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DEVELOPMENT OF A VIRTUAL DEVICE FOR CONTROLLING THE CONDITION OF INDUSTRIAL UNITS NODES USING LABVIEW TOOLS

This article is devoted to the research, construction, configuration and implementation of a virtual device for monitoring the condition of nodes of complex industrial units. Modern units used in heavy engineering require no less modern means of management, control and diagnostics of damage to such units and their components. The development of the structure of control tools is based on multi-level or multi-stage procedures of transformations of incoming measuring signals from aggregates. As the structure of the control device, a structure with a two-stage implementation of the spectral transformation of measurement signals – with a primary static transformation and a secondary static transformation – was chosen. The basis of the primary static transformation is the spectral transformation procedure based on the wavelet transformation. The basis of the secondary static transformation is the procedure of linear discrimination with the indication of the decisive rule. The article demonstrates and implements approaches to building a virtual device in terms of creating a block diagram, developing software, organizing the front panel of the device, setting up and carrying out simulation modeling for blocks of primary and secondary static transformations. The research uses the LabView platform. To prepare incoming measurement signals from nodes of industrial units, in the first block, the procedures of graduation, calibration and normalization of the target function are carried out. To receive input measuring signals from units of industrial nodes, the COM port of the computer is used which, according to the developed program, polls the COM port and inputs measuring signals to the primary static transformation procedure. The article describes a complete virtual control device that is formed and tested, which structurally contains all the blocks for achieving the control result and indicating the control result on the graphic interpretation of the computer.

Keywords: virtual device, LabView, computer components, block diagram, spectral transformation, static transformation, sensor of measuring signals, industrial unit.

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РОЗРОБКА ВІРТУАЛЬНОГО ПРИСТРОЮ КОНТРОЛЮ СТАНУ ВУЗЛІВ ПРОМИСЛОВИХ АГРЕГАТІВ ЗАСОБАМИ LABVIEW

Дана стаття присвячена дослідженню, побудові, налаштуванню і реалізації віртуального пристрою контролю стану вузлів складних промислових агрегатів. Сучасні агрегати, що використовуються у важкому машинобудуванні, потребують не менш сучасних засобів управління, контролю та діагностики ушкоджень таких агрегатів та їх вузлів. Розвиток структури засобів контролю спирається на багаторівневі чи багатоетапні процедури перетворень вхідних вимірювальних сигналів з агрегатів. В якості структури пристрою контролю обрана структура з двохетапною реалізацією спектрального перетворення вимірювальних сигналів – з первинним статистичним перетворенням і вторинним статистичним перетворенням. Основою первинного статистичного перетворення є процедура спектрального перетворення на базі вейвлет перетворення. В основу вторинного статистичного перетворення покладена процедура лінійної дискримінації з індикацією вирішувального правила. В статті продемонстровані і реалізовані підходи до побудови віртуального пристрою в розрізах створення блок-схеми, розробки програмного забезпечення, організації лицьової панелі пристрою, здійснення налаштування та проведення імітаційного моделювання для блоків первинного і вторинного статистичних перетворень. В дослідженнях використовується платформа LabView. Для підготовки вхідних вимірювальних сигналів з вузлів промислових агрегатів, у першому блоці, здійснюються процедури градуювання, калібрування та нормування цільової функції. Для отримання вхідних вимірювальних сигналів з вузлів промислових агрегатів використовується порт COM комп'ютера, який, за розробленою програмою, здійснює опитування COM порту і введення вимірювальних сигналів на процедуру первинного статистичного перетворення. В статті сформований і апробований цілісний віртуальний пристрій контролю, який структурно містить всі блоки для досягнення результату контролю та індикації результату контролю на графічній інтерпретації комп'ютера.

Ключові слова: віртуальний пристрій, LabView, комп'ютерні компоненти, блок-схема, спектральне перетворення, статистичне перетворення, датчик вимірювальних сигналів, промисловий агрегат.

Selecting research area. Modern and promising industrial units require no less of modern means of management, control and diagnostics of damage caused to such units. The development of the structure for such tools currently involves two stages of transformation [1, 2]:

- primary static transformation, when the target function is formed from the input measurement signals of the unit;

- secondary static transformation, when logical decisions regarding the condition of the unit are formed from the obtained target function.

A typical structure of the aggregate control system is presented in [3]. Similar structures are widespread in modern control systems of industrial units.

The autocoherence function is used as the target function in [3] for the primary static transformation. The control scheme for the nodes condition of the industrial unit functions as follows: the input measurement signal, which reflects the physical properties of the control object, passes through time discretization and is divided into two identical signals, one of which enters the spectral transformation unit unchanged, and the other signal initially passes the differentiation procedure, after which it also enters a similar block of spectral transformation. The spectral transformation in the specified blocks is performed according to [4] and with subsequent quadratic transformation. That is, the squares of the wavelet spectra are obtained in accordance with [5] at the output of the specified blocks.

