ICIC Express Letters
Volume **10**, Number **1**, January **2016** ISSN 1881-803X
pp. **219–227**

RESEARCH ON RISK ASSESSMENT OF POWER SUPPLY MODE FOR IMPORTANT POWER USERS BASED ON INTERVAL-VALUED INTUITIONISTIC TRAPEZOIDAL FUZZY NUMBER

Cunbin Li, Shuke Li and Yunqi Liu

School of Economics and Management
North China Electric Power University
No. 2, Beinong Road, Beijing 102206, P. R. China
liu_yunqi@163.com

Received July 2015; accepted October 2015

Abstract. *In the complex-large group decision-making, preference information of the decision makers can be described as interval-valued intuitionistic trapezoidal fuzzy number (IITFN), which is widespread in the decision-making practice. Based on interval-valued intuitionistic trapezoidal fuzzy number, this article presents a risk assessment model which is aimed at risk assessment of power supply mode for important power users. Moreover, a complete evaluation process and specific algorithm are given and the solution that directs at the problem of inconsistent assessment opinions between members is also proposed. Finally, the risk assessment of alternatives is conducted through an example in terms of reliability, adaptability, economy and power quality; meanwhile, the proposed model is verified. The study can contribute to the power supply mode selection and risk assessment for important power users.*
Keywords: Risk assessment, Interval-valued intuitionistic trapezoidal fuzzy number, Power supply mode, Important power users

1. **Introduction.** Important power users refer to the power consuming unit with an important position in the social, political, and economic life of the country or a region (city) and the cut-off of power supply for them will cause personal casualties, larger environmental pollution, larger political influences, and larger economic losses, serious social public disorder or power consuming site which has special requirements for power supply reliability [1]. Power supply mode selection is a basic content in the research of distribution network planning [2], which has aroused intense scholarly interest among researchers. literature [3] proposed an assessment system on typical power supply mode for important power users based on analytic hierarchy process and expert experience; literature [4] proposed a method to select distribution network feeding modes based on analytic hierarchy process and fuzzy comprehensive evaluation; literature [5] proposed a mathematical model for the planning of distribution with distributed generation based on improved immune clonal selection algorithm; literature [6] analyzed and compared the typical connection modes of high-voltage distribution network to complement analytical method of traditional connection mode utilizing the concept of load supply capability and considering the correlation between the economy and the reliability.

In the aspect of power supply risk research, literature [7] established the mapping relation between power supply risk and consumers' demand risk based on the thought of risk element transfer and utilizing trapezoidal fuzzy number; literature [8] established a learning Bayesian network and utilized its learning mechanism to optimize the network, which obtained a clear power supply risk transmission network and kinds of degree of association between risks; literature [9-11] carried on the studies on power supply risk respectively from different aspects with different methods, but the studies which directly start with the power supply mode to conduct risk assessment and analysis have not been found so far.

Intuitionistic fuzzy number proposed by Atanassov [12] has more flexibility and practicability than the traditional fuzzy number in dealing with fuzziness and uncertainty, because it simultaneously has considered three aspects of information: degree of membership, non-membership degree and hesitancy degree. Interval-valued intuitionistic trapezoidal fuzzy number [13] is an expanded form of intuitionistic fuzzy number, which is more detailed and accurate than any other expanded forms of intuitionistic fuzzy number in depicting the fuzziness and uncertainty of the objective world, and Wan [14] studied its operational rules, characters, sorting methods. In the aspect of conflict measurement, literature [15] carried out the research on conflict measurement of large group decision based on interval-valued intuitionistic trapezoidal fuzzy number preference.

In view of the above all, risk assessment of the power supply modes for important power users has important significance; however, there is little literature using interval-valued intuitionistic trapezoidal fuzzy number in the aspect of risk assessment of the power supply modes for important power users and taking into consideration disagreement in evaluation opinions of members. Based on those, this article built a risk assessment model of power supply modes for important power users based on interval-valued intuitionistic trapezoidal fuzzy number. The article is organized as follows. In Section 2, the related knowledge involved interval-valued intuitionistic trapezoidal fuzzy number is introduced; in Section 3, the process and methods of risk assessment based on interval-valued intuitionistic fuzzy number are proposed and specific steps of the assessment are described; in Section 4, an example analysis is presented and the proposed method is demonstrated; in Section 5, the conclusions are given.

