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SOFTWARE IMPLEMENTAYION OF IMPROVED RELIABILITY MODEL OF TECHNICAL REDUNDANT SYSTEM WITH A LIMITED NUMBER OF RESTORATIONS

This paper describes an algorithm and software implementation of improved reliability model of technical redundant system with a limited number of restorations. The correlation between the number of elements, the number of their restorations and the number of states of the system, time required for their formation, and calculations of results were investigated.

Keywords: software, reliability, technical system

***Introduction*.** An important component of the quality of complex technical systems is reliability - a property of a technical system to perform specified functions, preserving the value of operational index within the specified limits, which are corresponding to the terms of use and specified modes, maintenance, storage and transportation [1-3].

To analyze the reliability of technical systems mathematical tools of Markov random process are widely used that require previous design of mathematical model of reliability as a system of differential equations of Kolmogorov -Chapman [1, 2]. The main difficulty in the construction of the model is its large dimension, which can reach hundreds of thousands, even in the case of a small number of elements, especially if those items are renewable with a limited number of updates.

Overcoming this complexity is possible through the use of computational capabilities of modern computer tools for the automated construction of a graph of states and system transitions. This work is devoted to this task.

Problem and solution. In this paper a model of technical load redundant system with a limited number of restoration of elements is considered.

We should take into consideration the discipline of service to calculate the reliability of redundant renewable systems. In this paper direct restoration priority is used, i.e. the first element which stop working should be repaired first.

The main problem - a large number of states of system that depend on:

– number of reserve elements;
– number of restorations of element;
– number and availability of repair crews;
– priority of repair crews’ work.

In this paper, it is assumed that the test model of system existing reserve, it has several repair crews with direct priority, and takes into account all possible states of the node of system schematic diagram of which it is shown in [4].

Formation of system states is brute force combinations of elements states with taking into account the number of possible restorations, restorations, which are made, and the priority of recovery. Graph of states for system with multiplicity of reserve 1, one restoration and one repair crew with direct priority as shown in fig.1, where is assumed that the functional element is denoted – 0, element that refused - 1, [] is represented the number of made restorations; in {} – repair queue.

