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STUDY OF METHODS FOR ASSESSING THE LEVEL OF ENERGY SECURITY AND THE WAYS TO IMPROVE

The most common methods of energy security assessment have been studied, and possible deviations of results in the condition of their application have been estimated. The ways of their improvement as a result of the implementation of these methods in the conditions of the Republic of Armenia have been identified.

Keywords: *Energy security, electricity, method, managerial influence, weight of importance.*

Introduction

As is well known, the choice of method for assessing the level of energy security (ES) has a significant impact on the accuracy of the result obtained. Examining the work related to the assessment of the level of ES by a number of international and domestic experts and specialists, one can confirm that opinion, that depending on the infrastructural features of the state, the method of security assessment can be differentiated from the results obtained at the ES level. That is why we will consider the most common methods of assessing the level of ES.

The concept of ES level zones has become widespread in the scientific community, which allows to characterize the ES level as ES - situations in normal (N), pre-crisis (PC) or crisis (C) zones [1].

Materials and methods

The ES level assessment process is based on the following basic provisions [2]:

1. If one of the ES level assessment indicators is considered to be in a crisis situation, then regardless of the status of the other indicators in the system, the ES level of the country is evaluated as critical.
2. If two ES level assessment indicators are considered to be in a pre-crisis situation, then regardless of the status of other indicators in the system, the ES level of the country is assessed as critical.
3. If one of the ES level assessment indicators is considered pre-crisis, and other indicators are assessed as being within the normal zone, then regardless of the status of other indicators, ES level of the country is assessed as pre-crisis.
4. Each indicator used for ES level assessment has a minimum value threshold for descriptive situations,
5. The more the number of indicators below the value threshold defining the crisis situation, the deeper the crisis of the country's energy system.

Research methods

The most common methods of ES level assessment are [3]:

1. Scalar method,
2. Intersecting planes method,
3. Discriminant analysis method,
4. The method of fuzzy sets.

The scalar method is based on the principle of the point assessment, the purpose of which is to assess the country's ES level and to determine the situation zone as a result of point assessments and system of ES indicators.

The application of the scalar method makes it possible to consider the multidimensional function of ES level assessment indicators as one-dimensional [4]. To classify situations describing the ES level and to include them in situational zones, a point assessment system must be applied. When carrying out indicator analysis, it is important for the scalar indicators to have the same direction of influence on the ES level. When choosing a direction, we can consider the conditional direction of the influence, and carry out scaling of the indicators examining the direction of the unit change of the indicator on the ES level.

The schematic structure of the scalar method application for the assessment of ES level is presented in Fig.1.

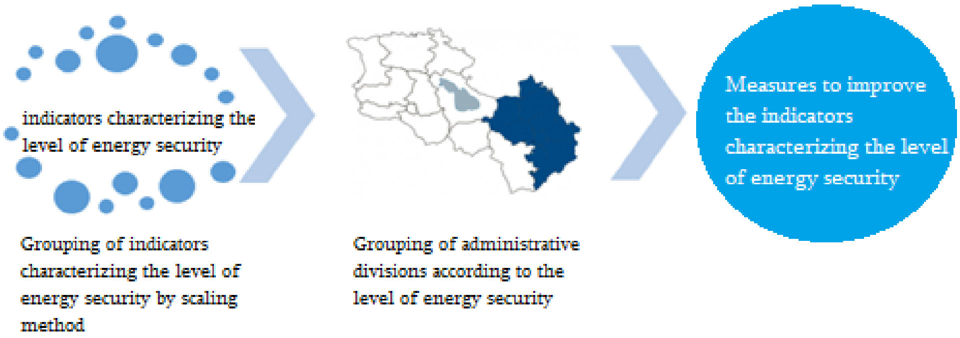

Fig. 1. *Schematic Diagram of the Scalar Method Application*

Using the scalar method, we can formulate a set of characteristic indicators of ES level and based on their calculation, assess the state ES level in different calculation periods.

With the aforementioned method, the following sets were formed: Electricity supply security for consumers (X1), Resource (fuel-energy) provision for the power supply system (X2), Reliability of fuel and power supply (X3), Depreciation of main production funds of the power system, provision of depreciation funds (X4), Environmental security of energy system (X5), Security of power supply and energy-efficient systems (X6), Education level for energy professionals (X7) [6].

