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Power System Analysis using LabVIEW

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Abstract: The focus of this research is on investigation of LabVIEW electric power tool for the analysis and design of electric power systems. Here, we are targeting the solution of different electrical engineering problems which we very often face in teaching the course of power system analysis and design. These include complex power calculations, star/delta and delta/star conversions, calculation of symmetric components of voltages or currents, vector and phasor analysis and others. In order to demonstrate the done work several practical virtual instruments where designed, analyzed and tested. Done examples gave excellent and practical results.

INTRODUCTION

Implementation of LabVIEW in power system analysis may be found in several papers. Two of the early works are the researches[1, 2]. Swain *et al*.[1], we find a short introduction to LabVIEW and its possible applications in electric power systems engineering. Basic equations of electric power in single-phase AC circuits in time domain and polar notation of complex quantities were used in order to find instantaneous and average values of power. There, we find a simple numeric example which was solved without showing the core code in the block diagram. Only results of calculation are given in the front panel. Benhamida *et al*.[2], practically authors solved the same problem exactly and also without giving the block diagram code. In both works authors did not use the specific Virtual Instrument (VI) which exists in electric power tool to directly find apparent power S, active power P and and reactive power Q at the same time. Salah *et al*.[3], LabVIEW was used as power quality analysis tool. The authors refer to and use fundamental vector values (VI) and power (VI) and suggest a flow chart to use virtual instruments as a power quality analysis tool. At the time being there are several published works related to electric power quality studies using LabVIEW. Good examples are[4, 5].

In this study, we concentrate on basic fundamental issues and suggest our own virtual instruments in order to solve several commonly used tasks in power system analysis teaching such as electric power calculations, calculations of symmetric components, conversion of star/delta to delta/star, creation of single phasor or three phase phasors and finding RMS values and phase shifts for generated electrical waveforms. In this regard, its worthy to note that one of the most important student learning outcomes that are required by students in order to gain ABET accreditation is to implement software packages in the learning process. Nowadays, this work is going on intensively at our faculty. This paper includes an abstract, key words, introduction, description and analysis of designed programs, conclusions and references.

DESCRIPTION AND ANALYSIS OF SUGGESTED PROGRAMS

Electric power measurement: One of the basic competencies that students must acquire is to find the