2. Interval-Valued Intuitionistic Trapezoidal Fuzzy Number (IITFN).

Definition 2.1. *Let membership [14] function of an intuitionistic fuzzy number in real number set be:*

$$\mu_{\tilde{a}}(x) = \begin{cases} \dfrac{x-a}{b-a}\mu_{\tilde{a}}, & a \le x < b \\ \mu_{\tilde{a}}, & b \le x \le c \\ \dfrac{d-x}{d-c}\mu_{\tilde{a}}, & c < x \le d \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Its non-membership function is:

$$v_{\tilde{a}}(x) = \begin{cases} \dfrac{b-x+v_{\tilde{a}}(x-a_1)}{b-a_1}, & a_1 \le x < b \\ v_{\tilde{a}}, & b \le x \le c \\ \dfrac{x-c+v_{\tilde{a}}(d_1-x)}{d_1-c}\mu_{\tilde{a}}, & c < x \le d \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

where $0 \le \mu_{\tilde{a}} \le 1$; $0 \le v_{\tilde{a}} \le 1$; $\mu_{\tilde{a}} + v_{\tilde{a}} \le 1$; a, b, c, d, a_1, $d_1 \in R$. Then, $\tilde{a} = \langle([a,b,c,d];\mu_{\tilde{a}}), ([a_1,b,c,d_1];v_{\tilde{a}})\rangle$ is named intuitionistic trapezoidal fuzzy number. When $b = c$, intuitionistic trapezoidal fuzzy number degraded into trapezoidal fuzzy number. If $\mu_{\tilde{a}}$, $v_{\tilde{a}}$ are both closed subinterval on the interval $[0,1]$, $\tilde{a}$ is named IITFN. Generally, there is $[a,b,c,d] = [a_1,b,c,d_1]$ in $\tilde{a}$, which is denoted by $\tilde{a} = \langle[a,b,c,d];\mu_{\tilde{a}}, v_{\tilde{a}}\rangle$. In this article those all refer to this kind of fuzzy number. $\pi_{\tilde{a}}(x) = 1 - \mu_{\tilde{a}}(x) - v_{\tilde{a}}(x)$ is the hesitancy function, the smaller its value is, the more determinate the fuzzy number is. Its membership function and non-membership function respectively are denoted by $\mu_{\tilde{a}} = [\underline{\mu}, \bar{\mu}]$, $v_{\tilde{a}} = [\underline{v}, \bar{v}]$. IITFN is shorthand for $\tilde{a} = \left([a,b,c,d]; [\underline{\mu}, \bar{\mu}], [\underline{v}, \bar{v}]\right)$.

Definition 2.2. *If* $\tilde{a}_i = \left([a_i, b_i, c_i, d_i]; \left[\underline{\mu}_i, \bar{\mu}_i\right], [\underline{v}_i, \bar{v}_i]\right)$ $(i = 1, 2)$ *are two IITFN, and* $\lambda \geq 0$*, there are the following theorems (where* $a_1 \geq 0$, $a_2 \geq 0$*):*

(1) $\tilde{a}_1+\tilde{a}_2=\left([a_1+a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2];\ \left[\underline{\mu}_1 + \underline{\mu}_2 - \underline{\mu}_1\underline{\mu}_2, \bar{\mu}_1 + \bar{\mu}_2 - \bar{\mu}_1\bar{\mu}_2\right], [\underline{v}_1\underline{v}_2, \bar{v}_1\bar{v}_2]\right)$;

(2) $\tilde{a}_1\tilde{a}_2 = \left([a_1a_2, b_1b_2, c_1c_2, d_1d_2];\ \left[\underline{\mu}_1\underline{\mu}_2, \bar{\mu}_1\bar{\mu}_2\right], [\underline{v}_1 + \underline{v}_2 - \underline{v}_1\underline{v}_2, \bar{v}_1 + \bar{v}_2 - \bar{v}_1\bar{v}_2]\right)$;

(3) $\lambda\tilde{a}_1 = [\lambda a_1, \lambda b_1, \lambda c_1, \lambda d_1];\ \left[1 - (1 - \underline{\mu}_1)^\lambda, 1 - (1 - \bar{\mu}_1)^\lambda\right], [(\underline{v}_1)^\lambda, (\bar{v}_1)^\lambda]$;

(4) $(\tilde{a}_1)^\lambda = \left(\left[(a_1)^\lambda, (b_1)^\lambda, (c_1)^\lambda, (d_1)^\lambda\right];\ \left[(\underline{\mu}_1)^\lambda, (\bar{\mu}_1)^\lambda\right], \left[1 - (1 - \underline{v}_1)^\lambda, 1 - (1 - \bar{v}_1)^\lambda\right]\right)$.

Definition 2.3. *With reference to thoughts of Xu [16] and Wang and Zhang [13], based on Hamming distance, the definition of distance between two IITFN can be given.*

The distance $d(\tilde{a}_i, \tilde{a}_j)(i \in R, j \in R, i \neq j)$ *between two IITFN* $\tilde{a}_i=\left([a_i, b_i, c_i, d_i]; [\underline{\mu}_i, \bar{\mu}_i], [\underline{v}_i, \bar{v}_i]\right)$ *and* $\tilde{a}_j = \left([a_j, b_j, c_j, d_j]; \left[\underline{\mu}_j, \bar{\mu}_j\right], [\underline{v}_j, \bar{v}_j]\right)$ *can be expressed as:*

$$d(\tilde{a}_i, \tilde{a}_j) = \frac{1}{16}\sum\left|\left(2 + \bar{\mu}_i - \underline{v}_i + \underline{\mu}_i - \bar{v}_i\right) h_i - \left(2 + \bar{\mu}_j - \underline{v}_j + \underline{\mu}_j - \bar{v}_j\right) h_j\right|,\ (h = a, b, c, d) \tag{3}$$

where $d(\tilde{a}_i, \tilde{a}_j)$ *meets the following properties:*

(1) $d(\tilde{a}_i, \tilde{a}_j) \geq 0$*;*

(2) $d(\tilde{a}_i, \tilde{a}_j) = 0$*;*

(3) $d(\tilde{a}_i, \tilde{a}_j) = d(\tilde{a}_j, \tilde{a}_i)$*;*

(4) $d(\tilde{a}_i, \tilde{a}_l) \leq d(\tilde{a}_i, \tilde{a}_j) + d(\tilde{a}_j, \tilde{a}_l)$*,* $\tilde{a}_l$ *is intuitionistic trapezoidal fuzzy number on any interval.*

