Utilization of computer assisted instruction for A.C. three-phase circuits

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Abstract: - Computer assisted instruction concept represents the computer technique integration in the process of the staff's training, this thing representing a modality in order to increase the efficiency of activity by logical thought development, stimulation of imagination and creativity as well as stimulation of interest in regard to the new. Lab VIEW – Laboratory Virtual Instrument Engineering Workbench is software tool, which gives possibility for realizing some interactive applications. Interface with the user (front panel) can be easy design to simulate the operation of real instruments, these applications realizing virtual instruments. Starting from the facilities given by software platform, in this paper is presented a lot of virtual instruments (VI) specific of the electrotechnics domain such as: study of three-phase circuits, phasor diagrams, measurement methods and harmonics analysis.

Key-Words: - virtual instruments, assisted instruction, interactive applications, harmonics analysis, phasor diagrams.

1 Introduction

The engineering, science, and technology field, at present, is very dynamic due to recent advances in computer and other technologies. These advances have resulted in numerous computer programs to solve traditional and novel problems. These programs use the computer's increased computational capabilities and assist in the design, development, and control of complex systems in a matter of minutes [1].

As a result, engineering, technology, and science programs are under pressure to incorporate the use of computers into their curriculum so their graduates can be well-trained in the use and application of these changing technologies and serve the needs of the industrial community. To address this need, most of the engineering programs and some of the engineering technology programs have introduced courses, programs, and laboratories in power systems to provide the graduates with the theoretical and practical knowledge, as well as experience. The study of electrical power systems requires a good background on advanced mathematics, and since most of the engineering technology programs do not require advanced mathematics, it is difficult to teach electrical power systems in these programs.

To address this issue, many software programs are currently used in academia to design and analyze different systems. With the advent of object-oriented programming, we have now programs that are interactive and user-friendly. National Instruments Corporation introduced a new program called LabVIEW - Laboratory Virtual Instrumentation Engineering Work Bench. Originally designed for test and measurement applications, the program has been modified over the years to design and analyze various complex systems. LabVIEW is a graphical programming environment and is based on the concept of data flow programming. The data flow programming concept is different from the sequential nature of traditional programming languages, and it cuts down on the design and development time of an application. It is widely accepted by industry, academia, and research laboratories around the world as a standard for data acquisition and instrument control software [2]. Since LabVIEW is based on graphical programming, users can build instrumentation called virtual instruments (VIs) using software objects. With proper hardware, these VIs can be used for remote data acquisition, analysis, design, and distributed control. The built-in library of LabVIEW has a number of VIs that can be used to design and develop any system. LabVIEW can be used to address the needs of various courses in a technology and science curriculum [2, 3, 5, 9,10]. The objective of this paper is to discuss the application of built-in VIs in LabVIEW to develop VI modules for use in an introductory electrical power systems course.

LabVIEW is extremely flexible and some of the application areas of LabVIEW [5] are Simulation, Data Acquisition, and Data Processing. The Data Processing library includes signal generation, digital signal processing (DSP), measurement, filters, windows, curve

fitting, probability and statistics, linear algebra, numerical methods, instrument control, program development, control systems, and fuzzy logic. These features of LabVIEW will help provide an interdisciplinary, integrated teaching and learning experience that integrates team-oriented, hands-on learning experiences throughout the engineering technology and sciences curriculum, engaging students in the design and analysis process beginning with their first year.

The study of electric power systems requires a good understanding of single phase and three phase circuits, and courses in electric circuits and electric machines are usually the prerequisite courses, among others, for the introductory power systems course. Almost every introductory electric power systems text provides a brief overview of electric circuits, and the instructors spend one to two weeks of their lecture time reviewing electric circuits.

Depending upon the student demographics, the instructor may spend more time discussing these topics. Use of programs to display waveforms of voltage, current, and power are common in the study of electric power systems because their use enhances the instruction process and student comprehension. The VI modules presented below are developed to assist faculty and students in this process and are used in the Circuits and Power Systems course at Valahia University of Targoviste (Romania) by this authors.

