ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 2 , February 2016

Software and Hardware Implementation Of Tasks Increasing Reliability Of Measuring Information

Yusupbekov N.R, Gulyamov Sh. M., Temerbekova B. M., Ergashev F.A., Rasuleva M.A.

Professor, Department of Automation of manufacturing processes, Tashkent State Technical University, Tashkent, Uzbekistan

Professor, Department of Automation of manufacturing processes, Tashkent State Technical University, Tashkent, Uzbekistan

Senior researcher, Department of Automat ion of manufacturing processes, Tashkent State Technical University, Tashkent, Uzbekistan

Senior researcher, Department of Automat ion of manufacturing processes, Tashkent State Technical University, Tashkent, Uzbekistan

Associate Professor, Department of Health and Safety, Tashkent State Technical University, Address: Universitetskaya

ABSTRACT*:* The authors propose a control algorithm based on the reliability of the information certain information redundancy in automated process control systems. Solved the problem of selecting and obtaining reliable data on the basis of use of redundant measurements of process parameters in industrial production.

KEYWORDS*:* Techno-economic indicator, the algorithm accuracy, the control accuracy of the information, redundancy, pre-control, physical relationships.

I. INTRODUCTION

One of the main difficulties to be overcome in the development of algorithms for the calculation of technical and economic indicators (TIC) is the presence of systematic errors and accidental releases, as well as the output from the class of accuracy of individual instruments used for the calculation of TIC - in an environment where there is no possibility of their regular verification. Because of this in the calculation of the TIC is not always possible to achieve the specified accuracy, even when using the most efficient algorithms for processing measurement information. This leads to the need to adjust the calculated values of the TIC through the use of additional data about the process: known physical relationships between individual parameters of production, sensor information, further established, etc.

II. STATEMENT OF A PROBLEM

To the algorithm control over the reliability of information, based on information redundancy in the automatic process control system (APCS).

Let the system carried out the measurement n values $x_1, x_2,..., x_n$ of process parameters. We say that there is a redundancy of information, if you know the equations relating the measured parameters:

$$\begin{cases} Y_1(x_1, x_2, \ldots, x_n) = 0; \\ Y_2(x_1, x_2, \ldots, x_n) = 0. \end{cases} \qquad (1)$$

Denote the $x_1^*, x_2^*, \ldots, x_n^*$ measurement results. By check

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$$\alpha \le x_i^* \le \beta \qquad (2)$$

for all $i = 1,2,..,n$, note the settings that it will not pass. Add to them those parameters, measurements which are currently not produced due to instrumentation problems. This detection process parameters have not been tested (2) and measured at a given time, we refer to the category of preliminary control [1]. Let all these parameters will, $(n-m)$ moreover $(n-m) < r$. We introduce a new notation

$$Xi = Yk; \quad i,k = 1,2,\ldots,n \qquad (3)$$

and establish a line that $i \to k$ does not have passed the preliminary control options will receive large numbers: $k = (m+1),\ldots,n$. Then by successive elimination of variables $\mathrm{Y}_n, \mathrm{Y}_{n-1},..., \mathrm{Y}_{m+1}$ system (1) can be converted to the form:

$$\begin{cases} Y_n = F_1(y_1, y_2,\ldots,y_m,..y_{n-1}); \\ Y_{n-1} = F_2(y_1, y_2,\ldots,y_m,..y_{n-2}); \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ Y_{m+1} = F_{n-m}(y_1, y_2,\ldots,y_m). \end{cases} \qquad (4)$$

$$\phi_1(y_1, y_2,..., y_m) = 0, \quad \phi_2(y_1, y_2,..., y_m) = 0. \qquad (5)$$

III. ANALYSIS OF PREVIOUS STUDIES

We call the transition from the equations (1) to (4) and (5) the transformation of the constraint equations. Note that this ratio must be done

$$q = (r - (n-m)) \ge 1,$$

otherwise the redundancy information is not stored.