When $\bar{\mu}_i = \underline{\mu}_i$, $\bar{v}_i = \underline{v}_i$, IITFN degraded into intuitionistic trapezoidal fuzzy number; at this time, the distance of the two intuitionistic trapezoidal fuzzy numbers is Hamming distance of those. In the actual evaluation process, $d(\tilde{a}_i, \tilde{a}_j)$ represents the assessment gaps between two evaluation members; $d(\tilde{a}_i, \tilde{a}_j) = 0$ represents the assessment results are concordant between two members; $d(\tilde{a}_i, \tilde{a}_j) = 1$ represents the assessment results are completely opposite.

With reference to research thoughts of Xu et al. [15], the following definitions are given.

Definition 2.4. *IITFN preference vectors*

Setting assessment value that the i member of evaluation group M given aimed to n attributes of decision-making items is IITFN $\tilde{a}^i_j = (j = 1, 2, \cdots, n)$*, then, assessment value vector* $\tilde{a}_i = (\tilde{a}^i_1, \tilde{a}^i_2, \cdots, \tilde{a}^i_n)$ *is named IITFN preference vector of the i member of evaluation group M, where* $i = 1, 2, \cdots, m$*.*

Definition 2.5. *Conflict function of evaluation members*

Conflict function of evaluation member i_1 *and evaluation member* i_2 *of evaluation group M can be expressed as:*

$$\varphi(\tilde{a}_{i_1}, \tilde{a}_{i_2}) = \sum_{j=1}^{n} \omega_j \cdot d\left(\tilde{a}^{i_1}_j, \tilde{a}^{i_2}_j\right) \tag{4}$$

where ω_j is the weight of evaluation attribute of the number j. For measuring conflict degree φ of preference vectors $\tilde{A}_{i_1}$ and $\tilde{A}_{i_2}$, threshold value γ and the condition $\varphi\left(\tilde{A}_{i_1}, \tilde{A}_{i_2}\right) \leq \gamma$ are introduced, namely when the conflict degree between the two preference vectors is less than the threshold γ, the opinions of the evaluation members represented by the two preference vectors are considered close enough, where γ is conflict degree which the whole assessment members can tolerate, $\gamma \in [0,1]$. Xu and Chen [17] divided different opinions into K clusters $(1 \le K \le m)$, n_k is the number of members in the cluster C^k, $(k = 1, 2, \cdots, K)$, $\sum_{k=1}^{K} n_k = m$, where threshold value γ determines whether or not the preference vector $\tilde{A}_i$ of evaluation member i can enter the cluster C^k: the greater the threshold value γ is, the easier to enter cluster C^k the preference vector $\tilde{A}_i$ of member i is; otherwise, the more difficult to enter cluster C^k the preference vector $\tilde{A}_i$ of member i is. In the same cluster C^k, if the conflict degree among its members is small enough, their assessing preferences can be considered basically identical.

Definition 2.6. *Group conflict index*

For the cluster C^k of group M, its conflict degree index ρ^k can be expressed as:

$$\rho^k = \frac{1}{C_{n_k}^2} \sum_{n_k} \varphi\left(\tilde{A}_{i_1}, \tilde{A}_{i_2}\right) \tag{5}$$

where $\tilde{A}_{i_1}, \tilde{A}_{i_2} \in C^k$, $C_{n_k}^2 = \frac{n_k(n_k-1)}{2}$, when $m > 1$, $\rho^k \ge 0$. The conflict degree of the whole large group can be expressed as:

$$\rho = \sum_{k=1}^{K} \frac{n_k}{m} \cdot \rho^k \tag{6}$$

Definition 2.7. *Setting expected value of trapezoidal fuzzy number $[a, b, c, d]$ is $E = (a + b + c + d)/4$, for the IITFN $\tilde{a} = \left([a, b, c, d]; \left[\underline{\mu}, \bar{\mu}\right], [\underline{v}, \bar{v}]\right)$, its score function and accuracy function respectively can be expressed as:*

$$S(\tilde{a}) = \frac{1}{2} E\left(\underline{\mu} - \underline{v} + \bar{\mu} - \bar{v}\right) \tag{7}$$

$$H(\tilde{a}) = \frac{1}{2} E\left(\underline{\mu} + \underline{v} + \bar{\mu} + \bar{v}\right) \tag{8}$$

3. **Risk Assessment Based on IITFN.** This article built evaluation method based on IITFN, and the procedure is as shown in Figure 1.

