Electric Measurements with LabVIEW

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Abstract: The paper presents a data acquisition system which consists in Hall effect sensors, a PCI 6023(National Instruments) data acquisition board, Lab VIEW graphical programming environment and the experimental results achieved by the authors concerning the behavior of ac electrical circuits. The instruments used in the measurement technique were developed as computer data base equipments, using well determined functions (the acquisition of parameters, signal processing/adapting) with the communication possibility on a serial interface or on a parallel port. Today, data acquisition boards are used and can be assembled directly into the computer, having the operation possibility of an oscilloscope. The appearance of the LabVIEW environment was motivated by the research automation activity and by the application development, based on a hierarchical instrument structure, which is composed by the user's interface and the visual programming elements.

Keywords: data acquisition, graphical programming, Hall effect, electric power

1 Introduction

The use of the LabVIEW graphical programming environment ensures the analysis and study of power measurement methods in single-phase and three-phase alternative current circuits [3, 6, 7]. The evolution in both electric measurement technique, in the electronic field and in the area of data acquisition systems, arguments the opportunity and justification of designing new instruments in order to improve the research activity in this area [2, 3].

2. Power Measurement in Single-Phase AC Circuits

2.1 Powers in AC Circuits

The instantaneous power [1,2,3,4] to an electric dipole is defined as the product of the instantaneous values of the voltage (u) to the terminal of the dipole and the current (i) that flows through the dipole:

$$p = ui \tag{1}$$

The instantaneous power can be classified into input and output power, depending on the association of the voltage (u) and the current (i), which respects the rule of receivers and generators. In a sine-wave steady-state with the T period, the active power (P) can be defined as the average value of the instantaneous power, considering a natural number of periods:

$$P = \overline{ui} = \frac{1}{nT}\int_{t_1}^{t_1+nT} pdt \tag{2}$$

For a single-phase circuit which functions under a sine-wave permanent rate, in which the voltage and current have the following expressions:

$$u(t) = U\sqrt{2}\sin\omega t \tag{3}$$

$$i(t) = I\sqrt{2}\sin(\omega t - \varphi) \tag{4}$$

it results:

- the active power: $P = UI\cos\varphi$
- the reactive power: $Q = UI\sin\varphi$ (5)
- the apparent power: $S = UI$

The complex apparent power (S) is defined into the simplified complex representation as the product between the complex voltage (U) and the conjugate complex current (I*):

$$\underline{S} = \underline{UI}^* = UI\cos\varphi + jUI\sin\varphi = P + jQ \tag{6}$$

The real part of the complex power (S) is the active power (P), the imaginary part is the reactive power (Q), the module is the apparent power (S) and the argument is equal to the phase displacement (φ) of the circuit:

$$P = \mathrm{Re}\{\underline{S}\};\ Q = \mathrm{Im}\{\underline{S}\};\ \ S = |\underline{S}| \tag{7}$$

For a single-phase circuit which does not function in sine-wave rate [4] and has the terminal voltage u(t):

$$u(t) = U_0 + \sum_{n=1}^{\infty} \sqrt{2} U_n \sin n\omega t$$

$$i(t) = I_0 + \sum_{n=1}^{\infty} \sqrt{2} I_n \sin(n\omega t - \varphi_n) \qquad (8)$$

there can be defined:

- the active power:

$$P = U_0 I_0 + \sum_{n=1}^{\infty} U_n I_n \cos \varphi_n \qquad (9)$$

- the reactive power:

$$Q = \sum_{n=1}^{\infty} U_n \cdot I_n \cdot \sin \varphi_n \qquad (10)$$

- the apparent power:

$$S = UI \qquad (11)$$

By taking into account the relations above, we can notice that $S^2 \neq P^2 + Q^2$ and therefore the notion of *deforming power* can be introduced:

$$D^2 = S^2 - P^2 - Q^2 \qquad (12)$$

The application below (fig. 1) which is realized by using the LabVIEW graphical programming environment, basing on the presented theoretical considerations [2,5,6,7], allows the graphical display of the time variation of the voltage, the current, the instantaneous and active power. Control elements are used in order to modify the voltage and the charge impedance parameters, and also other elements are used for indicating the voltage, the current, the power factor, the active, reactive and apparent power (in order to obtain an accurate view of the current, it is possible to multiply the amplitude 1, 10, 20, 50 or 100 times).

