UDC 389.14:621.317

Evaluation of experts competence on the measurement of electrical power using the method of analytic hierarchy

Velychko O. N.

D. Sc., Professor,
The State Enterprise "Ukrmetrtectstandart"

Gordienko T. B.

D. Sc., senior researcher, Associate Professor,
Odessa State Academy of Technical Regulation and Quality

Karpenko S. R.

Ph.D.,
The State Enterprise "Ukrmetrtectstandart"

Kolomiets L. V.

D. Sc., Professor,
Odessa State Academy of Technical Regulation and Quality

Abstract
The application of the process of analytic hierarchy for evaluating the experts competence on the measurement of electrical power is considered. The results of calculation of generalized priorities for each of the experts compared and global priorities for each experts competence range are given;

as well the most competent experts using special software have been identified.

Key words: EXPERT COMPETENCE, EVALUATION, MEASURING, METHOD OF ANALYTIC HIERARCHY

Making substantiated decisions in all fields (spheres) of activity should be based on experience, knowledge and intuition of experts. This requires carrying out the expert evaluation i. e. a procedure for determining the specific problems (questions) on the basis of expert opinions for further decision making.

For this evaluation, the correct approaches to the selection of experts (qualified specialists of a particular area, who are engaged in research, consulting, development of opinions, conclusions, scientific and technical expertise proposals on specific issues) should be applied. On the basis of practical experience, many researchers have attempted to develop methods for the selection of experts. However, in practice, to select experts who have the necessary qualities is difficult [1-3].

Methods of expert selection are based on two main approaches: subjective and objective. However, current methods can not completely solve the problem of a certain selection of experts, so the method of their selection should be based on a combination of different approaches (techniques). In any case, the level of experts competence is one of the main selection criteria.

Using analytic hierarchy process (AHP) [4-6], the several variants of expert competence evaluation can be implemented: the competence of any expert in any sphere (industry); the dynamics of improving competence of experts for many years for every single specialist.

Tasks for determining the competence of the expert with AHP are carried out in three hierarchical levels (Fig. 1). The first (top) level of the hierarchy appropriates for the purpose of evaluation, i.e. to determine the experts competence; the second level contains the criteria to determine the experts competence; the third (lower) level includes experts (expert group), for which it is necessary to define or compare the competence.

In general, the list of criteria (components) must be such as to display more complete the level of experts competence. Each criterion of experts competence can be estimated by using data on education, work experience in a particular field (sphere), specific position and other available information.

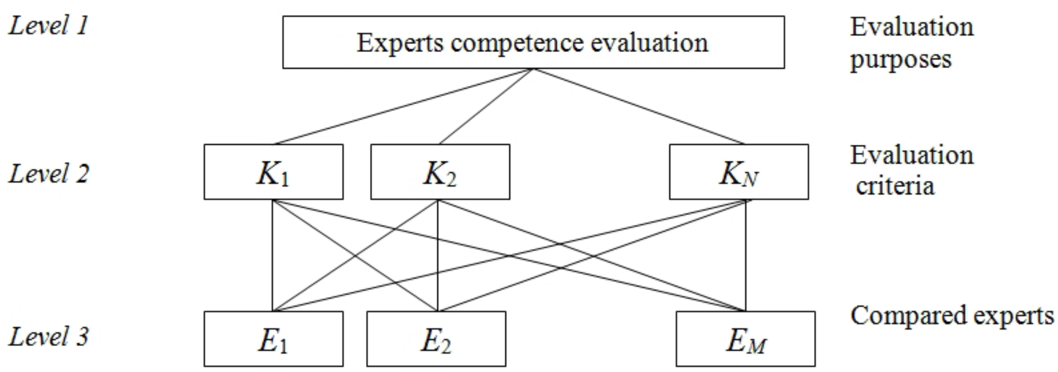

Figure 1. Structure of the simplest model of AHP implementation for evaluating the competence of the experts

In evaluating of the competence of experts, all the components that are compared and grouped as the criteria for an appropriate comparison should be taken into account. Each of the criteria is assessed by individual and pairwise comparison according to certain criteria and includes all the following steps using AHP.

Fig. 2 shows the competence of experts evaluation algorithm and Table 1 shows the formulas for calculating the numerical values of the components required to identify the most competent expert.