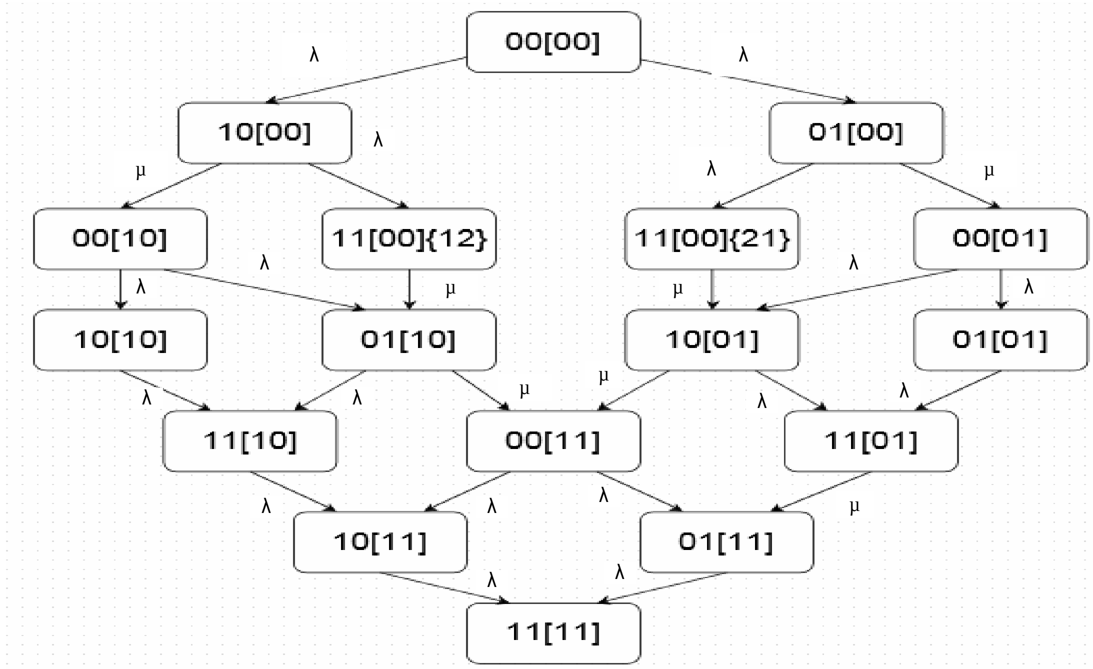


Fig.1. Graph of states.

The input data for the construction of reliability model is the number of elements in the node, the number of restorations and the number of repair crews, failure rate λ and restoration rate μ. After processing the input data the formation of all states of the system beginning. Then a system of equations of the Chapman-Kolmogorov is formed, which is soved using numerical methods. Then we proceed to the display of the graph of states and transition.

During the system design of improved reliability model was used multilevel architecture, was used as the program which provides interaction with MatLab.

During design, the architecture was selected classes that represent an element of node, node state and self-node (Fig.2).

The following tasks were completed:

- formation of system states
- reflection of the partial graph of states and transitions;
- calculating of reliability index and displaying them in graphs of probability of working state, downtime and critical failure.

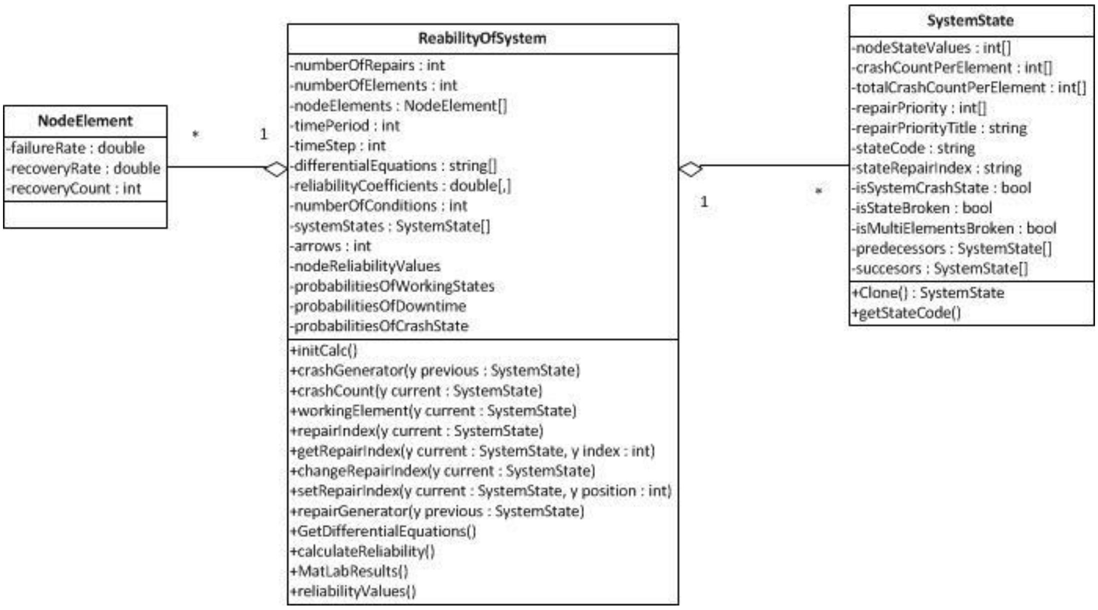


Fig.2. Class diagram of software implementation

As the main achievements we can specify the development of the algorithm of generating the graph of states for improved reliability model of technical redundant system with a limited number of restorations (Fig. 3), on which it was developed a software implementation as Windows Form Application (Fig.4).

