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ESTIMATION OF RELIABILITY OF TECHNICAL SECURITY SYSTEMS BY LIMITED FAILURE STATISTICS

The paper describes the method of estimating the reliability of technical security systems, which allows to forecast their failure-free operation with high probability based on the limited operational information.

Keywords: *failure, reliability, forecast, technical security systems.*

A breakthrough in the development of production of large and very large scale integrated circuits (VLSI) lead to wide computerization of all types of human activity. Technical security systems (TSS) are also not an exception. Over the last years, the developers of TSS have been extensively updating these systems for the conjunction with electronic computers (EC) and further integration into the security systems and complexes centrally controlled by means of specialized software from the operator's automated workstation.

Such amplification of the equipment resulted in the growth of EC role in failure-free operation of security systems. For instance, when processing the statistics of failures of radar observation equipment (ROE), which is a part of security system (complex), ECs related to every radar station were revealed to be the cause for a larger amount of all failures. The results of the processing of failure statistics related to the selected ECs [1] showed that the failures were basically caused by software (SW) breakdowns [2].

The current system of preventive maintenance and repair (PMR) of technical security systems implies mostly degradation failures of separate node components and units, the scheduled replacement and maintenance of which help to extend the TSS life. Meanwhile, the easily forecasted degradation failures of discrete semiconductor elements and mechanical node components and units were shifted by the hard-to-forecast software and VLSI failures which are commonly referred to the sudden ones. They are characterized by a jump of output parameters beyond the permissible limits specified by a manufacturer.

Recovery of electronic equipment after such failures consists either in detection and replacement of the node component (unit, constituent), including the failed VLSI, or in SW resetting (debugging, adjustment). Both variants require quick involvement of high class specialists, which are not affordable either for operating divisions, or for manufacturers.

The most obvious way out of the situation is the improvement of PMR system. Foreign practices [3] show the efficiency of the so called *system for support of product life cycle* (PLC support), based on modern information technologies. The system provides for that repair and resetting of the product are carried out by technical maintenance staff and by TSS operators with active off-site participation of manufacturer's experts, which is acceptable only for the products put into operation. It remains unclear – which information serves as the basis for any product to be purchased if it has the price and performance characteristics comparable to other products from the row.

According to the purpose of products under consideration, one of their most important features is the reliability. The current methods of estimation (forecast) of reliability imply

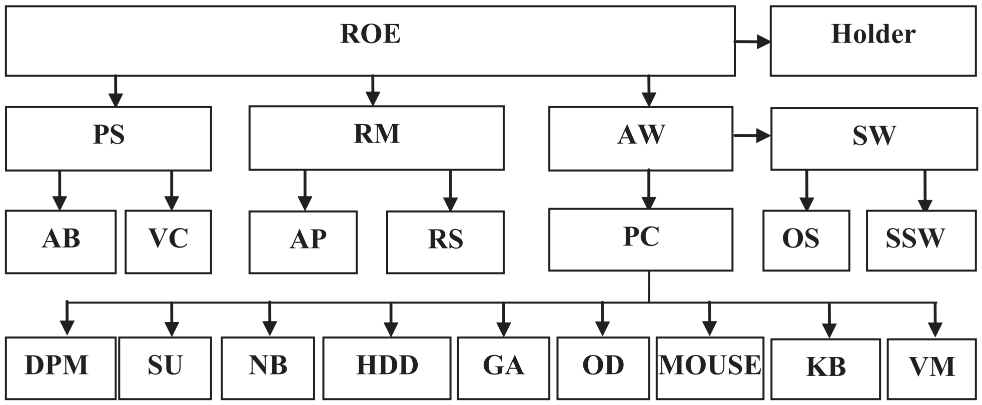

Fig. 1. Hierarchical configuration of the standard ROE

either a complete (long-term) or a forced (short-term) test cycle. In current conditions the long-term test cycle is not acceptable as the obsolescence of the product put into service comes before the tests are over. The forced tests should be performed with special test bench equipment which is quite expensive. Moreover, the product itself is actually destructed by imitative overloads, and the accuracy of such test results is quite doubtful as the failures of semiconductor elements do not have linear dependence on these overloads.

It is proposed to forecast the TSS failures based on operational statistics of selected products performance for the time period which makes 15 – 20 % of the complete test cycle [4], as well as on a priori information about failures of the similar node elements and units in other products.

Initially TSS under consideration seems to be a complex technical system (TS) and thus it undergoes decomposition procedure. This method, widely used in reliability theory, enables to divide the product into replaceable subsystems or constituent parts (CP), determinate logical and functional interrelation between them. Besides, the estimation of the system reliability as a whole consists in particular estimations of the reliability of subsystems.

In accordance with [5], the decomposition level is established based on:

– novelty of design of the product (specimen, system, complex) of special equipment (SE) and constituents of the product, manufacturing technology;

– complicated conditions of practical use and operation of the SE product (specimen, system, complex);

– degree of verification of design, operating and engineering documentation;

– availability of initial data necessary for particular estimations of CP reliability.

All other conditions being equal, the higher is the degree of verification of the product design and manufacturing technology, the higher is their reliability and maintainability, the lower is the detail level acceptable at the analysis of system. And vice versa – if the technical objects are based on the principally new design and technological solutions, if they are built on the new element base with the application of new materials, if there are no a priori reliability data for this technical object, then the structural configuration of the product shall be even more detailed.

