Analysis of the Problem of Ensuring the Reliability of the Information System

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Abstract

The article is devoted to the analysis of the problem of ensuring the operational reliability of communication equipment and automation and substantiating the approach to its solution based on the intellectualization of monitoring and diagnostics processes. The analysis of the state of the subject area of the study is carried out, the relevance of the topic of the work is substantiated, the problem situation is determined. A mathematical model of the influence of technical personnel training in troubleshooting on improving the operational reliability of communication equipment and automation has been developed, which is a formal modeling basis for the implementation of the process of knowledge formation for the diagnostic knowledge base on communication equipment and automation malfunctions.

Keywords

Communications and automation, learning expert system, IS reliability, mathematical model, reliability management system

1. Introduction

An example of an information system is a dispatch control point, which includes communication and automation equipment (CA). At present, a large increase in the number of communication and automation equipment can be explained by the increase in the importance of the tasks solved with its help. The increase in the number and complication of the internal structure of the CA directly depends on such an indicator as reliability. In this regard, the issues of ensuring the reliability of the CA equipment is a priority task [1,2].

Taking this into account, the scientific task of this work can be defined as the task of developing scientifically based models and methods of data processing and identifying from them the main factors and relationships that characterize the technical state of the CA equipment in order to form a diagnostic knowledge base of a training expert system based on them, and substantiate a methodical approach to its use, for further training of technical personnel in troubleshooting in CA equipment [3, 4, 5].

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2. Analysis of the problem of ensuring the reliability of IS and justification of the approach to its solution based on the intellectualization of control and diagnosis processes

The general trends of improving the quality of electronic means are due to the change in the appearance of the element base and the increasing complexity of the equipment. At the same time, it is noted that the first developments of CA equipment samples on a new microelectronic element base, providing a significant increase in the functional characteristics of CA equipment, were not accompanied by a corresponding increase in reliability. The reason for this situation is the contradiction between the high growth rates of complexity of CA equipment and the limited growth rates of reliability of electrical and radio products (ERP) components [6, 7].

The high sensitivity of the microprocessor element base to regime and operational factors, as well as to unregulated technological influences, creates objective obstacles to its widespread introduction into CA equipment. Figure 1 shows how, with the change of generations of the element base, the composition of factors that have a negative impact on the reliability of electrical and radio products (ERP) changes, and the characteristic of the relative sensitivity of ERP of different generations to the effects of these factors is given.

