

BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Tomul LVII (LXI), Fasc. 5, 2011
Secția
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

TEACHING DC MEASUREMENTS USING MODERN COMPUTER TECHNIQUES

BY

LĂCRĂMIOARA IFTODE* and CRISTIAN FOȘALĂU

“Gheorghe Asachi” Technical University of Iași,
Faculty of Electrical Engineering, Energetics
and Applied Informatics

Received, June 14, 2011

Accepted for publication: August 26, 2011

Abstract. This paper presents an approach of a practical application in the technical subjects' curriculum using the graphical programming environment – LabVIEW, namely the subject of “DC Measurement of Electrical Units” where the student has to perform a study about the influence of errors on electrical units, about their causes and their reduction in a given DC circuit.

Key words: *e-learning*; virtual laboratory; applet-view.

1. Introduction

The introduction of computers and computer software in schools and, therefore, in the educational process, is a necessity imposed by current requirements (Benetazzo *et al.*, 2000; Ferrero & Piuri, 1998; Kocijancic & O’Sullivan, 2002). Producing educational software is not an aim by itself. They are edited in order to be applied to the educational activity both of the teachers and of the students (Benetazzo *et al.*, 2000; Kocijancic & O’Sullivan, 2002). The computer, this modern and intelligent means, is a necessity of the present and even more of the future. When we use the computer in the educational

* Corresponding author: *e-mail*: lacra_iftode@yahoo.com

activities we contribute to major changes in terms of student work strategies and we renew the teaching and learning methods, thus radically changing the role of teachers (Kocijancic & O'Sullivan, 2002). The computer must be used so as to pursue the acquisition of new knowledge and the formation of skills that allow the student to adapt to the needs of a company that is in a constant evolution.

The *e-learning* concept includes traditional and modern methods and techniques using IT&C technologies (multimedia processing and asynchronous and synchronous communication) and leads the subject that uses it to gain experience in understanding and mastering knowledge and skills in a certain field of knowledge. (Bertocco *et al.*, 1998; Savu, 2002). Basically, *e-learning* offers easy and efficient access to the latest information and knowledge, new and efficient teaching, learning and evaluation methods, training and lifelong training. Thus, *e-learning* is an alternative to the lifelong education in the computerized society of today and of tomorrow. An *e-learning* system (for long distance training or virtual education) consists of a planned teaching–learning experience organized by an institution that provides mediated materials in a sequential and logical order to be assimilated by students in their own way, without compelling the participants to co-presence or to be synchronized (Bertocco *et al.*, 1998; Savu, 2002). The mediation is done in various ways from material provided on diskette or CD (or even by mail) to material transmission technology over the Internet.

Experimental laboratories represent an investment both in terms of financial resources and of space, investment that could be impossible for schools, especially when the number of students and undergraduate students and the number of subjects that require laboratory classes are growing (Pelgrum, 1992; Moldoveanu *et al.*, 2003). Remote laboratories are a solution to this problem provided that students and undergraduate students have access to real instruments from any place connected to the Internet without buying any commercial software (Pelgrum, 1992; Ionescu & Radu, 1995; Istrate, 2000; Achimas-Cadariu, 1998). The recent evolution of computer-based tools that have made possible the interconnection opens the way to the virtual teaching laboratories that can be accessed on the network, virtually removing all the problems of the real physical laboratories.

Virtual laboratories intended for the technical field can have two different approaches, namely

a) Experiment simulation with special programs based on laws and principles that underlie the studied phenomenon. In this case, helping physical devices are unnecessary, the results being obtained based on mathematical relations that underlie the simulation. The user has the task to understand the phenomenon and to collect and process the experimental data provided by the simulator. This possibility is very cheap; the *e-learning* programs are portable and can be applied to any technical field.

b) Making the real arrangement of the experiment using physical devices such as: meters, generators, electronic interface circuits, where the

interconnection and the action are done by remote control through the Intranet and the Internet. In this case the user is provided with real data taken from the measurement devices and remotely transmitted to the electronic environment. These experiments, though more intuitive and closer to the reality, need communication software systems and the introduction of more complex data and the used hardware devices need interfaces to communicate with the computer and that raises the costs of the experiment.