The numerical values a_{ij} ($i, j = 1, 2, ..., N$) of therelative importance, components are determined di rectly for each performing of the expert competence comparative analysis. In this case, the analysis of the expert available data, which describe their level for the individual components and determine the number of any dimension, is carried out.

The implementation of AHP provides specific criteria for expert evaluation and their components, which are shown in Table 2. Also the matrix values of pairwise comparisons determined for specific indexes A with normalized eigenvectors Ki (priority vector) for the selected criteria (Table 3), and the weighting coefficients for selected evaluation criteria (Table 4) are presented.

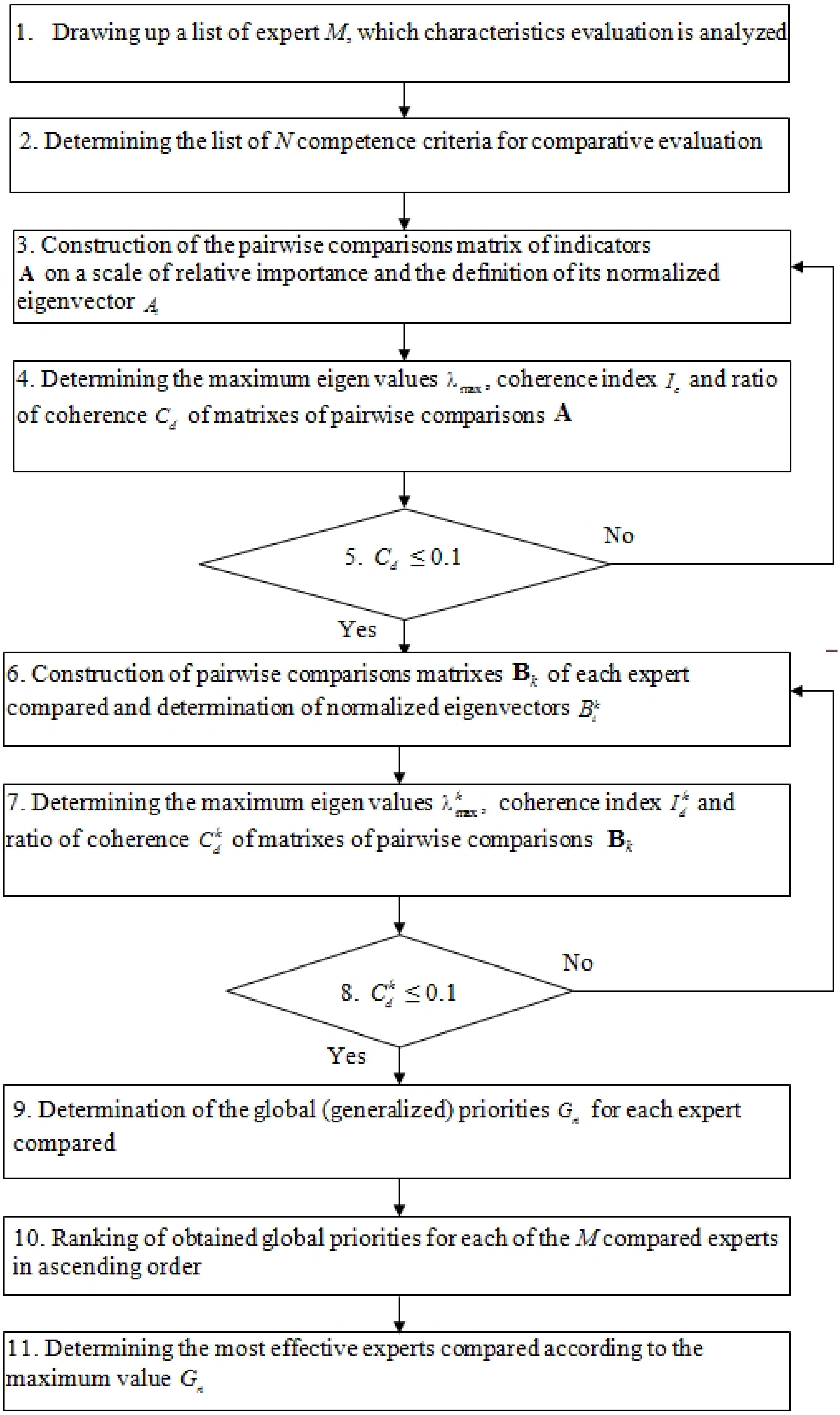

Figure 2. The algorithm for assessment of the expert competence for AHP

Table 1. Formulas for calculating the numerical values of the components

Algorithm element	Symbol	Calculation formula
The matrix of pairwise comparisons of criteria	$\mathbf{A}$	$\mathbf{A}=\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1N} \\ a_{21} & a_{22} & \dots & a_{2N} \\ \dots & \dots & \dots & \dots \\ a_{N1} & a_{N2} & \dots & a_{NN} \end{pmatrix}$ (1)
The normalized eigenvector of the matrix $\mathbf{A}$	A_i	$A_i=\sqrt[N]{\prod_{j=1}^{N} a_{ij}} \Big/ \sum_{i=1}^{N} \sqrt[N]{\prod_{j=1}^{N} a_{ij}}$ (2)
The ratio of the matrix coherence $\mathbf{A}$	C_d	$C_d=I_c/R_c$, (3) where: R_c – tabulated depending on the dimension of the matrix random coherence index
The coherence index of initial data of matrix $\mathbf{A}$	I_c	$I_c=\frac{\lambda_{\max}-N}{N-1}$ (4)
The largest eigenvalue of the matrix $\mathbf{A}$	$\lambda_{\max}$	$\lambda_{\max}=\sum_{j=1}^{N} \sum_{i=1}^{N} a_{ij}\cdot A_i$ (5)
The matrix of pairwise comparisons of experts according to established criteria	$\mathbf{B}_k$	$\mathbf{B}_k=\begin{pmatrix} b_{11}^k & b_{12}^k & \dots & b_{1M}^k \\ b_{21}^k & b_{22}^k & \dots & b_{2M}^k \\ \dots & \dots & \dots & \dots \\ b_{M1}^k & b_{M2}^k & \dots & b_{MM}^k \end{pmatrix}$ (6)
The normalized eigenvectors for matrices $\mathbf{B}_k$	B_i^k	$B_i^k=\sqrt[M]{\prod_{j=1}^{M} b_{ij}^k} \Big/ \sum_{i=1}^{M} \sqrt[M]{\prod_{j=1}^{M} b_{ij}^k}$ (7)
The ratio of matrices coherence $\mathbf{B}_k$	C_d^k	$C_d^k=I_c^k/R_c$ (8)
