Automated System for Assessing the Integral Indicator of Level of Implementation of Life Safety Rules

Aydin Muradaliyev
Azerbaijan Technical University
Baku, Azerbaijan
aydinmuradaliyev@aztu.edu.az

Simuzer Ismayilova
Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute
Baku, Azerbaijan
ismayilovasimuzer23@gmail.com

Samira Abdullayeva
Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute
Baku, Azerbaijan
samira.afqan@gmail.com

Islam Mammadov
Azerbaijan Scientific-Research and Design-Prospecting
Baku, Azerbaijan
islam.mammadov@gwu.edu

***Abstract* — Among the main properties of reliability of EPS facilities, including failure-free operation, maintainability, storability and durability, the quantitative assessment of which has been tested in practice and largely regulated, the issues of life safety of EPS personnel are of great importance. The possibility of quantitative assessment of integral indicators of life safety is one of the main directions for reducing injuries and deaths of personnel.**

The recommended method allows obtaining integral quantitative assessments of life safety of operational personnel performing tests, wear restoration and management of EPS facilities during operation. The results of the quantitative assessment of the integral indicator of life safety allow comparing life safety at various EPS enterprises, identifying "weak links" that are the main reason for the discrepancy between real life safety and the requirements imposed, and managing life safety by eliminating "weak links".

Keywords* — *life safety, rules, automated system, integral indicator

I. INTRODUCTION

Statement of the problem. Life safety in the EPS is determined by the efficiency of the equipment and devices (objects). Let us recall that efficiency, in turn, is determined by the reliability, cost-effectiveness and safety of objects [1].

However, unlike work efficiency, methods for quantitative assessment of life safety indicators in the EPS are in the stage of active development. This is explained not only by the diversity of life conditions, but also by the fact that the task is to assess the safety of not EPS objects, but personnel, people.

Quantitative assessment of life safety during maintenance and repair of objects (equipment, devices, installations, power lines) of *electric power systems (EPS)* is one of the main areas of reducing the risk of injury and death of personnel servicing EPS objects. A method and algorithm for quantitative assessment of life safety were proposed.

It is noted that among the main properties of reliability of EPS objects, including failure-free operation, maintainability, storability and durability, the quantitative assessment of the indicators of which is tested in practice and largely regulated, life safety occupies a special place. Such high significance is due to the assessment of the reliability of not EPS objects, but specifically the safety of EPS personnel.

As a result of calculations by the recommended method, integral quantitative assessments of life safety of operating personnel, personnel performing tests, wear restoration and management of EPS objects during operation can be obtained.

Let us recall that the assessment of personnel life safety is based on the axiom: "*life safety hazard occurs when the Life Safety Rules are violated. The actual life safety is higher, the higher the level of compliance with the provisions of the Life Safety Rules*".

It is noted that it is inappropriate to calculate life safety indicators based on statistics on injuries and deaths of personnel and that the existing indicators do not correspond to the specific features of the functioning of the EPS.

Considering the real interest of the Enterprise Management in improving life safety, an automated life safety calculation system can serve as an effective tool for managing life safety. At the same time, the use of this systemin audit checks of the state of life safety is not excluded, both by the power system and by organizations monitoring life safety.

All this is noted for one purpose only: the output documents should provide information and methodological support to the Management of the enterprise and ultimately contribute to improving life safety. In this regard, the development of appropriate recommendations for improving the level of life safety is of great practical importance.

II. COMPLIANCE WITH THE LIFE SAFETY RULES.

In the priorities of the concepts of knowledge and understanding, an erroneous opinion often arises. In terms of the level of cognition, a higher category is knowledge, which includes not only an understanding of the essence of the document, but also the ability to explain the need for its implementation. Under "understanding" is usually meant only the awareness of the essence of the document. Therefore, there can be no life safety without knowledge of the Life Safety Rules.

Knowledge testing and advanced training of personnel in life safety is carried out in accordance with [1].

In the Training Centers of the EPS, a test system for

monitoring knowledge of life safety is usually used. Despite many years of experience in using automated systems for monitoring personnel knowledge, periodic passing of an exam on life safety by the commission is still carried out today.

The level of knowledge on life safety can only be increased by switching to independent control methods. Knowledge of the Life Safety Rules is an essential condition for consciously taking into account the dangers when performing work related to the operation, testing and repair of power system facilities.

In general, the Life Safety Rules consist of various Rules. In the EES, they reflect three areas: labor protection, safety engineering, fire safety (their chapters, sections and provisions). The level of implementation of each provision of the Rules is proposed to be assessed on a five-point scale.