Besides the utility of an educational virtual laboratory, it can be also used as a research tool allowing scientists around the world to work on joint group projects. Using a virtual laboratory in the teaching–learning process presents a series of advantages for the educational activity such as: the compensation of the lack of very expensive equipment and devices; the possibility to endlessly multiply laboratory equipment; the possibility to perform experiments without risking harmful influences (radiation, high voltages, toxic substances, etc.); reduced staff; the possibility for the disabled to participate in the experiments.

In what follows a simulated virtual laboratory application for the study of the DC circuits intended for the students of a technical high school is described. The application is designed to be remotely accessed *via* a web browser containing all the elements of a real application starting with the theoretical considerations and ending with the experimental data processing. The application is designed in LabVIEW development environment in order to benefit both from the attractive information presentation charts on user-friendly front panels and from the extremely powerful libraries that facilitate the software development of the application. The paper is part of an *e-learning* system implemented in the high school and through this system other virtual laboratory experiments related to the electric field can be accessed.

2. Virtual Laboratory Architecture

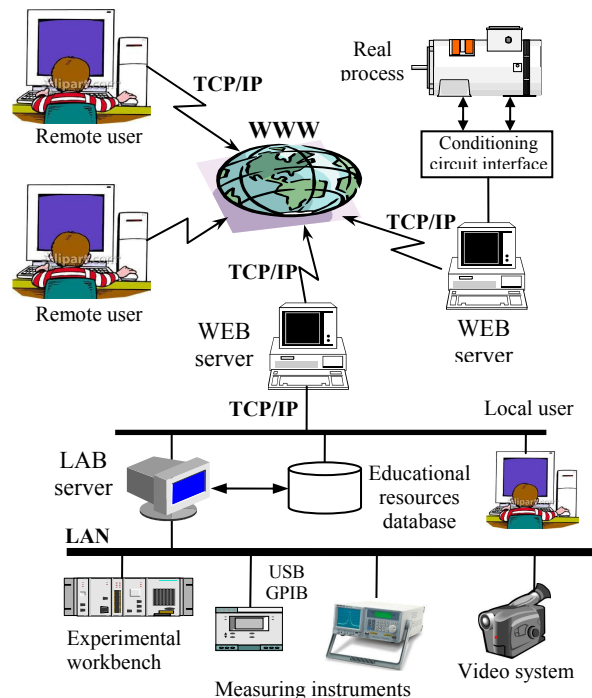
In Fig. 1 we present the general architecture of a virtual laboratory that includes both the software and the hardware components and is based on the experiments that will be performed.

Its structure is organized on three levels: the experiment level, the web server level and the user level. The experiment level contains all the hardware elements required by the experiment such as: the studied device (engine, electronic circuit, amplifier, transducer, etc.), signal generators, power units, relay blocks, switches, measuring instruments, oscilloscopes, signal analysers, etc. All these elements are compatible with the computer *via* serial or parallel communication interfaces (USB, GPIB, Ethernet).

A given experiment is performed and supervised by a local computer on which a server can be implemented containing all the software resources required by the experimental work: data acquisition programs, device communication programs, documentation and educational resources (stored in a

database), server-type applications, test-type knowledge check applications, etc. This computer manages the entire laboratory work and also establishes the communication with the server on the higher level. A local server can manage one or more laboratory works if they are spatially grouped. In the case of simulated works the experiment level is also materialized, at the local server level, through simulation programs. Usually, they are all assigned to a single server that has a proper capacity. The web server level is represented by a central computer that serves all the experimental works, on which runs the laboratory web page and that manages user access to the laboratory.

Fig. 1 – General architecture of a virtual laboratory.



The web server can also contain other elements of the institution *e*-learning platform such as: the learning resources of the non-technical subjects, user monitoring and evaluation applications and performance managing applications. The web server is maintained by an administrator who also has to manage the user database and to provide the access password.

The user level is made of all the persons who enter the virtual laboratory through the web interface. In order to enter an experiment, the user must first register providing personal data and afterwards receives a password from the laboratory administrator. Since an experiment can be performed only by a person at a certain time, it is necessary to establish a timetable (hourly and

daily schedule) for the usage of the laboratory resources.

