Complex assessment of the communications system efficiency

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Abstract

In modern conditions, when the world is abandoning analog means of communication and widely implemented software-controlled means, the question arises of the scientific choice of the development of communication systems. To do this, you need to quantify the quality of possible options for building communication systems in order to reasonably choose the best. Options for building promising communication systems differ in individual indicators, so it is necessary to justify a comprehensive indicator of the quality of the communication system. This will allow to scientifically substantiate decisions on further development of existing systems and to create modern communication systems.

In the article on the basis of the conducted analysis of the known methods of an estimation of efficiency of CS taking into account requirements of guiding documents the order of actions at check of satisfaction of actual requirements is formalized.

On the example of quantitative assessment of the reliability and readiness of the CS for the first time considered the possibility of implementing the proposed stages of assessment with the definition of probabilistic indicators of the results, which is the content of scientific novelty and difference from known works.

Key words: communications system, complex assessment, functioning efficiency.

Introduction

Improving the communications systems (CS) functioning in the modern conditions of their development is one of the urgent scientific and practical problems. Particular attention is paid to the problem of quantifying the effectiveness of these systems functioning, and not on individual indicators, but in a complex way, taking into account the influence of all indicators of quality on the result of the system's intended use.

In recent years, scientific research has been carried out on the quantitative assessment of the quality of compliance with certain requirements for the use of CS. In V. F. Oleynik (Oleynik V. F., 2000) the principles of constructing modern CS are formulated and the requirements for them are defined, but there are no recommendations for the quantitative assessment of quality indicators. In (Edward Golan, 2012; United States, 2015; Defense Information Network, 1998; Signal battalion, 2007) the prospective directions of the CS development are determined taking into account the experience of the advanced countries of the world. In (Zaytseva E. N., 2003; Kharybin A. V., 2006; Holovan' S. M., 2012; Volochiy B. Y., 2012; Hu Z., 2017), recommendations are given for assessing the reliability of particular samples of communications technology (CT), as well as reliability and survivability of CS as a whole. In (Yanliang Li, 2011; Robert Thomson, 2010; Haikuan Wang, 2013; Chunliang Chen, 2013; Lenkov S. V, 2009) the issues of diagnostic improvement were considered, and in (UddE, 1996; Senior J. M., 1998) – the metrological maintenance of the repair of CT. However, the previous studies were not systematic, but solved partial tasks. The analysis of works devoted to methods of estimating the efficiency of CS shows that not all of them are widely practically used, are not always optimal, do not take into account the specifics of the CT operation in real conditions.

Material and methods

The purpose of the article: to comprehensively assess the effectiveness of the COP and demonstrate, on the example of compliance with the requirements for reliability and readiness, a formal opportunity to streamline the actions for its assessment with the calculation of probabilistic quality indicators.

Results and discussion

Communication system and automated control systems are a set of interconnected, compatible and controlled by the subsystem tasks that meet the following requirements (Oleynik V. F., 2000):

high readiness for intended use – the ability of the CS at any time and in any circumstances to fulfill the tasks of ensuring the exchange of information among users;

stability – the ability of CS to perform tasks for its intended purpose under the influence of all the impressive factors (characterized by survivability, noise immunity and reliability of CS);

mobility – the ability of the CS to be deployed within the established time frame, to change the topology and capabilities in accordance with the conditions of the situation;

bandwidth – the ability of the CS to provide the flow of information services per time unit with a given quality;

security – the ability of CS and automation to provide protection against unauthorized access and imitation stability;

interoperability – the ability of CS and automation to ensure the interoperability of telecommunications and automation systems with other systems without additional couplings and additional software.

Nowadays, there is no single methodology for a comprehensive assessment of the satisfaction of these requirements for CS, which makes it difficult to assess the effectiveness of existing ones and justify the choice of rational options for their further development. It is most accessible to quantify the compliance of the CS with the requirements for reliability, readiness, mobility and bandwidth due to the criteria set by the guidance documents, but as the communications systems are developing, they also need to be scientifically substantiated (Zaytseva E. N., 2003; Kharybin A. V., 2006; Holovan' S. M., 2012; Volochiy B. Y., 2012; Hu Z., 2017).

