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Two-Sided Matching Decision Method of Electricity Sales Package Based on Disappointment Theory

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Abstract: In the context of "dual carbon", with the continuous deepening of the power system reform, the application of high proportion renewable energy is becoming increasingly widespread. All sectors of society have put forward higher requirements for electricity sales packages, which can guide the behavior of power users, promote energy conservation and emission reduction, and finally promote low-carbon operation of the power market economy.Therefore, the requirements of power users and power selling companies for the power selling package are increasing, which puts forward higher requirements to the power selling package recommended by the power selling company . However, the existing recommendation methods are unable to make appropriate recommendations for the users with lack of preference information. Therefore, this paper proposes a two-sided matching decision-making method of electricity sales package based on disappointment theory. First of all, according to the incomplete fuzzy preference relationship provided by the power user and the electricity sales package, the respective priority weight vector is obtained, and then the subjective satisfaction matrix of the power user and the electricity sales package to each other is obtained; Next, the adjusted satisfaction matrix is calculated by adding the influence of the theory of joy and disappointment; Then, based on the adjusted satisfaction matrix, an optimization model aiming at maximizing the total satisfaction of power users and electricity sales packages is established, and the optimal stable matching model of power users and electricity sales packages is obtained; Finally, taking an industrial park in Zhejiang Province as an example, by using the bilateral matching method proposed in this article, the optimal matching schemes for 5 power users and 6 electricity sales packages are obtained, which shows the effectiveness and rationality of the two-sided matching decision-making method of electricity sales package based on the disappointment theory proposed in this paper.

Keywords: renewable energy,disappointment theory; incomplete fuzzy preference relationship; satisfaction matrix; two-sided matching; field survey

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Nomenclature

P	Collection of power users
Q	Collection of electricity sales packages
μ	One-to-one mapping relationship
u_{ij}^{P}	Subjective satisfaction of the *i-th* power user with the *j-th* electricity sales package
u_{ij}^{Q}	Subjective satisfaction of the *j-th* electricity sales package with the *i-th* electricity user
R^{i}	Incomplete fuzzy preference relationships provided by power user *i*
T^{j}	Incomplete fuzzy preference relationships provided by electricity sales package *j*
ω^{P_i}	Priority weight vector for power user P_i
$\omega_j^{P_i}$	Priority weight of the *i-th* user for the *j-th* type of electricity sales package

ω^{Q_j}	Priority weight vector of electricity sales package Q_j
$\omega_i^{Q_j}$	Priority weight of the *j-th* electricity sales package for the *i-th* electricity user
Δ^{P_i}	A set containing effective preference information of user P_i
Δ^{Q_j}	A set containing effective preference information of package Q_j
d_{ij}^P	The disappointment value of P_i
e_{ij}^P	The joy value of P_i
d_{ij}^Q	The disappointment value of Q_j
e_{ij}^Q	The joy value of Q_j
$D_i(x)$	Disappointed value function of *i*
$E_i(x)$	Joy value function of *i*
α_i^P	Disappointment value sensitive parameter for the *i-th* user in set *P*
β_i^P	Joy value sensitive parameter for the *i-th* user in set *P*
$\overline{U^P}$	Satisfaction of electricity user *P* after adjustment
$\overline{U^Q}$	Satisfaction of package *Q* after adjustment
ω	weight coefficient

0. Introduction

In the context of the implementation of "dual carbon", the reform of the power system is deepening, all sectors of society pay more and more attention to the application of renewable energy, and the demand of power users for clean energy is also growing. Only by further increasing the proportion of renewable energy and making it deeply replace traditional fossil fuels, can the high carbon coal, natural gas and other power systems develop in a low-carbon or even zero carbon direction [1], and achieve a Low-carbon economy. A large number of power selling companies have emerged, and the demand for high-quality electricity from social power users is also constantly increasing [2]. High quality electricity refers to electricity with higher power quality indicators than those specified in existing public grid power supply regulations and restrictive standards [3]. For electricity sales companies, they need to attract electricity users by setting reasonable electricity sales package prices, improving power quality, increasing the proportion of renewable energy, and providing additional value-added services. For power users, they need to choose appropriate electricity sales packages based on different needs such as power supply reliability and electricity cost [4]. Therefore, the matching between electricity users and electricity sales package can not only improve the revenue of electricity sales companies, meet the demand of users for high-quality electricity, but also has great significance in promoting the operation of the Low-carbon economy.

At present, the main method for power users to choose the electricity sales package is that the electricity sales company recommends the electricity sales package, and then the power users make the decision. For power selling companies, recommending appropriate power selling package services for users is an effective way to improve the viscosity of power users to power selling companies and attract a large number of new users for power selling companies [13]. At present, there are two main methods for recommending electricity sales packages: indirect recommendation and direct recommendation. There are two main categories of existing indirect recommendation methods, namely statistical analysis recommendation method and mathematical modeling recommendation method. In statistical analysis, the main methods used include regression analysis, cluster analysis, and preference analysis. Reference [5] studied the impact of income, consumption expenditure and price on household electricity consumption based on Quantile regression analysis, avoiding sampling deviation, and providing more accurate electricity sales package for families; Reference [6] uses time load time series to cluster and analyze residential electricity customers, extracting customer behavior or load curves from the time series, in order to more targeted recommend electricity sales packages to users; Reference [7] used a preference analysis based approach to develop fair energy allocation policies and unified pricing mechanisms for energy trading in P2P markets. However, in statistical analysis methods, most rely more on reliable and sufficient data. If the data quality is low or the data volume is small, it may reduce the accuracy of recommendation results. In mathematical modeling, the main methods used are Collaborative filtering method and mixed recommendation method. Among mathematical modeling methods, Collaborative filtering method and hybrid recommendation method are two commonly used methods. Reference [8,9] measures the relationship between users or products through collaborative filtering, looks for similar neighbor sets, and then completes the recommendation. However, the attribute of the item itself is not considered in the recommendation, which is easy to reduce the accuracy of the recommendation; Reference [10] based on the collaborative recommendation algorithm, designed a recommendation method of electricity sales package in Spark environment, comprehensively considered the power users and electricity sales package volume to predict and score, and obtained the recommendation data; Reference [11] designs a recommendation system for electricity sales package based on collaborative filtering and hybrid Bayesian algorithm according to the electricity consumption characteristics of power users; Reference [12] is based on the artificial intelligence technology of collaborative filtering, and recommends the electricity sales package according to the energy consumption characteristics of intelligent building customers. Although the indirect recommendation method is widely used, because the collaborative filtering method needs to cluster users, it needs to set the number of clusters in advance, which leads to low accuracy and efficiency of clustering, and reduces the accuracy of the method. And since the model is based on historical data, the recommendation performance of the model may be limited when there is a lack of historical data or the data is too old. In the direct recommendation method, it is mainly through the use of iSelect [13], Check24 [14] and other power selling package recommendation platforms. However, this method is mainly based on the power selling price and lacks many key factors that have an important impact on the electricity price, so the recommendation results are not accurate. In addition, among the two major categories of recommendation methods mentioned above, when the power user and the electricity sales package evaluate each other, they do not take into account the situation that the power user may not know about the additional services of the electricity sales package and the electricity sales company may not know about the preferences of the power user. However, in the actual situation, due to various factors such as the source of information and the large number of electricity sales packages, it is often difficult for the power user to thoroughly understand the specific information of various electricity sales packages, Therefore, how power users make the best choice under limited cognition is an urgent problem to be studied.

To sum up, this paper proposes a decision-making method of user's electricity sales package considering incomplete fuzzy preference relationship. This method can take the subjective psychological feelings into account, and overcome the limitations of limited knowledge or understanding between the matching parties, and still accurately determine the optimal matching scheme under certain conditions of missing information. The process of this method is: First of all, the priority vector of power users and electricity sales package is determined based on incomplete fuzzy preference relationship; Then, a method to describe the satisfaction of electricity users and electricity sales packages based on the disappointment theory is proposed; Then, a multi-objective optimization model based on the two-sided matching method is proposed, which aims at maximizing the overall satisfaction of the matching between power users and electricity sales packages; Finally, a case study of power users in an industrial park in Zhejiang Province is carried out to verify the feasibility and effectiveness of the matching decision-making method of user's electricity sales package considering incomplete fuzzy preference.

The characteristic of disappointment theory is its asymmetric sensitivity, dual threshold effect, abstention effect, and intuitive effect. Asymmetric sensitivity refers to the fact that both matching parties are more sensitive to disappointment; The dual threshold effect refers to the existence of two thresholds for the sensitivity of both matching parties to risk. When one threshold is reached, the sensitivity to risk increases, and when the other threshold is exceeded, the sensitivity to risk decreases;

The abstention effect refers to the fact that both parties in the match will give up the option with higher returns due to fear of disappointment; Intuitive effect refers to the fact that when faced with a large number of risks and decision-making choices, both matching parties often make choices based on intuition.