The weight of the influence of the indicators characterizing the ES level, being in the range of $1 \leq r_{ir} \leq$ m, where *m* and r_{ir}- are the number and order of the indicators, respectively, is important in the application of the scalar method [7].

The weight of the influence of the indicators characterizing the ES level is determined as follows:

$$C_{ir}=1-(m)^{-1}(r_{ir}-1), \quad (1)$$

and the weight of the i indicator will be determined as follows:

$$B_{ir}= C_{ir}/(\sum_{i=1}^{m} C_{ir}), \quad (2)$$

$$B_i= (R)^{-1}\sum_{r=1}^{R}(C_{ir}/\sum_{i=1}^{m} C_{ir}): \quad (3)$$

Consider the above-mentioned indicators characterizing the country's ES level, and the application of the scalar method (Table) for 7 sets based on them.

Table. Determination of the order of importance of the indicators, characterizing the ES level for the country by scalar method

The set characterizing the ES level	|Order		C_{i1}	C_{i2}	B_{i1}	B_{i2}	B_i
	1	2					
K_1	4	3	0.57	0.71	0.142	0.178	0.16
K_2	5	7	0.43	0.14	0.108	0.035	0.072
K_3	3	2	0.71	0.86	0.178	0.215	0.197
K_4	6	4	0.29	0.57	0.072	0.142	0.107
K_5	1	1	1	1	0.25	0.25	0.25
K_6	2	5	0.86	0.43	0.215	0.108	0.161
K_7	7	6	0.14	0.29	0.035	0.072	0.051
$\sum$	-	-	4	4	1	1	1

The accuracy of the capacity calculation can be checked as follows:

$$\sum_{i=1}^{n} B_{ir} = 1,\ r=\overline{1,7},\ \sum_{i=1}^{n} B_i = 1\ . \tag{4}$$

Having obtained the order of importance of the sets of indicators characterizing the ES level, the following system of equations can be formulated [8].

$$\begin{cases} \frac{dK_1}{dt} = a_{11} + a_{12}K_2(t) + a_{13}K_3(t) + a_{14}K_4(t) + a_{15}K_5(t) + a_{16}K_6(t) + a_{17}K_7(t) \\ \frac{dK_2}{dt} = a_{21}K_1(t) + a_{22} + a_{23}K_3(t) + a_{24}K_4(t) + a_{25}K_5(t) + a_{26}K_6(t) + a_{27}K_7(t) \\ \frac{dK_3}{dt} = a_{31}K_1(t) + a_{32}K_2(t) + a_{33} + a_{34}K_4(t) + a_{35}K_5(t) + a_{36}K_6(t) + a_{37}K_7(t) \\ \frac{dK_4}{dt} = a_{41}K_1(t) + a_{42}K_2(t) + a_{43}K_3(t) + a_{44} + a_{45}K_5(t) + a_{46}K_6(t) + a_{47}K_7(t) \\ \frac{dK_5}{dt} = a_{51}K_1(t) + a_{52}K_2(t) + a_{53}K_3(t) + a_{54}K_4(t) + a_{55} + a_{56}K_6(t) + a_{57}K_7(t) \\ \frac{dK_6}{dt} = a_{61}K_1(t) + a_{62}K_2(t) + a_{63}K_3(t) + a_{64}K_4(t) + a_{65}K_5(t) + a_{66} + a_{67}K_7(t) \\ \frac{dK_7}{dt} = a_{71}K_1(t) + a_{72}K_2(t) + a_{73}K_3(t) + a_{74}K_4(t) + a_{75}K_5(t) + a_{76}K_6(t) + a_{77} \end{cases} : \tag{5}$$

The system of 5 equations makes it possible to assess the ES level taking as a basis the value of the indicators characterizing the ES level and the weight of their importance.

$$ESI = \sqrt[7]{\prod_{i=1}^{7} \frac{dK_i}{dt}} : \tag{6}$$

The intersecting planes method is based on indicator analysis and allows to present the obtained results through a two-dimensional plane.

As we have already mentioned, based on the calculations, the ES level is characterized by its situational zones, according to which we will have 3 zones of ES on two-dimensional planes for situations N, PC and C, respectively.

In plane building process, we are guided by the baselines underlying the ES level assessment.

Consider the two-dimensional image of ES level assessment with the method of intersecting planes $R^2 = \{X_1, X_2\}$, the graphical view of the country's ES level is presented in Fig. 2 [9].

