Method of Forming General Requirements for ICT Metrological Equipment

Sergii Gnatiuk[1], Lev Sakovich[2], Denys Bakhtiiarov[3], Aqeel Abdulhussein M. Al-Mudhafar[3], and Roman Odarchenko[3]

[1] International European University, 3a Olevskaya str., Kyiv, 03164, Ukraine
[2] Institute of Special Communication and information protection of the National Technical University of Ukraine "Kyiv Polytechnic Institute named after Igor Sikorsky," 37 Peremohy ave., Kyiv, 03056, Ukraine
[3] National Aviation University, 1 Liubomyra Huzara ave., Kyiv, 03058, Ukraine

Abstract

The example of special Means of Special Communication (MSC) shows the main provisions of the proposed method of forming general requirements for metrological equipment used during their maintenance and current repairs. Based on the results of experimental research of the obtained scientific results, recommendations for their practical use have been developed. It is positive that not only the activity of specialists during the implementation of the method is formalized, but software is obtained that allows the use of new scientific results in scientific institutions during the modernization of existing or development of promising samples of special communications for their effective maintenance using modern achievements discrete search theory in recovery. The use of the method does not require additional training of repair specialists, which was confirmed during the experimental verification of scientific results in the improvement of maintenance of the tropospheric communication station R-423 in the 10th territorial node of government communication.

Keywords

Means of special communication, MSC, metrological characteristics, compatible group search for a defect algorithm.

1. Introduction

Formulation of the problem. Modern and promising models of special communications are among the most science-intensive and high-tech types of industrial products, which are subject to increased requirements for quality and efficiency. The actual technical condition of special communications during their maintenance and all types of repairs is determined by analyzing the results of quantitative evaluation of the values of parameters and characteristics, which use metrological equipment [1, 2].

Analysis of recent research and publications. The technical level of modern means of special communication and metrological equipment allows to take into account a significant number of factors that significantly affect the determination of the technical condition of special communication means [3].

This became possible thanks to the works of such famous scientists as V. Kaminsky, L. Vitkin, V. Ignatkin, O. Vasilevsky—in the field of determining the controlled quality parameters of metrological equipment; S. Ksenz, B. Kredentser, L. Sakovich—in the field of technical diagnostics of means of special communication; V. Chinkov, P. Stolyarchuk, B. Stadnyk, E. Pokhodylo, E. Volodarsky—in the field of development of metrological equipment; A. Friedman, P. Novitsky, V. Yatsuk, M. Yakovlev—in the field of development of the theory of metrological reliability.

At the same time, it should be noted the imperfection of the existing methods of forming general requirements for metrological equipment (and, in particular, the parameters of special

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EMAIL: sgnatuk30@gmail.com (S. Gnatiuk); lev@sakovich.com.ua (L. Sakovich); bakhtiiaroff@tks.nau.edu.ua (D. Bakhtiiarov); almudhaffar2004@gmail.com (A, A. M. Al-Mudhafar); odarchenko.r.s@ukr.net (R. Odarchenko)
ORCID: 0000-0002-1541-7058 (S. Gnatiuk); 0000-0002-8257-7086 (L. Sakovich); 0000-0003-3298-4641 (D. Bakhtiiarov); 0000-0001-5306-4801 (A, A. M. Al-Mudhafar); 0000-0002-7130-1375 (R. Odarchenko)

communications), as they do not take into account the impact of diagnostic quality on maintenance of special communications.

The purpose of the paper is to develop and study a method of forming general requirements for metrological equipment on the example of special communication, which takes into account the functional dependences of the quality indicators of the diagnostic process.

2. Essence of the Method of Formation of General Requirements to the Metrological Equipment

The method of forming general requirements for metrological equipment is based on the process of substantiation of the minimum required values of metrological characteristics (MCH) of measuring equipment (ME) (as the main component of metrological equipment) used during maintenance and repair of special communications, to reduce their value with restrictions on the time of establishing the technical condition or recovery.