The facilities offered by the Internet communication allow extensions by creating virtual laboratory systems in which the resources of different institutions around the world can be jointly used. For example, a series of works can be implemented in the Genoa (Italy) University, some others in the Railway Technical High School in Iași (Romania) and others in the Technical University of Tai-Pei (China). This is how large-scale laboratories can be created so that they practically contain all the knowledge in a certain field.

3. Work Structure

In this paper we chose “DC Measurements” in a simulated environment in which all the phenomena related to the DC circuits are shaped by mathematical relations implemented in LabVIEW, the programming environment. In Fig. 2 it is shown the laboratory architecture which includes the “DC Measurements” work.

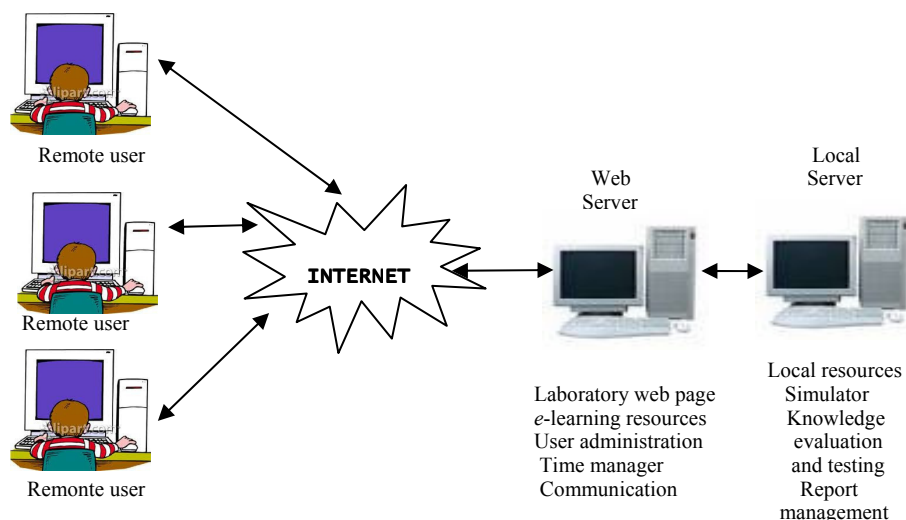


Fig. 2 – Laboratory architecture where the work is running.

The work is implemented on the local server where the simulator runs. The web page of the work runs also on this server, presented in Fig. 3.

The evaluation tests and the students’ reports managing database are also implemented on the local server. The reports are automatically sent to the tutor and classified in the report database. The tutor gives a mark to the report and is added to the mark obtained from the evaluation test. The obtained average is the final mark and is registered in the user managing database that runs on the web server. On the web server runs the general web page of the virtual laboratory as shown in Fig. 4.

The screenshot shows a web browser window displaying a virtual laboratory page. The browser's address bar shows 'LabVIEW'. The page header includes the logo of 'GRUP SCOLAR TEHNIC DE TRANSPORTURI CAI FERATE IASI' and the title 'VIRTUAL LABORATORY FOR ELECTRIC PROFILE'. The main content is divided into two columns. The left column contains a navigation menu with links: 'HOME CONTACT', 'DC measurements', 'Measurement of electrical quantities in an AC circuit', 'Diode characteristics', 'Operational amplifier', 'Inductive transducers', and 'DC Engine characteristics'. The right column is titled 'DC measurements' and contains sub-links: 'Theoretical considerations', 'Arrangement and requirements', 'Applications', and 'Final test'. Below these links is a text block explaining the aim of the measurement and defining DC voltage and current. A circuit diagram shows a DC source connected in series with an ammeter (A) and a resistor (R). A voltmeter (V) is connected in parallel across the resistor. A 'PDF' link is located at the bottom right of the content area. The footer of the page reads 'Copyright 2011'.

Fig. 3 – The web page of the work “DC Measurements”.

