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Analysis of Component Supply System for Electronic Devices

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Introduction

At designing, manufacture and exploitation of electronic devices works of their dependability and an effective utilization are provided. Deciding the given problems methods and means of supply service and repair of devices are developed, the system of necessary component supply for electronic devices is planned [1].

The insufficient quantity of stocks of components can increase time of restoration of device [2]. On the other hand plenty of stocks results in irrational use of resources. In this case cost of stocks can become commensurable with cost of the electronic device. In this connection, there is a problem in development of rational system of maintenance of electronic devices by components.

In the article the method of an establishment of requirements to an index of sufficiency of stocks a component is offered. The periodic way of replenishment of stocks is considered, as an index of sufficiency the probability of sufficiency of stocks is analyzed. Total expenses in exploitation of the electronic device for the period of replenishment are considered. Required level of probability of sufficiency of stocks a component defines by minimization of the given expenses.

Model of component supply system for electronic devices

Creation of system of components supply for electronic devices requires realization of some works. This is choice of structure of system, strategy of replenishment and index of sufficiency of stocks, the task of requirements to a index of sufficiency of stocks, development of methods and algorithms of calculation and updating of stocks a components.

In practice of necessary component supply for electronic devices various structures of stocks of components are applied [3]. The basic factor influencing the choice of structure is the quantity of electronics devices for which stocks of components is calculated – one device or group of electronics devices.

Strategies of replenishment represent a set of rules on the basis of which the stocks of components are replenished. A lot of strategies, including periodic updating [3], are provided. In this case a stocks of components periodically is restored through the fixed periods of replenishment to an initial level.

As an index of sufficiency of stocks of components the following indexes are applied, as a rule: probability of sufficiency of stocks, factor of availability of stocks and mean time of a delay in realization of the application for a component. The given parameters of sufficiency of stocks of components are applied to electronic devices which index of dependability is: survival probability, factor of availability and mean time of restoration. Application of these recommendations allows taking into account the amendment to values of an index of dependability of the electronic device, brought by limitation of stocks of components. The index of probability of sufficiency of stocks can be applied, as well for products, which index of dependability, is the time between failures.

It is quite obvious, that the certain sets of initial quantities of components providing a preset value of an index of sufficiency of stocks exist. Therefore at calculation of stocks among all sets the components it is natural for choosing in the certain sense a rational one. With this purpose the index of expenses for stocks of components is applied. As a rule it can be weight, volume or cost of stocks of components. In that case there is an opportunity to decide both direct and indirect problems of calculation of stocks of component.

Let's analyze further a case when stocks of components are formed for group of devices. Parameter of sufficiency of stocks of components is the probability of sufficiency $P_{S\Sigma}$ determined for the period of replenishment of stocks T_p. Calculation of stocks of components for a direct problem of calculation can be executed on the basis of the following conditions:

$$P_{S\Sigma}(T_p) = \prod_{l=1}^{L} P_{1Sl} \geq P_{S\Sigma *} \ , \tag{1}$$

$$C_S = \sum_{l=1}^{L} C_l n_l \rightarrow \min_{n_l} \ , \tag{2}$$

where P_{1Sl} – probability of sufficiency of stocks a component of type l; $P_{S\Sigma *}$ – required value of a index $P_{S\Sigma}(T_p)$; C_S – cost of stocks of the components necessary for maintenance of exploitation N of electronic devices during T_p; N – quantity of devices for which stocks a component are calculated; C_l – cost components of type l, ($l = \overline{1, L}$); n_l – volume of stocks a component of type l.

Probability of sufficiency P_{1Sl} we shall define under formulas:

$$P_{1Sl} = \sum_{k=0}^{n_l} \frac{X_l^k}{k!} \exp(-X_l), \quad (3)$$

$$X_l = NT_p \lambda_{1l} m_l, \quad (4)$$

where X_l – average of applications in repair institution on components of type l; λ_{1l} – failure rate a component of type l; m_l – quantity a component of type l in the electronic device.

Method of an establishment of requirements to an index of sufficiency of stocks of components

The analysis of a parameter of sufficiency of stocks of components is feasible by consideration of the total expenses C_{T_p} having a place in exploitation of the electronic device in time T_p. Requirements to the given index we shall establish on the basis of the following condition:

$$C_{T_p} \to \min_{n_l}, \quad (5)$$

$$C_{T_p} = C_R + C_D + C_{DR} + C_S N^{-1}, \quad (6)$$

where C_R – expenses for repair and checking of the device; C_D – cost of the devices used instead of devices having failure; C_{DR} – expenses for repair and checking of the devices used instead of devices having a failure.

