IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 4, Issue 2, April - May, 2016
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

An Approach for Black-start Group Decision-making Algorithm Based on Intuitionistic Fuzzy Valued Sugeno Integral Operator in the context of Energy Internet

Yaqian Fan[1], Zhaoneng Guo[2]

[1]Institute of electrical information Jinan University, Zhuhai, Guangdong province , China
[2]Institute of electrical information Jinan University, Zhuhai, Guangdong province , China

Abstract
In recent years, in order to improve the application ratio of renewable energy and reduce the requirements for the supply of polluting energy sources. Someone put forward the "energy Internet" technology framework which based on the advanced information technology and compared with the traditional energy supply system. In this context, the loss caused by large area blackout can't be overlooked, so optimization of black-start scheme for electric power system has a great significance for rapid restoration of power system after large area blackout. Most of the existing black-start decision-making methods are in the assumption that the index and weight in black-start are independent of each other, and research about group decision-making are few, but group decision-making results are more reliable than individual decision results. In this conditions, we introduce the intuitionistic fuzzy valued fuzzy measure and the intuitionistic fuzzy Sugeno integral operator in the black-start decision problem, and discuss the corresponding black-start decision methods. Compared with the existing methods, this method not only deal with the correlation between indicators and weights, but also make up for the shortcomings of existing algorithms. Finally, we use an example to illustrate the basic features of the proposed black-start decision method.

Keywords: *Energy Internet, Black-start Decision, Intuitionistic Fuzzy Valued Fuzzy Measure, Intuitionistic Fuzzy Sugeno Integral.*

1. Introduction

At present, due to the application of China's hydropower and bio ethanol are still in a great extent by the limits of the natural environment. In the choices of energy generation are still dependent on the traditional fossil energy, what is why China is the world's largest use of coal-fired power generation countries [1]. With the advent of the new energy revolution, new energy technology, intelligent technology, network technology and information technology have been continuously developing. The concept of "Energy Internet" appeared in people's field of vision, it will combine the Internet technology with renewable energy and create a strong foundation for the third industrial revolution. The success of the Energy Internet depends on how to efficiently use the distributed renewable energy sources and provide a stable energy supply.

In the context of Energy Internet, huge losses caused by large area blackout to people's lives can be imagined. Black-start process is the first stage of power system restoration, if local power system failure can not only lead to huge economic losses, but also may cause social problems and even political problems. Therefore, it has great significance for us to do some deep researches to the system to restore the power supply. It not only reduce the economic loss but also avoid the social unrest in a timely manner [2].

The advantages and disadvantages of the evaluation of the black-start scheme are generally used in the combination of quantitative and qualitative indicators. Black-start decision-making is essentially a group decision-making problem, which contains the factors that can't be identified and unknown information. Considering the subjectivity of human thinking and the factor of black-start decision information may not be complete, the fuzzy number is used to represent the index and the weight is more reasonable than the use of the exact value.

In recent years, there are a lot of research reports about the problem of evaluation of black-start program at home and abroad. For example, in ref. [3],the author combine the analytic hierarchy process (AHP) method with expert system technology to generate to evaluate the black start scheme; in ref. [4], the authors put forward a method for using data envelopment analysis to evaluate the relative effectiveness of black-start scheme; in ref. [5], the authors is combined the data envelopment analysis (DEA) method with the AHP method to evaluate and optimize the black-start scheme of power system; in ref. [6-7],the authors aimed at the results of the black-start from the three

aspects of the reliability of the decision-making results, the value of the decision index and the weight sensitivity did some analysis; in ref. [8], the author applied method of group-decision to the decision problem of black-start, in order to obtain higher reliability of decision-making; in ref. [9-10], the authors considered the correlation between indexes of black-start decision in black-start group decision-making as the basis.

