Research on Comprehensive Benefit Evaluation of Contract Energy Management Based on Grey Whitening Weight Function

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Abstract. As a large-scale central enterprise, power grid enterprises should promote contract energy management under the strict energy-saving situation. Based on the gray whitening weight function, this paper constructs a contract energy management evaluation system from three aspects: economic benefit, social benefit and environmental benefit. The expert scoring method is used to determine the weight of each index, and finally the comprehensive benefit of contract enterprise energy management is obtained. The results show that the contract energy management business has a huge driving effect on economic, social and environmental benefits. The value-added service of contract energy management has better comprehensive benefits. It can further promote contract energy management, improve China's energy structure, and promote sustainable development.

1. Introduction

Energy Performance Contracting (EPC) is a new type of energy-saving mechanism based on market operation developed from western developed countries after the global energy crisis in the mid-1970s. The contract is signed by energy-saving service companies and energy-using units. The form agrees on the energy-saving goal of the energy-saving project. The energy-saving service company provides necessary services to the energy-using unit to achieve the energy-saving goal, and the energy-using unit pays the investment and reasonable profit of the energy-saving service company with energy-saving benefits. The contractual relationship between energy-saving service companies and customers who need to save energy is called the “energy-saving service contract”.

Compared with general energy-saving service companies, the power grid has many advantages in contract energy management. Power grid enterprises have a large number of technical talents related to power distribution, power equipment research, manufacturing, and design. They have high education, good quality, solid technology foundation and rich experience. Power grid enterprises have accumulated abundant funds in the long-term development. Another advantage of the strong enterprise scale is that it has strong financing ability and can implement large-scale energy-saving projects that cannot be carried out by energy-saving service companies of general scale. Power industry is China's basic industry, having a wide range of power supply, rich marketing resources, a large number of
marketing departments and professionals. The number of power users is huge, and has formed a stable relationship with power users. These advantages for power companies to promote energy-saving service technology and energy-saving awareness are very favorable. Power grid enterprises are in the middle of the transmission, transportation, transformation, and distribution. The ability to reliably supply power is the most direct way for grid companies to provide power users with power supply capabilities and service quality. It is a comprehensive reflection of grid equipment level and scientific dispatch management level. High-reliability grid companies can successfully guide power users to actively carry out energy-saving renovations and jointly improve energy efficiency.

2. Construction of Contract Energy Management Evaluation System Based on Grey Whitening Weight Function

2.1. Construction of Contract Energy Management Index System
When evaluating the index of contract energy management, it should fully consider the economic, social and environmental benefits. Combined with its benefit characteristics, it can obtain the evaluation system of the value-added service benefits of contract energy management in power grid enterprises, as shown in Table 1.

Table 1. Contract Energy Management Comprehensive Benefit Evaluation Index System

| First grade indicators | Second grade indicators | Third grade indicators |
|------------------------|------------------------|-----------------------|
| Contract energy        | Profit level           | Profit increase       |
| management             | Operation level        | Financing level       |
| comprehensive          | Development potential  | Business development capability |
| benefit evaluation      | Satisfaction of related party | Expand business scope |
| index system            | Promoting of regional economic development | Customer satisfaction |
|                        | Promotion of technology | Tax increase |
|                        | Resource savings       | Reduce energy consumption |
|                        | Reduction of environmental pollution | Reduce waste emissions |

2.2. Contract Energy Management Index Weight Calculation
The analytic hierarchy process can be used to determine the weight of indicators. The first grade indicators in Table 1 are Criteria layer, and the third grade indicators are indicator layer. The calculation steps include the following aspects:

1. First, determine the weight of the criteria layer. Five experts were asked to score the economic, social and environmental benefits respectively. According to the judgment matrix, the eigenvalue method is used to calculate the maximum eigenvalue of the judgment matrix and the normalized eigenvector corresponding to the maximum eigenvalue. The calculation results are as follows:

   \[ V_1 = (0.5664, 0.2267, 0.2069)^T, \text{CI}_1=0.0168, \text{CR}_1=0.0323 \]

   \[ V_2 = (0.5542, 0.1538, 0.2920)^T, \text{CI}_2=0.0042, \text{CR}_2=0.0081 \]