The resulting squares of the spectra undergo a number of transformations, as a result of which sequences are formed that are identical to the spectral characteristics of the input measurement signals. The indicated sequences enter the input of the unit forming the autocoherence target function [6], at the output of which frequency-time indicators of autocoherence, time-frequency indicators of autocoherence and the total indicator of autocoherence are formed.

Grading, calibration and normalization of the autocoherence function takes place in the target function formation block [7].

For the secondary static transformation, the input values are the obtained output indicators of the primary static transformation – autocoherence indicators [6]. On the basis of the specified input values, the secondary static transformation forms a diagnostic decision regarding the condition of the control object [8].

A discriminant function is used to form a diagnostic solution in the secondary statistic transformation. In [9], the most used discriminant functions that provide diagnostic solutions are given. In the system considered in [3], a linear discriminant function was chosen for use as a discriminant function for monitoring the technical conditions of nodes in the industrial unit.

Research aims and objectives. The aim of the research presented in the article is to build a virtual device for controlling nodes of industrial units using a graphical environment.

To achieve this aim, the following tasks were set and solved:

- to determine the computer environment and components for the development of algorithmic and software of a virtual device for monitoring the status of industrial units nodes;
- to develop computer components of algorithmic and software procedures of primary static transformation;
- to develop computer components of algorithmic and software procedures of secondary static transformation;
- to develop software tools for a virtual device for monitoring the status of industrial units nodes;
- to develop a virtual control device for indicating the current condition of nodes of industrial facilities.

Formulating computer components and algorithmic and software procedures of primary static transformation. To implement the primary static transformation, which simplified scheme is shown in [3], a virtual device was created in the LabView graphical programming environment. The block diagram of the device is shown in Fig. 1, and the front panel in Fig. 2.
To ensure debugging of the device, testing was carried out in the "Highlight execution" step-by-step execution mode, which is shown in Fig. 3.

The block diagram of the virtual device of the primary static transformation, which is shown in Fig. 1, works as follows. The input measurement signal is divided into two identical signals, one of which is sent to the Continuous Wavelet Transform spectral transformation unit [10]. Another signal after differentiation on the Derivative block is also sent to a similar Continuous Wavelet Transform spectral transformation block. Taking into account that the wavelet transformation is chosen as the spectral transformation in [3], the quantitative indicators of the scale and shift and the type of the mother wavelet are set for the Continuous Wavelet Transform blocks. This is done using the Numeric "scale" and Enum "wavelet" control elements, respectively. The coefficients obtained at the outputs of the Continuous Wavelet Transform blocks are squared using Square elements [11]. The received spectrum squares are transformed into one-dimensional sequences identical to these spectra using the Transpose 2D Array Function elements ("flips" a two-dimensional array – swaps rows and columns, i.e. swaps shift and scale) and specially created Srednee.vi (calculates average values by rows of a two-dimensional array). The block diagram of the Srednee.vi block is shown in Fig. 4.

Indicators of the target function (autocoherence) of the signals are calculated using the Array Size Function blocks (determines the size of a one-dimensional array), Insert Into Array Function (combines two one-dimensional arrays into one one-dimensional array), For Loop structures (a loop for forming a service array of categories), elements of 1D ANOVA VI (implements variance decomposition). At the output, we get frequency-time, time-frequency and total autocoherence indicators.