The coherence index of matrices $\mathbf{B}_k$	I_c^k	$I_c^k=\frac{\lambda_{\max}^k-M}{M-1}$ (9)
The largest eigenvalues for matrices $\mathbf{B}_k$	$\lambda_{\max}^k$	$\lambda_{\max}^k=\sum_{j=1}^{M} \sum_{i=1}^{M} b_{ij}^k\cdot B_i^k$ (10)
Global (generalized) priorities for each of M comparable experts	G_n	$G_n=\sum_{i=1}^{N} B_i^0\cdot B_n^i$, (11) where: B_i^0, ..., B_n^i – components of the normalized eigenvectors of the local priorities are determined by the ratio(6)

For the proposed criteria of competence expert evaluation, the most eigenvalues of the matrix of pairwise comparison of criteria **A** determined by ratios (1) and (5) are $\lambda_{max} = 5.35$.

Table 2. Specific criteria for the evaluation of the expert competence and their components

Evaluation criterion	Criterion component
K_{1i} – education and scientific level in the field of metrology	K_{11} – undergraduate higher education (Bachelor) K_{12} – higher education (Specialist / Master); K_{13} – postgraduate (specialization); K_{14} – postgraduate study; K_{15} – doctoral studies
K_{2i} – total work experience	K_{21} – less than 5 years; K_{22} – from 5 to 10 years; K_{23} – from 10 to 15 years; K_{24} – from 15 to 20 years; K_{25} – from 20 to 25 years; K_{26} – from 25 to 30 years; K_{27} – from 30 to 40 years; K_{28} – more than 40 years
K_{3i} – work experience in the field of metrology	K_{31} – less than 1 year; K_{32} – from 1 to 3 years; K_{33} – from 3 to 5 years; K_{34} – from 5 to 8 years; K_{35} – from 8 to 10 years; K_{36} – from 10 to 15 years; K_{37} – from 15 to 20 years; K_{38} – more than 20 years
K_{4i} – work experience as an expert in the field of metrology	K_{41} – less than 1year; K_{42} – from 1 to 2 years; K_{43} – from 2 to 4 years; K_{44} – from 4 to 6 years; K_{45} – from 6 to 8 years; K_{46} – from 8 to 10 years; K_{47} – more than 10 years
K_{5i} – work at position	K_{51} – engineer; K_{52} – leading engineer; K_{53} – research associate; K_{54} – head (deputy head) of the sector as part of the department; K_{55} – head (deputy head) of department of the institute; K_{56} –head (deputy head) of the institute as part of the enterprise or organization; K_{57} – head (deputy head) of the enterprise, organization