Other resources of the *e-learning* platform can be found on this server. The web server has three main functions

- a) User management (UM).
- b) Laboratory timetable management (TM).
- c) Tutor communication management (CM).

a) This function was introduced in order to have a clear user list and to monitor students on the *e-learning* platform in case the application will be implemented in a distance learning system. Through an interactive web window the user is asked to provide some data such as: surname and name, age, affiliation, valid *e-mail* address. The UM program introduces these data in its own database and sends a message to the indicated address containing the username and the password.

b) Since an experiment can be performed by one user at a certain time, there is an implemented program at the web server level that divides the 24 h day into half-hour periods that are assigned to users according to their preferences. The program presents on a web interface the timetable and the user has the possibility to choose among the available periods of time when he/she

wants to perform the lab work. Once a cell in the timetable is assigned, it becomes unavailable to other users. When a user begins his/her lab work, the TM program begins the countdown indicating at any moment the left. When the time is up, the TM warns the user that the time has expired and closes the interface.



Fig. 4 – The general web page of the virtual laboratory.

c) By carrying out lab work the student gains a series of knowledge that will eventually be evaluated by making a lab work report and taking a test. The test result and the evaluation report are sent to the tutor by *e-mail* through the CM function of the web server. Using this function, the student can ask questions to which the tutor can answer on line or off line. In the future we intend to add to the work the possibility to communicate with the tutor by teleconference system that will also be managed by the CM.

The web page of the work has the following elements:

1. Theoretical considerations.
2. Installation scheme and requirements.
3. Practical application.

4. Final report.
5. Knowledge testing.

1. *Theoretical considerations* contain a review of the DC measurements issues. The file type is hypertext and contains references to the bibliographic resources on the Internet or from the application database. In this section the following aspects are presented:

a) the way of calculating the voltages and the currents in the given circuit;

b) the types of errors that appear in these measurements;

c) the error calculation according to the existing norms;

d) conclusions concerning the measurement precision.

The theoretical considerations remain open throughout the entire work.

2. *Installation scheme and requirements*. This section contains both the installation schemes with the two types: upstream and downstream (Fig. 5), (the schemes will be used in the practical application implemented in LabVIEW) and the requirements of this lab work. The file type for them is hypertext and contains references to the application database and possibly to other bibliographical resources needed to address the requirements.

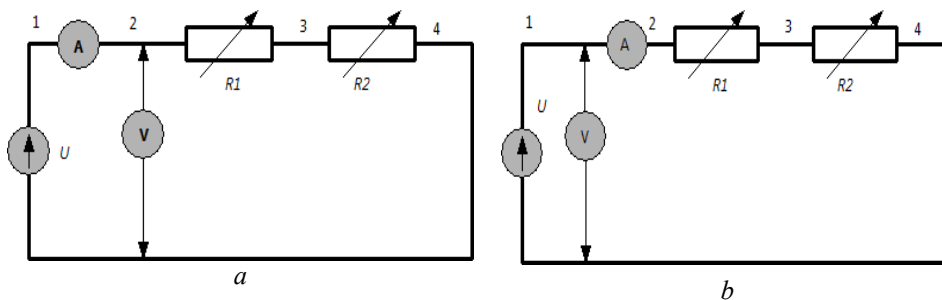


Fig. 5 – The installation schemes for the two types of DC measurements:
a – downstream setup; *b* – upstream setup.

The work requirements are also published on this file that contains references both to the file where the theoretical considerations are presented and that is open throughout the entire work and to the application database where the user will take a series of data needed to address the requirements.

3. *Practical application*. This is the main part of the virtual lab work where the user enters an applet-type application developed in Labview. The front panel and the block diagram of the practical application developed as virtual instruments in Labview are presented in Figs. 6 and 7.

The front panel of the virtual instrument shown in Fig. 6 contains an installation scheme for each of the two cases, upstream and downstream, a series of controls through which the user can provide data to the instrument, tables in

which the measurement results and their calculation results of some quantities will be shown. On the panel one can also see the button NEXT that allows the user, after filling in the set of data that are available, to run the program in order to fill in the table with experimental data.

