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A method for parameter estimation of a multichannel measuring system

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A B S T R A C T

High accuracy of multichannel information measuring systems depends on correct determination of parameters of information traffic channels and sensor management. At the same time, the development of information systems depends on the reliability and subsequent processing of the collected information. For this purpose, an analysis of the specifics of a multichannel measuring system is given and a testing algorithm and optimal structure for high-precision determination of the parameters of information traffic channels are developed.

1. Introduction

It is known that the design of information measuring systems (IMS), in the general case, involves solving a number of tasks associated with determining the optimal structure synthesized by IMS on the basis of selected criteria, with the provision of given metrological, operational and other characteristics [1-10]. The labor intensity of the above tasks of IMS synthesis is due to the complexity of formalization of solution methods. Currently, these tasks are greatly simplified by using the principle of aggregation, which involves creating an IMS from unified blocks or modules that are part of unit complexes, such as primary measuring systems (PMS), which have typical characteristics. The most important indicators of qualities of technical measuring instruments are their metrological characteristics [6]. Therefore, in the general case, the parameters of metrological characteristics (MC) of the system can serve as a basis for selection of criteria in IMS synthesis. The main of them include the parameters that characterize the accuracy of IMS [4-11].

2. General problem statement

The following requirements apply to the multichannel information measuring system under test (multisystem).

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To determine the estimated measurement error, the error accumulated after each block is usually calculated or the resulting error of the system based on the investigation of its individual components is analyzed. In this respect the aggregation gives essential advantages due to the unification of MC blocks and modules of primary measuring systems (PMS) in comparison with test measurements of IMS, implemented on the basis of individually made measuring instruments. In the latter case, it is reasonable to split the IMS into subsystems, such as PMS, to determine the metrological characteristics of these subsystems, and then to determine the resulting error by sequential summation of accumulated errors, which, in the general case, is a very time-consuming task [7].

Taking into account the fact that the primary transducers (PT), as a rule, are in more severe conditions during the operation of PMS than a test IMS (TIMS) or a measuring complex (MCX), and at the same time the continuously growing requirements to their accuracy, the development and creation of new sensors and transducers, which allow obtaining the measurement results (MR) that are invariant to external conditions, is always relevant [7]. At the same time, the use of newly developed sensors and transducers, which are not part of PMS complexes, makes it possible to divide conditionally IMS synthesis into two parts:

- PMS synthesis including newly developed transducers, which are part of the functional series of IMS unit complexes;
- synthesis of the general part of the IMS, containing a number of unified blocks of IMS unit complexes, which are capable of satisfying in their parameters the required indicators of system quality.

If the determination of the resulting error of the general part of the IMS can be carried out step by step by the above method on the basis of taking into account the standard nomenclature of the data of MC unified blocks, the determination of parameters characterizing the accuracy of the newly developed measuring equipment will, in general, be an individual task each time. In this regard, further we will assume that the general part of the IMS being synthesized is realized on the basis of unified blocks of IMS unit complexes and provides in its MC and other parameters the required quality indicators of the system [7].

Thus, one of the most important stages of creating test PMS is the synthesis of the primary part of the system related to the direct receipt of information from the objects or processes under study and to their transformation to a form suitable for transmission over a distance or for machine processing [5-7].

3. Solution

The properties of the multichannel measuring part of IMS, in the general case, are determined by the parameters a_i of the conversion function (CF) of measuring channels [4-8]. In turn, the parameters a_i are determined by properties of unifying transducers and sensors included into the measuring channels of IMS. In the general case they are random values, changing under the influence of various external factors, as well as over time. Within a multichannel IMS the values of the parameters a_{ij} are also random functions of numbers j of measuring channels, due to the non-identity of the characteristics of the transducers included in them [5], i.e.,

$$a_{ij} = F(t, j).$$

In this regard, the IMS containing N_k measurement channels, is characterized by a spatial three-dimensional matrix L^* of order $N_k \times n \times t_l$ of the parameters of its mathematical model [5]:

$$L^* = \left\| L_{ijt} \right\| \downarrow_{(i)}^{\rightarrow(j)} = \left\| L_{ijt_0} \middle| L_{ijt_1} \middle| L_{ijt_2} \middle| \dots \middle| L_{ijt_\lambda} \middle| \dots \middle| L_{ijt_l} \right\| \downarrow_{(i)}^{\rightarrow(j)} \quad (1)$$

where $j = 1 \dots . N_k$ is the number of the measuring channel of the system; $i = 1 \dots . n$ is the number of the parameter of CF of the given measuring channel; $t_\lambda = t_0 \dots \dots t_l$ is discrete instants of time, corresponding to the sensor polling cycles.

