GRAPHIC MEASUREMENT PROGRAMMING AND CREATION OF LABORATORY WORKS FOR ENGINEERING EDUCATION

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Abstract: In the educational process in the field of electronics and electrical engineering a breadboard method has been employing for implementing a laboratory practicum. The typical breadboard consists of kits of active and passive electrical network elements and a set of measuring instruments. Following this approach the student has to manipulate real network components which, however, are hidden inside the breadboard, and only their images on the breadboard's switching panel are within the student's reach. The demerit of the approach is that both breadboards and instruments are rather expensive and quite often become disabled. In this paper it is shown how this disadvantage can be avoided by using virtual instruments of the graphic software package LabVIEW.

Keywords: virtual instrumentation, laboratory work, engineering disciplines

1   INTRODUCTION

The introduction of modern commercially available graphic programming technologies for organizing practical and laboratory courses in engineering disciplines is necessary at least for two reasons.

First, labware in higher education becomes physically and morally outdated rather fast. Significant funds are required for its repairing, modernizing and replacing in the amount that higher educational institutions do not frequently have. The organization of virtual laboratory works allows to solve this problem with small material costs and without a remarkable reduction of the educational effects.

The second reason is stipulated by a growing necessity of carrying out laboratory works in the distant form, i.e. in the remote or local network mode. Software that allows the realization of virtual laboratory works can satisfy this requirement without any additional expenditures.

The system approach to decision of the above problems assumes the development of the methodology of creating laboratory works on the basis of a graphic programming technique. This technique can be realized by means of the *cooperative* use of various software packages each of which solves its own universe of problems, for example, one package for simulation, other for hypertext, third for instrumentation, etc. (see, for example, [1]). It seems to be, according to the authors' opinion, more preferable to solve those problems within the framework of a *single* package, as it results in a more compact, transferable and flexible software. The package LabVIEW [2], distributed by the National Instruments Corporation (USA) can play the role of such a homogeneous universal environment for the development of laboratory works. LabVIEW is a graphic alternative for the conventional programming allowing to solve the same problems as usual systems of textual programming, and, in addition to them, problems of creating systems for data acquisition, monitoring, test, measurements and control. With the help of LabVIEW it is possible to create the graphic programs called virtual instruments (VI) instead of writing the traditional textual programs.

The authors have some experience in the development of laboratory works for teaching engineering disciplines with using LabVIEW. This experience is shortly demonstrated in this paper. Possibilities of the offered methodology will be shown by an example of a virtual realization of a standard laboratory practicum on the theory of linear electrical networks consisting of 14 laboratory works that are under development nowadays at the Department of Computer-aided Measurement Systems and Metrology in the Tomsk Polytechnic University.

2   TRADITIONAL APPROACH: THE LABORATORY BREADBOARD

It has for a long time been an accepted education practice in the field of electronics and electrical engineering in higher educational institutions to apply a method of implementing a laboratory practicum

by the help of breadboards consisting of a kit of active and passive elements and a set of measuring instruments. For example, in some Russian technical universities the commercially available measurement installation "Luch" is applied (Fig. 1 and 2).

It is required in a laboratory work fulfilling that the student builds the definite network, in the given points of which measurements of certain physical quantities should be made. A singularity of this approach is that during switching the network the student deals with *images* of the network elements on the breadboard's switching panel (Fig. 2). At the same time, the elements themselves are inside the breadboard being unreachable for the student. The shortage of this approach is that both breadboards and instruments are rather expensive and quite often become disabled. This initiates actions of maintaining the breadboards with additional expenditures.