The characteristics of incomplete fuzzy preference are fuzziness, uncertainty, environmental dependence, relativity, and subjectivity. Ambiguity refers to the imprecise preferences given by both matching parties; Uncertainty refers to the hesitation phenomenon caused by the difficulty of predicting the consequences of each decision by both matching parties in decision-making; Relativity refers to the fact that the decision results given by both matching parties will be influenced by the environment, resulting in discrepancies in the decision results; Subjectivity refers to the fact that every decision is the result of matching the subjective experiences and judgments of both parties.

1. Construction of evaluation index system for power users and power selling companies

1.1. Power users' evaluation index of electricity sales package

The power quality and power supply service of the electricity sales package are the two main considerations for power users when selecting the electricity sales companies to launch different electricity sales packages.

1.1.1. Clean energy ratio of the package

"Carbon peaking" refers to the phenomenon where the total amount of carbon dioxide emissions reaches a historical peak at a certain point in time, during which there will still be fluctuations in the total amount of carbon emissions, but the overall trend is flat, and then the total amount of carbon emissions will gradually and steadily decline. "Carbon neutrality "refers to the phenomenon of neutralizing all carbon dioxide emissions, even achieving negative carbon emissions, through fixed carbon emissions, afforestation, and other methods on the basis of "carbon peaking" . Carbon peaking and carbon neutrality will have a huge impact on all aspects of our lives. The development of clean energy is an important means to help China achieve carbon peak and carbon neutrality goals.

In 2003, the British energy white paper "Our Energy Future: Creating a Low-carbon economy" put forward the concept of a Low-carbon economy for the first time. Since then, global energy has gradually entered a transitional stage towards a green and low-carbon energy structure. China has gradually promoted the development of clean energy into marketization, developing a clean energy structure system consisting of wind power, photovoltaic power generation, tidal power generation, hydropower, biomass power generation, and other clean energy source.

According to data from the National Bureau of Statistics, the main power generation mode in China is still traditional thermal power generation. However, the proportion of clean electricity consumption in total energy consumption has been increasing year by year, from 20.5% in 2017 to 25.5% in 2021.

In order to adapt to the accelerating adjustment of the global energy structure and the unchangeable trend of clean energy power generation, electricity sales companies need to increase the proportion of clean energy power generation in the package when formulating electricity sales plans, and promote the development of "green electricity". At the same time, this will also become a crucial factor to power users when choosing electricity packages. Now we define the proportion of clean energy power supply to the total power supply in the electricity sales package as QJ. If , then the proportion of clean energy is relatively small; If , then the proportion of clean energy is moderate; If , the proportion of clean energy is relatively high, and electricity users will also have higher satisfaction with it.

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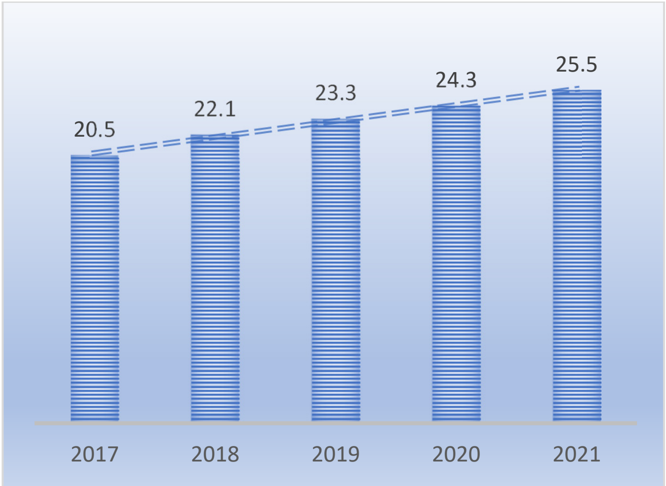

Figure 1. The proportion of clean energy consumption to total energy consumption from 2017 to 2021.

1.1.2. Power quality

The factors that measure power quality mainly include voltage sag, harmonic and three-phase voltage unbalance.

Voltage sag is a common voltage disturbance phenomenon in the distribution system. It is an accidental event. No matter how to improve the reliability of the power system, voltage sag will still exist. Therefore, the degree of voltage sag and the frequency of voltage sag have become one of the important standards to measure the quality of power supply by power supply companies. Voltage sag refers to the sudden event that the effective value of bus voltage drops sharply and rapidly and lasts for a very short time [16]. In the power grid, the duration of this phenomenon is mostly 0.5~1.5s. The International Institute of Electrical and Electronic Engineers (IEEE) defines voltage sag as the phenomenon that the effective value of the supply voltage rapidly drops to 90% - 10% of the rated value, and then returns to the normal value. Voltage sag is mainly caused by short circuit fault, transformer excitation and induction motor startup. The short circuit fault mainly includes three-phase grounding short circuit, single-phase grounding short circuit, two-phase interphase short circuit and two-phase grounding short circuit. Voltage sag will lead to unit shutdown, misoperation of production machinery, machine damage and other consequences, resulting in equipment damage, shutdown and even scrap, and production line interruption. And its coverage is extremely extensive. So far, the semiconductor industry, petrochemical industry, automobile manufacturing and chemical fiber industry have suffered huge human and material resources and financial losses caused by voltage sag [17]. Therefore, the smaller the amplitude and frequency of the voltage sag of the electric energy provided by the power selling company, and the corresponding anti-interference core technology for different sensitive loads, the higher the power stability of the electricity sold by the company, and the more popular it will be with the power users. A simple and effective voltage sag detection method is proposed in Reference [18]. By sampling the signal for a period, the voltage amplitude is calculated from formula (1) to determine whether the voltage sag occurs.

$$U_{RMS} = \sqrt{\frac{1}{N}\int_{t_0}^{t_0+T} u_i^{\,2}(t)dt} \tag{1}$$

Where, U_{RMS} is the effective value of voltage; N is the number of sampling points in a period; T is the signal period.

Harmonic current refers to the current of each sinusoidal component whose frequency is an integral multiple of the frequency of the original periodic current when the non-sinusoidal periodic current function is expanded in Fourier series. With the rapid development of science and technology, a large number of power electronic nonlinear devices, such as computers, monitors, induction cookers, washing machines, etc [19]. There are also traditional nonlinear devices, such as transformers, rotating electrical machines and fluorescent lamps [20], which are more and more widely used in low-voltage distribution networks and ordinary power users. Although the single harmonic impact of these new harmonic sources is small, due to their large number, the cumulative harm can not be ignored, which will cause serious harmonic pollution. The harm of harmonic current is mainly reflected in two aspects: first, harmonic current will cause power loss and increase the burden of users' electricity charges; The second is that the increase of current will cause the equipment temperature to rise, accelerate the insulation aging and greatly shorten the service life of the equipment. Therefore, when formulating the power selling plan, the power selling company needs to consider the impact of harmonic current comprehensively, install some adaptive filters to reduce harmonic, thus reducing losses, reducing the burden of electricity charges of power users, and to protect equipment and lines to a certain extent, and effectively control the daily operation and maintenance costs [21]. The detection methods of harmonic active current, reactive current and load harmonic current are described in detail in reference [22]. In the study of power grid power quality, the total harmonic distortion rate (THD) is generally used to characterize the harmonic level of the power grid, and the specific formula is as follows:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} U_h^{\,2}}}{U_1} \times 100\% \tag{2}$$

Where U_1, U_h is the amplitude of the h harmonic voltage and the amplitude of the fundamental voltage.

Three-phase voltage unbalance refers to the inconsistent amplitude or phase angle of three-phase voltage. When three-phase voltage unbalance occurs, negative sequence current and zero sequence current will be generated correspondingly, which will cause serious loss and great voltage drop to the power line, and interfere with the communication system, resulting in the heating, vibration and loss of the rotating motor and transformer, and affecting the service life of the electrical equipment [23]. Its degree is characterized by three-phase voltage unbalance, which is generally calculated by the ratio of the effective value of the negative sequence component of voltage or current to the positive sequence component. Three-phase voltage imbalance has different degrees of impact on the power supply and distribution system, mainly on transformers, electrical equipment and transmission lines. It will lead to the increase of transformer load loss, the reduction of overload capacity, the increase of core eddy current loss and the intensification of heating, and reduce the service life of the transformer. For ordinary power users, three-phase load asymmetry will lead to the deviation of the neutral point, resulting in the problem of user voltage deviation, leading to the unstable operation of electrical equipment. In the process of current transmission, the greater the three-phase unbalance, the greater the line loss, and the lower the economy of power transmission [24]. Therefore, when power users choose power selling companies, three-phase voltage unbalance is also an important consideration index. The lower its value, the more economical and high-quality power supply they enjoy. In three-phase power system, three-phase unbalance is usually expressed quantitatively by three-phase voltage unbalance rate (PVUR):

$$PVUR = \frac{\max\{|V_A - \overline{V}|, |V_B - \overline{V}|, |V_C - \overline{V}|\}}{\overline{V}} \times 100\% \tag{3}$$

wherein V_A, V_B, V_C, respectively represents the A, B, C phase voltage and $\overline{V}$ means the value of three-phase voltage.

1.1.3. Power supply service

Power supply service mainly consists of ordinary power supply service and value-added service.