Its essence is to scientifically substantiate the values of metrological characteristics of measuring equipment based on the use of functional dependences obtained in [4, 5], linking the value of the probability of correct estimation of the measurement parameter of special communication equipment with the average recovery time during maintenance and mathematical expectation deviation in the definition of a faulty element or a typical element of replacement of special means of communication. This task is performed under the condition and taking into account the performance of tests according to the conditional algorithm of diagnosing any form and type, which are built according to the recommendations of modern achievements of technical diagnostics.

The use of the proposed method involves taking into account the following limitations: the implementation of the current repair of special communications by the aggregate method; choice of measuring equipment from the established list; if there is one error in the evaluation of the measurement result of the parameter, the faulty element must be in the unit (unit, thesis, unit) which is being replaced.

The implementation of the proposed method involves taking into account the following assumptions: during maintenance or current repairs, the presence of no more than one defect in the MSC is assumed; in the process of determining the technical condition of the MSC is not allowed the presence of more than one error in the evaluation of the measurement result of the parameter; the procedure for performing inspections is set by the CAD MSC of the optimal form by the criterion of minimum T_v; maintenance or current repair MSC is performed by the crew of hardware communication or hardware technical support; the qualification of specialists corresponds to the position according to the staff list; the communication hardware and the technical support station have serviceable technological equipment and a complete set of documentation.

The limitations and assumptions correspond to the actual operating conditions of the MSC in the field.

The mathematical apparatus of the method is based on the use of methods of measurement theory, probability theory, discrete search theory, graph theory and discrete mathematics to obtain functional dependences of ME deviation of the technical state of the MSC from its true value under given constraints and assumptions, and computer simulation variables on the results.

The main functional dependences and analytical expressions used in the method are given in Table 1 [6, 7].

The initial data are as follows:

L is number of TRE;

t_y is average troubleshooting time;

μ is number of specialists;

T_{vd} is allowable recovery time.

If $\mu = 1$ and the MSC has built-in diagnostic tools, then enter the following:

K_1 is is the depth of the defect search with built-in diagnostic tools;

K_2 is the average number of ME inspections;

p_1 is the probability of correct evaluation of the test result by built-in diagnostic tools;

t_1 is average time of inspection by built-in diagnostic tools;

t_2 is average time of ME verification;

M is the maximum value of the CAD selection module.

Table 1
Indicators of quality of diagnostic support

Type of redundancy	Characteristic CAD	P	T_v	ρ
Temporary $U = 1$	Repeat r the first B checks	$(2-p)^r p^K$	$\frac{t(K+r)+t_y}{P}$	$P(1-p)\times \times\frac{\left[L+K-1-p\left(L+r-2^{K-r}\right)\right]}{2p}$
Functional $U = 2$	Distribution of MSC of B parts	$p^{K-log_2 B}$	$\frac{t\,log_2(L/B)+t_y}{P}$	$0.5\left(\frac{L}{B}+\log_2\frac{L}{B}-1\right)\times \times(1-p)\,p^{\log_2(L/B)-1}$
Constructive $U = 3$	Binary CAD of the minimum form	p^K	$\frac{Kt+t_y}{P}$	$0.5\left(\frac{Z}{l}+\log_2\frac{Z}{l}-1\right)\times \times(1-p)\,p^{\log_2(Z/l)-1}$
Information and structural $U = 4$	Modified inhomogeneous	$p_1^{K_1}\ p_2^{K_2}$	$\frac{K_1 t_1+K_2 t_2+t_y}{P}$	$0,5\left[\begin{array}{l}(1-p_1)\,p_1^{K_1-1}p_2^{K_2}\times \\ \times\sum_{i=1}^{K_1}\left(1+(M-i)!\right)+ \\ +p_1^{K_1}(1-p_2)\,p_2^{K_2-1}\times \\ \times\sum_{i=1+K_1}^{K_1+K_2}\left(1+(M-i)!\right)\end{array}\right]$

If $\mu=1$ and the built-in diagnostic tools are absent, we enter the following:

t is average time of performance of check;

K is the average number of inspections;

Z is the number of elements of the MSC;

l is the number of elements in the TRE;

U is type of redundancy of MSC ($U=1$ temporary, $U=2$ functional, $U=3$ constructive);

B is division of the MSC into B parts;

r is repetition of the first inspections on CAD.