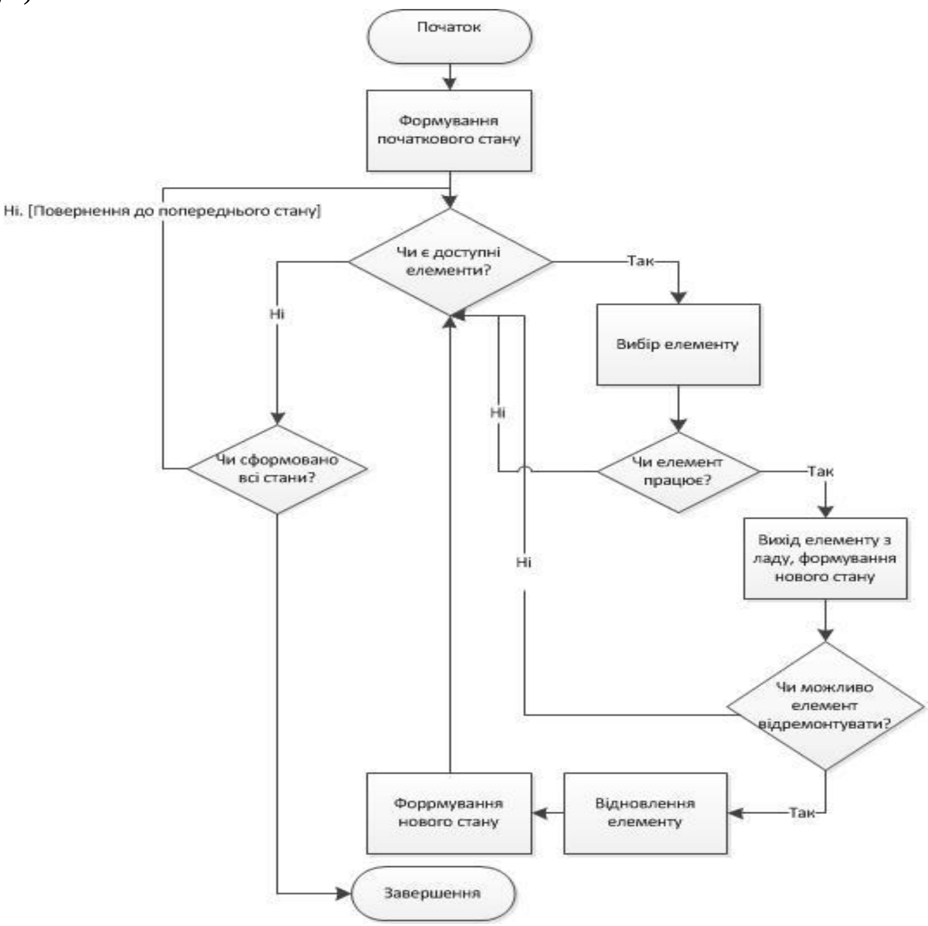


Fig.3. An algorithm for generating the graph of states

To receive the results remains to modify the algorithm to be able to work with systems with more elements in the node, to analyze the numerical methods and choose the one that would ensure the required speed and accuracy of the calculations.