The so-called power supply service refers to the service that the power supply company provides customers with some corresponding valuable business activities in the form of labor services in order to enable customers to purchase electricity and meet their production and living needs. Due to the social, systematic, special, developmental characteristics of power supply service and the imbalance between power supply capacity and user load, it is slightly different from the general service industry, which generally includes basic services such as meter reading and charging, fault repair, complaint reporting, inquiry and consultation. The well-known foreign scholars Parasuraman, Zeithaml and Berry built the service quality gap module in 1985, believing that service quality is the gap between customer expectations and customer experience, and proposed 10 dimensions that affect perceived service quality and customer perceived service, including responsiveness, accessibility, security, reliability, ability, politeness, communication, credibility, understanding and tangibility. Reference [25] elaborates the relevant contents of power supply service quality, and clarifies the connection and interrelation between the service of power supply companies and customers' expectations of service quality. In short, if the power supply company can sell electricity in accordance with the four principles of "high quality, convenience, standardization and sincerity", the higher the quality of electricity sold by the power supply company, the better the psychological feelings it brings to customers, and the more attractive the electricity sales package will be.

In the context of the opening of the power selling side, value-added services are diversified, mainly including high-quality power supply information services, high-quality power network trading services, high-quality power supply demand services for users, and high-quality power supply services for high-end users, which can be subdivided into electricity engineering, energy efficiency services (contract energy management, comprehensive energy conservation, contract energy consumption consulting), customer services, high-quality power value-added services, etc [26]. In the open electricity sales market, electricity sales companies mainly rely on the price of the electricity sales package and its services to improve their competitiveness and attract electricity customers. Among them, value-added services are highly scalable, and power selling companies can improve customer satisfaction by providing high-quality personalized high-quality value-added services for electricity [27]. In order to meet the special needs of power users, power selling companies can provide specific personalized services for power selling packages; In order to promote the low-carbon development of the power industry and respond to the national green development requirements, power selling companies can provide power selling packages with energy-saving services; In order to improve the application rate of clean energy, power selling companies can launch customized electricity selling packages for clean services; In the current era of "Internet plus", in order to promote the networking of power consumption, power sales companies can provide power sales packages containing new networking services, keeping pace with the times; Furthermore, by integrating several value-added models and integrating resources, we can launch the electricity sales package with the highest value-added comprehensive service model, which fully responds to the personalized needs of power users [28].

From the perspective of power users, the power supply services of power companies can be characterized by five grades: very bad, poor, average, better and excellent. First of all, according to their subjective experience of electricity use, power users will score from 0 to 10 on the 10 basic and value-added services provided by the power company, including meter reading, fault repair, complaint reporting, inquiry and consultation, electricity engineering, contract energy management, comprehensive energy conservation, contract energy consultation, customer service, and high-quality electricity value-added service. The higher the score, the more satisfied the power users are with the service. Then, the total satisfaction of power users with power supply service DE is calculated according to the following formula:

$$DE = \sum_{i=1}^{10} \omega_i x_i, i = 1, 2, \dots 10 \tag{4}$$

Wherein, ω_i is the weight of each power supply service, x_i is the score given by power users for each service, and for convenience, let $\omega_1 = \omega_2 = \dots = \omega_{10} = 0.1$. If $90 < DE \leq 100$, the power supply service is excellent; if $80 < DE \leq 90$,then the power supply service is better; if $70 < DE \leq 80$, then the power supply service is average; if $60 < DE \le 70$,The power supply service is poor; if $50 < DE \le 60$, then the power supply service is bad.

1.2. Evaluation index of power selling company to users

When selecting users, power selling companies mainly include the user value and investment ability of users into the main reference indicators.

1.2.1. User value

User value can be characterized by current value, potential value and lifetime value [29].

User value refers to the value that customers can bring to the enterprise, which can be expressed by the monetary contribution that customers bring benefits to the enterprise. This value is also called customer lifetime value from the perspective of the enterprise, that is, the sum of net profits that enterprises obtain from customers throughout their life cycle. The traditional customer lifetime value consists of current value and potential value, as shown in Figure 2.

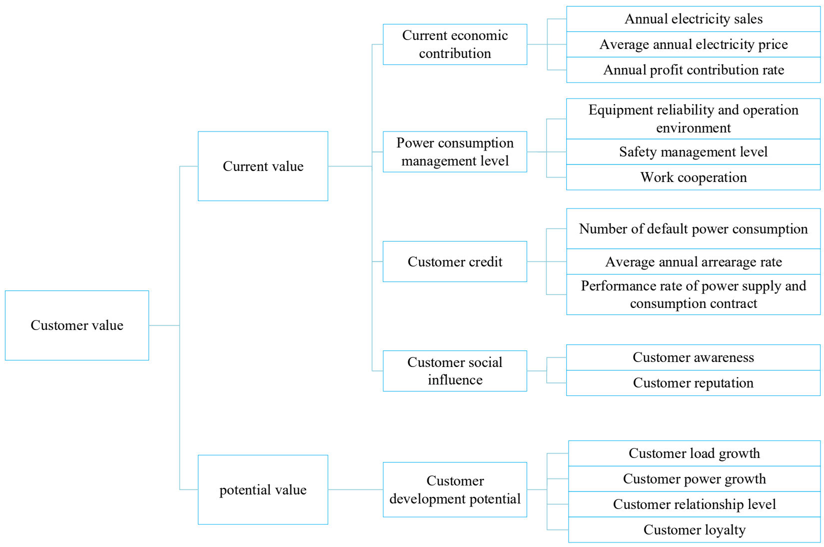

Figure 2. Power user value evaluation system.

Reference [30] proposes a power user value analysis system based on analytic hierarchy process. First, establish the fuzzy consistency judgment matrix.

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

Then use formula (6) to calculate the weight of each element

$$w_i = \frac{1}{n^2 - n}(2\sum_{k=1}^{n} r_{jk} - 1), i = 1 \sim n \quad (6)$$

Finally, the comprehensive value of power users can be obtained by using formula (7).

$$Z = \sum_{j=1}^{m} x_{ij} w_j \quad (7)$$

Customer lifetime value consists of customer's current value and potential value. The higher the customer's lifetime value, the greater the value of cooperation between the company and the customer, and the more benefits can be obtained from it.

1.2.2. User investment ability

The user's investment ability can be described from the user's reputation and quality.

As an intangible asset of enterprises, the reputation of enterprise users has become one of the main sources of user competition. The higher the reputation of an enterprise user, the higher the stability, efficiency, profitability and growth ability of the user's operation, and the greater the social responsibility it bears. The more it can form its own strong values in the society, the greater its social influence [31]. Therefore, power selling companies can make long-term profits by cooperating with reputable enterprise users, and can promote their own power selling packages through their own social influence to attract more high-quality power users.

Enterprise quality is a comprehensive ability of an enterprise to use human, material and financial resources to complete its business and production activities. It includes the ability of survival, adaptability, competitiveness, development and innovation. Therefore, enterprise quality is a complex comprehensive organism, which is not only the unity of production and operation factors and their reasonable organization, but also the coordination and unity of internal factors and external conditions of the enterprise [32]. The higher the quality of an enterprise user, the stronger the enterprise user's ability to cope with risks and challenges, and the more stable the development. The higher the benefit of the cooperation between the power selling company and it, the more inclined the power selling company is to cooperate with it.

Reference [33] proposes a method for evaluating investment capacity based on *TOPSIS* method. First of all, set an ideal value vector $(x_{i1}^*, x_{i2}^*, ..., x_{im}^*)$ for several evaluation objects describing the user's investment ability which represents the optimal investment ability of the power user. Set the actual value of the evaluation object as $(x_{i1}, x_{i2}, ..., x_{im})$, and the weighted distance between them is y_i:

$$y_i = \sum_{j=1}^{m} w_j f(x_{ij}, x_j^*), i = 1, 2, ..., n \tag{8}$$

Where w_j is the weight coefficient and $f(x_{ij}, x_j^*)$ is the distance between x_{ij} and x_j^*. If it $(x_1^+, x_2^+, ..., x_m^+)$ is a positive ideal scheme and $(x_1^-, x_2^-, ..., x_m^-)$ is a negative ideal scheme, the distance between the evaluation object used to describe the investment ability and the positive ideal points and the distance between the evaluation object and the negative ideal points are respectively shown as follows:

$$y_i^+ = \sqrt{\sum_{j=1}^{m} w_j (x_{ij} - x_j^+)^2}, i = 1, 2, ..., n \tag{9}$$

$$y_i^- = \sqrt{\sum_{j=1}^{m} w_j (x_{ij} - x_j^-)^2}, i = 1, 2, ..., n \tag{10}$$

User investment ability can be expressed as C_i:

$$C_i = \frac{y_i^-}{y_i^+ + y_i^-} \tag{11}$$

The larger C_i is, the stronger the power user's investment ability is and the more favorable it can obtain from the power selling company.

