The Electricity Customer Satisfaction Weight Study Based on Comprehensive Weight Determination

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Abstract. In evaluating electric network marketing, this article establishes a multi-factor and multi-level index system based on the present situation of Chinese electricity industry and the existing marketing satisfaction index system at all countries. When determining the index weight, the article employs the original data derived from the questionnaire and proposes a method which integrates CRTIC method and AHP method. The weight is confirmed according to the weight given by experts for investigation direction and survey data of satisfaction questionnaire so as to effectively combine the suitable weight given subjectively by experts and the objective weight based on data. Hence, it not only avoids uncertainty caused by experts’ subjective judgment, but also avoids the problem of insufficient relativity with industrial characteristics caused by simply using objective analysis. The method in this article had been used in electricity customer satisfaction survey in some Chinese province in 2016 and has achieved a very good effect, thus testing and verifying the rationality, effectiveness and feasibility of the method.

Introduction

The electricity industry is an important public infrastructure of national economy and social development. With the development and advancement of the electric power supply technology, and the gradual market development and maturity and constant deepening of government institutional reform, Chinese electricity industry is faced with new challenges. In recent years, the masses increase their electricity demands year by year, and the prominent problems, for example, distribution network has insufficient power supply capacity, grid structure is weak, reliability remains to be improved, etc. As China decontrols the electricity market and the power-sold side is opened to social capital, various affiliated companies in the power industry invest in founding or buying shares of electricity-sale companies one after another and lay out the power-sold side market, and power supply and electricity-sale companies compete for high-quality customers. In the competitive market, the power supply companies must complete transforming the model of “managing customers” into “serving customers”, transforming its service tenet into customer-focused and market-oriented one theoretically, and really improves the service quality, only in this way, can they constantly cultivate new markets and keep their competitive advantages so as to promote the sustainable, healthy and stable development of the electricity market. Therefore, today when the market supply-demand relation is changed and power customers’ status is effectively improved, the investigation of power customer satisfaction is of more value.

There are many satisfaction evaluation methods, and Literature [1] makes mean analysis only through the built satisfaction model, without considering about the influences from a single weight on the overall satisfaction rating. Literature [2] builds a model only in the AHP method, and the model is under subjective influence from modeling experts, without considering about the influences from objective weights. Literature [3] applies both the subjective and objective methods for fitting, but it doesn’t well interpret the sources of model setting. Literature [4] analyzes many subjective and objective weight assignment methods, and compares the correlation among different objective and subjective weight assignment methods. But as many methods are adopted, some of objective weight assignment method are greatly correlated with subjective ones, which can cause
conclusion biases. Literature [5] applies the expert appraisal, weighted statistics and AHP methods, and its disadvantage is that it doesn’t consider about the influences from index variability or conflicts on weight distribution, which can be solved in the CRITIC method.

**Evaluation System Model**

**Grid Satisfaction Model**

The grid satisfaction model should consider about the investigated customers’ actual situations, while building the comprehensive evaluation index system, the paper mainly makes discussion in several expert seminars, analyzes the problems power supply companies at various levels and power customers pay attention to in recent years, and obtains issues which cover power use installation, rush repair, fee payment, complaint and so on based on the target group selected in the survey. Through these issues, it concludes the issues in every power use link so as to help the power sector understand the customer-related weak links in every respect; it sets the indexes on the next level which segment those on the previous level and are well-arranged via every link in order to facilitate further discussion and analysis. After discussion, it finally divides power customer satisfaction evaluation model into three levels, and the third level directly reflects the basic characteristics of power customer satisfaction and contains 68 factors. The second level is about various directions the investigated users concern about and contains 8 factors, and the concrete model is as shown in Table 5. Due to layout reasons, only list to Secondary Index

**Evaluation Index System Rating Method**

**Questionnaire Design**

The questionnaire indexes are designed in the AHP method in the survey. In the concrete design process, on account of the target group set in the survey, namely the high-voltage incremental power customers in China’s certain province in 2016, the paper completes a series of work such as questionnaire design, weight setting, etc. in the form of organizing expert seminar, which basically safeguards the justice, objectiveness and reasonability of the evaluation system. The experts consist of the experts from the power supply expert database and law enforcement official directory database, marketing principals of the power company in China’s certain province, and university professors in related specialties. For the questionnaire design, experts design the hierarchical structure model as shown in Table 5 (Due to layout reasons, only list to Secondary Index) based on the previous satisfaction survey experience, internal satisfaction questionnaire of the power company, complaints and reporting information received by supervision department, and the investigated object’s characteristics.