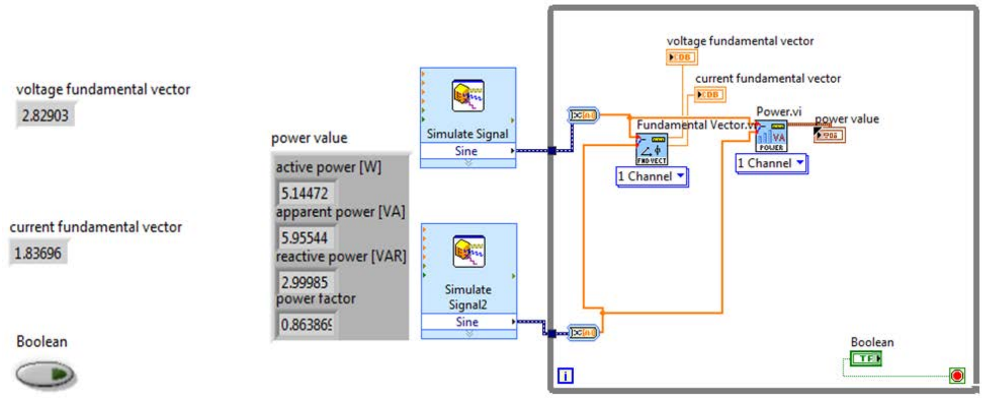

Fig. 1: Electrical power calculation using power VI

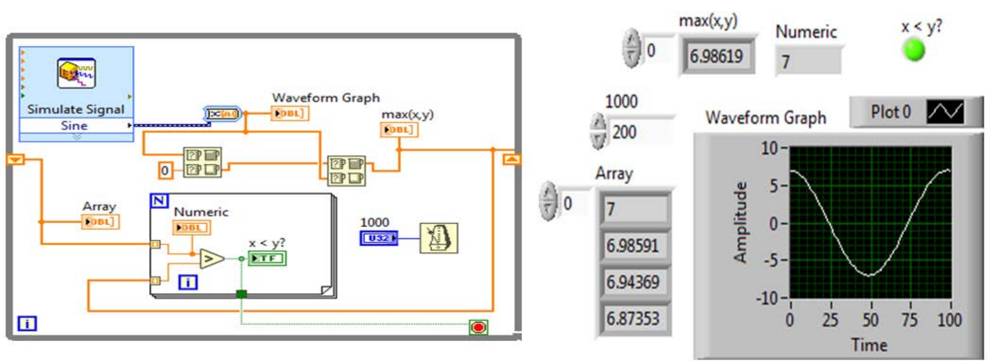

Fig. 2: Finding wave form peak value

apparent power (S), the active power (P) the reactive power (Q) and the Power Factor (PF). Normally these variables are calculated using common equations:

$$P = V\,I \cos\phi,\ Q = VI \sin\phi,\ S = V\,I \text{ and } PF = P/S$$

Voltage and current are in RMS values, φ is the phase angle between voltage and current. LabVIEW electric power tool includes an electric power VI which finds all the above variables at once. Two ways may be used in order to calculate these values and both give the same result. The implementation of power VI is very practical when the inputs are online voltage and current. This is shown in Fig. 1.

Application of the above given equations requires knowledge of V, I RMS values and the phase angle between them which are: V = 2.8288 V, I = 2.1216 A and Φ = 30°. Fortunately, electric power tool includes a specific RMS VI which yields the RMS value for a given online input waveform. In this regard, we have worked out an alternative solution which is shown in Fig. 2.

In this case, we determined at first the waveform peak value and then the RMS value is found by dividing the peak value by √ 2. This VI permits quantization of the analog waveform (sample and hold) at the required frequency also. This VI could be used for further power system analysis such as noise content or harmonic distortion evaluation. Normally v(t) and i(t) represent the instantaneous time functions of the voltage and current and the instantaneous power will be equal to:

$$p(t) = v(t)^{*}\, i(t). \text{ If } v(t) = V_m \cos(\omega t+\phi_v) \text{ and } i(t) = \cos(\omega t+\phi_i) \text{ then } p(t) = v(t)^{*}i(t) = V_m I_m \cos(\omega t+\phi_v)\cos(\omega t+\phi_i)$$

This equation could be rewritten in a more informative way as follows:

$$VI\cos\phi\{1+\cos 2(\omega t+\phi_v\}+VI\sin\phi \sin 2(\omega t+\phi_v)$$

where, $\varphi = \varphi_v - \varphi_I$. The first term of the previous equation determines energy flow to the load and the second term represents the fluctuating reactive power. As an example when v(t) = 100 cos ωt and i(t) = 80 cos (ωt-60°) then P(t) = 8000 cos ωt cos (ωt 60°)[6]. Figure 3 and 4 illustrates the waves of S, P and Q types of power. Practical study of these energy types curves helps the students to comprehend the nature of reactive power and how the average value of it is zero while the active power is always positive and have a non zero average value.

