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ANALYSIS OF RISKS WHILE CONNECTING TO THE POWER SUPPLY SYSTEM OF THE ADMINISTRATIVE BUILDING OF THE KINETIC ENERGY STORAGE UNIT FOR THE PURPOSE OF LOAD REGULATION

Sergey Shevchenko[1]; Natalia Savchenko[2]

[1]National Technical University „Kharkiv Polytechnic Institute“, Kharkiv, Ukraine
[2]Donbas National Academy of Civil Engineering and Architecture, Kramatorsk, Ukraine

Summary. *On the basis of the analysis of the risks arising from the power supply of the building's power supply system from the kinetic electronics to the time of maximum load, according to the network analysis method developed by T. Saati, a strategy for compensating groups and individual risks in directions: transfer and reduction was developed.*

Key words: *risk, kinetic energy storage unit, power supply system, risk analysis methods, risk compensation.*

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Statement of the problem. Under conditions of the fuel-and-energy crisis in Ukraine great attention is paid to the problems of gained energy stored by means of various in design energy storage units. Stored energy can be used during the hours of maximum loading for its regulation in the power supply systems of different objects. The most attractive from the economic point of view is the use of kinetic energy storage unit (KESU) in power supply systems of administrative buildings but it is connected with the range of risks hence their analysis for further compensation is required currently.

Analysis of the available investigations results. In electric power industry the methods of risks assessment are not practiced yet, thus difficulties in the sphere of risk minimization and cost estimation for their control occur. Risks and uncertainties are found in all projects concerned with power engineering, special difficulties are in the projects of reconstructive and unconventional energy, they are listed in [1]. General classification of risks which occur in power supply systems is given in [4, 6, 7, 8]. Methods of risks reduction in power engineering are developed in papers [2, 3, 4, 9]. However risks and methods of their reduction during the object power supply systems operation taking into account connection of kinetic energy storage units and their supply for loading regulation are not developed in the above mentioned papers.

The objective of the paper. To determine theoretical-methodical aspects of risks analysis during kinetic energy storage unit connection to the power supply system of administrative in order to regulate loadings and to investigate the range of risks groups and subgroups, their influence on building power supply system operation with kinetic energy storage unit. To develop compensatory measures of identified risks.

Statement of the task. In electric power industry the methods of determination of complete risks range are not practiced yet that is why it is impossible to make their accurate quantitative assessment in advance. Thus difficulties in the sphere of risk minimization and cost estimation for their control occur. For this reason the main problem of this work is to determine and investigate the general risks during the power supply systems operation with kinetic energy storage unit of public buildings. In order to solve the stated task the method of hierarchical analysis (MHA) developed by T. Saati [2], [3] is used.

The method of hierarchical analysis (MHA) is used for ratio scales derivation from discrete as well as from continuous paired comparison in multilevel hierarchical structures. MHA has specific aspects concerned with different from concurrence deviations and this deviation measuring and also with dependences within groups (levels) and between the groups of hierarchical structure elements [2].

The advantage of MHA is that the system hierarchical presentation can be applied for description of the effect of priority changes on the upper levels on the priority elements on the lower levels, hierarchies give more detailed information about the system structure and functions on the lower levels, hierarchies are firm and flexible; they are firm in the sense that small changes have little effect and flexible because additions to well-structured hierarchy do not destroy its characteristics. Natural systems made hierarchically i.e. in the form of modular structure and then of module aggregate are built more effectively than the systems made-up in whole [3].

Using MHA for modeling it is necessary to built hierarchical or lace structure for problem presentation and then comparing this structure elements in pairs, to get domination matrices from which ratio scales are derived [2].

In general hierarchical structure consists of three levels: the first level is the aim from the point of view of control, the second level – criteria that the next levels depend on, and the third or the lowest level – the list of alternatives.

Modern sources of information offer a lot of risks classification versions but power engineering field is specific. Most authors offer to distinguish two large risks groups: internal and external and then divide them into subgroups: strategy, operational, technological and technical, political, regulatory and market risks [1, 4, 5, 7, 8].

The first stage of MHA is the development of hierarchical structure combining all risks groups and influencing the risks compensation alternatives. To develop such hierarchical structure the risks groups which occur during the building power system supply from kinetic energy storage unit should be determined and analyzed. These risks groups are summarized in Table 1.