3 ALTERNATIVE APPROACH: THE GRAPHIC MEASUREMENT PROGRAMMING

3.1 Correspondence between traditional and alternative approaches

The above mentioned singularity of the traditional approach allows rather easily to go over from its hardware realization to the virtual program specification by using such a package as LabVIEW. At this change-over it is necessary to ensure the correspondence between two approaches reduced in Table 1.
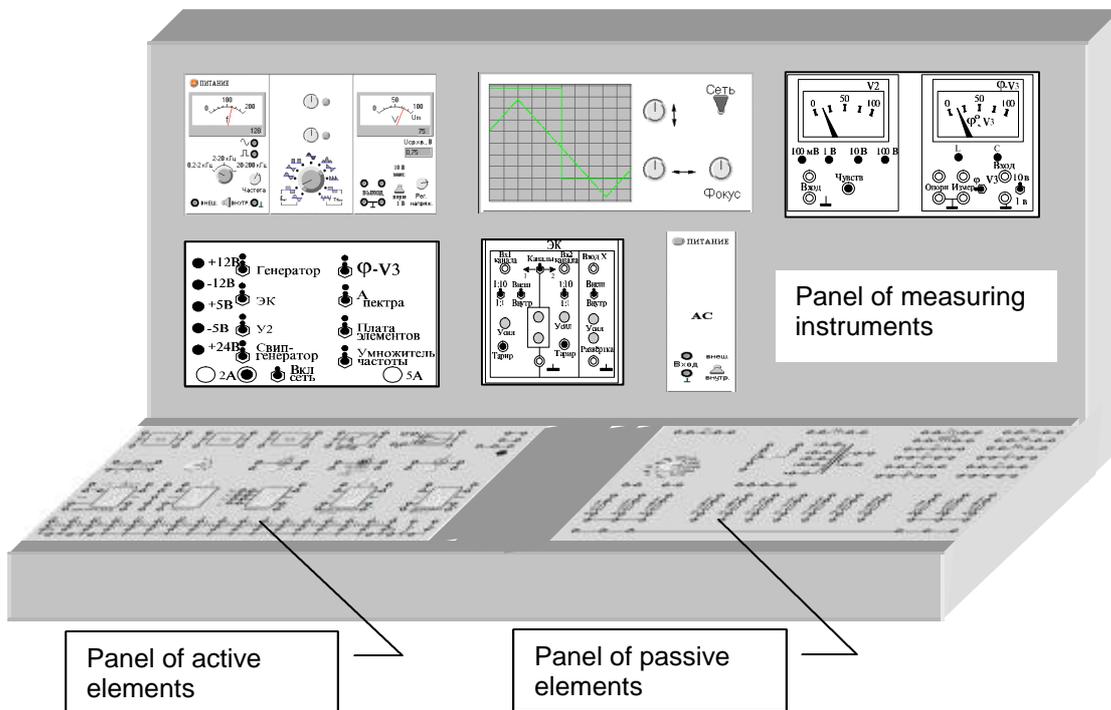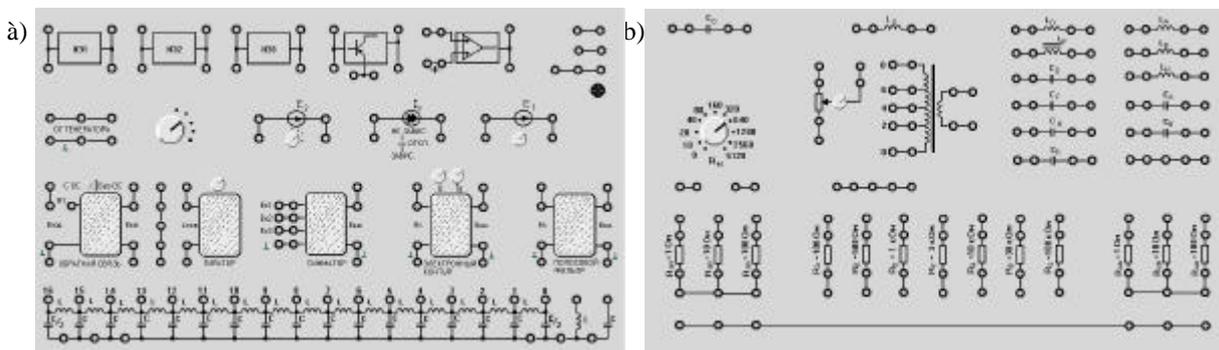
Figure 1. Laboratory installation "Luch"

Figure 2. Panels of active (à) and passive elements (b) of the laboratory installation

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Table 1. Correspondence between traditional and alternative approaches.