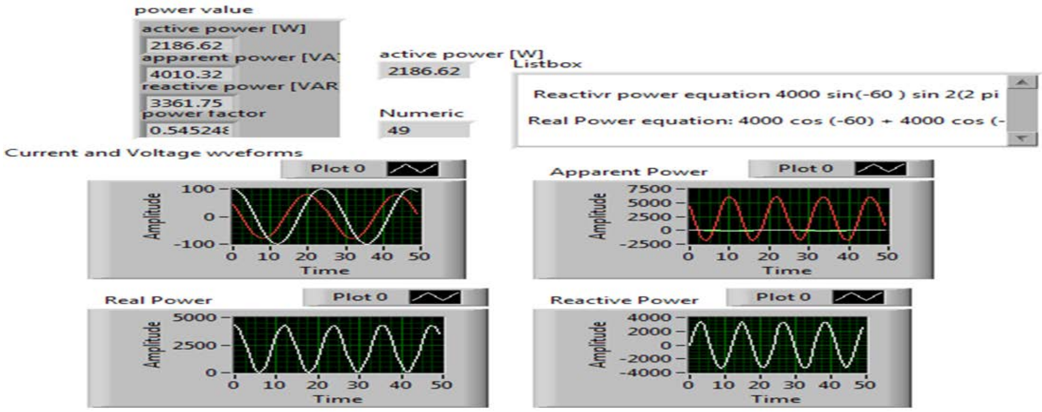

Fig. 3: Electric power wave forms

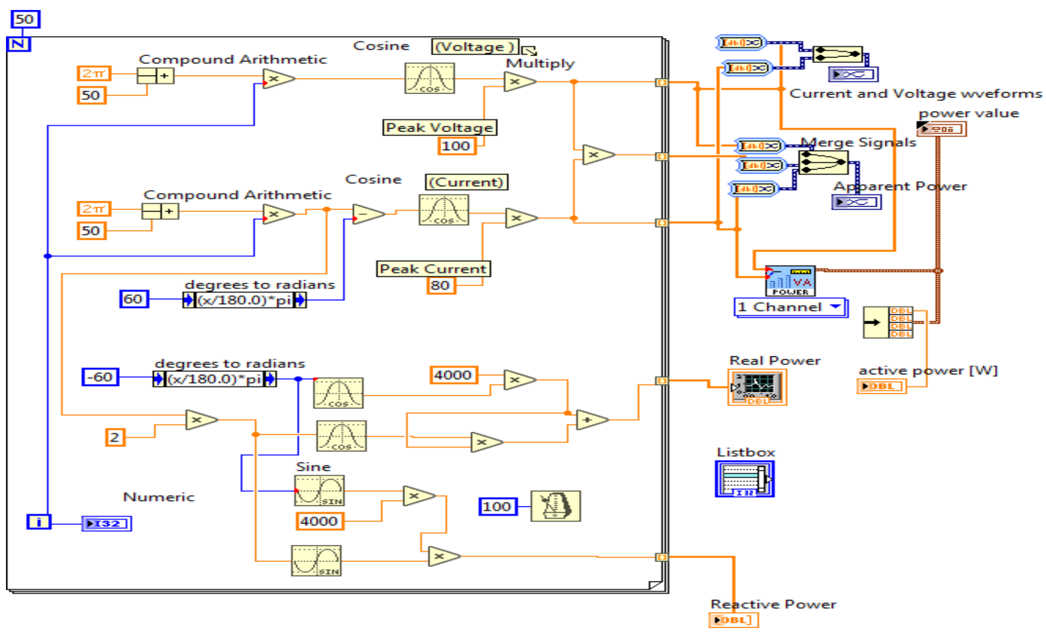

Fig. 4: Block diagram for finding electric power wave forms

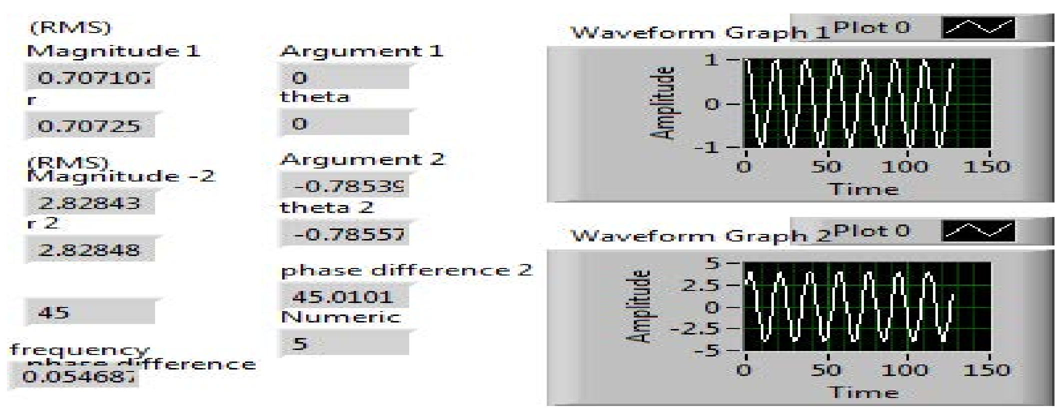

Fig. 5: Finding peak values and phase angel between two wave forms

As mentioned above, the knowledge of the phase difference between voltage and current waveforms is important in order to evaluate P. Q and PF. To meet this requirement, we designed the VI shown in Fig. 5 which