Table 1

Classification of risks

Group of risks	Risk detailing [1], [4], [5], [6], [7], [8]
1. Operational	1.1 Risks related to service personnel errors
	1.2 The emergence of deviations in information systems and internal control systems
	1.3 The presence of insufficient number of control systems
2. Technological and technical	2.1 Installation failure
	2.2 Increasing network imbalances
	2.3 The wrong choice of process equipment
	2.4 Irregular prevention and repair of equipment
3. Regulatory	3.1 Changes in energy policy
	3.2 Tariff change
	3.3 Regulation in the field of security
4. Financial	4.1 Increase of operational costs
	4.2 Violation of the terms of the investment agreement

The developed model of hierarchical structure representing connections between all levels and their influence on the given alternatives is shown in Figure 1. The model has two hierarchical levels of the importance of criteria in relation to the main aim and three alternatives concerned with the second level criteria.

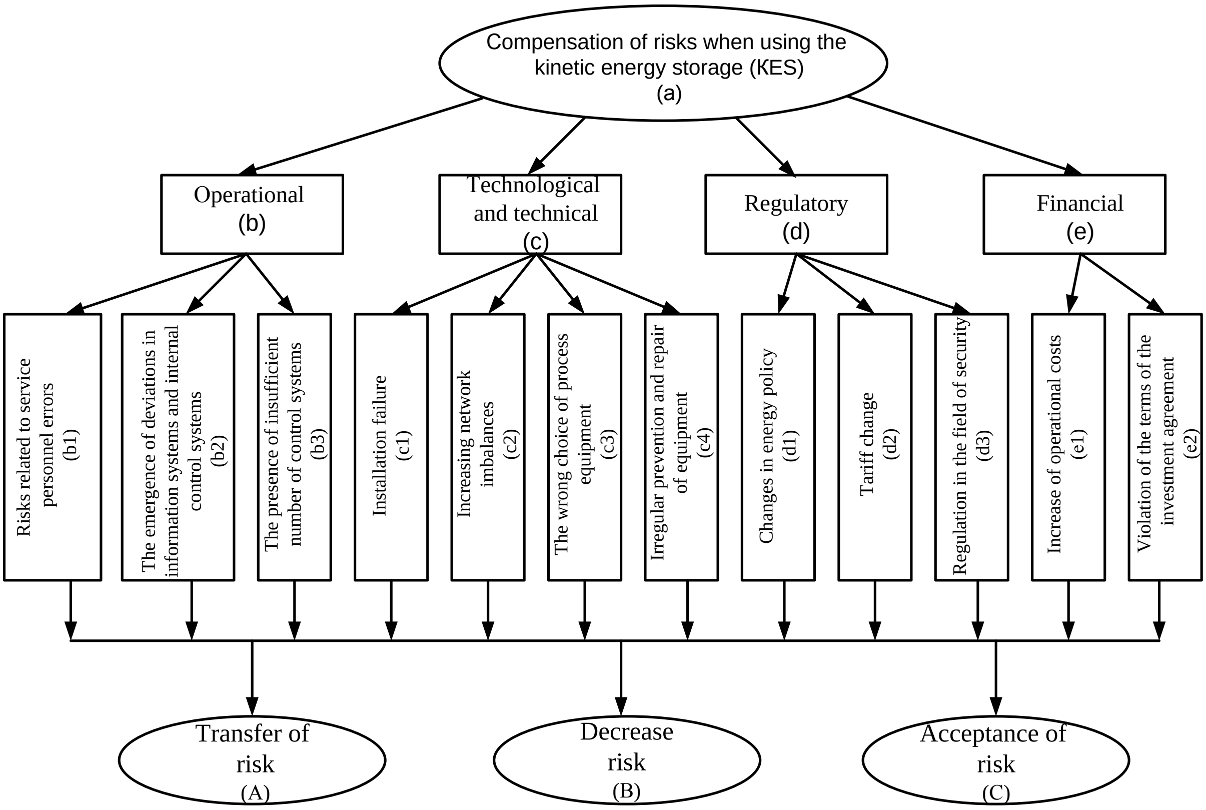

Figure 1. Model of the hierarchical structure of the task of compensation of risks

The following notions are used in the model.

