SYNTHESIS OF DIAGNOSTIC EQUATIONS FOR SYSTEMS OF COMBINED DIAGNOSING

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Abstract. *The task of the industrial control of products of the radio-electronic equipment is considered. It is marked, that the efficiency of diagnostic maintenance of productions depends on such parameters as reliability of the control and degree of localization of defects. The high meanings of these parameters can be supplied only with the combined approach. Thus the basic task is the choice of optimum space of parameters of diagnosing, in which the technical condition of objects is described. For this purpose in clause the restrictions are determined, and the criterion function of a task of optimum synthesis of the equations of diagnostics is deduced*

Keywords: *diagnostic maintenance, reliability, localization of defects, solvability measure, spatial decomposition*

Now the theory of recognition quickly develops. One of the basic directions of its use is diagnostics of complex objects and processes. So, for example, in order to increase quality and reliability of the radio-electronic equipment's products, the diagnosing systems of their manufactures' processes are widely used. The designing of such systems is rather complex procedure and requires the system approach. The realization of such an approach is connected to construction of mathematical model in optimum space of diagnosing parameters.

Today basically two basic methods for the decision of diagnostics tasks are used. These are the methods of functional diagnosing and the methods based on the objects' decomposition. In the last methods the objects decomposition can be carried out at different detailization levels, where decomposition fragments can be complex or elementary components.

At use of the functional diagnosing methods the diagnostics task consists in the decision of the equations, which are described in the space of generalized parameters of diagnosing. In this case the high reliability of the accepted decisions is provided, as the area of objects serviceability is described by functional dependencies of elementary components' parameters [1]. However, these methods are characterized by low depth of defects localization, as the diagnostics equations, generally, have no the single solution concerning elementary components' parameters.

At use of methods, based on objects' decomposition, the diagnostics equations' solvability raises with increase of a detailization degree of decomposition fragments. In a limiting case, when the objects decomposition is on the elementary components' level, the diagnostics equations have the single solution concerning elementary components' parameters, that corresponds to depth of defects localization on the level of elementary components. However, in this case, the reliability of the decisions' accepting is considerably reduced because of rough area approximation of objects' serviceability by the independent admissions on the meanings of elementary components' parameters [1].

It is obvious, that to supply high reliability of the decisions accepting with localization of defects on the elementary components' level, only the combined approach will allow. Thus, the basic task is the synthesis of the equations in some optimum space of the diagnosing parameters of different objects decomposition levels.

Generally any optimization task assumes presence of some variety, on which the optimization is carried out. In this case, such diagnostic variety can be the system of the diagnostics equations, which is made for objects, represented by multilevel mathematical model of spatial decomposition [2]:

$$Y = F(X,R). \qquad (1)$$

In the given expression $X = \{X^{\nu} = \{X_j^{\nu}\}\}$ - vector of the test signals, $Y = \{Y^{\nu} = \{Y_j^{\nu}\}\}$ - vector of object reactions on these test signals, and $\boldsymbol{R} = \{\boldsymbol{R}^{\nu} = \{\boldsymbol{R}_j^{\nu}\}\}$- vector of the diagnosing parameters. The top indexes $\nu = \overline{1,E}$ in the given vectors determine horizontal profiles of the spatial model of objects. Their meanings designate accordingly functional $\nu = 1$, fragmentary $\nu = \overline{2,E-1}$ and elementary $\nu = E$ decomposition levels. The vertical profiles of spatial model are determined by the bottom indexes $j = \overline{1,m^{\nu}}$, where m^{ν}- the number of fragments (elements) of spatial decomposition on the appropriate horizontal decomposition levels.

The system of the equation (1) generally is superfluous, as each elementary component of object has repeated representation according with number of the horizontal decomposition levels of the objects' spatial models. It predetermines in (1) the presence of the dependent equations. From here the optimization task will consist in the fact, that by exception of dependent equations from (1), to receive such system of the equations, which solution on the one hand will allow to determine the malfunctions occurrence place on the elementary components' level, and on the other hand will supply maximum accessible reliability of the decisions acceptance.

The first of the given conditions imposes quantitative restriction on the equations system and consists in the fact that the number of the equations was equally to number of the elementary components' parameters. The second condition establishes restriction on qualitative structure of the diagnosing parameters set. To satisfy these restrictions, at formation of the required equations system it is necessary to prefer those equations, which are described in more generalized parameters. The given task we shall decide, being based on results of the analysis of the diagnostics equations' solvability for each of the horizontal profiles of the objects' spatial model.