Let's analyze the case when the flow of events translating the system from one state to the others is Poisson flow. For description of change of states of the device in exploitation use the Markov stochastic process. Let's consider the following states of the device (fig. 1): X_0 – the state of serviceability and the device is used to destination; X_{R1}, …, X_{RM}, …, X_{RZ} – states of repair and checking because of the failure by the first, …, M, ..., Z components (M – quantity in the device a component for which in repair establishment there are stocks, $M = \sum_{l=1}^{L} m_l$; Z – quantity in the device a component at which failure their replacement on serviceable is stipulated, $Z = \sum_{l} m_l$); X_{E1}, …, X_{EM}, …, X_{EZ} – states of expectation of delivery of the first, …, M, ..., Z components.

For a stationary mode of exploitation of the device (Fig. 1) the following system of the equations will be used:

$$\begin{cases} \sum_{i=1}^{Z} \mu_{Ri} P_{Ri} - \left(\sum_{i=1}^{Z} \lambda_i \right) P_0 = 0, \\ (1 - P_{S1}) \lambda_1 P_0 - \mu_{E1} P_{E1} = 0, \\ P_{S1} \lambda_1 P_0 + \mu_{E1} P_{E1} - \mu_{R1} P_{R1} = 0, \\ \cdots \\ (1 - P_{SM}) \lambda_M P_0 - \mu_{EM} P_{EM} = 0, \\ P_{SM} \lambda_M P_0 + \mu_{EM} P_{EM} - \mu_{RM} P_{RM} = 0, \\ \lambda_{M+1} P_0 - \mu_{E(M+1)} P_{E(M+1)} = 0, \\ \mu_{E(M+1)} P_{E(M+1)} - \mu_{R(M+1)} P_{R(M+1)} = 0, \\ \cdots \\ \lambda_Z P_0 - \mu_{EZ} P_{EZ} = 0, \end{cases} \quad (7)$$

where P_0, P_{Ri} и P_{Ei} – stationary probabilities of a finding of the device in states X_0, X_{Ri} and X_{Ei}, ($i = \overline{1, Z}$). In (7) the equations for all states of the device are presented.

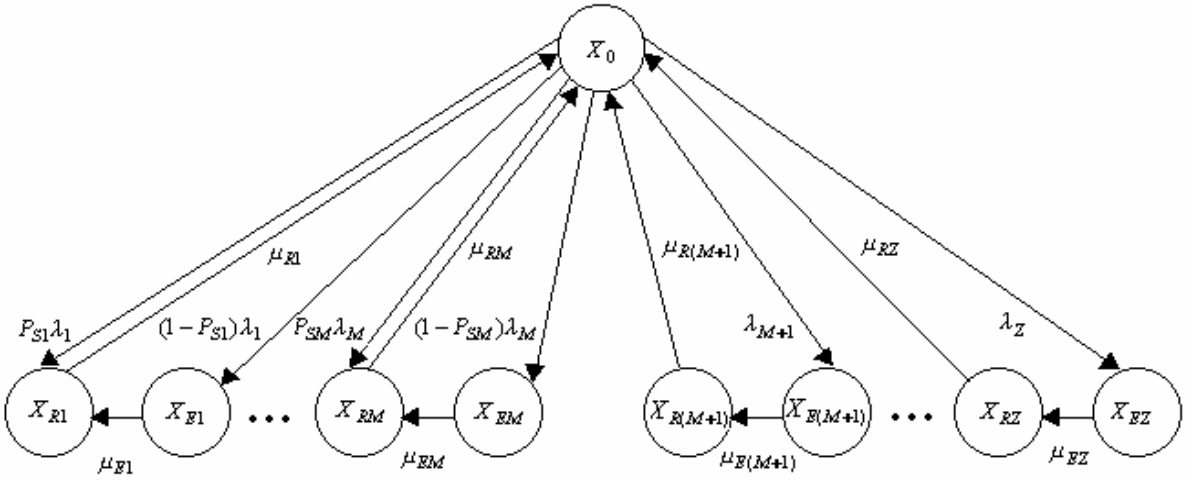

Fig. 1. Graph of change of states of the electronic device in exploitation at failures of components

$$P_0 + \sum_{i=1}^{Z} \left(P_{Ri} + P_{Ei}\right) = 1 \ . \qquad (8)$$

In Fig. 1 and in the formula (7) designations are used: λ_i – failure rate components i, ($i = \overline{1,Z}$); μ_{Ri} – intensity of repair and checking at failure components i, $\mu_{Ri} = \tau_{Ri}^{-1}$, τ_{Ri} – mean total time of repair and checking at failure components i. Such designations are used also: μ_{Ei} – intensity of expectation of delivery serviceability components i, $\mu_{Ei} = \tau_{Ei}^{-1}$, τ_{Ei} – mean waiting time of delivery serviceability components i; P_{Sj} – probability of sufficiency of stocks components j of the electronic device, ($j = \overline{1,M}$).