This choice is not accidental:

- the five-point system is familiar, as it resembles the usual system of knowledge assessment;
- based on the practice of calculations, it is stated [5] that for the maximum values of indicators measured in an ordinal scale, it is advisable to use assessments in the range from 3 to 6;
- according to H.A.Sturges, 5 is the optimal number of intervals when the number of measurements changes in the range [11÷23] [6], which, as a rule, reflects the maximum number of provisions in the sections of the Rules.

An assessment of the actual level of compliance with the Life Safety Rules can be performed by a participant in the "life activity", i.e., the performer of a specific job during the operation, testing and repair of EPS facilities, or by an Expert in Life Safety.

The person responsible for monitoring the implementation of the Life Safety Rules, heads of the enterprise departments may participate as Experts. The advantage of this method (direct five-point assessment of the level of implementation of the Life Safety Rules) is the Expert's knowledge of the actual level of implementation of the provisions of the Life Safety Rules.

A serious drawback is the subjectivity of the assessments. In this case, assessments depend not only on the knowledge and qualifications of the Expert. Ensuring the independence of the examination, reducing subjectivity can be achieved by clarifying the concept of "level of implementation of the provisions of the Life Safety Rules" corresponding to a particular assessment.

Table 1 provides information on the components of the Life Safety Rules, the types of personnel activities and the generalized names of objects. The latter fully correspond to the classification given in [2]. (fig. 1) shows the structural diagram of the assessment of the integral indicator of life safety during testing of a power transformer.

TABLE I. COMPONENTS OF INFORMATION ON LIFE SAFETY

Components of the Life Safety Rules	**Types of personnel activities**	**Generalized names of EPS objects**
Labor Protection Rules (LPR) Safety Regulations (SR) Fire Safety Riles (FSR)	Operation Trials Repairs	Territory, industrial buildings and structures. Hydraulic structures, water management, hydraulic turbine units. Thermal and mechanical equipment of power plants and heating networks. Electrical equipment of power plants and networks.

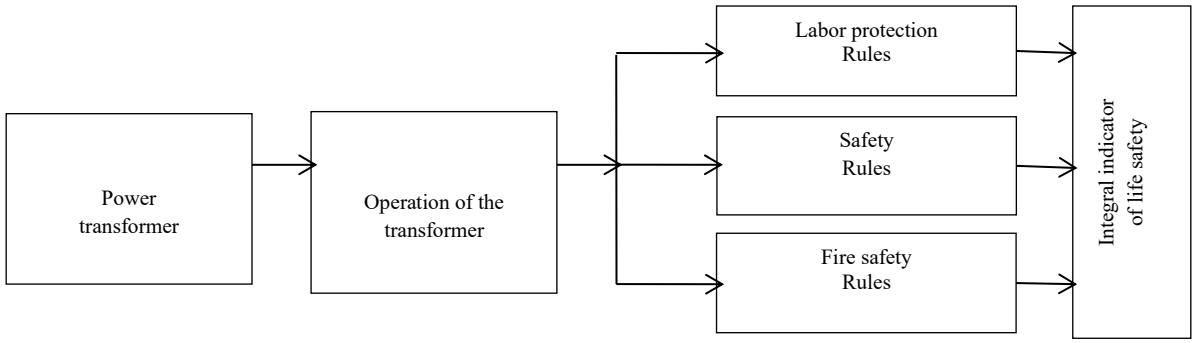

Fig.1. Structural diagram of the assessment of the integral indicator of life safety.

In [4], the concept of "performance level" of provisions of the Life Safety Rules is introduced, assessed on a five-point scale - from non-performance of the Rules to exemplary performance. As a result of the survey, each provision of the sections of the Life Safety Rules is assigned a score from 1 to 5 in accordance with the level of its performance.

Thus, if the Life Safety Rules contain Rules from which provisions with i=1, m_g is selected, then the results of the examination will contain $m_{\Sigma} = \sum_{i=1}^{3} m_{c,i}$ sets of assessments.

It should be immediately noted that finding the arithmetic mean of these assessments from the point of view of measurement theory is incorrect, since the ranks of the ordinal measurement scale do not allow such mathematical operations [3].

III. DATA PROCESSING METHODOLOGY

Fig. 2 shows the calculation results in the form of a computer fragment of the life safety assessment protocol for testing a power transformer.

The protocol includes three sections, a conclusion and an Appendix. The first section (table P1) provides quantitative assessments of life safety, the second - qualitative characteristics of life safety. The third section provides recommendations for improving life safety.

The conclusion provides an assessment of life safety during testing of power transformers. The appendix provides the numbers of provisions of the Life Safety Rules, the knowledge of which does not meet the requirements.

Taking into account the random nature of integral assessments. The advantages of the above calculation method include simplicity, clarity, and the availability of manual counting. But there are also some peculiarities. The results of the examination, in fact, are temporary and random.