2 A.c. three-phase circuits

A.c. three-phase circuits are circuits supplied by a three-phase voltage system (symmetrical and direct sequence system):

$$u_1 = \sqrt{2}U \sin \omega t$$
$$u_2 = \sqrt{2}U \sin(\omega t - \frac{2\pi}{3}) \qquad (1)$$
$$u_3 = \sqrt{2}U \sin(\omega t + \frac{2\pi}{3})$$

For the case in which the voltage system supplies a balanced three-phase load, the expressions of the current system are:

$$i_1 = \sqrt{2}I \sin(\omega t - \varphi)$$
$$i_2 = \sqrt{2}I \sin(\omega t - \frac{2\pi}{3} - \varphi) \qquad (2)$$
$$i_3 = \sqrt{2}I \sin(\omega t + \frac{2\pi}{3} - \varphi)$$

If the impedances on phases are not identical, the load is unbalanced, and the absorbed currents from source can

be computed with methods which do not depend by configuration of three-phase circuit. For the star-connected balanced three-phase loads the following equation yields:

$$\underline{I}_1 + \underline{I}_2 + \underline{I}_3 = \underline{I}_0 \qquad (3)$$

Tacking into account the impedance value of the neutral conductor $\underline{Z}_0$, it results the voltage value of neutral point displacement:

$$\underline{U}_0 = \underline{Z}_0 \cdot \underline{I}_0 . \qquad (4)$$

Starting from the presented theoretical reasons, the applications were achieved. These applications simulate the three-phase circuit operation, representations in cartesian and complex coordinates as shown Fig.1, Fig. 2 and Fig.3.
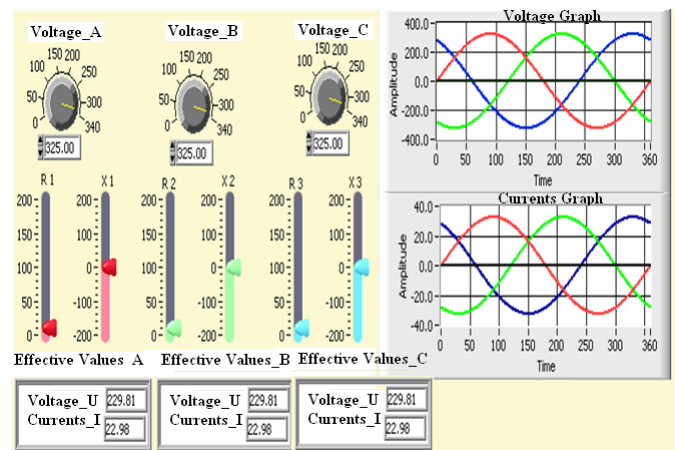

Fig.1 Graph representation – three-phase system (symmetrical, balanced)
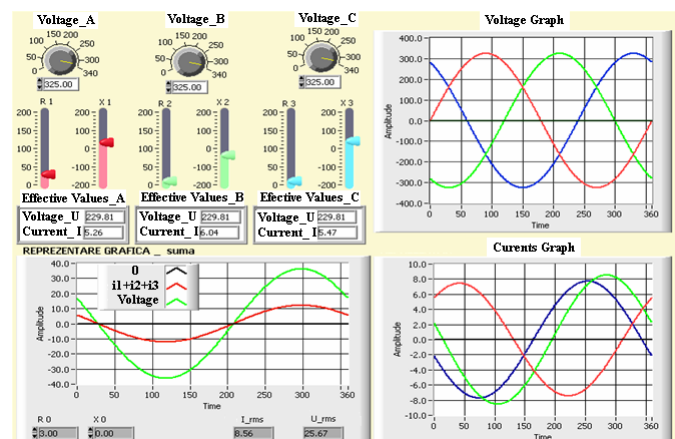

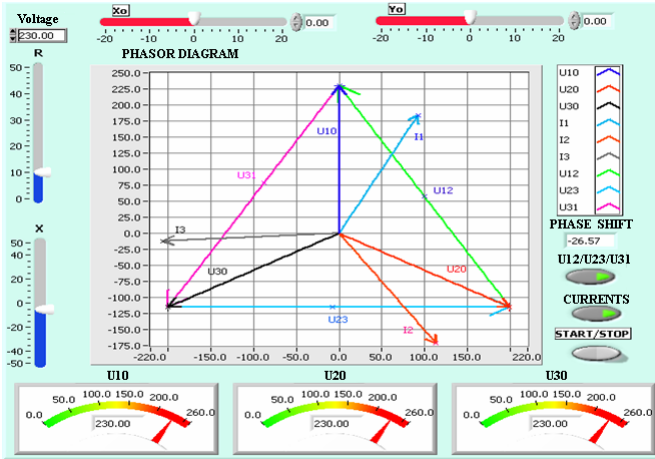Fig.2. Graph representation – three-phase system (symmetrical, unbalanced)

Fig.3. Phasor diagram – voltages, currents

a.

b.