If $\mu>1$, then use a group search for defects and additionally enter the following:

D is type of group search for defects ($D=1$ independent group search of defects, $D=2$ zone group search of defects, $D=3$ joint group search of defects);

m is CAD selection module;

t is average time of inspection.

For $D=2$, the following is additionally introduced: n is is the number of defect search zones (number of subsystems or MSC blocks).

3. The Main Stages of the Method of Formation of the General Requirements to the Metrological Equipment

The algorithm for implementing the proposed method involves the following steps: obtaining and analyzing the original data; under the condition of performance of works by one expert ($\mu=1$) and presence in MSC of the built-in means of diagnosis use algorithms of Figs. 1 and 2; for $\mu=1$ and the absence of built-in diagnostic tools in the MSC using the algorithms of Figs. 3 and 4; under the condition of group search of defects depending on its type use algorithms of Figs. 5–7.

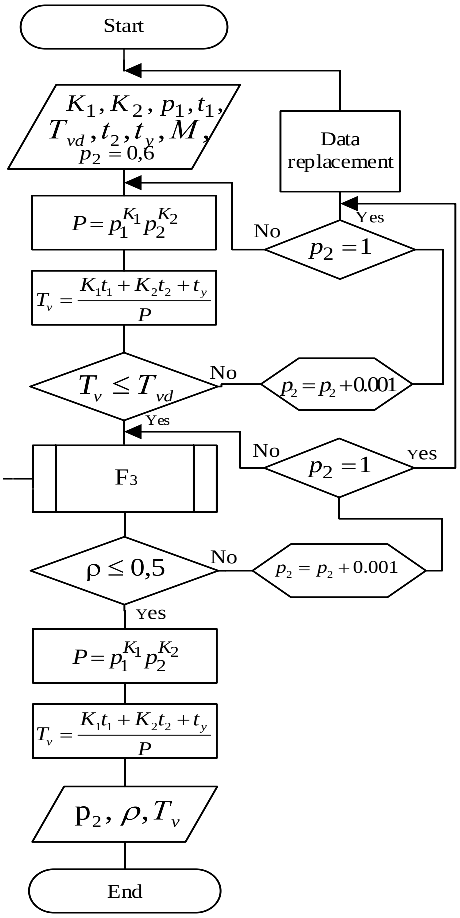

Figure 1: Block diagram of the algorithm for calculating the minimum allowable value of the probability of correct evaluation of the test result by external means of measuring equipment

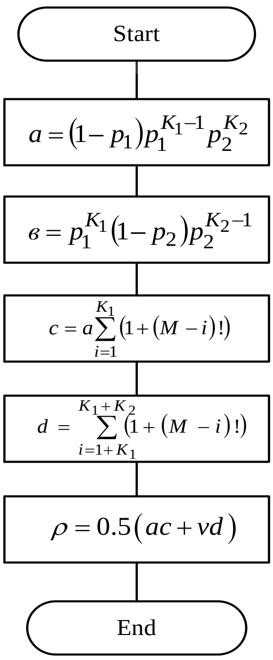

Figure 2: F3 “Calculation of the mathematical expectation of the deviation of the diagnosis”

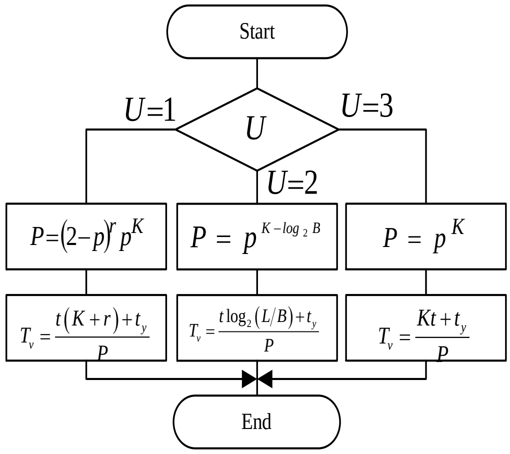

Figure 3: F1 “Calculation of the average recovery time”