Traditional approach	Alternative approach
Set of measuring instruments and signal sources	Set of virtual instruments
Panels of active and passive elements	Set of graphics images of networks under investigation, set of nominal values (constants) of the network elements, set of front panels with adjustable parameters of the elements
Measurement procedure of network element parameter	Program of calculation of a value of a parameter on a mathematical model of the network under investigation and passing of this parameter to a virtual instrument for indication as a measurement result

3.2 Problems of the alternative approach

As it is evident from Table 1, the alternative approach results in the necessity to solve at least two main problems.

The first one consists in the necessity to create compact and ease programmable mathematical models of the objects under investigation (in our example, of electrical networks) and their elements. In contrast to well known CAD packages (for example, PS-Spice or DesignLab), which have rather exact firmware models (e.g. the model of a transistor can be described by more than 60 parameters), the package LabVIEW requires the development of user's own models. It is necessary to note that for the laboratory works the requirements to an accuracy of the models are fairly low. The mathematical model should provide a possibility of calculation of "measured" parameters and their passing to virtual instruments for the representation as a measurement result.

The second problem is that at the alternative (virtual) realization of an experimental stage of the laboratory work, it is required to ensure the same level of educational effects as at the traditional approach. That is, knowledge, skills and experience, which are gained by the student during the assembly of the network investigated and making real measurements, should be reached also in the virtual variant.

In the following section an example of a possible solution of these problems will be considered.

4   EXAMPLE OF THE ALTERNATIVE APPROACH IMPLEMENTATION

Earlier in the Tomsk Polytechnic University all laboratory practical works on the theory of electrical networks were oriented to the realization on the educational hardware measurement system "Luch" including a set of electronic measuring instruments, such as a functional generator, voltmeter, phase meter, spectrum analyzer, oscilloscope, and kits of the investigated active and passive elements. Now these laboratory exercises are supposed to be fulfilled with the use of a computer-based virtual variant at the full preservation of all functionalities of the hardware variant.

For this purpose a software has been developed including the following main subsystems:
- a library of mathematical models of networks under investigation,
- a library of virtual measuring instruments imitating the operation of real instruments of the installation "Luch",
- a library of boards of the network elements with adjustable parameters.

4.1   Stages of a laboratory work

Every separate computerized laboratory work can be realized in a unified form. It consists of the following stages:
- the registration of the student,
- the study of explanations and comments concerning with fulfilling the work,
- answering testing questions,
- the selection of formulae for the investigated network analysis,
- carrying out measurements by means of virtual instruments, and
- the preparation of a report with tables and graphics on the laboratory work.

Each stage is realized in a special window in which a stay of the student is noted by the system if he/she has executed all the prescribed operations.

In the window "Comments" the student theoretical issues underlying the work.

In the window "Questions for auto-checking" the student should choose the right answer of a set of the answers presented.

In the window "Choice of the formulae" a series of the formulae are shown to the student from which he (she) should select the right ones for the given laboratory work. The number of errors is remembered by the system for the student.

In the window "Carrying out measurements" the student fulfills a basic stage of the work, i.e., the programme of experimental investigations.

In the window "Report preparation" the student can fill in the tables by calculated and experimental data, to plot appropriate points on the graphs and to compare the obtained graph with a curve constructed by the computer.

All the actions of the student and results of his work are automatically noted by the system and are saved on the disk under an individual name.

4.2 Carrying out measurements by means of virtual instruments

Let us consider an example of the software realization for the laboratory work "The elementary linear circuits with harmonic signals". Its main objectives are to study a symbolical method of networks with harmonic signal analysis, to check up experimentally a validity of the first and second Kirchhoff laws and to learn to build the vectorial diagrams.

The experimental part of the work consists of the following operations [3]:
- to assembly the network under investigation (see Fig. 3),
- to apply the harmonic signal with frequency $f = 5$ kHz to the input of the network; to set-up the value of Rm from the range 40... 320 Ohm; to short-circuit the resistor Ra,
- assuming a phase of the input signal to be equal to zero, to measure by the voltmeter the module of voltage on the resistor Ri (point A) and by the phase meter the initial phase in the same point;
- to short out the resistor Ri and to remove the short-circuit of the resistor Ra; to measure the module of voltage on C and Rm (point B) and its phase angle.
- instead of the capacitor C to connect an inductor L between points A and B; and, for the obtained network, to repeat the previous operations at the frequency $f = 500$ Hz.