Fig.4. Three-phase system – voltages (a), currents (b)

3 Connections in three-phase circuits

Technical importance of three-phase concept consists of the fact that production, transmission and distribution of electric power is mainly achieved by means of them. In three-phase systems is used star connection and triangle connection. For star connection, the relations between the line voltages and phase voltages are:

$$u_{12} = u_1 - u_2$$
$$u_{23} = u_2 - u_3 \qquad (5)$$
$$u_{31} = u_3 - u_1$$

By means of Kirchhoff's first law, the relation between currents is:
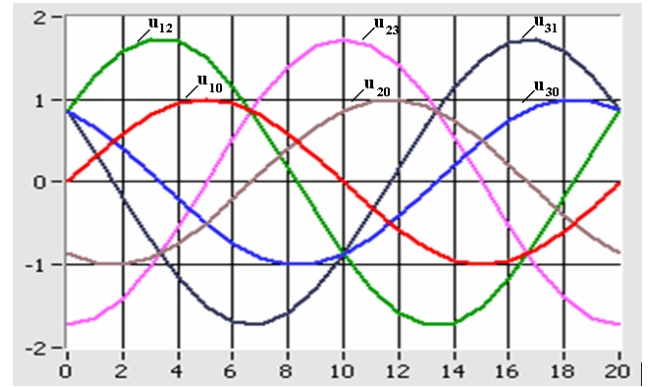
$$i_1 + i_2 + i_3 = i_n \qquad (6)$$

For the case of non-sinusoidal symmetrical regime operation, relation between the line voltage and phase voltage is: $U_1 = \sqrt{3}U_f$, respective between the line current and phase current is: $I_1 = I_f$.

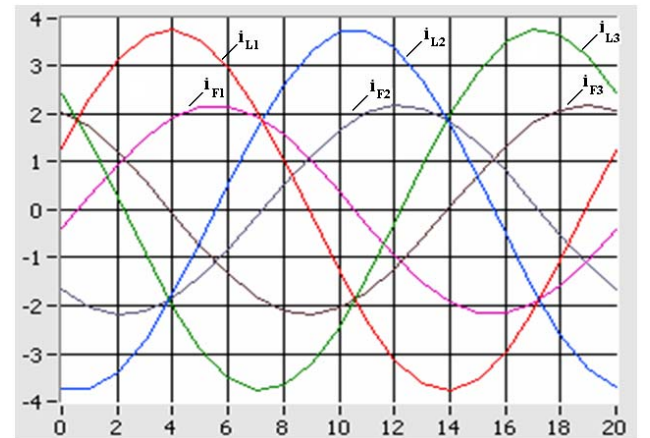In the case of triangle connection, the relations between currents are:

$$i_1 = i_{12} - i_{31}$$
$$i_2 = i_{23} - i_{21}$$
$$i_3 = i_{31} - i_{23} \qquad (7)$$
$$i_1 + i_2 + i_3 = 0$$

In symmetrical sinusoidal regime, the relations between the root mean square (r.m.s.) values of the line current/voltage and phase current/voltage are:

$$I_1 = \sqrt{3}I_f$$
$$U_1 = U_f \qquad (8)$$

Three-phase circuits can operate in non-symmetrical regimes; some aspects concerning the operation of star-connected circuits with neutral conductor having the impedance $\underline{Z}_n$. Complex values of voltages and currents are:

$$\underline{I}_1 = \frac{\underline{U}_{1R}}{\underline{Z}_1} = \underline{Y}_1 \cdot \left(\underline{U}_{10} - \underline{U}_{N0} \right)$$

$$\underline{I}_2 = \frac{\underline{U}_{2R}}{\underline{Z}_2} = \underline{Y}_2 \cdot \left(\underline{U}_{20} - \underline{U}_{N0} \right)$$

$$\underline{I}_3 = \frac{\underline{U}_{3R}}{\underline{Z}_3} = \underline{Y}_3 \cdot \left(\underline{U}_{30} - \underline{U}_{N0} \right) \qquad (9)$$

where:

$\underline{U}_{N0}$ - voltage drop on the neutral conductor

$\underline{Z}_{1,2,3}$ - impedances on phases

$\underline{Y}_{1,2,3}$ - admittances on phases

By means of Kirchhoff's first law, it results the voltage drop:

$$\underline{U}_{N0} = \frac{\underline{U}_{10}\,\underline{Y}_1 + \underline{U}_{20}\,\underline{Y}_2 + \underline{U}_{30}\,\underline{Y}_3}{\underline{Y}_1 + \underline{Y}_2 + \underline{Y}_3 + \underline{Y}_0} \tag{10}$$

Particular cases:

1. $\underline{Y}_0 = 0 \;\; (\underline{Z}_0 = \infty)$ – lack of neutral conductor
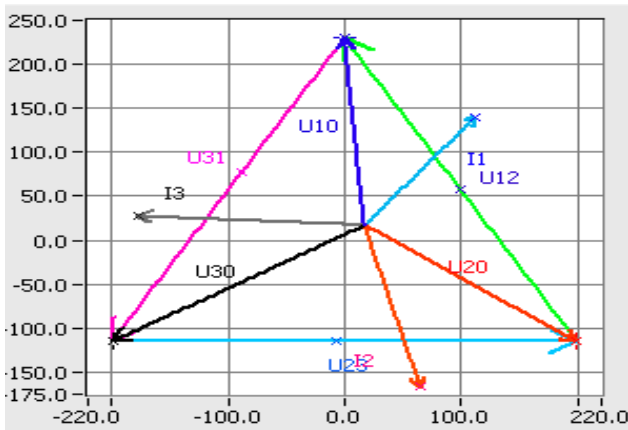
$$\underline{U}_{N0} = \frac{\underline{U}_{10}\,\underline{Y}_1 + \underline{U}_{20}\,\underline{Y}_2 + \underline{U}_{30}\,\underline{Y}_3}{\underline{Y}_1 + \underline{Y}_2 + \underline{Y}_3} \tag{11}$$

2. $\underline{Y}_0 \neq 0$; $\underline{Y}_1 = \underline{Y}_2 = \underline{Y}_3 = \underline{Y}$ - symmetrical load
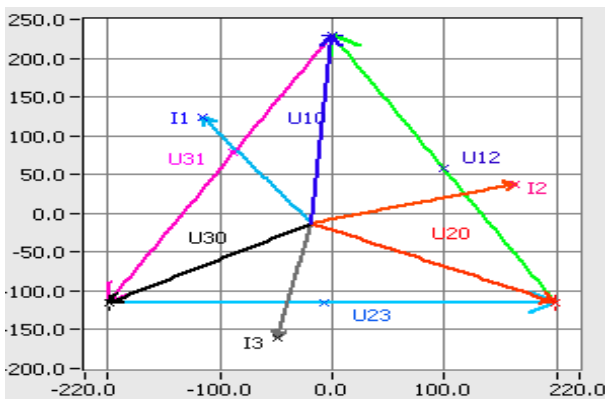
$$\underline{U}_{N0} = \frac{\underline{U}_{10} + \underline{U}_{20} + \underline{U}_{30}}{3 + \dfrac{\underline{Y}_0}{\underline{Y}}} \tag{12}$$

3. $\underline{Y}_0 = 0$; $\underline{Y}_1 = \underline{Y}_2 = \underline{Y}_3 = \underline{Y}$ - symmetrical load

$$\underline{U}_{N0} = \frac{\underline{U}_{10} + \underline{U}_{20} + \underline{U}_{30}}{3} \tag{13}$$

a.

b.

Fig.5. Neutral point displacement - three-phase system (symmetrical, unbalanced)

LabVIEW can command DAQ boards to read analog input signals (A/D conversion), generate analog output signals (D/A conversion), read and write digital signals, and manipulate the on-board counters for frequency measurement, pulse generation, etc. The voltage data goes into the plug-in DAQ board in the computer, which sends data into computer memory for storage, processing, or other manipulation.
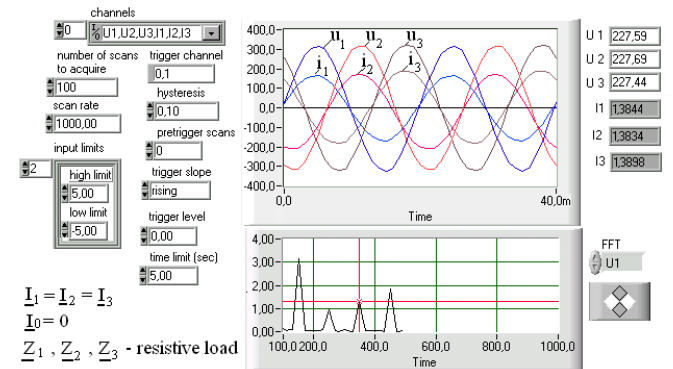