In a case, when $\lambda_i = \lambda$, $\tau_{Ri} = \tau_R$, $\tau_{Ei} = \tau_E$, $P_{Sj} = P_S$, ($i = \overline{1,Z}$; $j = \overline{1,M}$), for stationary probability of a finding of the device in an serviceability state P_0 we shall receive:

$$P_0 = \left[\ 1 + \frac{\tau_R}{T_0} + \frac{\tau_E}{T_0}\left(\ 1 - P_S \frac{M}{Z} \right) \ \right]^{-1}, \qquad (9)$$

where T_0 – time between failures of the device, $T_0 = \left(Z\lambda\right)^{-1}$.

The time of serviceable work of the electronic device T_p corresponds to certain total time of a finding in nonserviceability states T_{NS} and time of a finding under repair T_R. From here total time of stay of the device in all possible states equally $\Theta = T_p + T_{NS}$.

The electronic devices used instead of having failure, in serviceability state should occupy T_{NS} time. Under repair and checking considered devices will be T_{R1} time, which is the following:

$$T_{R1} = T_R T_{NS} T_{\Sigma}^{-1} . \qquad (10)$$

$$C_R = T_R \tau_R^{-1} C_r , \qquad (11)$$

$$C_D = T_{NS} T_{lt\gamma}^{-1} C_{ED} , \qquad (12)$$

$$C_{DR} = T_R T_{NS} T_p^{-1} \tau_R^{-1} C_r , \qquad (13)$$

where $T_{lt\gamma}$ – γ – percentile lifetime of the device; C_r – total cost of repair and checking of the device; C_{ED} – cost of the electronic device.

For definition T_R and T_{NS} we shall consider, that

$$P_j \xrightarrow[\Theta \to \infty]{} T_j \Theta^{-1} , \qquad (14)$$

where P_j – stationary probability of a finding of the device in a state j; T_j – total time of stay of the device in a state j for the period of exploitation $(0, \Theta)$. Then we shall receive:

$$T_R = \tau_R T_0^{-1} T_p , \qquad (15)$$

$$T_{NS} = (1 - P_0) P_0^{-1} T_p . \qquad (16)$$

Taking into account (9), (15) and (16), for C_R, C_D and C_{DR} we shall receive:

$$C_R = T_p T_0^{-1} C_r , \qquad (17)$$

$$C_D = \left[\ \frac{\tau_R}{T_0} + \frac{\tau_E}{T_0}\left(\ 1 - P_S \frac{M}{Z} \right) \ \right] \frac{T_p}{T_{lt\gamma}} C_{ED} , \qquad (18)$$

$$C_{DR} = \left[\ \frac{\tau_R}{T_0} + \frac{\tau_E}{T_0}\left(\ 1 - P_S \frac{M}{Z} \right) \ \right] \frac{T_p}{T_0} C_r . \qquad (19)$$

Substituting (17), (18) and (19) in (6), and also having accepted $n_l = n$, $m_l = m$ and $C_l = C$ from magnitude of expenses C_{Tp} it is convenient to proceed to magnitude Y, which we shall define as follows:

$$Y = n(P_S) - P_S G , \qquad (20)$$

$$P_S = \sum_{k=0}^{n} \frac{X^k}{k!} \exp(-X \ ) , \qquad (21)$$

$$X \ = N T_p M (Z L T_{0*})^{-1} , \qquad (22)$$

$$G = \tau_E X Z \vartheta^{-1} \left[\ C_r (C_{ED} T_{0*})^{-1} + T_{lt\gamma}^{-1} \right], \qquad (23)$$

Table 1. Dependence of probability of sufficiency P_S from X and G

G	X								
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
10	0.9960	0.9900	0.9825	0.9730	0.9640	0.9510	0.9380	0.9240	0.9100
30	0.9960	0.9900	0.9825	0.9730	0.9970	0.9940	0.9920	0.9890	0.9860
50	0.9960	0.9900	0.9825	0.9980	0.9970	0.9940	0.9920	0.9890	0.9860
70	0.9952	0.9898	0.9984	0.9968	0.9963	0.9944	0.9920	0.9896	0.9848
90	0.9952	0.9898	0.9984	0.9968	0.9963	0.9944	0.9920	0.9896	0.9980
150	0.9952	0.9987	0.9984	0.9968	0.9963	0.9944	0.9986	0.9984	0.9980

where T_{0*} – required value of a index T_0; ϑ – share of cost of the electronic device, determined by components. Requirements to probability of sufficiency of stocks a components we shall define with the formula:

$$P_{S\Sigma*} = P_S^L . \quad (24)$$

In Table 1 dependence of probability of sufficiency P_S is given from X and G. Values X and G are determined according to (22) and (23). The dependence submitted in Table 1 is received by search of a minimum of expression (20). For the given purposes the created computer program was used.