Fig. 3. Investigated network

Fulfilling this programme, the student selects the scheme of the network under investigation in the window "Carrying out measurements" (Fig. 4). The measurement of the parameters of the network elements is performed by means of a choice of the researched element (for example, Ra), its parameter (for example, voltage) and measuring instrument (for example, the voltmeter). There is a group of buttons which allow to get an access to front panels of the signal source, to the measuring instrument or to the set of researched elements (Fig. 5). The student can change states of controls on these panels and to save the instrument readings.
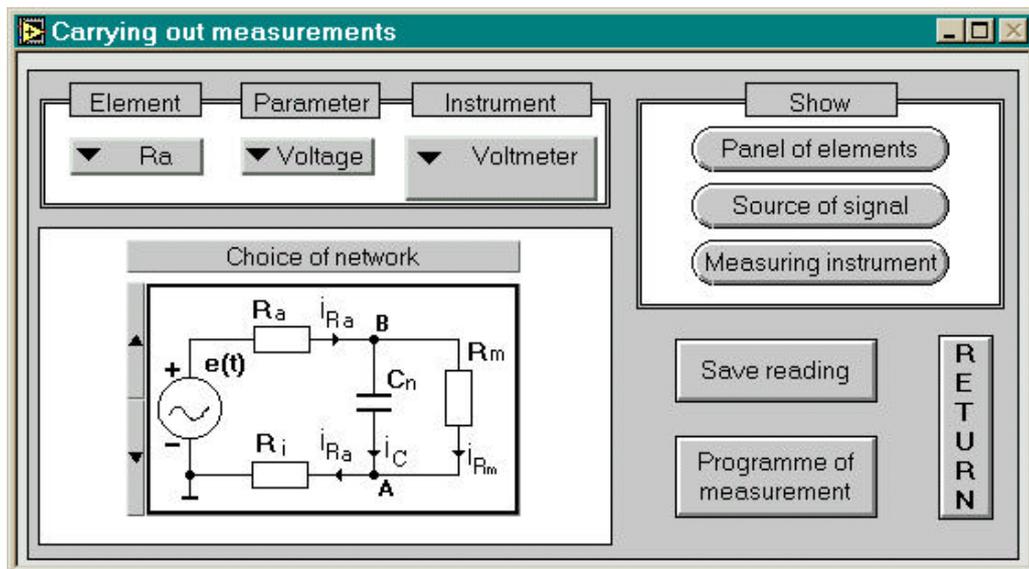
Fig. 4. Window of carrying out measurements

4.3 Mathematical model

In this case a simple mathematical model that provides shaping "measurement results" for virtual instruments, indicating values of voltage and phase, can be constructed on the basis of the method of nodal potentials. Let us consider the network with a capacitor (see Fig. 3) for an example of the construction of the mathematical model.

For the given in Fig. 3 network the first and second Kirchhoff laws make up the system of the initial *topological* equations:

$$\begin{cases} i_{R_a} - i_C - i_{R_m} = 0 \\ i_{R_a} R_a + u_C + i_{R_a} R_i = e(t). \\ i_m R_m - u_C = 0 \end{cases} \tag{1}$$

As it is well known, the Kirchhoff laws are valid for instantaneous values of voltages and currents. If the input voltage varies under the harmonic law $e(t) = A \sin(\omega t + \alpha) = A \cos(\omega t + \beta)$, then, at a steady state, voltages on the linear elements of the network and currents of the branches will vary under the harmonic law too.

Fig. 5. Panel of adjustable elements

Taking into account that the *component* equation for an ideal capacitor has the form $i_C = C \dfrac{\partial u_C}{\partial t}$, from the system (1), we find the voltage u_C on the capacitor as a solution of the differential equation

$$\frac{\partial u_C}{\partial t} = \frac{1}{C(R_a + R_i)} \left[e(t) - u_C \frac{R_a + R_i + R_m}{R_m} \right]. \tag{2}$$

The equation (2) corresponds to a Cauchy normal form of differential equation $\dfrac{\partial y}{\partial x} = F(x, y)$ and is solved by the method of the explicit number integration of Euler.