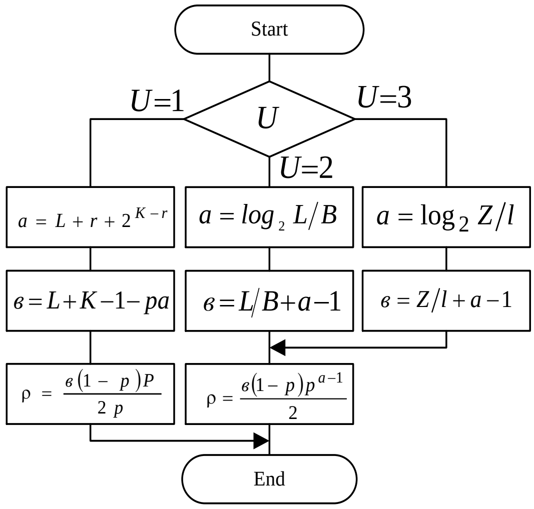

Figure 4: F2 “Calculation of the mathematical expectation of the deviation of the diagnosis”

4. Research Method of Forming General Requirements for Metrological Equipment

Consider the influence of the dimension of the object L on the quality of recovery p, P, ρ, T_v during the implementation of possible types of group search for defects (1 - independent group search for defects, 2 - zone group search for defects, 3 - joint group search for defects) with restrictions $T_v \le 20\,(m)$ and $\rho \le 0.5$ (Figs. 8–11). Their analysis shows that with given restrictions on the quality of restoration of the object with a small dimension, it is possible to use an independent group search for defects, which reduces the requirements for ME ($p_1 < p_2 < p_3$), in addition, this type of group search for defects provides with increasing L decrease P_1 and ρ_i for due to the increase in p_1. But based on the analysis of the behavior of the average recovery time in all cases, it is advisable to use a joint group search for defects ($T_{v3} < T_{v2} < T_{v1}$), although when increasing the dimension of the MSC to $L = 100$ obtain $\rho_3 > \rho_2 > \rho_1$ by increasing the requirements for MSC ($p_1 > p_2 > p_3$). In all cases for the set restrictions on T_v and ρ realization of all types of group search of defects is possible.

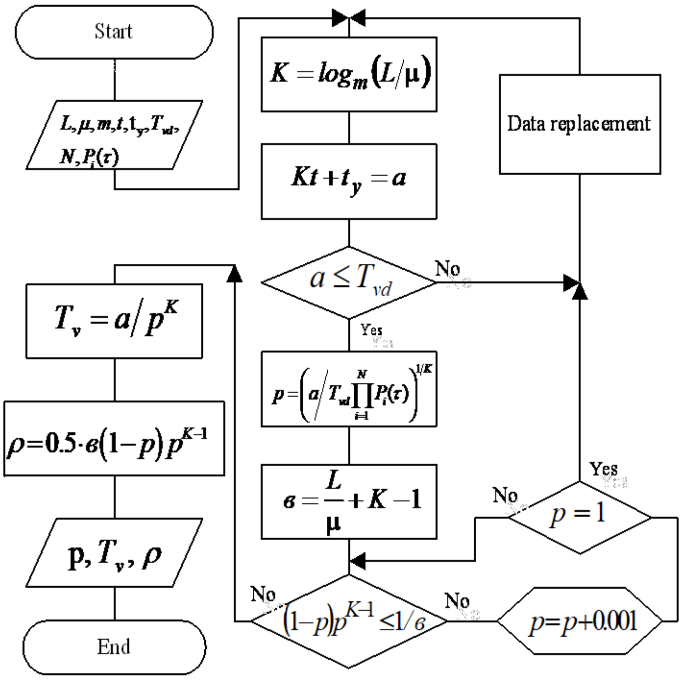

Figure 5: Block diagram of the algorithm for finding the minimum required value of the probability of correct evaluation of the test result in an independent group search for defects