**Consistency Calculation**

The consistency calculation of questionnaire can fully manifest the reasonability and validity of questionnaire design, and calculating the consistency of the questionnaire judgment matrix can obtain the scientificness of the judgment matrix, namely, obtain the reasonability of weight design so as to verify the scientificness of the survey [7].

The consistency ratio \( CR \) can reflect the consistency of the judgment matrix, and it is generally considered that the judgment matrix has consistency when \( CR < 0.1 \). Where, \( CR = CI/RI \), the mean random consistency index \( RI \) is available in Table 1.
Table 1. Mean Random Consistency Index Value.

| n  | RI  |
|----|-----|
| 3  | 0.58|
| 4  | 0.90|
| 5  | 1.12|
| 6  | 1.24|
| 7  | 1.32|
| 8  | 1.41|
| 9  | 1.45|
| 10 | 1.49|
| 11 | 1.51|

The consistency index CI can be solved through Formula 1, where, n is the judgment matrix order. The smaller the CI value is, the more consistent the judgment matrix is. The CI formula is as follows:

\[
CI = \frac{\lambda_{max} - n}{n-1}
\]  

(1)

Lastly, CR is solved, from Table 2, it is observed that the consistency index verification value in the survey is far smaller than 0.1 and complies with the requirement, that is to say, the judgment matrix has meaningful consistency.

Table 2. Consistency Ratio (CR).

|     | G   | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CR  | 0.0165 | 0   | 0.002 | 0   | 0   | 0.0039 | 0.0013 | 0   | 0   |

Weight Determination Methods

AHP (Analytic Hierarchy Process)

First, build a hierarchical structure model. The satisfaction evaluation model is established based on AHP, and the detailed process is as shown in 1.1.

Second, construct the judgment matrix. To determine the influences from sub-factors on a certain factor, it is necessary to compare the importance of these sub-factors, quantize the information after comparison with the numbers 1–9 (1–9 respectively manifest that the importance of sub-factors tends to be from equally important, slightly important, relatively important, significantly important to absolutely important) and their reciprocals, and employ these values to rank the importance of various sub-factors which is expressed by the judgment matrix \( A = (a_{ij})_{n \times n} \), where:

\[
a_{ij} > 0, \quad a_{ii} = 1, \quad a_{ji} = 1/a_{ij}
\]  

(2)

Third, single hierarchical arrangement. According to the judgment matrix \( A \) for every hierarchy as listed above, the maximum eigenvalue \( \lambda_{max} \) of \( A \) can be solved and its corresponding eigenvector \( W \) is solved with the characteristic equation \( AW = \lambda_{max}W \), the data in \( W \) manifest the importance of the sub-factors to the factor on the previous level, the factors in the eigenvector \( W \) are under normalization processing, so that the weight of every sub-factor on the same level is obtained for the corresponding factor on the previous level, and the coefficient vector \( W \) is as shown below:

\[
W = \left( \frac{x_1}{\sum x_1}, \frac{x_2}{\sum x_1}, \ldots, \frac{x_m}{\sum x_1} \right)
\]  

(3)

Fourth, hierarchy general ranking. Through the single hierarchical arrangement, the weight on every level can be obtained to the factors on the previous level, the weights of the factors on lower levels are transformed into the synthetic weight of the general objective through calculation, and this process is hierarchy general ranking, in the synthetic weight calculation process, calculation is conducted from the highest level to the lowest one, and the synthetic weight of the factors on the lowest level is finally obtained.

CRITIC Method

First, data pre-processing. To eliminate the influences on results from dimensions, all the satisfaction indexes in the electricity industry are positive, and the formula below can be applied
\[ Z_{ij} = \frac{x_{ij}}{\max_{1\leq i \leq n} x_{ij}} \]  

(4)

Data are processed, where, \( x_{ij} \) is the value of the \( j \)th index of the \( i \)th city.

