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AUTOMATION OF THE PROCESS OF MONITORING THE PARAMETERS OF INTERBLOCK ELECTRICAL CONNECTIONS

The utilization of traditional automated systems and industrial robots is typically restricted to environments that are well-structured. These systems often lack the ability to effectively handle complexity and uncertainty, resulting in limited adaptability. As a result, their application in small and medium-sized enterprises is constrained. The automated system for monitoring the parameters of interconnection connections based on adaptive algorithms is an innovative approach aimed at improving the productivity of production and reliability of cable and wire products. Within the framework of this work, an analysis of the existing methods for monitoring the parameters of interblock electrical connections was carried out, which made it possible to identify their features and shortcomings. This analysis highlighted the need to develop new approaches to control these parameters using adaptive algorithms.

In the context of this problem, the use of adaptive algorithms provides the system with the ability to minimize the error rate of signal reproduction. This helps to increase the accuracy and reliability of the control process, as the system is able to respond to unforeseen situations and correct its work in real time. In addition, the key element of this work is the development of a block diagram of a modular type of control system. This scheme provides flexibility and scalability of the solution, since each module of the system is responsible for a specific aspect of controlling the parameters of interconnection connections. This approach simplifies the management and maintenance of the system, as well as makes it more accessible for implementation in a variety of industries.

The results of this study testify to the relevance of the problem of controlling the parameters of interblock electrical connections and confirm the prospects of using an automated control system with adaptive algorithms. The use of such a system can significantly increase the productivity of production and reliability of products used in the fields of instrumentation and mechanical engineering.

Keywords: interblock electrical connections, parameter control, pulse and combined control methods, continuous control methods, automated control system, adaptive algorithms.

БУКОВСЬКИЙ ОЛЕГ, ВИСЛОУХ СЕРГІЙ
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АВТОМАТИЗАЦІЯ ПРОЦЕСУ МОНІТОРИНГУ ПАРАМЕТРІВ МІЖБЛОЧНИХ ЕЛЕКТРИЧНИХ З'ЄДНАНЬ

Використання традиційних автоматизованих систем і промислових роботів зазвичай обмежується добре структурованим середовищем. Цим системам часто не вистачає здатності ефективно справлятися зі складністю та невизначеністю, що призводить до обмеженої адаптивності. Як наслідок, їх застосування на малих і середніх підприємствах обмежене. Автоматизована система моніторингу параметрів міжсистемних з'єднань на основі адаптивних алгоритмів є інноваційним підходом, спрямованим на підвищення продуктивності виробництва та надійності кабельно-провідникової продукції. В рамках даної роботи проведено аналіз існуючих методів контролю параметрів міжблочних електричних з'єднань, що дозволило виявити їх особливості та недоліки. Цей аналіз підкреслив необхідність розробки нових підходів до керування цими параметрами за допомогою адаптивних алгоритмів.

У контексті даної проблеми використання адаптивних алгоритмів забезпечує системі можливість мінімізації частоти помилок відтворення сигналу. Це сприяє підвищенню точності та надійності процесу контролю, оскільки система здатна реагувати на непередбачені ситуації та коригувати свою роботу в режимі реального часу. Крім того, ключовим елементом даної роботи є розробка структурної схеми системи управління модульного типу. Така схема забезпечує гнучкість і масштабованість рішення, оскільки кожен модуль системи відповідає за окремий аспект контролю параметрів міжсистемних з'єднань. Такий підхід спрощує управління та обслуговування системи, а також робить її більш доступною для впровадження в різноманітних галузях.

Результати дослідження свідчать про актуальність проблеми керування параметрами міжблочних електричних зв'язків та підтверджують перспективність використання автоматизованої системи керування з адаптивними алгоритмами. Застосування такої системи дозволяє істотно підвищити продуктивність виробництва і надійність продукції, що використовується в галузях приладобудування і машинобудування.

Ключові слова: міжблочні електричні зв'язки, контроль параметрів, імпульсний та комбінований методи керування, безперервні методи керування, автоматизована система керування, адаптивні алгоритми.