The specific steps of assessment method are described as follows.

Step 1: Setting language assessment set $S = (S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8)$ represents (extreme poor, very poor, poor, below the average, average, above the average, good, very good, extreme good), language assessment set can be computed by nine level linguistic evaluation scale employed in literature [18] and be translated into trapezoidal fuzzy numbers.

Step 2: To determine the weight of each attribute, we provided weights of attribute according to entropy theory [19]:

$$\omega_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{9}$$

where $\omega_j \in [0,1]$, $\sum_{j=1}^{n} \omega_j = 1$, $H_j = \frac{1}{m} \sum_{i=1}^{m} \left(1 - \frac{\underline{\mu}_j^i + \bar{\mu}_j^i}{2} - \frac{\underline{v}_j^i + \bar{v}_j^i}{2}\right)$, $j = 1, 2, \cdots, n$.

Step 3: Calculate the conflict function $\varphi\left(\tilde{A}_{i_1}, \tilde{A}_{i_2}\right)$ between two members. Preferences of group members are clustered into several clusters $\left\{C^k / 1 \le k \le m\right\}$ on the base of the conflict function, and then the preference vector of the cluster C^k is figured out:

$$\tilde{A}^k = \left(\frac{1}{n_k} \sum_{i=1,\, i \in C^k}^{n_k} \tilde{a}_1^i, \cdots, \frac{1}{n_k} \sum_{i=1,\, i \in C^k}^{n_k} \tilde{a}_n^i\right) \tag{10}$$

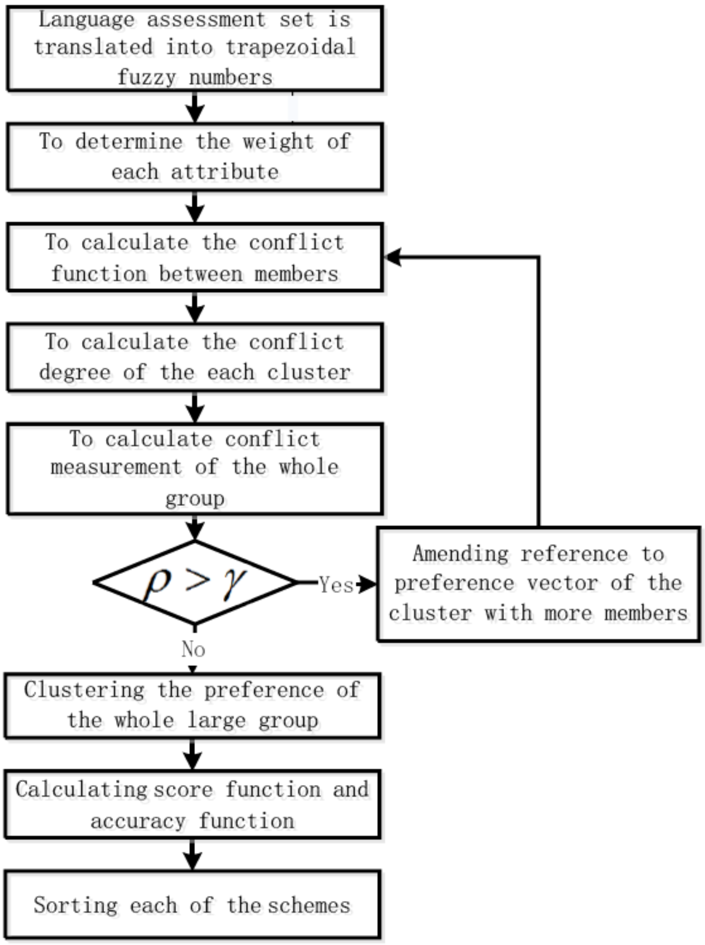

Figure 1. Flow chart of assessment method based on IITFN

Step 4: Calculate the conflict degree ρ^k of the each cluster, and then calculate conflict measurement ρ of the whole group. When $\rho > \gamma$, move on to Step 5; otherwise, move on to Step 6.

Step 5: Giving a feedback $\tilde{A}^k*$ which is the preference vector of the cluster with the maximum number of members to the members of other clusters, ask the members of other clusters to revise their preference vector with reference to $\tilde{A}^k*$ by using the following formula:

$$\tilde{A}_i = \lambda_i \tilde{A}_i + (1 - \lambda_i)\tilde{A}^k* \tag{11}$$

where $i \notin C^k*$, $0 \leq \lambda_i < 1$, and then return to Step 3.