2. Matching method between power user demand and power selling package of power selling company

2.1. Overview of two-sided matching problem (TSMDM)

The purpose of two-sided matching problem is to find the best matching method between objects on both sides according to the preference information or evaluation results provided by

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matching objects, so as to maximize the interests of both sides. In this paper, set the power user as a matrix $P=\{P_1,P_2,...,P_n\}$, P_i representing the *i-th* user in the power user set, $i\in\{1,2,...,n\}=I$ .Set the electricity sales package as a collection $Q=\{Q_1,Q_2,...,Q_m\}$ ($n\le m$). Q_j refers to the *j-th* electricity sales package in the electricity sales package set, $j\in\{1,2,...,m\}=J$. Two-sided matching is a one-to-one mapping μ from set P to set Q. Where $\mu(P_i)=Q_j$ means that the power user P_i matches the electricity sales package Q_j, and vice versa. It should be noted that there will be *m-n* packages that will not be selected.

The existing definitions are as follows: u_{ij}^P indicates the user P_i's satisfaction with the package Q_j, and u_{ij}^Q indicates the adaptation degree of the package Q_j to the user P_i. If there are two situations: 1. $\exists P_i,P_l\in P,Q_j,Q_k\in Q,\mu(P_i)=Q_k,\mu(P_l)=Q_j$,making $u_{ij}^P>u_{ik}^P$ and $u_{ij}^Q>u_{lj}^Q$ .2. $\exists P_i\in P,Q_j,Q_k\in Q,\mu(P_i)=Q_k,\mu(Q_j)=Q_j$,making $u_{ij}^P>u_{ik}^P$, then the two-sided match is unstable, otherwise it is a stable two-sided match.

Next, we introduce a binary variable x_{ij} to indicate whether P_i and Q_j is matched. The conditions for stable two-sided matching can be defined as follows:

$$x_{ij}+\sum_{u_{ih}^P>u_{ij}^P}x_{ih}+\sum_{u_{kj}^Q>u_{ij}^Q}x_{kj}\ge 1,i\in I,j\in J \tag{12}$$

$$x_{ij}=\begin{cases}1,\mu(P_i)=Q_j\\0,\mu(P_i)\ne Q_j\end{cases} \tag{13}$$

2.2. Incomplete fuzzy preference relationship

For convenience, the assumption $X=\{x_1,x_2,...,x_p\}$ is a set of fixed options of the decision-maker, which x_i represents the fuzzy preference degree of the *i*-th element in the decision-maker set X. We use a matrix $A=(a_{ij})_{p\times p}$ to describe it. $a_{ij}\in(0.5,1)$ indicates that for decision-maker, x_i is better than x_j; $a_{ij}\in(0,0.5)$ indicates that the x_i is not preferred to x_j ;and $a_{ij}=0.5$ indicates that x_i and x_j are equally preferred. In order to make the results more rigorous, we stipulate $a_{ij}+a_{ji}=1,i,j=1,2,...,p$.

In fuzzy preference matrix *A*, if some elements are unknown, then *A* is called incomplete fuzzy preference relation matrix. If at least one element other than diagonal is known in each row and column, then *A* is called an acceptable incomplete fuzzy preference matrix, otherwise it is unacceptable.

2.3. Subjective satisfaction

Generally speaking, a power user has different preferences for different power sales packages, and for a certain power sales package, the power company has different preferences for different power users. Therefore, we can rank the satisfaction of electricity users and electricity sales packages.

We assume that it is used $U^P=(u_{ij}^P)_{n\times m}$ to express the subjective satisfaction matrix of the electricity sales package given by the power users according to their own demand for electricity, and the element u_{ij}^P represents the subjective satisfaction of the power user P_i with the electricity sales package Q_j ,which reflects the P_i's preference for Q_j. The greater the value, the higher the degree of preference. In the same way, $U^Q=(u_{ij}^Q)_{n\times m}$ represents the subjective satisfaction matrix of power users given by the power sales package according to their preferences for power users, and the element u_{ij}^Q represents the subjective satisfaction of the power sales package Q_j to power user P_i.

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We assume that $R^i = (r^i_{jl})_{m\times m}$ is used to represent the incomplete fuzzy preference relationship of power user P_i for m kinds of electricity sales packages, where r^i_{jl} represents the result of P_i comparing electricity sales package Q_j with the electricity sales package Q_l. $0 < r^i_{jl} < 0.5$ means that the preference of power user P_i for the package Q_j is less than that for the package Q_l; $0.5 < r^i_{jl} < 1$ means that the preference of power user P_i for the package Q_j is higher than that for the package Q_l; $r^i_{jl} = 0.5$ means that the preference of power users P_i for the package Q_j is the same as that for the package Q_l .In addition, if power users cannot compare the two packages, data will be missing, as $r^i_{jl} = \varphi$ indicated by.

In order to obtain the priority weight vector of each power user for all electricity sales packages, we need to introduce an indicator matrix $\Delta = (\delta_{ij})_{m\times m}$, where

$$\delta_{ij} = \begin{cases} 0, a_{ij} = \varphi, \\ 1, a_{ij} \neq \varphi, \end{cases}, i, j = 1,2,\ldots,m \tag{14}$$

The priority weight vector of power user P_i can be obtained by the *LLSM* method proposed in reference[29]. The specific steps are as follows:

First, use the indicator matrix to obtain the matrices *D* and *Y*

$$D = \begin{pmatrix} \sum_{j=2}^{m} \delta_{1j} & -\delta_{12} & \cdots & -\delta_{1,m-1} \\ -\delta_{21} & \sum_{\substack{j=2 \\ j\neq 2}}^{m} \delta_{2j} & \cdots & -\delta_{2,m-1} \\ \vdots & \vdots & \cdots & \vdots \\ -\delta_{m-1,1} & -\delta_{m-1,2} & \cdots & \sum_{\substack{j=2 \\ j\neq m-1}}^{m} \delta_{m-1,j} \end{pmatrix}, \quad Y = \begin{pmatrix} \sum_{j=1}^{m} \delta_{1j} (\ln a_{1j} - \ln a_{j1}) \\ \sum_{j=1}^{m} \delta_{2j} (\ln a_{2j} - \ln a_{j2}) \\ \cdots \\ \sum_{j=1}^{m} \delta_{m-1,j} (\ln a_{m-1,j} - \ln a_{j,m-1}) \end{pmatrix} \tag{15}$$

Next, the matrix *D and Y* are substituted into the formula to $W = (W_1, W_2, \ldots, W_{m-1})^T = D^{-1}Y$ obtain the *W* vector, and then the vector *W is* substituted into the formula (16) to obtain the P_i priority weight vector of power users $\omega^{P_i} = (\omega_1^{P_i}, \omega_2^{P_i}, \ldots, \omega_{m-1}^{P_i})^T$.

$$w = \begin{cases} \dfrac{\exp(W_i)}{\sum_{j=1}^{m-1} \exp(W_j) + 1}, i = 1,2,\ldots,m-1 \\ \dfrac{1}{\sum_{j=1}^{m-1} \exp(W_j) + 1}, i = m \end{cases} \tag{16}$$

If $R^{i'}$ is an unacceptable incomplete fuzzy preference relation matrix, the priority weight vector can be obtained through the following steps:

1.Remove the rows and columns with only one known element (assuming that the first row, the first column, ($1 < l < m$)) to obtain a new acceptable incomplete fuzzy preference matrix $R^{i'}$;

2.Use the above method to obtain an incomplete priority weight vector $\omega^{P_i'} = (\omega_1^{P_i}, \omega_2^{P_i}, \ldots, \omega_{m-1}^{P_i})^T$;

3.Insert - *M* in the line next to line *l-1* of the vector $\omega^{P_i'}$, or - *M* in the line above line *l*+*1*.- *M* shows that the decision-makers have no clear preference for the first type of electricity sales package.

Finally, power users P_i ' subjective satisfaction with the electricity sales package Q_j can be expressed by u_{ij}^P .

$$u_{ij}^P = \begin{cases} \dfrac{\omega_j^{P_i} - \min\limits_{Q_j \in \Delta^{P_i}} \left\{\omega_j^{P_i}\right\}}{\max\limits_{j \in J}\left\{\omega_j^{P_i}\right\} - \min\limits_{Q_j \in \Delta^{P_i}} \left\{\omega_j^{P_i}\right\}}, & Q_j \in \Delta^{P_i} \\ -M, & Q_j \notin \Delta^{P_i} \end{cases}, \quad i \in I \tag{17}$$

Similarly, we set $T^j = (t_{ik}^j)_{n \times n}$ to represent the incomplete fuzzy preference relationship of the electricity sales package Q_j for n power users.