The solution of the problem of CS efficiency complex estimation is expedient to perform in the following sequence (Fig. 1):

as a result of the source data collection and analysis, determine the factors affecting the quality indices of the CS and establish the functional dependencies of these indicators values on the managed variables for obtaining the normed values of the quantitative assessment of compliance (Π_i);

the expert survey of leading specialists in the organization of communications quantitatively assess the weighting factors of all indicators of quality CS (K_i);

comprehensive assessment of the effectiveness of the COP in the form of a quantitative assessment of the probability of its compliance $0 < E = \sum_{i=1}^{6} K_i \Pi_i \leq 1$, where $0 \leq \Pi_i \leq 1$; $0 < K_i < 1$; $\sum_{i=1}^{6} K_i = 1$;

as a result of ranking according to the degree of reduction of the value of E to determine the most promising options for the development of CS.

One of the most important indicators of the CS quality is reliability, without which their use is meaningless. Let us consider the possibility of a formalized assessment of this requirement for CS.

The reliability of the COP is the ability to provide communication with the support of performance indicators, which are set by the requirements and maintained by the communication subsystem with the implementation of all types of repairs, maintenance and cost resources.

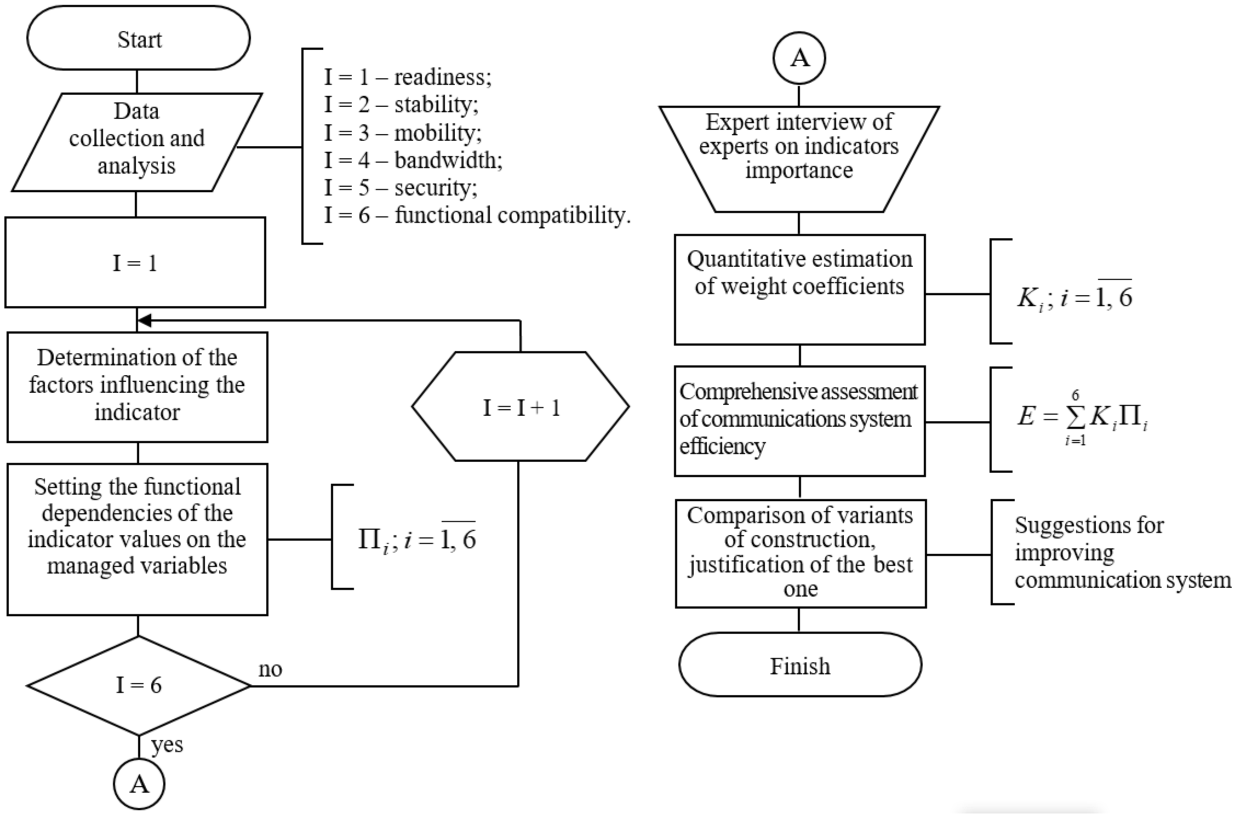

Fig. 1 – Block diagram of the algorithm for comprehensive evaluation of the efficiency of the communication system