Step 6: Cluster the preference of the whole large group. This step is to calculate preference vector of the group by using preference vector of each cluster, which can be expressed as:

$$\tilde{A} = \sum_{k=1}^{K} \frac{n_k}{m} \tilde{A}^k \tag{12}$$

Step 7: Sort each of the schemes by using the score function and the accuracy function.

$$\begin{cases} \tilde{a}_1 > \tilde{a}_2, & S(\tilde{a}_1) > S(\tilde{a}_2) \\ \tilde{a}_1 > \tilde{a}_2, & S(\tilde{a}_1) = S(\tilde{a}_2); H(\tilde{a}_1) > H(\tilde{a}_2) \\ \tilde{a}_1 = \tilde{a}_2, & S(\tilde{a}_1) = S(\tilde{a}_2); H(\tilde{a}_1) = H(\tilde{a}_2) \end{cases} \tag{13}$$

4. **Example Analysis.** In the example analysis of the article, there are 20 experts to evaluate the risk of power supply mode for certain important power user, there are three alternatives to form solution set $\{A_1, A_2, A_3\}$, the following four indexes are selected to

TABLE 1. The preference vector table of evaluation to the scheme A_1 that group members give

NO.	a_1	a_2	a_3	a_4
$\tilde{A}_1$	([0.3, 0.6, 0.4, 0.6]; [0.7, 0.8], [0.0, 0.1])	([0.0, 0.9, 0.1, 0.4]; [0.4, 0.2], [0.7, 0.5])	([0.8, 0.4, 0.6, 0.6]; [0.2, 0.9], [0.5, 0.6])	([0.6, 0.9, 0.4, 0.1]; [0.9, 0.6], [0.7, 0.0])
$\tilde{A}_2$	([0.2, 0.5, 0.4, 0.1]; [0.1, 0.1], [0.2, 0.7])	([0.1, 0.4, 0.9, 0.7]; [0.9, 0.0], [0.9, 0.4])	([0.2, 0.6, 0.6, 0.2]; [0.1, 0.2], [0.6, 0.1])	([0.6, 0.7, 0.9, 0.9]; [0.0, 0.3], [0.6, 0.8])
$\tilde{A}_3$	([0.3, 0.6, 0.7, 0.5]; [0.9, 0.8], [0.4, 0.3])	([0.1, 0.0, 0.2, 0.4]; [0.5, 0.7], [0.8, 0.9])	([0.8, 0.5, 0.6, 0.0]; [0.6, 0.2], [0.9, 0.7])	([0.0, 0.7, 0.7, 0.6]; [0.5, 0.0], [0.7, 0.2])
$\tilde{A}_4$	([0.4, 0.3, 0.6, 0.9]; [0.7, 0.1], [0.0, 0.8])	([0.3, 0.5, 0.7, 0.3]; [0.1, 0.9], [0.1, 0.2])	([0.9, 0.5, 0.8, 0.9]; [0.6, 0.7], [0.3, 0.5])	([0.8, 0.1, 0.2, 0.0]; [0.2, 0.4], [0.8, 0.4])
$\tilde{A}_5$	([0.5, 0.7, 0.5, 0.8]; [0.4, 0.8], [0.4, 0.3])	([0.3, 0.1, 0.9, 0.9]; [0.6, 0.5], [0.9, 0.8])	([0.8, 0.3, 0.9, 0.1]; [0.6, 0.3], [0.4, 0.8])	([0.3, 0.1, 0.0, 0.2]; [0.7, 0.7], [0.4, 0.6])
$\tilde{A}_6$	([0.3, 0.9, 0.6, 0.6]; [0.5, 0.1], [0.7, 0.0])	([0.2, 0.9, 0.8, 0.6]; [0.2, 0.9], [0.1, 0.3])	([0.7, 0.3, 0.4, 0.8]; [0.1, 0.4], [0.2, 0.5])	([0.4, 0.9, 0.5, 0.5]; [0.4, 0.6], [0.7, 0.5])
$\tilde{A}_7$	([0.5, 0.6, 0.7, 0.4]; [0.7, 0.2], [0.2, 0.8])	([0.6, 0.0, 0.8, 0.3]; [0.3, 0.1], [0.0, 0.7])	([0.8, 0.7, 0.2, 0.0]; [0.7, 0.8], [0.0, 0.8])	([0.4, 0.1, 0.5, 0.6]; [0.3, 0.2], [0.4, 0.4])
$\tilde{A}_8$	([0.5, 0.8, 0.8, 0.2]; [0.2, 0.4], [0.3, 0.6])	([0.9, 0.2, 0.0, 0.1]; [0.3, 0.2], [0.0, 0.2])	([0.9, 0.5, 0.8, 0.2]; [0.0, 0.3], [0.0, 0.7])	([0.6, 0.5, 0.1, 0.7]; [0.4, 0.8], [0.7, 0.2])
$\tilde{A}_9$	([0.3, 0.4, 0.0, 0.6]; [0.0, 0.0], [0.2, 0.6])	([0.3, 0.9, 0.6, 0.4]; [0.0, 0.5], [0.9, 0.1])	([0.1, 0.8, 0.2, 0.9]; [0.9, 0.5], [0.8, 0.3])	([0.2, 0.4, 0.5, 0.5]; [0.8, 0.1], [0.6, 0.6])