In the same way, it can be concluded that the subjective satisfaction degree of the electricity sales package Q_j with the power user P_i can be expressed by u_{ij}^Q .

$$u_{ij}^Q = \begin{cases} \dfrac{\omega_i^{Q_j} - \min\limits_{P_i \in \Delta^{Q_j}} \left\{\omega_i^{Q_j}\right\}}{\max\limits_{i \in I}\left\{\omega_i^{Q_j}\right\} - \min\limits_{P_i \in \Delta^{Q_j}} \left\{\omega_i^{Q_j}\right\}}, & P_i \in \Delta^{Q_j} \\ -M, & P_i \notin \Delta^{Q_j} \end{cases}, \quad j \in J \tag{18}$$

Where $\Delta^{P_i} = \left\{Q_j \mid \omega_j^{P_i} \neq -M, j \in J\right\}$ is a set containing user P_i 's effective preference information; $\Delta^{Q_j} = \left\{P_i \mid \omega_i^{Q_j} \neq -M, i \in I\right\}$ is a set containing the effective preference information of the package Q_j .

2.4. Two-sided matching decision based on disappointment theory

The theory of disappointment was first put forward by Bell in reference [34]. He believed that disappointment is a psychological reaction of decision makers by comparing actual results with expected results. The two-way choice between power users and electricity sales packages is the product of satisfying two-sided satisfaction at the same time. It is a psychological evaluation of the currently selected objects by both sides, and is related to the psychological perception of disappointment and joy. Disappointment is the sense of dissatisfaction when the actual result does not meet the expected standard of the decision-maker; Joy is the satisfaction generated when the actual result exceeds the expected standard of the decision-maker.

Assume that the priority weight vector value $Q = \{Q_1, Q_2, ..., Q_j, ..., Q_m\}$ of power user P_i for the electricity sales package is ranked from low to high: $u_{i1}^P < u_{i2}^P < ... < u_{ij-1}^P < u_{ij}^P < u_{ij+1}^P < ... < u_{im}^P$. If P_i and Q_j match, at this time, the satisfaction of power user P_i is not only related to the electricity sales package Q_j , but also related to other electricity sales packages. On the one hand, because the packages in the collection $\left\{Q_1, Q_2, ..., Q_{j-1}\right\}$ are inferior to Q_j , power user P_i will feel happy because they do not match them; On the other hand, because the packages in the collection $\left\{Q_{j+1}, Q_{j+2}, ..., Q_m\right\}$ are better than Q_j , power user P_i will be disappointed because they do not match them.

In the same way, the same is true for the electricity sales package Q_j .

Therefore, to evaluate the satisfaction of power users and electricity sales packages with the matching results, we need to consider the disappointment - joy perception of both sides, so that we can more accurately describe the satisfaction degree of power users and electricity sales packages.

Because there is a lack of subjective evaluation elements in the subjective satisfaction matrix of power users $U^P = (u_{ij}^P)_{n\times m}$ and the subjective satisfaction matrix of electricity sales packages $U^Q = (u_{ij}^Q)_{n\times m}$, so we build a collection

$$\Theta^{P_i} = \left\{Q_j \mid u_{ij}^P \neq -M \,\&\, u_{ij}^Q \neq -M, j \in J\right\}, i \in I \tag{19}$$

$$\Theta^{Q_j} = \left\{P_i \mid u_{ij}^P \neq -M \,\&\, u_{ij}^Q \neq -M, i \in I\right\}, j \in I \tag{20}$$

Set (19) refers to the set of electricity sales packages that can match each other P_i in the electricity sales package set Q. Set (20) represents the set of power users that can match each other Q_j in the power user set P for the power sales package.

If the power user P_i matches the P_i electricity sales package Q_j, $\overline{u_{ij}^P}$ means that the correction of subjective satisfaction degree after adding the disappointment - joy feeling of the power user, according to the definition, $\overline{u_{ij}^P}$ can be expressed as:

$$\overline{u_{ij}^P} = \begin{cases} u_{ij}^P - d_{ij}^P + e_{ij}^P & Q_j \in \Theta^{P_i} \\ u_{ij}^P & Q_j \notin \Theta^{P_i} \end{cases}, i \in I \tag{21}$$

In formula (21), d_{ij}^P represents the user P_i's disappointment value and e_{ij}^P represents the user P_i's joy value.

For the matching object $Q_j \in \Theta^{P_i}$, if there is a certain electricity sales package $Q_l \in \Theta^{P_i}$,leading to $u_{ij}^P < u_{il}^P$,than the power user P_i will be disappointed when matching with the electricity sales package Q_j instead of matching Q_l. Set the collection $\Delta_{ij}^{DP} = \{Q_l \mid u_{ij}^P < u_{il}^P \,\&\, Q_l \in \Theta^{P_i}\}$ as a collection of objects that will cause P_i disappointment after matching with Q_j. At this time, the user P_i's disappointment value can be calculated using the following formula:

$$d_{ij}^P = prob(P_i, Q_l) \sum_{Q_l \in \Delta_{ij}^{DP}} D_i(u_{il}^P - u_{ij}^P), \forall Q_l \in \Delta_{ij}^{DP}, Q_j \in \Theta^{P_i}, i \in I \tag{22}$$

In the same way, it will also exist $Q_l \in \Theta^{P_i}$, leading to $u_{ij}^P > u_{il}^P$, so that P_i will feel happy when matching with Q_j instead of Q_l. Set the collection $\Delta_{ij}^{EP} = \{Q_l \mid u_{ij}^P > u_{il}^P \,\&\, Q_l \in \Theta^{P_i}\}$ as the collection of objects that P_i will produce a sense of joy after matching with Q_j. At this time, the user P_i's happiness value can be calculated by the following formula:

$$e_{ij}^P = prob(P_i, Q_l) \sum_{Q_l \in \Delta_{ij}^{EP}} E_i(u_{ij}^P - u_{il}^P), \forall Q_l \in \Delta_{ij}^{EP}, Q_j \in \Theta^{P_i}, i \in I \tag{23}$$

In formulas (22) and (23), the $prob(P_i, Q_l)$ reciprocal of the number of electricity sales packages that disappoint power user P_i and the reciprocal of the number of electricity sales packages that delight power user P_i,which are respectively expressed as follows:

$$prob(P_i, Q_l) = \begin{cases} \dfrac{1}{|\Delta_{ij}^{DP}|}, & Q_j \in \Delta_{ij}^{DP} \\ 0 & Q_j \notin \Delta_{ij}^{DP} \end{cases}, i \in I, j \in J \tag{24}$$

$$prob(P_i, Q_l) = \begin{cases} \dfrac{1}{|\Delta_{ij}^{EP}|}, & Q_j \in \Delta_{ij}^{EP} \\ 0 & Q_j \notin \Delta_{ij}^{EP} \end{cases}, i \in I, j \in J \tag{25}$$

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In the same way, if the electricity sales package Q_j matches the power user P_i, $\overline{u_{ij}^Q}$ represents the correction of subjective satisfaction after adding electricity sales package Q_j's disappointment-joy feelings, $\overline{u_{ij}^Q}$ can be expressed as:

$$\overline{u_{ij}^Q} = \begin{cases} u_{ij}^Q - d_{ij}^Q + e_{ij}^Q \\ u_{ij}^Q \end{cases} \tag{26}$$

$$d_{ij}^Q = prob(Q_j, P_k) \sum_{P_k \in \Delta_{ij}^{DQ}} D_i(u_{kj}^Q - u_{ij}^Q), \forall P_k \in \Delta_{ij}^{DQ}, P_i \in \Theta^{Q_j}, j \in J \tag{27}$$

$$e_{ij}^Q = prob(Q_j, P_k) \sum_{P_k \in \Delta_{ij}^{EQ}} E_i(u_{ij}^Q - u_{kj}^Q), \forall P_k \in \Delta_{ij}^{EQ}, P_i \in \Theta^{Q_j}, j \in J \tag{28}$$

$$prob(Q_j, P_k) = \begin{cases} \frac{1}{|\Delta_{ij}^{DQ}|}, & Q_j \in \Delta_{ij}^{DQ} \\ 0 & Q_j \notin \Delta_{ij}^{DQ} \end{cases}, i \in I, j \in J \tag{29}$$

$$prob(Q_j, P_k) = \begin{cases} \frac{1}{|\Delta_{ij}^{EQ}|}, & Q_j \in \Delta_{ij}^{EQ} \\ 0 & Q_j \notin \Delta_{ij}^{EQ} \end{cases}, i \in I, j \in J \tag{30}$$

The specific expressions of disappointment function $D(\cdot)$ and joy function $E(\cdot)$ are as follows:

$$D(x) = 1 - \alpha^x, x \ge 0 \tag{31}$$

$$E(x) = \gamma(1 - \beta^x), x \ge 0 \tag{32}$$

In the formula(31) and (32), α and β are the disappointment and joy parameters, γ indicating the degree of influence of the feeling of joy on the evaluation results, $0 < \beta < 1$ $0 < \alpha < 1$,, $0 < \gamma < 1$. The smaller α, the greater the sensitivity of power users to the disappointment of the electricity sales package and the less likely they are to choose the electricity sales package; The larger β, the greater the sensitivity of power users to the joy of the electricity sales package, and the more likely they are to choose the electricity sales package.

