Models for Estimation Downtime of a Systems with Redundancy and Maintenance

Leonid Ozirkovskyy, Taras Panskyi, Alexander Sydorchuk

Abstract: **The object of consideration is fault-tolerant radioelectronic system with redundancy and maintenance without automatic replacement of modules that are out of order. A structural-automatic model for such systems, which allows to determine the reliability indexes of such systems is developed.**

Keywords: **reliability, fault-tolerant systems, maintenance, reliability indexes.**

INTRODUCTION

Often choosing an effective strategy for increasing the reliability of fault-tolerant systems developers are faced with system downtime during their repair or maintenance. The system becomes unworkable in case of failure the module without automatic replacement its reserve module. To bring the system from this state, in different cases, but in general need to spend a long time: the arrival of repairman or repair crews, finding a suitable reserve module, replacing the faulty module and so on. During this time the system is not working, although it can be properly. This state is called downtime. These systems include:

- base stations of mobile communication (GSM, CDMA)
- Storage systems of information (RAID-arrays)
- information processing systems (telecommunications equipment)

A feature of such systems is that they are in states where systems modules may not be able to work and at this time is carried out or is expected repair, and only the exhaustion available repairs will lead to catastrophic failure.

STATEMENT OF THE PROBLEM

Minimization of downtime is a problem to be solved for such systems. Downtime is estimated a probability of downtime, which in turn depends on λ (the probability of failure system modules), and μ (quality of maintenance). To minimize downtime to find the right ratio of λ / μ. It is necessary to develop models for estimation of reliability parameters: the probability of downtime, function of availability.

The object of consideration are two systems:

- Ø fault-tolerant system with majoritarian structure (MS) which works by the principle 2 of 3 and consists of similar modules working configuration that provide realization of the algorithm function with a given quality level, and majority element [2,3,4].
- Ø Fault-tolerant radio-electronic system with n similar modules which has sliding reserve of m modules. Further will call such fault-tolerant system - m / n. Provides a recovery (unlimited, limited) of modules which are out of order [2,3].

CONSTRUCTION OF MODELS AND RESEARCH OF RELIABILITY PARAMETERS

To estimate the reliability of fault-tolerant reserved systems with downtime is necessary to construct their structural-automatic model (SAM). SAM constructed for fault tolerant systems with majoritarian structure presented in Table 1 for the system with the similar modules and sliding reserve - in Table 2

Table 1

Structural-automaton model of fault tolerant systems with majoritarian structure

Event	Condition	Formula	Alternative:	Modification
Відмова осн. мод.				
	(V1>1) AND (V2=0)	V1*L	1	V1:=V1-1; V4:=V4+1
	(V1>1) AND (V2>0)	V1*L	1	V1:=V1-1;V4:=V4+1
Відмова резерву				
	V2>0	V2*L	1	V2:=V2-1; V4:=V4+1
Відмова маж. ел.				
	V3>0	V3*Lm	1	V3:=V3-1; V5:=V5+1
Відновлення				
	V4>0	V4*M	1	V4:=V4-1; V2:=V2+1
підключення				
	(V2>0) AND (V1<N)	1/Tp	1	V1:=V1+1; V2:=V2-1

Table 2

Structural-automaton model of fault tolerant systems with similar modules and sliding reserve

Відмова осн. модуля				
	(V1>2) AND (V2>0)	L1*V1	1	V1:=V1-1; V3:=V3+1
	(V1>2) AND (V2=0)	L1*V1	1	V1:=V1-1; V3:=V3+1
Ремонт модуля				
	V3>0	M1*V3	1	V2:=V2+1; V3:=V3-1;
відмова рез. модуля				
	V2>0	L2*V2	1	V2:=V2-1; V3:=V3+1
підключення				
	(V2>0) AND (V1<N)	1/T	1	V2:=V2-1; V1:=V1+1

The research of reliability parameters carried out for such input data λ=(1000·μ; 100·μ; 10·μ; 1·μ; 0.1·μ; 0.01·μ; 0.001·μ) under conditions that time you connect is equal repairing time(T_p=T_n) and in a limited and unlimited recovery.

Developed SAM are inputs for software module ASNA, which generates automatic the diagram of states and transitions, forms and solves systems of differential equations the Chapman-Kolmogorov. The result is - distributed probability of staying in the states. As a result of analysis received distribution is necessary to identify conditions in which the system is unworkable, because there is

Leonid Ozirkovskyy - Lviv Polytechnic National University , S. Bandery Str., 12, Lviv, 79013, UKRAINE, E-mail:lozirkovsky@lp.edu.ua

maintenance, but not catastrophic failure occurred. These states are called downtime states.

Constructed a models for each fault tolerant system and received maximal values of downtime for the fault-tolerant system based on majority voting structure (see Table 3) and for systems with similar modules with sliding reserve (Table 4).