The flow chart of one measurement channel of the IMS is shown in Fig. 1:

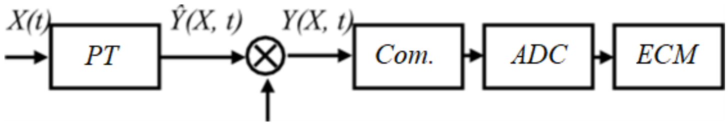

Fig. 1. TIMS measurement channel

It should be noted that when designing a multichannel IMS with a limited amount of information, the designer, in the general case, is forced to assume that the parameters of FP of all measuring channels remain constant over time and, regardless of changes in external conditions, are equal to their nominal values, that is:

$$a_{ij}t, = a_{ijH}. \quad (2)$$

In reality, condition (2) is not satisfied, so the obtained MR at the last stage of the measurement process should be corrected, which can be calculated as follows.

Spatial three-dimensional matrix L^* of the CF parameters MPR1....MCX N_k, taking into account (2), degenerates into a two-dimensional matrix of the order $N_k \times n$ of nominal parameters of CF of the measuring channels [2]:

$$L_1^* = \|A_{ijH}\| = \left\| \begin{matrix} a_{11H} & a_{21H} \cdots & a_{i1H} \cdots & a_{n1H} \\ a_{1jH} & a_{2jH} \cdots & a_{ijH} \cdots & a_{njH} \\ a_{1Njn} & a_{2Njn} \cdots & a_{iNjH} \cdots & a_{nNjH} \end{matrix} \right\|. \quad (3)$$

The matrix L_1^* here is an idealized matrix L^*.

When implementing an IMS system, in which the parameters MM of the CF are described by the matrix L_1^*, it is necessary to write the a priori known values of parameters a_{ijH} to write into the memory of the IMS, which leads to a significant expansion of the data volume and, accordingly, it results in a significant expansion of the data volume and a waste of time for unnecessary calculations.

In real conditions the a priori information about the parameters a_{ijH}, as a rule, is limited and, therefore, the parameters of the corresponding columns of the matrix L_1^* are assigned their average statistical values. At the same time, the parameters of the same name a_{ij} MM of various MCX included in IMS, are considered as random values with the normal law of distribution, characterized by mathematical expectation $M_{[a_{ij}]}$ and variance $\delta^2_{[a_{ij}]}$. Thus, the values of the parameters a_{ijH} are considered independent of the number of MCX, and their mathematical expectations are used as their estimates:

$$a_{ijH} = M_{[a_i]} \quad (4)$$

Taking into account (3.4), the spatial three-dimensional matrix L_2^*:

$$L_2^* = \|M_{[a_i]}\| = \|M_{[a_1]} M_{[a_2]} \dots . . M_{[a_i]} M_{[a_n]}\|. \quad (5)$$

The values $M_{[a_i]}$ are assigned to all elements of the corresponding columns of the matrix L_1^* and entered into the PC ROM.

Thus, row vector (5) is an idealized matrix L_1^*. However, the constructive measures to stabilize the parameters a_{ijt_λ}, as a rule, do not allow fulfilling conditions (2) and (4) practically. Therefore, the real IMS will have a measurement error characterized by a spatial three-dimensional matrix of the form:

$$\Delta L^*_{HC} = L^* - L^*_2 = \left\| L^*_{ijt_\lambda} \right\|^{\to(t)}_{\underset{(i)}{\downarrow}} \to (j) - \left\| M_{[a_i]} \right\|. \quad (6)$$

The error of the measurement result at $t_\lambda = \bar{t}$ and $j = \bar{j}$ ($\bar{t}$, $\bar{j}$ are fixed values of t_λ and j) can be represented by (6) in the following form:

$$\delta_{ijt} = \sum_{i=1}^{n} \left(a_{i\bar{j}\bar{t}} - M_{[a_i]} \right) x^{i-1}. \quad (7)$$

As can be seen from (7), the MR error in each case can be reduced to the difference between the real current values of the parameters of the CF of transducers and the idealized values $M_{[a_i]}$ taken as their nominal values.

Obviously, its calculation for the subsequent correction of MR, obtained with the help of multichannel IMS, is a very time-consuming task. Besides, the correcting value directly depends on the difference of values of current parameters of CF of transducers, a priori unknown for the given instants of time and taken as their nominal values $M_{[a_i]}$.

Thus, to exclude errors (7) from the MR it is necessary to obtain additional information about the current values of the parameters a_{ijt_λ}. Obtaining this information can be achieved by carrying out additional measurements formed in the system of test values. This allows obtaining highly accurate MR without resorting to special measures for stabilizing the characteristics of individual sensors and PTs and in the absence of a priori information about the nature of changes in the CF parameters. Based on the analysis carried out in the previous section of the article, the errors of the IMS are calculated in the known way.

