Evaluation of power demand-side management factors in the new electric power system reform based on FAHP

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Abstract. In the new round of the electric power system reform, it makes full use of all kinds of supporting service resources, including demand side response and load optimization technology. Therefore, under the background of new electric power system reform and facing different power demand-side management factors, this paper has proposed a method of power demand-side management factors based on fuzzy analytic hierarchy process. Taking one power grid corp as an example, Technology is the important factor of power demand-side management. The result shows that the FAHP method can evaluate the power demand-side management and offer advice for power demand-side management.

Introduction

A new round of electricity reform requires us continue to implement demand side management and improve the system of using electricity orderly and sparingly. In 2015, State Grid Corporation and Southern Power Grid have saved electricity 118.15 billion kilowatt hours and 23.98 billion kilowatt hours, due to implement power demand side management. Currently, based on the Internet, new technologies and new energy sources, the current information data revolution is affecting all fields. Energy storage technology, distributed generation, renewable energy have brought forward new requirements on the power demand side management. Power demand side management emphasizes all participants take cooperative measures,about the power of generation, transmission, sale, using. Highlight the principle of energy conservation and emission reduction, and strive to achieve the balance of power supply and demand. Therefore, it is significant to study the power demand side management in the new electricity reform based on the FAHP method.

At present, the research scope of the power demand-side management has been extended continuously, and new perspectives and new ideas have emerged. For example, the literature[1-2] based on load control and energy saving technology, from a new combinational electrical load analysis method and the key technology, explore the demand-side management respectively. The literature[3] based on the smart grid, proposes a real-time pricing dynamic game mechanism for the demand-side management for power retailers. The literature[4] from the perspective of transmission network planning, explore the demand-side management problems. The literature[5] designs a decision support system for demand-side management. The literature[6-7] considering microgrid and distributed power planning, build the operation model of demand-side managements. However, the existing literatures seldom study the influence factors of power demand-side management, and

do not grasp the breakthrough point to solve the problems of power demand-side management.

In view of the above questions, this paper explores the influence factors of power demand-side management. Based on requirements of the new electric power system reform on energy-saving and emission-reduction, it uses fuzzy analytic hierarchy process to construct evaluation model. With the example of a city power grid corp, explore the deeper problem of power demand-side management, to promote the whole society to achieve safe, green, intelligent electricity consumption.

Experimental

Influence factors

The influence factors of power demand side management are many, and that scope is wide. In order to make the results more objective, the author has invited experts to establish the evaluation group, researching influence factors of power demand-side management. Discuss and determine 20 influence factors of the power demand-side management(A), mainly related to several aspects of guarantee, economy, propaganda,technology and management. In the system, guarantee factor(B1) includes institutional guarantee(C1), energy efficiency standards(C2), professional personnel(C3) and specialized agencies(C4). Economic factors(B2) includes electricity price structure(C5), auxiliary incentives(C6), demand side bidding(C7) and energy planning and investment(C8). Propaganda factor(B3) includes propaganda of energy saving knowledge(C9), information release(C10), technology transfer(C11) and personnel training(C12). Technical factors(B4) includes energy saving technology(C13), load management technology(C14), energy substitution technology(C15), energy storage technology(C16). Management factors(B5) includes energy performance management(C17), energy information management(C18), power quality management(C19), electrical safety(C20).

Construction of the model

Fuzzy analytic hierarchy process is a kind of scientific evaluation method based on analytic hierarchy process. This paper has used the fuzzy analytic hierarchy process to construct the hierarchical structure model of power demand side management of influence factors，as shown in Figure 1. According to the principle of comprehensive, systematic and comparable, the evaluation index of power demand side management of influence factors has be established. Fuzzy judgment matrix is constructed by triangular fuzzy number method. And calculate the comprehensive fuzzy value of the index.The fuzzy comprehensive evaluation is completed, after removing fuzziness and calculating weights.

A																			
B1				B2				B3				B4				B5			
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20

Fig. 1-Hierarchical structure model

Constructe fuzzy judgment matrix

In the process of building the evaluation index system, the qualitative indicators of the influencing factors of the power demand side management should be quantified. In this paper, based on the idea of fuzzy mathematics, it is required to complete the evaluation of the power demand side influence factors on the different level, and draw the digital measurement scale map, as shown in Figure 2. Invited experts to complete comparison among various factors, and according to the comparison of the results, determine the final values. Triangular fuzzy numbers are used to

construct the fuzzy judgment matrix.

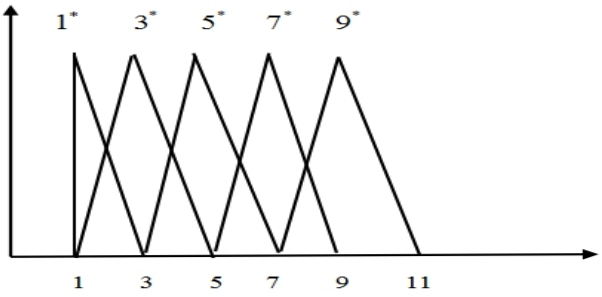

Fig. 2-Measurement scale

Calculate fuzzy value of comprehensive index

In order to make the evaluation result more objective, it is often necessary to invite a number of experts to participate in the evaluation process, and based on the evaluation results of the experts, to obtain the comprehensive fuzzy value. According to the following formula, calculate the evaluation criteria of the comprehensive fuzzy value.

$$N_i^k = \sum_{j=1}^{m} E_{ij}^k \times \left[\sum_{i=1}^{m} \sum_{j=1}^{m} E_{ij}^k \right]^{-1} \quad i = 1,2,\cdots,m \tag{1}$$