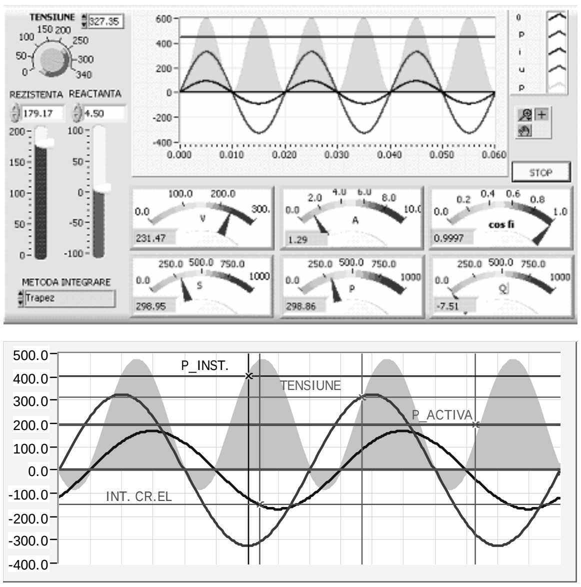


Fig.1. Single-Phase AC Circuits Operation and Power Measurement - simulation

2.2 Signal Conditioning

The acquisition data board is a complex system which allows parameter measurement and monitoring from a technological process, using transducers which can transform studied physical measures into electrical voltage [1,3,4,6,7]. For single-phase ac circuits, it is necessary to obtain signals with voltage-range amplitude, to be applied at the input of the board. For phase/line voltages, resistive voltage dividers (do not ensure galvanic isolation) or voltage measurement transformers (ensure galvanic separation) can be used. Shunts (current-voltage converter) or current measurement transformers can be used for currents. The use of both voltage dividers and shunts must be done by taking into account the current through the voltage divider, the voltage drop on the shunt, the power dissipation, parasite resistances, self-heating effects, dynamic effects.

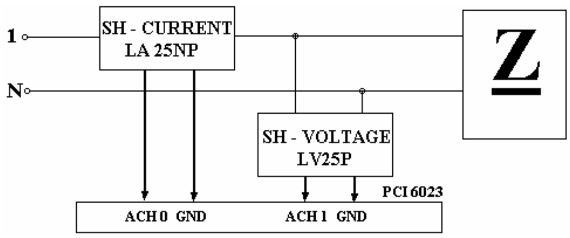
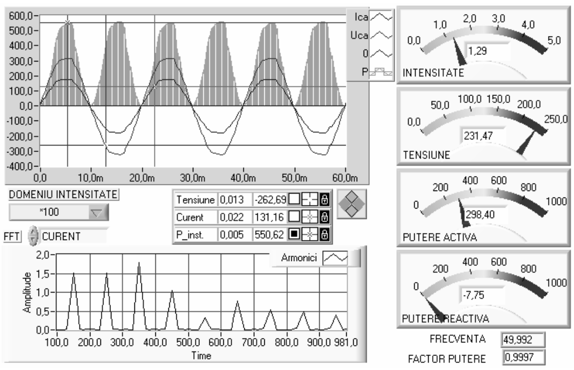


Fig.2. Data acquisition system



a)

b)

Fig.3. Experimental results

The use of voltage-current measurement transformers ensures the energetic system's

galvanic isolation of the measuring system, but it introduces ratio and angle errors and realizes an inadequate perturbation transfer. The adopted solution was to use current and voltage transducers based on the Hall effect. The block diagram of the acquisition system is presented in fig.2 and fig.3 presents the experimental results.
Remark: The voltage values and the parameters of the consumers in fig. 3a, were introduced into the application realized for simulation (fig.1).

