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GENERAL PRINCIPLES FOR CREATING METHODS FOR PLOTTING A FUNCTION OF EQUATIONS OF WEAK SETS OF LOADING IN THE POWER SUPPLY SYSTEMS

On the base of theoretical research and expert procedures, this paper defines the general principles for plotting a function of equations of weak sets of power supply sub systems capacity. The results obtained may be used for creating synthetic parametric methods for plotting such functions.

Key words: *weak set of capacity, function of levels, direction, directed level of membership function.*

In [1 – 2] the authors suggest a new approach to simulation of complex systems in conditions of data uncertainty applying the apparatus of theory of weak sets which is developed by them. Weak set $\tilde{\tilde{A}}$ in the universe X, unlike the fuzzy set $\tilde{A}$, is set not by the membership function μ_A: X $\to$ M_α, but by the function of levels $\nu_A : X \to M_{\alpha\omega}$, where $M_{\alpha\omega} = M_\alpha \times M_\omega \setminus \{(\vee M_\alpha; -)\}$ – the space of directed membership levels, $M_\alpha = [0; 1]$ – the space of non-directed (ordinary) membership levels, $M_\omega = \{ +; -\}$ – the space of directions, $\vee M_\alpha = 1$ – maximal element of space M_α . Elements of space $M_{\alpha\omega}$ are arranged pairs of the type (α; +), (β; –), α, β $\in M_\alpha$ and are called positive (if (α; +)) and negative (if (β; –)) directed levels of membership. For convenience these pairs are also designated α^+, β^- correspondingly. In the space of non-directed membership levels there is the ordinary total linear ordering, and in the space of direction the linear ordering $\{(+, +), (+, -), (-, -)\}$ is set. The directed membership levels in space $M_{\alpha\omega}$ are strictly ordered by binary relations of the strict ordering of the kind

$$\forall(\alpha, \omega_\alpha), (\beta, \omega_\beta) \in M_{\alpha\omega}\,((\beta, \omega_\beta) > (\alpha, \omega_\alpha) \Leftrightarrow (\beta > \alpha \ \wedge\ \omega_\beta = \omega_\alpha) \vee (\omega_\beta > \omega_\alpha)), \qquad (1)$$

and diagonal relation of equality on $M_{\alpha\omega}$ looks like:

$$\forall(\alpha, \omega_\alpha), (\beta, \omega_\beta) \in M_{\alpha\omega}\,((\alpha, \omega_\alpha) = (\beta, \omega_\beta) \Leftrightarrow \alpha = \beta \ \wedge\ \omega_\alpha = \omega_\beta). \qquad (2)$$

Further on in this paper the relations (1) and (2) correspondingly will be meant to be the relations of ordering and equality on the set $M_{\alpha\omega}$ correspondingly. In particular, fulfillment of relation ≥ will mean the fulfillment of relations (1) or (2).

[3] shows the way to simulate the ambiguous parameters of power supply system (PSS) by weak sets, level functions of which do not set to the universal elements any specific grade of membership to the weak set, but only the directed levels of membership. In case of simulating the ambiguous parameters of PSS, the letter is expedient to be interpreted as follows. Positively directed membership levels – as the lower exact plane of possible values of membership grade of the universe corresponding elements, when upper plane of the membership of these elements shall not be regulated and is only restricted by the largest element $\vee M_\alpha$ of the space with directed membership levels.

The negatively directed membership levels shall be interpreted as the upper exact plane of the possible values of membership grades when the lower exact plane of the universe elements membership which have the negative membership level shall not be set and is only restricted by minimum element $\wedge M_\alpha = 0$ of the space M_α.

The only one source of information which is known today for plotting membership function, of fuzzy sets and functions of levels of weak seta – expert evaluation of parameters of these functions.

