Models of Fault-Tolerant Systems with Reconfiguration of the Core of Structure of “K of N”

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Abstract - Models of fault-tolerant system with a combined structural redundancy, which includes the structure of “K of N” with N-th number of technical systems in the core and their sliding redundancy are presented. Exploitation of system does not provide for maintenance and therefore the using procedures of reconfiguration of the core of structure of “K of N” are examined. Possibilities of models researching two variants of realization of the procedure reconfiguration of the core of structure of “K of N” are demonstrated.

Keywords - reliability, fault-tolerant system, the structure of “K of N”.

I. STATEMENT OF THE PROBLEM

In designing of highly reliable information and computing systems, information and control systems, systems of logic control, which are totality of the software and hardware radio electronic means (REM), the fault-tolerant system (FTS), which was underpinned by the principle of majority of the hardware or time redundancy.

FTS based on structure of “K of N” are divided on software and hardware REM with maintenance and without it in practice of designing. Reliability of the serviced software and hardware REM with structure of “K of N” increases through the use of maintenance and sliding redundancy. For not serviced hardware and software REM, intended for long-term continuous operation, reliability increases by means of the use of procedure reconfiguration of the core of structure of “K of N” and sliding redundancy. Introduction the procedure of reconfiguration of the core of structure of “K of N” allows saving majority principle, with decreasing the number of operability technical systems in the core of structure of “K of N”. This means that for hardware and software REM without maintenance the use reconfiguration of the core of structure of “K of N” is one of possible ways to increase their reliability in the long-term operation.

In [1] the fault-tolerant system based on structure of “K of N” such as “2 of 3” and “3 of 5” with reconfiguration are examined. Fault-tolerant system with the structure of the type “2 of 3” reconfigure in not reserved system, and in case of fault-tolerant system with the structure of the type “3 of 5” in the duplicate system. In the second variant the reserve is loaded. Models of such systems are designed with assumption however, that the majority voting element (recovery means) is fault-free. This causes the absolute reliability of the procedure of reconfiguration. This reduces the degree adequacy of the proposed models. Also the possibility of using the sliding redundancy is not considered.

There is a need creation of models with a higher degree of adequacy that could to consider the change the rule of decision and the appropriate the reconfiguration of the core of structure of “K of N”, sliding redundancy technical systems of the core, unreliable job of majority voting element and the switch of sliding redundancy based on the above.

II. BEHAVIOR OF FAULT-TOLERANT SYSTEM ARE IMPLEMENTED IN THE DEVELOPED MODELS

Structure of fault-tolerant systems.

The object of modeling is the fault-tolerant system based on structure of “K of N”, which is presented in [2]. The core of the fault-tolerant system is formed from technical systems or subsystems, the reliability of which does not meet the requirements and its increases through the use of the appropriate fault-tolerant system. Sliding redundancy are provides the combination of one technical system in loaded reserve and a certain amount of technical system in the unloaded reserve. Transferring of technical system in loaded reserve in software and hardware REM mean a supply of voltage power and software downloads. When technical systems in loaded reserve connect to the composition of the core, the next technical systems in unloaded reserve is transferred on its place.

The list of procedures that shape the behavior of fault-tolerant systems.

Step 1. Detection of faulty of the technical system in the core and its disconnection.

Step 2. Connecting technical system in the loaded reserve into the core. The procedure creates an alternative, associated with the connection or does not connection technical system in the loaded reserve into the core that arises resulting from the failure of the switch. When not connected the technical system into the core the number of technical system does not change. At the next need for replace the technical system in the core, it can be connected.

Step 3. Transferring of technical system from unloaded reserve in loaded reserve. This procedure is characterized by duration, which determines the expenditure of time to download software. The procedure can be successful and does not successful. In one case is transferring of technical system from unloaded reserve in loaded reserve. Otherwise are excluded the technical system from the unloaded reserve. The next time request to the unloaded reserve switch can transferring in the loaded reserve other technical system.

Step 4. The procedure reconfiguration of the core of structure of “K of N”. This procedure provides the change the rule of decision in the majority voting element and changes the number of technical system in the core. Two variants of reconfiguration of the core of structure of “K of N” are proposed in the work.

1. In the first variant of (model №1), the reconfiguration of the core of structure of “K of N” occurs in case of failure the second technical system in the core, i.e., (V1 = n - 2). At the failure of the second technical system in the core the detector of...
deviation gives command in the structure of “K of N” to reconfiguration. For example, if in the core 9 technical systems and the rule of decision was "5 of 9", then after reconfiguration in the core is 7, and the rule of decision is changed to "4 of 7". Unreliability of the majority voting element generates an alternative associated with conducting and does not conducting reconfiguration of the core of structure of “K of N”. In one case the procedure reconfiguration of the core of structure of “K of N” is successfully. Otherwise, the fault-tolerant system continues to work unchanged and in another failure of technical system in the core passes into a state of catastrophic failure.

2. In the second variant of (model №2), the reconfiguration of the core of structure of “K of N” is pre accidents occurs when the number of technical systems in the core is the minimum to run properly the fault-tolerant system, i.e., (V1 = (n +1) / 2). In the case when in the core is an odd number of technical systems, then the "excess" technical system of the core is transferred in sliding redundancy. For example, if in the core 9 technical systems and the rule of decision was "5 of 9", then after reconfiguration in the core is 5, and the rule of decision is changed to "3 of 5". Unreliability of the majority voting element generates an alternative associated with conducting and does not conducting reconfiguration of the core of structure of “K of N”. In one case the procedure reconfiguration of the core of structure of “K of N” is successfully. Otherwise, the fault-tolerant system continues to work unchanged and in another failure of technical system in the core passes into a state of catastrophic failure.

The development of models of fault-tolerant system adopted, that the duration of all processes, that occurring in the system have exponential distribution and the intensities of flow events is constant in time values. The development of models of fault-tolerant systems involves the use of advanced technology of analytical modeling system behavior, which provides automation development of model as a graph of states and transitions on the basis of the developed structure-automaton models [2].

III. EXAMPLE OF THE SOLUTION PROBLEMS OF RELIABILITY DESIGNING

1. Comparison of the reliability of fault-tolerant system of model №1 with the fault-tolerant system without to use procedure reconfiguration of the core of structure of “K of N”, at different number of technical systems in the core. With these values of parameters: \( \lambda n = 100 \) of failures/10^6 hours; \( Ti = 0.1 \) hours; \( P_{ME} = 0.999 \).

![Fig.1 The dependence of the reliability of fault-tolerant system from time](image)

Research showed, that application reconfiguration of the core of structure of “K of N” in compared with the system without reconfiguration allows improvement in reliability mean time to catastrophic failure: for the fault-tolerant of the type "4 of 7" more than 2 times, for the fault-tolerant of the type "3 of 5" more than 1.5 times.

IV. CONCLUSIONS

The developed models allows to consider the replacement decision rules and the appropriate reconfiguration of the core of structure of “K of N”, sliding redundancy of technical systems of the core, unreliability of majority voting element and the switch of sliding redundancy, that greatly increases their degree of adequacy. Application of the procedure reconfiguration of the core of structure of “K of N" allows to use resource not worked and to save majority principle, with decreasing the number of operability technical systems in the core of structure of “K of N”. This increases the reliability and mean time to failure.

REFERENCES