1. The aim or main criteriaрій (risks compensation while using KESU) – a.
2. Criteria of the first level (risks groups – operational, technological and technical, regulatory, financial) – b, c, d, e.
3. Criteria of the second level (subgroups of the first level risks)l– в1, в2, в3, c1, c2, c3, c4, d1, d2, d3, e1, e2.
4. Alternatives of the aim achievement (transfer of risk, decrease of risk, acceptance of risk) – A, B, C.

The second stage of MHA is the development of the algorithm for the aim achievement i.e. it is necessary to determine the influence of the risks groups on the system in whole. Let us use the methods described in [9]. They are as follows: first, matrices of pairwise comparisons of intermediate criteria relatively to the criteria of upper level are recorded, for comparison the scale of relative importance developed by T. Saati [3] is used, secondly, the transition from complex matrices to priority vectors is carried out, thirdly, the test of pairwise comparison matrices quality or calculation of concurrence index are done.

Let us develop matrices of pair-wise comparisons for criteria [X] for each hierarchy level according to the model of hierarchical structure shown in Figure 1 on the example of the aim achievement model (A).

For criteria of the first level we have matrix of pairwise comparisons relatively to the main criteria:

$$A_{(bcde)a}. \tag{1}$$

For criteria of the second level we have matrix of pairwise comparisons:

$$A_{(b1,b2,b3,)b};\ A_{(c1,c2,c3,c4)c};\ A_{(d1,d2,d3)\ d};\ A_{(e1,e2)e}. \tag{2}$$

For each matrix of the pairwise comparisons [X] we carry out transition to the priority vectors [3, 9]. The calculation of the normalized characteristic vector W of positive square matrix [M] is done on the basis of equation:

$$XW = \lambda_{\max} W, \tag{3}$$

where $\lambda_{\max}$ – is maximum characteristic value of matrix [X].

For positive square matrix [X] the right characteristic vector W corresponding to maximum characteristic value $\lambda_{\max}$, accurate to the constant multiplier C can be calculated by formula [9]:

$$\lim_{k\to\infty} \frac{[X]^k e}{e^T [X]^k e} = CW, \tag{4}$$

where $e = \{1, 1, 1, \ldots, 1\}^T$ – is the unit vector; $k = 1, 2, 3, \ldots$ – exponent, C – constant, T – transportation sign.

Determinations of the characteristic vector W are performed until required accuracy is reached:

$$e^T \left| W^{(l)} - W^{(l+1)} \right| \le \xi, \tag{5}$$

where l – is iteration index such that $l = 1$ corresponds to $k = 1$ etc., ξ – acceptable error, assuming $\xi = 0{,}01$.

To determine the maximum characteristic value we use formula:

$$\lambda_{\max} = e^T [X] W. \tag{6}$$

According to the stated methods and formulae (1), (2) we have:

– for the first level criteria

$$A_{(\mathrm{bcde})\mathrm{a}} \to W_{(\mathrm{bcde})\mathrm{a}},$$

– for the second level criteria

$$W_{(b1,b2,b3,)b};\ W_{(c1,c2,c3,c4)c};\ W_{(d1,d2,d3)\ d};\ W_{(e1,e2)e}.$$

The test of pair-wise matrix quality [X] is estimated by indeces [3]:

– concurrence index (ІУ)

$$IУ = (\lambda_{\max} - n)/(n-1), \tag{7}$$

– conformity relation (*ВУ)*

$$ВУ = IУ/M(IУ), \tag{8}$$

where M(ІУ) – is the mean value (mathematical expectation) of the concurrence index developed by the random manner pair-wise comparisons matrix [*X*].

The acceptable value of the conformity relation is ВУ ≤ 0,10 [3].

It should be noticed that developed above equations and given MHA dependences make it possible to range risks and to compensate them while using the systems of kinetic energy storage units of administrative buildings.

Analysis of the numerical results. To develop the matrix of the criteria of pairwise comparisons[X] for each hierarchy level it is necessary to collect data. According to the available guidelines the group of experts should not exceed 20 persons [9]. In our case the group of experts consisting of two Doctors of Sciences, two Candidates of Sciences and three experts with high experience in the field of power engineering was organized and questioned.

The resulting data processing was carried out in accordance with the described methods in Microsoft Excel environment making possible to automate the results obtaining at any output parameters change.