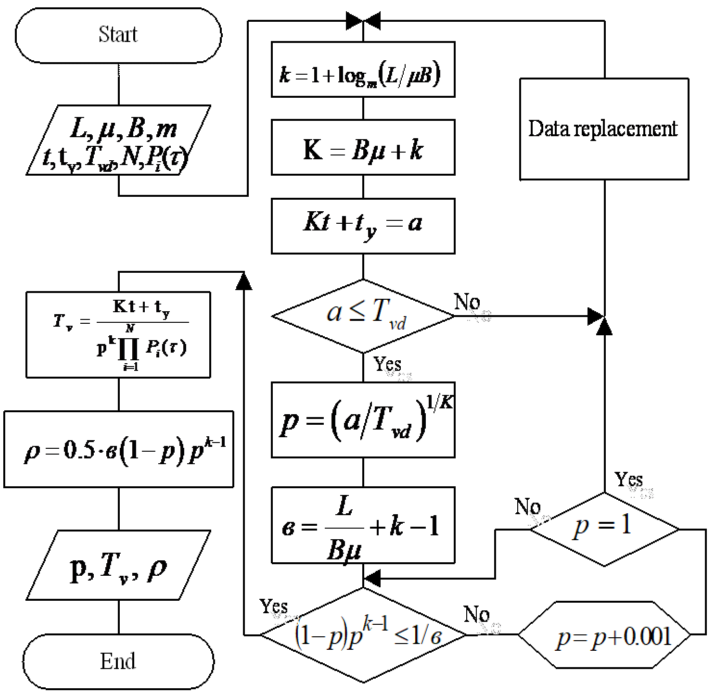

Figure 6: Block diagram of the algorithm for finding the minimum required value of the probability is correct evaluation of the result of the inspection during the zone group search of defects

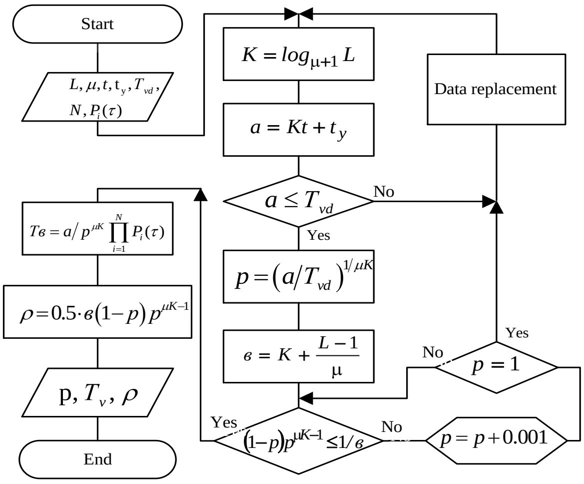

Figure 7: Block diagram of the algorithm for finding the minimum required value of the probability of correct evaluation of the test result in a joint group search for the defect

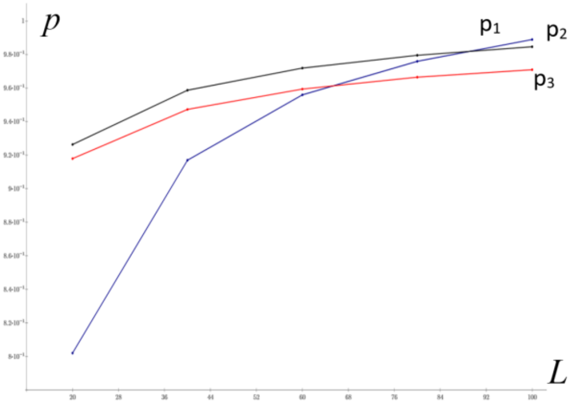

Figure 8: Dependencies of the required value of the probability of correct evaluation of the test result on the dimension of the object and the type of group search for defects for the given restrictions on T_v and ρ

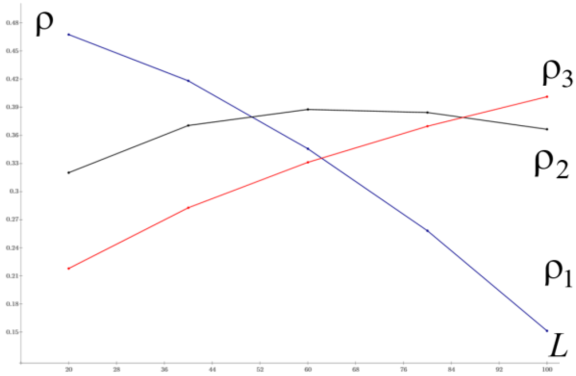

Figure 10: Dependences of mathematical expectation of deviation of the diagnosis at one error of the expert in estimation of result of performance of check on dimension of MSC and a kind of group search of defect for the set restrictions on T_v and ρ