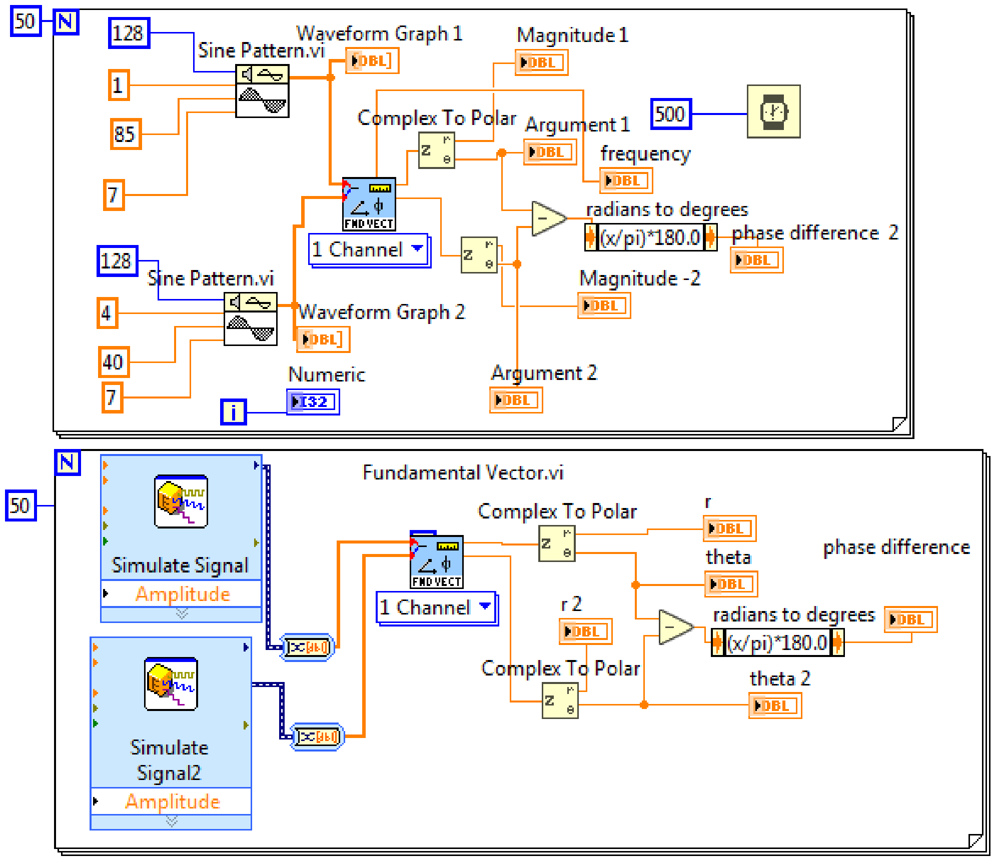

Fig. 6: Two block diagrams for finding peak values and phase angel between two wave forms

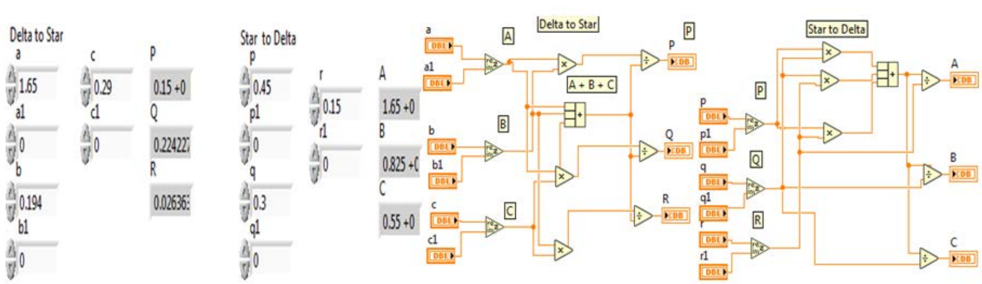

Fig. 7: Star-delta and delta-star conversions

allows to find the phase difference between any two waveforms. Practical investigation of both VI's give the same results (Fig. 6).