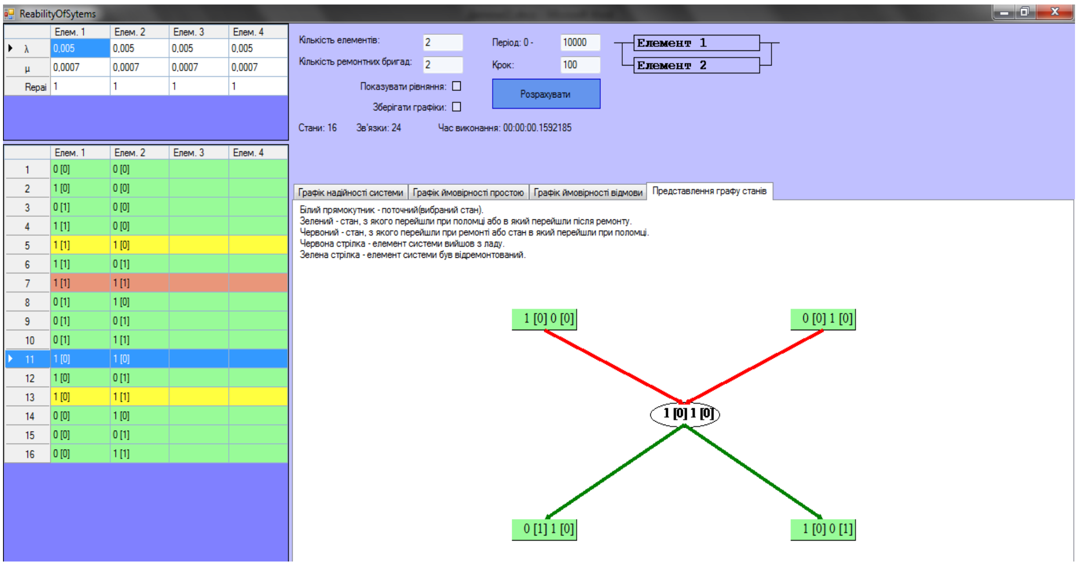


Fig. 4. The main window of the part of the graph states.

The program generates all state of technical reservation system with limited restorations and calculates reliability characteristics. After a series of experiments, it was determined that the program generates states for 5 elements in the system, but the more elements are, the less restorations are available.

The number of elements and the number of states for them and the largest number of possible restorations are given in Table 1.

Table 1. Number of elements, the number of states for them, the largest number of possible restorations

Number of elements	States	The largest possible number of restorations (in sum)
1	482	240
2	584	20
3	570	8
4	393	4
5	786	4

As seen from Table 1, with increased number of elements and recoveries - the number of states of the system increases significantly. Relevance of time of elements processing in one restoration and with the maximum number of restorations is given in Table 2.

Table 2. Temporal characteristics of elements processing in one restoration and with the maximum number of restorations

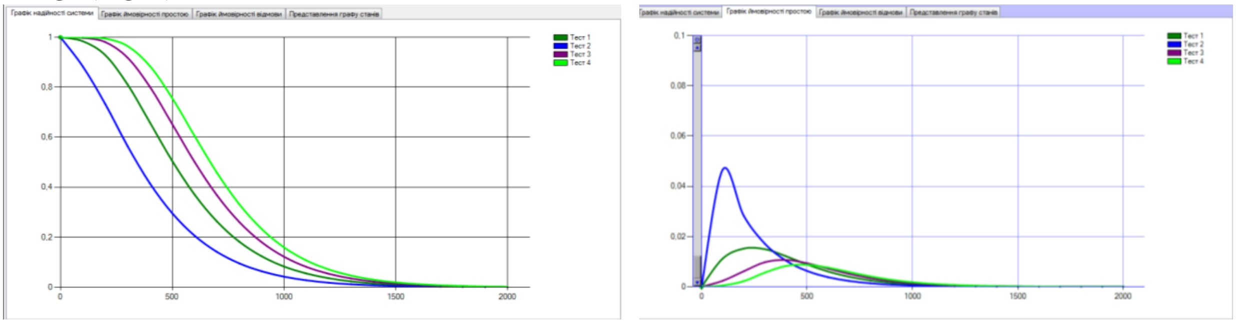
Number of elements	The processing time at 1 restoration (for element)	The processing time at the maximum number of restorations
1	< 1 sec	6:20 min
2	< 1 sec	12:20 min
3	1.4 sec	15 min
4	1:43 min	1:43 min
5	-	14 min

It was also investigated how the state of processing and the number of states dependent on increasing the number of repair crews. Table 3 presents the results for different number of elements, assuming that the number of restorations for each element is one.