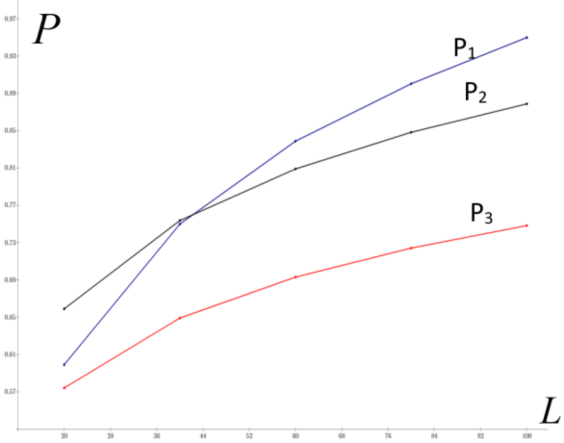

Figure 9: Dependences of the probability of correct diagnosis on the dimension of MSC and the type of group search for the defect for the given restrictions on T_v and ρ

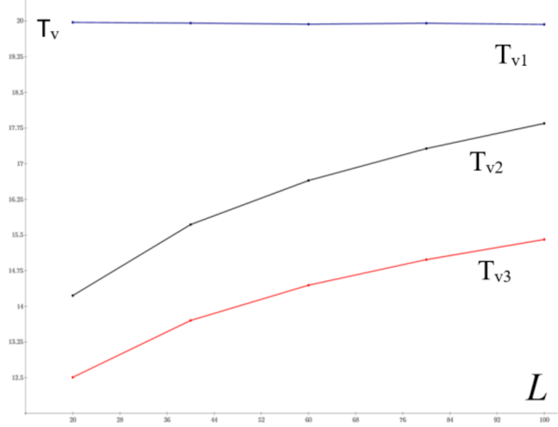

Figure 11: Dependences of the average recovery time of the GCC on its dimension and type of group search for the defect for the given restrictions on T_v and ρ

After obtaining the minimum allowable value of p, at which $T_v \le T_{vd}$ and $\rho \le 0.5$, according to known methods determine MCH ME: accuracy class (K_T), the division price and the length of the scale of analog ME [8–10] or the number of digits (r) digital ME. The cost of the ME will be minimal.

5. Example of Application of the Proposed Method

The order of use of the method is considered on the example of the selection of ME for maintenance of the path R-423 [11] for the following initial data from [7]:

$L = 51, T_{vd} \le 20\ m$,

$t = 3\,m,\ t_y = 5\,m$,

$n = 2,\ m = 2,\ \mu = 2$.

The conditional algorithm of joint group search of defect is given in Fig. 12. The results of calculations are given in Table. 2.

Table 2
The results of modeling a group defect search

Group defect search type	p	ρ	P	T_v, m
Autonomic	0.989	0.150	0.950	20.00
Joint	0.967	0.383	0.786	16.23