To sum up, the satisfaction evaluation matrix of power users after adding disappointment - joy perception is:

$$\overline{U^P} = (\overline{u_{ij}^P})_{n \times m} = \begin{pmatrix} \overline{u_{11}^P} & \overline{u_{12}^P} & \cdots & \overline{u_{1m}^P} \\ \overline{u_{21}^P} & \overline{u_{22}^P} & \cdots & \overline{u_{2m}^P} \\ \vdots & \vdots & \cdots & \vdots \\ \overline{u_{n1}^P} & \overline{u_{n2}^P} & \cdots & \overline{u_{nm}^P} \end{pmatrix} \tag{33}$$

The satisfaction evaluation matrix of the electricity sales package is:

$$\overline{U^Q} = (\overline{u_{ij}^Q})_{n \times m} = \begin{pmatrix} \overline{u_{11}^Q} & \overline{u_{12}^Q} & \cdots & \overline{u_{1m}^Q} \\ \overline{u_{21}^Q} & \overline{u_{22}^Q} & \cdots & \overline{u_{2m}^Q} \\ \vdots & \vdots & \cdots & \vdots \\ \overline{u_{n1}^Q} & \overline{u_{n2}^Q} & \cdots & \overline{u_{nm}^Q} \end{pmatrix} \tag{34}$$

2.5. Multi-objective optimization model

Next, after obtaining the satisfaction matrix of power user set P and the satisfaction matrix of power sales package set Q, a two-objective optimization model will be constructed, and the optimal stable matching of both parties will be obtained by solving the model.

Set x_{ij} as a binary decision variable. When the user P_i matches the package Q_j, $x_{ij}=1$, otherwise $x_{ij}=0$.

With the maximum satisfaction of power users and electricity sales package as the optimization objective, a stable two-sided matching multi-objective optimization model can be established:

$$\max Z_1=\sum_{i=1}^{n}\sum_{j=1}^{m}\overline{u_{ij}^{P}}x_{ij} \tag{35}$$

$$\max Z_2=\sum_{j=1}^{m}\sum_{i=1}^{n}\overline{u_{ij}^{Q}}x_{ij} \tag{36}$$

$$\sum_{j=1}^{m}x_{ij}\le 1, i\in I \tag{37}$$

$$\sum_{i=1}^{n}x_{ij}\le 1, j\in J \tag{38}$$

$$x_{ij}+\sum_{u_{ih}^{P}>u_{ij}^{P}}x_{ih}+\sum_{u_{kj}^{Q}>u_{ij}^{Q}}x_{kj}\ge 1,\forall(P_i,Q_j)\in\Omega \tag{39}$$

$$x_{ij}\in\{0,1\},\quad i\in I, j\in J \tag{40}$$

In the above model, formula (35) and formula (36) are objective functions, which describe the maximization of satisfaction between power users and electricity sales packages. Equations (37) and (38) are inequality constraints, which respectively ensure that each object in user P can only match one package in package Q at most and one power selling package in package set Q can only match one user in user set P. Equation (39) is a stable two-sided matching constraint, including two situations: 1. Power user P_i and electricity sales package Q_j match each other; 2. If the power user P_i does not match the electricity sales package Q_j, then the power user P_i will match the electricity Q_j sales package with a higher degree of preference or the electricity sales package Q_j will match the power user P_i with a higher degree of preference.

In order to facilitate the solution, the weight coefficient ω is introduced to transform the two-objective optimization model into a single-objective optimization model:

$$\max Z=\omega\sum_{i=1}^{n}\sum_{j=1}^{m}\overline{u_{ij}^{P}}x_{ij}+(1-\omega)\sum_{j=1}^{m}\sum_{i=1}^{n}\overline{u_{ij}^{Q}}x_{ij} \tag{41}$$

$$\sum_{j=1}^{m}x_{ij}\le 1, i\in I \tag{42}$$

$$\sum_{i=1}^{n}x_{ij}\le 1, j\in J \tag{43}$$

$$x_{ij}+\sum_{u_{ih}^{P}>u_{ij}^{P}}x_{ih}+\sum_{u_{kj}^{Q}>u_{ij}^{Q}}x_{kj}\ge 1,\forall(P_i,Q_j)\in\Omega \tag{44}$$

$$x_{ij}\in\{0,1\},\quad i\in I, j\in J \tag{45}$$

In the model (41), Z represents the total satisfaction of the matching parties, ω is a weight coefficient, $0<\omega<0.5$ indicating that the feeling of power users is more important than the adaptation degree of the electricity sales package; $0.5 < \omega < 1$ indicating that the adaptability of the electricity sales package is more important than the satisfaction of the power users; $\omega = 0.5$ indicating that both parties are equally important. In this paper, we will take $\omega = 0.5$ for analysis.

Based on the two-sided matching theory, and adding the disappointment - joy perception effect of power users and electricity sales packages, the stable two-sided matching process between power users and electricity sales package is shown in Figure 3:

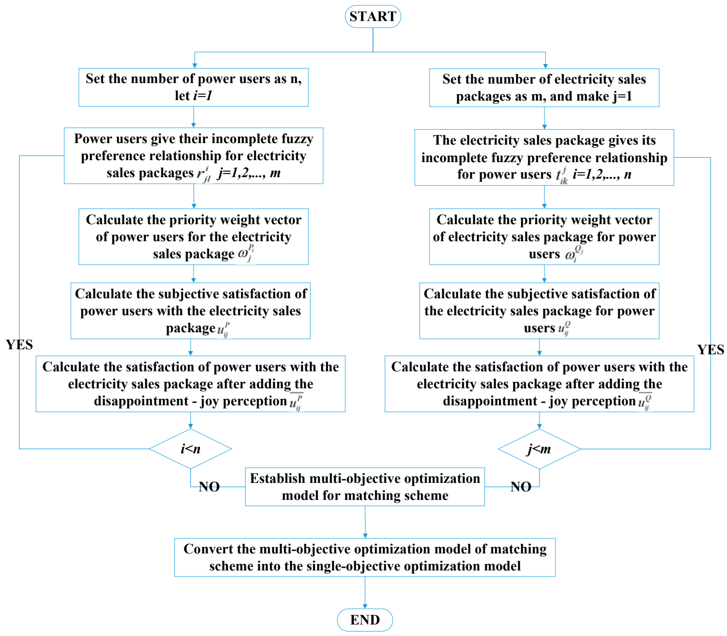

Figure 3. Stable two-sided matching process between power users and electricity sales package.

3. Actual case analysis

3.1. Case background

An industrial park in Zhejiang Province currently has 5 power users $P = \{P_1, P_2, P_3, P_4, P_5\}$ and 6 electricity sales packages $Q = \{Q_1, Q_2, Q_3, Q_4, Q_5, Q_6\}$. We need to match them one by one according to their respective preferences, so as to maximize their respective satisfaction and overall satisfaction, and give a stable matching model. For power users, the main factors to be considered in the evaluation of electricity sales package are power quality and power supply service; For the electricity sales package, the main considerations for power users are user value and user investment ability. Let the incomplete fuzzy preference relationship between each power user and each electricity sales package be expressed as R^i and T^j .The priority weight vector is expressed as w^{P_i} and w^{Q_j} .Subjective satisfaction is expressed as U^P and U^Q .The sensitivity parameters of both parties to disappointment are $\alpha^P_i = \alpha^Q_j = 0.8$,the degree of disgust to disappointment is $\gamma^P_i = \gamma^Q_j = 0.5$, the sensitivity parameter of joy is $\beta^P_i = \beta^Q_j = 0.8$, and the disappointment value is D^P and D^Q , and the weight when the double-objective optimization model is converted to the single-objective optimization model is $\omega = 0.5$.

3.2. Case analysis

3.2.1. Incomplete fuzzy preference relationship

Based on the survey results, the incomplete fuzzy preference relationship P_i provided by each power user is expressed by $R^i(i=1,2,\ldots,5)$, and the incomplete fuzzy preference relationship Q_j of each power sales package is recorded as $T^j(j=1,2,\ldots 6)$, as follows:

$$R^1=\begin{pmatrix} 0.5 & \varphi & \varphi & \varphi & \varphi & \varphi \\ \varphi & 0.5 & 0.35 & 0.65 & \varphi & 0.75 \\ \varphi & 0.65 & 0.5 & \varphi & 0.55 & 0.55 \\ \varphi & 0.35 & \varphi & 0.5 & 0.75 & \varphi \\ \varphi & \varphi & 0.45 & 0.25 & 0.5 & 0.65 \\ \varphi & 0.25 & 0.45 & \varphi & 0.35 & 0.5 \end{pmatrix} R^2=\begin{pmatrix} 0.5 & 0.25 & \varphi & 0.55 & \varphi & 0.35 \\ 0.75 & 0.5 & 0.15 & 0.65 & \varphi & 0.15 \\ \varphi & 0.85 & 0.5 & \varphi & \varphi & 0.75 \\ 0.45 & 0.35 & \varphi & 0.5 & \varphi & \varphi \\ \varphi & \varphi & \varphi & \varphi & 0.5 & \varphi \\ 0.65 & 0.85 & 0.25 & \varphi & \varphi & 0.5 \end{pmatrix}$$

