ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 9 , September 2019

Organization Of The Optimum Development Of The Interface Of The Technological Process, Influence Of Errors And Noise On The Functioning Of Intellectual Control Systems

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ABSTRACT:The main requirements for an intelligent measuring channel are considered in the article when designing automated control and control systems. The methods for estimating errors are classified and the constituent groups are classified, and some methods for calculating the errors of measuring means and measuring modules of automatic control systems are given.

KEY WORDS: Intelligent digital systems, sensors, amplifiers, converters, resolving power, system bus, measuring channel, metrological characteristics, measuring module, error, random variables, correlation coefficient.

I.INTRODUCTION

In terms of developing intelligent digital control systems, it is necessary to solve various problems of organizing the interface between the technological object and the control system.

Vital to the creation of intelligent digital control systems is the measurement methods and principles and the development technology of primary sensors. Sensors must display the physical variables of the process, both in static and dynamic modes of operation.

Signalling issues between the measuring system and the control system is an important task. The signals generated by the primary sensors must be coordinated with both the measuring devices and the control system interface. To do this, it is important to take protective measures against the effects of various external electrical disturbances that adversely affect the quality of the signal generated by the sensor. The type of signal carrier current, voltage or luminous flux - is usually selected depending on the nature of the disturbing factors.

The components of the interface between the process and the control system are sensors, actuators and matching devices.

II. SIGNIFICANCE OF THE SYSTEM

For most physical quantities, there are many different measuring technologies characterized by a relationship between the generated signal and the measured quantity. The measuring device (sensor) consists of two parts - the primary sensing element and the transducer.

The measurement result is the reaction of the primary sensing element, which at the transmitter output is an electric quantity in the form of current or voltage. The main advantages of electrical sensors are their flexibility and variety of signal processing methods.

An actuator converts electrical energy into mechanical or physical quantities to affect a controlled process or process.

As part of the actuator, two parts can be distinguished:

1. Converter (or amplifier),
2. Power converter (or actuator).

The converter converts the input signal into a mechanical or physical quantity. The amplifier changes the low-power control signal received from the output interface of the control computer to activate the converter.

In most cases, the amplifier and the converter are structurally integral.

III. LITERATURE SURVEY

The requirement for actuators is power consumption, resolution, repeatability of the result, operating range and so on. May vary significantly depending on the specific application. For successful process control, choosing the right actuators is just as important as measuring sensors.

When deciding how to transfer information between the control system and the physical process, two important factors are decisive - the bandwidth and the noise level.

Bandwidth is an important parameter for many technical applications - data transfer, system buses, feedback control, but in different cases the term can have different meanings. In information transfer and feedback control, the bandwidth denotes the range of variable parts within which the amplitude-frequency response remains less than a predetermined value. For system names, the bandwidth is synonymous with the term “bandwidth.” When processing control and monitoring, the bandwidth is defined as the operating frequency range of the sensor or actuator — only those physical quantities whose operating frequencies lie in the pass band can be properly measured or changed. This condition means that the reaction speed of the measuring sensor is sufficient to accurately display changes in the output measured parameter, while the signal should not distort because no matching dynamic characteristics of the sensor and controlled technical process.

IV. METHODOLOGY

Almost any measurement signal is subject to disturbances and noise in the processes of formation and transmission. Reducing the effect of noise is one of the main problems of signal transmission.

This problem is especially acute when transmitting analog signals caused by electrical disturbances.

When designing an automated control loop and selecting a regulator, it is imperative to consider the presence of disturbances and noise. Reliable functioning of the created automated control system is largely dependent on the quality of the measuring channel. At the same time, the right choice of measuring instruments, timely correct calibration, matching of automation elements and devices by impedance, shielding and cabling, correct implementation of the grounding system fundamentally determines the quality of monitoring and control systems.

A measuring channel is a set of technical means of a measuring system that fulfills a complete function from the perception by the primary sensing element of the measuring quantity of the form of a signal, signal conversion (analog - digital and digital - analog conversion) to obtain the result, either as a digital code or the final operation of the actuator .

Thus, in order to create high-quality automated process control systems, in addition to the factors listed above, it is necessary to take into account the methodological ones that are allowed in the process of unified tests and the instrumental errors that are formed in the production of measuring instruments.