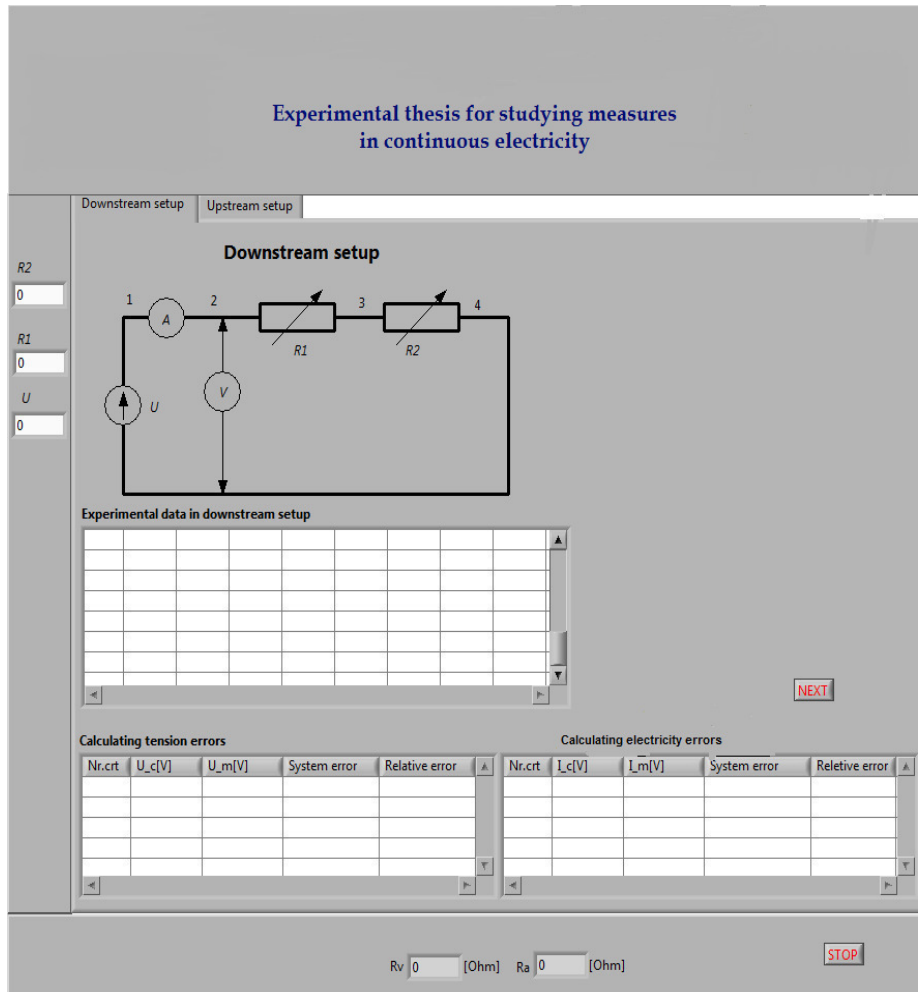


Fig. 6 – The front panel of the “DC Measurements” practical application.

The functions implemented by the main instrument are made in two sequences: a first stage that is the reading of the data introduced by the user and the GPIB command of the function generator and a second stage, graphically presented in Fig. 7, where the experimental data acquisitions, the data numerical processing and the result report are done.