Table 3. Time characteristics under different number of elements and repair crews

Repair crews / Number of elements	1	2	3	4
1	<1sec, 4 states	-	-	-
2	<1 sec, 17 states	<1 sec, 16 states	-	-
3	1.4 sec, 78 states	1,6 sec, 78 states	1,3 sec, 64 states	-
4	2 min, 393 states	2 min, 393 states	2 min, 393 states	1,5 min 256 states

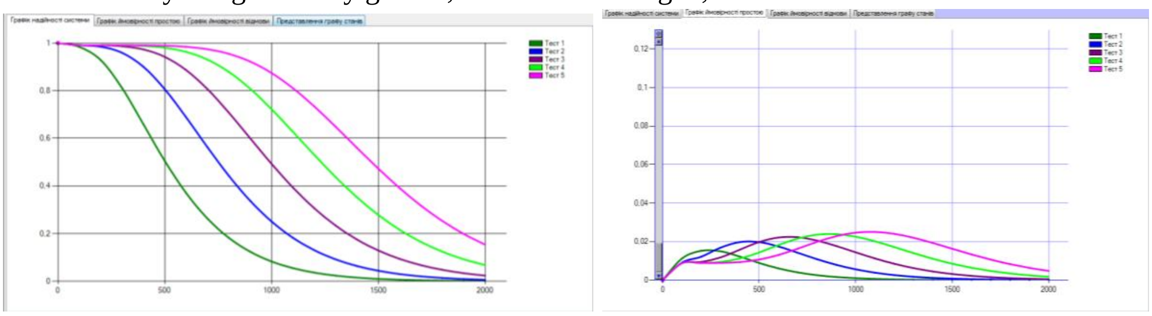
The numerical indicators of reliability can be shown in the form of graphs for the specified time range (Fig. 5).



a) b)

Fig. 5. Graphs of probability of no-failure operation (a) and the probability of downtime (b) of technical system for different number of elements

As seen from the graphs, probability of no-failure operation of the system increases disproportionate to number of items: if for 2 elements it increases significantly, with further increase of the number of elements the reliability increase is less. At the same time the probability of downtime greatly reduced when adding the second element, and with adding next elements it fluctuated within narrow limits. With increase of number of restorations for a sustainable number of elements the increase of reliability is significantly greater, as reflected in Fig. 6, 7:



a) b)

Figure 6. Graphs of probability of no-failure operation (a), downtime (b) for 2 elements with different number of restorations

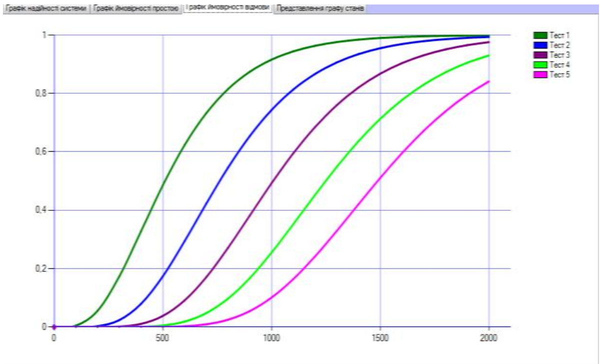
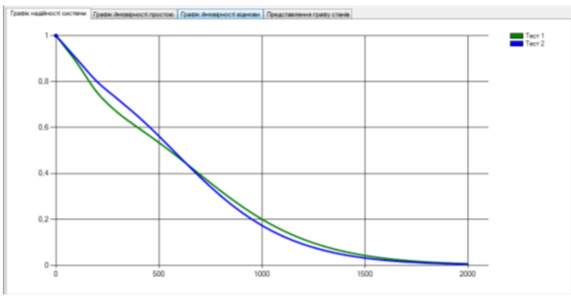
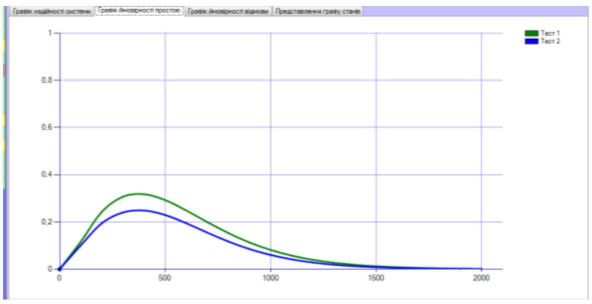


