 1 - \frac{1}{8*(8+1)} \sum_{i=1}^{8} D_j(v_i) w_i = 0.99724$$

$$N_4(p_0) = 1 - \frac{1}{8*(8+1)} \sum_{i=1}^{8} D_j(v_i) w_i = 0.99876$$

$$N_5(p_0)=1-\frac{1}{8*(8+1)}\sum_{i=1}^{8}D_j\left(v_i\right)w_i=0.99983$$

It is obvious that the RRs of regulatory business in the examined PGE belongs to Very High level.

5 Conclusion

This paper constructs an evaluation model reflecting the RRs faced by the regulatory business in PGEs under the new regulatory relationship. According to the case study of a typical provincial PGE, the following conclusions can be obtained:

1) The price execution risk is the most important evaluation indicator, which is essential to judge the risk of regulatory business.

2) According to the qualitative analysis result, the power gird enterprise performs poorest in transmission and distribution price regulation.

3) The risk assessment model proposed performs well in evaluating the RRs of regulatory business in PGEs. It can be further applied in other fields.

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References

[1] Wu, S., Duan, Q., Li, C., You, P. (2019) Research on Incentive-Constraint Compatible Mechanism of Power Grid Investment Regulation ——Analysis of the promotion and improvement of supervision policy since the new power reform. Price: Theory & Practice, 4: 153-156.

[2] Duan, Q., Wu, S., Xu, G. (2019) Research on Improving Incentive Price Regulation of China’s Power Grid. Economic Theory and Business Management, 9: 98-109.

[3] Wang, X., Liu, S., Wu, L. (2020) Cost Collection of Power Grid Enterprises Under the Mode of Power Transmission and Distribution Cost Supervision. Power & Energy, 41(05) 645-646+653.

[4] Rezaei, J. (2015) Best-worst multi-criteria decision-making method. Omega-international Journal of Management Science, 49-57.

[5] Mohammadi, M., Rezaei, J. (2019) Bayesian best-worst method: A probabilistic group decision making model. Omega, 102075.

[6] He, Y., Liu, Y., Zhou, S. (2017) Risk evaluation for electric power communication network based on matter-element extensible model. Power System Protection and Control, 14: 64-69.