The results of the calculations of pairwise comparisons matrix criteria [X] for the first hierarchy level are given in Table 2.

Therefore the comparison for the second hierarchy level is also realized.

Table 2

Identification of the most important group of risks in order to compensate them

Group of risks	Operational	Technological and technical	Regulatory	Financial	Normalized estimates of the priority vector	Rank
Operational	1	1/3	4	1	0,2164	2
Technological and technical	3	1	5	3	0,5216	1
Regulatory	1/4	1/5	1	1/2	0,0801	4
Financial	1	1/3	2	1	0,1820	3
Sum	5,2500	1,8666	12,0000	5,5000		
Consistency index ІУ=0,024						
Coherence relation ВУ=0,027=2,7%						

According to the calculations we have ВУ=0,027 ≤ 0,10 resulting in the conclusion that experts evaluations in matrix are agreed and do not require revision.

The main result of the pairwise comparisons is the alternative determination importance. In this regard it is necessary to carry out the comparison of the results significance for each concurrence criteria. The calculations of the priority values as part of each risks group are represented in Tables 3 – 6. The importance of the alternatives determination is shown in Table 7.

Table 3

Calculation of priority values as part of operational factors

Operational risks	Transfer of risk	Decrease risk	Acceptance of risk	Normalized estimates of the priority vector
Transfer of risk	1	1/5	1	0,134
Decrease risk	5	1	7	0,747
Acceptance of risk	1	1/7	1	0,120
Sum	7,000	1,343	9,000	

Table 4

Calculation of priority values as part of technological and technical factors

Technological and technical	Transfer of risk	Decrease risk	Acceptance of risk	Normalized estimates of the priority vector
Transfer of risk	1	1/6	1/5	0,084
Decrease risk	6	1	1	0,472
Acceptance of risk	5	1	1	0,444
Sum	12,000	2,166	2,200	

Table 5

Calculation of priority values as part of regulatory factors

Regulatory risks	Transfer of risk	Decrease risk	Acceptance of risk	Normalized estimates of the priority vector
Transfer of risk	1	1	1/7	0,111
Decrease risk	1	1	1/7	0,111
Acceptance of risk	7	7	1	0,778
Sum	9,000	9,166	1,285	

Table 6

Calculation of priority values as part of financialy factors

Financial risk	Transfer of risk	Decrease risk	Acceptance of risk	Normalized estimates of the priority vector
Transfer of risk	1	5	5	0,714
Decrease risk	1/5	1	1	0,143
Acceptance of risk	1/5	1	1	0,143
Sum	1,400	7,000	7,000	

Table 7

Determining the importance of alternatives

Alternative	Operational risks	Technological and technical risks	Regulatory risks	Financial risk	Assessment of the importance of alternatives	Rank
Transfer of risk	0,134	0,084	0,111	0,714	0,2115	3
Decrease risk	0,747	0,472	0,111	0,143	0,4427	1
Acceptance of risk	0,120	0,444	0,778	0,143	0,3458	2

According to the calculations results we have the highest value 0,4427 for the alternative „decrease risk“ – the possibility to decrease consequences of risks. The risks which can not be decreased or transferred are on the second place and have the value 0,3458. The risks which can be partially compensated by transferring to other responsible person have the lowest value 0,2115.

The calculations results are shown in Figure 2.

Fig. 2 depicts the conformity of alternatives to the risks groups.

The results of the investigations. From the diagram shown in Fig. 2 we have come to conclusion that the group of operational risks can be decreased (0,747), for example by qualified staff employment, application of more accurate control systems. This group also include acceptance of risks (0,134) for example the staff mistakes caused by tiredness and inattention. For the group of technological and technical risks it is possible to decrease the risk due to proper equipment choice, the risks are acceptable (0,444), for example the risk of the network disbalance and the risk of equipment failure, transfer of risk (0,0837) is possible due to warranty maintenance. For the group of regulatory risks, the alternative risks acceptance is most important as they can not be effected. For the group of financial risks the most significant alternative is the risk transfer (0,714) due to insurance.