$\tilde{A}_{10}$	([0.5, 0.0, 0.4, 0.1]; [0.3, 0.2], [0.0, 0.9])	([0.2, 0.1, 0.2, 0.3]; [0.4, 0.8], [0.8, 0.5])	([0.8, 0.2, 0.7, 0.6]; [0.3, 0.7], [0.0, 0.2])	([0.0, 0.9, 0.7, 0.5]; [0.7, 0.4], [0.7, 0.7])
$\tilde{A}_{11}$	([0.9, 0.9, 0.5, 0.5]; [0.6, 0.9], [0.5, 0.1])	([0.5, 0.7, 0.6, 0.6]; [0.7, 0.4], [0.4, 0.3])	([0.4, 0.3, 0.9, 0.9]; [0.3, 0.6], [0.2, 0.5])	([0.1, 0.5, 0.3, 0.6]; [0.2, 0.4], [0.0, 0.8])
$\tilde{A}_{12}$	([0.3, 0.0, 0.3, 0.3]; [0.2, 0.2], [0.7, 0.6])	([0.0, 0.7, 0.3, 0.1]; [0.6, 0.6], [0.1, 0.7])	([0.0, 0.5, 0.3, 0.5]; [0.9, 0.3], [0.9, 0.1])	([0.4, 0.7, 0.9, 0.2]; [0.0, 0.4], [0.3, 0.7])
$\tilde{A}_{13}$	([0.6, 0.0, 0.6, 0.5]; [0.0, 0.4], [0.5, 0.6])	([0.9, 0.3, 0.8, 0.4]; [0.8, 0.7], [0.0, 0.5])	([0.1, 0.1, 0.1, 0.6]; [0.8, 0.0], [0.8, 0.2])	([0.2, 0.1, 0.1, 0.9]; [0.0, 0.7], [0.8, 0.1])
$\tilde{A}_{14}$	([0.7, 0.5, 0.7, 0.2]; [0.0, 0.5], [0.2, 0.4])	([0.7, 0.6, 0.0, 0.8]; [0.1, 0.0], [0.0, 0.2])	([0.8, 0.8, 0.2, 0.4]; [0.4, 0.1], [0.4, 0.6])	([0.6, 0.4, 0.2, 0.0]; [0.4, 0.6], [0.2, 0.4])
$\tilde{A}_{15}$	([0.1, 0.2, 0.2, 0.9]; [0.5, 0.2], [0.5, 0.6])	([0.8, 0.7, 0.9, 0.3]; [0.3, 0.4], [0.9, 0.4])	([0.1, 0.6, 0.3, 0.5]; [0.8, 0.4], [0.1, 0.1])	([0.5, 0.1, 0.5, 0.1]; [0.6, 0.8], [0.4, 0.4])
$\tilde{A}_{16}$	([0.8, 0.0, 0.6, 0.6]; [0.1, 0.9], [0.2, 0.5])	([0.4, 0.9, 0.7, 0.4]; [0.6, 0.3], [0.6, 0.9])	([0.8, 0.4, 0.2, 0.5]; [0.6, 0.2], [0.7, 0.0])	([0.9, 0.4, 0.6, 0.5]; [0.9, 0.8], [0.7, 0.7])
$\tilde{A}_{17}$	([0.6, 0.4, 0.6, 0.7]; [0.9, 0.4], [0.3, 0.4])	([0.9, 0.0, 0.8, 0.9]; [0.6, 0.8], [0.7, 0.9])	([0.1, 0.7, 0.0, 0.0]; [0.0, 0.0], [0.9, 0.4])	([0.5, 0.1, 0.6, 0.8]; [0.2, 0.0], [0.6, 0.7])
$\tilde{A}_{18}$	([0.5, 0.3, 0.9, 0.1]; [0.9, 0.4], [0.5, 0.6])	([0.1, 0.6, 0.4, 0.2]; [0.8, 0.1], [0.3, 0.3])	([0.9, 0.7, 0.4, 0.6]; [0.7, 0.0], [0.0, 0.9])	([0.0, 0.2, 0.6, 0.7]; [0.9, 0.1], [0.1, 0.9])
$\tilde{A}_{19}$	([0.3, 0.3, 0.3, 0.2]; [0.3, 0.0], [0.2, 0.3])	([0.7, 0.6, 0.7, 0.3]; [0.4, 0.9], [0.2, 0.6])	([0.6, 0.4, 0.9, 0.7]; [0.5, 0.8], [0.6, 0.4])	([0.7, 0.7, 0.6, 0.1]; [0.6, 0.3], [0.6, 0.3])
$\tilde{A}_{20}$	([0.7, 0.3, 0.9, 0.6]; [0.1, 0.8], [0.0, 0.9])	([0.7, 0.7, 0.9, 0.1]; [0.5, 0.8], [0.9, 0.1])	([0.1, 0.2, 0.3, 0.6]; [0.7, 0.2], [0.8, 0.7])	([0.1, 0.3, 0.6, 0.1]; [0.5, 0.0], [0.1, 0.7])

conduct risk evaluation: reliability risk a_1, adaptability risk a_2, economic risk a_3, power quality risk a_4, and the weight vector of index is $W = (0.41, 0.14, 0.41, 0.04)$. Firstly, each expert respectively evaluated the four indexes and gave preference information of interval-valued intuitionistic trapezoidal fuzzy number form for the scheme A_1, 20 preference vectors can be obtained that constitute preference vector set $\left\{\tilde{A}_i\right\}$ $(i = 1, 2, \cdots, 20)$, after the preference vector set data are standardized, and the results of those are as shown in Table 1.