For the creation of membership functions of fuzzy sets on the base of expert evaluation, there had been developed many methods [4, 5]. Analogical methods for plotting functions of levels of weak sets are still unknown. This paper pioneers the analysis of peculiarities in plotting function s of weak sets levels on the base of expert procedures and formulates principles for creating correspondent methods on the example of weak sets levels' functions of PSS elements capacity, suggested by the authors in [3].

Backgrounding the principles for plotting membership functions of weak sets levels, we proceed from the experience of using the known methods for plotting membership functions of fuzzy sets.

Methods for plotting membership functions of fuzzy sets using expert evaluations and their parameters may be divided into direct and indirect methods, which, in turn, are into methods for one expert and methods for group of experts. Direct methods stipulate for direct designation of membership degree to universe elements or setting the analytical function which will act as the membership function. Expert information is indirect methods is the initial for further plotting membership functions using these or those rules depending on chosen method. Therefore the result of expert procedure is usually easier to obtain with the help of program expert systems for indirect methods rather than using direct methods. Today there are plenty of scientific papers, dedicated to the elaboration of direct and indirect methods for plotting membership functions of fuzzy sets. Papers [4, 5] highlight the existing methods for plotting membership functions of fuzzy sets.

By analogy with methods for plotting membership functions of fuzzy sets for weak sets, we will also distinguish between direct and indirect methods for plotting functions of the directed membership levels. **Direct** will be called methods, according with which the expert directly designated the directed membership levels to the elements of the universe, interpreting them as lower exact plane of possible membership levels of unknown weak set in case of positively directed membership levels upper exact plane of membership levels (in case of negatively directed membership levels). **Indirect** methods of plotting function of weak levels are methods in which the information received from an expert dos not directly set the membership levels and is the initial determination by this or that method, which satisfies the previously set conditions stipulating for single-valued result of plotting the function of levels. Among indirect methods we single out the so-called **parametrical** method, according to which the type of levels function shall be set axiomatically or chosen by an expert or a person, making a decision the fixed standard set of possible graphs of these functions, each of which shall be set by this or that number of parameters. Later on, in a dialogue with PC, an expert evaluates the values of parameters of function of the type,

which was selected on the previous stage of work. In the result there is a specific function of weak set levels. If the use of expert evaluations of one expert will be sufficient for method of plotting function of weak set levels, such a method will be called a **method for one expert**. If a method will require the use of export evaluation of a group experts, such a method will be called a method for group of experts. Further we consider the main principles for plotting function of levels weak sets levels of PSS elements' capacity on the base of indirect parametrical evaluations of these functions by one expert or a group of experts.

In [3] the authors introduced the notion of the usual set of active capacity of the electric net node $\{p\}$ with the known capacity P as the sets of the type $\{p \mid 0 \le p \le P\}$ and a weak set of capacity with the function of levels $\nu_P(p)$, which

$$\exists p \ge 0(\nu_P(p) = 1^+); \tag{3}$$

$$\exists p \ge 0\ (\nu_P(p) = 0^-); \tag{4}$$

$$\forall p_1, p_2 \in \text{н}_P^{-1}(]0^-;1^+[)\,(\,p_1 < p_2 \Rightarrow \nu_P(p_1) > \nu_P(p_2)\,); \tag{5}$$

$$\forall p_0 \in \text{н}_P^{-1}(]0^-;1^+[)\,\forall \varepsilon > 0 \exists \delta > 0 \forall p \ge 0(\rho_R(p, p_0) < \delta \Rightarrow \rho_M(\nu_P(p), \nu_P(p_0)) < \varepsilon)). \tag{6}$$

Condition (3) allows to formulate the **first principle** for plotting functions of levels of weak sets of PPS elements capacity, according with which for the node of electricity supply network with the indefinite loading P, an expert can create such a loading $p \ge 0$, which will completely satisfy the condition $p \le P$, that is formally set by equality $\nu_P(p) = 1^+$. Analogical condition (4) allows to formulate the **second principle**: for the node of electricity supply network with the indefinite loading an expert may name such a capacity p, which will exceed the unknown capacity of this node, which formally corresponds to the equity $\nu_P(p) = 0^{-}$.

