# ANALYSIS OF POWER QUALITY PARAMETERS USING A GRAPHICAL USER INTERFACE

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*Abstract* − **The paper presents the main features of an original program with graphical interface used to process the data obtained from measurements concerning the electric energy from a rectifying substation corresponding to an urban transportation system, using a CA 8352 data acquisition system. The program provides complete information required for the adoption of optimal measures for the quality parameters improving, through compensation and filtering in order to provide the conformity with the EU norms. The program is easy to use owing to the friendly interface, being accessible to an operator with medium knowledge regarding the acquired data gathering and respectively the monitoring of the quality parameters of the electric energy. The main advantage consists in the possibility to perform an advanced interpretation of the data, highly superior to the analysis capacity of an ordinary analyzer and the results can be comparatively studied in order to improve the calculation method and also treating the data acquired from various types of analyzers in an unitary mode. The data processing is made with an accuracy that is highly superior to that provided by the analyzer and it can be adapted to the specific features of the system in the test points owing to its flexibility and to the possibility of improvement.**

*Keywords*: *graphical user interface, power quality, analysis, software.*

## 1. INTRODUCTION

The analysis of electric energy quality requires complex apparatus that are difficult to use and do not provide all the expected achievements. On the other side the apparatus dedicated to the electric energy quality analysis is expensive and requires the operator's special training.

One can notice a generous offer of equipment for test, diagnosis and calculations that require the operator's special training because each equipment has a different interface toward the operator [1], [2]. Our interface provides a real support to the user as it makes possible the analysis in a unitary manner.

The original interface described by this paper is accessible to an operator with medium knowledge regarding the acquired data gathering and respectively the monitoring of the quality parameters

of the electric energy. The program main advantage consists in the possibility to perform an advanced interpretation of the data, highly superior to the analysis capacity of an ordinary analyzer and the results can be comparatively studied in order to improve the calculation method.

The data processing is made with an accuracy that is highly superior to that provided by the analyzer. Another advantage consists in the on-line monitoring – the acquired data can be accessed through the network and processed using the program directly from a PC.

There will be presented a series of experimental data acquired with a CA 8352 analyzer from a rectifying substation used by an urban transportation system from Craiova, Romania. The sampled signals are submitted to the processing by an original software. These signals are acquired by the analyzer who gets them under the form of analogue signals provided by medium voltage transducers.

The transducers used to current measurement are of Rogowski type and provides a very good answer time. The voltage was measured through direct connecting to the low voltage network of the secondary belonging to the transformer that supply the rectifier. Fig.1 depicts the principle schematic of the test system along with the proposed interface.
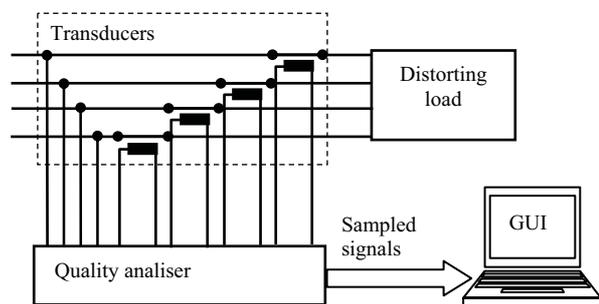


Figure 1: The principle schematic of the of analyzer

## 2. THEORETICAL MATTERS

### 2.1. Fourier Transform

The program functionality relies on principles that provide it with additional features as compared to

similar industrial programs. The very good quality of the harmonic analysis (accuracy, selectivity) relies on the discrete Fourier transform (DFT), simultaneously with the minimization of the specific errors.