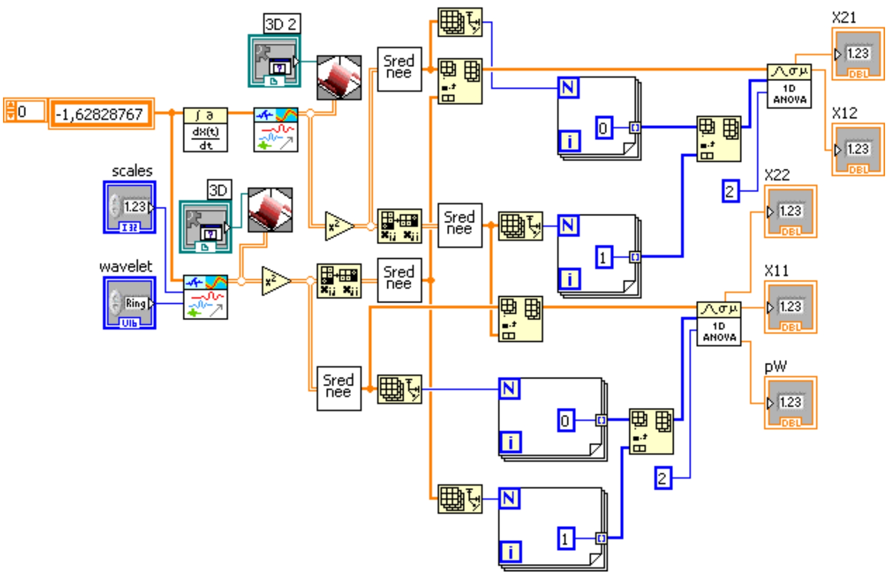

Fig. 1. Block diagram of the virtual device of the primary static transformation

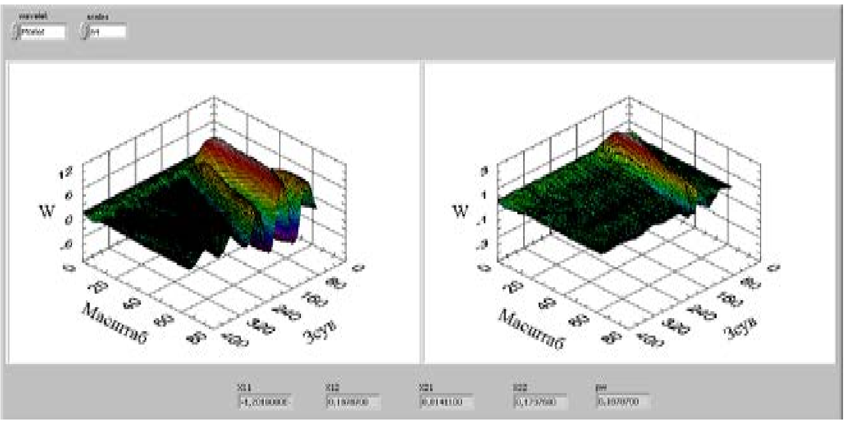

Fig. 2. The front panel of the virtual device of the primary static transformation

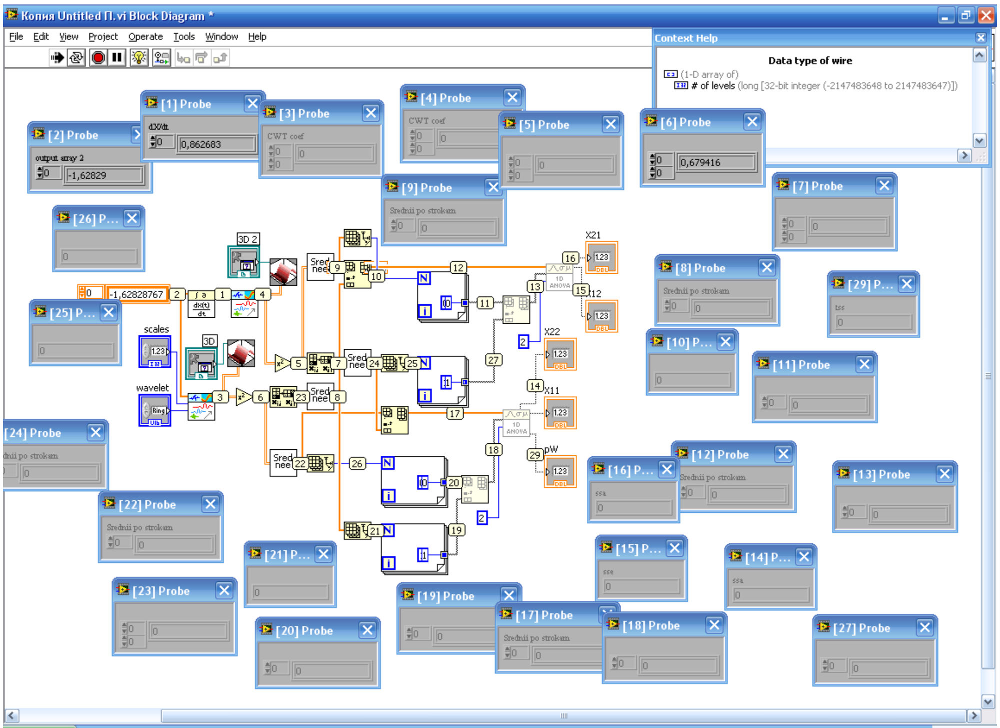

Fig. 3. The process of testing and debugging the virtual device of the primary static transformation

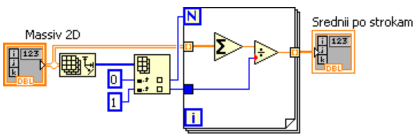

Fig. 4. Block diagram Srednee.vi

Display of the calculated indicators of the target function (autocoherence) is done using Numeric Indicator elements; visualization of spectral coefficients takes place in the ActiveX container that holds the 3D graph control with conversion of 3D Surface VI data types.