Traditionally, as the main indicator of reliability of CS, a readiness factor A_c (Reliability of technology, DSTU 2860–94) is used, which represents the probability of technical reliability of all CT facilities and the readiness to operate in the full range of all communications lines. However, for a more objective feature of the CS is the probability of a system's technical readiness for the exchange of information between subscribers at least in one direction of communication P_c, which in the literature on the theory of reliability is defined as the probability of connection or the probability of a working state of at least one of the possible connection directions:

$$P_c = 1 - \prod_{j=1}^{S}(1 - A_j),$$

where A_j – readiness factor of the j-th direction of communications, S – number of communications directions between subscribers in CS. This expression quantifies the upper limit of network reliability, and the values of the lower limit are calculated according to (Popovskii V. V., 2014) by the expression:

$$P_{CH} = \prod_{j=1}^{S}(1 - U_j) = \prod_{j=1}^{S} A_j,$$

where $U_j = 1 - A_j$ – rate of the j-th direction of communications. Approximate estimation methods of Ezari-Proshan and Polissky are used to simplify calculations, which are reduced to the consideration of incomplete connecting and unconnected events, which are determined by lower estimates (Reliability of technology, DSTU 2860–94).

Let us consider the possibility of formalizing the quantitative assessment of the value of one of the basic requirements for CS – readiness for use, which depends on the personnel training, the technical condition of the CT, and technical, diagnostic and metrological support. It is possible to quantify this during the control of the technical support of communications in order to study thoroughly the state of the CT and the organization of the personnel work.

The sequence of actions of the first stage is formalized in the form of graphic diagrams of fig. 2, and a list of relevant operations is given in table 1, which takes into account the factors that influence the readiness of individual CT samples.

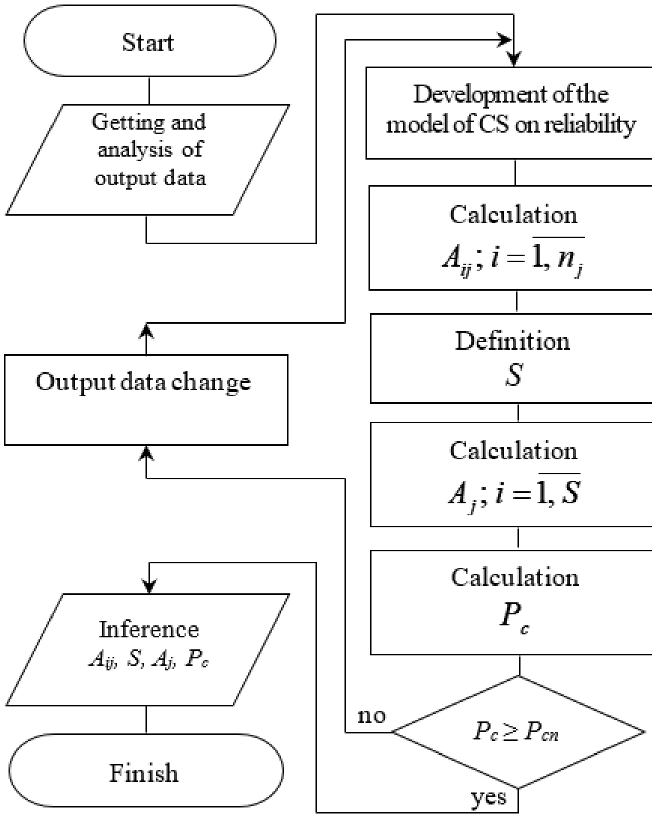

Fig. 2 – Block diagram of the algorithm for calculating the connection probability of the communications system

Table 1 – List of operations for assessing the technical condition of communications means samples

