ACCURACY OF SIGNAL CONVERSION IN POWER MEASUREMENTS WITH LEM CONVERTERS

Marek Kurkowski [1)], Pawel Ptak[1)], Zygmunt Biernacki[1)], Tadeusz Zloto[2)]

[1)] Institute of Electronics and Control Systems, Czestochowa Technical University,
e-mail: biernac@el.pcz.czest.pl , marekekb@poczta.onet.pl , ptak@el.pcz.czest.pl
[2)] Institute of Machine Technology and Production Automation,
Czestochowa Technical University, Poland, e-mail: zloto@itm.pcz.czest.pl

Summary: Among the phenomena significantly aggravating the quality of electric energy in the grid two are especially important: voltage fluctuations and deformations of voltage and current sinusoids.

The aim of the study described in the present paper was to improve the accuracy of signal converting in power measurements in non-linear receivers. The measurements of voltage and current were performed by means of a PC with measuring a card PCL-818L and with application software DasyLab 6.0 enabling the registration and converting of signals.

1. INTRODUCTION

The deformation of voltage and current waveforms are caused by higher harmonics present in the current consumed by non-linear receivers, such as power-electronic devices.
The analysis of higher harmonics sheds light on the causes of distortion, and, consequently, enables prevention.

Every periodical deformed wave can be decomposed into a series of sinusoid waves with frequencies being integral multiplications of the basic frequency, which is equal to 50 Hz in Poland. Harmonic distortions are characteristic of the steady state and should not be confused with impulse-type interference.

The source of harmonic deformations is all kinds of devices transforming sinusoid waves or using only a part of waveform (impulse signal), such as impulse power packs, inverters, energy saving light bulbs [11].

Even-number harmonics (i.e. the 2nd, 4th, and so on) do not pose any serious problems. The 3rd harmonics and its triplens add up in the neutral conductor. Because of that the current in the neutral conductor can exceed the currents in the phase conductors significantly and can therefore heat up to a dangerous extent.

If a non-linear receiver, such as a rectifier system is fed by sinusoid voltage, then the current waveform is non-sinusoid. Such deformed current wave can be decomposed into a series of harmonics, with different phases and amplitudes, which can be determined mathematically by means of development into the Fourier series, as long as the mathematical formula of the function in question is known. Thus, a non-linear receiver can be considered a source of harmonics.

Higher harmonics induce a number of negative phenomena in the system of energy transmission, among which the influence on the operation of inductive machines is especially disturbing [11].

An important parameter pertaining to harmonics is the THD (Total Harmonic Distorsion) factor. The factor is defined as the ratio of the rms of higher harmonics to the rms of the first harmonic of the signal examined:

$$THD_F = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1} \cdot 100 \, [\%] \qquad (1)$$

Alternatively, the factor can be defined as the ratio of the higher harmonics rms of the signal examined to the rms of the whole waveform:

$$THD_R = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{\sqrt{I_1^2 + \sum_{n=2}^{\infty} I_n^2}} \cdot 100 [\%] \qquad (2)$$

2. MEASURING SYSTEM

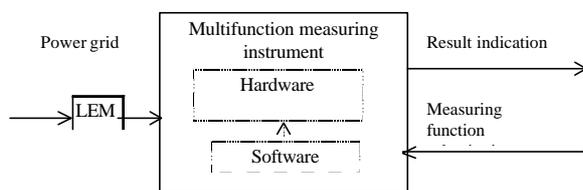The figure below represents the general structure of the measuring system.

Fig.1. Configuration of the mulifunction measuring device

Niezbêdn[1] separacjê galwaniczn[1] komputerowego uk³adu pomiarowego od sieci elektroenergetycznej uzyskano poprzez zastosowanie przetworników pomiarowych LEM typu LV i LA. Bezpoœredni pomiar wartoœci skutecznej i wy¿szych harmonicznych zastosowan[1] metod[1] cyfrow[1] umo¿liwia pomiar nie tylko wartoœci skutecznej sygna³u ale tak¿e zawartoœæ wy¿szych harmonicznych w mierzonym przebiegu oraz wspó³czynnik szczytu i odkszta³cenia.

The necessary galvanic separation of the computer measuring system from the power grid was obtained by means of measuring converters LEM type LV and LA. The direct measurement of rms value and of higher harmonics by means of the digital method enables the measurement not only of the signal rms value but also of the higher harmonic contribution to the characteristic measured and of the peak and distortion factors.