Second, translate the evaluation index information content into weight value. Various objective index weights are determined by the intra-index variability and inter-index conflict. The first one is the intra-index variability, it represents the value gaps among various evaluation objects of uniform indexes, and is expressed in the form of standard deviation \( \sigma_j \), the smaller \( \sigma_j \) is, the smaller the value gaps among various evaluation objects are, namely, the smaller the variability is. The second one is inter-index conflict \([10]\), it is based on the inter-index correlation, where, \( r_{ij} \) is the correlation coefficient between evaluation indexes \( i \) and \( j \), if there is a strong positive correlation between two indexes, it shows that the two indexes have low conflict. The calculation method is as shown below:

\[ R_j = \sum_{i=1}^{n} (1 - r_{ij}) \]  

(5)

It is assumed that \( C_j \) represents the information content contained in the \( j \)th evaluation index, and it can be expressed as:

\[ C_j = \sigma_j \sum_{i=1}^{n} (1 - r_{ij}) = \sigma_j R_i, \quad j = 1, 2, \ldots, n \]  

(6)

The value of \( C_j \) represents the information content contained in the \( j \)th evaluation index, the smaller \( C_j \) is, the smaller the information content of the corresponding index is. Lastly, after summing up the intra-index variability and inter-index conflict, and the objective weight of the \( j \)s index can be obtained with Formula (7):

\[ P_j = \frac{C_j}{\sum_{i=1}^{n} C_j}, \quad j = 1, 2, \ldots, n \]  

(7)

Comprehensive Weighting Method

Lastly, the CRITIC method and AHP are fit with Formula (8), which not only guarantees that the model and questions in the questionnaire can be well applied in the electricity industry, and make weights be with more information contents so as to obtain more suitable final weighted value.

\[ W = \frac{\sqrt{\sum_{i=1}^{m} P_i W_i}}{\sqrt{\sum_{i=1}^{m} P_i \sqrt{\sum_{i=1}^{m} W_i}}} \]  

(8)

Case Analysis

The paper takes high-voltage incremental power customers in some Chinese province in 2016 as the example, and incorporates industrial customers, commercial customers, government customers, public institution customers, military customers and other customers into the respondents, customer satisfaction is the primary index, and the other eight factors are the

Analysis on Subjective Weight in AHP

The judgement matrix of importance at various levels can be obtained according to experts’ discussion and research, with G-hierarchy as example, as shown in Table 3:
Table 3. G-Hierarchy Judgment Matrix.

|   | G | A1 | A2  | A3 | A4  | A5  | A6  | A7  | A8  |
|---|---|----|-----|----|-----|-----|-----|-----|-----|
| A1| 1 | 1/5| 1/3 | 1/3| 1/3 | 1   | 1/2 | 1   |     |
| A2| 5 | 1  | 3   | 3  | 4   | 3   | 4   | 4   |     |
| A3| 3 | 1/3| 1   | 2  | 2   | 2   | 2   | 3   |     |
| A4| 3 | 1/3| 1/2 | 1  | 1/2 | 2   | 1   | 2   |     |
| A5| 3 | 1/3| 1   | 2  | 1   | 2   | 2   | 3   |     |
| A6| 1 | 1/4| 1/2 | 1  | 1/2 | 1   | 1   | 1   |     |
| A7| 2 | 1/3| 1/2 | 1  | 1/2 | 1   | 1   | 2   |     |
| A8| 1 | 1/4| 1/3 | 1/2| 1/3 | 1   | 1/2 | 1   |     |

With Formula (2) and Formula (3), the corresponding eigenvector \( W \) of the eigenvalue in the judgment matrix can be solved, and \( W' \) is obtained after normalization:

\[ W' = [0.0518, 0.3176, 0.1553, 0.1054, 0.1553, 0.0678, 0.0908, 0.0560] \]

Namely, various index weights are obtained in AHP.