Conditional number	Contents of the operation
1	The sample is functional, ZIP-0 is complete, the documentation is correct, the electrical safety equipment is working.
2	The sample is workable, complete with components, ready for use.
3	Timely and qualitatively full maintenance.
4	The complete set of ZIP-0 is not less than 50% of each nomenclature and instrument is not less than 85%.
5	Completeness of ZIP-0 is not less than 50% of each nomenclature and instrument is not less than 75%.
6	The value of the parameters are brought to the standards by the crew by means of regulation in the process of checking the sample.
7	Detected disadvantages are removed by the crew with the involvement of repair body specialists and using the ZIP-0 not later than in 4 hours.
8	Detected disadvantages are removed by the crew using ZIP-0 not later than in 1 hour.
9	Broken up to 20% of subscriber tracks or the same type of products, there is no connection inside the signal center, measuring instruments are not approved.

A comprehensive assessment of the CS availability is a step-by-step process:

at the first stage quantitatively assess the technical state of individual CT samples;

then receive a quantitative estimation of the communications hardware (CH) technical condition, which takes into account the factors affecting the readiness quality;

further evaluate the technical condition and readiness for use by the appointment of the communications equipment group of the same type at the signal center;

at the final stage, receive a comprehensive assessment of the readiness of the signal center, depending on its purpose.

Graphic diagram of the presentation of the CT state assessing process (Fig. 3) allows, using the mathematical apparatus of logic algebra, considering possible options for assessing the technical condition:

$$X = X_5 \vee X_4 \vee X_3 \vee X_2 = \bigvee_{i=2}^{5} X_i;$$

$$X_5 = x_1 x_3 \overline{x_9};\ X_4 = x_1 x_3 x_9 \vee x_1 \overline{x_3} x_4 x_6 x_8 \overline{x_9} \vee \overline{x_1} x_2 x_4 x_6 x_8 \overline{x_9};\ X_3 = x_1 \overline{x_3} x_4 x_6 x_8 x_9 \vee \overline{x_1} x_2 x_4 x_6 x_8 x_9 \vee$$
$$\vee \overline{x_1} x_2 x_4 \overline{x_6} x_7 \overline{x_9} \vee \overline{x_1} x_2 x_4 x_6 x_7 \overline{x_8 x_9} \vee \overline{x_1} x_2 \overline{x_4} x_5 x_7 \overline{x_9};$$

$$X_2 = \overline{x_1 x_2} \vee \overline{x_1} x_2 \overline{x_4 x_5} \vee \overline{x_1} x_2 \overline{x_4} x_5 \overline{x_7} \vee$$
$$\vee \overline{x_1} x_2 \overline{x_4} x_5 x_7 x_9 \vee \overline{x_1} x_2 x_4 x_6 \overline{x_7 x_8} \vee$$
$$\vee \overline{x_1} x_2 x_4 x_6 x_7 \overline{x_8} x_9;$$

where X – CT technical condition;

X_i – technical condition assessment $(i = \overline{2,\ 5})$;

x_i – positive assessment of the operation and of the table 1;

$\overline{x_i}$ – negative assessment of the operation and of the table 1.

This is necessary to quantify the quality indicators of the process of determining the state of CT.

Let us consider the possibility of quantitative estimation of the mathematical expectation (ME) of the deviation of the evaluation of the technical state of the CT specimen from the actual one in the presence of one error in determining the result of the operation of Table 1 on the example of the evaluation "good". According to (Z. Hu, 2017), the ME of the discrete value is equal to the sum of the product of the value of the random variable on the probability of its appearance. In this case we receive:

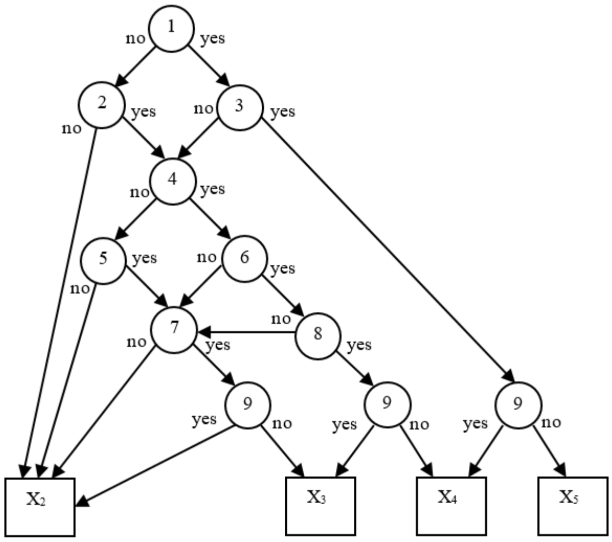

Fig. 3 – Graphic diagram of the operations algorithm for assessing the technical condition of communications means samples

the error in the first step does not affect the result;

the error in the second step (operation 2) gives the largest deviation of the assessment of the state of the CT, which is equal to $2(1-p)p$;

errors in other steps lead to a rejection of the assessment of the CT state on $(1-p)p^5$; where p – the probability of a correct assessment of the operation result of Table 1.