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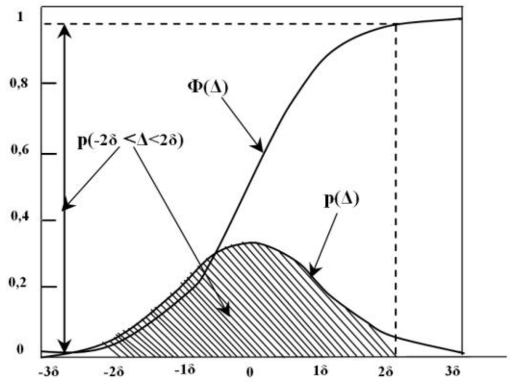
V. EXPERIMENTAL RESULTS

To estimate the errors of measuring instruments and measuring channels of automation equipment, two methods are used - point and interval error estimates. Point errors are defined as in the form of the mathematical expectation of the error and standard deviation. Interval estimation covers all possible values of measurement error with probability [1]. This probability is called the confidence or reliability of the error estimate.

Figure 1 illustrates the interval error estimation.



Error Δ

Here, Δ is the measurement error; P (Δ) is the density of the distribution of errors Δ; Φ (Δ) is the error distribution function:

$$\Phi(\Delta) = \int_{\infty}^{\Delta} \mathrm{P(x)}\, dx$$

For the normal law of error distribution (Gauss law), the distribution density of a centered random variable Δ is described by the function:

$$\mathrm{P}(\Delta) = \frac{1}{\delta\sqrt{2\pi}} e^{-\Delta 2/2\delta 2} = \frac{1}{\delta\sqrt{2\pi}} e^{-0{,}5(\Delta/\delta)2} \qquad (1)$$

whereδ – is rms error.

If the measurement error Δ is within the interval Δ1 <Δ <Δ2, then the probability of this event is calculated as:

$$\mathrm{P}(\Delta_1 < \Delta < \Delta_2) = \int_{\Delta_1}^{\Delta_2} \mathrm{P}(x)dx = \Phi(\frac{\Delta_2}{\delta}) - \Phi(\frac{\Delta_1}{\delta}) \qquad (2)$$

In the most typical case of symmetrical boundaries, we obtain:

$$P(-\Delta_0 < \Delta < \Delta_0) = \Phi(\frac{\Delta_0}{\sigma}) - \Phi(\frac{-\Delta_0}{\sigma}) = 2\Phi(\frac{\Delta_0}{\sigma}) - 1 \qquad (3)$$

Here we use the property of symmetry, the distribution function of the Gauss law.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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Thus, an interval is specified in seven that contains the error of the measured parameter Δ, then the probability that the error Δ does not go beyond the boundaries of the interval can be found by formula (3) for the normal distribution. The probability P is also called the reliability of the error estimate and is denoted by the symbol γ.

$$\gamma = 2\Phi\left(\frac{\Delta_0}{\delta}\right) - 1 \quad (4)$$

To obtain a more reliable estimate of the measurement error or to narrow the confidence interval for a given value of reliability γ, it is recommended to use average values for the result of multiple measurements. When the standard error of the averaging result is determined by:

$$\sigma_{rms} = \frac{\sigma_x}{\sqrt{N}} \quad (5)$$

whereσ_x – is rmserror of the measuring instrument;

N –is the number of single measurements, then substituting in (4) in place of τ valueσ_{rms} , we obtain [2]

$$\gamma = 2\Phi\left(\frac{\Delta_0}{\delta}\right)\sqrt{N} \quad (6)$$

Using this formula, one can determine the required number of single measurements N required to obtain a confidence interval $[-\Delta_0, +\Delta_0]$ for a given reliability γ, or to obtain the desired reliability for a given confidence interval $[-\Delta_0, +\Delta_0]$.

In principle, the errors that arise when creating automated systems for measuring and processing measurement signals can be divided into instrumental and methodological.

Instrumental errors include standardized errors during the manufacturing process of the measuring device, and they are recorded in its operational documentation. And, errors that cannot be taken into account in the process of certification tests, and which cannot be entered into the passport of measuring instruments and appear under various specific conditions of use, are methodological.

Instrumental errors, as usual, are determined by the manufacturer and indicated in the operational documentation of the measuring instruments, and it consists of two components: systematic and random.

To increase the accuracy of the measurement, that is, to reduce the share of the random component, one can achieve by averaging the results of multiple measurements.

Suppose that with the help of the measuring module N measurements were performed, as a result of which the values x_1, x_2, ...,x_N.were obtained. Averaging of the measurement results is performed according to the arithmetic mean formula [2].

$$X_{rms} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad (7)$$

We assume that the measurement results x_1, x_2, ...,$x_N$are independent random variables. Then the variance of their arithmetic mean will be equal to

$$D(X_{rms}) = D\left(\frac{1}{N}\sum_{i=1}^{N} X_i\right) = \frac{1}{N^2} D\left(\sum_{i=1}^{N} X_i\right) = \frac{1}{N^2} N D(X_i) = \frac{\sigma_X^2}{N} \quad (8)$$

In (7), two properties of the dispersion operator were used: 1) the variance of the product of a random variable and a constant is equal to the variance of a random variable times the square of the constant, and 2) the variance of the sum of the random variables is equal to the sum of the variances of each of them. [2]

If we take into account that the measurement of manufacturers is the same device i.e. variance $D(x_i) = \sigma_X^2$, all measurements are the same and equal, and random variables are not correlated.