The number of hierarchy levels within the complex system affects the visibility of its structure. With a large number of levels the task of TS analysis becomes hard to observe, that being able to have a negative impact on the accuracy of estimation. When there are few levels, the number of subsystems at one level grows – it becomes difficult to establish connections between them. The level of "subdivision" of the technical system depends on the expected results of estimation of its reliability, usefulness of information for the analyses of possible consequences and product failure criticality.

Estimation of reliability of SE products and its CP is done with consideration of their maintainability and failure-free operation. Maintainability of the unit (module) is estimated by the possibility of the module replacement at site of operation (geographically).

Detailed specification of ROE structural configuration is performed on the basis of the analysis of its *structural arrangement* and in accordance with the restriction taken in such cases — up to the unit (module) unrepairable at site of operation [5]. The obtained hierarchical structure of the concerned product is shown in Fig. 1, where the modern standard portable system of radar observation is held together with four functionally completed parts: secondary power source (PS), radar module (RM), holder and operator's automated workstation (AW). PS consists of accumulator battery (AB) and voltage converter (VC). RM consists of rotary support (RS) and antenna post (AP). The parts of AW are personal electronic computer (PC) and software (operating system (OS) and set of special software (SSW)). There are nine constituents under PC: data processing module (DPM) which is a motherboard assembled with an installed central processing unit and random access memory, supply unit (SU), network board (NB), hard disk drive (HDD), graphic adapter (GA), optical drive (OD), MOUSE, keyboard (KB) and video monitor (VM).

Based on the failure statistics analysis of each of the above indicated CP for the limited time interval [1] the reliability forecast for the whole product has been prepared.

Calculation algorithm includes the acquisition of statistics information about the occurred failures of products under test. This information shall contain the data of the failure type and time of occurrence (time from the beginning of tests or putting into operation).

For analysis the data are divided by time interval attributes. The shorter are the selected time intervals, the more accurate are the calculations made. In practice when making calculations it is reasonable to use the intervals of 150 hours, which corresponds to the average operating time of products for a month. Then, based on the data obtained, the calculation of failure rate parameter (FRP) at each time interval is done:

$$\omega(t) = \frac{n(\Delta t)}{N(\Delta t)}, \qquad (1)$$

where $n(\Delta t)$ is the number of failures for a time interval; $N(\Delta t)$ is the number of test specimens. And the failures are divided into degradation failures and sudden failures:

$$n = n' + n'', \qquad (2)$$

where n' is the total number of CP sudden failures, the flows of which are considered as the *stationary* Poisson processes; n'' is the total number of CP degradation failures, the flows of which are considered as the *non-stationary* Poisson ones.

The total number of CP failures n'', the flows of which are considered as the non-stationary Poisson ones, is specified on the basis of the forecast of the number of failures n_{Fi} at the time interval $t_i^A \to t_i^R$ (real test time → resource time) by means of interpolating polynomials. The number of degradation failures of the *i*-th CP for the resource time is specified as the total sum of the actual number of degradation failures during the object test and the forecasted number of failures by the following formula

$$n_i^R = n_i^A + n_{Fi}, \qquad (3)$$

where n_i^A is the actual number of degradation failures for the test period; n_{Fi} is the forecasted number of degradation failures.

Whereas, the total number of degradation failures of all CPs during the object test is calculated by the formula:

$$n'' = \sum_{k=1}^{P} \sum_{i=1}^{Y} n_{ik}^{P}, \qquad (4)$$

where Y is the number of constituent parts of the product.

On the next stage the FRP average value and its upper confidence bound are calculated :

$$\omega_U = \frac{\omega_j^{av}}{r}, \qquad (5)$$

where r is the coefficient of calculation of confidence bounds obtained from tables [6], $\omega^{av}{}_j$ is the average estimation of FRP of the *j*-th CP at the time interval Δt:

$$\omega_j^{av} = \frac{n_j(\Delta t)}{N_{av}(\Delta t)} \qquad (6)$$

where n_j is the number of failures of *j*-th CP at the time interval Δt; $N_{av}(\Delta t)$ is the average number of products with no failures from the beginning of the test at the time interval Δt.

In conclusion we should make sure that the upper bound of failure rate parameter does not exceed the bound specified at the stage of preparation of the technical specification (TS) for the product development:

$$\omega_U \le \omega_{sp}, \qquad (7)$$

where ω_{sp} is the value of the object FRP specified in TS.

Based on the results of check of the condition fulfillment (7) the decision is taken whether the test specimen corresponds to reliability requirements or not.

To sum up, the article demonstrates the improvement of the previous method for the analysis of product reliability [1]. It consists in simplification of the analysis of the structural configuration of product under consideration. The CPs with the same FRP are not considered in the algorithm as a separate calculation branch, besides, there is no analysis of correspondence of constituent parts to the purchaser's requirement at the initial stage of estimation. Algorithm simplification enables to reduce error risks under calculations and increases the accuracy of a trend line when interpolating time dependencies of CP FRP.

Application of the described method provides for obligatory data support system for reliability estimations. For this purpose the author of the paper proposed and realized the organizational and informative system for acquisition of reliability data. It implies a careful acquisition of information about failures of products in operation and most crucially, circulation of the data among operators, manufacturers and purchasers. Operators are a bit burdened by the system, but it helps to control the state of products and take appropriate measures to increase the product reliability.

The adequacy of the method offered to forecast reliability has been confirmed by comparative estimation analysis of reliability of radar observation equipment (ROE), based on the data of product trial operation and results of ROE reliability forecast by the limited operational information [1, 4].

This method is likely to be applicable to forecast reliability of other types of modern electronic equipment.

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