A function that describes a periodic analogue signal $x(t)=x(t+T)$ can be expressed as a Fourier series of harmonic functions under the form:

$$x(t) = C_0 + \sum_{k=1}^{\infty} C_k \sin\left(k \frac{2\pi}{T} t + \gamma_k\right) \qquad (1)$$

The periodic signals processed by the program have a discrete character, the sampling corresponding to the moments:

$$t \in \left\{ t_0,\, t_1,\, t_2, ..., t_n, ..., t_N \right\} \qquad (2)$$

that usually are related through the relation:

$$\Delta t = t_{n+1} - t_n \qquad (3)$$

So the current moment can be expressed as:

$$t_n = n\Delta t,\ \ \forall n = 0, ..., N-1 \qquad (4)$$

The quantity $f_e = 1/\Delta t$ represents the sampling frequency. Consequently the sampled signal can be expressed as:

$$x(t_0) \equiv x_0,\ x(t_1) \equiv x_1, ..., x(t_n) \equiv x_n, ..., x(t_N) \equiv x_N \quad (4)$$

this representing an approximation of the real analogue signal [3], [4], [5].

The sampled signals representation in the frequency domain is possible if the discrete Fourier transformation is used. If a period $T$ of the signal contains $N$ samples, respectively $T = t_N - t_0 = 1/f$, where $f$ is the fundamental frequency, the discrete Fourier transform can be expressed as the Riemann sum with N terms corresponding to the Fourier transform for the analogue signal:

$$X_d(k) \equiv X_d(kf) = \Delta t \sum_{n=0}^{N-1} x(t_n) e^{-j2\pi(kf)t_n} \qquad (5)$$

This corresponding to the truncation of the series of harmonic functions up the to N-th term. The magnitudes and spectral phases become:

$$C_0 = \frac{1}{T} \sum_{n=0}^{N-1} x_n;\ C_k = \frac{2}{T} \sqrt{\left(\text{Re}\left[X_d(k)\right]\right)^2 + \left(\text{Im}\left[X_d(k)\right]\right)^2} \quad (6)$$

$$\gamma_k = \arctan \frac{\text{Re}\left[X_d(k)\right]}{\text{Im}\left[X_d(k)\right]} \qquad (7)$$

The harmonic component with the highest order that can be calculated in this way has the frequency $f_{max} = k_{max} \cdot f$, called Nyquist frequency, equal to half of the sampling frequency:

$$f_{max} = f_s / 2 \qquad (8)$$

This way one can determine the order of the fastest harmonic component that must be considered:

$$k_{max} = f_s / (2f) = N/2 \qquad (9)$$

A fast numerical algorithm for the calculation of the discrete Fourier transform (DFT) is known as the Fast Fourier Transform (FFT) [6].

## 2.2. The calculation of some quality parameters

The program functionality relies on principles that provide it remarkable features. After the performing of the harmonic analysis of a sampled periodic signal in N points along a period, one gets a harmonic spectrum whose highest order is $N/2$ [7]. As a consequence, the original signal can be approximated as:

$$x(t) \cong X_0 + \sum_{k=1}^{N/2} X_k \sqrt{2} \sin(k\omega t + \gamma_k) \qquad (10)$$

where the following symbols were used :

$X_0$ - d.c. component, equal to the spectral magnitude $C_0$; usually the d.c. components in power applications are null.

$X_k$ - RMS value of the component of order k, related to the spectral magnitudes through the relation:

$$X_k = C_k \sqrt{2};\ k = 1, ..., N/2$$

$\omega$ - fundamental angular speed of the signal; ($\omega = 2\pi f$).

Based on the harmonic spectrum one calculates:
- The RMS value:

$$X = \sqrt{\sum_{k=0}^{N/2} X_k^2} \qquad (11)$$

- The distorting residue:

$$X_d = \sqrt{\sum_{k=2}^{N/2} X_k^2} \qquad (12)$$

- The total factor of harmonic distortion:

$$THD = \frac{X_d}{X} \cdot 100\ \ [\%] \qquad (13)$$

The powers are calculated after the determination of the harmonic spectrums of the voltages and currents. One presents the relations used for the simple case of a single-phase circuit. They can be easily extended to three-phase circuits in various configurations. [8]
- Spectral active powers:

$$P_k = U_k I_k \cos(\gamma_{Uk} - \gamma_{Ik});\ k = 1, ..., N/2 \qquad (14)$$

• Spectral reactive powers:

$$Q_k = U_k I_k \sin(\gamma_{Uk} - \gamma_{Ik}); \ k = 1,...,N/2 \qquad (15)$$

• The total active power for the ordinary case when the d.c. component is null:

$$P = \sum_{k=1}^{N/2} P_k \qquad (16)$$

• The total reactive power:

$$Q = \sum_{k=1}^{N/2} Q_k \qquad (17)$$

• The apparent power:

$$S = U \cdot I \qquad (18)$$

• The distorting power:

$$D = \sqrt{S^2 - P^2 - Q^2} \qquad (19)$$

• The overall power factor:

$$k_P = \frac{P}{S} \qquad (20)$$

## 3. THE INTERFACE IMPLEMENTATION

A graphical user interface (GUI) is a graphical display that contains devices, or components, that enable a user to perform interactive tasks.