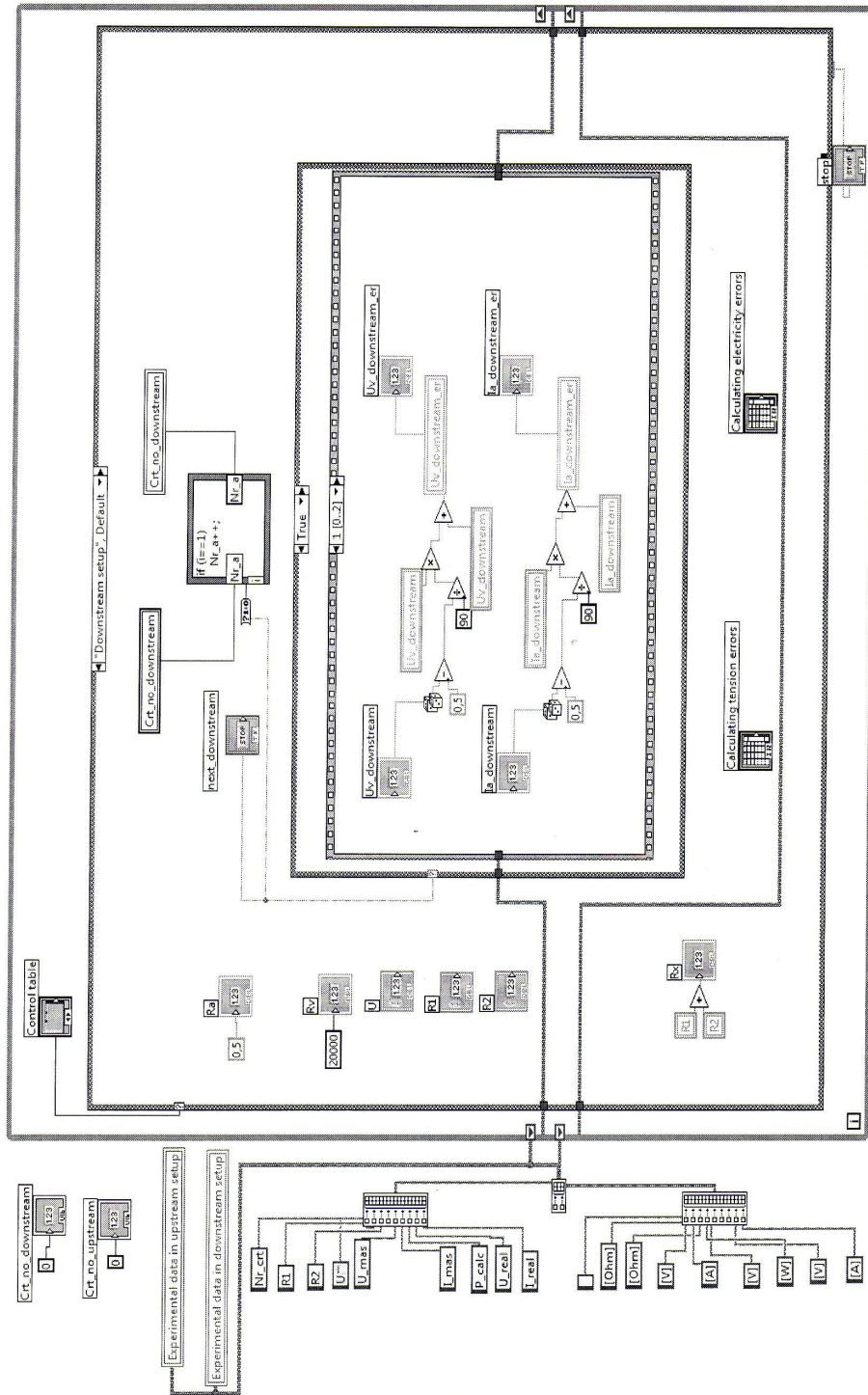


Fig. 7 – The connection diagram of the main instrument.

- it manages the user interface;
- it calculates the requested quantities;
- it generates errors for the current and the voltage;
- it shows the calculation results in tables;
- it ensures the selection of the two installations.

The connection diagram of the main instrument contains a series of structures that have the functions previously presented; these structures interconnect with other nodes in the instrument diagram and are performed automatically when all the input data are available providing output results. These are used to repeat some code blocks or to perform conditioned codes in a certain order.

As it can be seen in the diagram, an outer WHILE loop was used whose output is forced by pressing STOP, inside of which two CASE structures were placed, structures that contain the two important elements, that is the case selector and the case identifier (True), elements used to identify the two installation schemes: upstream and downstream. The inner structure of the SEQUENCE type offers the possibility to induce an error both for the current and for the voltage and forces to perform codes frame by frame, from left to right (Fig. 8).

