Bulgarian Academy of Sciences. Space Research Institute.
Aerospace Research in Bulgaria. 18. 2003. Sofia

FAILURE RESISTANCE ALGORHYTM

*Antonio Andonov, Zoya Hubenova**
Higher School of Transport "T. Kableshkov",

**Space Research Institute – Bulgaran Academy of Sciences*

Abstract:

An important part of the general problem of building up an efficient and reliable control systems is the problem for identification of their dynamic characteristics. The current information about the dynamic status of a functioning system provides for organization of optimum control adapting to the changing external conditions, on the one hand, and for taking timely and proper decisions in case of failure of subsystems, on the other hand.

In the paper, the structure of an adaptive, multiple-connection automated control system with dynamic characteristics identification is proposed, using a combined control principle: adaptive control with relatively slow parameter change, as a result of parameter interference and change of the system's control part structure with leap parameter change, as a result of failures in the individual subsystems.

The modern ACSs are very sophisticated, due to the great variety of problems solved by them. The availability of a great quantity of functionally necessary elements and the relations between them in the system put to the fore the problem for enduring their failure resistance. A system's reliability is its property to preserve with time within certain fixed limits the value of its parameters, characterizing its ability to perform the required functions, i.e., to preserve its efficiency status in preset modes and application conditions.

Efficiency status is the status of an object, where all parameters, characterizing its ability to perform the prescribed functions comply with the requirements of the normative and technical or design documentation. Reliability is a combination of the following properties: failure-free operation, longevity, maintainability and possibility for preservation. Failure-free operation is the system's property to continuously preserve its efficiency status within a fixed period of time. The three remaining aspects of reliability characterize only the technical properties of the system and the extent to which they depend on the specificity of the ACS' operation. This is the reason why further we shall consider reliability only in the sense of failure-free operation.

There are two main ways to ensure system reliability. The first one suggests preservation of the efficiency status of all ACS elements, i.e., synthesis of a reliable system of reliable elements. This suggests higher requirements for the elements' reliability, which results in drastic increase of the system's cost. That is why, such an approach is expedient only within certain limits.

With the second approach, the system status with failure is regarded as one of the multitude of its possible statuses; in this status, the ACS' reliability is ensured by means of definite system structure building up. In this way, synthesis of a reliable system of non-reliable elements is accomplished.

An important part of the general problem of building up an efficient and reliable control systems is the problem for identification of their dynamic characteristics. The current information about the dynamic status of a functioning system provides for organization of optimum control adapting to the changing external conditions, on the one hand, and for taking timely and proper decisions in case of failure of subsystems, on the other hand.

In the paper, the structure of an adaptive, multiple-connection automated control system with dynamic characteristics identification is proposed, using a combined control principle: adaptive control with relatively slow parameter change, as a result of parameter interference and change of the system's control part structure with leap parameter change, as a result of failures in the individual subsystems.

The structure of such an ACS, from an organizational point of view, has a two level hierarchy. The lower level comprises the system control part, the top one comprises a coordinator, changing the control part of the system at times of failures while readjusting its parameters in the presence of parameter interference on the controlled object. The failure diagnostics, accomplished by the coordinator, provides for the fitting of additional elements or subsystems in the ACS' control part circuit, or to form a new structure, by means of switching to trouble-free systems.

The building of such ACSs calls to determine the identification methods, providing the possibility for carrying out a reliable and timely diagnostics of possible faults in the system's operation, alongside with the assessment of the current status of the operating system. It is obvious, that these methods shall have certain properties, such as: high speed, noise resistance, high sensitivity, adequacy for high-order complex systems, potential to detect the most typical faults, relatively simple algorithm. All these features determine the diagnostics reliability.

These features are manifested best by the active statistic methods for dynamic characteristics' identification, using pseudo-random test signals with determined parameters and limited intensity, which do not disturb the normal operation mode of the examined system. The passive identification methods are characterized by relatively low speed and low accuracy [1].

For the purpose of simplifying the computing procedures and accelerating operation speed, it is expedient to use recursive algorithms for indirect evaluation of the dynamic characteristics – the decomposition coefficients of the time characteristics in a generalized Fourier series, according to the system of orthogonal functions. Moreover, these algorithms are independent of the series of the examined system:

Let $\mathbf{k} = (k_1, k_2, ..., k_m)$ are the parameters of the controlled object (CO), $\mathbf{c} = (c_1, c_2, ..., c_n)$, $\mathbf{n} < \mathbf{m}$, are the readjustable parameters of the controller (C), compensating the change of **n** most substantial parameters of the controlled object; $\mathbf{A} = (a_1, a_2, ..., a_n)$ – the identified parameters of the closed control system, for example, the decomposition coefficients of the pulse transition function in series, according to the system of orthogonal functions. Where needed, the vector space of parameters **A** could be extended to a dimension $\mathbf{n} + \mathbf{m}$ in accordance with the vector space dimension of the closed control system parameters. And the vector **A** components are selected according to the criterion for maximum sensitivity to the change of the corresponding parameters of the closed ACS.