The GUI components can be menus, toolbars, push buttons, radio buttons, list boxes, and sliders. In MATLAB software, a GUI can also display data in tabular form or as plots, and can group related components.
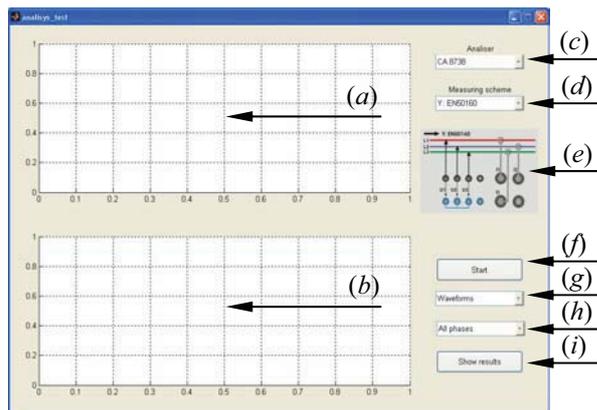


Figure 2: Presentation of the interface: *a)* graphical space allocated to the voltages waveforms and harmonic spectrum; *b)* graphical space allocated to the currents waveforms and harmonic spectrum; *c)* Selection of the analyzer type; *d)*Selection of the measuring scheme; *e)* Image of the measuring scheme; *f)* Data import; *g)* Switching between displaying modes (waveform /harmonic spectrum) ; *h)* Phases selection; *i)* Showing the file with results.

The left side of the interface is used to display the waveforms of voltages (up side) and respectively of currents (down side) as well ass their harmonic spectrum. In the right side one can see the command controls – pushbuttons and the pop-up menus (Fig. 2 *(a), (b)*).

The created interface allows the import of numerical data from a set of usual types of power quality analyzers.

The first stage consists in choosing the type of analyzer. Therefore a pop-up menu was designed (see section „Analyzer type" Fig. 2 *(c)*).

The following step consists in choosing the type of the measuring scheme used by the analyzer. The standard schematics are available from a pop-up menu (see section „measuring scheme" Fig. 2 *(d)*).

Under the pop-up menu a graphical representation of the measuring scheme is provided (Fig. 2 *(e)*)

Another stage consists in importing the numerical data acquired from a previously determined time-range. They are stored in a common memory space that makes them available for the program's sequential access.

Fig. 3 depicts a partial view from such an input file.



Figure 3: The file with numerical data in ASCII format submitted to the processing

The data can be exported by the analyzer in two format: ASCII text and binary. The maximum number of signals accepted by the program is 8 (depending on the studied connection type).

The data import is possible through the simple press of the START button, that results in the data import into program memory. Afterward the voltage and current waveforms along the previously determined acquisition time-range are displayed (Fig. 2 *(f)*).

For an accurate display of the waveform the analysis allows the specification of a smaller interval easily, through the specification of the analysis starting moment. After the specification of a new interval, the waveforms corresponding to the new period are displayed and after a short time the harmonic

spectrum of the voltages and currents will be displayed too.

The user can review the waveforms or can switch between the 2 displaying mode using the pop-up menu „Waveforms/Harmonic spectra" (Fig.2 *(f)*).

Also through the pop-up menu „Phases" one can ask the program to display each current/voltage phase at a time (Fig. 2 *(g)*).

Then the program calculates using the time-evolution of the voltages and currents a pre-determined set of power quality parameters and can generate a Microsoft Word file that includes these information (RMS values, distorting residue, peak values, THDi, THDu, powers, power factor). After the pressing of the „Show Results" button one can display the Microsoft Word file (Fig. 2 *(h)*). The name of this file is suggestive, including the exact date when the data were acquired as well as the moment when the waveforms analysis started [8],[9].