Obviously, if it is found $y_1, y_2,..., y_m$ satisfying (5), $y_1^*, y_2^*,\ldots,y_m^*$, $(x_i^* = y_k^*)$ then from (4) other variables that satisfy Equations source can be determined (1). Naturally, the relations (4) can not be performed:

$$\phi_1(y_1^*, y_2^*,\ldots,y_m^*) = l_1, \quad \phi_2(y_1^*, y_2^*,\ldots,y_m^*) = l_q, \qquad (6)$$

where $l_1, l_2,..., l_q$ - residual coupling equations.

the reliability of the control task is $v_1, v_2,..., v_m$ to calculate such amendments to the measurement results, in which the corrected values $\tilde{y}_1 = y_1 + v_1$; $\tilde{y}_2^* = y_2^* + v_2$; …, $\tilde{y}_m = y_m^* + v_m$, $(\tilde{x}_i \to \tilde{y}_k)$ satisfy the conditions (5), and together with those found at (4) the initial values $y_{m+1},..., y_n$ satisfy all the equations (1). It can be shown that the process of adjustment has to take into account the separation instrumentation at their errors [2]. Block diagram of the considered reliability of the control algorithm in the control system information has the form shown in Figure 1.

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International Journal of Advanced Research in Science, Engineering and Technology
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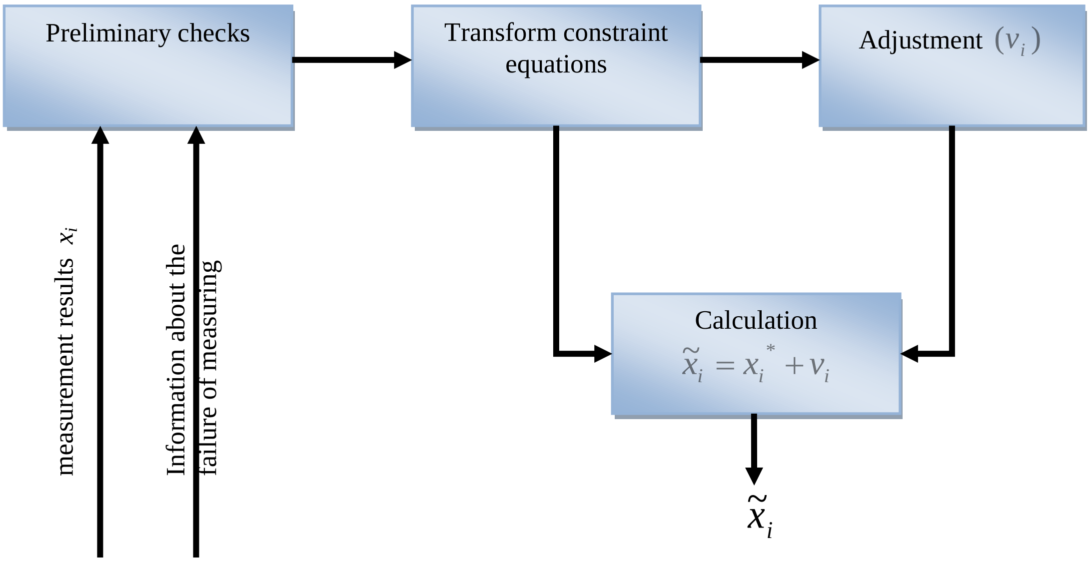

Fig.1. Block diagram of control accuracy of the information.

Objective

Viewed algorithm consists of two phases: detection of monitored events and the development of appropriate control actions. It controlled events - a measurement errors detected by the control unit prior and unequal to zero discrepancies in the equations (5). Control actions under the control of reliability $\tilde{x}_i$, $i = 1,2,..,n$, calculating corrected values that satisfy equations (1) and are therefore quite authentic [3]. Under certain assumptions about the measurement errors are corrected $\tilde{x}_i$ values and the most reliable.

IV. THE RESULTS OF THE RESEARCH

Refer to the separate units of the algorithm. Work units will be considered on the assumption that the constraint equation (1) are linear. If they are nonlinear, these equations must be subjected to linearization.
So, we believe that we have the following constraint equation:

$$\begin{cases} b_{10} + b_{11}x_1 + b_{12}x_2 + \ldots + b_{1n}x_n = 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_{r0} + b_{r1}x_1 + b_{r2}x_2 + \ldots + b_{rn}x_n = 0. \end{cases} \tag{7}$$

Enter the matrix $B_{q,n}$:

$$\begin{pmatrix} b_{10} & b_{11} & \ldots. & b_{1n} \\ \ldots & \ldots & \ldots & \ldots. \\ b_{r0} & b_{r0} & \ldots. & b_{rn} \end{pmatrix}$$