Table 3. Values of the matrix of pairwise comparisons for the selected criteria

	K_1	K_2	K_3	K_4	K_5	A_i
K_1	1	0.333	0.2	0.143	2	0.068
K_2	2	1	0.333	0.333	0,5	0.106
K_3	5	3	1	0.333	3	0.260
K_4	7	3	3	1	5	0.478
K_5	0.5	2	0.333	0.2	1	0.088

Table 4. The weighting coefficients for the selected criteria for evaluation

i	W_{1i}	W_{2i}	W_{3i}	W_{4i}	W_{5i}
1	2	1	2	3	1
2	5	3	3	4	3
3	6	4	4	5	5
4	7	5	5	6	6
5	9	6	6	7	7
6	–	7	7	8	8
7	–	8	8	9	9

Checking the coherence of the input data used to construct the matrix **A** obtained by the coherence index I_c = 0.088 and ratio (3), and coherence ratio C_d = 0.079 defined by the expression (4) have shown that the coherence ratio meets the requirements of inequality ($C_d \leq 0.1$). The coherence of criteria established for the evaluation of experts is shown.

In order to assess the competence of the experts, it should be determined the specific input data for the calculation of the matrix elements $\mathbf{B}_k$ using the statement (6) for the pairwise comparison of experts' competence for each of these criteria. In addition to determining the normalized eigenvectors for each pairwise comparison matrix $\mathbf{B}_k$ using the statements (7) and checking the consistency of local priorities included in the matrix of pairwise comparisons $\mathbf{B}_k$ using the statements (8)–(10) for C_d^k, I_c^k and $\lambda_{\max}^k$.

A figure determined in accordance with the scale of the Saaty relative importance[4] should be existed in matrices elements $\mathbf{B}_k$ for pairwise comparisons of experts for each *k*-th criterion. For the transition from the current quantitative criteria values evaluation for these numbers, we use a special procedure, which basic steps are shown below.

For each (*k*-th) criterion the possible range of variation was evaluated and the maximum value of this range was attributed to the number 9 from the Saaty scale, and number 1 to the minimum. For these criteria, the real current values of each expert compared were obtained.

Quantitative characteristics of experts obtained for the *k*-th criterion are ranked in the ascending order. The result is a sequence of real numbers, which is used in subsequent calculations. The obtained numbers sequences in full scale are associated with numbers in sequence of Saaty scale.

Calculating the ratio of the generalized *k*-th criterion value in Saaty scale for the first expert to other specialists is carried out using specialized mathematical software. This relation is used as the first line matrix elements of pairwise comparisons $\mathbf{B}_k$ for *k*-th analyzed criterion.

The same action is performed for the second, third, ..., the *M*-th expert and the elements of the second, third, ..., *M*-th line of the matrix of pairwise comparisons $\mathbf{B}_k$ are obtained. All these operations are performed for each of the *k* criteria and all the necessary data for analysis of pairwise comparison matrix $\mathbf{B}_k$ are obtained.

When estimating the total priorities G_p are determined by using the statement (11) for each of the *M* compared experts. Global priorities for each expert ($n = 1, 2, ..., M$) rank and identify the most competent specialist – an expert who has received the maximum value G_p or the most competent group of experts with the highest values G_p for a particular expert evaluation. As one of the options to determine the group of experts the Pareto method can be applied. It is based on the results of analysis of global priorities G_p of the experts.

AHP is used as a useful tool for comparative evaluation of experts' competence on the basis of data on the above criteria for various industries (sectors), associated or related sectors (industries), as well as to determine the dynamics of the competence increasing for years for each expert individually.

For a comparative analysis of metrological support of the organizations engaged in measuring of electrical power, the group expert evaluation (questionnaire) according to the specially designed criteria was conducted. In this reviewing 26 experts working in the field of metrology participated. Quantitative characteristics of the competence of these specialists were evaluated using special software "Competence AHP 1.0" ("Kompetentnost MAI 1.0").