   \[ V_3 = (0.5590, 0.1822, 0.2188)^T, \text{CI}_3=0.0042, \text{CR}_3=0.0081 \]

   \[ V_4 = (0.6600, 0.1392, 0.2008)^T, \text{CI}_4=0.0042, \text{CR}_4=0.0081 \]

   \[ V_5 = (0.4919, 0.3112, 0.1969)^T, \text{CI}_5=0.0042, \text{CR}_5=0.0081 \]
The values of CR1, CR2, CR3, CR4 and CR5 are all less than 0.1, so the five judgment matrices pass the consistency test. Using equation $\lambda_i = \frac{1}{\sum_{k=1}^{n} \frac{1}{C_{ik}}}$, expert weights $\lambda_1 \sim \lambda_5$ are 0.0588, 0.2353, 0.2353, 0.2353, and 0.2353, respectively.

Combined with the weight of the experts, the weight calculation results of each expert's weight calculation are weighted and the results are as follows:

$$U_1 = (0.5757, 0.1984, 0.5759)^T$$

Judging from the final determination of weights, experts pay more attention to economic benefits for the application of value-added services of power grid enterprises in industrial and commercial users.

(2) Economic benefit indicator layer weight determination

Five experts were invited to construct a judgment matrix for the four indicators of economic benefit index. Using the eigenvalue method, the maximum eigenvalue of the judgment matrix and the normalized eigenvector corresponding to the largest eigenvalue are calculated. The calculation result is as follows:

$$W_1 = (0.5216, 0.1419, 0.1627, 0.1739)^T, \ CI_1=0.0031, \ CR_1=0.0035$$

$$W_2 = (0.3840, 0.1684, 0.1932, 0.2543)^T, \ CI_2=0.0063, \ CR_2=0.0071$$

$$W_3 = (0.4771, 0.1602, 0.1846, 0.1780)^T, \ CI_3=0.0384, \ CR_3=0.0432$$

$$W_4 = (0.3665, 0.2560, 0.1714, 0.2062)^T, \ CI_4=0.0608, \ CR_4=0.0683$$

$$W_5 = (0.3435, 0.2603, 0.2251, 0.1711)^T, \ CI_5=0.0127, \ CR_5=0.0142$$

The values of CR1, CR2, CR3, CR4 and CR5 are all less than 0.1, so the five judgment matrices pass the consistency test. The calculated expert weights $\lambda_1 \sim \lambda_5$ are 0.5354, 0.2634, 0.0432, 0.0273, and 0.1307, respectively.

Combined with the weight of the experts, the weight calculation results of each expert's weight calculation are weighted and the results are as follows:

$$U_2 = (0.4559, 0.1683, 0.1801, 0.1958)^T$$

(3) Social benefit indicator layer weight determination

Five experts were invited to construct a judgment matrix from three indicators of social benefit index. Using the eigenvalue method, the maximum eigenvalue of the judgment matrix and the normalized eigenvector corresponding to the largest eigenvalue are calculated. The calculation result is as follows:

$$W_1 = (0.5542, 0.1538, 0.2920)^T, \ CI_1=0.0042, \ CR_1=0.0081$$

$$W_2 = (0.4299, 0.2720, 0.2981)^T, \ CI_2=0.0168, \ CR_2=0.0323$$

$$W_3 = (0.5602, 0.2693, 0.1704)^T, \ CI_3=0.0042, \ CR_3=0.0081$$

$$W_4 = (0.4299, 0.2981, 0.2720)^T, \ CI_4=0.0168, \ CR_4=0.0323$$

$$W_5 = (0.5664, 0.2267, 0.2069)^T, \ CI_5=0.0042, \ CR_5=0.0081$$
The values of $CR_1$, $CR_2$, $CR_3$, $CR_4$ and $CR_5$ are all less than 0.1, so the five judgment matrices pass the consistency test. The calculated expert weights $\lambda_1 \sim \lambda_5$ are 0.2857, 0.0714, 0.2857, 0.0714, and 0.2857, respectively.