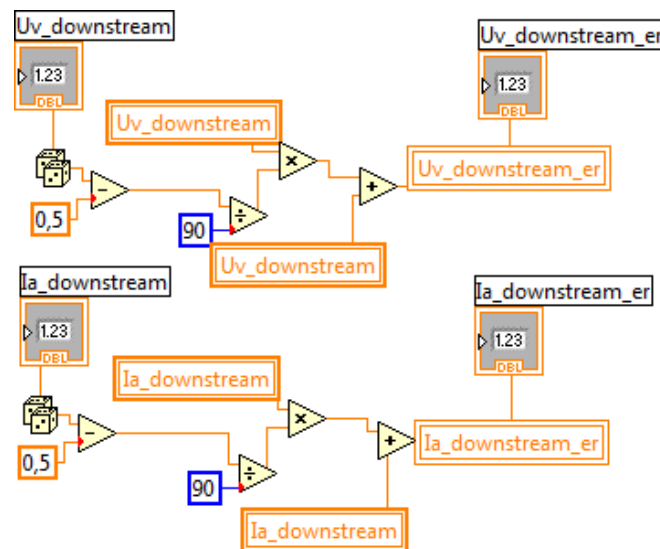


Fig. 8 – Error generating sequence, “Random Number” function.

In order to generate random errors in the calculation of these quantities, the function Random Number 0-1 was introduced in the connection diagram, this function being below the range of numerical functions and having the role to change the current and voltage values while the program runs both in the upstream installation and in the downstream one. As it can be seen, this type of structure, based on conventional text language, performs the operation of

“manufacturing” some random errors that will lead to getting some results of the calculated quantities that are bigger or smaller in comparison with the reference quantity.

4. *Final report* is a Word file, in which the student fills in a series of available tables with data and interpretes the obtained results during the lab work. It is mandatory that the report contain conclusions about the measurement precision and the influence factors. The report is downloaded from the web page, filled in and sent by *e-mail* to the tutor.

5. *Final test* contains a series of questions concerning both the theoretical part and the practical one of the lab work. The tests are multiple choice ones with only one correct answer. The result is immediately sent to the test managing program, is transmitted to the user and automatically sent to the tutor who takes it into account when giving the final grade.

4. Results and Discussions

In order to test the efficiency of the proposed learning method using the developed virtual lab, it has been applied to three classes, that is 73 students from the Railway Technical High School in Iaşi. The students had to access the lab and to perform the entire lab work during three months. The results were sent to the tutor and they were classified. Also, after the three months of test performance, every student received a questionnaire with the following ten questions:

1. The utility of the virtual lab work in comparison with a real lab work.
2. The quality of the graphic interface.
3. The degree of understanding the theoretical considerations.
4. The degree of understanding the work requirements.
5. The easiness of collecting lab data.
6. The easiness of filling in the test.
7. The degree of difficulty of the evaluation test questions.
8. The facilities of communication with the tutor.
9. The connection quality.
10. Improvement suggestions.

The students had to evaluate each question on a scale from 1 to 5, where 1 is the lowest level and 5 the highest one.

The number of answers for each question and the percentage are given in Table 1. Analysing these answers we observe that the virtual lab method presents a high interest among the students, 90% of them giving answers of levels 4 and 5. The students suggested that the graphic interface needed improvement in terms of image and that the installation schemes should be presented in a more suggestive way.

As regards the degree of understanding of the presented information in this work, 85% of the respondents consider that the theoretical part is well selected so that the user of this method can understand and easily fulfill the

requirements. Concerning the requirements, it can be mentioned that 84% of the users of this virtual lab consider that the requirements are clearly, concisely and correctly written, easy for everyone to understand.

Table 1

Answer level	Question number								
	1	2	3	4	5	6	7	8	9
1	1 (2%)	5 (6.84%)	–	2 (3%)	–	–	4 (6%)	2 (3%)	7 (10%)
2	3 (5%)	13 (18%)	4 (6%)	–	–	3 (5%)	2 (3%)	3 (5%)	16 (23%)
3	4 (6%)	25 (35%)	8 (11%)	10 (14%)	5 (6.84%)	7 (10%)	19 (26%)	21 (28%)	8 (11%)
4	21 (29%)	11 (15%)	12 (17%)	23 (32%)	10 (14%)	35 (48%)	25 (35%)	19 (26%)	18 (25%)
5	44 (61%)	19 (26%)	49 (68%)	38 (52%)	58 (80%)	28 (39%)	23 (32%)	28 (38%)	24 (33%)

Collecting data in a virtual lab is quite easy and simple, the respondents having the possibility to run the program as many times as they want and to fill in the requested data by a simple click and this can be seen in their answers; only 6% are unhappy with the easiness of collecting data, most of them not having paid attention to the teacher's explanations how to use the program or not having attended the classes when working this method.