Implementing algorithmic and software procedures of secondary static transformation. The method for evaluating the geometric distance of the nominal value features of the spectral coefficients and the value of the spectral coefficients of the studied sample was chosen to perform the procedures of secondary static transformation implementing linear discrimination. To implement the secondary static transformation, a virtual device was created, the block diagram of which is shown in Fig. 5. The process of testing and debugging in the "Highlight execution" step-by-step execution mode is shown in Fig. 6.

For the block diagram of the virtual device of the secondary static transformation (Fig. 5), the input parameters are the minimum and maximum value of the training sample, and the step of the training sample volume. These values are set by the corresponding Numeric controls. The selection of the model is embedded in the Vertical Toggle Switch control element. This model characterizes the gradual growth of the geometric distance between the diagnosed conditions as the size of the feature space increases. To calculate the target probability function based on the given input parameters, three Formula Node structures with the corresponding formulas are used (int N = (Nmax – Nmin)/Nstep + 1 is used to calculate the number of repetitions of the main cycle body, N = nmax/nstep is used to calculate the number of repetitions of the body nested loop, int x = k + 1; int y = N*Nstep + Nmin; if(B==1) S = S + a/pow(k + 1,2); else S = S + a/(k + 1); z = pow(S,2)/(2*sqrt(pow(S,2) + + 2*(k + 1)/y)) used to calculate the geometric distance between the diagnosed conditions and the argument of the probability integral), two For Loops, the Error Function VI element (calculation of the integral of the probability).

ActiveX container that holds the 3D graph control with conversion of 3D Surface VI data types is used for graphical display of the obtained calculations, and Array element [10, 11] is used for numerical display.

For a more convenient visual analysis of the obtained results, the function of automatic search and display of the maximum value of the target function on the surface depicted in 3D Surface VI is carried out. The specified function is implemented using Array Max & Min Function elements (search for the maximum value in a two-dimensional matrix), Index Array Function (getting the coordinates of the maximum value found in a two-dimensional matrix), methods and functions of the 3D Surface VI object – "Cursors", "RemoveAll", "Add", "Plots", "Item", "Row", "Columm", "SnapMode", "Name", "Plot", "NameVisible". The following functions [11] were used for the calculations: POWER(), ERF(), INDEX(), MATCH(), MAX(), and conditional formatting was also applied for convenient visual analysis of the obtained results – automatic selection of maximum values for given values in green parameters (see Fig. 7).

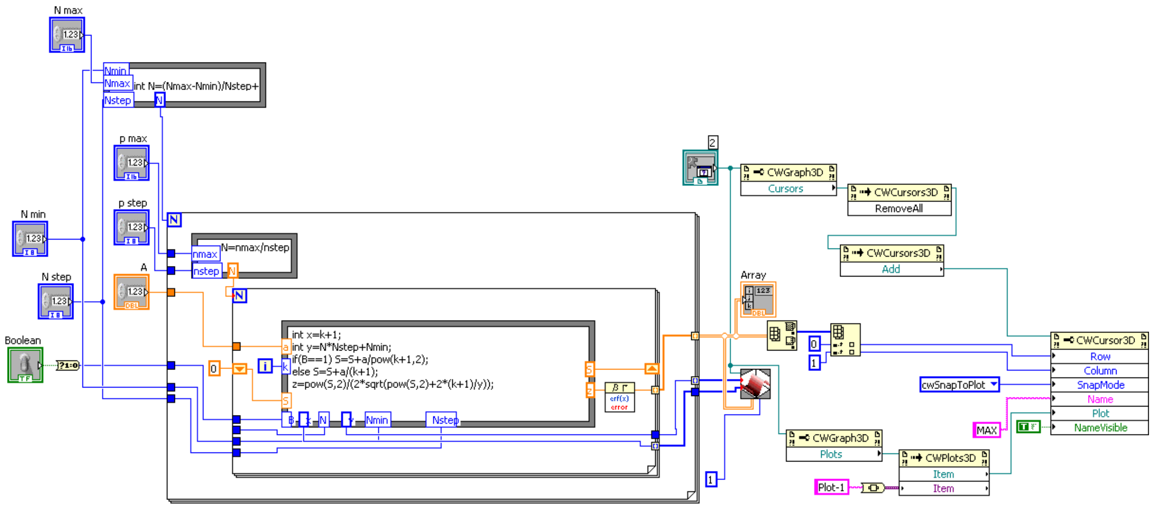

Fig. 5. Block diagram of the virtual device of the secondary static transformation