We show how the unit "transform constraint equations" will replace (2), we transform the matrix $B_{q,n}$ into the matrix $C_{r,n}$:

$$b_{ji} = c_{jk}; \quad j = 1,2,..., r; \quad k = 0,1,2,..., n \quad i = 0,1,2,..., n. \tag{8}$$

We exclude y_n from the j-th equation:

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International Journal of Advanced Research in Science, Engineering and Technology
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$$y_n = -\frac{1}{c_{jn}}\left[c_{j0} + c_{j1}y_1 + c_{j2}y_2 + ... + c_{j,n-1}y_{n-1}\right],$$

it is substituted in the matrix coefficients *Cr*, *n* and obtain $C^{(1)}_{r-1,n-1}$:

$$C^{(1)}_{jk} = C_{jk} - \frac{C_{jk}}{C_{jn}},\ j = 1,2,\ldots,(r-1);\ k = 0,1,2,\ldots,(n-1).$$

Eliminating system with variable y_{n-1} matrix $C^{(1)}_{r-1,n-1}$

$$y_{n-1} = -\frac{1}{C^{(1)}_{j,n-1}}\left[C^{(1)}_{j0} + C^{(1)}_{j1}y_1 + \ldots + C^{(1)}_{j,n-2}y_{n-2}\right],\ j = 1,2,\ldots,r-1,$$

We arrive at the matrix $C^{(2)}_{r-1,n-2}$ with elements

$$C^{(2)}_{jk} = C^{(1)}_{jk} - (C^{(1)}_{jk} / Cj^{(1)}_{n-1})$$

Here: $j = 1,2,\ldots,(r-2)$, $k = 0,1,2,\ldots,(n-2)$

At all

$$y_{n-s} = -\frac{1}{C^{(3)}_{j,n-s}}\left[C^{(s)}_{j0} + C^{(s)}_{j1}y_1 + \ldots + C^{(s)}_{j,n-s-1}y_{n-s-1}\right], \tag{9}$$

$$s = 0,1,\ldots,(n-m-1),\quad j = 1,2,\ldots,(r-s);\ C^{(s+1)}_{jk} = C^{(3)}_{jk} - \frac{C^{(3)}_{jk}}{C^{(3)}_{j,k-s}}; \tag{10}$$

$$s = 0,1,\ldots,(n-m+1),\quad j = 1,2,\ldots,(r-s-1),\quad k = 0,1,\ldots,(n-s-1).$$

After excluding y_{m+1} obtain a matrix with the elements $C^{(n-m)}_{jk}$; $j = 1,2,\ldots,(r-(n-m))$; $k = 0,1,\ldots,m,$ which is present in the form of vectors A_0 and matrices A: a_{j0}; $j = 1,2,\ldots,q$; $a_{jk} = C_{ij}$; $j = 1,2,\ldots,q$; $k = 1,2,\ldots,m$ both; Matrix A and vector A_0 define the system of equations (5), when these linear equations.

Referring now to the block "Adjustment". In accordance with the method of least squares adjustment is performed as follows. We believe that the measurement error - additive random variables with zero expectation and variance, driven to a certain δ_0 weight through *Pi*:

$$D\left[y^*_1\right] = \frac{\delta_0^2}{P_1};\quad D\left[y^*_2\right] = \frac{\delta_0^2}{P_2};\ \ldots;\ D\left[y^*_m\right] = \frac{\delta_0^2}{P_m}.$$

When assigning weights take into account the difference of measuring instruments for errors. On this distinction, as mentioned above, the second group is based judgments about the reliability of the information.