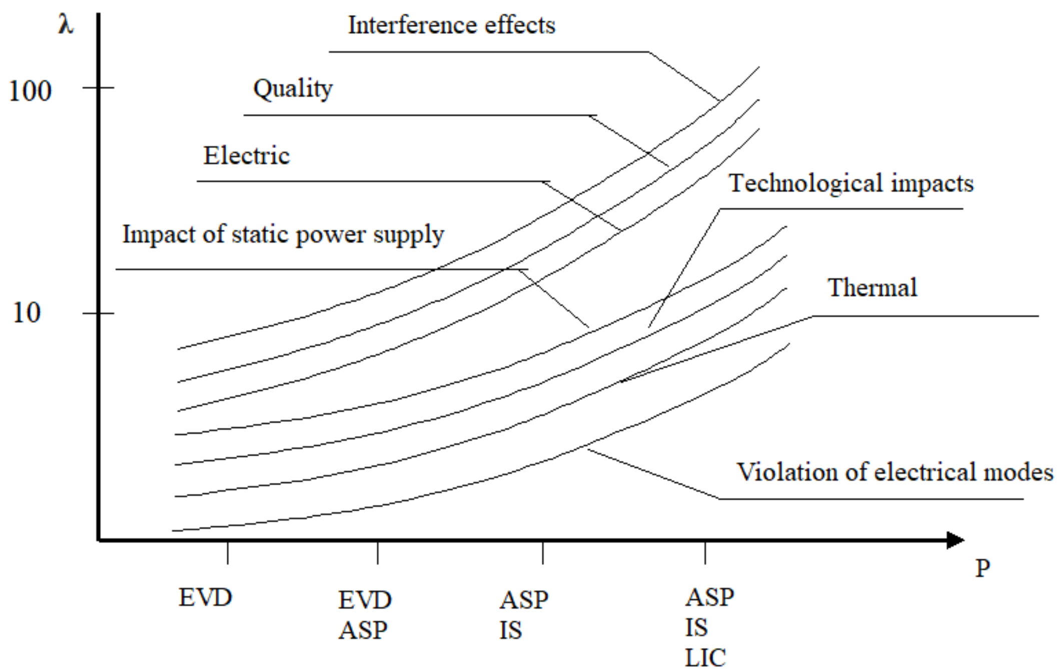

Figure 1: Dependence of the sensitivity of the element base of the CA equipment to the effects of factors that reduce their reliability

Stagnation of ERP reliability growth (Figure 2), which are used for the development and production of CA equipment, reduces the ability of its developers to provide high reliability indicators of equipment by circuit and structural methods [8].