Then, setting threshold value of tolerable conflict degree is $\gamma = 0.10$. If group conflict degree is beyond the tolerable range, the preference of group members needs to be revised according to Step 5 of the method, and after that clustering calculations are conducted, and clustering results are shown in Table 2.

Table 2. The clustering results obtained from the modified preference of group members ($\gamma = 0.10$)

Cluster C^k	The number of members	The members of cluster	The preference vectors of clusters	The conflict degree of clusters
Cluster C^1	18	$\tilde{A}_1, \tilde{A}_2, \tilde{A}_3, \tilde{A}_5, \tilde{A}_6, \tilde{A}_7, \tilde{A}_8, \tilde{A}_9, \tilde{A}_{10}, \tilde{A}_{11}, \tilde{A}_{12}, \tilde{A}_{14}, \tilde{A}_{15}, \tilde{A}_{16}, \tilde{A}_{17}, \tilde{A}_{18}, \tilde{A}_{19}, \tilde{A}_{20}$	$\begin{pmatrix} ([0.19, 0.39, 0.59, 0.84]; [0.14, 0.33], [0.00, 0.27]), \\ ([0.13, 0.34, 0.55, 0.82]; [0.14, 0.32], [0.00, 0.38]), \\ ([0.17, 0.32, 0.51, 0.75]; [0.16, 0.33], [0.00, 0.36]) \end{pmatrix}$	0.1003
Cluster C^2	2	$\tilde{A}_4, \tilde{A}_{13}$	$\begin{pmatrix} ([0.17, 0.25, 0.40, 0.58]; [0.03, 0.17], [0.00, 0.48]), \\ ([0.23, 0.46, 0.61, 0.85]; [0.21, 0.49], [0.00, 0.26]), \\ ([0.23, 0.43, 0.57, 0.79]; [0.24, 0.51], [0.00, 0.35]) \end{pmatrix}$	0.0981

The preference vector of group members is obtained by the calculation utilizing Formula (12):

$$\tilde{A}(1) = \left\{ \begin{array}{l} ([0.19, 0.35, 0.56, 0.79]; [0.14, 0.30], [0.00, 0.30]), \\ ([0.14, 0.34, 0.58, 0.85]; [0.16, 0.34], [0.00, 0.35]), \\ ([0.16, 0.32, 0.51, 0.76]; [0.15, 0.37], [0.00, 0.38]) \end{array} \right\}$$

Group preference vector is the consistent results which whole experts group achieved by coordinating their evaluations to the scheme A_1. The group preference vectors of the scheme A_2 and the scheme A_3 can be obtained respectively by above method, and the results are shown as follows:

$$\tilde{A}(2) = \left\{ \begin{array}{l} ([0.11, 0.30, 0.51, 0.70]; [0.25, 0.41], [0.00, 0.28]), \\ ([0.23, 0.41, 0.54, 0.73]; [0.20, 0.39], [0.00, 0.36]), \\ ([0.16, 0.40, 0.60, 0.71]; [0.15, 0.37], [0.00, 0.31]) \end{array} \right\}$$

$$\tilde{A}(3) = \left\{ \begin{array}{l} ([0.19, 0.40, 0.55, 0.78]; [0.18, 0.38], [0.00, 0.01]), \\ ([0.21, 0.37, 0.62, 0.75]; [0.17, 0.39], [0.00, 0.31]), \\ ([0.18, 0.42, 0.60, 0.73]; [0.20, 0.41], [0.00, 0.30]) \end{array} \right\}$$

Finally, integrated interval-valued intuitionistic fuzzy numbers as well as the score function and accuracy function for each scheme are worked out, and the results are as shown in Table 3.

It is obtained from Table 3 the sequence of the risk of each power supply mode, which is shown as follows: mode $A_3 \succ A_2 \succ A_1$, and the greatest risk is the mode A_3.

5. **Conclusions.** (1) In this article, the interval-valued intuitionistic fuzzy number theory was applied in risk assessment of power supply mode for important power users and

Table 3. The integration of IITFN-WAA for alternatives

Scheme	Integrated interval-valued intuitionistic fuzzy numbers	Score function	Accuracy function
A_1	$([0.16, 0.33, 0.54, 0.80]; [0.14, 0.33], [0.00, 0.33])$	0.0426	0.2001
A_2	$([0.15, 0.36, 0.55, 0.73]; [0.19, 0.40], [0.00, 0.31])$	0.0598	0.2106
A_3	$([0.20, 0.39, 0.60, 0.75]; [0.20, 0.39], [0.00, 0.00])$	0.1394	0.1396

the risk assessment of alternatives was conducted from four aspects: the reliability, adaptability, economy and power quality, which can provide the basis for power supply mode selection and risk assessment.