The following assumptions are made, regarding the proposed model for the closed ACS:

1. The identified parameters of the model are constant and even:

$$a_1 (k_0, c_0) = a_{i0} \quad ,i = 1, 2, ... n ,$$

where:

$$k_0 = (k_{10}, k_{20}, ..., k_{m0}) \quad , c_0 = (c_{10}, c_{20}, ..., c_{n0})$$

2. For an arbitrary population of changing parameters $\mathbf{k(t)}$ there exists such a population of readjustable parameters $\mathbf{c(t)}$, so that at the end of the adjustment cycle the following is valid:

$$a_{ir} (k ,c) = a_{i0} ,$$

where **r** is a discrete time interval, corresponding to the end of the consecutive adjustment cycle.

On the so made proposals for the model, the readjustable parameters of the controller, compensating the changes of the controlled object, as grounded in [1], are determined using the equations:

$\Delta A_r = B_{r-1} \Delta c_r$,

where:

$\Delta A_r = (\Delta a_{1r}, \Delta a_{2r}, ..., \Delta a_{nr})$, $\Delta a_{ir} = \Delta a_{ir} - \Delta a_{10}$

Δc_r is the vector, determining the controller parameter changes of the series **nx1**;

B_{r-1} = **bij** is a matrix with dimensions **n x n**, $b_{ij} = (\partial a_1 / (\partial c_j)_{r-1}$. The **B matrix** parameters are function of k_{r-1}, c_{r-1} and are calculated at the end of the transition **(r - 1)** self-adjustment cycle. The controller's readjustable parameters are determined by the ratio:

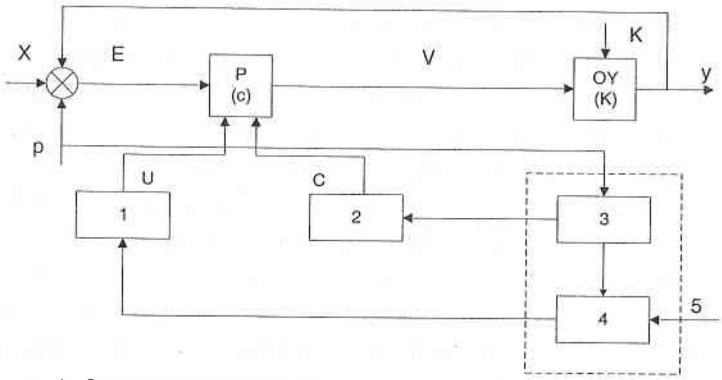
$c_r = c_{r-1} + \Delta c_r$

In this way, the status of the control system is defined by the vector of the identified parameters, which changes continuously in the presence of parameter interference, and can also undergo a leap change, as a result of possible failures in the individual subsystems. In this case, the task for the system's classification can be formulated in terms of the theory of pattern recognition: the presented population of identified parameters shall be related to one of the earlier established diagnoses (statuses) The status population of the diagnosticated **R** is broken down to a series of sub-populations Q_i, Q_0 – a population of statuses, corresponding to a faulty system. Q_I , **I = 1, 2, ..., N** - a population of statuses, corresponding to a faulty system, whose fault is caused by the failure of the i subsystem. The diagnostics is performed dependent on the distance of the current vector **A** to the vectors of the corresponding populations A_{Q0}, A_{QI} or on the distance to the references A_{Q0}*, A_{QI}*, whose coordinates are equal to the mean value of the coordinates, included in the specific population. With such an approach, all control solutions for one type of failure or other shall be provided in advance. The design stage of the discussed system class is finalized with training of the coordinator. The issues of the selection of the most informative parameters and their order are specified, as well as the issues of coding the vector components of the identified parameters for the purpose of forming a solving logic function (SLF).

The two tasks – self-adjustment and control of the system's status, carried out by the coordinator, can be solved within the frame of a single specialized digital computing equipment (SDCE). Its operation algorithm contains the following sequence of operations:

- Periodic measurement of the components of vector A of the identified parameters **A**;
- Classification of the system's statuses (formation of the SLF);
- On available failt, a vector of the controlling actions **U** is formed with combined binary components (1,2), switching the control part of the ACS.

The discussed approach is most efficient in constructing digital (microprocessor) ACS with high reliability and operation quality requirements. The digital controller has hardware excess, which means that it has to provide for change of the control system structure at the expense of the connections between the input devices, processors, storage components, and output devices. The coordinator and the control part are organized as a multiprocessor control set.



1 - Control action formation unit
2 - Adjustment coefficient forming unit
3 - Identification unit
4 - Solving logic function formation unit
5 - Output information

References

P. Eikhoff, Fundamentals of control system identification, M. Mir,1993.

АЛГОРИТЪМ ЗА ОСИГУРЯВАНЕ НА ОТКАЗОУСТОЙЧИВОСТ

*Антонио Андонов, Зоя Хубенова**

ВТУ"Т. Каблешков", катедра "СОТ

**ИКИ – БАН*

Резюме

Важно място в общия проблем за построяване на ефективни и надежни системи за управление заема проблемът за идентификация на динамичните им характеристики. Познаването на текущата информация за динамичното състояние на функциониращата система позволява, от една страна да се организира оптимално управление с адаптация към изменящите се външни условия, а от друга - да се вземат своевременни и правелни решения при възникване на откази в отделни подсистеми. В настоящата работа се предлага структура на адаптивна многосвързана система за автоматично управление с идентификация на динамичните характеристики, използваща комбиниран принцип на управление: адаптивно управление при относително бавно изменение на параметрите вследствие на параметрически смущения и изменение на структура на управляващата част на системата при скокообразно изменение на параметрите вследствие откази на отделни подсистеми.