Conditions (5), in fact, sets the strictly declining function of levels of weak sets of PSS node capacity on the interval of capacity values, which is complete prototype of the open interval]0; 1[under the reflection ν_P, that is $\text{н}_P^{-1}(]0^{-};1^{+}[)$. This condition allows to formulate the **third principle** for plotting function of levels of weak sets of capacity, according with which the degree of expert's confidence that the set value of capacity does not exceed the capacity of PSS element must decrease as the set capacity value increases. Let us assume that relating to capacity p_1 an expert has a certain level of confidence that p_1 does not exceed the real capacity P of electricity supply network.

Let the exact plane of this level of confidence equals $\nu_P(p_1)$. It is obvious that any big capacity p_2 has much more possibilities to overcome that same real capacity P of the electricity supply network node. Since the exact plane of confidence that $p_2 \le P$ is set by the membership degree $\nu_P(p_2)$, we come to the condition (5).

Condition (6) sets the **fourth principle** according to which the function of levels of weak set of capacity must be continuous the interval of capacity values $\text{н}_P^{-1}(]0^{-};1^{+}[)$. The last principle is quite natural from the point of view of the selected objects of simulations and process of expert evaluation of their values. Really, the reason for intermittent change of boundary value of expert confidence in some point $p_0 \in \text{н}_P^{-1}(]0^{-};1^{+}[)$ may only be explained by expert's failure on this stage of expert procedure on previous stages.

The **fifth principle** which is necessary to consider during expert procedures must obviously consist in the following: parameters, which must be evaluated by the expert, must not be of formal character without the possibility of their strict formulation on the base of understanding of applied task, clearly understood to the expert. Proceeding from the first two and the fifth principle, it is possible to make an important conclusion that in the indirect parametrical procedure of plotting function of levels of weak sets of loading, an expert should by assigned to evaluate the two parameters, which are clear for him, $P_{\min}$ and $P_{\max}$, where $\mathrm{P}_{\min}$ corresponds to the biggest possible value of capacity, relating to which even lower plane of experts confidence that such a capacity does not exceed the capacity of electricity supply network node, equals to 100 %, and $\mathrm{P}_{\max}$ corresponds to the lowest possible capacity value, for which even the upper level of expert's confidence that such a capacity does not exceed the capacity of network node equals zero. Evaluation of these parameters allow to consider that any capacity $p \le P_{\min}$ does not exceed the unknown capacity of the network node, and any values $p \ge P_{\max}$ exceed this capacity. Concerning the interval of possible values of PSS element's capacity $]P_{\min}; P_{\max}[$, according to principles 1 - 4 on this interval, the dependence $\nu_P(p)$ must be described by strictly decreasing continuous function, which is set by two parameters.

Paper 4 presents the standard set of functions' graphs, used by different authors in indirect parametrical procedures of plotting membership functions of fuzzy sets. From this set the authors had selected the graphs, corresponding to the above requirements to the expert procedures of plotting functions of levels of weak sets of capacity with accuracy to the change of usual Cartesian coordinate axes on the directed axes, introduced by the authors in paper [6] for presenting of functions of weak sets levels. Analogues of these graphs in the directed axes are presented in fig. 1, 2. Fig. 1 presents the strictly declining continuous the interval of possible values of capacity $]P_{\min}; P_{\max}[$ function of levels. This dependence $\nu(p)$ with the accuracy to the corresponding change in coordinate system may be approximated by normal Law of Gausse, which, as is known, is set by two parameters. Such a function of levels of weak sets we will call the normal one. Fig 1 presents the graph of usual declining linear function the interval of possible values of capacity $]P_{\min}; P_{\max}[$. Such a function of levels of weak sets we will call the linear one. This function may be set by any two points, which lie on the line of its graph. If we always use points $(P_{\min}; 1^{+})$ and $(P_{\max}; 0^{-})$,it is obvious, that the linear function of levels of weak sets of capacity will be set by two parameters

$P_{\min}$ and $P_{\max}$.