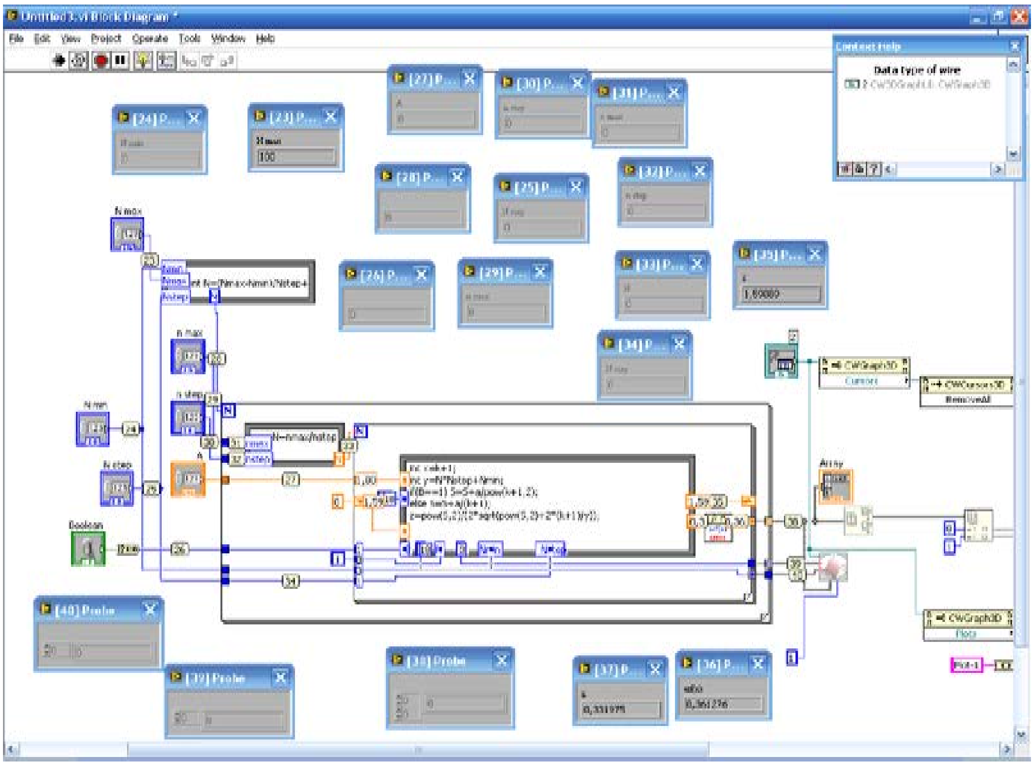

Fig. 6. The process of testing and debugging a secondary static transformation virtual device

A more complex example of using the OpenOffice Calc table processor is the program for constructing histograms of the laws for distribution of random component spectral coefficients, which is shown in Fig. 8. The specified program uses a more complex set of functions, namely [11]: MIN(), MAX(), IF(), FREQUENCY() – array formula, SUM(), OFFSET(). Dynamic named ranges are also applied, which allows you to change the input parameters, including the dimension, which automatically affects the graphical representation of the distribution laws of the random component spectral coefficients on the graph.

Developing a virtual control device on the LabView platform. The implementation of primary and secondary static transformations requires transferring real physical signals from sensors installed on nodes of industrial units to the computer. Reception and processing of electrical signals is carried out through the COM port [12] (regardless of the actual connection – wired or wireless using Bluetooth technology [13].

A virtual device was created in the LabView graphical programming environment to receive and process the input measurement signals by a computer. Its block diagram is shown in Fig. 9.

To connect the software to the COM port, the VISA Configure Serial Port VI block is used, with the following communication settings and appropriate control elements: Enable Termination Char, termination char, timeout, VISA resource name, baud rate, data bits, parity, stop bits, flow control. The output parameter of the VISA Configure Serial Port VI block is VISA resource name out, which is fed to the input of the VISA Flush I/O block. The Buffer Function in the scheme is necessary to clear the buffer of the COM port from possible residual information. From the output of the VISA Flush I/O Buffer Function block, the VISA resource name out parameter signal enters the continuous cycle of the While Loop structure (the end of the cycle is manual).