Statement of the problem

Since all methods of control of interblock electrical connections are based on the measurement of currents and voltages, the most general classification feature can be called the degree of their automation. In accordance with this feature, all methods of control of interblock electrical connections can be divided into manual and automated. Such a division characterizes not only the share of human participation in the measurement process, but also the means by which the control of interblock electrical connections can be carried out.

The analysis of the structural and technological characteristics and prospects for the development of structural modules of systems for monitoring the parameters of interblock electrical connections showed that a comprehensive solution to the problems of their design and production is possible only on the basis of the development and implementation of methods and means of mathematical synthesis [1]. However, not enough attention was paid to the systematic study and development of this urgent task, which is confirmed by a small number of publications on this topic, so this study is devoted to the automation of the process of controlling the parameters of interblock electrical connections based on adaptive algorithms.

Manual methods of control of interblock electrical connections imply, first of all, manual control of the sources of measuring signals, as well as manual registration of reviews of the device under study, and may differ from each other in the nature of the applied influences. Methods of this type are the least effective in terms of self-heating and the duration of the measurement process [1].

In automated methods of monitoring interconnect electrical connections, the performance of some labor-intensive operations (such as the supply of measuring actions or the registration of device responses) is carried out automatically using special hardware. Various devices and devices can be used as hardware to automate the process of monitoring interblock electrical connections.

Analysis of recent sources

In the modern production of cable and wire products, the automation of the processes of controlling its parameters is of great importance. Separate scientific papers [1] and [2] are devoted to the general issues of control of the parameters of interblock electrical connections. In this context, it is important to consider the possibilities and benefits of using adaptive algorithms in automated control systems.

The authors of the papers [3–6] investigated the automation of the process of testing electrical interconnection connections. They looked at the possibilities of using robots and automated systems and described in some detail the developed systems and testing methodology, which can be useful for production processes. A possible prospect for further research is the use of adaptive algorithms [7]. This will enable the automated control system to respond to the variability of cable properties that may arise during pilot production.

Studies [8, 9] have contributed to solving the problems of error protection in insulation resistance control systems. They noted the importance of checking the key parameters of cable products.

The paper [10] is devoted to the study of adaptive control of computer networks based on fuzzy logic. This approach can be useful for the development of systems for monitoring the parameters of interblock electrical connections using adaptive algorithms.

The results of these studies indicate the need for further improvement of existing solutions and focus on the importance of developing an automated control system, which will significantly reduce the time spent on the control process and will mean an increase in productivity, as well as the reliability of the products themselves due to the partial elimination of the influence of the human factor on the production process. This can be achieved by using adaptive algorithms in the creation of an automated system for monitoring the parameters of interblock electrical connections.

The aim of the article is to analyze the existing methods of control of interblock electrical connections, to establish their advantages and disadvantages, as well as to develop an appropriate automated control system with the justified use of adaptive algorithms in them and, on this basis, to develop a block diagram of an automated system of modular type, to describe its main components and general principles of operation.

In accordance with the set goal, a number of goals are defined to be implemented in this article:

– to review the existing methods of control of interblock electrical connections, to carry out a detailed analysis of each of the methods, to consider their advantages and disadvantages;

– to determine the advantages of using adaptive algorithms and to justify the need to develop an appropriate automated control system with their application;

– to develop a block diagram of the modular type of the system, to highlight its main components and the general principle of operation.

Statement of the main material

Automated methods of control of interblock electrical connections are implemented by various measuring systems, the capabilities of which are limited only by the capabilities of the element base of their hardware. However, the efficiency of these systems largely depends on the nature of the measuring influences applied to the device in the process of monitoring interblock electrical connections. Therefore, an important classification feature of control methods is the nature of influences, according to which they can be divided into continuous, impulse and combined [2].

Continuous methods: the device is sequentially supplied with time-permanent measuring effects with a gradually changing amplitude [3]. Depending on the type of device tested and the means of control of interconnect electrical connections used, the form of such influences may differ.

Most often, among the continuous methods of monitoring interblock electrical connections, the method with a stepwise variable amplitude of measuring influences is used (Figs. 1a and 1b). In this case, as a rule, digital hardware is used, and measurements of interconnect electrical connections are carried out by various computer systems.