In ref. [9-10], although the project put forward by the authors are more or less consider the influence of the correlation between indexes and the correlation between expert experience knowledge for the decision result, but algorithm based on intuitionistic fuzzy valued Sugeno integral operator which introduces the concept of intuitionistic fuzzy importance measure. This concept not only consider the degree of importance and unimportance, but also considers the uncertainty of index. This is more reasonable and objective compared with the group decision method based on Chonquet integral operator. It developed logic of traditional weighted fuzzy integral method and approach to integral synthesis method, it not only takes into account the importance of the factors and behavior in evaluation of system status, but also emphasizes the correlation and restriction between factors and these influences on the evaluation results. It is more meaningful for the results of black-start decision. In this context, considering the correlation between indexes and the correlation between expert experience knowledge and other relevant factors, we chose to use intuitionistic fuzzy values Sugeno integral operator to make decisions for evaluation of black-start scheme. Firstly, we introduce the concept of intuitionistic fuzzy sets and intuitionistic fuzzy Sugeno integral operator. And then proposes a black-start decision method for intuitionistic fuzzy valued Sugeno integral operator. At last, we got the results through the calculation of the example.

2. Intuitionistic fuzzy valued Sugeno integral

2.1 The concept of intuitionistic fuzzy sets

In general, the group decision problem always contains a large amount of fuzzy information, and the process of actual decision-making is always under the condition of incomplete information. Since the fuzzy set theory was proposed by Zadeh in 1965, it has been widely used to study the problem of fuzzy decision-making. In 1986, Atanassov further expanded the fuzzy set and put forward the concept of intuitionistic fuzzy sets. Intuitionistic fuzzy set is a extension of fuzzy set, which has the ability to express uncertain information more than fuzzy set, so it is more suitable to deal with the uncertainty and fuzzy problem in the process of decision-making [11].

Definition 1 Suppose X is a non-empty classic collection, $X=(\mathrm{x}_1,\mathrm{x}_2,\cdots\mathrm{x}_n)$, the three reorganization of X like $A=\{<x,t_A(x),f_A(x)>|\,x\in X\}$ is called an intuitionistic fuzzy set of X, among them, $t_A:X\to[0,1]$ and $f_A:X\to[0,1]$ are the membership functions of X, they respectively represent the element x in X belong to membership degree of A and non-membership degree of A as well $0=t_A(x)+f_A(x)=1$. For convenience, we make a simple note of the general form of the direct fuzzy set as $A=(t_A(x),f_A(x))$ and use $\Omega(x)$ to represent the set of all intuitionistic fuzzy sets on X.

For each intuitionistic fuzzy set of X, $\pi_A(x)=1-t_A(x)-f_A(x)$ is called intuition index of element X in intuitionistic fuzzy set A, It indicates that the element x belongs to A's hesitation degree, obviously $0\le\pi_A(x)\le1$, $x\in X$.

2.2 Operation of intuitionistic fuzzy sets

Atanassov (1999) did some researches on the operation rules of intuitionistic fuzzy sets.

Definition 2 Suppose X is a non-classical set, $A,B\in\Omega(X)$, $A=(t_A(x),f_A(x))$ and $B=(t_B(x),f_B(x))$. The following definition:

(1) $A=B$ if and only if $t_A(x)=t_B(x)$ and $f_A(x)=f_B(x)$, $x\in X$;

(2) $A\le B$ if and only if $t_A(x)=t_B(x)$ and $f_A(x)\ge f_B(x)$, $x\in X$;

(3) $A\cap B=(t_A(x)\wedge t_B(x),f_A(x)\vee f_B(x)),x\in X$;

(4) $A\cup B=(t_A(x)\vee t_B(x),f_A(x)\wedge f_B(x)),x\in X$;

(5) $\tilde{a}\oplus\tilde{b}=(t_{\tilde{a}}+t_{\tilde{b}}-t_{\tilde{a}}t_{\tilde{b}},f_{\tilde{a}}f_{\tilde{b}})$;

(6) $\lambda\tilde{a}=(1-(1-t_{\tilde{a}})^{\lambda},(f_{\tilde{a}})^{\lambda}),\lambda>0$.

2.3 Comparison of intuitionistic fuzzy sets

Definition 3 When comparing the two intuitionistic fuzzy sets, we can use the score function [12] and the exact function [13] to solve the sort problem of intuitionistic fuzzy sets.