Then expressions for the network currents will have the following form:

$$\left. \begin{aligned} i_C &= \frac{1}{(R_a + R_i)} \left(e(t) - u_C \frac{R_a + R_i + R_m}{R_m} \right) \\ i_{R_a} &= \frac{e(t) - u_C}{R_a + R_i} \\ i_{R_m} &= \frac{u_C}{R_m} \end{aligned} \right\} \tag{3}$$

Nodal potentials u_A and u_B are defined by the following formulae:

$$\left. \begin{aligned} u_A &= u_C + i_{R_a} R_i \\ u_B &= i_{R_a} R_i \end{aligned} \right\} \tag{4}$$

The appropriate graphic program realization is shown in Fig. 6. In a similar way simple models can be constructed for all remaining laboratory works of the practicum. The teacher can easily modify or refine them in the case of necessity.

5 CONCLUSION

The paper represents in part preliminary outcomes of realization of the project "Creation of Our paper represents some central preliminary outcomes of the realization of the project "Creation of educational laboratory systems on the basis of new information technologies" which was started in 1997 in the framework of the Development Programme for the Tomsk Polytechnic University (TPU). Our purpose in this project is to provide the teachers with a possibility to teach students by the help of the popular computer technology of a virtual instrumentation [4].
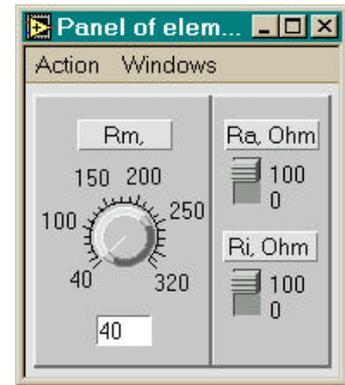
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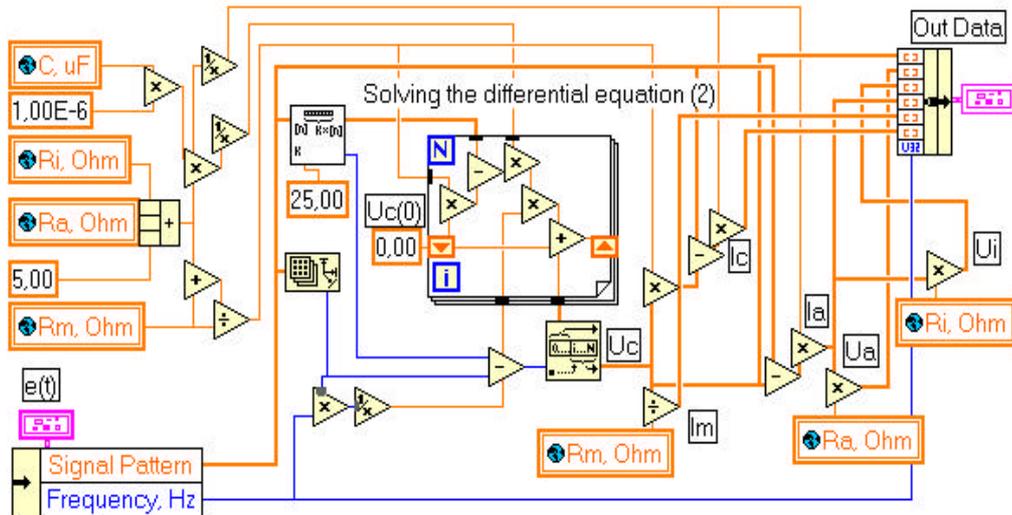Vienna, AUSTRIA, 2000, September 25-28

Figure 6. A fragment of LabVIEW diagram realizing the mathematical model

The outcomes of this system implementation showed that graphic measurement programming and, in particular, virtual instrumentation can serve as an important direction for increasing the learning efficiency and raising the students' training quality up to a level of the international standards [5]. Main directions of the further work in the project are the following:

- further refinement of the tutoring technologies, in particular, the development of their network versions and the provision of their translation into the distant education form;
- permanent organization of the didactical seminars for the university teachers for distributing experiences of both the participants of the project and international experts in the field;
- continuous organization of reference sites in the Internet;
- carrying out demonstration studies with students of various specialities.

The approach considered in this paper has been proved in practice to facilitate a rather simple and ease creation of an effective educational means. The subjects of learning can be of a various nature, e.g., electrical, mechanical or geophysical.

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