Combined with the weight of the experts, the weight calculation results of each expert's weight calculation are weighted and the results are as follows:

$$ U_3 = (0.5416, 0.2264, 0.2300) $$

(4) Environmental benefit indicator layer weight determination

Five experts were invited to construct a judgment matrix from two indicators of environmental benefit index. Using the eigenvalue method, the maximum eigenvalue of the judgment matrix and the normalized eigenvector corresponding to the largest eigenvalue are calculated. The calculation result is as follows:

$$ W_1 = (0.5, 0.5)^T $$

$$ W_2 = (0.432, 0.568)^T $$

$$ W_3 = (0.568, 0.432)^T $$

$$ W_4 = (0.568, 0.432)^T $$

$$ W_5 = (0.634, 0.366)^T $$

The second-order judgment matrix must pass the consistency test and does not need to do the CR test. Since the second-order judgment matrix passes the consistency test completely, $CR=0$. Therefore, the weighted average of the five eigenvectors is taken as the final result.

$$ U_3 = (0.540, 0.460)^T $$

(5) Each indicator layer weight determination result

Based on the calculation of the weights of the criteria layer and each indicator layer, the final weights of each indicator can be finally obtained, as summarized below:

Table 2. Indicator Layer Weight Result Table

| Target layer                 | Criteria layer          | Indicator layer             | Indicator layer number |
|------------------------------|-------------------------|-----------------------------|------------------------|
| Contract energy management   | Economic benefits       | Profit increase             | 0.2625                 |
| Comprehensive benefits       |                         | Financing level             | 0.0969                 |
|                              |                         | Business development capability | 0.1037              |
|                              | Social benefits         | Expand business scope       | 0.1127                 |
|                              |                         | Customer satisfaction       | 0.1074                 |
|                              | Environmental benefits  | Tax increase                | 0.0449                 |
|                              |                         | Technological innovation level | 0.0460               |
|                              |                         | Reduce energy consumption   | 0.1221                 |
|                              |                         | Reduce waste emissions      | 0.1038                 |

3. Contract Energy Management Benefit Evaluation

On the basis of determining the weight of each index, the comprehensive benefit evaluation based on the gray whitening weight function can be applied to the contract energy management value-added service. The specific steps are as follows:

(1) Expert assessment

Invite 5 experts to evaluate the total of 9 index values of $X_1 \sim X_9$, and give the evaluation scores of the index values within the range of 0–100. The score results are shown in Table 3:
Table 3. Contract Energy Management Indicators Score Sheet

| Index                        | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 |
|------------------------------|----------|----------|----------|----------|----------|
| Profit increase              | 88       | 82       | 78       | 90       | 88       |
| Financing level              | 86       | 81       | 82       | 92       | 90       |
| Business development capability | 92     | 87       | 90       | 95       | 93       |
| Expand business scope        | 80       | 78       | 80       | 86       | 72       |
| Customer satisfaction        | 86       | 81       | 79       | 83       | 76       |
| Tax increase                 | 78       | 75       | 76       | 84       | 79       |
| Technological innovation level | 82   | 79       | 86       | 87       | 76       |
| Reduce energy consumption    | 90       | 86       | 82       | 92       | 90       |
| Reduce waste emissions       | 90       | 88       | 83       | 93       | 90       |

(2) Determining the evaluation of gray matter and its whitening weight function
The scores from 0 to 100 are divided into four gray categories: excellent, good, medium, and poor. The upper limit measure whitening weight function is selected, and the score ranges and gray numbers of the four gray categories are shown in the table 4.

| Gray     | Excellent | Good | Medium | Poor |
|----------|-----------|------|--------|------|
| Ranges   | [85,100]  | [75,85) | [60,75) | [0,60) |
| Gray number | [85,100, --] | [75,85, --] | [60,75, --] | [0,60, --] |

Assume that when the score takes the boundary value of 60, 75, 85, its whitening weight function value is 1/2 of the adjacent score. For example, when the score = 85, the whitening weight function value for the gray class "excellent" is 1/30.