Over time, the identified deficiencies will be eliminated, and a repeated examination with another expert may give a different result. It, of course, will not differ fundamentally from the first.

In addition, the integral indicator of the level of fulfillment of the BJ_{Σ} Rules calculated as the geometric mean of the integral indicators of the levels of fulfillment of each of the three BJ_i Rules. However, this formula is objective if the i=1,3 and BJ_{Σ} with BJ_i differ randomly.

PROTOCOL
level of implementation of the Life Safety Rules

Table P1. Results of diagnostics of implementation of sections of the Life Safety Rules.

Number and title of the Rules	Number of provisions Rules	Integral assessment	Numbers of provisions assessed on:		
			satisfactorily	badly	unacceptable
1. Labor protection Rules	m_1=	BJ_1^* =			
2. Safety Rules	m_2=	BJ_2^* =			
3. Fire safety Rules	m_3=	BJ_3^* =			
Integrated assessment of the imple-mentation of the Life Safety Rules		BJ_{Σ}^* =			

Table P2. Scale of qualitative characteristics of life safety indicators.

Quantitative characteristics	Change interval
unacceptable	0 - 0,2
badly	0,2 - 0,4
satisfactorily	0,4– 0,6
Good	0,6 – 0,8
Indicative	0,8 – 1,0

Recommendations.

1. Integrated assessment of the level of compliance with the Life Safety Rules BJ_{Σ}^* = _____ and in accordance with table 2 is estimated as _____
2. The integrated assessment of the level of implementation of the provisions _____ are classified as "unsatisfactory" and require decisive measures to eliminate the discrepancy between the knowledge of the Life Safety Rules and the requirements.
3. The appendix contains the provisions of the Rules, the insufficient level of implementation of which requires retraining of personnel.
4. As follows from Table P1, the unacceptable level of implementation of the provisions is ____% of the total number of assessments.

Conclusion

1. The level of life safety is assessed as _____

Date_____ Expert _____

Fig. 2. Computer fragment of the protocol for assessing life safety during testing of a power transformer.

Below is a sequence of calculations that allow for the random nature of the examination results.

1. Based on the examination results, a generalized histogram of the distribution of assessments of the levels of implementation of all provisions is constructed. The frequency of each assessment is calculated using the formula:

$$f_{\Sigma}^*(k) = [\sum_{i=1}^{3} r_{i,k}] / \sum_{i=1}^{3} m_{c,i} \qquad (1)$$

where $r_{i,k}$ - is the number of manifestations of the k-th level of compliance with the provisions of the Life Safety Rules.

2. The discrete values of the statistical distribution function $F_{\Sigma}^*(k)$ are calculated using the formula:

$$F_{\Sigma}^*(1) = f_{\Sigma}^*(1)$$
$$F_{\Sigma}^*(k) = \sum_{\kappa=2}^{4} f_{\Sigma}^*(k) \qquad (2)$$
$$F_{\Sigma}^*(5) = 1$$

3. Similarly, the frequency of assessments of the level of performance of each Rule $f_{v,i}^*(k)$ and the discrete values of the statistical distribution function of the $F_{v,i}^*(k)$ are calculated using the formulas:

$$f^*_{v,i}(k) = r_{i,k} / m_{c,i} \quad (3)$$

$$F^*_{v,i}(k) = \sum_{k=1}^{5} f^*_{v,i}(k) \quad (4)$$

with k=1,5 and i=1,3

4. The absolute value of the discrepancy of the statistical distribution function $\Delta^*_{i,k}$ is calculated using the formula:

$$\Delta^*_{i,k} = \left| F^*_{\Sigma}(k) - F^*_{v,i}(k) \right| \qquad i=1,3 \quad k=1,5 \quad (5)$$

5. For each group of k=5 random values of $\{\Delta_{i,k}\}_{n;5}$ the following are calculated:

- The largest value according to the formula:

$$B^*_э(\Delta^*_i) = \Delta^*_{i,max} = \max\{\Delta^*_{i,1}; \Delta^*_{i,2}; \Delta^*_{i,3}; \Delta^*_{i,4}; \Delta^*_{i,5}\} \quad (6)$$

- Arithmetic mean value according to the formula:

$$M^*_э(\Delta^*_i) = 0,2\sum_{k=1}^{5} \Delta_{i,k} \quad (7)$$

- The magnitude of the scattering amplitude is determined by the formula:

$$L^*_э(\Delta^*_i) = \Delta^*_{i,max} - \Delta^*_{i,min} \quad (8)$$

with

$$\Delta^*_{i,min} = \min\{\Delta^*_{i,1}; \Delta^*_{i,2}; \Delta^*_{i,3}; \Delta^*_{i,4}; \Delta^*_{i,5}\} \quad (9)$$

Each of the three indicators (statistics) is supplemented by the index “e”, which highlights their experimental values.