(2) In the assessment process of complex large group, actual situation that the preference information of decision makers is interval-valued intuitionistic trapezoidal fuzzy number is widespread in the decision making practice. This article first clustered preference of group members into several clusters, preference vector of the cluster which has the maximum number of members is fed back to members of other clusters, then members of the other clusters are required to revise their preference vector until the conflict degree of each cluster reaches tolerable range, and finally the risk of each scheme is ranked by using the score function and accuracy function.

(3) In this article, the proposed method considered the fuzziness of information for decision basis and intuitionistic fuzziness of preference information of policy-makers, which made the assessment results more accurate. The model is convenient for the analysis and coordination of large group opinions and is suitable for group decision support system, which has a significant practical application value.

It is noted that the threshold value γ of tolerable conflict degree is a key index in this article, and how to select the threshold value needs further research.

Acknowledgement. This research is partially funded by the National Natural Science Foundation of China (71271084), the science and technology project of the China State Grid Corp. (521820140017), the Fundamental Research Funds for the Central Universities (2014XS55 and 2015XS32) and the Project for the Beijing's Enterprise-Academics-Research Co-Culture Post-Graduate.

REFERENCES

[1] GB/Z 29328-2012, *Specific Configuration of Power Supply and Self-emergency Power Supply for Important Power Users*, China Standards Press, Beijing, 2013.

[2] L. Wang, S. Lu and J. Yu, Mathematical matching model of distribution network based on matching recognition theory, *Proc. of the Chinese Society of Universities for Electric Power System & Its Automation*, vol.23, no.4, pp.106-110, 2011.

[3] R. Li, Y. Li, H. Xu et al., Assessment on typical power supply mode for important power consumers based on analytical hierarchy process and expert experience, *Power System Technology*, vol.38, no.9, pp.2336-2341, 2014.

[4] C. Zhang, H. Chen, X. Xi et al., A study of distribution network feeding modes selection based on analytic hierarchy process and fuzzy comprehensive evaluation, *Power System Technology*, vol.30, no.22, pp.67-71, 2006.

[5] Y. Xu and X. Li, An improved immune clonal selection algorithm based planning method for distribution network with distributed generators, *Power System Technology*, vol.34, no.8, pp.97-101, 2010.

[6] S. Ge, Y. Guo, H. liu et al., Load supply capability based analysis of HV distribution network connection mode, *Power System Technology*, no.2, pp.405-411, 2014.

[7] S. Tian, M. Pan, J. Yuan et al., Power supply risk element assessment for important consumers equipped with standby power supplies, *Power System Technology*, vol.39, no.1, pp.35-42, 2015.

[8] C. Li and M. Huang, Power supply risk transmission analysis based on learning Bayesian networks, *Journal of Central South University: Science and Technology*, vol.42, no.8, pp.2338-2344, 2011.

[9] W. Zhao, M. Zhou and D. Wang, Research on fuzzy comprehensive evaluation of the power supply production risk, *Journal of Shanxi Finance and Economics University*, no.29, pp.15-16, 2007.

[10] Y. Zheng, X. Liu, Y. Liu et al., Classification of power supply quality levels for premium power park based on process immunity time and acceptable resulting status, *Power System Technology*, vol.38, no.1, pp.211-216, 2014.

[11] P. Liu, Q. Jin, J. Deng et al., Research on problems of power quality of power supply system with three-phase V/V connected traction transformer, *Engineering Journal of Wuhan University*, vol.48, no.1, pp.92-101, 2015.

[12] K. T. Atanassov, Intuitionistic fuzzy sets, *Studies in Fuzziness & Soft Computing*, vol.20, no.1, pp.87-96, 2010.

[13] J. Wang and Z. Zhang, Multi-criteria decision-making method with incomplete certain information based on intuitionistic fuzzy number, *Control and Decision*, vol.24, no.2, pp.226-230, 2009.

[14] S. Wan, Multi-attribute decision making method based on interval-valued intuitionistic trapezoidal fuzzy number, *Control and Decision*, vol.26, no.6, pp.857-860, 2011.

[15] X. Xu, Q. Wan, X. Chen et al., Study for a conflict measure for large group decision based on interval-valued intuitionistic trapezoidal fuzzy number, *Chinese Journal of Management Science*, vol.22, no.8, pp.115-122, 2014.

[16] Z. Xu, On similarity measures of interval-valued intuitionistic fuzzy sets and their application to pattern recognitions, *Journal of Southeast University: English Edition*, vol.23, no.1, pp.139-143, 2007.

[17] X. Xu and X. Chen, Research on the group clustering method based on vector space, *Systems Engineering and Electronics*, no.27, pp.1034-1037, 2005.

[18] H. Wen, Q. Chen and B. Chen, Research on performance evaluation of OHSMS based on trapezoidal fuzzy numbers, *Journal of Safety Science and Technology*, vol.8, no.6, pp.210-215, 2012.

[19] J. Ye, Fuzzy decision-making method based on the weighted correlation coefficient under intuitionistic fuzzy environment, *European Journal of Operational Research*, vol.205, no.1, pp.202-204, 2010.