Similarly, we obtain the ME deviation of the estimation for all possible cases, if that probability of correct estimation of the results of all operations is the same and equal to p:

$$\rho_2 = 2(1-p)p^2 + 2(1-p)p^5 =$$
$$= 2(1-p)p^2(1+p^3);$$
$$\rho_3 = (1-p)p^5 + (1-p)p^5 + (1-p)p^5 +$$
$$+(1-p)p^5 + (1-p)p^5 = 5(1-p)p^5;$$
$$\rho_4 = 2(1-p)p + (1-p)p^5 + (1-p)p^5 +$$
$$+(1-p)p^5 = (2+3p^4)(1-p)p;$$
$$\rho_5 = (1-p)p^5 + (1-p)p^4 + (1-p)p^2 =$$
$$= [p^2(p+1)+1](1-p)p^2.$$

The minimum value of the probability of a correct assessment of the state of the CT is obtained with the maximum number of inspections:

$$P_5 = p^3;\ P_4 = p^6;\ P_3 = P_2 = p^7.$$

The results are shown in Fig. 4 and 5. Let us consider the requirements for the meaning p of the conditions $P \geq 0{,}9$і $\rho \leq 0{,}5$:

$\rho_4 = (2 + 3p^4)(1 - p)p \leq 0{,}5$ – solution exists for $p \geq 0{,}8$;

$P_3 = p^7 \geq 0{,}9$ – solution exists for $p \geq 0{,}988$.

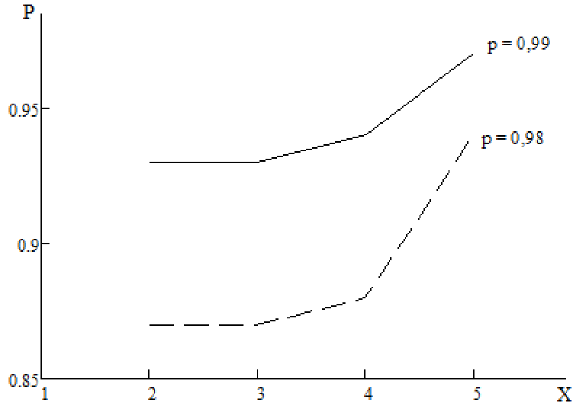

Fig. 4 – Dependences of the minimum value of the correct estimation probability of special communications

Performing operations in Table 1 requires the simultaneous evaluation of several logical conditions. It is known that the probability of making the correct decision under several logical conditions is (Sakovych L. M., 2003):

one, two $p = 0{,}995$;
three, four $p = 0{,}950$;
five and more $p = 0{,}900$;
which corresponds to the results obtained.

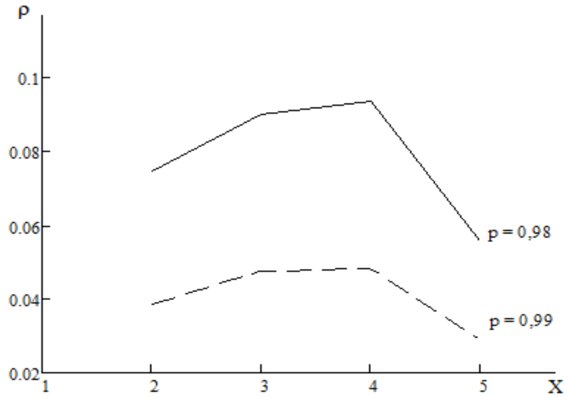

Fig. 5 – Dependences of mathematical expectation of estimation deviation of special communications means samples

Using the obtained results to evaluate the technical condition of individual CT samples, personnel training, technical and metrological maintenance of their operation allows us to formalize the process of assessing the technical state of the CA as a whole (Fig. 6).

