Research on Evaluation of Power Supply Companies External Service Quality Based on Improved Grey Interrelated Analysis Method

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***Abstract*—Power system reform makes electric power enterprises face market environment is more complex, electric power customer satisfaction directly affects the power supply enterprise to improve the benefit, therefore, the power supply enterprise conducts electricity service quality evaluation and improvement of deficiencies become the urgent problem, this plays a vital role in improve enterprise competition ability and realize sustainable development. This paper analyzes the influence power supply enterprise external service quality of various factors so as to construct the power supply enterprise external service quality evaluation index system. The weight of each index is calculated by the AHP method and the entropy weight method, the mentalistic method is introduced to combined subjective weight and objective weight so the combined weights better balance between the two aspects of subjective and objective factors. In the traditional grey relation analysis, distinguish coefficient is 0.5, but it has certain defect so this paper use a new method to solve the distinguish coefficient and then establish the improved grey relational comprehensive evaluation model. The empirical analysis shows that the evaluation model is effective, and it have realistic meanings for the power supply enterprises to improve service quality.**

***Index Terms*—power supply enterprises; service quality; combination weighting; improved grey interrelated analysis method**

I. INTRODUCTION

Power is the foundation of the national economy energy, and is also necessary energy of the masses in the life. So, electricity market operation is good or bad, will directly relates to safety operation and healthy development of the national economy and the people's livelihood. In order to strengthen the management of the power supply service quality, improve the service level, in 2007 the state grid power promulgated the "national grid power supply service quality evaluation management measures (try out)" [1], demanding the power supply service quality evaluation for the power supply companies. The electrical power system reform make enterprise faced more complicated and changeable of market situation. Electric power customer be decided to change with the market power, customer satisfaction is important premise to win in market competition for the power supply enterprises. Power supply enterprises realized only truly improve the service quality, in order to constantly cultivate and maintain competitive advantage, so as to achieve healthy, stable and sustainable development.

Many foreign scholars used more "multiple attribute model" to assess the quality of service. American scholars Parasuraman, Zeithaml and Berry in 1988 designed the service quality evaluation method-SERVQAL. It was composed of 22 indexes. At first it is mainly used in the services and retail organizations customer-perceived service quality evaluation. It is a good solution to the problem of service quality evaluation [3]. But it should be pointed out that, more overseas for service quality evaluation from the customer's point of view, and less to analysis the reasons for forming the final result. In the domestic, research on service quality management and evaluation theory is still in its infancy, mainly focused on introduce practice experience of improve service quality in the foreign, and research and application of the service quality theory [4].

Relevant research about power supply enterprise external service quality evaluation, scholars in addition to using qualitative analysis model SERVQAL, all sorts of empowerment methods are used to determine the weight of each index, fuzzy comprehensive evaluation method, EDA input-output evaluation method, the comprehensive method introduced into the power supply service quality evaluation of external. Reference [1] determine evaluation index system of the electricity supply quality of service for the State Grid Corporation's, which identifies 24 indicators of external evaluation. Reference [5]in considering the quality of the information on the impact of weight, based on the basis of entropy method and the SERVQUAL service quality model established the power external evaluation model, and made a empirical research example of a power supply enterprise.

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Reference [6] proposed combining power service quality evaluation model of the fuzzy math, fuzzy analytic hierarchy process, group decision making. Reference [7] presented the power supply service quality evaluation index system and two evaluation methods: evaluation method based on fuzzy partial order and fuzzy comprehensive evaluation. Reference [8] established evaluation system from the "property of power services business - the specific business process analysis - Analysis of power supply service encounter" three-dimensional analysis point of power supply enterprise specialized business, the analysis is a relatively new idea.

This paper based on analyzes the factors that affect the supply quality of service, the subjective weighting method-AHP and objective weighting method-entropy weight method to combine empowerment that is to determine the weights more practical and scientific; So as to construct a improvement of the grey relational comprehensive evaluation model, namely, the gray relational degree evaluation model based on the combination empowerment. The empirical analysis shows that the comprehensive model is feasibility and effectiveness, and provided a theoretical guidance for power supply enterprises to improve service quality and have realistic meanings.