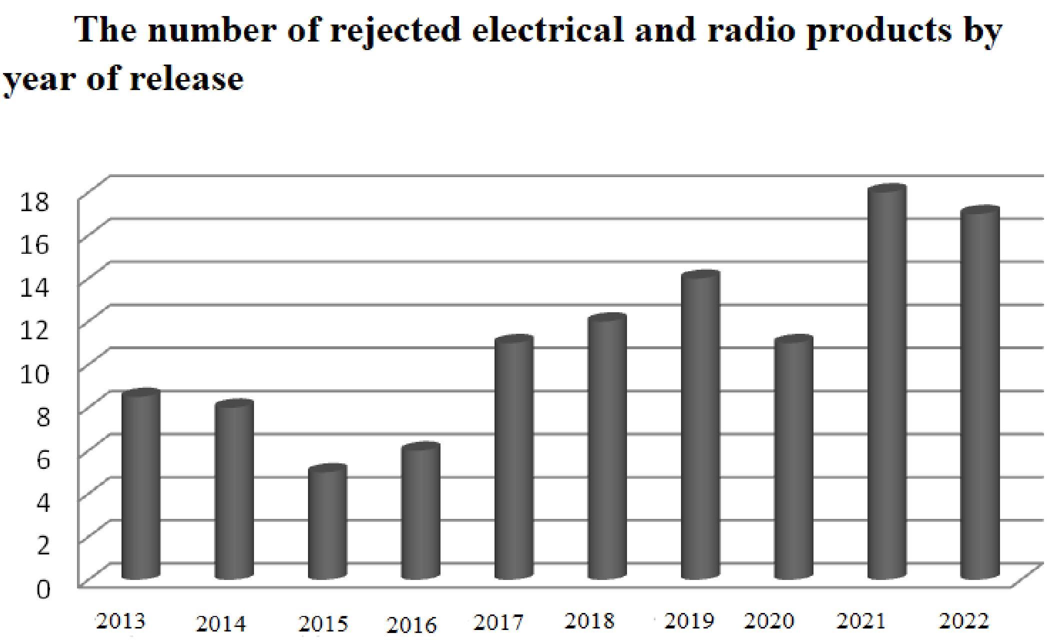

Figure 2: The number of rejected ERIS used in CA equipment by year of release

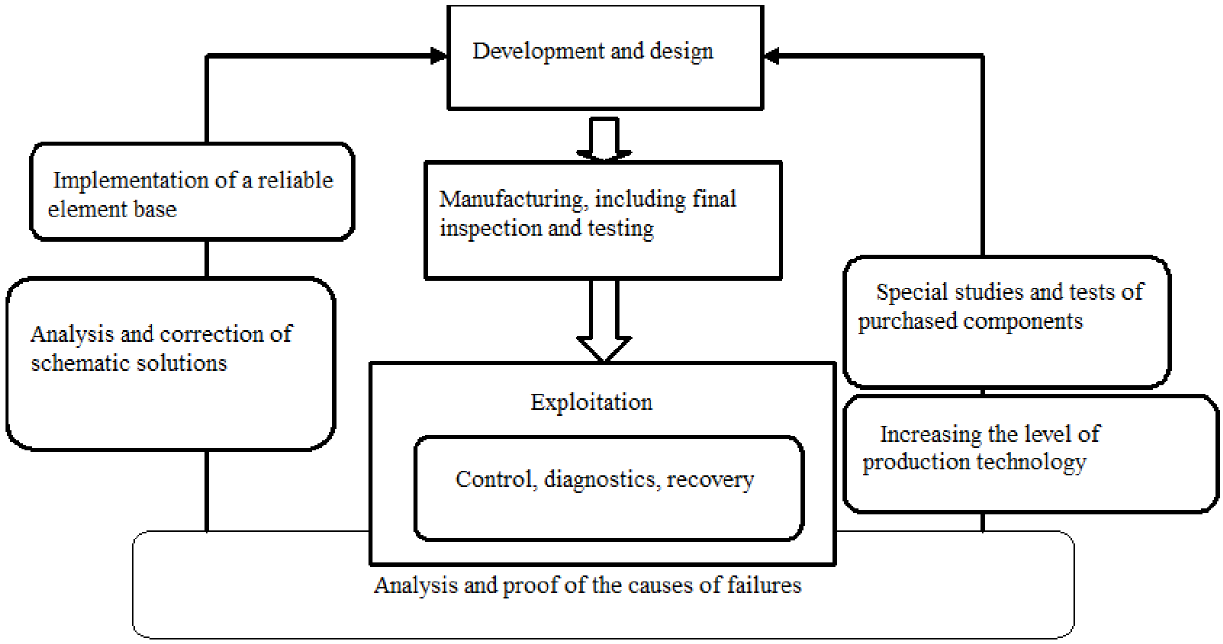

Figure 3: The structure of an integrated approach to managing the reliability of CA equipment

Summarizing the above, it can be argued that for the present time there is a significant contradiction between the high growth rates of complexity of systems and the limited growth rates of reliability of components. This increases the urgency of the problem of ensuring the required reliability of the CA equipment and forces us to look for ways to solve it not only in the field of technological, circuit and design solutions, but also in the direction of developing diagnostic software. The existing reliability programs are a priori focused on some of the most general data on possible malfunctions of the CA equipment [9,10,11]. This leads to the fact that objective knowledge about the cause-and-effect relationships of the occurrence, development and manifestation of a malfunction in the form of a failure is ignored, does not take into account the design and technological features of the developed samples of equipment. One of the most important conditions for the implementation of an integrated approach to reliability management, aimed at ensuring the required reliability indicators, is the implementation of effective diagnostic procedures for CA equipment (Figure 1, 2, 3) in operation.

2.1. Mathematical model of the influence of technical personnel training in troubleshooting on improving the operational reliability of the IS

It should be noted that the main purpose of creating and using a system of technical monitoring and diagnostics (STMD) [12, 13, 14] is, ultimately, to ensure reliability, while maintaining a high value of the coefficient of technical use of the CA equipment.

If the CA equipment is considered a subsystem of the control room (CR), then it is advisable to assess the place of the indicators characterizing the STMD of the CA, which is a set of the object of control, which is the equipment of the CA, controls and performers who monitor, and, if necessary, diagnose, in accordance with the requirements of operational and technical documentation, in the system of indicators characterizing the reliability of the CR. The generalized reliability indicator meets this goal to the greatest extent [15, 16].

Generalized reliability indicator of the P_{CR} [17]:

$$P_{CR} = P^{*}_{CR}\, P_{CA} \tag{1}$$

where P_{CA} is a generalized indicator of the reliability of the CA equipment (Equation 1), P_{CR}, is a generalized indicator of the reliability of the DP without taking into account the CA equipment [18].

Thus, the task in the requirements for an CR the requirements for the reliability of the CA equipment. Let's analyze the CA indicator, which in essence represents the probability of the correct functioning of the CA equipment at an arbitrary moment of application, which is the simultaneous occurrence of the following events: A_1 – at the time of t_K submission of the executive command for use, the CA equipment is in working condition; A_2 – during the time from the moment t_K of the submission of the executive command to the moment t_n of the beginning of the processing of this command, the CA equipment remained in working condition and prepared for the execution of the received command; A_2 – during the period from the moment t_n to the moment of operation at the stage of ensuring the passage of CR objects, the CA equipment functioned correctly [19]. Then