Figure 7. Graphs of critical failure probability for 2 elements with different number of restorations

As seen on the graphs, with increase of the number of restorations for 2 items from 1 to 5, the probability of no-failure operation of the system significantly increases (decreases the downtime at the beginning of the system work, but with further work it increases for some time, but only slightly), with increase not much different as the number of restorations; critical failure probability decreases in proportion to reliability. Also, the case of increasing the number of repair crews is considered, but on a constant number of elements and restorations to them:



a)



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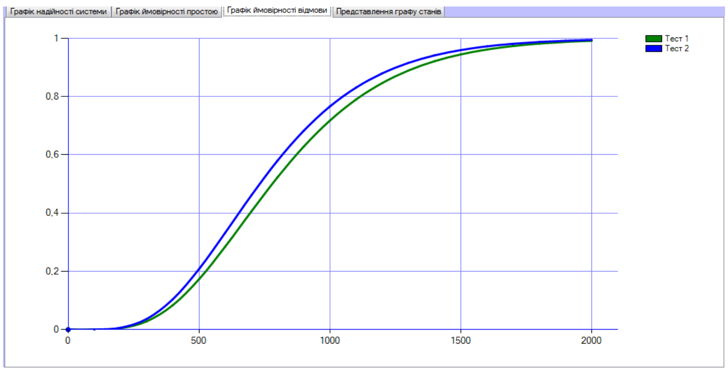

c)

Fig 8. Graphs of probability of no-failure operation (a), downtime (b) and the probability of critical failure (c) for two elements with different number of repair crews

Fig. 8 presents graphs for probability of no-failure operation of the system with two elements that can be repaired once. As we see initially the reliability at two repair crews is higher than when there is only one crew, this is due to the decrease of the system downtime, but after a certain point in time reliability of the system begins to decline faster compared with the first option (one repair crew). The probability of downtime at two repair crews reduces, but increases the probability of critical failure.

The software product allows to create states of the system and brings them to the table:

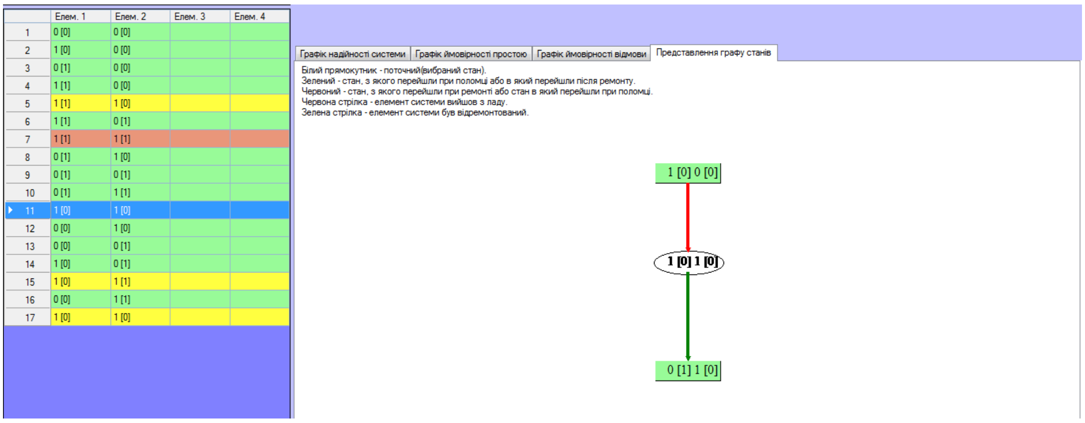

Fig. 9. The results of calculations for technical reservation system of two elements

Fig. 9 depicts the results of calculations for two elements with one restoration and one repair crew of direct priority. It displays all the states of the system, also in the selection of any state from the table, under "Presentation of the state's graphs" its relations with other states can be seen.