An example of continuous methods for monitoring interblock electrical connections is the so-called oscillographic method, where an analog oscillator or special attachments to oscilloscopes are used as a source of measuring effects to take a series of characteristics [4]. In this case, the nature of the measuring effects may have a sinusoidal form (Fig. 1c).

The main disadvantage of continuous methods of monitoring interblock electrical connections is that during the measurement process, current constantly flows through the device under study, and its amplitude can increase. This leads to the accumulation of heat in the structure of the tested device, which causes distortion of the control of interblock electrical connections and the occurrence of a methodical measurement error. This error will be the largest when testing power devices, as well as when repeatedly checking the characteristics of the same device. In addition, when using continuous methods of monitoring interblock electrical connections, the influence of the effect of current carrier capture on the measurement results increases [5].

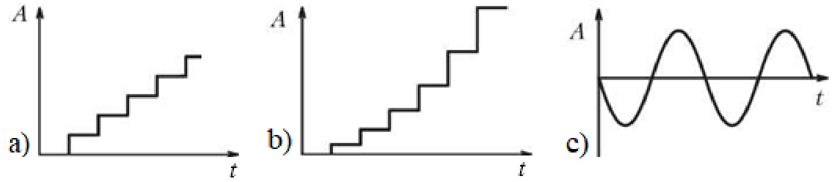

Fig. 1. Forms of measuring influences applied to the device by continuous methods of control of interblock electrical connections

Pulse methods: when controlling interblock electrical connections, a sequence of measuring pulses of different amplitudes is applied to the device, in the pauses between which there are no electrical effects on the device [6]. Monitoring of interconnect electrical connections is carried out by recording the response of the tested device during the action of each pulse. Due to the fact that the current flows through the device under study only at the moments of action of measuring pulses, both the total heating of the device and the effect of the media capture effect in the device are reduced in comparison with continuous methods.

The most common method is that a sequence of rectangular measuring pulses with an increasing amplitude is applied to the device. At the same time, the duration of pulses and pauses between them remains constant (Fig. 2a) [4].

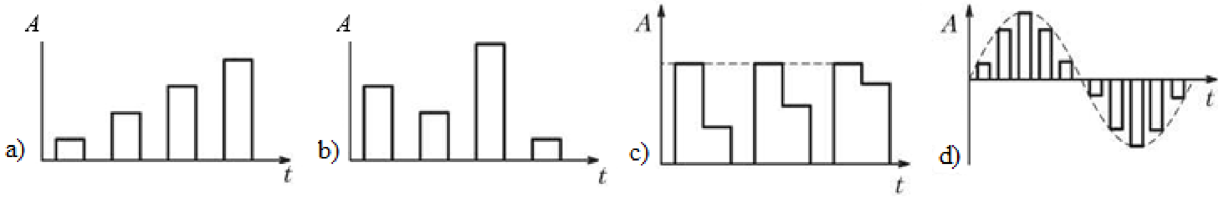

Fig. 2. Forms of measuring influences applied to the device by pulse methods of control of interblock electrical connections

A modification of the described method is the method of control of interblock electrical connections, according to which the amplitude of pulses in the process of voltage measurement varies randomly within the user-defined range (Fig. 2b). This method is used for experimental selection of parameters of impulse influences.

Pulse methods, as well as continuous methods, are used in testing devices whose interblock electrical connections have areas with negative differential resistance. In this case, each measuring pulse is preceded by the opening of a pulse of greater amplitude (Fig. 2c).

The pulse method of control of interblock electrical connections is also used in specialized set-top boxes that allow measuring and observing on the oscilloscope screen a series of indicators obtained using pulse modulation of the signal (Fig. 2d).

Pulse methods of control of interblock electrical connections are widespread and are implemented, as a rule, by high-speed computer systems.

Combined methods: from the point of view of influencing the self-heating, the studied interconnect electrical connections are intermediate relative to continuous and pulse ones, since the measurement process is carried out at a temperature determined by the value of the constant component of the influencing signal [7]. Similar to pulse measurement methods, the effectiveness of combined measurement methods significantly depends on the choice of parameters of the measuring pulse sequence, as well as the degree of their compliance with the individual properties of the device under study.