$$P_{CA} = P\{A_1\}\ P\{A_2\}\ P\{A_3\} \tag{2}$$

Indicators $P\{A_1\}$ $P\{A_2\}$ $P\{A_3\}$ are the probabilities of trouble-free operation of the CA equipment in various modes at time intervals τ_e, τ_{dov}, τ_{func}, that is, they are indicators of the reliability of the CA equipment (Equation 2). Probability $P\{A_2\}$ it depends on the reliability of the equipment that ensures the delivery of the executive team and the reliability of the CA equipment, as well as the time during which this training was carried out. As a rule, in practice $P\{A_2\} \approx 1$.

Probability $P\{A_1\} = K_T\{t_K\}$ is the coefficient of technical use of the CA equipment.

According to [18], this indicator is the ratio of the mathematical expectation of the time intervals of the object's stay in working condition for a certain period of operation to the sum of the mathematical expectations of the time intervals of the object's stay in working condition, downtime caused by maintenance, and repairs for the same period of operation: K_T and $\{t_K\} = M[\tau_p]/M[\tau_e]$.

The probability of K_T it is in close connection with the indicators of the operational properties of the second group and the organization of the operation of the CA equipment (in particular, with the effectiveness of all operational measures aimed at maintaining or improving the reliability of the CA equipment [20]). And the totality of the properties of the CA equipment is reflected, which, with this structure of operation, causes the possibility of an A_1 event. This combination, first of all, includes the reliability and manufacturability of the CA equipment. Taking into account the results obtained in [19], when assessing the coefficient of technical use of the CA equipment (Equation 3), it should be assumed that

$$K_{TM}\{t_K\}=K_r\{t_K\}K_n\{t_K\} \tag{3}$$

Where $K_r\{t_K\}$ the availability coefficient, which makes sense of the probability of finding the CA equipment in working condition at any time, except for the planned periods during which its intended use is not provided; $K_n\{t_K\}$ — a coefficient that takes into account the share of the total operating time of the CA equipment allocated for scheduled maintenance. Value τ_{dov} during operation, it may change depending on the condition of the CA equipment at the time of receipt of the executive command (Equation 4, 5).

Consider the readiness indicator $K_r\{t_K\}$. In accordance with:

$$K_r\{t_K\}=\frac{M[\tau_\rho]}{M[\tau_e]-M[T_{cn}]} \tag{4}$$

or

$$K_r\{t_K\}=\frac{M[\tau_\rho]}{M[\tau_\rho]-M[T_{ch}]} \tag{5}$$

In expressions the values $M[T_{cn}]$, $M[T_{ch}]$ the mathematical expectations of the time of planned and unplanned reduction of readiness are characterized, respectively.

From the obtained ratio it can be seen that the readiness indicator $K_r\{t_K\}$.

It is the most critical of those previously considered for unplanned decreases in the availability of CA equipment [21]. The value of $M[T_{ch}]$ is clearly due to the failures that occur, i.e. it characterizes the structural and technological components of the reliability of the CA equipment, and directly depends on the time characteristics of the troubleshooting processes. Therefore, taking into account the fact that the readiness indicator is a component of the generalized reliability indicator, it is advisable to use it to assess the impact of STMD characteristics on the reliability and operational efficiency of the CA equipment [22].

It is obvious that the mathematical expectation of the time of an unplanned decrease in readiness can be represented by the following ratio (Equation 6):

$$M[T_{ch}] = M[\tau_{ob}] + M[\tau_n] + M[\tau_{sb}] + M[\tau_{pr}] + M[\tau_{pn}] + M[\tau_{razb}], \tag{6}$$

Where $M[\tau_{ob}]$ – mathematical expectation of the time spent on detecting the failure of the CA equipment; $M[\tau_n]$ – the mathematical expectation of the time required for the arrival of the technical calculation to the DP, at which the failure of the CA equipment occurred (Equation 7);

$M[\tau_{sb}]$ – mathematical expectation of the time of the organization of the technical diagnostics system necessary to establish the place of failure in the CA equipment, i.e. connecting the diagnostic equipment to the failed CA equipment;

$M[\tau_{pr}]$ – mathematical expectation of the time of implementation of diagnostic programs for CA equipment; $M[\tau_{pn}]$ — mathematical expectation of the time of troubleshooting based on the information obtained during the implementation of diagnostic programs; $M[\tau_{razb}]$ – mathematical expectation of the time of bringing the CA equipment into a state of readiness for use for its intended purpose.