Star to delta and delta to star conversions: Another Common issue in power system analysis is to convert star to delta or delta to star impedances. This issue was tackled by Swain *et al.*[1] and Benhamida *et al.*[2]. Both works refer to the front panel only and they did no show the core code which is the most important. Knowing the controls and indicators only is not sufficient to carry out conversions. In order to fill this gap we offer the VI shown in Fig. 7.

We have shown the complete detailed VI, though it is always possible to create a sub VI by selection[6]. In order to verify the results we examined the example (2) page 10-9 and found that the results are identical. Important to note that this VI could be used for impedance, reactance and resistance controls simultaneously.

SYMMETRIC AND UN SYMMETRIC COMPONENTS

In addition, to the analysis of balanced electric power systems, recent developments of LabVIEW electric power

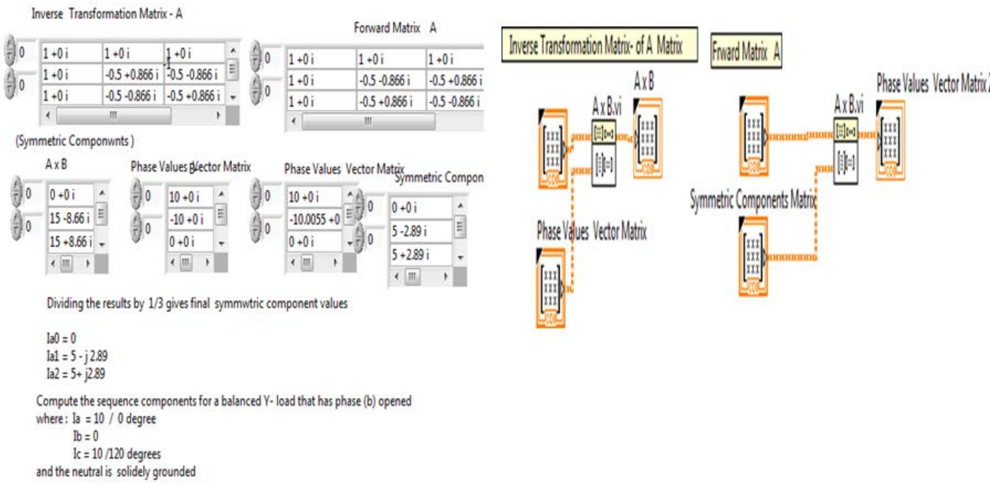

Fig. 8: Symmetric component calculations using forward and inverse transform matrixes