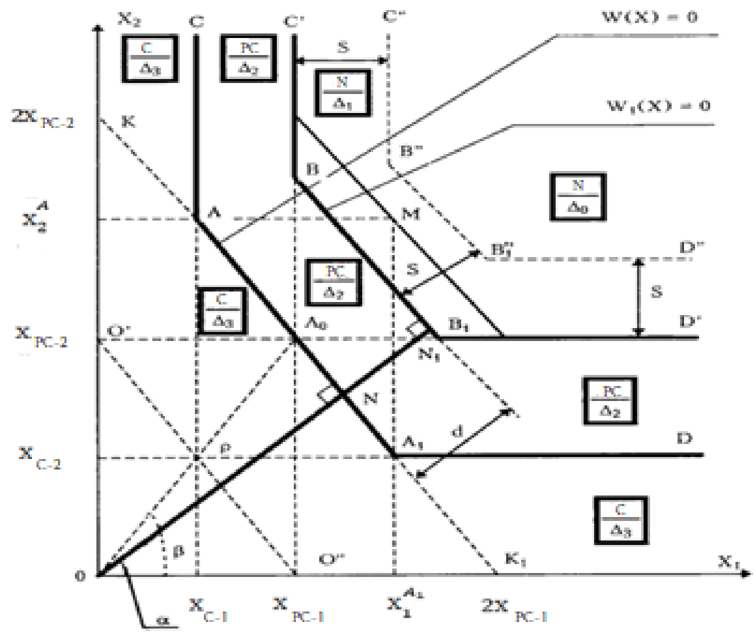

Fig. 2. *Graphic Image of the Method of Intersecting Planes for ES Level Assessment*

where Δ_0, Δ_1, Δ_2 *and* Δ_3 are respectively the levels of N in ES, but there are significant risks of situational change in normal (N), pre-crisis (PC) and crisis (C) situations.

If we separate the N, PC and C zones of the ES level from each other by planes, then the situational zone for the indicator will be described at a distance from the S point, and up to the next dividing plane will describe the current state of the indicator.

Guided by the principle of ensuring a stable level of country's ES, the fluctuation in the level of indicators should be restricted to surface limited with lines $C'BB_1D'$ and $C''B''B_1''D''$ [10].

In case of crisis situation, the following restrictions are applied:

$$X_i \leq X_{PC,i},\ i=1,\ldots,m,\ W(X_1, X_2, \ldots X_m) \leq 0. \tag{7}$$

In case of pre-crisis situation the following restrictions are applied:

$$X_{C,i} \leq X_i \leq X_{PC,i},\ i=1,\ldots,m,\ W(X_1, X_2, \ldots X_m) > 0,\ W_1(X_1, X_2, \ldots X_m) \leq 0. \tag{8}$$

In case of normal situation, the following restrictions are applied:

$$X_i > X_{PC,i},\ i=1,\ldots,m,\ W_1(X_1, X_2, \ldots X_m) > 0. \tag{9}$$

To assess the country's ES level, a system of intersecting planes for indicators characterizing the situation must be created and mathematical addition or division for each of the two indicators must be performed.

$$X_1 X_{PC,2} + X_2 X_{PC,1} = X_{PC,1} X_{PC,2}\ . \tag{10}$$

Since the line $KAA_0A_1K_1$ is parallel to the line O'O '' and passes through the point $A_0(X_{PC,1}, X_{PC,2})$, thus O''K=$X_{pc,1}$, and O'K=$X_{pc,2}$. To determine the coordinates of the points A and A_1, it is necessary to consider the fact that point A_1 lies on the line KAA0A1K1, so the following expressions are correct:

$$(2X_{PC,1})^{-1}\ X_1^{A_1} + (2X_{PC,2})^{-1} X_{C,2} = 1. \tag{11}$$

The coordinates of point A can be determined in the same way.