The diagnostic aspect of the STMD in the presented amount is taken into account by the terms $M[\tau_{pn}]$ and $M[\tau_{pr}]$, with $M[\tau_{pn}]$ it is one of the main components of time $M[\tau_{ch}]$. It should be noted that the random time $M[\tau_{pn}]$ in accordance with the logic of the process of troubleshooting and elimination of failure includes the times of all cycles consisting of processing diagnostic information by the calculation team, deciding on the location and causes of the malfunction, actions to restore the operability of the CA equipment and checking the restoration of operability using diagnostic tools. Other summands: $M[\tau_{ob}]$, $M[\tau_p]$, $M[\tau_{sb}]$, $M[\tau_{razb}]$ to a greater extent, they characterize the organization of the operation process.

In the process of implementing measures to bring the CA equipment from a state caused by a failure to a state of readiness for the implementation of the specified functioning algorithms, the personnel of the troubleshooting calculation performs certain groups of operations. These groups of operations can be divided into two fundamentally different classes. One class should include groups of operations, the sequence of which is predetermined in advance and regulated by the relevant instructions. In another class, it is necessary to allocate groups of operations, the logical sequence of which largely depends on the current situation and is determined mainly by the personnel of the troubleshooting calculation. Based on the above analysis, all groups of operations that determine the times can be assigned to the first class $M[\tau_{ob}]$, $M[\tau_p]$, $M[\tau_{sb}]$, $M[\tau_{razb}]$, whereas in the second group of operations that determines the time $M[\tau_{pn}]$.

To identify and evaluate the characteristics of the personnel of the calculation for troubleshooting when performing operations of each of the classes, it is necessary to build mathematical models that allow describing the essential patterns of the implementation of operations of the selected classes. However, in both cases, an approach based on the concept of operational efficiency is effective. At the same time, in accordance with [14], operational efficiency is understood here as timely and error-free performance by personnel of the required actions to find faults in the CA equipment. Violations of one operation or several consecutive operations, which is most characteristic of the random nature of their manifestation, are essentially short-term. Therefore, when considering such violations, it is advisable to proceed from the possibility of operational failures in the diagnostic system (faulty CA equipment, diagnostic tools and troubleshooting calculation).

And although in some cases the causes of operational failures may be various factors (irrational design of technical means, shortcomings of the documentation used and the algorithms performed, the psychophysical state of personnel, environmental conditions, etc.), the determining factor, other things being equal, is the professionalism (qualifications and experience) of the persons involved in troubleshooting. When determining the nature of the distribution of the time of occurrence of operational failures, it is necessary to proceed from the fact that this event itself is different from the event expected in this situation – timely and error-free execution of the required actions. On the other hand, since the required actions always have a given volume, the maximum of the distribution density function should not correspond to zero time. Based on these considerations, asymmetric distributions, in particular the truncated normal law, are most suitable for describing the duration of work of a given volume.

Let's use the α-distribution, whose parameters in this case will be $\alpha_B = \frac{m_B}{\sigma_B}$, the relative average productivity of the personnel of the calculation for troubleshooting during the implementation of troubleshooting operations in the CA equipment , $\beta_в = \frac{\vartheta_{rab}}{\sigma_B}$ the relative volume of operations performed to search for possible malfunctions in the CA equipment.

At the same time T_B и σ_B – respectively, the mathematical expectation and the standard deviation of performance, a τ_{rab} is the absolute volume of operations performed during the implementation of troubleshooting operations in the CA equipment.

Then the density of the α – distribution can be determined by the following expression (Equation 7).

$$f(t) = \frac{\beta_{\text{B}}}{t^2\sqrt{2\pi}} e^{-0,5}(\frac{\beta_{\text{B}}}{t} - \alpha)^2 \tag{7}$$

Figure 4 shows graphs of the dependence of the probability density function $f(t)$ for α – distribution at different values $\alpha_{\text{B}} f(t)$ (Equation 8).