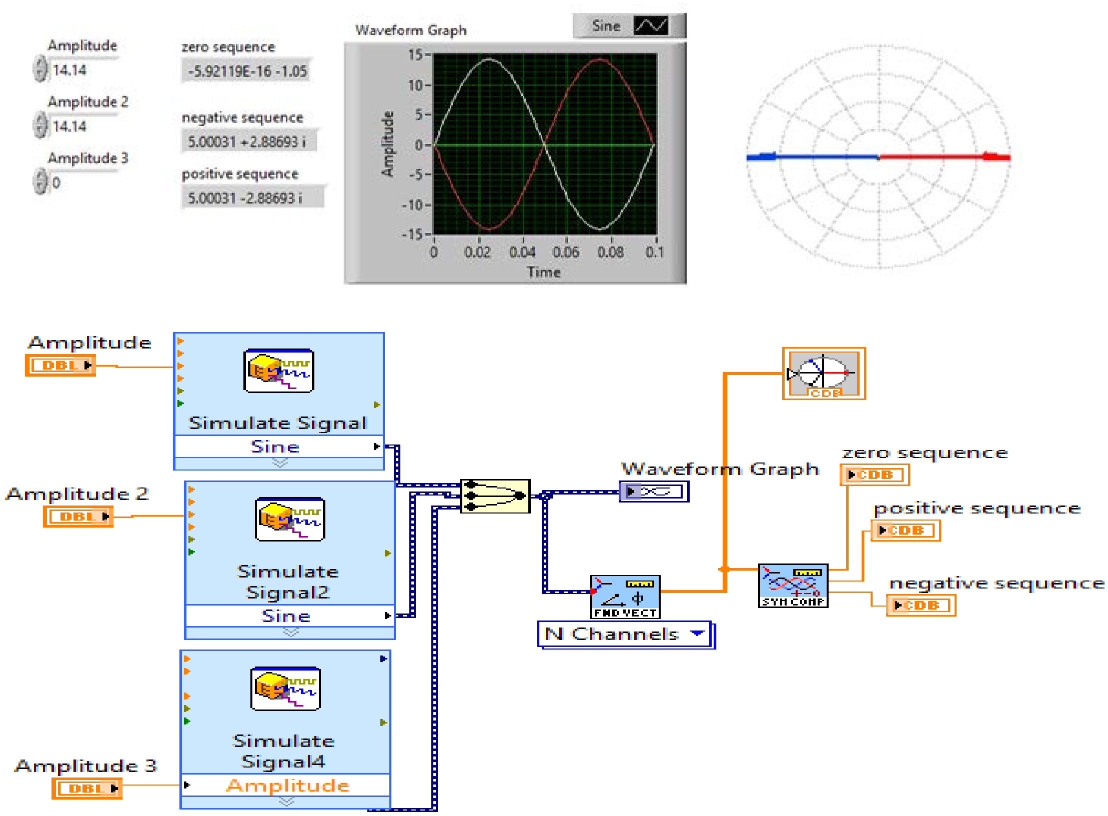

Fig. 9: Finding symmetric component using wave forms data

tool allow the analysis of unbalanced power systems too. Finding the symmetric components is the basis for unbalanced power system analysis and protection. This question is not left without paying the necessary attention. At first, we developed a program to carry out the forward transforms by finding the symmetric components from the phase values. And then another VI is developed to carry out inverse transforms in order to find phase values through the knowledge of symmetric components. Both programs are given in Fig. 8 and 9. In order to verify both VI's, we examined the example 1 of Stevenson[7] and the results coincided completely.

Nevertheless it is of great importance to find symmetric components for a three phase waveforms. In