Now let review the results when repair crews will be two:

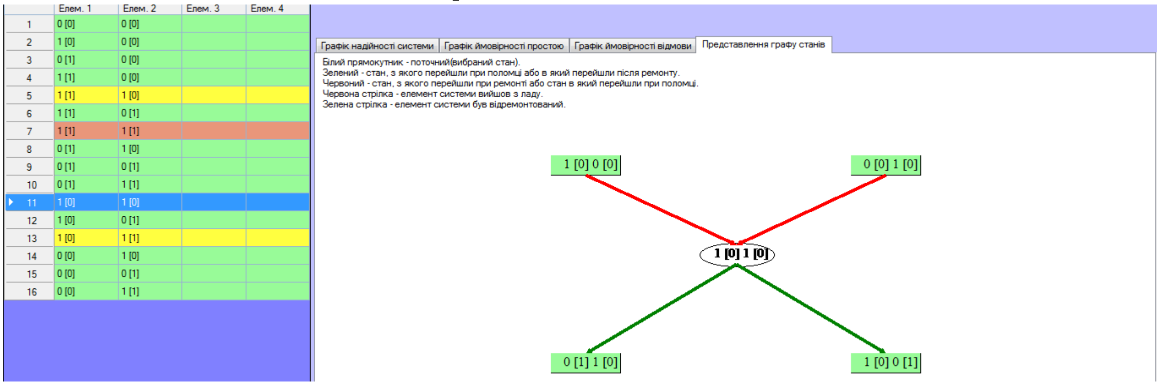

Fig. 10. The results of calculations for technical reservation system of two elements when with repair crews

The partial graph of states depicts two transitions from state 11 [00] (the first and second elements failed, but were not repaired). As it can be seen now the order of failure does not matter, because the number of repair crews increased.

The software system enables automated graphs building for numerical indicators of reliability of technical systems (in this case with 3 elements (Figure 11) with different number of restorations (first element - 0, the second - 3, the third - 1)):

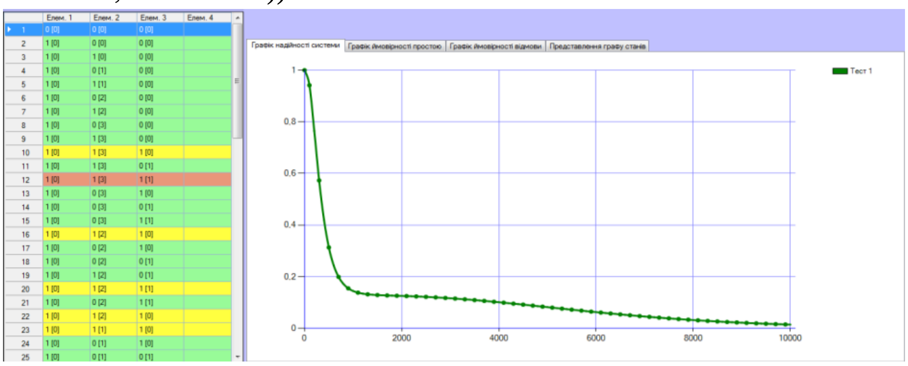

Fig. 11. The results of calculations for a system of three elements with different number of restorations

Also, software builds automatically a system of differential equations for calculation of reliability characteristics of the latter technical system under study(Figure 12).

