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A METHOD OF ESTIMATING THE RELIABILITY OF HIGHLY RELIABLE REDUNDANT SYSTEMS BASED ON CONTINUOUS MODELS

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ABSTRACT

The paper deals with the method of assessing the reliability characteristics of highly reliable systems on the example of data centers, including many servers, some of which are considered as backup. The technique is based on the construction of approximate continuous models, which simplifies the calculations of highly reliable systems with redundancy. The paper presents the calculated relations that allow to estimate the average time between system failure and the average time of system recovery on the basis of the proposed approach. An example of the calculation of reliability characteristics. It is noted that the accuracy of calculations of reliability characteristics increases with the number of elements in the system. Classes of problems on calculation of reliability characteristics in the field of computer equipment are given, where the offered technique can bring undoubted benefit: calculation of reliability of the equipment of large computer systems and computer networks.

1. INTRODUCTION

Currently, computer systems and data centers (data centers) are an important part of both individual information management systems and the Internet as a global network. Their operation is subject to strict requirements for reliability: constant performance 24 hours a day, 7 days a week. The data center includes servers that are combined by standard network tools [1, 2]. High reliability of such systems is determined by hardware redundancy at different levels: backup of hard disks in RAID server subsystems, use of backup servers as part of the data center. It is known that the calculation of the reliability characteristics of redundant systems is a rather complex task, especially with a large number of system elements, including backup elements. Establishing a failure criterion in systems such as data centers is not an easy task.

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2. RESEARCH METHOD

The aim of this study is to develop a method for calculating the characteristics of the reliability of the data center as a highly reliable redundant system based on approximate continuous models.

Let us consider in more detail the methodology for assessing the reliability of the data center, consisting of elements-servers as a system with numerous backup elements. Suppose that the analysis of the data center operation allows us to formulate the criterion of data center failure as a simultaneous failure of a certain proportion of servers in the total number N. Thus, the failure of m servers out of the total number N, where $y = m/N$, and $m < N$, leads to the failure of the data center.

One of the methods used to assess the reliability of such systems is the construction of the corresponding algebraic equations relating the probabilities of the system States. The number of equations depends on the number of reserve elements. For the systems under consideration, the number of reserve elements can reach tens. Under these conditions, these discrete methods of analysis of such systems become very cumbersome and time-consuming.

Methods of reliability analysis of redundant systems based on approximate continuous models are known [3].

The advantages of using continuous diffusion models are explained by several reasons. First, for multi-element systems the discreteness factor is not so essential and complicates the practical application of discrete methods. Secondly, for systems with a large number of similar elements, the relativity of the failure criterion begins to manifest itself. It is difficult to prove that the system is serviceable at 10 failed elements and is faulty at 11 failed from 100. It is more expedient to pass to a share of the failed processors and to investigate values of characteristics of reliability at change of this share.

The given considerations justify the choice of continuous models for the analysis of system reliability.

The method of system reliability analysis based on continuous methods has the following form.

The initial equations for continuous methods of performance evaluation are the equations of death and reproduction:

$$\frac{dP_{i,n}(t)}{dt} = \lambda_{n-1} \cdot P_{i,n-1}(t) - (\lambda_n + \mu_n) \cdot P_{i,n}(t) + \mu_{n+1} \cdot P_{i,n+1}(t) \tag{1}$$

The state of the system at an arbitrary time n-failed elements denoted by E_n, the intensity of transitions of the system from state E_n to state $E_{n+1} - \lambda$ and μ - the intensity of transitions from E_{n+1} as E_n (λ_n and μ_n - analogues of intensities of failures and restorations). $P_{i,n}(t)$ — the probability of finding the system at the time t in the E_n state, provided that at the time t=0 the system is in the E_i state with i failed elements.

For systems with a large number of States, it is convenient to enter normalized variables $iN^{-1} = x$, $nN^{-1} = y$, where N is the total number of elements, and then represent the previous equation in the difference form:

$$\frac{\partial P(x,y,t)}{\partial t} = \lambda \cdot (y - \Delta y) \cdot P(x, y - \Delta y, t) - [\lambda(y) + \mu(y)] \cdot P(x, y, t) + \mu(y + \Delta y) \cdot P(x, y + \Delta y, t) \quad (2),$$

where $\Delta y = N^{-1}$.

In these notations, the values of x and y physically correspond to the proportion of failed elements at the time $t = 0$ and $t \neq 0$. As N increases, the change step Δy tends to zero, and the value y has a virtually continuous distribution. To construct continuous approximate solutions, we introduce another Markov process for which the step of changing the parameter y is k times smaller than for the original one.

On this mathematical basis it is possible [3, 4] to obtain that for the model with parameters λ=const, μ=const, the expressions for mean time between failures T_O and recovery time of T_B have the form:

$$T_O = \frac{e^{\beta \cdot y_1} - 1}{\mu - \lambda}, \quad (3),$$

$$T_B = \frac{1 - e^{-\beta \cdot (y_2 - y_1)}}{\mu - \lambda} \quad (4),$$

where $\beta = 2N \cdot \frac{\mu - \lambda}{\mu + \lambda}$,

y_1 — share of failed elements leading to system failure;

y_2 — share of failed elements leading to system shutdown, $y_2 \geq y_1$.

In accordance with the expressions (3) and (4), it is quite simple to conduct, for example, a study of the dependence of the mean time between failures and the average recovery time of the system on the value of the share of failed elements established as a criterion for the failure of the entire system.

3. ANALYTICAL RESULT

The main result of the study is the obtained expressions for estimating the mean time between failures and the average recovery time of a highly reliable system based on approximate continuous models. The considered technique considerably simplifies the analysis of reliability of systems with many reserve elements. It is interesting to note that in the case of time-varying λ and μ solutions of discrete problems are extremely cumbersome, for continuous models they can be obtained quite simply. The technique can be used for the number of elements in the system, constituting tens. Additional studies are required to estimate the error of calculations for the number of elements in the system of 20 or less.

4. CONCLUSION

This technique can be used to assess the reliability and efficiency of the organization of data centers, when data processing is carried out on many computers connected by a computer network, as well as the efficiency and reliability of the organization of computer networks. The accuracy of this technique increases with the number of elements in the analyzed system. In General, it can be noted that the assessment of the reliability of information systems based on continuous reliability models significantly simplifies engineering calculations and has good prospects for use.

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