3. Power Measurement in Three-Phase AC Circuits

For a random receiver (Z), consisting in linear impedances, forming a system with *n* nodes which is alimented through a circuit with *n* conductors [1], the total complex apparent power (S) transmitted to the receiver is:

$$\underline{S} = \underline{V}_1 \underline{I}_1^* + \underline{V}_2 \underline{I}_2^* + \ldots + \underline{V}_k \underline{I}_k^* + \ldots + \underline{V}_n \underline{I}_n^* \quad (13)$$

By expressing the potentials of the nodes using the potential differences reported to a point N having a random potential, the expression (3.1) becomes:

$$\underline{S} = \underline{U}_{1N} \underline{I}_1^* + \underline{U}_{2N} \underline{I}_2^* + \ldots + \underline{U}_{kN} \underline{I}_k^* + \ldots \underline{U}_{nN} \underline{I}_n^* \quad (14)$$

The definitions of active and reactive power give the following results:

$$P = \mathrm{Re}\{\underline{S}\} = \mathrm{Re}\{\underline{U}_{1N} \underline{I}_1^* + \underline{U}_{2N} \underline{I}_2^* + \underline{U}_{nN} \underline{I}_n^*\} =$$
$$= U_{1N} I_1 \cos(\underline{U}_{1N}, I_1) + U_{2N} I_2 \cos(\underline{U}_{2N}, \underline{I}_2) +$$
$$+ U_{nN} I_n \cos(\underline{U}_{nN}, \underline{I}_n)$$

$$P = P_1 + P_2 + \ldots + P_k + \ldots + P_n = \sum_{k=1}^{n} P_k \quad (15)$$

$$Q = \mathrm{Im}\{\underline{S}\} = \mathrm{Im}\{\underline{U}_{1N} \underline{I}_1^* + \underline{U}_{2N} \underline{I}_2^* + \cdots +$$
$$+ \underline{U}_{nN} \underline{I}_n^*\} = U_{1N} I_1 \sin(\underline{U}_{1N}, I_1) +$$
$$+ U_{2N} I_2 \sin(\underline{U}_{2N} \underline{I}_2) + \ldots + U_{nN} I_n \sin(\underline{U}_{nN}, \underline{I}_n)$$

$$Q = Q_1 + Q_2 + \ldots + Q_k + \ldots + Q_n = \sum_{k=1}^{n} Q_k \quad (16)$$

The total active power P (respectively the reactive power – Q) consumed by a random receiver with *n* phases and alimented through a line of *n* conductors, is equal to the sum of n active single-phase powers (or reactive single-phase powers) which are given by the $\underline{I}_k$ line currents, with the $\underline{U}_{kN}$ voltages between the n conductors and the N point.

The alternative three-phase circuits have the following voltage system:

$$u_1 = \sqrt{2} U \sin \omega t$$
$$u_2 = \sqrt{2} U \sin(\omega t - \frac{2\pi}{3}) \quad (17)$$
$$u_3 = \sqrt{2} U \sin(\omega t + \frac{2\pi}{3})$$

If the voltage system supplies a three-phase balanced receiver, the current system will be:

$$i_1 = \sqrt{2} I \sin(\omega t - \varphi)$$
$$i_2 = \sqrt{2} I \sin(\omega t - \frac{2\pi}{3} - \varphi) \quad (18)$$
$$i_3 = \sqrt{2} I \sin(\omega t + \frac{2\pi}{3} - \varphi)$$