$$R^3=\begin{pmatrix} 0.5 & 0.35 & \varphi & 0.25 & 0.75 & 0.25 \\ 0.65 & 0.5 & \varphi & 0.45 & \varphi & 0.35 \\ \varphi & \varphi & 0.5 & \varphi & \varphi & \varphi \\ 0.75 & 0.55 & \varphi & 0.5 & 0.35 & 0.75 \\ 0.25 & \varphi & \varphi & 0.65 & 0.5 & 0.65 \\ 0.75 & 0.65 & \varphi & 0.25 & 0.35 & 0.5 \end{pmatrix} R^4=\begin{pmatrix} 0.5 & \varphi & 0.65 & 0.45 & 0.55 & 0.65 \\ \varphi & 0.5 & \varphi & \varphi & \varphi & \varphi \\ 0.35 & \varphi & 0.5 & 0.75 & 0.25 & 0.55 \\ 0.55 & \varphi & 0.25 & 0.5 & 0.15 & \varphi \\ 0.45 & \varphi & 0.75 & 0.85 & 0.5 & 0.15 \\ 0.35 & \varphi & 0.45 & \varphi & 0.85 & 0.5 \end{pmatrix}$$

$$R^5=\begin{pmatrix} 0.5 & 0.65 & 0.75 & \varphi & 0.55 & 0.25 \\ 0.35 & 0.5 & \varphi & 0.65 & 0.25 & 0.15 \\ 0.25 & \varphi & 0.5 & 0.35 & 0.55 & 0.65 \\ \varphi & 0.35 & 0.65 & 0.5 & 0.35 & \varphi \\ 0.45 & 0.75 & 0.45 & 0.65 & 0.5 & 0.45 \\ 0.75 & 0.85 & 0.35 & \varphi & 0.55 & 0.5 \end{pmatrix}$$

$$T^1=\begin{pmatrix} 0.5 & 0.65 & \varphi & 0.55 & 0.75 \\ 0.35 & 0.5 & 0.25 & 0.35 & 0.65 \\ \varphi & 0.75 & 0.5 & \varphi & 0.35 \\ 0.45 & 0.65 & \varphi & 0.5 & 0.65 \\ 0.25 & 0.35 & 0.65 & 0.35 & 0.5 \end{pmatrix} T^2=\begin{pmatrix} 0.5 & \varphi & \varphi & \varphi & \varphi \\ \varphi & 0.5 & 0.05 & 0.45 & 0.55 \\ \varphi & 0.95 & 0.5 & 0.35 & \varphi \\ \varphi & 0.55 & 0.65 & 0.5 & 0.75 \\ \varphi & 0.45 & \varphi & 0.25 & 0.5 \end{pmatrix}$$

$$T^3=\begin{pmatrix} 0.5 & 0.25 & \varphi & 0.65 & \varphi \\ 0.75 & 0.5 & 0.65 & \varphi & \varphi \\ \varphi & 0.35 & 0.5 & 0.75 & \varphi \\ 0.35 & \varphi & 0.25 & 0.5 & \varphi \\ \varphi & \varphi & \varphi & \varphi & 0.5 \end{pmatrix} T^4=\begin{pmatrix} 0.5 & \varphi & 0.35 & 0.55 & 0.15 \\ \varphi & 0.5 & \varphi & \varphi & \varphi \\ 0.65 & \varphi & 0.5 & 0.25 & 0.75 \\ 0.45 & \varphi & 0.75 & 0.5 & 0.15 \\ 0.85 & \varphi & 0.25 & 0.85 & 0.5 \end{pmatrix}$$

$$T^5=\begin{pmatrix} 0.5 & 0.25 & 0.45 & 0.65 & 0.15 \\ 0.75 & 0.5 & 0.15 & 0.55 & 0.75 \\ 0.55 & 0.85 & 0.5 & 0.05 & \varphi \\ 0.35 & 0.45 & 0.95 & 0.5 & 0.25 \\ 0.85 & 0.25 & \varphi & 0.75 & 0.5 \end{pmatrix} T^6=\begin{pmatrix} 0.5 & \varphi & 0.35 & 0.55 & 0.15 \\ \varphi & 0.5 & \varphi & \varphi & \varphi \\ 0.65 & \varphi & 0.5 & 0.25 & 0.75 \\ 0.45 & \varphi & 0.75 & 0.5 & 0.15 \\ 0.85 & \varphi & 0.25 & 0.85 & 0.5 \end{pmatrix}.$$

3.2.2. Calculation of subjective satisfaction

Based on the incomplete fuzzy preference relationship between power users and electricity sales package, the priority vector of all power users and electricity sales package is calculated, taking w^{Q_1} and w^{P_1} as an example:

$w^{Q_1}=(0.3589,0.1354,0.1456,0.2589,0.1152)$, $w^{P_1}=(-M,0.3052,0.2189,0.2456,0.1386,0.1210)$.

Based on the priority weight vectors w^{P_1} and w^{Q_1}, calculate the subjective satisfaction of power users with the electricity sales package u_{ij}^P and the subjective satisfaction u_{ij}^Q of power users with the electricity sales package, making $U^P=(u_{ij}^P)_{5\times 6}$, $U^Q=(u_{ij}^Q)_{5\times 6}$ .The following matrix can be obtained:

$$U^P=\begin{pmatrix} -M & 1 & 0.6468 & 0.7692 & 0.1818 & 0 \\ 0.0614 & 0.1335 & 1 & 0 & -M & 0.2628 \\ 0.0838 & 0.3519 & -M & 1 & 0.2210 & 0 \\ 1 & -M & 0.5410 & 0 & 0.5904 & 0.7575 \\ 1 & 0 & 0.3656 & 0.0232 & 0.4863 & 0.9572 \end{pmatrix}$$

$$U^Q=\begin{pmatrix} 1 & -M & 0.2825 & 0 & 0 & 0.6153 \\ 0.1244 & 0.1320 & 1 & -M & 0.9421 & 0.3230 \\ 0.1679 & 1 & 0.4072 & 0.7908 & 0.0052 & -M \\ 0.4825 & 0.5767 & 0 & 0.1124 & 0.4621 & 0 \\ 0 & 0 & -M & 1 & 1 & 1 \end{pmatrix}$$

3.2.3. Calculate the disappointment value and joy value of both parties

After obtaining the subjective satisfaction matrix of both parties, the disappointment value, joy value and adjusted satisfaction of the matching objects in P and Q will be calculated. For each power user P_i and electricity sales package Q_j, set the sensitivity parameters of disappointment $\alpha_i^P=\alpha_j^Q=0.8$, the degree of aversion to disappointment $\gamma_i^P=\gamma_j^Q=0.5$, and the sensitivity parameters of joy $\beta_i^P=\beta_j^Q=0.8$, among which $i=1,2,\ldots,5, j=1,2,\ldots,6$.

Take R^1 as an example, calculate the disappointment value, joy value and adjusted satisfaction of the power user. According to the subjective satisfaction matrix, the potential object set $\theta^{P_1}=\{Q_3,Q_4,Q_5,Q_6\}$ in Q that can match P_1 is derived. We can get

$$prob(P_1,Q_1)=prob(P_1,Q_2)=0\,,\ prob(P_1,Q_3)=prob(P_1,Q_4)=prob(P_1,Q_5)=prob(P_1,Q_6)=\frac{1}{4}.$$

It is known from the above results that P_1 cannot match Q_1 and Q_2, namely $\overline{u_{11}^P}=\overline{u_{12}^P}=1$. If P_1 matches Q_3 not Q_4. P_1 will be disappointed because $u_{13}^P<u_{14}^P$ .If P_1 matches Q_3, the set of matched objects that cause P_1 to experience disappointment is $\Delta_{13}^{DP}=\{Q_4\}$, and the value of disappointment is $d_{13}^P=\frac{1}{4}\{1-\exp((0.7692-0.6468)\ln 0.8)\}=0.0029$. Similarly, if P_1 matches Q_4, Q_5 or Q_6, the disappointment value is

$$d_{14}^P=0$$

$$d_{15}^P=\frac{1}{4}\{1-\exp((0.6078-0.1708)\ln 0.8)+1-\exp((0.7592-0.1708)\ln 0.8)\}=0.0248$$

$$d_{16}^P=\frac{1}{4}\{1-\exp((0.6468-0)\ln 0.8))+(1-\exp((0.7692-0)\ln 0.8))+(1-\exp((0.1818-0)\ln 0.8))\}=0.0376$$

In addition, if Q_3 matches P_1, but not with Q_5 or Q_6, P_1 will feel happy because $u_{13}^P>u_{16}^P$, $u_{13}^P>u_{15}^P$ .Therefore, if Q_3 matches P_1, the set of matching objects that make P_1 feel happy is $\Delta_{13}^{EP}=\{Q_5,Q_6\}$ then the joy value is

$$e_{13}^P=\frac{1}{4}\{(0.5-0.5\exp((0.6468-0.1818)\ln 0.8))+0.5-0.5\exp((0.6468-0)\ln 0.8))=0.0131$$