Suppose $\tilde{a}=(t_{\tilde{a}},f_{\tilde{a}})$ and $\tilde{b}=(t_{\tilde{b}},f_{\tilde{b}})$ are two intuitionistic fuzzy sets, we called $S(\tilde{a})=t_{\tilde{a}}-f_{\tilde{a}}$ and $S(\tilde{b})=t_{\tilde{b}}-f_{\tilde{b}}$ are the score function of $\tilde{a}$ and $\tilde{b}$ respectively, $H(\tilde{a})=t_{\tilde{a}}-f_{\tilde{a}}$ and $H(\tilde{b})=t_{\tilde{b}}-f_{\tilde{b}}$ are the exact function of $\tilde{a}$ and $\tilde{b}$ .If $S(\tilde{a})<S(\tilde{b})$, then $\tilde{a}<\tilde{b}$; if $S(\tilde{a})=S(\tilde{b})$, then:

(1)if $H(\tilde{a})<H(\tilde{b})$, then $\tilde{a}<\tilde{b}$;

(2)if $H(\tilde{a})=H(\tilde{b})$, then $\tilde{a}=\tilde{b}$.

2.4 Intuitionistic fuzzy valued fuzzy measure

In 2004, Ban put forward the concept of intuitionistic fuzzy measure as follows:

Definition 4 Suppose $(X,\Re)$ is a measurable space, $\tau:\Re\to X$,if τ satisfies the following conditions:

（1） $\tau(\phi)=(0,1)$, $\tau(X)=(1,0)$;

（2） $\forall A,B\in\Re, A\subset B$,then $\tau(A)\le_L\tau(B)$;

Then, τ is called the intuitionistic fuzzy valued fuzzy measure for $\Re$.

2.5 Intuitionistic fuzzy valued Sugeno integral

Definition 5 Suppose set $X=(1,2,\cdots,n)$ and function $x_i=(t_i,f_i)\in L$ can be expressed as a discrete form $x_1,\cdots,x_n$, $\tau=(\tau_1,\tau_2)$ is defined intuitionistic fuzzy valued fuzzy measure of the power set $P(X)$ in the set X, at this point the intuitionistic fuzzy valued Sugeno integral S: $L^n\to L$ is represented as

$$S(x_1,x_2,\cdots x_n)=\left(\bigvee_{i=1}^{n}\left[t_{(i)}\wedge\tau_1((i),\cdots(n))\right],\ \bigwedge_{i=1}^{n}\left[f_{(i)}\vee\tau_2((i),\cdots,(n))\right]\right)$$

among them, $x_{(i)}$ is represented the replacement of x_i ,making $x_{(1)}\le_L x_{(2)}\le_L\cdots\le_L x_{(n)}$,that $t_{(i)}$ is represented the replacement of t_i ,making $t_{(1)}\le t_{(2)}\le\cdots\le t_{(n)}$, $f_{(i)}$ is represented the replacement of v_i, making $f_{(1)}\ge f_{(2)}\ge\cdots\ge f_{(n)}$, at this time, the function S is also called intuitionistic fuzzy valued Sugeno integral operator in the n-Dimensional.

3. An approach for black-start decision-making based on intuitionistic fuzzy valued Sugeno integral

The basic framework of black-start decision support system mainly includes generation verification and evaluation of black-start scheme, and so on [14]. Among them, optimal selection of black-start scheme is the core function of black start decision support system. Based on this, the following is to construct a black-start decision method based on intuitionistic fuzzy Sugeno integral operators.

3.1 Selection of evaluation index of black start scheme

There are a lot of factors affecting the recovery of black-start, the degree of the impact of each index is different, and there are indexes are related. Therefore, the system scheduling personnel who are in black-start decision need to select those indexes which can reflect the black-start schemes and describe easily as the evaluation index of black-start scheme. Some indexes are qualitative indexes, others are quantitative indexes. Through reference to some literature [6-10], we select the following indicators as the partly evaluation indexes of the black-start scheme and introduce their effects briefly:

(1) Rated capacity of awaiting starting unit x_1: If awaiting starting unit with large rated power capacity can start to supply power quickly, it can provide the power for the start of the other units and the recovery of the important load. It can also accelerate the recovery of the whole system frame and the load, shortening load outage time. That is in a certain range, bigger value x_1 is, better the power system recovered.

(2) State of awaiting starting unit x_2: The initial state of the unit is determined by the temperature of the cylinder of the turbine unit. The higher the initial temperature of the same type unit is, the shorter power outage time as much as possible;

(3) Ramp rate of the awaiting starting unit x_3:

(4) The electrical energy required to the awaiting starting unit x4: In the early stage of black-start, the power supply of the system is very limited, and the lower power rating is, the little power consumption is, which can be considered as a priority;

(5) The number of switching operations required to start the power supply for the awaiting starting unit x_5: If the number of devices needed to operate on the recovery path between the start and the black start power is more,

the number of required operation is more, and the system will be more difficult to recover quickly.