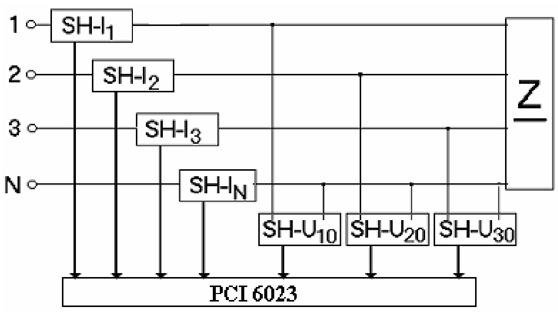
If the phase impedances are different, the receiver is not balanced and the absorbed currents from the source can be calculated with methods that are related to star connected three-phase balanced receivers, it results:

$$\underline{I}_1 + \underline{I}_2 + \underline{I}_3 = \underline{I}_0 \quad (19)$$

Regarding the impedance value of the neutral conductor (Z_0), the voltage value will be:

$$\underline{U}_0 = \underline{Z}_0 \cdot \underline{I}_0 . \quad (20)$$

The block diagram of the data acquisition system is presented in fig.4. The measuring methods for active/reactive power in three-phase ac circuits, depend on the type of the consumer and the number of conductors in the electric energy supply system.



I_1/I_2/I_3 – *LA55P*; **I_N** – *LA25NP*;
U_{10}/U_{20}/U_{30} – *LV25P*

Fig.4. Data Acquisition System – block diagram

For three-phase circuits with neutral conductor (*n*=4), the generalized theorem becomes:

$$P = \mathrm{Re}\{\underline{S}\} = \mathrm{Re}\left\{\sum_{k=1}^{4} \underline{U}_{kN} \underline{I}_k^*\right\} \quad (21)$$

The total active power in this case can be measured by using the 4 wattmeter method (if a random value is given to the potential of the N point) or using the 3 wattmeter method (if the potential of the N point is equal to the one of the neutral conductor).

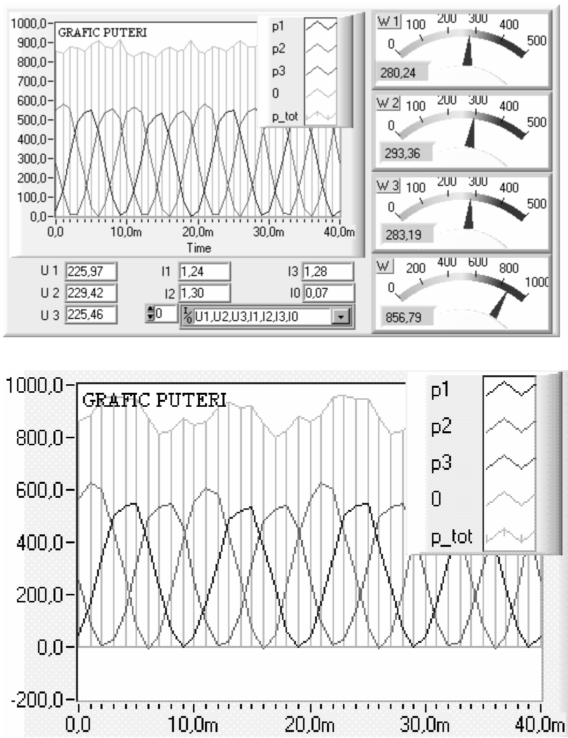


Fig.5. Data Acquisition System –experimental results

4 Conclusion

The implementation of the applications (simulating and data acquisition) into the LabVIEW graphical programming environment has been realized basing on theoretical aspects and experimental determinations in the laboratory, using accurate devices. These applications can be used both for studying the measurement methods of power (student/personnel training because of the ability of modifying the parameters of the circuits and of the effect display) and for performing high accuracy measurements.

The use of the presented signal conditioning system enlarges the data acquisition abilities in the electric system, in order to study the operation of electric machines, converters, transient rates. The flexibility of the instrument is given by the possibility of including other operations in the measurement process (analysis, operation automation, access to the data basis, sending data on the Internet, etc.).

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