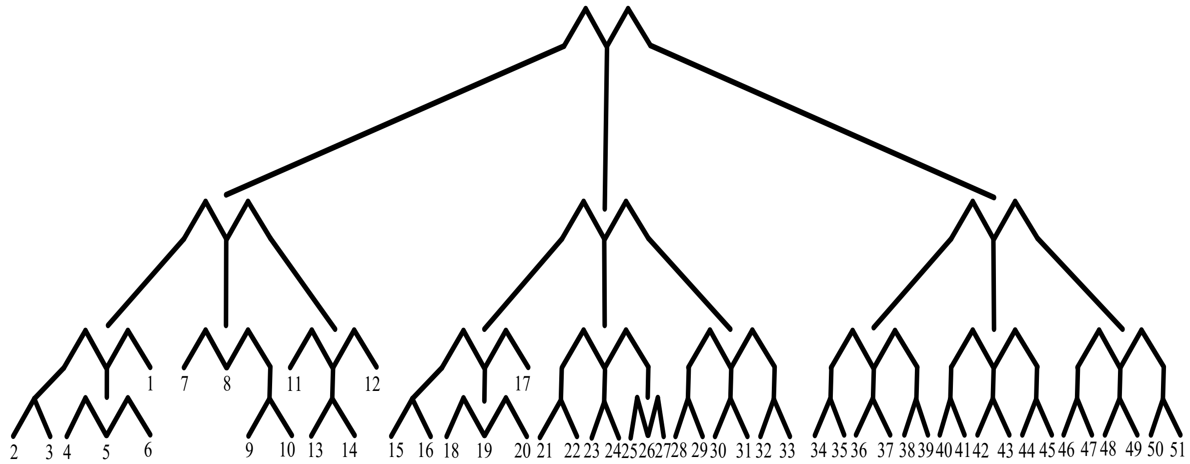

Figure 12: Conditional algorithm of joint group search of defect

In this case, the zone group defect search does not provide the required value of the recovery time, because $T_v > 30$ m. The best result is provided by use of joint group search of defects, thus in comparison with independent group search of defects requirements to ME decrease and value decreases to 20%.

The best result of the prototype [11] provides a joint group search for defects: $p = 0.995; P = 0.911$; $T_{vd} \le 17.3$ m.

The effect of using the proposed method is to reduce the requirements for ME ($p = 0.967$ instead $p' = 0.995$), as well as to reduce the average recovery time of MSC during CR by 6.4% ($T_v = 16.23$ m instead $T_v = 17.3$ m of the prototype). That is, the effect of the implementation of the method is equal to a 3% reduction in the requirements for the probability of correct assessment of the test result. This not only reduces the recovery time, but also significantly reduces the cost of ME used during the CR of the P-423 tract.

The novelty of this method is a comprehensive consideration of these factors and the development of a new algorithm for its implementation using the new analytical expressions obtained in the paper and the functional dependences of maintenance MSC indicators on controlled variables [12–15].

6. Scientific and Methodological Recommendations for the Practical Use of Research Results

The method proposed in the paper should be used when improving the system of technical operation of existing MSC, or when creating new models, in order to meet the requirements for the average recovery time with minimal ME costs.

Ensuring a fairly high level of efficiency of the State system of special communication and information protection of Ukraine is possible with a comprehensive solution to the problems of developing promising and operation of existing models of MSC with their appropriate technical support with minimizing the cost of maintenance, CR, and elimination of accidents and combat damage. Solving this problem requires not only the training of specialists in the operation and repair of the MSC, but also the creation of the necessary material and technical base, and a significant part of its cost is metrological equipment (and, in particular, ME). Therefore, the task of reasonable choice of the nomenclature of metrological equipment is relevant. This task is solved in order to ensure the necessary requirements for the reliability and maintainability of the MSC, provided the minimum cost of metrological equipment.

The accepted limitations and assumptions in the implementation of the proposed method fully comply with the conditions of technical operation, maintenance, CR and elimination of multiple defects of the MSC by the staff crews of hardware or hardware in the field.

Experimental verification of the received methodical recommendations on the basis of the offered method was carried out in 10 territorial nodes of the governmental communication and the State research institute of Special communication.

The method developed in the paper differs from the known availability of source data, taking into account not only the circuit and design features of the MSC, but also the use of all types of their redundancy to improve the efficiency of diagnostic software, which reduces the average recovery time and reduces the requirements for MCH ME, that is reduces their cost. The use of the method does not require additional training of repair specialists, which was confirmed during the experimental verification of scientific results in the improvement of maintenance of the troposphere communication station R-423 in the 10th territorial node of government communication.

The obtained results are brought not only to the formalized methodology, but also to the corresponding software that allows their use in scientific institutions and industry of Ukraine.

7. Conclusions

The paper offers general provisions, essence, main stages, research results and an example of application of the method of formation of general requirements to the metrological equipment used during maintenance and current repair of special communication means.

Based on the results of experimental research of the obtained scientific results, recommendations for their practical use have been developed. It is positive that not only the activity of specialists during the implementation of the method is formalized, but software is obtained that allows the use of new scientific results in scientific institutions during the modernization of existing or development of promising samples of special communications for their effective maintenance using modern achievements discrete search theory in recovery.

Applying the developed method to other complex technical systems will give a correspondingly different effect. The use of the method does not require additional training of repair specialists, which was confirmed during the experimental verification of scientific results in the improvement of maintenance of the tropospheric communication station R-423 in the 10th territorial node of government communication.

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