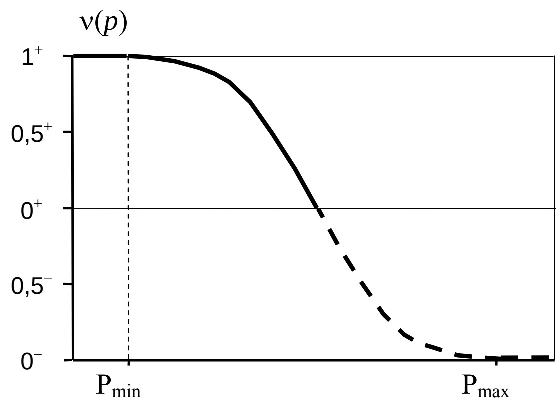

Fig. 1. General view of functions of levels of normal weak set of capacity

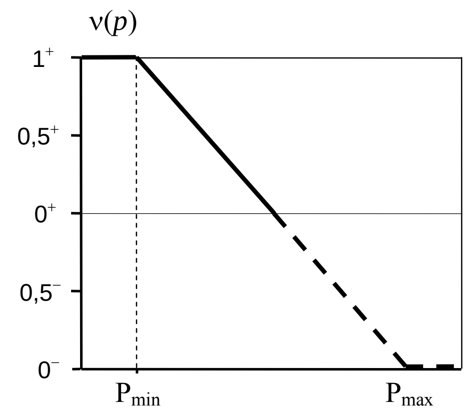

Fig. 2. General view of functions of levels of linear weak set of capacity

To check what of the selected functions will be of priority for experts, authors had planned and conducted the expert procedures on evaluation of parameters and choice functions types of levels of weak sets of capacity in the nodes of Vinnytsia high voltage electric power supply grids which are not viewed by the dispatcher. In the conducted researches the dispatchers and engineers from grope of modes of dispatcher services acted as experts of electric power supply nets modes. The most experienced specialists of the above category with working experience over 3 years who were able to realize and understand the informal content of expert procedure were selected as experts. Apart from the presented types of functions in fig 1, 2, experts were allowed the possibility to choose three more types of graphs of functions which are set by more than two parameters.

The result of the researches showed that in majority of cases the experts selected the linear and normal type of functions' levels, and the other types of these functions were seldom chosen . For different nodes of electricity supply networks, different as well as the same expert had chosen both, identical and different types of functions, for the case with linear function there had been set, as a rule, the significantly smaller length of segment [$P_{\min}$; $P_{\max}$], then for the case with normal function. Expert for the set node of network, the experts' choice of levels' functions type was influenced by time, day of the week, season, for which the expert evaluation of weak set of capacity was performed. The authors posed a problem to elicit a regularity in the experts' choice of normal or linear type of function of weak sets levels of capacity.

Such a regularity was elicited in the result of the circumstances' analysis, conducted by the authors with experts participation. The main factor which influenced the choice of type of levels' function, was the experts confidence in evaluations. If the expert realized the mode of capacity consumption in the node, to be controlled under set circumstances, the spread of possible values of capacity [P_1; P_2] was set as relatively small and linear type of levels function was chosen (fig. 2). It corresponded to the fact that during the increase in possible value of node loading, the lower and then the upper border of experts' confidence that the capacity is consumed by the node, diminished uniformly. If the expert felt uncertain, that is, was uncertain as for the mode of capacity consumption in the set mode under set circumstances, he set the significantly bigger spread of possible capacity values [$P_{\min}$; $P_{\max}$] (fig. 3), containing some reserve of uncertainty. An expert could not act otherwise since the rules of expect procedure required the unknown value of node capacity to contained in the set range of values. In this case an expert chose the normal type of function of levels (fig. 1). Now, according to the interpretation of the directed levels of weak set of capacity, close to values $P_{\min}$ and $P_{\max}$ the limiting confidence of an expert coincided in accordance with the normal function of levels slowly, which partially compensated for "superfluous" spread of possible values of node capacity. Really, fig. 3 shows that in the result of slow decrease in positively directed levels on section [$P_{\min}$; P_1] and negatively directed – on section [P_2; $P_{\max}$] the upper and lower border of experts confidence remained close to 100% and 0 % correspondingly. At the same time on the section [P_1; P_2] the decrease in limiting confidence approximated to linear law, which corresponds to properties of Gaussian function.