$\underline{I}_1 = \underline{I}_2 = \underline{I}_3$
$\underline{I}_0 = 0$
$\underline{Z}_1, \underline{Z}_2, \underline{Z}_3$ - resistive load

Fig. 6. Resitive Load – symmetrical sinusoidal regime (Data Acquisition)

$\underline{I}_0 \ll \underline{I}_1 = \underline{I}_2 = \underline{I}_3$
$\underline{Z}_1, \underline{Z}_2, \underline{Z}_3$ - resistive & inductive load
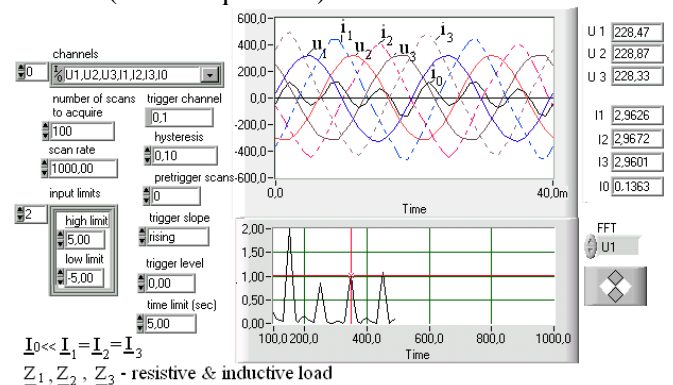
Fig. 7. Resitive&Inductive Load – symmetrical sinusoidal regime (Data Acquisition)

$\underline{I}_0 \neq 0$
$\underline{Z}_2, \underline{Z}_3$ - resistive load
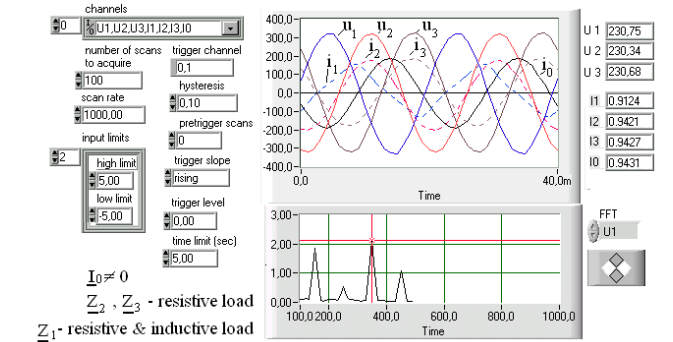$\underline{Z}_1$ - resistive & inductive load

Fig. 8. Resitive&Inductive Load – non-symmetrical sinusoidal regime (Data Acquisition)

4 Conclusions

The VI modules presented in this paper are tested with the input values from various examples in textbooks and results matched with the results of the examples. The modules presented in this paper are developed using simplified models. Although this is sufficient for introducing the concepts, elaborate models must be incorporated into the modules to address the complex real world situations. A number of software packages are currently being used in engineering, technology, and sciences curriculum. While some of them require a

programming background, others are designed for specific course requirements. LabVIEW has features and built-in virtual instrument modules identical to most of the features found in all these software packages. MATLAB is extensively used for studying circuits and power systems, and a number of books and literature are available on this topic. MATLAB requires writing codes. LabVIEW on the other hand, provides a graphical environment to solve complex problems. No or minimal programming knowledge is necessary to design and develop the VI modules. LabVIEW has provision to transfer data between LabVIEW, Excel, and MATLAB and call MATLAB and Excel from the LabVIEW environment. Therefore, one can use LabVIEW to address the needs of various courses. This will be beneficial for students and faculty and introduce standardization across the curriculum.

Computer assisted instruction concept represents an efficient method for the staff training by means of modeling, simulation and analysis of electromagnetic processes. Effectiveness of activity is assured by the way information is processed and transmitted of information, flexibility applications and possibility of implementing interactive applications.

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