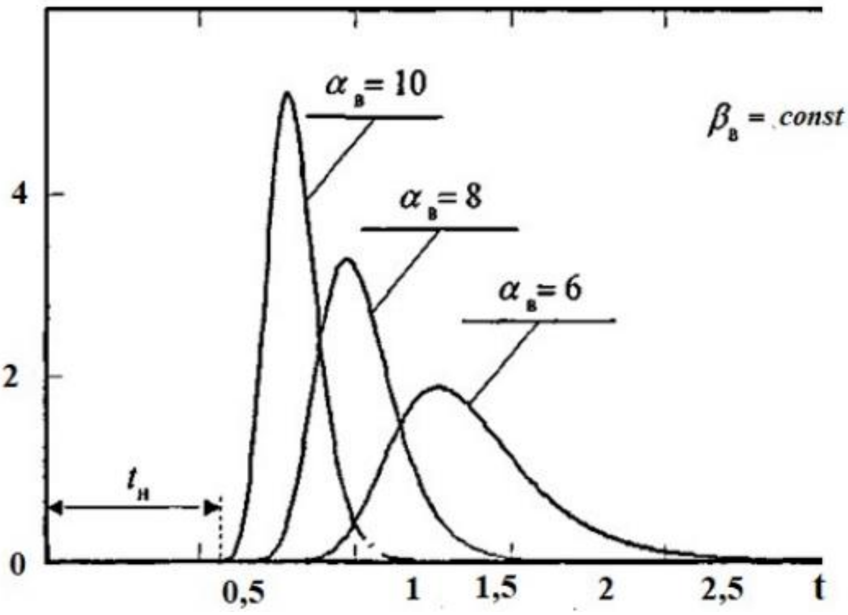

Figure 4: Graphs of the probability density function $f(t)$ for various values of α_B

From the presented figure it can be seen that a larger value of α_B corresponds to α_B smaller value of the most likely expected time to solve the problem of finding and troubleshooting in the CA equipment. It is quite obvious that the probability of solving the problem of finding and troubleshooting a malfunction in the CA equipment can be found on the basis of the following expression.

$$P(t)=\int_0^t f(t)dt = \int_0^t \frac{\beta_B}{t^2\sqrt{2\pi}} e^{-0,5(\frac{\beta_B}{t}-\alpha)^2} dt. \quad (8)$$

Graphical dependencies constructed on the basis of expression (8) corresponding to the graphs shown in Figure 4 are shown in Figure 5. From the graphs shown in Figure 5, it can be seen that some time has passed since the beginning of the troubleshooting process and the establishment of its causes t_n, during which the probability of successful completion of the process is almost zero. This is the time needed to clarify the current diagnostic situation, assess the signs that externally characterize the malfunction, analyze and compare the "image" of the malfunction with similar situations that occurred in the previous diagnostic experience. This time is the longer, the lower the value of the qualification and experience characteristics α_B, and the greater the value of the complexity of the current diagnostic situation β_B, moreover, dependence on, α_B, stronger than from β_B.

In addition, taking into account the finiteness of the troubleshooting process, as well as the limited time that can be allocated to this process, based on the above dependencies, setting the lower level of probability of solving the problem of troubleshooting, it is possible to assess the required level of qualification of the calculation for troubleshooting in the CA equipment. It follows from this that in order to reduce the time t_B it is necessary to increase the indicator T_B it is also necessary to reduce its spread σ_B by improving the skills of the staff.