Generally, for any horizontal profiles of spatial model of object $\mu = \overline{1,E-1}$ the equation of diagnostics can be described in space of parameters $\boldsymbol{R}^{\mu}$, and in parameters' space $\boldsymbol{R}^{\eta}$, where $\eta = \overline{2,E}$, $\eta > \mu$. For an estimation of the solvability of these equations we shall take a measure, which will determine the variables number, included in the solution [3]. The given measure of the equations' solvability can be found under the formula:

$$\lambda^{\mu}\left(\aleph^{\mu}\ \boldsymbol{R}^{(\cdot)}\right) = \sum_{j=1}^{m^{(\cdot)}}\left(n_j^{(\cdot)} - rank\ \boldsymbol{M}\left[\aleph_j^{\mu}, \boldsymbol{R}_j^{(\cdot)}\right]\right) \equiv$$
$$\equiv n^{(\cdot)} - rank\ \boldsymbol{M}\left[\ ^{\mu}, \boldsymbol{R}^{(\cdot)}\right] \qquad (2)$$

where $(\cdot) = \mu,\eta$; $\boldsymbol{M}\left[\aleph_j^{\mu}, \boldsymbol{R}_j^{(\cdot)}\right]$ - test matrixes formed with the help of matrixes of the private derivatives of initial equations in some space of definition of the parameters of the test signals $\aleph_j^{\mu}$ [3]; $n^{(\cdot)}$ and $n_j^{(\cdot)}$ - accordingly a common number of parameters and a number of fragment parameters j of the horizontal profiles $(\cdot)$.

For the diagnostics equations in the space of parameters $\boldsymbol{R}^{\mu}$ we can always choose such set of the test signals, that the given equation will have the single solution, and the measure of the solvability will be equally to zero. For the diagnostics equations in space of parameters $\boldsymbol{R}^{\eta}$, with the same set of the test signals, the meaning of the tests matrixes' rank will not change. Thus owing to validity of an obvious inequality $n^{\eta} \geq n^{\mu}$, the equation of diagnostics, generally, will not have the single solution, and the measure of solvability will not be equally to zero. From here it is obvious, that to satisfy the conditions shown above, the required equations system should contain all equations in parameters space $\boldsymbol{R}^{\mu}$, and should be complemented by the equations in space of parameters $\boldsymbol{R}^{\eta}$, of the number which will be determined the meaning of the solvability measure $\lambda^{\mu}\left(\aleph^{\mu}\ \boldsymbol{R}^{\eta}\right)$.

Taking into account, shown above, it is possible to offer such a procedure of a choice of the diagnostic parameters' optimum space for the combined diagnosing systems. Since a level $\mu = E-1$, for each of horizontal profiles $\mu = \overline{1, E-1}$ the diagnostics equations in the parameters space $\boldsymbol{R}^{\mu+1}$ are formed and the solvability measure is determined:

$$\lambda_*^{\mu}\left(\aleph_*^{\mu}\ \boldsymbol{R}^{\mu+1}\right) = n^{\mu+1}\ - \\ - \max_{\aleph_*^{\mu} \in \aleph^{\mu}} rank\ \boldsymbol{M}\left[\aleph^{\mu}, \boldsymbol{R}^{\mu+1}\right] \cdot \tag{3}$$

The meanings of the received solvability measures will determine the capacity of the diagnosing parameters' subset for the appropriate horizontal profiles of the objects' spatial model:

$$\boldsymbol{R}_*^{\mu+1} = \left\{\boldsymbol{R}_{*p}^{\mu+1}\right\};\ p = \overline{1, \lambda_*^{\mu}\left(\aleph_*^{\mu}\ \boldsymbol{R}^{\mu+1}\right)}. \tag{4}$$

Upon termination of such consecutive analysis the required optimum space of the diagnosing parameters will be determined as the diagnosing parameters vector:

$$\boldsymbol{R}_* = \left\{\boldsymbol{R}_*^{1}, \boldsymbol{R}_*^{2}, \ldots, \boldsymbol{R}_*^{E}\right\} \subset \boldsymbol{R}, \tag{5}$$

where the coordinates number of the vectors $\boldsymbol{R}_*^{2}, \boldsymbol{R}_*^{2}, \ldots, \boldsymbol{R}_*^{E}$ are determined according to expression (4), and the coordinates number of the vector $\boldsymbol{R}_*^{1} = \left\{\boldsymbol{R}_{*k}^{1}\right\}$ is determined by the maximal meaning of the rank of the test matrix on the level $\mu = 2$:

$$k = \overline{1, \max_{\aleph_*^{1} \in \aleph^{1}} rank\ \boldsymbol{M}\left[\aleph^{1}, \boldsymbol{R}^{2}\right]}. \tag{6}$$