II. CONSTRUCTION OF THE EXTERNAL POWER SUPPLY SERVICE QUALITY EVALUATION INDEX SYSTEM

A. Construct principles of external evaluation index system

External evaluation of the electricity services quality (customer satisfaction measurement) is mainly filled by the scene, issuing questionnaires or telephone customer service system supporting a return visit for information collection, etc. records for customer service quality evaluation on the supply of information, and then using Statistical tools and mathematical models of the original survey data were statistically analyzed to identify our customer satisfaction with quality of service. Therefore, the construction of evaluation index system should follow the following principles:

(1) Overall principle. The external service quality evaluation should strive to achieve comprehensive reflects customers' satisfaction of the quality of service, therefore, index factors must be widespread and have representative;

(2) Materiality principle. Establish service quality evaluation index system, we should grasp the needs of customers, evaluation index factors must be the most important things of the customers think. Meanwhile, because the customers demand is changing, so the weight of each index should be different according to the actual situation;

(3) Clarity principles. Indexes must be clearly defined, cannot exist difficult to understand the definition of each index factor, the degree of distinction must be more respondents distinguish;

(4) Comparability principles. Refers to different companies or between subordinate branches and between the same company comparison and evaluation of different time are comparable, moreover each index factors are fair for each of the evaluation objects;

(5) Testability principles. Evaluation index must be measurable and quantifiable. The evaluation index must be statistic, calculate and analysis.

B. To establish the evaluation index system of Power Supply Companies service quality

This article from the business that accepts, measurement fee services, fault repair service, demand side management (DSM), power quality, 95598 phone service, business hall services and complaints whistle service eight big aspect of the power supply enterprise service project classification, for each category and then set a total of 30 specific indicators, which constitute the external evaluation index system, as shown in Table 1.

TABLE I.

POWER SUPPLY SERVICE QUALITY EVALUATION SYSTEM

External Power Supply Service Quality Evaluation System A	Business acceptance B1	Timeliness of services received C1
		Rational design of business C2
		Timely completion of transmission rate C3
		Convenience for business applications C4
		Attitude of construction workers C5
	Metering and charging services B2	Meter reading accuracy C6
		The timeliness of bill payment C7
		The accuracy of the bill payment C8
	Fault repair service B3	Ease of fault repair C9
		Fault repair timeliness in place C10
		Failure rate of one-time repair C11
		return rate of repair after C12
	Demand side management (DSM) B4	Reasonable of price C13
		Timely notification of Blackouts and brownouts C14
		Timely restoration of electricity C15
		The publicity degree of DSM C16
	Power qualityB5	Voltage stability C17
		Reliability of electricity supply C18
		Security of electricity supply C19
	95598 phone service B6	Phone through rate C20
		Attitude satisfaction of operator C21
		The business level of operator C22
		95598 Comprehensive online services C23
	Operating room services B7	The efficiency of operating room C24
		Operating room environment C25
		Attitude of satisfaction C26
		Convenience outlets C27
	Complaints reporting service B8	Convenience to report complaints C28
		Timeliness of complaint handling reportC29
		Satisfaction with complaint handling report C30

III. DETERMINE THE COMBINED WEIGHTS

In order to improve the evaluation of power supply service external quality, so it needs scientific determine various indexes weights. Weight of indicators refers to the relative important degree of the indexes in the overall evaluation, how to determine the weight coefficient is the

core problem in comprehensive evaluation. The method to determine the weighing mainly divided into two kinds of subjectively and objectively weighting. Subjectively is mainly get by experts with experience subjective judgment, common determination methods of subjective weight have: AHP, Delphi method, G1 method and eigenvector etc. The objectivity of subjectively weighting method is limited because restriction of the decision maker's experience and the information of index contains is uncertainty. Objective to determine the weighing method basically have: variation coefficient weighting, entropy weight method, the collection value iteration method and pull class method, etc. Objective weighting by each index is in the actual data entered evaluation are calculated, it does not depend on the person's subjective judgment, consequently of this kind of method is objectivity, but sometimes objectivity strong results can appear not practical situation. Due to one-sidedness use the single empowerment method, so in this paper adopted the AHP method and entropy weight method as the basic weight vector, using multiplication principle constitutes a combination weights, making determine weight more scientifically and rationally [9].