6. According to the data of [4], the critical values of similar indicators are calculated, which designate as: $B^*_\alpha(B^*_э)$, $M^*_\alpha(\Delta^*_i)$, $L^*_\alpha(\Delta^*_i)$.

7. The nature of the discrepancy between $F^*_\Sigma(k)$ and $F^*_i(k)$ is assessed according to the criterion:

$$\begin{gathered} \text{If } B^*_\alpha(\Delta^*_i) < B^*_k(\Delta^*_i) \\ \text{and } M^*_э(\Delta^*_i) < M^*_\alpha(\Delta^*_i) \\ \text{and } L^*_\alpha(\Delta^*_i) < L^*_\alpha(\Delta^*_i) \\ \text{then } H \Rightarrow H_1 \\ \text{otherwise, } H \Rightarrow H_2 \end{gathered} \quad (10)$$

where H_1 and H_2 are respectively the assumption of random and non-random discrepancies of integral indicators.

Taking into account the random nature of D^*_i assessments is essential when determining the Rules, the implementation of which is non-randomly narrower than the average level of implementation of all Life Safety Rules.

III. CONCLUSION

1. One of the main areas of reducing injuries and fatalities of personnel at EPS facilities is the transition from qualitative to quantitative characteristics of life safety;
2. The issues of quantitative assessment of the integral indicator of life safety, in contrast to the assessment of the integral indicator of the efficiency of EPS facilities, are at the research stage. This is largely due to the difference in the practical problems being solved;
3. Statistics of injuries and fatalities of personnel require increasing the efficiency of analysis of each case. At the same time, it should not serve as a basis for quantitative assessment of life safety indicators. Life safety indicator - average "life expectancy" for characterizing EPS personnel is unacceptable;
4. Life safety depends on the damageability of EPS facilities. For example, the longer the service life of facilities, the lower their reliability, and the higher the danger of maintenance. Probabilistic life safety indicators characterizing the occurrence of accidents and man-made disasters as sources of danger, if relevant information is available, can be useful.
5. A method and algorithm for quantitative assessment of the recommended integral indicator of life safety have been developed. The calculation method for this indicator is based on information on the levels of compliance with the provisions of the Life Safety Rules.;
6. The results of the quantitative assessment of the integral indicator of life safety allow:
   - compare life safety at various enterprises of the EPS, their divisions;
   - identify "weak links" that are the main reason for the discrepancy between real life safety and the requirements;
   - manage life safety by eliminating "weak links";
   - calculate objective integral indicators of life safety for various types of maintenance, testing and repair of various types of EPS facilities
7. Quantitative assessment of life safety indicators provides information and methodological support to the Enterprise Management in improving the life safety of personnel.
8. A method and algorithm have developed that allow taking into account the random nature of integral life safety indicators. The application of the method allows identifying indicators that are not accidentally worse than average estimates.

REFERENCES

[1] E.M.Farhadzadeh, A.Z.Muradaliyev, S.M. Ismailova, “Quantitative assessment of the integral indicator of life safety of EPS personnel”, (Life Safety. №.4, Moskva, 2017), pp. 9-14.

[2] A.V.Barinov, N.I. Sedykh, V.A. Sednev et al. “Life Safety. Study Guide”, (Academy of the State Fire Service of the Ministry of Emergency Situations of Russia, 2014), 350 p.

[3] V.V. Dmitriev. “Definition of the integral indicator of the state of a natural object as a complex system”, (Society, Environment, Development (Terra Humana) No. 4/2009), pp. 146-165.

[4] GOST 27002-2009. “Reliability in engineering. Basic concepts. Terms and definitions”, (Standartinform, Moscow, 2011), 26 p.

[5] A.I. Orlov. “New paradigm of statistical and experimental data analysis in economic and management problems”, (Scientific journal of Kub.SAU №98(04), 2014), pp.1-21.

[6] E.M.Farhadzadeh, Y.Z.Farzalyiev, A.Z.Muradaliyev, “Transition from qualitative to quantitative approach to decision-making on increasing reliability of electric power system facilities”, (Electricity №8, Moskva, 2016), 23-31 p.

[7] D.A.Novikov. “Statistical methods in pedagogical research”, (MZ-Press, Moscow, 2004), 66 p.

[8] S.G. Fedorcenko, G.S.Fedorcenko, “Integral measure of energy security assessments”, (“Problems of regional energy” 1(24),Tiraspol, 2014), pp. 1-16.