(3) Grey comprehensive evaluation
According to table 4, using the gray whitening weight function to process the indicator score table, the gray weight table can be calculated as follows:

Table 5. Contract Energy Management Gray Weight Table

| Index                        | Excellent | Good | Medium | Poor |
|------------------------------|-----------|------|--------|------|
| Profit increase              | 0.4231    | 0.5769 | 0.0000 | 0.0000 |
| Financing level              | 0.4000    | 0.6000 | 0.0000 | 0.0000 |
| Business development capability | 1.0000 | 0.0000 | 0.0000 | 0.0000 |
| Expand business scope        | 0.0308    | 0.6000 | 0.3692 | 0.0000 |
| Customer satisfaction        | 0.0339    | 0.9661 | 0.0000 | 0.0000 |
| Tax increase                 | 0.0000    | 1.0000 | 0.0000 | 0.0000 |
| Technological innovation level | 0.1429 | 0.8571 | 0.0000 | 0.0000 |
| Reduce energy consumption    | 0.6316    | 0.3684 | 0.0000 | 0.0000 |
| Reduce waste emissions       | 0.6364    | 0.3636 | 0.0000 | 0.0000 |

Based on the known index weights and gray weights, the comprehensive clustering results of contract energy management are shown in the following table:
Table 6. Results of Comprehensive Benefit Evaluation of Contract Energy Management

|                              | Excellent | Good   | Medium | Poor   | Evaluation results |
|------------------------------|-----------|--------|--------|--------|--------------------|
| Economic benefits            | 0.4463    | 0.4815 | 0.0723 | 0.0000 | Good               |
| Social benefits              | 0.0515    | 0.9485 | 0.0000 | 0.0000 | Good               |
| Environmental benefits       | 0.6338    | 0.3662 | 0.0000 | 0.0000 | Excellent          |
| Comprehensive benefit        | 0.4103    | 0.5481 | 0.0416 | 0.0000 | Good               |

According to the principle of maximum membership degree, the economic benefits of the contract energy management business are good, the social benefits are good, the environmental benefits are excellent, and the comprehensive evaluation results are good. That is, the value-added service of contract energy management has better comprehensive benefits. It is recommended to carry out and promote.

4. Conclusion
Contract energy management plays an important role in promoting the innovation and development of value-added services for power grid enterprises. The empirical analysis based on the gray whitening weight function shows that the contract energy management business has a huge impetus to economic, social and environmental benefits. The value-added service of contract energy management has better comprehensive benefits. As China attaches more importance to the environment, the application of contract energy management in China will have broader prospects.

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References
[1] Lu Haiming, Liu Xiangdong. Research and application of power customer segmentation and value-added service system [J]. North China Electric Power, 2016 (10): 8-13.
[2] Song Caihua, Lan Yuanjuan, Wang Yongcai et al. Application of comprehensive value assessment method in customer segmentation of power enterprises [J]. Electronic Design Engineering, 2014, 22(12): 111-116.
[3] Liu Wei, Tong Yang, Luo Zhikun et al. Design of Power Value-added Service System for Diversified Electricity Markets [J]. Hunan Electric Power, 2013, 33(4): 31-33.
[4] WonChul Yang, JaeHee Kim, SangSoo Kim. A Study on the Development of Value-added Service in Consideration of Korea Power Market [J]. International Conference on Control, Automation and Systems, 2007, 17(20):384-387.
[5] Sun Ic Kim, Jong Min Ko, Moon Jong Jang. Development of value-added service systems based on an AMR data in power industry[J]. 2006 SICE-ICASE International Joint Conference, 2007, 18(21): 165-169.
[6] He Yongxiu, Peng Xiaodong, Liu Zhiyan et al. Basic services and value-added services of power companies [J]. Power Demand Side Management, 2014 (02): 51-55.
[7] Liu Lin, Wang Xue, Zhang Yibin. Research on Evaluation of Value-added Service of Smart Grid Based on Enterprise Ecology [J]. Journal of North China Electric Power University (Social Science Edition), 2014, (02): 26-31.
[8] Chen Shoujun, L1 Jianqiang, Wei Yanan. Comprehensive Benefit Evaluation of Smart Grid Based on Evidence Integration Soft Set [J]. East China Electric Power, 2013, 41(12): 2590-2594.
[9] Zhao Liang, Li Lili, He Bo et al. Smart grid evaluation index system and calculation method
suitable for China's national conditions[J]. Power System Technology, 2015, (12): 3520-3528.

[10] Koji, T. Integrated Smart Grid Evaluation System[J]. Toshiba Leading Innovation, 2011, 66(12): 24-27.

[11] Zhang Jian, Pu Tianjiao, Wang Wei et al. Comprehensive Evaluation Index System for Smart Grid Demonstration Project[J]. Power System Technology, 2011, 35(6): 5-10.