The report that needs to be filled in and sent to the tutor can be downloaded from the lab work web page and is a Word file with tables that the student must fill in with the result data after calculations and that is why 87% of the respondents think that they are easy to fill in and 13% consider that using other materials besides Labview complicates the lab work.

Regarding the evaluation test applied to the 73 users of this method, over 90% of them chose the answer levels 3, 4 and 5. This means that the test questions are of average difficulty and any respondent can answer after carefully reading the theoretical considerations and, of course, after passing through all the stages of the lab work.

The way of communication with the tutor is relatively simple and the students' answers prove it since 92% answered the question using the levels 3, 4 and 5 showing that they were happy with the way they connected with the tutor, the connection being established *via e-mail* or through the CM function of the web server.

4. Conclusions

A simulated virtual lab application intended for the students of a technical high school who the DC circuit is studied, is designed in the LabVIEW developing environment, having the possibility to be remotely accessed *via* a web browser. It contains all the elements of a real application

starting with the theoretical considerations and ending with experimental data processing. The application is designed in the LabVIEW developing environment to benefit both from the attractive graphic possibilities of presenting the information on user friendly front panels and from the extremely powerful function libraries that facilitate the software development of the application.

REFERENCES

- Achimas-Cadariu A., *Ghid practic pentru educație la distanță*. Edit. Alternative, București, 1998.
- Benetazzo L., Bertocco M., Ferrarsi F., Ferrero A., *A Web-Based Distributed Virtual Educational Laboratory*. IEEE Trans. Inst. Meas., **49**, 2, 349-355 (2000).
- Bertocco M., Ferraris F., Offelli C., Parvis M., *A Client-Server Architecture for Distributed Measurement Systems*. Proc. IMTC 98, St. Paul, MN, USA, May 1998, 67-72.
- Ferrero A., Piuri V., *A Simulation Tool for Virtual Laboratory Experiments in a WWW Environment*. Proc. IMTC 98, St. Paul, MN, USA, May 1998, 102-107.
- Ionescu M., Radu I., *Didactica modernă*. Edit. Dacia, Cluj-Napoca, 1995.
- Istrate O., *Educația la distanță. Proiectarea materialelor*. Edit. Agata, Botoșani, 2000, 25.
- Kocijancic S., O'Sullivan C., *Integrating Virtual and True Laboratory in Science and Technology Education*. 32nd ASEE/IEEE Frontiers in Educ. Conf., Boston, MA, USA, 2002.
- Mazda F.F., *Electronic Instruments and Measurement Techniques*. Univ. Press, Cambridge, UK, 1987.
- Moldoveanu M., Oproiu G.-C., *Repere didactice și metodice în predarea disciplinelor tehnice*, Edit. Printech, București, 2003.
- Pelgrum W.J., *Cercetarea internațională despre utilizarea calculatoarelor în învățământ*. Perspective, **XXII**, 3 (83), 1992.
- Savu T., *Tehnologii LabVIEW pentru laboratoare virtuale*. Simp. „Tehnol. Educ. pe platforme electron. în învățăm. ing.”, Univ. Tehn. și de Constr., Bucuresti, 9-10 mai 2002.
- * * * *LabVIEW User Manual*. National Instruments Corp. Austin, Texas, USA, April 2003.

ÎNVĂȚAREA MĂSURĂRILOR ÎN CURENT CONTINUU UTILIZÂND TEHNICI INFORMAȚIONALE MODERNE

(Rezumat)

Se prezintă un model de aplicație a unei lecții de laborator de la disciplinele tehnice din învățământul preuniversitar. Lucrarea este concepută după conceptul de laborator virtual, fiind implementată utilizând mediul de programare grafică LabVIEW. Elevii au posibilitatea experimentării unor montaje de laborator a căror funcționare este simulată prin relațiile matematice ce guvernează fenomenul și, de asemenea, de a interpreta rezultatele obținute. Cunoștințele dobândite sunt testate on-line, prestația elevului fiind apreciată printr-o notă finală de către tutore.