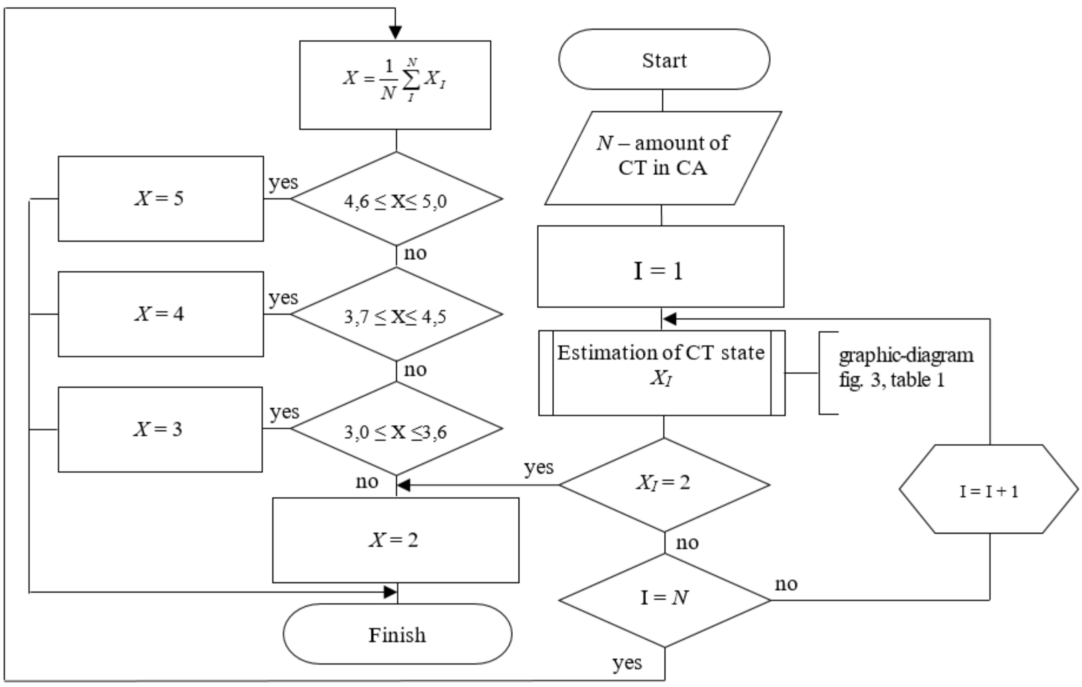

Fig. 6 – Block diagram of the algorithm for evaluating the technical state of the hardware communications

An assessment of the technical state of individual CA allows us to further assess the technical condition of a group of the same type of equipment. All CT is subdivided into *n* 15 groups, the order of assessment of which is shown in Fig. 7, where n_i – the number of tested CAs that received an assessment $X_i = \overline{2,\ 5}$; N – total number of samples of equipment in the group; z_i – percentage of CA that received an assessment i; Z – general assessment of a group of the same type of communications means.

At the final stage of the assessment of the signal center readiness, take into account the number of well-trained and functioning CT, which received positive assessments ($Z > 2$) by groups.

According to the requirements, the communication node is ready for use, if the ratio of a decent and functioning CT to its full-time number for the main groups is $\eta_o \geq 0{,}75$ and for the non-core groups is $\eta_н \geq 0{,}5$. In assessing the readiness of the CS, it is advisable to compare them to the obtained values η_o, which in the future is equal to $П_1$ according to Fig. 7, and inequality $\eta_н \geq 0{,}5$ use as a constraint. Thus, the approach taken in this work allows to objectively and comprehensively evaluate the degree of readiness of signal centers during verification.