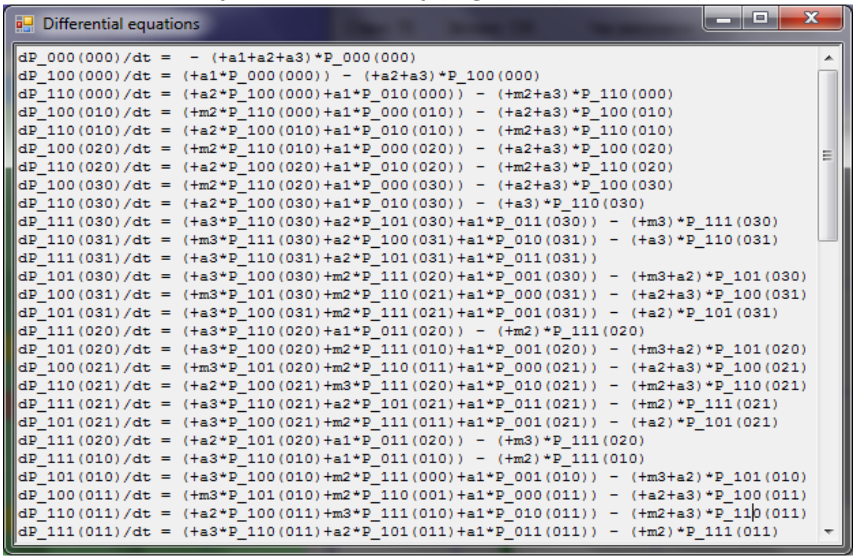

Fig. 12. Differential equations that describe the states and transitions between them of the system

Table 4. Dependence of the number of states on the number of restorations for 5 elements

Number of restorations	Number of states	Number of connections
0	32	80
1	64	176
2	136	396
3	312	924
4	786	2265

Table 4 shows the dependence of states and the number of connections on the number of restorations for 5 items. As it can be seen, the number of states with addition of a repair increases first at half, and then a more than two times as the number of connections between states.

When conducting research the following results were gained: with increasing multiplicity reserve and the number of restorations, the number of states increases almost exponentially. The Table. 5 shows the dependence of the number of states on the number of restorations for the reserve of multiplicity 1:

Table 5. Dependence of the number of states on the number of restorations for the reserve of multiplicity 1

Number of restorations	Number of states
0	4
1	17
2	40
3	73
4	116

Table 6 shows the dependence of the number of states on the multiplicity of reserve in the absence of restorations:

Table 6 Dependence of the number of states on the reserve multiplicity in absence of the restorations

Multiplicity of reserve	Number of states
0	2
1	4
2	8
3	16

4	32

This shows us that the calculation complexity increases sharply with changing number of elements and the number of restorations. We need to resolve the systems of differential equations, which number is equal to the number of system states [4], for calculating the reliability index.

Conclusions. This paper describes an algorithm and software implementation of improved reliability model of technical redundant system with a limited number of restorations, which takes into account the following input parameters as: number of elements of system, number of admissible restorations, number of repair crews. Unlike others, this reliability model allows us to combine different parameters, and for each element to establish their own (for each element its own failure rate, restoration rate and number of restorations are given). Along with the ability to change the number of elements of technical redundant system, there is the ability to change the number of repair crews.

1. Половко А.М., Гуров С.В. Основы теории надежности. – СПб.: БХВ-Петербург, 2006. – 704 с. 2. Ермаков А.А., Основы надежности информационных систем: учебное пособие. Ермаков А.А. – Иркутск: ИрГУПС, 2006. 3. Васілевський О. М. Нормування показників надійності технічних засобів / О.М. Васілевський, В.О. Поджаренко. – Вінниця: ВНТУ, 2010. – 129с. 4. Mandziy B. Analysis of reliability a test model of technical system with constant redundancy and repair unit / Bohdan Mandziy, Maksym Seniv, Bohdan Kuts // Proc. of the VIth Intern. scient. and techn. conf. CSIT-2012, Lviv, November. 21–24, 2012. – Lviv, 2012. – P. 75-77