One example of the use of combined methods is the function of measuring two parameters, one of which varies and the other remains constant. For example, when measuring the characteristics of a cable (Fig. 3), influential signals are applied to its inputs, which can change over time (signal A_n), or remain constant (signal A_y). The output signals, in turn, can be pulses with variable amplitude.

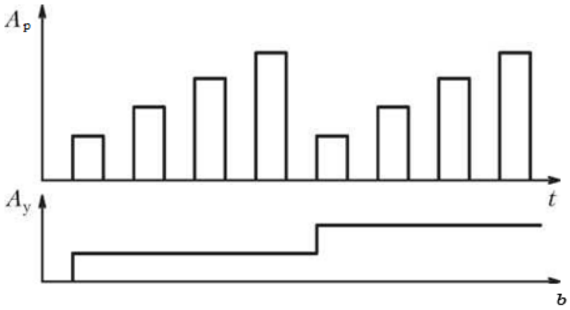

Fig. 3. Form of measuring influences for taking a series of initial characteristics by the combined method

The need for such measurement methods is due to the effect of the current carrier capture effect on the characteristics of the device. The degree of this effect is proportional to the magnitude of the constant electrical signal affecting the device, so the characteristics of the same device in different modes of its operation may differ [8, 9]. Accordingly, the parameters measured in one mode of operation of the device may not accurately characterize its operation in another mode as part of any other device. Therefore, in the context of monitoring inter-unit electrical connections, the most accurate will be the mode of operation of the device in which it will work in the final device. For this reason, combined measurement methods with a resting point are used. In this case, a constant shift of influence makes it possible to maintain the intensity of media capture in the structure of the device at a given level, and short measuring pulses – to achieve less self-heating of the device compared to continuous methods.

To filter signal interference and analyze parameters, it is advisable to use filters based on the recursive adaptive least-squares algorithm. In the case of a signal received, one or more implementations of this process must be processed. To do this, you need to find the filter coefficients w, which minimize the error rate (1) of signal reproduction [10].

$$J(w) = \sum_{t=0}^{T-1} |e(t)|^2 \rightarrow \min. \tag{1}$$

If you continue the matrix recording t-coordinates, then we get the formulas for the column vector of the output signal a (2) and input reproduction errors e (3) [10].

$$a = U^T w \tag{2}$$

$$e = m - U^T w, \tag{3}$$

where m— vector-column of sampling signal counts; $U = [u(0), u(1), \dots u(T\text{-}1)]$ — is a matrix whose columns display the contents of the delay line at different cycles.

The error rate expression (1) can be rewritten with the representation a in matrix form

$$J(w) = e^T e \rightarrow min. \tag{4}$$

Substituting (2) and (3) for (4), we get (5)

$$J(w) = (m\text{-}U^T w)^T (m\text{-}U^T w) = m^T m\text{-} w^T Um\text{-} m^T U^T w + wUU^T w. \tag{5}$$

To determine the minimum value of the objective function, it is necessary to calculate the gradient of this function and equate the resulting value to zero (6).

$$\text{grad}J(w) = \text{-}2Um + 2UU^T w = 0, \tag{6}$$

Thus, the optimal solution is:

$$w = (UU^T)^{-1} Um, \tag{7}$$

In the process of receiving the signal, the filter coefficients can be directly calculated according to equation (7) at each subsequent step. At the same time, the size of the matrix Ucontinues to increase, and the inverse of the matrix $(UU^T)^{-1}$ must be recalculated each time. However, the cost of calculations can be reduced when you consider that each step only requires adding a new column to the matrix U and a new element to the vector m so that the value can be computed recursively. The use of an adaptive least-squares algorithm will provide the ability to obtain useful signals in the process of monitoring the connection with almost no distortion [10, 11].

Based on the results of the analysis of the state of control of the parameters of interblock electrical connections, the task was set to create a system that will automate the control process. This will significantly save time spent on manual control operations, which will increase the productivity of work, as well as the reliability of the products themselves due to the partial elimination of the influence of the human factor on the production process.