The results of the experts' competence evaluation with using the software are shown in Table 5 (the least competent experts are indicated by shading). Software window with the evaluation of the final results is shown in Fig. 3.

Table 5. Results of experts competence evaluation

Expert	01	02	03	04	05	06	07	08	09	10
Global priority	0.013	0.015	0.047	0.013	0.009	0.048	0.053	0.024	0.046	0.055
Place	24–25	22–23	13	24–25	26	11–12	5–6	18–20	14	2
Expert	11	12	13	14	15	16	17	18	19	20
Global priority	0.052	0.054	0.053	0.042	0.038	0.024	0.052	0.051	0.048	0.015
Place	7–8	3–4	5–6	15	17	18–20	7–8	9	11–12	22–23
Expert	21	22	23	24	25	26	Total			

Global priority	0.054	0.040	0.024	0.059	0.020	0.049	Unsatisfactory (amount /%)
Place	3–4	16	18–20	1	21	10	10/38

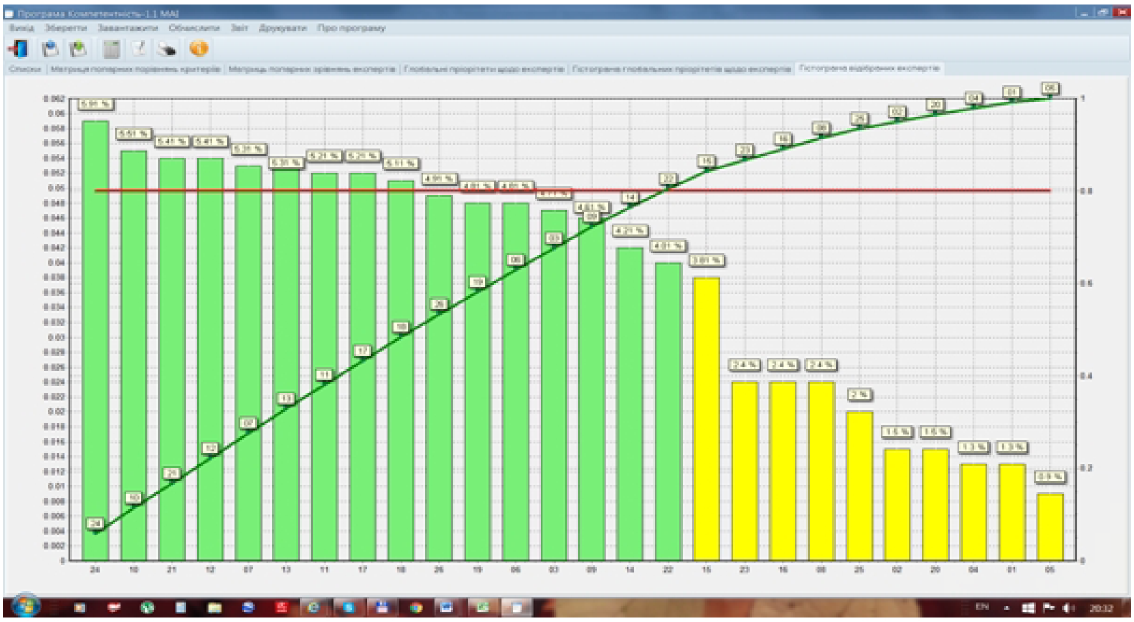

Figure 3. Software Window “Competence AHP 1.0” with the final results of the evaluation

For the obtaining evaluation results from the total number of experts 28% of experts have been rejected (ten specialists: 05, 01, 04, 20, 02, 25, 08, 16, 23 and 15).

References

1. Velychko O. M., Gordiyenko T. B., Kolomiets L. V. (2015) Methodologies of expert’s competence evaluation and group expert evaluation. *Metallurgical and Mining Industry*. No 2. p.p. 262–271.
2. Litvak B. G. (1996) Expert estimations and making decision. Moscow: Patent, 271 p.
3. Orlov A. I. (2002) Expert estimations. Moscow. 31 p.
4. Saaty T. L. (1992) The Hierarchon: A Dictionary of Hierarchies. Pittsburgh, Pennsylvania: *RWS Publications*.
5. Drake P. R. (1998) Using the Analytic Hierarchy Process in Engineering Education. *International Journal of Engineering Education*, No 14 (3). p.p. 191–196.
6. Navneet Bhushan (2004) Strategic Decision Making: Applying the Analytic Hierarchy Process. London: *Springer-Verlag*.