The above 5 important evaluation indexes, the first 3 are the income type index, after 2 are the cost type index. Because of different regional power grid situation, for a particular power grid, there may be some specific important indicators of black-start, according to the specific circumstances of the indicators to be modified.

3.2 Determination of index correlation and index weight

In the evaluation of black-start scheme decision, the determination of index weight also plays an important role in the selection of the scheme. At present, there are some researches on the determination of index weights [11], which can be divided into the following three categories according to the different sources of data: the subjective weighting method, the objective weighting method and the combination of subjective and objective weight method.

The traditional black-start scheme decision is usually carried out under the assumption that the indexes are independent and mutually independent. In fact, many of the indexes in the black-start scheme are interrelated and influence. For example: there is a strong positive correlation with the indexes selected x_1 and x_4 in this paper. In addition, in order to make the black-start decision schemes are more scientific and more reasonable, we also consider the effect of preference decision expert which may have their own professional knowledge and practical experience. Therefore, the expert evaluation of black-start decision is interacting.

Considering two factors above, when we make a decision with black-start, it isn't enough to give each indicator or expert weight alone, it should also give the relationship between the different indicators and different experts associated weights. Only in this way can we effectively solve the problem of correlation between indicators and expert preferences.

3.3 Pretreating indexes of black-start scheme

Since the selected indexes of the black-start scheme the selections some are quantitative, and others are qualitative. Quantitative indicators can be expressed in a specific numerical value, and qualitative indicators generally need to use text description. For qualitative variables with text descriptions, we establish hierarchical linguistic variables to quantify. As shown in Table 1, it's 5 five-grade linguistic variables for the state of awaiting starting unit x_2:

Tab.1: Scaling values of five-grade linguistic variables

Grade	Scale value
state of extremely cold	1
state of cold	3
state of warm	5
state of hot	7
state of extremely hot	9

Because there are a large number of data in the black-start scheme can't be expressed by the exact value, so we have to pretreat them [15], and turn them into fuzzy data;

For income indicators:

$$x_{ij} = \frac{x'_{ij} - x'_{\min}}{x'_{\max} - x'_{\min}} \tag{1}$$

For cost indicators:

$$x_{ij} = \frac{x'_{\max} - x'_{ij}}{x'_{\max} - x'_{\min}} \tag{2}$$

In the formula: x'_{ij} is the original data of the j index in the program I. Additionally, $x'_{\max}$ and $x'_{\min}$ are the maximum and minimum values of the index j in all alternatives separately. Then, we convert the fuzzy data into intuitionistic fuzzy values $x_{ij} \to (t_{ij}, f_{ij})$:

$$t_{ij} = \begin{cases} x_{ij} - rx_{ij}, & x_{ij} - rx_{ij} \geq 0 \\ x_{ij}, & x_{ij} - rx_{ij} \leq 0 \end{cases} \tag{3}$$

In the formula: $r \in [0,1]$; Considering the complexity of the decision index, we suppose the index fuzzy value exist uncertainty $\pi_{ij} = 1 - t_{ij} - f_{ij}$, and $f_{ij} = 1 - \pi_{ij} - t_{ij}$.

3.4 An approach for black-start decision-making based on intuitionistic fuzzy valued Sugeno integral operator

When we do some multiple attribute decision-makings by using intuitionistic fuzzy valued Sugeno integral operators which requires us to use intuitionistic fuzzy importance measure of attribute index set, intuitionistic fuzzy valued decision matrix and intuitionistic fuzzy importance measure of expert. They were used to calculate the experts on the comprehensive evaluation of the program set. Then, the program is sorted and selected, and the specific steps are as follows:

Step 1: Determine the program, indicators and expert set. Hypothesis in multi attribute group decision making.

Supposing in multi attribute group decision-making, $E=\{e_1,e_2,\cdots,e_r\}$ is expert set, $A=\{a_1,a_2,\cdots,a_m\}$ is alternative set, $X=\{x_1,x_2,\cdots,x_n\}$ is decision attribute set of alternative schemes.