Table 3

Maximums probabilities of a downtime of fault tolerant system based on majority voting structure

	Необмежене відновлення			Обмежене відновлення
	Резерв 2	Резерв 10	Резерв 5	Резерв 2 , ремонти 2
μ=0,001λ	4,16E-01	0,798	0,642	4,11E-01
μ=0,01λ	4,15E-01	0,796	0,64	3,96E-01
μ=0,1λ	4,08E-01	0,788	0,624	0,396
μ=1λ	0,337	0,579	0,515	0,283
μ=10λ	0,0425	0,0431	0,043	3,54E-02
μ=100λ	5,83E-04	0,000561	0,000571	0,000565
μ=1000λ	6,59E-06	0,00000628	0,00000584	5,94E-06
μ=10000λ	1,79E-07	6,14E-08	6,58E-08	6,13E-08

Table 4

Maximums probabilities of a downtime of fault tolerant system with the similar modules with sliding reserve

	обмежене відновлення			необмежене відновлення		
	R=2	R=5	R=10	R=2	R=5	R=10
λ=100μ	9,98E-01	9,94E-01	9,87E-01	6,63E-01	8,63E-01	9,41E-01
λ=10μ	9,49E-01	9,07E-01	8,64E-01	6,50E-01	8,47E-01	9,22E-01
λ=μ	6,26E-01	5,48E-01	4,75E-01	5,49E-01	7,02E-01	7,45E-01
λ=0,1μ	1,83E-01	1,62E-01	1,40E-01	2,20E-01	2,31E-01	
λ=0,01μ	2,71E-02	2,61E-02	2,45E-02	2,91E-02		
λ=0,001μ	2,96E-03	4,72E-03	5,02E-03	3,08E-03		

Results of the research when changing the number of reserve modules and the ratio λ / μ is presented in Figure 1-3.

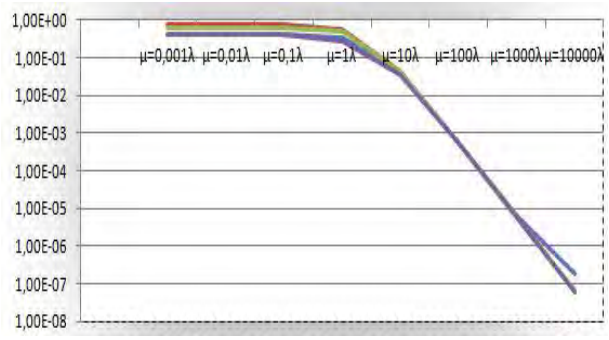

Fig. 1 Dependence of the maximum probability of a downtime on the ratio of μ to λ fault tolerant system based on majority voting structure

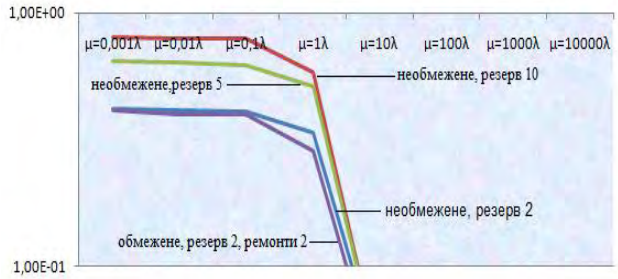

Fig. 2 Dependence of the maximum probability of a downtime on the ratio of μ to λ fault tolerant system based on majority voting structure

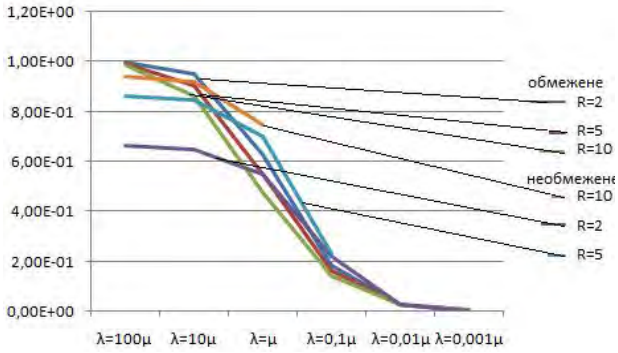

Fig. 3 Dependence of the maximum probability of a downtime on the ratio of μ to λ fault tolerant system with the similar modules with sliding reserve

As can be seen from this graph, the probability of downtime begins to fall sharply from the value λ = 0,1 μ, that is μ = 10 λ. So, when designing such a system, including reliability, also need to minimize downtime.

CONCLUSION

Constructed structural-automaton model of fault- tolerant systems with majoritarian structure and systems of the similar modules with sliding reserve which provides maintenance and repair. The developed model unlike the resulted in [2,3] allows to:

- To carry out a multivariate analysis of parameters of reliability fault-tolerant reserved systems taking into account the downtime.
- Set the limiting probability of a downtime and depending on its importance choose parameters of maintenance.
- Receive the values function of readiness at the minimum value of probability of downtime.

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