A. AHP method determining the weight

AHP decomposing complex problems into component factors, and will these factors dominating relations group formed by recursive class times structure. Through the way the binary comparison factors determine the hierarchy of the relative importance. And then integrate the judgments of decision makers to determine the relative importance of overall decision-making programs. The whole process embodies the decision-making thinking characteristics, that is, decomposition, comprehensive judgments. Analytic hierarchy process (AHP) method determining the weight steps as follows:

(1) Establish a hierarchical structure, and layered the assess system

The most important of AHP is to construct a hierarchical structure model, decomposing problems into many elements, and according to the properties of these elements into several teams, form different layers. The same hierarchy elements on the next level play a dominant element, and at the same time, it has been a hierarchy element on the domination of the victors. These levels can be divided into three categories:

The top level: this level is only one element, generally it is to analyze the problem the intended target or ideal results, that is target layer.

The middle level: the intermediate links involved, it consists of several levels, including the consider standards and guidelines, also called rule layer.

The lowest level: this level for achieving goals indicates the selection of various measures, decision-making plan etc, also be called measures layer or scheme layer.

(2) Construct the binary comparison judgment matrix

Judgment matrix said in a level, one factor of this level between relevant factors with comparison of the relative importance. According to the binary comparison importance ratings law, see table 2, through the data collection questionnaire investigation, expert scoring etc, rating relative importance of elements at, get judge matrix of each level [10]. Generally speaking, judgment matrix is scientific or not directly related to the decision-making quality, so the determine of personnel structure and experts number should be especially careful.

TABLE II.

BINARY COMPARISON IMPORTANCE RATINGS LAW

score	the important degree
one	Equally important
three	Slightly important
five	Obvious important
seven	Strongly important
nine	Absolutely important
two, four, six, eight are the median of the above adjacent judgment	

(3) Level single sort

Level single scheduling problems attributed to calculation judgment matrix root and the characteristics of characteristic vector, the actual process, if don't require high accuracy, can use some of the simpler approximation algorithms, have root method, and quadrate method and power method. Using the computer can calculate the biggest arbitrary precision roots and characteristics of the eigenvectors. Using MATLAB to calculate eigenvalues and eigenvectors of the calculation command: [V, D] = eig (A). This calculation command refers to calculate feature vector matrix V and eigenvalue diagonal matrix D of matrix A [11]. From the matrix D we can get the maximum eigenvalue of judgment matrix, eigenvectors corresponding to the maximum eigenvalue normalized to get the weight of each index.

(4) Consistency inspection

In order to ensure the effectiveness of hierarchical sort, consistency inspect to the judge matrix must are given. Consistency inspection usually use consistency ratio CR as inspection standards, defined as:

$$CR = \frac{CI}{RI} \tag{1}$$

Among them: CI for consistency index, its computation formula is:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

RI is average immediately consistency index, exact value such as shown in table 3.

TABLE III.

BINARY COMPARISON IMPORTANCE RATINGS LAW

Judgment matrix order number n	one	two	three	four	five	six	seven	eight	nine	ten	eleven	twelve
RI	0	0	0.58	0.90	1.12	1.26	1.32	1.41	1.45	1.49	1.52	1.54

Generally when CR < 0.1, think judgment matrix have satisfactory consistency; When CR ≥ 0.1, should be adjusted to judgment matrix, then recalculate weight vectors and to validate the consistency, until pass the test.