Step 2: Constructing intuitionistic fuzzy valued decision matrix. First, we need to divide the indexes into the income indicators and cost indicators. Then, converting the original data into fuzzy data by using the formula (1) and the formula (2) respectively. Next, construct a matrix of n multiply m that used the decision attribute as the row and used the alternative scheme as a column. After conversion, filled the fuzzy data into the matrix:

$$R=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

In the fuzzy conditions of incomplete information, we suppose that intuitionistic fuzzy valued $\tilde{a}_{ij}$ can be used to express the evaluation of the attribute index $j(j=1,2,\cdots,n)$ of the empirical expert degree candidate scheme $a_i(i=1,2,\cdots,m)$. That is $\tilde{a}_{ij}=(t_{ij},f_{ij})$, among them, t_{ij} express that empirical experts think the degree of importance to No. j attribute index x_i in the scheme a_i, f_{ij} express that empirical experts think the degree of unimportance to No. j attribute index x_i in the scheme a_i. Then the formula (3) is used to convert the fuzzy matrix R into the intuitionistic fuzzy valued decision matrix of the first k expert:

$$R^k=\begin{bmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \cdots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \cdots & \tilde{a}_{2n}^k \\ \vdots & \vdots & & \vdots \\ \tilde{a}_{m1}^k & \tilde{a}_{m2}^k & \cdots & \tilde{a}_{mn}^k \end{bmatrix}$$

Step 3: Determine the intuitionistic fuzzy importance measure of the expert set E an expert and other experts.

Step 4: Make an aggregation operation $(\tilde{a}_i^1,\cdots,\tilde{a}_i^r)(i=1,2,\cdots,m)$ to the comprehensive evaluation $\tilde{a}_i$ that experts to the scheme a_i by using intuitionistic fuzzy valued Sugeno integral operator, formula is same as the formula showed in Step 5.

Step 5: According to the definition.3 in paragraph 2.3 that the order comparison to the final evaluation value, and get the best solution and alternative.

4. Sample Analysis

In this paper, we use the power system data from ref. [10] to illustrate the basic features of the proposed model and method.

4.1 Determine the schemes, indicators, expert set

There are totally 6 evaluated black-start, as follows $a_1,a_2,\ldots,a_n$; there are totally 5 evaluation index of black-start, as follows: rated capacity of awaiting starting unit x_1, state of awaiting starting unit x_2, ramp rate of the awaiting starting unit x_3, the electrical energy required to the awaiting starting unit x_4 and the number of switching operations required to start the power supply for the awaiting starting unit x_5; there are totally 3 expert of black-start, as follows e_1,e_2,e_3.

4.2 Constructing intuitionistic fuzzy valued decision matrix

The accuracy of the various schemes of the numerical example is shown in table 2:

Tab.2: Index values of the candidate black-start strategies

Scheme	x_1 /MW	x_2	x_3/MW^{-1}	x_4/MW	x_5
1	300	3	60.00	15	5
2	200	7	33.30	10	4
3	125	5	62.50	6	3
4	125	3	31.25	6	3
5	50	7	16.70	3	1
6	200	9	57.00	10	4

Among them, index 1, 2, 3 are income indexes, index, index 4, 5 are cost indexes. Then we use the formula (1) and the formula (2) to converts the raw data into fuzzy data, and then use the formula (3) the fuzzy data conversion data for intuitionistic fuzzy. Now we use the index 1 and index 4 to take some examples as following:

Conversion of index 1: From Tab.2 we know, the accurate rata of x_1 are: $x_1=\{300,200,125,125,50,200\}$, so $x_{\min}=50$, $x_{\max}=300$. Because the index 1 is income index, we convert the quantitative data to fuzzy data by using the formula (1) and get $X_1=\{1.0,0.6,0.3,0.3,0,0.6\}$. Then, we convert the fuzzy data to intuitionistic fuzzy value by using the formula (3), make $r_1=0.2,\pi_{i1}=0.1$, and get:

$$t_{i1}=\{0.8,0.48,0.24,0.24,0.0,0.48\}$$
$$f_{i1}=\{0.1,0.42,0.66,0.66,0.9,0.42\}$$