Now considering the following 3 points on the same line $A(X_{c,1}, X_2^A)$, $A_0(X_{pc,1}, X_{pc,2})$, $A_1(X_1^{A_1}, X_{c,2})$, the following connection can be made for them:

$$\begin{bmatrix} X_{C,1} & X_2^A \\ X_{PC,1} & X_{PC,2} \\ X_1^{A_1} & X_{C,2} \end{bmatrix} = 1. \tag{12}$$

As it is known in multidimensional space the planes W(X) = 0 and W_1(X) = 0 are parallel if (A'/A'') = (B'/B'') = … = (C'/C''). If the parameters of the plane W_1(X) = 0 are the same as the plane W(X), they will differ from each other only by a free term of an equation, which characterizes the distance of the plane from the coordinate axis, and the distance between the two planes can be determined as follows [11]:

$$d = |H'' - H'| / ((A')^2 + (B')^2 + \ldots (C')^2)^{1/2}. \tag{13}$$

In order to fully analyze the indicators characterizing the ES level, it is also necessary to introduce crisis values ($X_{c,i}$, i = 1 … m) and pre-crisis limit values ($X_{PC,i}$, i = 1 … m) in the presented methodology.

The discriminant analysis method is based on the theory of image recognition, in the ES level study, if the calculation value of describing indicators is known but their limit values are unknown, then the country's ES level can be classified based on the statistics.

If the function of the classified indicators is denoted E(X) and if E $(X_1, X_2 \ldots X_m)$ = 0 then there is a plane dividing crisis and pre-crisis situations, and if $E_1(X_1, X_2 \ldots X_m)$ = 0 then there is a plane dividing pre-crisis and normal situations and the following can be given:

$$K \in \begin{cases} A_C, if\ E(X) \geq 0, X_i \geq X_{C,i} \\ A_{PC}, if\ E_1(X) \geq 0,\ E(X) \geq 0,\ X_{C,i} > X_i \geq X_{PC,i}\ . \\ A_N, if\ E_1(X) < 0,\ X_i < X_{PC,i} \end{cases} \tag{14}$$

In order to determine the ES level, it is necessary to use a probabilistic method, which corresponds to the situation when the dividing planes coincide.

If for the situation A(X_h) the X_h forms h = C, PC, N are known, then the recognition of the unknown a(X_0) situation with the parameters X_0 is performed as follows:

$$X_0 \in X_h \Rightarrow a(X_0) \in A(X_h), \; h = C, PC, N. \quad (15)$$

Two types of errors are possible during the study - (P_1(K)) is the absence of response and (P_2(K)) is false response.

To reduce these errors, formulate the reduction function F(K) under the given q_h (h=1,2) conditions, which will be called the Bayesian method, which is the following:

$$F(K) = c_1 q_1 P_1(K) + c_2 q_2 P_2(K), \quad (16)$$

where q_h (h=1,2) is the probability of two situations occurring together, c_1 and c_2 is the value "paid" as a result of the error.

The rule K of determining the function F(K) has the following form:

$$K_1 \begin{cases} X \in R^m, \frac{P_1(X)}{P_2(X)} \geq \frac{c_2 q_2}{c_1 q_1} \\ X \in R^m, \frac{P_1(X)}{P_2(X)} < \frac{c_2 q_2}{c_1 q_1} \end{cases}, \quad (17)$$

The G_j functionals will be determined as follows:

$$G_j = \lg(c_j q_j) - 1/2(X - M_j)^T S_j^{-1}(X - M_j) - 1/2\lg|S_j| \;. \quad (18)$$

Under normal distribution conditions, situation X can be considered as a part of the set of situations A(X_1) if:

$$(\lg(c_1 q_1) - 1/2(X - M_1)^T S_1^{-1}(X - M_1) - 1/2\lg|S_1| - \lg(c_2 q_2) - 1/2(X - M_2)^T S_2^{-1}(X - M_2) - 1/2\lg|S_2| \geq 0 \quad (19)$$

where M_h and S_h are the mathematical expectation of the parameters of order *h* and the covariance matrix, respectively.

M and S assessments are determined as follows:

$$M = \frac{1}{N}\sum_{j=1}^{N} X_j, \quad (20)$$

$$S = \frac{1}{N-1}\sum_{j=1}^{N}(X_j - M_{ji})(X_j - M_j)^T. \quad (21)$$

Taking into account the equation (9) we can write the linear discriminant function of G_j that has the following form:

$$E(X) = X^T S^{-1}(M_1 - M_2) - 1/2(M_1 + M_2)^T S^{-1}(M_1 - M_2) - lg(c_2 q_2 / c_1 q_1) = 0, \quad (22)$$

where E(X) is the linear discriminant function, and B=$S^{-1}(M_1 - M_2)$ is the discriminant vector, which is the normal of the H hyper plane.