During the measuring cycle, digital samples of actual values of voltage and phase current are recorded. They provide a basis for calculating the required values associated with the ongoing measuring function (e.g. voltage or current rms, active power, active power coefficient) as well as for calculating intermediate values stored in the memory and used for subsequent analysis needed for other measuring functions.
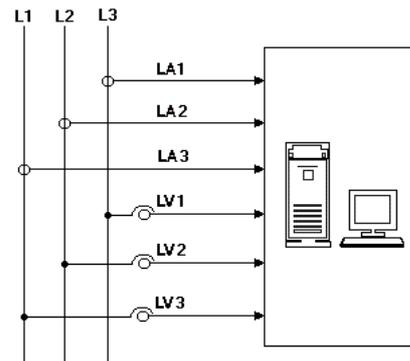

Fig. 2. Measuring schema

The use of virtual technology for the examination of three-phase power converters will be presented on the example of virtual instruments for the measurements of reactive power, developed on the basis of DasyLab system - a computer program for measurement automation, analysis and visual presentation. Such virtual instruments are fully comparable to real instruments.

The study focuses on two-system converters and instruments for measuring reactive power in the three-phase, three-conductor grid [3, 4]. The tests were performed with symmetrical feeding voltages and with the simulation of load asymmetry.To do that two virtual instruments were created in DasyLab system: one of them consistent with the two wattmeters method (the Aron system), measuring reactive power and playing the role of a two-system standard varmeter, and the other consistent with the measuring system applied in the above mentioned power converters produced in Poland. By performing a number of measurements by means of those instruments, following the method of

experiment planning, one can determine the measurement error of the examined converter as a function of loas asymmetry.

Below is presented a method of constructing a virtual two-system standard varmeter and a reactive power converter, equivalent to the schema of the examined converters [5]. These two instruments were combined into the virtual instrument for error measurements.
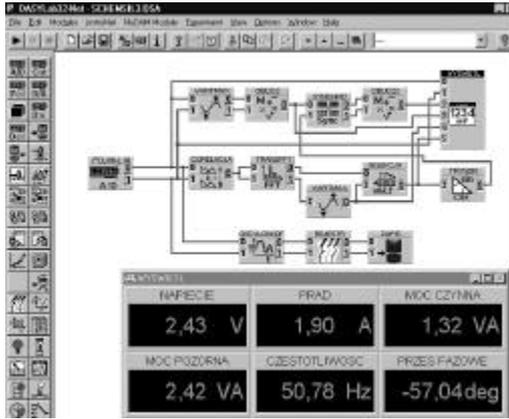

Fig. 3. System for signal recording and analysis

3. THE EXPERIMENT

The two-system virtual varmeter performs such function which would be fulfilled by two reactive power wattmeters in the Aron system for sinusoid waveforms. Its indications comply with the formula below, where U_{10}, U_{03}, I_1, I_3, $\boldsymbol{j}_1$, $\boldsymbol{j}_3$ are, respectively, phase voltages, conductor currents and phase angles of the receiver.

$$Q_p = \sqrt{3}\left[U_{03}I_1\cos\left(60° - \boldsymbol{j}_1\right) + U_{10}I_3\cos\left(120° - \boldsymbol{j}_3\right)\right] \quad (3)$$

The two virtual varmeters were subsequently used as a basis for describing an instrument operating according to the formula

$$\boldsymbol{dQ} = \frac{Q - Q_p}{Q_p}\,100\% \quad (4)$$

where Q_p is the correct value of power measured by the Aron system,

Q is the value of reactive power measured by the examined power converter.

In order to obtain the mathematical model describing a converter error occurring by the measurement of reactive power, the Box-Wilson method [7] was applied, which enables defining a multi-variable function. The object under examination (Fig.5) is described as

$$\boldsymbol{dQ} = f\left(X_{L1},\, X_{L2},\, X_{L3}\right) \quad (5)$$

The plan of the experiment was developed in which the input values X_{L1}, X_{L2}, X_{L3}, were determined, for which measurements were subsequently performed and the object responses $\boldsymbol{dQ_1}$, $\boldsymbol{dQ_2}$, $\boldsymbol{dQ_3}$ were obtained. The input values (load parameters) are set by means of a potentiometer or entered digitally. Also the value of phase 1 voltage (E_1) is set. The form of function (5) is not exactly known, but it is assumed to be continuous and to have one extremum. The unknown non-linear characteristics (5) is approximated in the neighbourhood of a point by means of linear regression function (6), in which only inductive load is considered for simplicity.

$$\underline{\boldsymbol{dQ}} = b_0 + b_1 X_{L1} + b_2 X_{L2} + b_3 X_{L3} \quad (6)$$