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However, one should not forget that averaging gives an effect only for the random component of the error. This circumstance asserts that when the number of columnsσ_{rms} is small, the total error is determined by the systematic component.
To calculate the complete, including the systematic component of the error of the measuring channel, which consists of a measuring sensor, a measuring module, which includes signal converters, operational amplifiers, resistors, ADCs, microprocessor parts of the module, etc., all current electromagnetic interference must be taken into account and intrinsic noise of the components of the measuring channel.

The initial data for the calculation of the measuring channels are [3]
- Metrological characteristics of measuring instruments
- Accuracy of the measurement method (methodological error)
- Characteristics of influencing quantities (e.g. ambient temperature, humidity);
- Characteristics of the measured signal.

Errors are summarized by homogeneous groups, which they are divided into:
- systematic and random;
- Random errors in turn consists of: correlated and uncorrelated;
- Additive and multiplicative;
- Basic and additional.

There are three ways [4] to add errors:
- Algebraic

$$\sigma_E = \sum_{i=1}^{N} \sigma_i \quad (9)$$

where$i$ - error number, N - their amount in number
- geometric

$$\sigma_E = \sqrt{\sum_{i=1}^{N} \sigma_i^2} \quad (10)$$

whereσ_i −rms value of the i^{th} error;
- taking into account the correlation:

$$\sigma_E = \sqrt{\sum_{i=1}^{n} \sigma_i^2 + 2\sum_{i=1}^{n}\sum_{j \prec i}^{n} R_{ij}\sigma_i\sigma_j} \quad (11)$$

Here $j \neq i$, because members with $j = i$ are already counted in the sum $\sum_{i=1}^{n} \sigma_i^2$, $j \prec i$ but in order to summarize only the terms below the diagonal of the correlation matrix, because due to its symmetry

$$R_{ij}\sigma_i\sigma_j + R_j\sigma_i\sigma_j = 2R_{ij}\sigma_i\sigma_j \quad (12)$$

When $R_{ij} = -1$ expression (12) goes into the formula of algebraic summation:

$$\sigma_E = \sqrt{\sum_{i=1}^{N} \sigma_i^2 + 2\sum_{i=1}^{N}\sum_{j \prec i} R_{ij}\sigma_i\sigma_j} = \sqrt{(\sum_{i=1}^{N} \sigma_i)^2} = \sum_{i=1}^{N} \sigma_i \quad (13)$$

Where σ_i does it develop with its sign, i.e., correlated errors with opposite signs are partially mutually compensated if their correlation coefficient is unity.
When $R_{ij} = -1$ errors are subtracted in pairs, in accordance

$$\sigma[X \pm Y] = \sqrt{\sigma_X^2 + \sigma_y^2 \pm 2\sigma_X\sigma_Y} = \sqrt{(\sigma_X \mp \sigma_Y)^2} = |\sigma_X \mp \sigma_Y| \quad (14)$$

That is, when finding the sum of random variables, a negative correlation coefficient reduces the total error, and when finding the difference, it increases the error.

Therefore:

$$\delta_\varepsilon = \sqrt{\delta_i^2 + \delta_j^2 - 2\delta_i\delta_j} = \sqrt{(\delta_i - \delta_j)^2} = |\delta_i - \delta_j| \qquad (15)$$

Thus with a negative correlation, the errors are partially compensated if they have the same sign.
Given that in practice it is rather difficult to obtain satisfactory estimates of the correlation coefficients, therefore, the following assumption is introduced:

When $|R_{ij}| \geq 0.7$, then consider $|R_{ij}| = 1$;
When $|R_{ij}| \geq 0.7$, it is accepted that $|R_{ij}| = 0$.

VI.CONCLUSION AND FUTURE WORK

The measuring channel is one of the most difficult parts in the operation of process automation systems. To obtain reliable measurement and control results, it is deeply scientific to make the choice of measuring instruments taking into account errors, metrological characteristics, with the established methodological selection of measuring modules and devices in order to avoid the appearance of dynamic errors.

Therefore, it is necessary to take into account the influence of all errors, interference and noise on the operation of control systems, coordination with the impedance of elements and automation devices that determine the quality of control and management systems.

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