The linear discriminant function is determined as follows:

$$E(X) = B^T X - G = 0\,. \quad (23)$$

If the actual distribution does not have a normal form, a linear discriminant function can be defined as the Fisher function minimizing the distance between two wholes.

$$F = \frac{(M_1 - M_2)}{\sigma^2}\;, \quad (24)$$

where $M_i = B^T M_j$ is the projection of the j whole on the vector B, $\sigma^2 = B^T SB$ is the dispersion of the projected wholes.

As a result, differentiating the function F according to B, we will get the same vector.

Using the discriminant method to characterize the ES situation, it can be presented as an equation of the plane passing through the intersections describing the situation and the hyperplane of the existing situation perpendicular to it.

$$(M_1 - M_2)^T X - 1/2(|M_2|^2 - |M_1|^2) = 0. \quad (25)$$

Since the indicators characterizing ES can have different measurement units that are in some cases incompatible, we will present the indicators in a standardized form [12].

$$X_i^0 = \frac{X_i - M(X_i)}{\sigma(X_i)}, \quad (26)$$

where M (X_i) and σ(X_i) are the mathematical expectation of the indicators and average squared deviations, respectively.

Thus, it can be said that the characteristic of the ES situation are the importance coefficients of the indicators that form this situation, as a result of which the ES level and its characteristic situation will be determined as follows:

$$M_{ESI} = N^{-1} \sum_{i=1}^{N} X_i , \forall X_i \in A_h. \quad (27)$$

The method of fuzzy sets is based on the principle of continuity of situations characterizing the ES level, and an exponential function is used to solve the problem.

$$f(x) = \exp[b(x-c)^2], \quad (28)$$

where b and c are the parameters that determine the image of the function.

The recognition of the given situation is carried out by the continuation of the situations characterizing the levels of indicators characterizing ES based on the following equation:

$$\gamma_s = max_k\{min_i\{Sup_{x \in X,}(min\{\ \mu_i(x), V_{sik}(x)\})\}\}, \quad (29)$$

where γ_s is the continuity of the observed situation *s*, X is the range of values of the indicators i, $\mu_i(x)$ is the function of the continuity of observed situation *i*, V_{sik} is a function of the continuity of *k* assumption presented by the professional group in relation to the observed situation s of *i* indicator.

Results and discussions

Examining the most common methods of ES level assessment, it can be noticed that they are mostly based on a system of indicator determination, which aims to develop a reliable schedule-program for the provision of the country's energy resources and for increasing their management efficiency and consumption continuity.

The principle of individual analysis of indicators is mostly applied in methodologies for estimating the observed ES level, at the same time the conclusion about the country's ES level is made on the basis of absolute or relative differences of the values obtained in the calculation and base periods.

Conclusion

Four methodologies for assessing the level of ES were considered, which are based on the principle of indicator analysis. For the purpose of assessing the level of ES, as a result of the research, in order to assess the level of energy security of the Republic of Armenia with the mentioned models, it was proposed to improve the methodologies of assessing the level of ES in the following directions:

1. In the case of the scaling method, the methodology used to assess the level of ES is based on the weight of the capacity, it was suggested to use in addition to the principles of scaling the relationship between the indicators characterizing the level of ES, which is presented in the form of a system of equations, the sum of the free members of which is limited with the $\sum_{i=1}^{n} K_i = 1$ expression. The values of the free members are formed based on the results of the carried out capacity calculations.
2. In the case of applying the method of intersecting planes, the methodology used to assess the level of ES is carried out based on the situational analysis of the indicators characterizing the level of ES. At the same

time, there is significant complexity in the application of the method, which becomes more obvious when the problem under consideration is not meet the requirements of the two-dimensional plane, it is recommended to use this method after determining the weight of the indicators characterizing the level of ES, using higher efficiency as a primary indicator which are more significantly correlated with other indicators, at the same time creating the opportunity to solve the given problem more quickly.

3. Discriminatory analysis and methods of indeterminate multitude are based on an artificial intelligence software system endowed with the feature of individual decision making, h owever, the main disadvantage of these methods is that the decision is made on the basis of the continuity of the ES level situation or the process of their recognition based on statistical data. It is proposed to assess the level of EA as a result of the joint application of the methods based on statistical data and their continuity, as a result of which it will be possible to clearly distinguish the situation zone of the ES level and to make an operative decision.

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