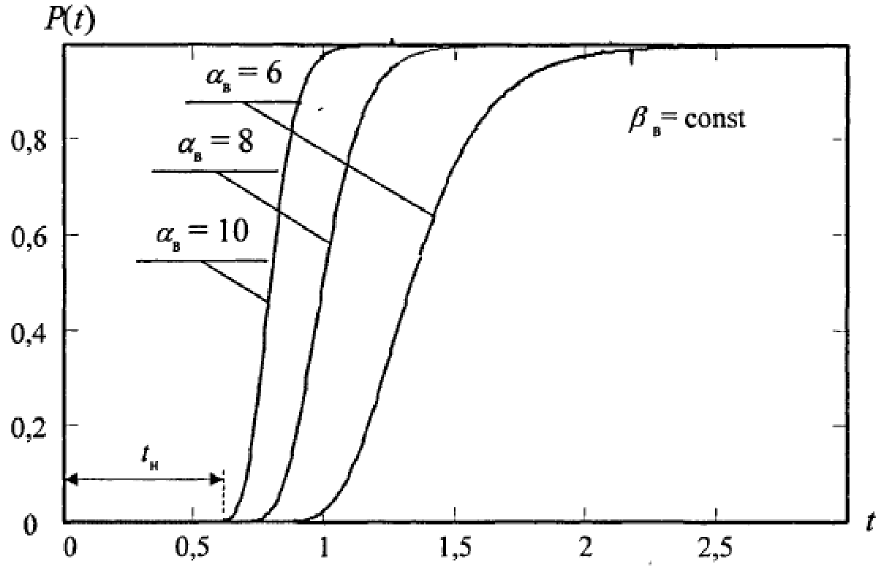

Figure 5: Functions: P(t)

Taking into account the above, the mathematical expectation of the troubleshooting time can be found based on the following expression:

$$M[\tau_{pn}] = \int_0^t f(t)dt = \int_0^t \frac{\beta_B}{t^2\sqrt{2\pi}} e^{-0,5(\frac{\beta_B}{t} - \alpha)^2} dt. \quad (9)$$

Based on the analysis of the above ratios, the following conclusion can be drawn between the reliability indicators of the CA equipment, indicators characterizing the process of diagnosing the CA equipment, such as the average operational duration of diagnosis (Equation 9, 10).

$$M[\tau_d] = M[\tau_{sb}] + M[\tau_{pr}] + M[\tau_{pn}] + M[\tau_{razb}], \quad (10)$$

and indicators m_B, σ_B taking into account the level of qualification and experience of the personnel of the troubleshooting calculations, there is a close relationship. This indicates the importance and relevance of the task of creating an expert diagnostic system, whose knowledge base and data should incorporate the experience of diagnosing CA equipment.

3. Conclusion

The complication of the CA equipment determines the high relevance of the tasks of checking the operability and troubleshooting. This fact is mathematically justified when analyzing the relationship between the indicators characterizing the degree of training of the calculation personnel for troubleshooting in the CA equipment and its operational reliability indicators. There is a close relationship between the quality indicators of the technical diagnostics system, such as the average operational duration of diagnosis, the probability of detecting a malfunction in a given time, indicators characterizing the level of qualification of the personnel of the calculations involved in its maintenance, an indicator taking into account the suitability for use in the control process, and especially the diagnosis of its information support, and indicators of the operational reliability of the CA equipment the relationship, the essence of which is revealed by the relations, obtained within the framework of this study, when developing a mathematical model of the influence of the training of technical personnel in troubleshooting on improving the operational reliability of the CA equipment. The effectiveness of solving the problem of ensuring the specified indicators of operational reliability of the CA equipment depends on many factors, among which, one of the most important is the degree of qualification (training) of the personnel of the calculations for troubleshooting the CA equipment. Given the complexity of the diagnostic task itself, the solution of which is carried out under conditions of a high degree of uncertainty and is characterized by rather limited possibilities of deterministic presentation of diagnostic information that has a precedent, and therefore depends on specific cases, the training of qualified specialists should be carried out on the basis of artificial intelligence approaches. This is due to the fact that it is artificial intelligence as a new scientific direction that a priori has the ability to take into account the fullest possible amount of useful information, different in nature, structure and form, which can be presented in knowledge and data bases. It is advisable to base the developed models intended for the intellectualization of fault finding in the CA equipment on the principles of abduction when observing the condition, precedent in identifying characteristics, integration in the accumulation of diagnostic information, rationality in the management of technical condition. The realization of the pragmatic potential of empirical information can be carried out within the framework of the empirical knowledge base. Empirical knowledge is understood as the information obtained as a result of diagnostic experiments, reflecting the stochastic relationship between the essential parameters of the object under study. These principles will be embodied in the structure of the empirical knowledge base.

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