So the elements in the intuitionistic fuzzy valued decision matrix are:

$$\{\tilde{a}_{11},\ldots,\tilde{a}_{61}\}=\{(0.8,0.1),(0.48,0.42),(0.24,0.66),(0.24,0.66),(0.0,0.9),(0.48,0.42)\}$$

***Conversion of index 4*:** From Tab.2 we know, the accurate rata of x_4 are: $x_4=\{15,10,6,6,3,10\}$, so $x_{\min}=3$, $x_{\max}=15$.Because the index 4 is cost index，we convert the quantitative data to fuzzy data by using the formula (2) and get $X_4=\{0.0,0.42,0.75,0.75,1.0,0.42\}$.Then, we convert the fuzzy data to intuitionistic fuzzy value by using the formula (3), make $r_4=0.2,\pi_{i4}=0.1$ and get:

$$t_{i4}=\{0.0,0.34,0.6,0.6,0.8,0.34\}$$
$$f_{i1}=\{0.9,0.56,0.3,0.3,0.1,0.56\}$$

So the elements in the intuitionistic fuzzy valued decision matrix are:

$$\{\tilde{a}_{14},\ldots,\tilde{a}_{64}\}=\{(0.0,0.9),(0.34,0.56),(0.6,0.3),(0.6,0.3),(0.8,0.1),(0.34,0.56)\}$$

Similarly, we convert indicators data of the index 2, 3, 5 to intuitionistic fuzzy value one by one and get decision matrix of intuitionistic fuzzy value as follows:

$$R^k=\begin{bmatrix}(0.80,0.10) & (0.20,0.70) & (0.76,0.14) & (0.00,0.90) & (0.00,0.90)\\ (0.48,0.42) & (0.60,0.30) & (0.29,0.61) & (0.34,0.56) & (0.20,0.70)\\ (0.24,0.66) & (0.40,0.50) & (0.80,0.10) & (0.60,0.30) & (0.40,0.50)\\ (0.24,0.66) & (0.20,0.70) & (0.26,0.64) & (0.60,0.30) & (0.40,0.50)\\ (0.00,0.90) & (0.60,0.30) & (0.00,0.90) & (0.80,0.10) & (0.80,0.10)\\ (0.48,0.42) & (0.80,0.10) & (0.70,0.20) & (0.34,0.56) & (0.20,0.70)\end{bmatrix}$$

4.3 Determine the intuitionistic fuzzy importance measure of the experts for each attribute index set

The intuitionistic fuzzy importance measure of expert e_1 for the 5 indicators of black-start decision-making:

$\tau(x_1)$=(0.15, 0.65), $\tau(x_2)$=(0.15, 0.55), $\tau(x_3)$=(0.25, 0.35), $\tau(x_4)$=(0.25, 0.65), $\tau(x_5)$=(0. 2，0.7), $\tau(x_1, x_2)$=(0.25, 0.65), $\tau(x_1, x_3)$=(0. 3，0.6), $\tau(x_1, x_4)$=(0. 35，0.55) , $\tau(x_1, x_5)$=(0.3, 0.6), $\tau(x_2, x_3)$=(0.4, 0.5), $\tau(x_2, x_4)$=(0.35, 0.55), $\tau(x_2, x_5)$=(0.35, 0.45), $\tau(x_3, x_4)$=(0.5, 0.4), $\tau(x_3, x_5)$=(0.45, 0.55), $\tau(x_4, x_5)$=(0.4, 0.6), $\tau(x_1, x_2, x_3)$=(0.45, 0.55), $\tau(x_1, x_2, x_4)$=(0.5, 0.4), $\tau(x_1, x_2, x_5)$=(0.45, 0.35), $\tau(x_1, x_3, x_4)$=(0.55, 0.25), $\tau(x_1, x_3, x_5)$=(0.55, 0.45), $\tau(x_1, x_4, x_5)$=(0.55, 0.35), $\tau(x_2, x_3, x_4)$=(0.6, 0.3), $\tau(x_2, x_3, x_5)$=(0.65, 0.3), $\tau(x_2, x_4, x_5)$=(0. 55，0.2), $\tau(x_3, x_4, x_5)$=(0.7, 0.15), $\tau(x_1, x_2, x_3, x_4)$=(0.75, 0.15), $\tau(x_1, x_2, x_3, x_5)$=(0.7, 0.1), $\tau(x_1, x_2, x_4, x_5)$=(0.7，0.2), $\tau(x_1, x_3, x_4, x_5)$=(0.85, 0.15), $\tau(x2, x3, x4, x5)$=(0.9, 0.1), $\tau(x1, x2, x3, x4, x5)$=(1, 0).