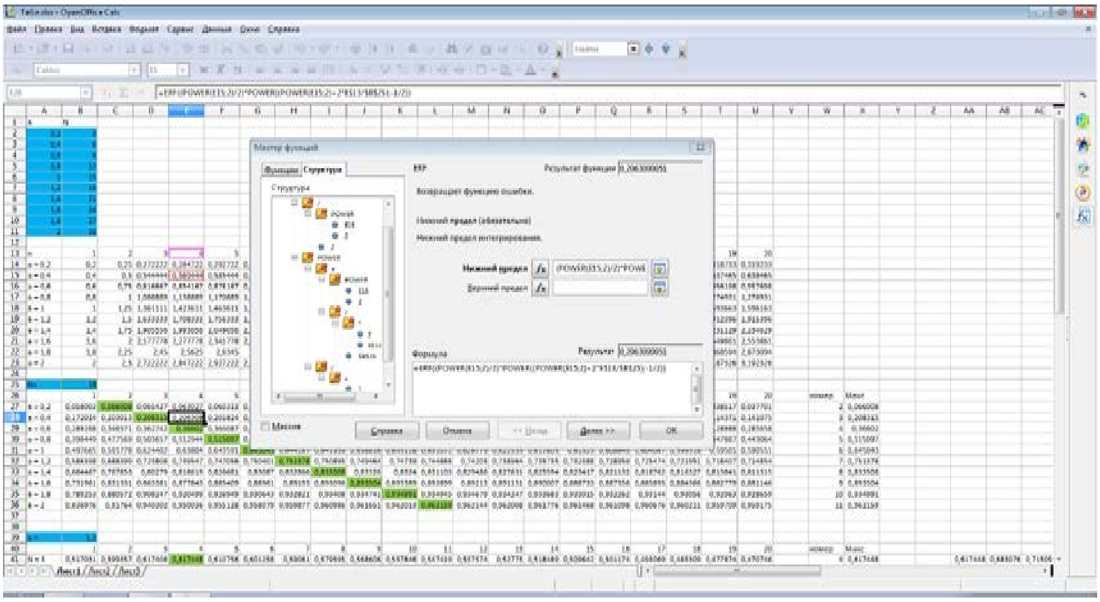

Fig. 7. Using OpenOffice Calc to determine the target function

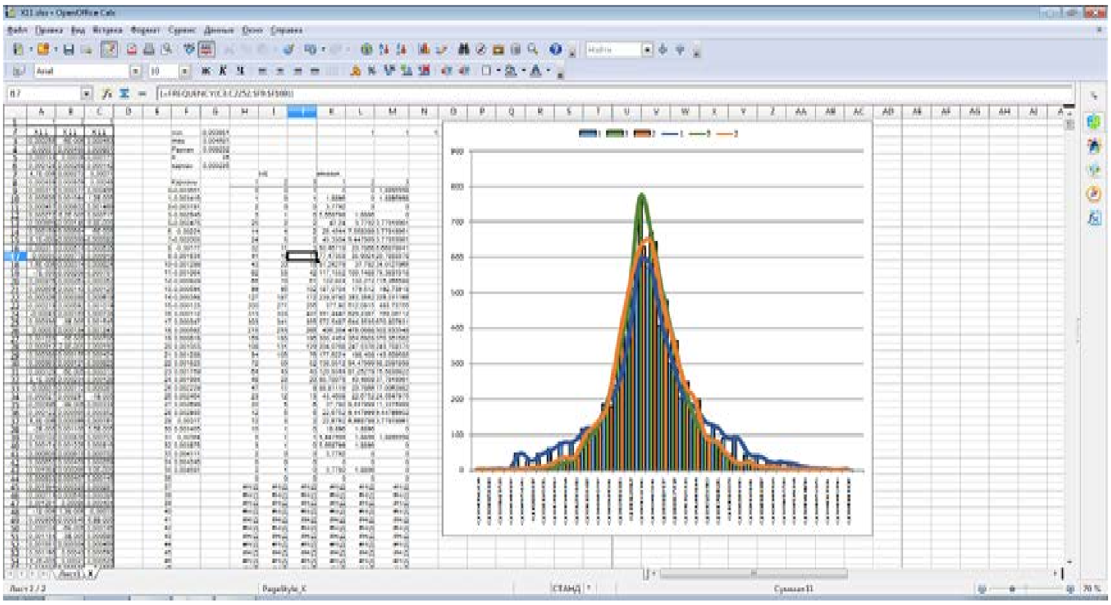

Fig. 8. Using of OpenOffice Calc for construction of histograms of distribution laws