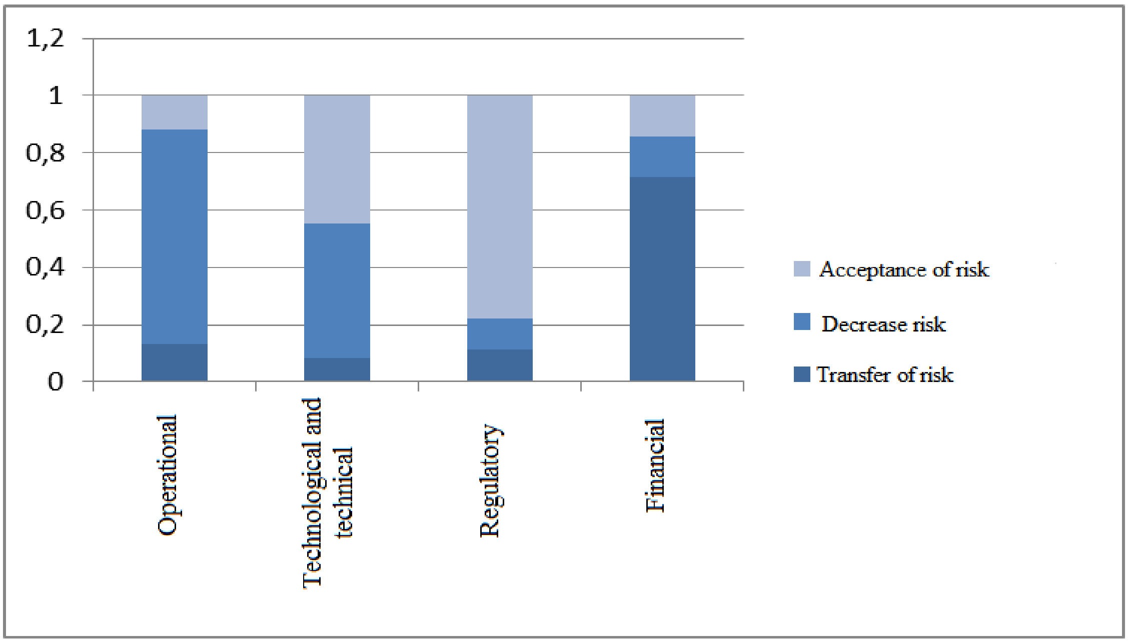

Figure 2. Conformity of alternatives to risk groups

From the given diagram it can be also concluded that the achievement of the main aim i.e. risks compensation by KESU use in the power supply system of the administrative building is possible due to the influence of operational, technological and technical, financial risks on the groups.

It should be noticed that the chosen method of risks analysis and obtained results provide the determination of risks groups subjected to compensation by decrease or transfer resulting in the improvement of effectiveness of the building power supply system operation with KESU connection.

Conclusions. The application of the method of hierarchy analysis developed by T. Saati enables us to estimate all internal and external risks which occur during KESU use in the power supply systems, their influence on the power supply system operation, to determine the directions of the innovation policy of these risks compensation.

Evaluation of four risks groups resulting from KESU use in the building power supply system is performed in this paper. According to the carried out analysis and obtained results we come to the conclusion that all groups of the considered risks can be decreased or transferred except regulatory ones which should to be accepted.

The obtained results can be applied for the improvement of energy efficiency when the low-voltage circuits are used.

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АНАЛІЗ РИЗИКІВ ПРИ ПІДКЛЮЧЕННІ ДО СИСТЕМИ ЕЛЕКТРОПОСТАЧАННЯ АДМІНІСТРАТИВНОЇ БУДІВЛІ КІНЕТИЧНОГО ЕНЕРГОНАКОПИЧУВАЧА З МЕТОЮ РЕГУЛЮВАННЯ НАВАНТАЖЕННЯ

Сергій Шевченко[1]; Наталя Савченко[2]

[1]Національний технічний університет «Харківський політехнічний інститут», Харків, Україна
[2]Донбаська національна академія будівництва і архітектури, Краматорськ, Україна

Резюме. *На основі аналізу ризиків, які виникають при живленні системи електропостачання будівлі від кінетичного електронакопичувача у часи максимуму навантаження, за методом аналізу мереж, розробленим Т. Сааті, розроблено стратегію компенсації груп та окремих ризиків за напрямками перенесення та зменшення.*

Ключові слова: *ризик, кінетичний енергонакопичувач, система електропостачання, методи аналізу ризиків, компенсація ризиків.*

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