## 4. RESULTS

In order to perform experiments we selected a file with data acquired by the analyzer at a moment with maximum consumptions, when the current through the load reaches very high values. After the data import one selected from the entire amount of data (Fig. 4) a sequence that includes a voltage of almost 400 V and a current of almost 600 A.

The sequence has a default value of 6 periods, this allowing an accurate display of the waveforms (Fig. 5). After that the program performs a decomposition of the waveforms and after a short time it displays the harmonic spectrum of the voltages and currents (Fig. 6). The axis Y becomes the axis for weight and the axis X becomes the axis of harmonic orders instead of the time axis.

Each phase is represented by a distinct color, that is used also for the representation of the harmonic spectrum and for that of the waveform (Fig. 5 and 6). The default setting makes the program to display the current harmonics whose weights are higher than 2%. One can see a current waveform specific for an inductive load and a dominant harmonic of order 5.

In the upper right corner of each graph the RMS value of the analyzed quantity (voltage or current) is displayed. The detailed information are saved in the Microsoft Word file created at the end of the calculation process.
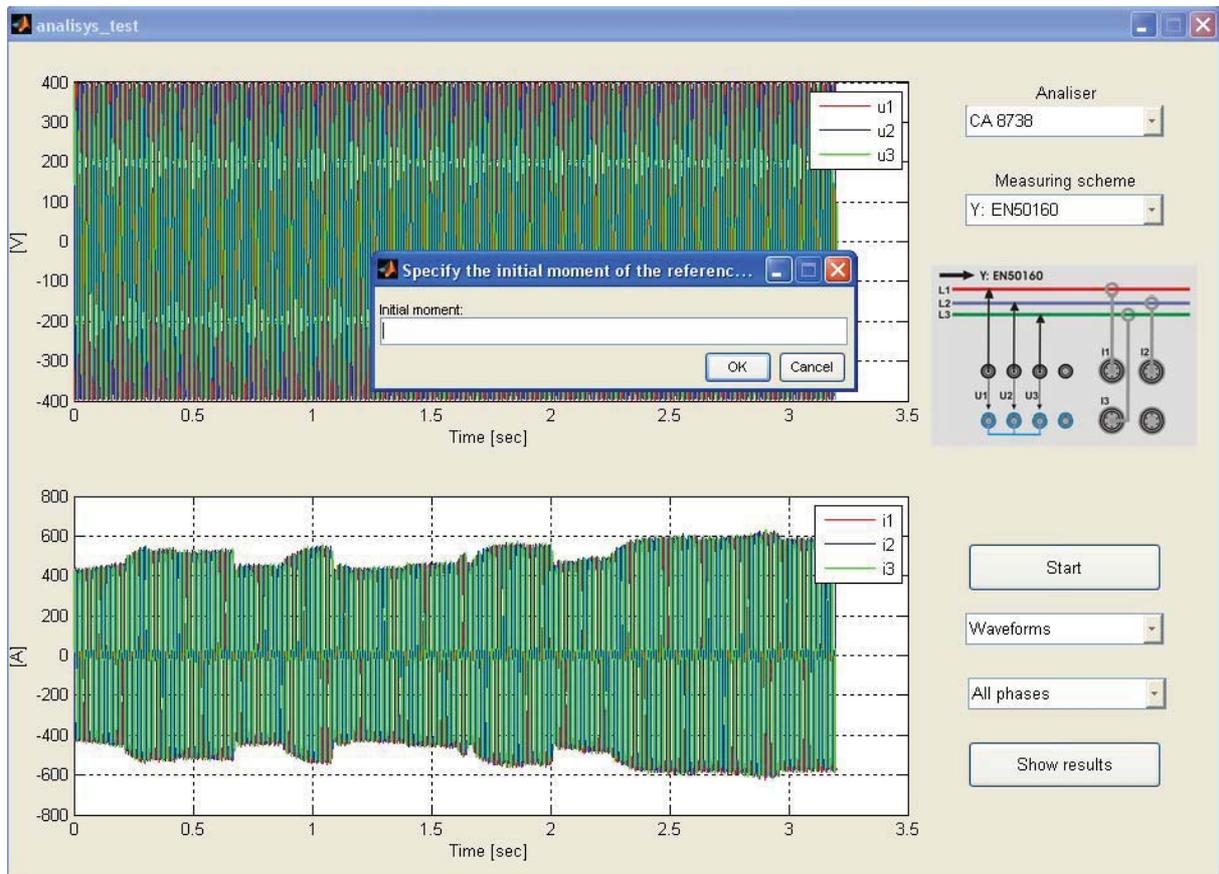