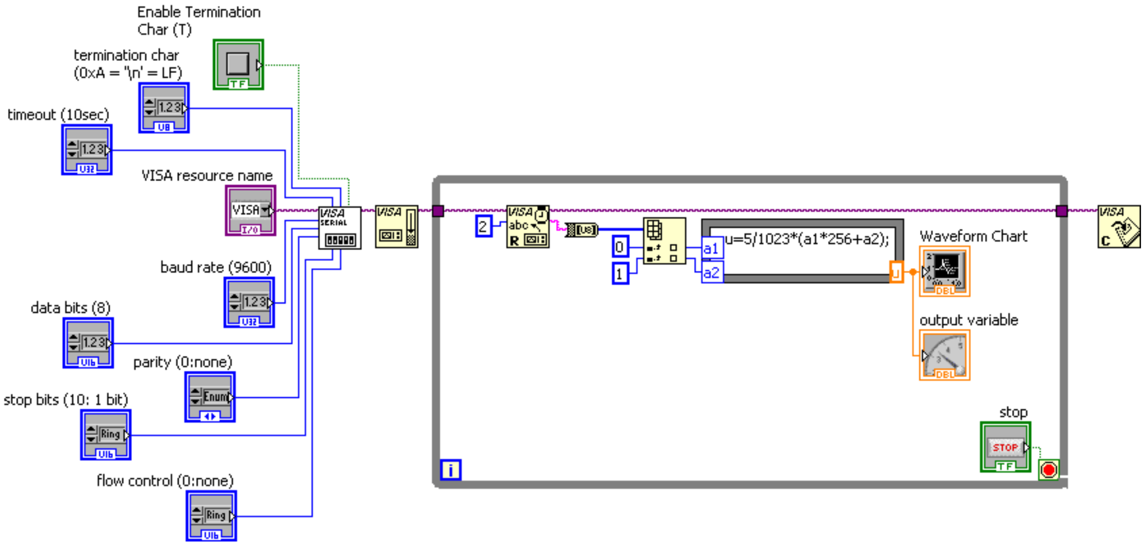

Fig. 9. Block diagram of a virtual device for receiving input measurement signals

In the body of the continuous cycle of the While Loop structure, the VISA resource name out parameter enters the input of the VISA Read Function block, which reads the information received from the sensors installed on the nodes of the industrial unit into the buffer of the COM port in the form of a String variable. The String To Byte Array Function block is used to convert the received information into a numeric variable type, from the output of which the received information in the form of an array consisting of two bytes is sent to the Index Array Function block, which separates and outputs the value of each of the received bytes separately.

To obtain the measured value of electrical signals, the received bytes are sent to the Formula Node structure, where the calculation formula is implemented $u = 5/1023*(a1*256 + a2)$.

At the output of the Formula Node structure, the measured value of the signals from the sensors is received. At the end of reading (manual interruption of the continuous cycle of the While Loop structure), the COM port is closed using the VISA Close Function element.

As a result of using a virtual device (see Fig. 9) to receive input measurement signals, further processing of these signals is possible using the previously discussed primary and secondary static transformation devices. The front panel of such a device is implemented with LabView tools according to Fig. 10.

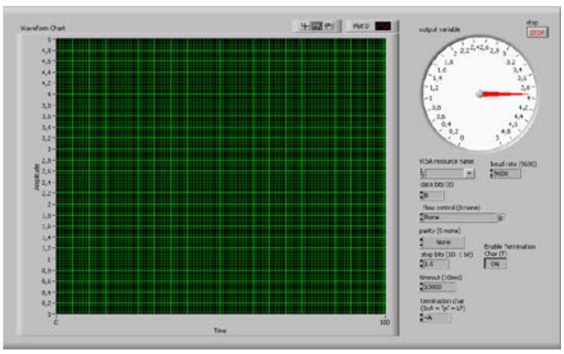

Fig. 10. The front panel of the virtual device for receiving incoming measurement signals

To set up a virtual device for receiving input measurement signals, a control and transmission control device parameters block was created. The image of this block is shown in Fig. 11.

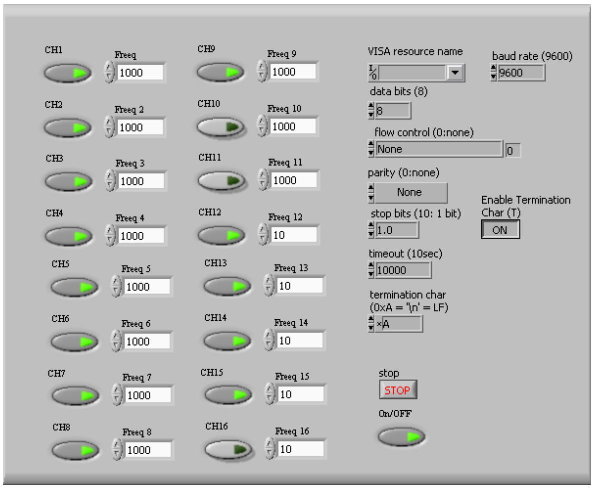

Fig. 11. Block for control and transmission of control device parameters

Fig. 11 shows the following settings and parameters: device status (on-off), measurement channel status (on-off), measurement frequency of corresponding channels (on-off). The data is converted into a String variable using the Build Array Function, Boolean Array To Number Function, Number To Decimal String Function, and Concatenate Strings Function elements. The VISA Write Function block implements the recording of received settings and parameters through the COM port in the device for monitoring and diagnosing the condition of industrial facilities [11].