The implementation of the method of design of measuring equipment described here allows obtaining at the outputs of MCX1,...., MCX *n* unified signals in the form of AC frequency or digital code, interfaced with the subsequent functional modules of the MCX unit complexes in the multichannel IMS.

In the general case, the structure of a multichannel IMS, in which the test algorithm to improve measurement accuracy is implemented, has the form shown in Fig. 2.

With the appropriate MCX and PMS the measurement information coming to the controller is sequentially collected on the personal computer and the results are processed.

A measuring channel includes a primary transducer (PT) and a group of (or one) unifying transducers (UT). A personal computer (PC) communicates with each of the measuring channels through a programmable controller (C) on the D_i bus (information on the measured value), the Y_1 bus (control of the measuring process). The sensors can be polled both in cyclic mode and selectively by control signals from PC. In this case the A bus (between C and PC) is used.

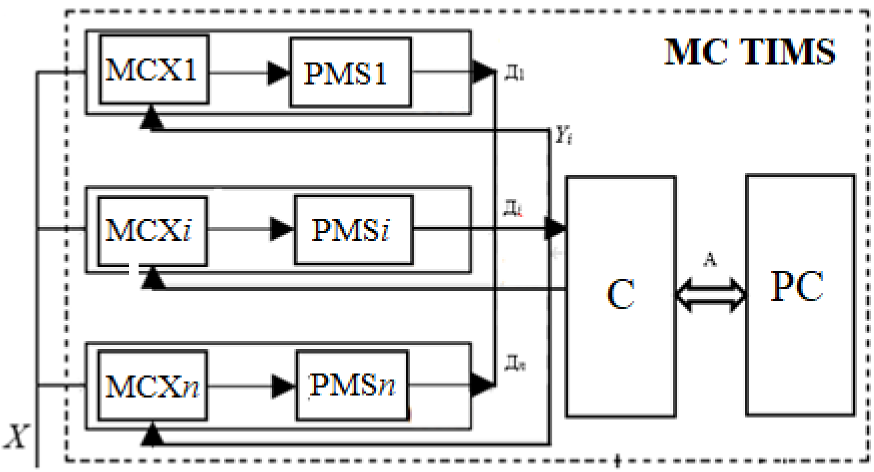

Fig. 2. The structure of a multichannel IMS

4. Example of subsystem development

It should be noted that if TIMS is intended for studying a process (object) characterized by parameters of different physical nature, then sensors are grouped by the type of the parameter to be measured. For instance, in the implementation of IMS gauging the amount of oil in the pipeline (Fig. 3), we can consider temperature transducers, pressure transducers, density transducers, flow rate transducers and so on [7].

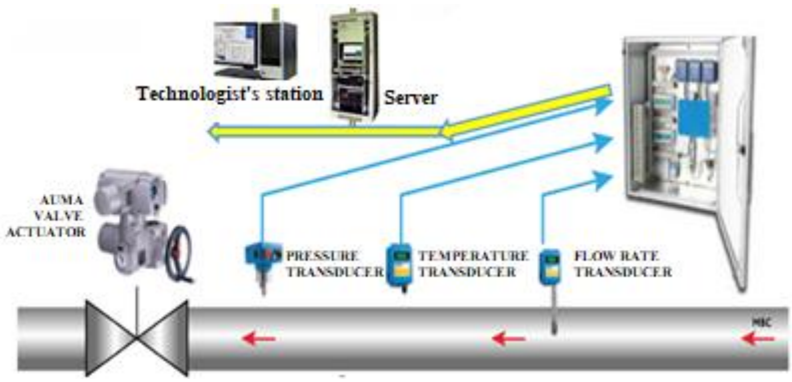

Fig. 3. IMS gauging the amount of oil in the pipeline

Depending on the CF of the measurement channels of PMS, the corresponding PCs will be programmed, in the general case, by different basic test algorithms. For this purpose, it is necessary to provide the possibility of their reprogramming for implementation of any of possible algorithms, i.e., it is necessary to develop the universal infoware of the information measuring system on the basis of the test measurement method [6].

The test IMS and all necessary controls must be equipped with modern components. All functional units of the IMS unit complexes and standard interface devices, based on the complexity of the end goal of the problem to be solved and a number of other factors that can be taken into account for any operating conditions.

5. Conclusion

A method for parameter estimation of a multichannel measuring system is proposed, the essence of which is as follows:

1) In the presented test process of measurements the results of all measuring operations are collected in the form of useful information, the corresponding test equations are formed, their solution (processing) is carried out, as a result of which high accuracy of measurements is provided and error correction takes place.

2) As can be seen from the obtained result, the error of the measurement result in each case can be corrected for the difference between the real current values of the CF parameters and their idealized nominal value.

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