The intuitionistic fuzzy importance measure of expert e_2 for the 5 indicators of black-start decision-making:

$\tau(x_1)$=(0.15, 0.75), $\tau(x_2)$=(0.25, 0.65), $\tau(x_3)$=(0.2, 0.7), $\tau(x_4)$=(0.15, 0.65), $\tau(x_5)$=(0.25, 0.55), $\tau(x_1, x_2)$=(0.35, 0.65), $\tau(x_1, x_3)$=(0.3, 0.5), $\tau(x_1, x_4)$=(0.25, 0.55), $\tau(x_1, x_5)$=(0.4, 0.3), $\tau(x_2, x_3)$=(0.45, 0.35), $\tau(x_2, x_4)$=(0.35, 0.35), $\tau(x_2, x_5)$=(0.5, 0.3), $\tau(x_3, x_4)$=(0.35, 0.45), $\tau(x_3, x_5)$=(0.5, 0.2), $\tau(x_4, x_5)$=(0.45, 0.35), $\tau(x_1, x_2, x_3)$=(0.55, 0.35), $\tau(x_1, x_2, x_4)$=(0.5, 0.3), $\tau(x_1, x_2, x_5)$=(0.65, 0.25), $\tau(x_1, x_3, x_4)$=(0.45, 0.25), $\tau(x_1, x_3, x_5)$=(0.65, 0.15), $\tau(x_1, x_4, x_5)$=(0.6, 0.2), $\tau(x_2, x_3, x_4)$=(0.55, 0.35), $\tau(x_2, x_3, x_5)$=(0.7, 0.1), $\tau(x_2, x_4, x_5)$=(0.65, 0.15), $\tau(x_3, x_4, x_5)$=(0.7, 0.2), $\tau(x_1, x_2, x_3, x_4)$=(0.7, 0.1), $\tau(x_1, x_2, x_3, x_5)$=(0.85, 0.15), $\tau(x_1, x_2, x_4, x_5)$=(0.8, 0.1), $\tau(x_1, x_3, x_4, x_5)$=(0.8, 0.1), $\tau(x2, x3, x4, x5)$=(0.9, 0.1), $\tau(x1, x2, x3, x4, x5)$=(1,0).

The intuitionistic fuzzy importance measure of expert e_3 for the 5 indicators of black-start decision-making:

$\tau(x_1)$=(0.15, 0.55), $\tau(x_2)$= (0.2, 0.5), $\tau(x_3)$= (0.15, 0.45), $\tau(x_4)$=(0.3, 0.6), $\tau(x_5)$=(0.2,0.8), $\tau(x_1, x_2)$=(0.3, 0.4), $\tau(x_1, x_3)$=(0.25, 0.45), $\tau(x_1, x_4)$=(0.45, 0.55), $\tau(x_1, x_5)$=(0.35, 0.55), $\tau(x_2, x_3)$=(0.35, 0.65), $\tau(x_2, x_4)$=(0.42, 0.38), $\tau(x_2, x_5)$=(0.42, 0.48), $\tau(x_3, x_4)$=(0.4, 0.3), $\tau(x_3, x_5)$=(0.3, 0.4), $\tau(x_4, x_5)$=(0.45, 0.45), $\tau(x_1, x_2, x_3)$=(0.45, 0.35), $\tau(x_1, x_2, x_4)$=(0.6, 0.3), $\tau(x_1, x_2, x_5)$=(0.55, 0.35), $\tau(x_1, x_3, x_4)$=(0.55,0.25), $\tau(x_1, x_3, x_5)$=(0.5, 0.2), $\tau(x_1, x_4, x_5)$=(0.65, 0.15), $\tau(x_2, x_3, x_4)$=(0.6, 0.1), $\tau(x_2, x_3, x_5)$=(0.55, 0.15), $\tau(x_2, x_4, x_5)$=(0.7, 0.1), $\tau(x_3, x_4, x_5)$=(0.6, 0.3), (x_1, x_2, x_3, x_4)=(0.75, 0.25), $\tau(x_1, x_2, x_3, x_5)$=(0.65, 0.35), $\tau(x_1, x_2, x_4, x_5)$=(0.85, 0.15), $\tau(x_1, x_3, x_4, x_5)$=(0.75, 0.15), $\tau(x2, x3, x4, x5)$=(0.8, 0.1), $\tau(x1, x2, x3, x4, x5)$=(1, 0).