In the formula

N_i^k ----comprehensive fuzzy value of the influence factor i on the K floor

E_{ij}^k ----important degree of the factor i influences the factor j

Remove fuzziness and calculate weight

Using the method of removing fuzziness, obtain the possibility degree of triangular fuzzy number. By the normalization, get the final weight vector w. Get the final results, according to the formula(2-4).

$$V(N_1 \geq N_2) = SUP_{x \geq y}[(U_{N1}(x), U_{N2}(y))] \tag{2}$$

$$V(N_1 \geq N_2) = m(d) = \begin{cases} 1 & m_1 \geq m_2 \\ \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} & \cdots\cdots m_1 \leq m_2, u_1 \geq l_2 \\ 0 & otherwise \end{cases} \tag{3}$$

$$d(C_i) = V(N \geq N_1, N_2, \cdots N_k) = \min(N \geq N_i) \qquad i = 1,2,\cdots k \tag{4}$$

Finish fuzzy comprehensive evaluation

Suppose that one class index is $U = (u_1, u_2, \cdots u_n)$, comment set is $V = (v_1, v_2, \cdots v_n)$, weight is $W = (w_1, w_2, \cdots w_n)$. Similarly, suppose that secondary index is $U_i = (u_{i1}, u_{i2}, \cdots u_{in})$, comment set is $V_i = (v_{i1}, v_{i2}, \cdots v_{in})$, weight is $W_i = (w_{i1}, w_{i2}, \cdots w_{in})$. According to the formula(5,6), get the final evaluation result.

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \quad (5)$$

$$B = W \times R \quad (6)$$

Case study

In order to verify the evaluation of the effectiveness of the model of power demand side management influence factors. This paper takes the power demand side management of one city power grid enterprises as the object of the evaluation. And it invites seven experts to complete evaluation index selection, and determines the above 5 first indexes and 20 secondary indexes ultimately, as shown in Figure 1, and also invite 3 experts to complete the influencing factors of fuzzy comprehensive evaluation. In the evaluation of the first level indicators, the evaluation matrix can be obtained based on the results of expert evaluation. According to the formula，we can sort out these fuzzy numbers to get the fuzzy matrix, as shown in Table 1.

Table1-Fuzzy matrix

	B1	B2	B3	B4	B5
B1	(1, 1, 1)	(1/3, 1/2, 1)	(1/2, 1/2, 1)	(1, 1, 1)	(1, 1, 1)
B2	(1, 2, 3)	(1, 1, 1)	(3/2, 1, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)
B3	(1, 2, 2)	(1, 1, 3/2)	(1, 1, 1)	(1/2, 1/2, 1)	(1/2, 1/2, 1)
B4	(1, 1, 1)	(1, 2, 3)	(1, 2, 2)	(1, 1, 1)	(1, 1, 1)
B5	(1, 1, 1)	(1, 2, 3)	(1, 2, 2)	(1, 1, 1)	(1, 1, 1)

Then use statistical software to complete the statistics and analysis of fuzzy matrix. According to this formulas, calculate the weight vector of the index. And get the standardized weights, by the gravimetric technique. Therefore, the evaluation of the two level index weight can be obtained.

At this time, the weight of the power demand side influence factors is evaluated, and the results also reflect the influence degree of each factor in the power demand side management. According to the results, the city power grid corp should focus on improving the technical level of power demand side management, but also should pay attention to management factors, economic factors and publicity factors, and can not ignore the security factors. In addition, in order to explore the comprehensive level of power demand side management, power demand side management influence factors of comment sets can be "good, good, in general, not good, very bad" in the example. Invite experts to complete the objective evaluation of secondary indicators, and form the fuzzy judgment matrix R.

The final results are calculated according to the weight of the index and the comments given by experts. According to this formula(5,6), the fuzzy membership degree of each factor in the first grade index is obtained, A=(0.37, 0.30, 0.18, 0.13, 0.03). Taking the objective situation into account, the comments "very good, good, general, bad, very bad" can be given a weighted value, Z=(10,8.5,7,5,1). The final results of the comprehensive evaluation are obtained, A*Z=8.22. This shows that the power demand side management of the city power grid enterprise is “good”. But there's still room for improvement.

Results and Discussion

In this paper, the fuzzy analytic hierarchy process is used, setting up an example and a multi index system to study the power demand side management factors. It turned out that echnical factors are the key factors that affecting the power demand side management factors of the power grid corp. Therefore, take measures about echnical factors, focus on the development of load management technology and alternative energy technology. The results show that the model based on the fuzzy analytic hierarchy process can evaluate the influence factors of power demand side management objectively.

In reality, there are different situations in each area, demand side management will also face different problems. In order to adapt to the requirements of the new electricity reform and the actual situation in the region, to further improve the level of demand side management, we need to seize the main contradiction, and find the key factors affecting the power demand side management. For example, if economic factors is the key factors influencing power demand side management, then we need to take measures in the aspects of the adjustment of price structure, the implementation of ancillary rewards, demand side bidding, energy planning and investment and so on.

This paper has an important role in the research of power demand side management under the background of new electricity reform. Enhance market participants to participate in power demand side management. The power company will update the production technology, promote the demand response actively, improve the comprehensive management level, enhance their comprehensive competitive ability. And power demand side management is conducive to achieve the efficient use of energy in our country, to ease the pressure of energy demand, achieve the balance of energy supply and demand. At the same time, it can reduce the discharge of pollutants effectively, and play a significant role in the ecological civilization construction in our country.

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