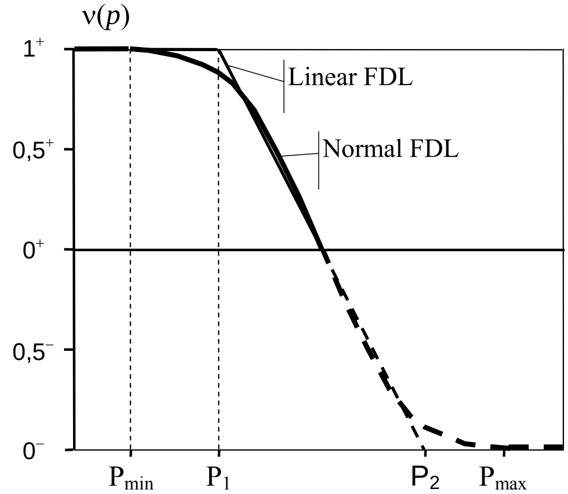

Fig. 3. Linear and normal functions of directed levels of weak sets of capacity

Thus, the received results and their analysis showed that the normal and linear types of functions of levels weak set of electricity supply network node capacity are the most natural for expert evaluation of this weak set.

Conclusions

The paper basing on the results of theoretical researches and expert procedures substantiates the general principles of plotting function of levels of weak sets of electric power supply systems nodes capacity. It had been shown that in indirect parametrical expert procedures the plotting functions of levels of weak sets it is expedient to use functions which are set by two parameters P_{min} and P_{max} there had been exposed the energy content of these parameters. It had been substantiated that the functions of levels which are chosen by the expert, must be continuous and strictly decreasing on the interval of values]P_{min}; P_{max}[. It had been shown that the normal and linear functions of levels are expedient to use as such functions. The results obtained may be used for creation of indirect parametric methods for plotting function of levels of weak sets of capacity in power elements of electric power supply systems.

REFERENCES

1. Мокін Б. І. Слабкі множини та їх застосування до розв’язання задач прийняття рішень в умовах невизначеності даних / Б. І. Мокін, В. В. Камінський // Вісник ВПІ. – 2004. – № 3. – С. 102 – 108.

2. Мокін Б. І. Слабкі множини як альтернатива нечітким множинам в моделюванні невизначених параметрів складних систем / Б. І. Мокін, В. В. Камінський // Вісник ВПІ. – 2006. – № 6. – С. 226 – 230.

3. Мокін Б. І. Математичне моделювання невизначених параметрів режиму електромереж з допомогою слабких множин / Б. І. Мокін, В. В. Камінський // Вісник ВПІ. – 2005. – № 6. – С. 89 – 96.

4. Модели принятия решений на основе лингвистической переменной / [А. Н. Борисов, А. В. Алексеев, О. А. Крумберг и др.] – Рига: Зинатне, 1982. – 256 с.

5. Нечеткие множества в моделях управления и искусственного интеллекта / [А. Н. Аверкин, И. З. Батыршин, А. Ф. Блишун, В. Б. Силов, В. Б. Тарасов] / Под. ред. Д. А. Поспелова – М.: Наука, 1986. – 312 с.

6. Мокін Б. І. Геометрична інтерпретація слабких множин та їх систем нечітких реалізацій / Б. І. Мокін, В. В. Камінський // Вісник ВПІ. – 2006. – № 4. – С. 34 – 47.

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