Similarly, if P_1 matches Q_4, Q_5, or Q_6, P_1's happy value is

$$e_{14}^{P}=\frac{1}{4}\{0.5-0.5\exp((0.7692-0.6468)\ln 0.8)+0.5-0.5\exp((0.7692-0.1818)\ln 0.8)+0.5-0.5\exp((0.7692-0)\ln 0.8)=0.0174$$

$$e_{15}^{P}=\frac{1}{4}\{(0.5-0.5\exp((0.1818-0)\ln 0.8))\}=0.0022$$

$$e_{16}^{P}=0$$

Further calculate the P_1 satisfaction of other objects after adjustment

$$\overline{u_{13}^{P}}=0.6570,\overline{u_{14}^{P}}=0.7866,\overline{u_{15}^{P}}=0.1556,\overline{u_{16}^{P}}=-0.0376$$

Similarly, the disappointment value d_{ij}^{P} and joy value e_{ij}^{P} ($i=1,2\ldots5$, $j=1,2\ldots6$) of each power user for each electricity sales package can be calculated. Set $D^P=(d_{ij}^{P})_{5\times6}$, $E^P=(e_{ij}^{P})_{5\times6}$,

$$D^P=\begin{pmatrix} - & - & 0.0029 & 0 & 0.0248 & 0.0376 \\ 0.0066 & 0.0031 & 0 & - & - & 0.0375 \\ 0.0097 & 0.0361 & - & 0 & 0.0032 & - \\ 0 & - & 0.0064 & 0.0444 & 0.0040 & 0.0114 \\ 0 & 0.0343 & - & 0.0329 & 0.0089 & 0.0058 \end{pmatrix}$$

$$E^P=\begin{pmatrix} - & - & 0.0131 & 0.0174 & 0.0022 & 0 \\ 0 & 0.0025 & 0.0650 & - & - & 0.0071 \\ 0 & 0.0090 & - & 0.0611 & 0.0043 & - \\ 0.0446 & - & 0.0064 & 0 & 0.0075 & 0.0135 \\ 0.0536 & 0 & - & 0.0005 & 0.0102 & 0.0275 \end{pmatrix}$$

Calculate the disappointment value d_{ij}^{Q} and joy value e_{ij}^{Q} ($i=1,2\ldots5$, $j=1,2\ldots6$) of each power selling company's power selling package to power users. Equally Available:

$$D^Q=\begin{pmatrix} - & - & 0.0499 & 0.0969 & 0.0749 & 0.0180 \\ 0.0216 & 0.0599 & 0 & - & - & 0.0494 \\ 0.0168 & 0 & - & 0.0114 & 0.0740 & - \\ 0 & - & 0.0863 & 0.0796 & 0.0282 & 0.1039 \\ 0.0431 & 0.0750 & - & 0 & 0 & 0 \end{pmatrix}$$

$$E^Q=\begin{pmatrix} - & - & 0.0068 & 0.0212 & 0.0212 & 0.0184 \\ 0.0240 & 0.0235 & 0 & - & - & 0.0047 \\ 0.0020 & 0 & - & 0.0210 & 0.0008 & - \\ 0.0107 & - & 0 & 0.0018 & 0.0101 & 0 \\ 0 & 0 & - & 0.0531 & 0.0640 & 0.0506 \end{pmatrix}$$

3.2.4. Adjust the satisfaction matrix

According to the disappointment value matrix, the joy value matrix and the satisfaction matrix, the satisfaction matrix of the adjusted electricity customers and the electricity selling companies is calculated as follows:

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$$\overline{U^P} = \left(\overline{u_{ij}^P}\right)_{5\times6} = \begin{pmatrix} -M & 1 & 0.6570 & 0.7866 & 0.1592 & -0.0376 \\ 0.0548 & 0.1329 & 1.0650 & 0 & -M & 0.2324 \\ 0.0741 & 0.3248 & -M & 1.0611 & 0.2221 & 0 \\ 1.0446 & -M & 0.5410 & -0.0444 & 0.5939 & 0.6570 \\ 1.0536 & -0.0343 & 0.3656 & -0.0092 & 0.4878 & 0.9789 \end{pmatrix}$$

$$\overline{U^Q} = \left(\overline{u_{ij}^Q}\right)_{5\times6} = \begin{pmatrix} 1 & -M & 0.2394 & -0.0969 & -0.0749 & 0.6157 \\ 0.1268 & 0.0956 & 1.0282 & -M & 0.9421 & 0.2783 \\ 0.1531 & 1.0237 & 0.4072 & 0.8004 & -0.0680 & -M \\ 0.4932 & 0.5767 & -0.0863 & 0.0346 & 0.4440 & -0.1039 \\ -0.0431 & -0.0750 & -M & 1.0531 & 1.0640 & 1.0506 \end{pmatrix}$$

3.2.5. Construct stable TSMDM model

Based on the satisfaction matrix $\overline{U^P}$ and $\overline{U^Q}$, establish a two-objective optimization model with the goal of maximizing the overall satisfaction of both parties:

$$\begin{aligned} &\max \quad Z_1 = \sum_{i=1}^{5}\sum_{j=1}^{6}\overline{u_{ij}^P}x_{ij} \\ &\max \quad Z_2 = \sum_{i=1}^{5}\sum_{j=1}^{6}\overline{u_{ij}^Q}x_{ij} \\ &\sum_{j=1}^{6}x_{ij} \le 1, i = 1,2,\ldots,5 \\ &\sum_{i=1}^{5}x_{ij} \le 1, j = 1,2,\ldots,6 \\ &\sum_{\overline{u_{ih}^P} > \overline{u_{ij}^P}} x_{ih} + \sum_{\overline{u_{kj}^Q} > \overline{u_{ij}^Q}} x_{kj} + x_{ij} \ge 1, \forall\left(P_i, Q_j\right) \in \Omega \\ &x_{ij} \in \{0,1\}, i = 1,2,\ldots,5, j = 1,2,\ldots,6 \end{aligned}$$

Let $\omega = 0.5$, and then convert the two-objective optimization model into a single-objective optimization model, as follows:

$$\begin{aligned} &\max Z = 0.5\sum_{i=1}^{5}\sum_{j=1}^{6}\overline{u_{ij}^P}x_{ij} + 0.5\sum_{i=1}^{5}\sum_{j=1}^{6}\overline{u_{ij}^Q}x_{ij} \\ &\sum_{j=1}^{6}x_{ij} \le 1, i = 1,2,\ldots,5 \\ &\sum_{i=1}^{5}x_{ij} \le 1, j = 1,2,\ldots,6 \\ &\sum_{\overline{u_{ih}^P} > \overline{u_{ij}^P}} x_{ih} + \sum_{\overline{u_{kj}^Q} > \overline{u_{ij}^Q}} x_{kj} + x_{ij} \ge 1, \forall\left(P_i, Q_j\right) \in \Omega \\ &x_{ij} \in \{0,1\}, i = 1,2,\ldots,5, j = 1,2,\ldots,6? \end{aligned}$$

Solve the above model, and the optimal solution of the model is $X^* = (x_{ij}^*)_{5\times 6}$ expressed by matrix:

$$X^* = \begin{pmatrix} 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Using the above matrix, the optimal matching results between 5 power users and 6 power sales packages are obtained: $\mu = \{(P_1, Q_5), (P_2, Q_3), (P_3, Q_4), (P_4, Q_1), (P_5, Q_6)\}$. No power users match power sales packages Q_2.

4. Conclusions

In this paper, a two - sided matching decision-making method based on disappointment theory is proposed. Firstly, this method is based on incomplete fuzzy preference relationships, which expands the applicability of recommendations; Secondly, by incorporating the influence of disappointment theory, the accuracy and efficiency of recommendations are improved; Finally, the goal is to maximize the overall satisfaction between power users and electricity sales packages, which can ensure the optimality and stability of recommendation results. The advantages of the methods proposed are listed as follows. Firstly, the method proposed in the article is based on the incomplete fuzzy preference relationship between power users and electricity sales packages, which can overcome the problem of missing preference data caused by different knowledge and cultural backgrounds of power users; Secondly, the two-sided matching decision-making method proposed in this article also incorporates the influence of disappointment theory, which can not only better measure the satisfaction between power users and electricity sales packages, but also help set decision-making goals and greatly improve decision-making efficiency. In addition, by comparing the preference information of two matching objects one by one, this method greatly reduces the burden in the process of extracting preference information, can extract preference information faster and more flexibly, and ensures good recommendation results. At the same time, this method will also promote the development of Low-carbon economy under the background of "double carbon" landing.

However, the bilateral matching decision-making method proposed in this article also has certain limitations:1.The method only considers the one-to-one problem but didn't consider the one-to-many matching problems.2.The method only considers the accurate evaluation of electricity sales packages by power users, without further discussing the fuzzy preference relationships or hesitant preference information that may exist in real life.

Therefore, in future research, the focus of research will be to address the above two shortcomings: the consensus issues and complex preference structure issues of power users will be deeply considered, and further in-depth research will be conducted on the matching problem between power users and electricity sales packages to more accurately and efficiently recommend electricity sales packages.

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