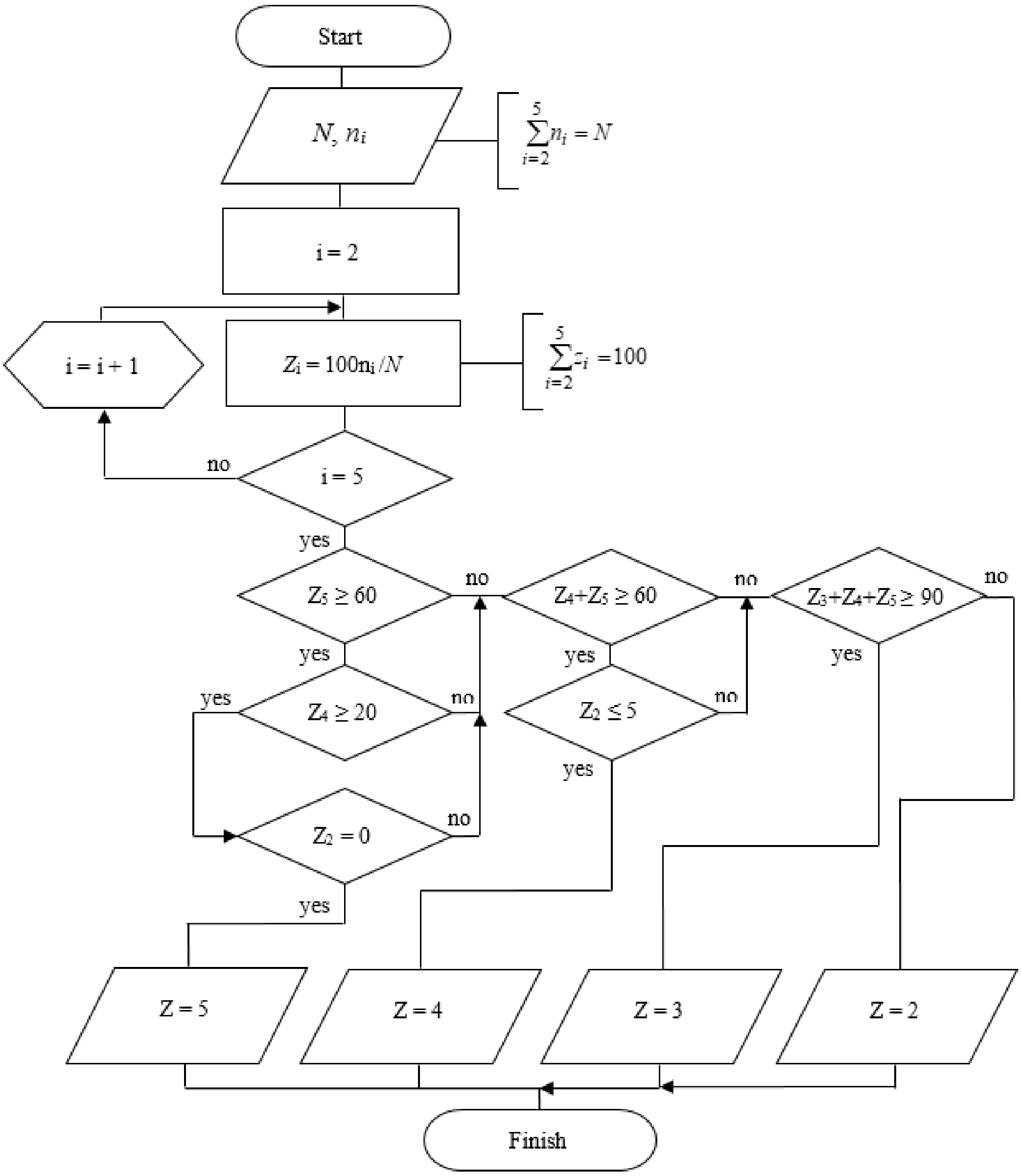

Fig. 7 – Block diagram of the algorithm for evaluating the technical condition of groups of the same type communications means

Conclusions

In the article on the basis of the conducted analysis of the known methods of an estimation of efficiency of CS taking into account requirements of guiding documents the order of actions at check of satisfaction of actual requirements is formalized.

On the example of quantitative assessment of the reliability and readiness of the CS for the first time considered the possibility of implementing the proposed stages of assessment with the definition of probabilistic indicators of the results, which is the content of scientific novelty and difference from known works.

Further tasks of the study are to determine the factors influencing other indicators of CS quality and to establish functional dependences of the values of these indicators on controlled variables, as well as to conduct an expert survey of leading specialists in communication and quantitative assessment of weight indicators of individual SS indicators.

The implementation of these tasks allows to obtain a comprehensive assessment of the effectiveness of the CS.

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