For a given $y^*_1, y^*_2, \ldots, y^*_m$ need to find those $\tilde{y}_1, \tilde{y}_2, \ldots, \tilde{y}_m$ in which

$$Q(\tilde{y}_1,\ldots,\tilde{y}_m) = \sum^{m} P_i v_i^2 = \min, \tag{11}$$

$$\begin{cases} a_{10} + a_{11}\tilde{y}_1 + \ldots + a_{1m}\tilde{y}_m = 0; \\ a_{q0} + a_{q1}\tilde{y}_1 + \ldots + a_{qm}\tilde{y}_m = 0. \end{cases} \tag{12}$$

By Lagrange method of undetermined multipliers we introduce $k_1, k_2, \ldots, k_q$ and consider the function m, q of the variables:

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International Journal of Advanced Research in Science, Engineering and Technology
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$$\phi(\tilde{y}_1,...,\tilde{y}_m,k_1,...,k_q)=Q(\tilde{y}_1,...,\tilde{y}_m)-k_1\left[a_{10}+\sum_{i=1}^{m}a_{ij}\tilde{y}_i\right]-...-k_q\left[a_{q0}+\sum_{i=1}^{m}a_{qj}y_i\right], \quad (13)$$

Necessary conditions for the extremum ϕ give m equations:

$$\frac{\partial\phi}{\partial\tilde{y}_1}=\frac{\partial\phi}{\partial\tilde{y}_2}=...=\frac{\partial\phi}{\partial\tilde{y}_m}=0. \quad (14)$$

These equations are added q to equations (12) and search for a solution $\tilde{y}_1,\tilde{y}_2,...,\tilde{y}_m$.

Enter: the matrix parameters $\tilde{Y}$ and Y^*, the V matrix correction, matrix equations residuals connection of L, Lagrange multipliers matrix K, as well as the diagonal matrix of weights obtain R.

$$A_0+A\tilde{Y}-AV=L. \quad (15)$$

Since according to (12) $A_0+A\tilde{Y}=0$,

$$AV+L=0. \quad (16)$$

We rewrite equation (14):

$$\begin{cases}\frac{\partial\phi}{\partial\tilde{y}_1}=2P_1v_1-k_1a_n-...-k_qa_{q1}=0\\ \dots\dots\dots\dots\dots\dots\dots\dots\\ \frac{\partial\phi}{\partial\tilde{y}_m}=2Pv_m-k_1a_{1m}-...-k_1a_{qm}=0.\end{cases} \quad (17)$$

These equations can be written in matrix form as follows, to read:

$$V=-P^{-1}A^T\,G^{-1}L. \quad (18)$$

Found a way to V turn a $\sum P_iv_i^2$ minimum.

Amendment (18) allow us to calculate by (15) $\tilde{Y}$ and corresponding to $\tilde{X}$ satisfy the constraint equation and, therefore, are quite reliable. These estimates constitute the essence of "Calculation $\tilde{x}_i$" block.

We note some features of the algorithm. Obviously, the information output unit "preliminary control" rarely changes - not in every measurement cycle. Therefore, also in each measurement cycle work unit "Transforming communications equations" [4].

Further, if the communication equation really is linear (that, for example, has a place for mass balance equations), the unit operation is simplified "Adjustment". The $S=-P^{-1}A^TG^{-1}$ matrix should be calculated at that pace, the unit "Conversion coupling equations" works in some. Then quickly every time after receiving the results of measurements x^* - you need to perform a calculation $L=A_0+AY^*$, multiplication $V=SL$ and addition Y^*+V.

Here are some parameters of reliability of the control algorithm developed for process control in industrial production of "Navoiazot". The algorithm includes the control of the process variable 17, 15 based on the equations of connection. Its implementation requires about 2,000 cells of RAM computer.

The problem solved by the selection of reliable data through the use of redundant measurements and flow equations material flow connections with each other.

Given a technological system, in which the measured n threads, and, measurement x_i - value of each i-th stream is made simultaneously k_i independent methods. The values x_i bound $m(m<n)$ independent linear equations of material balance

$$f_j(x_1,...,x_n)=0. \quad (19)$$

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Taking as x_i measurement produced k_i one of the methods can form different $S(S = \prod_{i=1}^{n} k_i)$ sets of measured values of flows. Substitution f_j in each *i*-th set of results (due to random errors that are present in the measurement results x_i) to appear in the right-hand sides of equations (19) imbalance H_{i1}. Solution system

$$f_j = H_{i1}, \quad j = 1, \dots, m \tag{20}$$

to find the true values $x_1, x_2, \dots, x_n$ is impossible since $m < n$. Therefore, we agree to consider valid the totality of the measured values of flow, which is the most probable. It can be shown that such aggregate is at least function

$$\mathrm{I(L)} = \min \sum_{j=1}^{m} a_j H_{j1}^2, \tag{21}$$

$$L \in [1, S]$$

Where j - weight j - th imbalance.