The intuitionistic fuzzy importance of three experts e_1, e_2, e_3 are:

$\tau(\{e_1\})$=(0.3, 0.6), $\tau(\{e_2\})$=(0.4, 0.5), $\tau(\{e_3\})$=(0.4, 0.3), $\tau(\{e_1,e_2\})$=(0.6, 0.2),$(\{e_2,e_3\})$=(0.7, 0.2), $\tau(\{e_1,e_3\})$=(0.7, 0.1), $\tau(\{e_1, e_2,e_3\})$=(1, 0).

5. Conclusions

In this paper, we study the application of the intuitionistic fuzzy valued measure and the intuitionistic fuzzy valued Sugeno integral in the black-start group decision-making, we consider the correlation between the index and the preference of each expert, not only we

introduce the degree of important and unimportant but also join the concept of the hesitation degree. The hesitation degree can show the unknown information scientifically. It is more reasonable for us to provide the optimal scheme of black-start. Finally, through calculating the calculation example, it has been verified. It is good for the power dispatch staff to get a good support.

References

[1]Zhou Haiming,Liu Guangyi et al,Study on the Energy Internet Technology Framework[J].China Electric Power Research Institute,2014,11:140-144

[2]LINDEBNEYER D,DOMMEL H W,ADIBI M M. Power system restoration-a bibliographical survey[J]. International Journal of Electrical Power and Energy Systems,2001,23(3):219-227.

[3]Gao Yuanwang,Gu Xueping,Liu Yan,et al.Automatic derivation and assessment of power system black-start schemes[J].Automation of Electric Power Systems,2004,28(13):50-54

[4]Liu Yan,Gu Xueping,Zhang Dan.Data Envelopment Analysis Based Relative Effectiveness Assessment of Power System Black-start Plans [J].Proceedings of the CSEE,2006,26 (5) : 32-37.

[5]Lin jinkeng,Jiang Yuemei,et al.Asessment of effective schemes for power system black-start based on DEA/AHP[J]Automation of Electric Power Systems,2007,31(15):65-69.

[6]Lin Zhenzhi,Wen Fushuan,Xue Yusheng.Sensitivity analysis on the values and weights of indices in power system black-start decision-making[J].Automation of Electric Power Systems,2009,33(9):20-25.

[7]Lin Zhenzhi,Wen Fushuan,Xue Yusheng,et al.Reliability analysis on the group decision-making results of black-start strategies in smart grids[J].Automation of Electric Power Systems,2010,34(9):17-22.

[8]Lin Zhenzhi,Wen Fushuan,Xue Yusheng,et al.Black-start decision-making in smart grids using multi-attribute group eigenvalue method[J].Automation of Electric Power Systems,2010,34(5):18-23.

[9]Zeng Shunqi,Lin Zhenzhi,Wen Fushuan,et al.A Vague set theory based model and approach for black-start decision-making[J].Automation of Electric Power Systems,2011,35(2):18-22

[10]Liu Weijia,Lin Zhenzhi,Wen Fushuan et al. An approach for black-start decision-making based on intuitionistic fuzzy choquet integral operator[A].Journal of North China Electric Power University,2011,38(4):1-7.

[11]Chen Xiaohong. Complex Large Group Decision-making Method and Its Application [M].Science Press,2009

[12]Chen S M, Tan JM. Handling multicriterial fuzzy decision-making problems based on vague set theory [J].Fuzzy Sets and Systems,1994,67(2)163-172.

[13]Hong D J,Choi C H. Multicriteria fuzzy decision-making problems based on vague set theory[J].Fuzzy Sets and Systems,2000,114(1):103-113. .

[14]FELTES J W,GRANDE-MORAN C.Black start studies for system restoration[C].Proceedings of IEEE Power and Energy Society General Meeting , July 20-24,2008, Pittsburgh, PA,USA.

[15]Wang HongxuConversion formula from Fuzzy data to Vague data[J].Computer engineering and Applications,2010,46(25):47-48.