B. Entropy weight method to determine the weights

Entropy weight method is an objective evaluation method, its essence is if a indexes has a big gap between for the all evaluating objects, its resolution ability is strong, contains more information, its role should also be greatly in comprehensive evaluation, and the weight is big. Due to the types of supply service is many, so difference of index is bigger between different businesses. Accordingly, according to the characteristics of external evaluation indexes and considering influence of survey information discrete degree for index weights, using the entropy weight technology can effectively ensure the accuracy and objectivity of evaluation [12]. The general steps of entropy weight method to empowerment as follows:

(1) According to index build initial matrix X:

$$X = (x_{ij})_{m\times n} \left(i = 1,2,\cdots,m;\ j = 1,2,\cdots,n\right) \quad (3)$$

Where, i denotes evaluation object and the j denotes index value

(2)Solve the characteristics of gravity, the formula is:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (4)$$

Where, i denotes evaluation object and the j denotes index value; n denotes the number of evaluate objects.

(3)Calculate the Entropy index of j, e_j:

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad (5)$$

Where, $e_j \geq 0$。

(4)Calculate the Entropy Index W：

W=（$w_1, w_2, \cdots\cdots w_m$）

$$W_j = \frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)} \quad (6)$$

Where, m is the number of evaluation index.

C. To determine the Combination weights

In this paper, adopt mentalist method to combined subjective weight and objective weight. Suppose AHP get the weight of each index is:

$$V_i = (\sigma_{i1}, \sigma_{i2}, \cdots \sigma_{im})$$

And Entropy weight method get the weight of each index is:

$$U_i = (\delta_{i1}, \delta_{i2}, \cdots, \delta_{im})$$

Thus, we get the combined weights is:

$$\omega_i = \frac{V_i U_i}{\sum_{i=1}^{m} V_i U_i}, 0 \leq \omega_i \leq 1, \sum_{i=1}^{m} \omega_i = 1 \quad (7)$$

IV. IMPROVED GREY RELATIONAL EVALUATION METHOD

Correlation analysis was a kind of method of analyzing and processing of the gray system random amount, the basic idea is to judge related degree between the factors based on the similarity degree between curves. Its main through the gray relational degree this quantitative index system to quantitative analysis system development process and to gauge the relevance between the factors [13,14]. The main steps are as follows:

If the number of evaluation objects is n, the number of evaluation index is m, which we get the original data matrix:

$$X = x_{ij} \ (1 \leq i \leq n, 1 \leq j \leq m)$$

(1)To regulate assessment matrix

Since the original data matrix in this article the data is obtained through questionnaires and other means and then by statistical data, its performance in the form of scores, that is, the bigger the better, so its no longer be normalized.

(2)To determine the optimal sample collection

As for the score of this raw data, choosing the maximum value of the index data as a reference value, m reference values constitute the optimal samples set:

$$X_0 = (x_{01}, x_{02} \cdots\cdots x_{0m})$$

(3)To solve the difference sequence:

$$\Delta_{oi}(j) = \left|x_{ij} - x_{oj}\right| \ (1 \leq i \leq n, 1 \leq j \leq m) \quad (8)$$

(4)Calculate the Grey relational coefficient

Gray correlation coefficient $\xi_i(j)$ of x_{ij} is determined by:

$$\xi_i(j) = \frac{\min\limits_{1\leq i\leq n, 1\leq j\leq m} \Delta_{oi}(j) + \rho \max\limits_{1\leq i\leq n, 1\leq i\leq m} \Delta_{oi}(j)}{\Delta_{oi}(j) + \rho \max\limits_{1\leq i\leq n, 1\leq j\leq m} \Delta_{oi}(j)} \quad (9)$$

Where, ρ is the resolution ratio, the range is $0 \leq \rho \leq 1$

In the past, in general calculation distinguish coefficient ρ is 0.5, but when distinguish coefficient ρ is 0.5, no matter how the reference sequences and compare sequences, the limit of corresponding correlative coefficient is 0.3333. Obviously, it's not reasonable. Distinguish coefficient ρ as the coefficient of maximum, should be fully embodies in the system the effect of each factor to the correlation degree, at the same time should have anti-interference function, or can weaken the error effect of unusual values to the correlation space in the observation sequence. The method of determine the distinguish coefficient in this paper is as follows:

$$\Delta_k = \frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m}\left|x_{0j} - x_{ij}\right| \qquad (10)$$

Hypothesis $\delta = \Delta_k / \Delta_{\max}$, the value range of ρ is: $\delta \le \rho \le 2$,and it should meet:

When $\Delta_{\max} \succ 3\Delta_k$,

$$\delta \le \rho \le 1.5\delta$$

When $\Delta\max \prec 3\Delta_k$,

$$1.5\delta \le \rho \le 2\delta$$

(5)Calculate the gray correlation index based on the weight

Considering the importance differences of each index, to obtain the weighted gray correlation:

$$R^T = \xi W = [R_1, R_2 \cdots\cdots R_n]$$

Where,

$$R_i = \sum_{j=1}^{m}\xi_i(j)w_j \quad (i = 1,2,\cdots,m) \qquad (11)$$

Sort the various programs according to the size of the weighted correlation, the larger of the value is excellent, the smaller is bad.

V. CASE STUDY

A. Determine the evaluation matrix

Select six Electricity Board in an area as an evaluation object, design questionnaires and return visit record of telephone customer service system to investigate customers of the six power supply bureau, statistical indicators and calculated index value of each second level indicators, and then get the index value of eight first level indicators, and so as the raw data of evaluation, as shown in Table 4(Out of 10 points for each indicator).

TABLE IV.

THE EXTERNAL EVALUATION RAW DATA OF THE QUALITY OF SUPPLY SERVICE

B1	B2	B3	B4	B5	B6	B7	B8
8.905	9.054	8.851	9.027	9.122	8.311	8.946	6.662
8.698	9.104	8.936	8.772	8.980	8.599	8.639	7.035
8.793	9.117	8.946	9.198	8.532	8.198	8.595	6.874
9.256	9.488	9.281	8.951	9.037	8.512	9.256	7.415
9.510	9.592	9.327	9.122	9.102	8.674	9.531	8.694
8.988	9.695	9.134	7.671	8.915	8.037	8.634	6.024

Note: data source [15].

B. Determine the combined weights

Using AHP method obtains each index weight vector for:

V_i =[0.1179,0.1367,0.1326,0.1333,0.1329,0.1142,0.1156, 0.1168],

Using formula (4), (5), (6) we can get weight vector based on entropy weight:

U_i =[0.11,0.19,0.15,0.18,0.16,0.05,0.07,0.09],

Using the formula (7) we can get combination weight vector that is used in this paper:

W=[0.1010, 0.2023, 0.1549, 0.1869, 0.1656, 0.0445, 0.0630, 0.0819]

C. Grey Evaluation of Power Supply Quality

Its maximum value of the indicators as a reference vector X0, using formula (8) calculate the difference sequence, constitute a sequence difference matrix, and to find out the biggest difference and least difference, use the formula (9)、（10）to calculate the gray correlation coefficient, such as Table 5.

TABLE V.

GRAY CORRELATION COEFFICIENT

B1	B2	B3	B4	B5	B6	B7	B8
0.526	0.517	0.581	0.791	1.000	0.628	0.535	0.232
0.453	0.537	0.628	0.604	0.820	0.892	0.430	0.270
0.484	0.542	0.634	1.000	0.522	0.563	0.418	0.252
0.726	0.768	0.935	0.725	0.883	0.792	0.710	0.324
1.000	0.869	1.000	0.896	0.971	1.000	1.000	1.000
0.563	1.000	0.774	0.298	0.757	0.490	0.429	0.187

By the formula (11) we can calculate the weighted gray correlation, evaluation results are shown in Table 6.

TABLE VI.

SIX POWER SUPPLY BUREAU RANKED THE QUALITY OF SERVICE

Evaluation objects	1	2	3	4	5	6
Correlation	0.642	0.589	0.602	0.762	0.949	0.624
Sort Results	3	6	5	2	1	4

VI. CONCLUSION

Combined weights model based on the AHP method and entropy weight, better balance between the two aspects of subjective and objective factors. Comprehensive evaluation model is proposed based on improved grey interrelated analysis. Empirical analysis shows that the method is effective and feasible, it provided a reference for power supply enterprises to understand their service quality. Empirical analysis results show that this method is effective, this paper have realistic meanings for power supply enterprises to improve their service quality.

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