For every variable 6 different values were assumed, which gives $N = 6^3 = 216$ results altogether. Having a series of the results at one's disposal ($\boldsymbol{dQ_1}$, $\boldsymbol{dQ_2}$,...$\boldsymbol{dQ_n}$) and applying matrix calculus, one can determine constant coefficients b_0, b_1, b_2, b_3 of the model described by Eqn. (6). For instance, for the known values of the input circuit elements 216 measurements were performed and the error formula was obtained:

$$\boldsymbol{dQ} = -0{,}0003 - 2{,}2746 \cdot Xl_1 - 2{,}2745 \cdot Xl_2 + 4{,}5491 \cdot Xl_3 \quad (7)$$

The errors predicted from the mathematical model were compared with the real errors obtained in the measurements. To do that load values Xl_1, Xl_2, Xl_3, were substituted into Eqn.(7) and the result ($\boldsymbol{dQ_{wzór}}$) was compared to real errors ($\boldsymbol{dQ_{pomiar}}$). The greatest difference

did not exceed 3,1 %. On the basis of Eqn. (7) a virtual instrument was created calculating error dQ resulting from load asymmetry.

4. CONCLUDING REMARKS

The method discussed in the present paper can be used for determining the influence of current-supply asymmetry on the value of the Aron system error occurring by the reactive power measurement. It is also possible to examine the influence of fluctuations and deviations of feeding voltage on the measurement result in various measuring systems. The changes can be of incidental character (as it is in reality).

The use of the measuring card and of LEM converters ensures high accuracy of processing the measuring signals. Such accuracy could not be achieved by means of traditional methods.

The results obtained from measurements and analyses confirm the usefulness of the system developed for the non-sinusoid circuits. The experience of constructing instruments can also be helpful for creating more complex measuring systems with virtual instruments.

One of the main advantages of recording signals by means of a computer is the possibility of performing subsequent digital analysis with the use of statistical methods or FFT.

The presented virtual method of analysing measurement methodology can also be of didactic usefulness for technical university teachers.

REFERENCES

[1] Bobrowski W.: Pomiary wy¿szych harmonicznych w sieci. (Measurements of higher harmonics in the grid) Wiadomoœci Elektrotechniczne 4/99.

[2] Jakubiec B., Babka R., Olesiak K.: Zastosowanie programu DasyLab do cyfrowego pomiaru mocy przemiennika PWM (The use of DasyLab for the digital measurement of power of converter PWM). PES-2, s. 103-110, Zakopane-Koœcielisko, 1999.

[3] Kurkowski M.: Analiza sygna³ów przy u¿yciu pakietu DasyLab, (Signal analysis by means of DasyLab package) XXXII MKM'2000, Rzeszów-Jawor, 11-15.09. 2000 r. Materia³y T.2, s. 389-394.

[4] Kusmierek Z.: Zastosowanie komputerowych technik pomiarowych do badania jakoœci energii elektrycznej,(The use of computer measuring techniques for testing electric energy quality) JUEE, t. I, z. 1, 47 53, 1995.

[5] Mindykowski J.: Ocena jakoœci energii elektrycznej w systemach okrêtowych z uk³adami przeksztaˆtnikowymi, (The assessment of electric energy quality): Okrêtownictwo i ¯egluga, Gdañsk 2001.

[6] P. Ptak, M. Kurkowski, Z. Biernacki, T. Z³oto: *Digital measuring system for recording deformed functions,* 3rd International Conference Measurement 2001, ss. 268-271, Bratislawa, Slovak Republic, 14 – 17 May 2001.

[7] PC-LabCard Lab & Engineering Add-on's for PC–PCL 818 L, User's manual.

[8] *Przetworniki pomiarowe*. (Measuring converters) Katalog LZAE Lumel 1994.

[9] Wepa R.: *Dwusystemowe przetworniki mocy biernej i warunki poprawnego pomiaru.* (Two-system reactive power converters and measurement conditions) XXIX Miêdzyuczelniana Konferencja Metrologów. MKM'97 t.2 str.589-596, Na³êczów 1997.

[10] Wepa R.: *Systemy wirtualne w pomiarach mocy obwodów trójfazowych*. (Virtual systems in the measurements of power in three-phase circuits) XXX Miêdzyuczelniana Konferencja Metrologów MKM'98 s. 505-510, Miêdzyzdroje 1998.

[11] Harmonic/Power Analyzer HA-2000, User's Manual, Amprobe Instruments Inc., 1994.