Analysis on Objective Weight in CRITIC Method

Comprehensive index is obtained after de-dimensionalizing the data collected with Formula (4), as shown in Table 4:

Table 4. De-Dimensionalized Indexes.

|   | A1 | A2  | A3 | A4  | A5  | A6  | A7  | A8  |
|---|----|-----|----|-----|-----|-----|-----|-----|
| A City| 1  | 1   | 1  | 1   | 1   | 1   | 1   | 1   |
| B City| 0.9902 | 0.9868 | 0.9917 | 0.9841 | 0.9942 | 0.9828 | 0.9820 | 0.9830 |
| C City| 0.9808 | 0.9883 | 0.9888 | 0.9971 | 0.9910 | 0.9981 | 0.9727 | 0.9996 |
| D City| 0.9751 | 0.9831 | 0.9877 | 0.9962 | 0.9833 | 0.9949 | 0.9783 | 0.9795 |
| E City| 0.9959 | 0.9843 | 0.9917 | 0.9875 | 0.9924 | 0.9894 | 0.9747 | 0.9862 |

With Formula (5), Formula (6) and Formula (7), the information content and weight are solved; the weight \( W'' \) is calculated as follows:

\[ W'' = [0.2019, 0.0642, 0.0567, 0.1468, 0.0891, 0.1469, 0.1513, 0.1431] \]

Comprehensive Weight Fitting in the Comprehensive Weighting Method

The weight \( W' \) and the weight \( W'' \) are fitted with Formula (8) to calculate the comprehensive weight \( W''' \):

\[ W''' = [0.1153, 0.1609, 0.1058, 0.1402, 0.1325, 0.1125, 0.1321, 0.1001] \]

AHP can well solve the professional weight distribution of the electricity industry and increase the applicability of the weight model in the industry. The CRITIC weighting method can improve the variable explanatory ability and show the intra-index variability and inter-index conflict, and its disadvantage is that it cannot analyze the actual situations of all trades, it can improve the applicability of the system in the electricity industry by introducing AHP and the CRITIC method into the customer satisfaction index evaluation of the electricity industry, and the intra-index variability and inter-index conflict can be shown through the survey data, then innovative weighting methods can be inferred. The index system weight is as shown in Table 5 after calculation. Due to layout reasons, only list to Secondary Index

Conclusion

As the electricity market is opened gradually, the customer satisfaction index evaluation of the electricity industry has won increasingly attention from related companies, as satisfaction survey can help companies know customers’ important service demands and improve their operation...
directions, and a perfect satisfaction evaluation system and reasonable index weights are more beneficial to the validity of satisfaction evaluation results. In the process of determining the weight in the comprehensive weighting method which integrates the AHP method and the CRITIC method, the paper not only considers about not only the fact that weight should comply with the industrial characteristics of the electricity industry, but also intra-index variability and inter-index conflict after collecting survey data, all of which make evaluation weight more objective and scientific. The obtained weight indexes can also comply with the reality, and is more helpful for the electricity industry decision-makers to make corresponding strategies according to the customer satisfaction evaluation results.

The paper evaluates the customer satisfaction evaluation weight of the high-voltage incremental power customers in some Chinese province in 2016 in the comprehensive weighting method, avoids the uncertainty caused by experts’ subjective and direct decisions in the previous customer satisfaction evaluation weights. The weight determined by the comprehensive weighting method can reflect the influences on overall satisfaction from various indexes more accurately, thus verifying its rationality, effectiveness and feasibility.

Table 5. Weight Values of the Index System.

| Primary Index | Secondary Index                     | Subjective Weight | Objective Weight | Comprehensive Weight |
|---------------|------------------------------------|-------------------|------------------|----------------------|
| Power User Satisfaction | Power Operation Expansion Installation | 0.3176            | 0.0642           | 0.1609               |
|               | Power Operation Expansion Market Behavior | 0.1553            | 0.0567           | 0.1058               |
|               | Power Supply Capacity              | 0.0518            | 0.2019           | 0.1153               |
|               | Power Supply Quality               | 0.1054            | 0.1468           | 0.1402               |
|               | Meter Reading and Fee Payment      | 0.1553            | 0.0891           | 0.1325               |
|               | Fault Repair                       | 0.0908            | 0.1513           | 0.1321               |
|               | Complaint and reporting            | 0.056             | 0.1431           | 0.1009               |
|               | Business Window                    | 0.0678            | 0.1469           | 0.1125               |

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