What is achieved in a system of automated accounting of the production of complex fertilizers JSC "Ammophos" (Almalyk). Digestible Components of production product (nitrogen, phosphorus and others.) are obtained by the process of mixing flows in a certain ratio. The control system provides several direct or indirect measurement values of these flows. As a result of their use received 6 systems of equations (20). Equations communication flows (19) are defined by the balance of nutrients in the raw material and the product, as well as the conditions for compliance with some of the calculated values of the measured values of flow. Solution of the problem is the selection of input values from the streams of the total of the measured values, substitution into (20) provides that the condition (21). To solve the problem using the initial information on the quantities of raw materials and process flows, the indicators of quality of these flows (concentration, humidity, specific weight, etc.) of the stocks of raw materials and products for shipment. Part of the original information is stored during the day in the magazines business manager, shift supervisors. Part (on the flux) is planned and prepared in the form of daily reports and data. All this background information (about 116 values of 30 parameters) daily flows into the control system of the enterprise, where it is processed. The results of problem solving are issued in the form of a document containing a daily and a cumulative total from the beginning of the month, data about the calculated and measured values of currents.

V. CONCLUSION

The results of solving the problem of how the data are used daily operational records, as well as to check the accuracy of the self-supporting devices for the detection of systematic errors. Figure 2,3 shows graphs measuring the value of differences between calculated and measured values of the two streams based on the averaging interval. The figure shows that for the detection of bias is sufficient interval of 5-15 days for such flows as ammonia and phosphoric acid. Comparison of calculated and measured Bp Wee values on the key indicator - the development (Figure 3) indicates sufficient for operational accounting accuracy of coincidence and correlation (correlation coefficient 0.967).

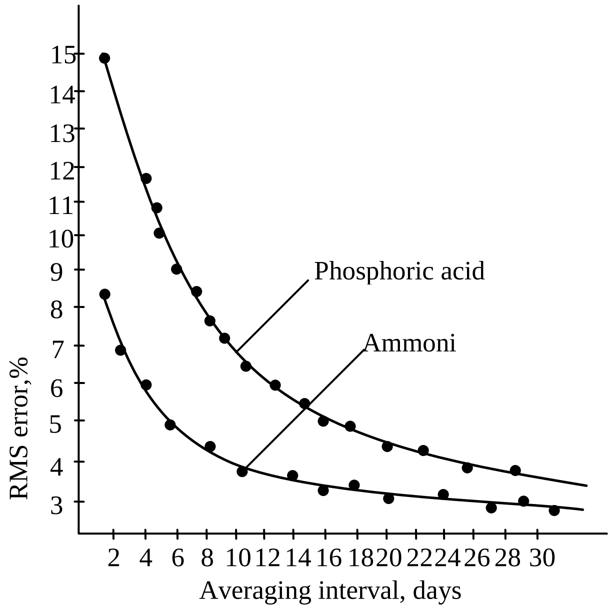

Fig.2. Changes in the mean square error, depending on the averaging interval

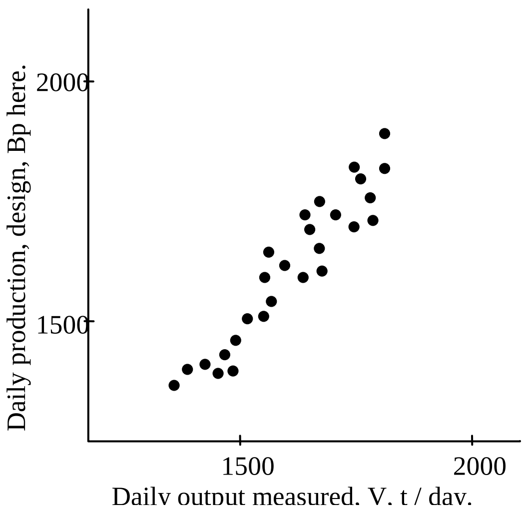

Fig.3. The correlation of daily field workings

The results of this task are used as daily operational data of factory records, as well as to check the accuracy of factory self-supporting devices for the detection of systematic errors.

Hence there follows the conclusion about the possibility of using the calculated values of the process streams in a reliable account of intra-enterprise system.

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