Carrying out calculations it is necessary to take into account dimension of magnitudes T_0, T_{0*}, T_p and $T_{lt\gamma}$. Also it is necessary to take into account and a share of calendar time during which the electronic device is in the working state.

Conclusions

1. The restorable electronic devices are being investigated. The system of necessary components supply for realization of repair of devices is analyzed. The method of an establishment of requirements to a index of sufficiency of stocks a component is offered.
2. The case when stocks are formed for group of devices is analyzed. Index of sufficiency of stocks of the component is probability of sufficiency $P_{S\Sigma}$. The given probability is defined during the period of updating of stocks T_p.
3. The level of probability of sufficiency of stocks of components, at which total expenses in exploitation of the device C_{T_p} are minimal, is required. Expenses are calculated during the time, equal to the period of updating T_p. The model of exploitation takes into account, that at failure of the electronic device instead of him other serviceable device is used.
4. For the description of change of states of the device in exploitation stochastic Markov process is used. For definition of expenses the special computer program is created. Required values of probability of sufficiency of stocks for some values X and G are submitted in Table 1.

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The restorable electronic devices are being investigated. The system of necessary components supply used for realization of repair of devices is analyzed. The method of an establishment of requirements to an index of sufficiency of stocks a component is offered. The periodic ways of updating of stocks are being investigated. As an index of sufficiency the probability of sufficiency of stocks are being analyzed. The level of probability of sufficiency of stocks a component, at which total expenses in exploitation of the device are minimal, is required. The model of exploitation takes into account, that at failure of the electronic device instead of him other serviceable device is used. Expenses are calculated for the time, equal to the period of updating. At definition of expenses the created computer program is used. Some calculated values of probability of sufficiency of stocks are submitted in the table. Ill. 1, bibl. 3 (in English; summaries in English, Russian and Lithuanian).

В. Ступак. Анализ системы обеспечения компонентами электронных устройств // Электроника и электротехника. – Каунас: Технология, 2006. – №. 8(72) – С. 83–86.

Рассматриваются восстанавливаемые электронные устройства. Анализируется система обеспечения необходимыми компонентами, используемыми для проведения ремонта устройств. Предлагается метод установления требований к показателю достаточности запасов компонент. Рассматривается периодический способ пополнения запасов. В качестве показателя достаточности анализируется вероятность достаточности запасов. Требуемым уровнем вероятности достаточности запасов компонент предлагается считать такой, при котором суммарные затраты в эксплуатации устройства минимальны. В модели процесса эксплуатации учитывается, что при отказе электронного устройства вместо него используется другое работоспособное устройство. Затраты рассчитываются за время, равное периоду пополнения. При определении затрат используется разработанная компьютерная программа. Искомые значения вероятности достаточности запасов для ряда значений влияющих величин представлены в таблице. Ил. 1, библ. 3 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Stupak. Elektroninių įtaisų aprūpinimo komponentais sistemos analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 8(72) – P. 83–86.

Nagrinėjami pataisomieji elektroniniai įtaisai. Analizuojama aprūpinimo remonto darbams atlikti reikalingais komponentais sistema. Siūlomas reikalavimų komponentų atsargų pakankamumą apibūdinančiam rodikliui nustatymo metodas. Nagrinėjamas periodinis atsargų papildymo būdas. Kaip komponentų atsargų pakankamumą apibūdinantis rodiklis analizuojama atsargų pakankamumo tikimybė. Sumines eksploatacijos išlaidas minimizuojančią komponentų atsargų pakankamumo tikimybę siūloma laikyti reikiamų šios tikimybės lygiu. Eksploatacijos proceso modelyje numatyta, kad elektroniniam įtaisui sugedus naudojamas kitas darbingas elektroninis įtaisas. Nagrinėjamos eksploatacijos išlaidos, patirtos per atsargų papildymo periodą. Apskaičiuojant eksploatacijos išlaidas naudojama sudaryta kompiuterinė programa. Ieškomos komponentų atsargų pakankamumo tikimybės vertės pateiktos lentelėje. Il. 1, bibl. 3 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).