An automated system for monitoring the parameters of interblock electrical connections based on adaptive algorithms, based on the use of a combined method with mathematical processing of measurement results, is proposed. The general structural diagram of the system is presented in Fig. 4.

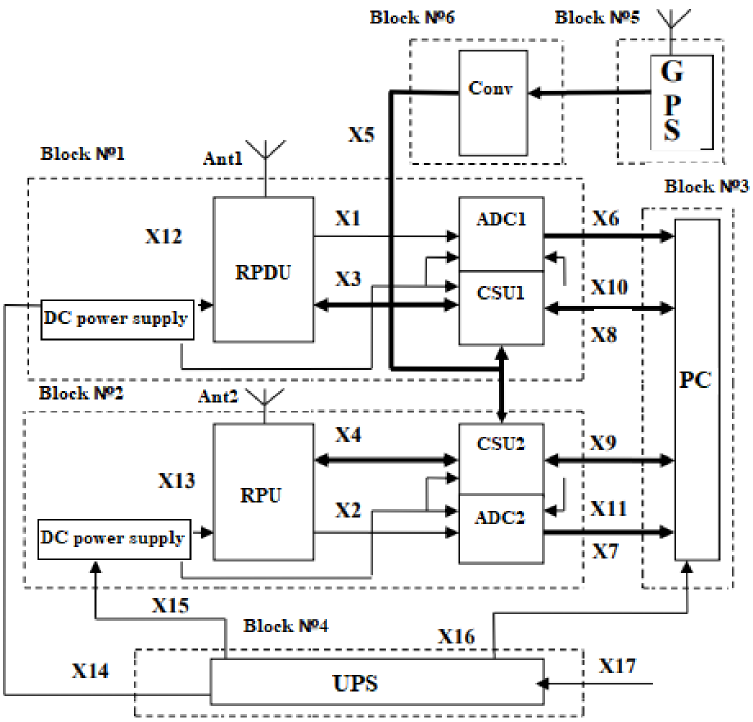

Fig. 4. General block diagram of the system for monitoring the parameters of interblock electrical connections

The structural diagram of the automated control system is built on a modular principle and consists of a set of interconnected blocks.

The transceiver channel (Block No. 1) includes an upgraded transceiver, a power supply, an analog-to-digital converter (ADC1), a control and synthesis unit (CSU1), which includes a subunit of a software-controlled digital synthesizer, a microprocessor subunit of control and a subunit of a highly stable reference generator.

The second receiving channel (Block No. 2) consists of an upgraded receiver, an AC adapter, an analog-to-digital converter (ADC2), a control and synthesis unit (CSU2), which includes subunits of a software-controlled digital synthesizer, a microprocessor control and a highly stable reference generator.

These two blocks receive information, convert it from analog to digital form, and then process and control it using control and synthesis blocks. After that, the information is transmitted to a personal computer (Block No. 3), which is used to process the data obtained, analyze the results of control and make decisions on this basis.

The automated system also includes an uninterruptible power supply (Block No. 4), which provides stable power supply to all units of the system to avoid data loss or malfunctions in the event of power outages, as well as a GPS receiver (Block No. 5) and a converter (Block No. 6) to receive and convert signals from the global positioning system.

The process of monitoring the parameters of interblock electrical connections involves the use of specialized software, which is implemented using adaptive algorithms, which will provide the ability to analyze and control the characteristics of cable and wire products in real time.

Conclusions

As a result of the analysis of methods for controlling the parameters of interblock electrical connections, their shortcomings and features of use have been determined. The necessity of developing an appropriate automated control system based on the use of adaptive algorithms has been substantiated.

The paper proposes a structural diagram of an automated system that has a modular principle of construction. This makes it possible to further improve it on the basis of advanced technologies of electronic components, adaptive interference reduction and distortion correction in the radio channel, as well as improvement of data channel control flows. Developments in the first two areas will provide increased reliability and signal processing, and advances in the third direction, which is of exceptional importance for the network, will give it additional flexibility and survivability.

The use of an automated parameter control system will increase the productivity of the manufacturing process and the reliability of electronic products.

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