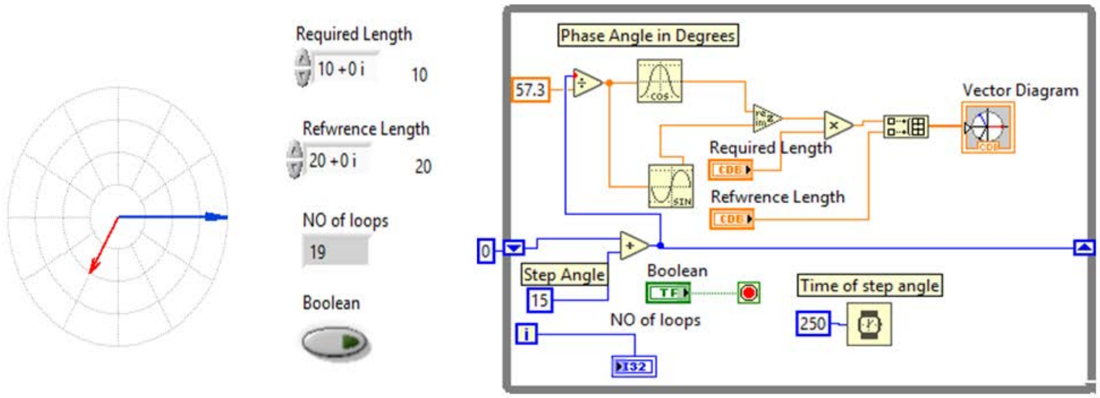

Fig. 10: Representation of single phase rotating phasor VI

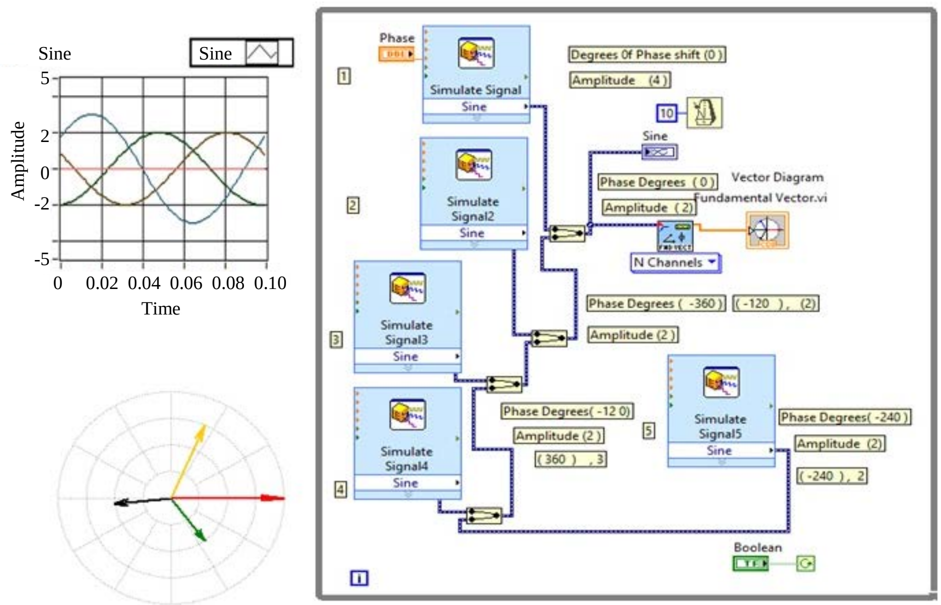

Fig. 11: Representation of three phase rotating phasors VI

such a case we can find the peak values and phase differences and apply the above VIs. At the same time the Electric Power Tool permits to carry out these activities directly when utilizing symmetric component VI's. Figure 9 represents such a case where the symmetrical component VI calculates the symmetric components of a three phase system. The program illustrates the three vectors of the system also. This program demonstrates how changes in amplitudes and phases relationships changes the symmetric components. This program was intestinally designed to give an alternative solution for example (11.1) of Stevenson[7] where the third phase is opened. Of course we have got the same answers too.

Phasor representation: In power system analysis the phasor concept is widely used. Phasor is a rotating vector at a given velocity. Thus, creating and simulating phasors is an important activity. We worked on this problem and designed a VI that creates a phasor with the required magnitude and argument. This program is represented in Fig. 10. In this VI a reference vector is used and the length of created phasor is scaled as a percentage of the reference vector. Velocity of phasor is defined by the timing function within the while loop. Stopping rotation of the phasor is done by utilizing the iteration terminal of the while loop.

As a development to this VI a three phase rotating phasor's set VI is given in Fig. 11. In this VI the phasor's lengths and arguments are programmable. Manipulation of phasors magnitudes and arguments helps the investigation of symmetric components of the electric power system. The shown phasor set characterizes three phasors with different lengths and phases. This yields a three sequence sets, positive, negative and zero at the same time. There are many important electric power issues and problems that could be analyzed and investigated using LabVIEW environment. Such issues include defining the ABCD constants of transmission line, building of vector diagrams of transformers and transmission lines, investigation of power flow problem and others. Because of the limited size of the paper, these issues will be considered in another paper.

CONCLUSION

Considering the excellent advantages of data flow programming, LabVIEW environment could be used as a tool to solve any problem related to power system analysis and design. Several virtual instruments that are designed and illustrated in this paper could be used in teaching and in the analysis of electric power systems. Illustrated examples prove correctness of suggested virtual instruments.

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