Generalizing, told above, for restrictions determined by the requirement of the maximum accessible reliability of the decisions accepting and the requirement of the depth of defects localization on the elementary components' level, criterion function of optimum synthesis of the equations of diagnostics can be described by expressions of a kind:

$$\lambda_*(\aleph, \boldsymbol{R}) = n - \max_{\aleph_* \in \aleph} rank\ \boldsymbol{M}[\aleph, \boldsymbol{R}], \tag{7}$$

where

$$n = \sum_{\mu=1}^{E-1} \sum_{j=1}^{m^{\nu}} \left(\max_{\aleph_*^{1} \in \aleph^{1}} rank\ \boldsymbol{M}\left[\aleph^{1}, \boldsymbol{R}_j^{2}\right] + n_j^{\mu} \right) - n^{E};$$

$$rank\ \boldsymbol{M}[\aleph, \boldsymbol{R}] = \sum_{\mu=1}^{E-1} \sum_{j=1}^{m^{\nu}} rank\ \boldsymbol{M}\left[\aleph_j^{\mu}, \boldsymbol{R}_j^{\mu+1}\right].$$

The diagnostics equation, which correspond determined, thus, the diagnosing parameters space shall write down as:

$$\boldsymbol{Y}_* = \boldsymbol{F}(\boldsymbol{X}_*, \boldsymbol{R}_*), \tag{8}$$

where

$$\boldsymbol{Y}_* = \left\{\boldsymbol{Y}_*^{1}, \boldsymbol{Y}_*^{2}, \ldots, \boldsymbol{Y}_*^{E}\right\} \subset \boldsymbol{Y};$$

$$\boldsymbol{X}_* = \left\{\boldsymbol{X}_*^{1}, \boldsymbol{X}_*^{2}, \ldots, \boldsymbol{X}_*^{E}\right\} \subset \boldsymbol{X}.$$

The process of diagnosing, thus, will be carried out in two stages. At the first stage the system of the equations (8) is solved, the meanings of coordinates of a vector of parameters $\boldsymbol{R}_*$ are checked on the admission, and the decision on serviceability of object is made by the results of this control. If the object is faulty, at the second stage the localization of a place of occurrence of defects is carried out. This localization is consists in the decision of system of the equations $\boldsymbol{R}_* = \boldsymbol{\Phi}\left(\boldsymbol{R}^{E}\right)$ and the check on the admission of the parameters vector coordinates $\boldsymbol{R}^{E}$. Those elements will be faulty, the parameters' meanings of which are left behind allowable limits.

The described above procedure of diagnosing represents strategy, where the functional checks, which reveal presence of defects in objects, precede checks of more detailed levels of decomposition, on which the localization of the revealed defects is carried out. The lacks of such strategy are necessity of presence of all set of means for realization of control and measuring operations at all levels of representation unit under test. Thus, functional checks require sets of devices, which in themselves have high cost, cost of systems of diagnosing considerably raises. Besides the extremely wide variety of functions of modern products of the radio-electronic equipment results in absence of universality of diagnostic experiments. The task becomes complicated as well because the methods of invariant decomposition of complex fragments on today are not yet enough advanced and also are not universal. The essential lack of the given strategy is also that at connection to objects of power supplies at the expense of primary defects there can be secondary defects.

In-circuit methods of diagnosing do not result in occurrence of secondary defects, and the means of realization of control and measuring operations are characterized by simplicity, low cost and universality.

Proceeding from above described it is possible to offer strategy of diagnosing, where the control and measuring information turns out only by in-circuit methods. Thus localization of defects at a level an elementary component at once is provided. And if there are elementary components, which are suspected as faulty, the final decision on serviceability of objects is accepted by results of the control on the admission of the generalized parameters of quality, which meaning can be received by results of in-circuit checks deciding opposite of the rather previous strategy a task. Such process of acceptance of the decisions can be interpreted as modeling of functional checks of fragments of spatial decomposition and object as a whole. The given strategy will be a new version of strategy of the combined diagnosing, and it is possible to consider construction of the appropriate systems as optimum synthesis of systems by criterion of minimal cost.

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