At the end of the setting (manual interruption of the continuous cycle of the While Loop structure), the COM port is closed using the VISA Close Function element.

The programs and principles used and described in the research are implemented in practice [14]. During implementation, a virtual device for monitoring the condition of industrial units nodes was created, the front panel of which is shown in Fig. 12.

The virtual control device has the following control elements:

- COM port settings – Enable Termination Char, termination char, timeout, VISA resource name, baud rate, data bits, parity, stop bits, flow control;
- setting of measurement channels – Push Button (channel status – on-off), Numeric control (measurement frequency);
- the condition of the device for monitoring the nodes condition in industrial units – Push Button (channel condition – on-off);
- stopping the operation of the virtual device – Button Stop;
- number of scales and type of mother wavelet Numeric "scale" and Enum "wavelet", respectively;
- selection of the spectrum display of ComboBox channels [11].

The virtual control device has the following display elements:

- Waveform Chart with the function of data accumulation, allowing observing changes in the measured value of the nodes condition in industrial units;
- Gauge indicator of instantaneous values;
- ActiveX container that holds the 3D graph control is necessary for visualization of spectral coefficients;
- Array – displays the covariance matrix;
- Round Led indication of the control result;
- String Indicator indication of the control result in text form [11].

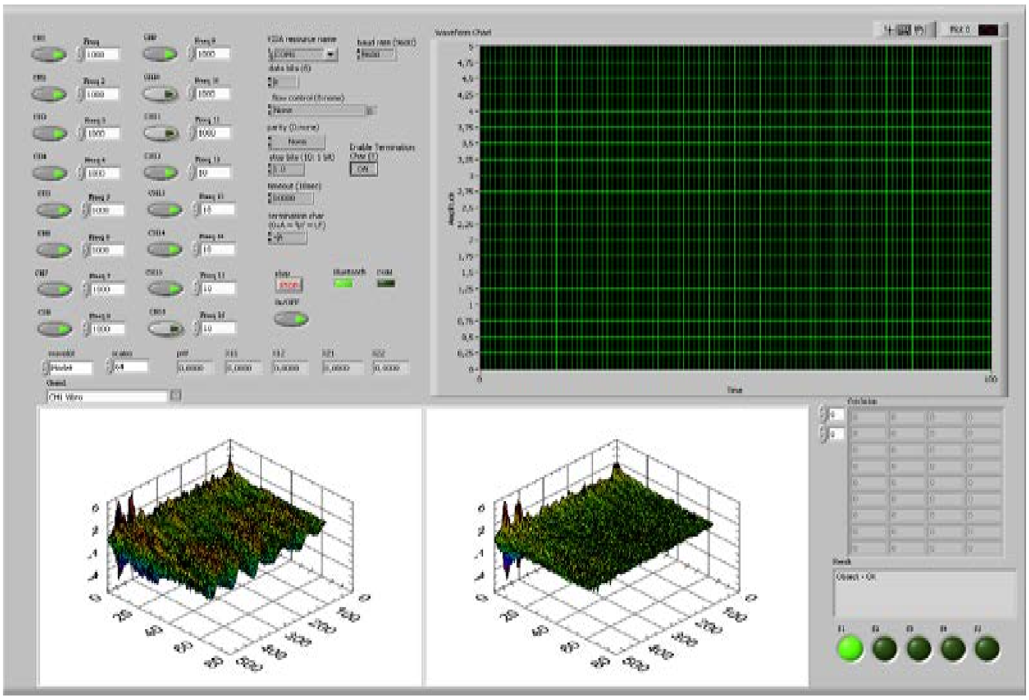

Fig. 12. A virtual device for monitoring the nodes condition in industrial units

Conclusions. The following results were obtained as a result of the research, construction, configuration and implementation:

- the structure of algorithmic support of control devices in the form of primary and secondary static transformation is formed;
- the spectral transformation of signals by means of LabView using the standard Wavelet Analysis VIs library and the WA Continuous Wavelet Transform element is implemented and investigated;
- computer components and algorithmic and software procedures of the primary static transformation are formed;
- algorithmic and software procedures of secondary static transformation are implemented;
- software for monitoring the condition of industrial units nodes on the LabView platform is developed.

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