Figure 4:  The choice of the initial time from which the 6 period analysis is performed.
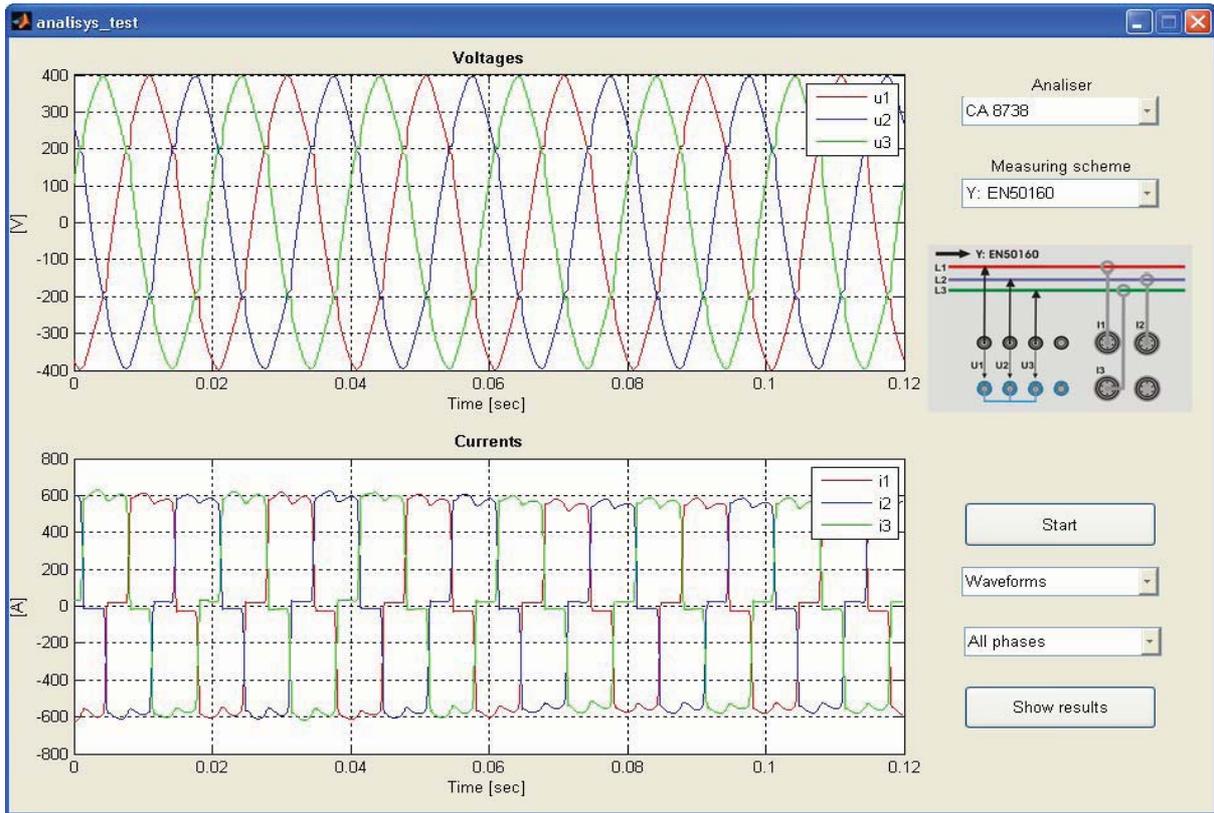
Figure 5: The waveforms of currents and voltages from the 6 periods sequence
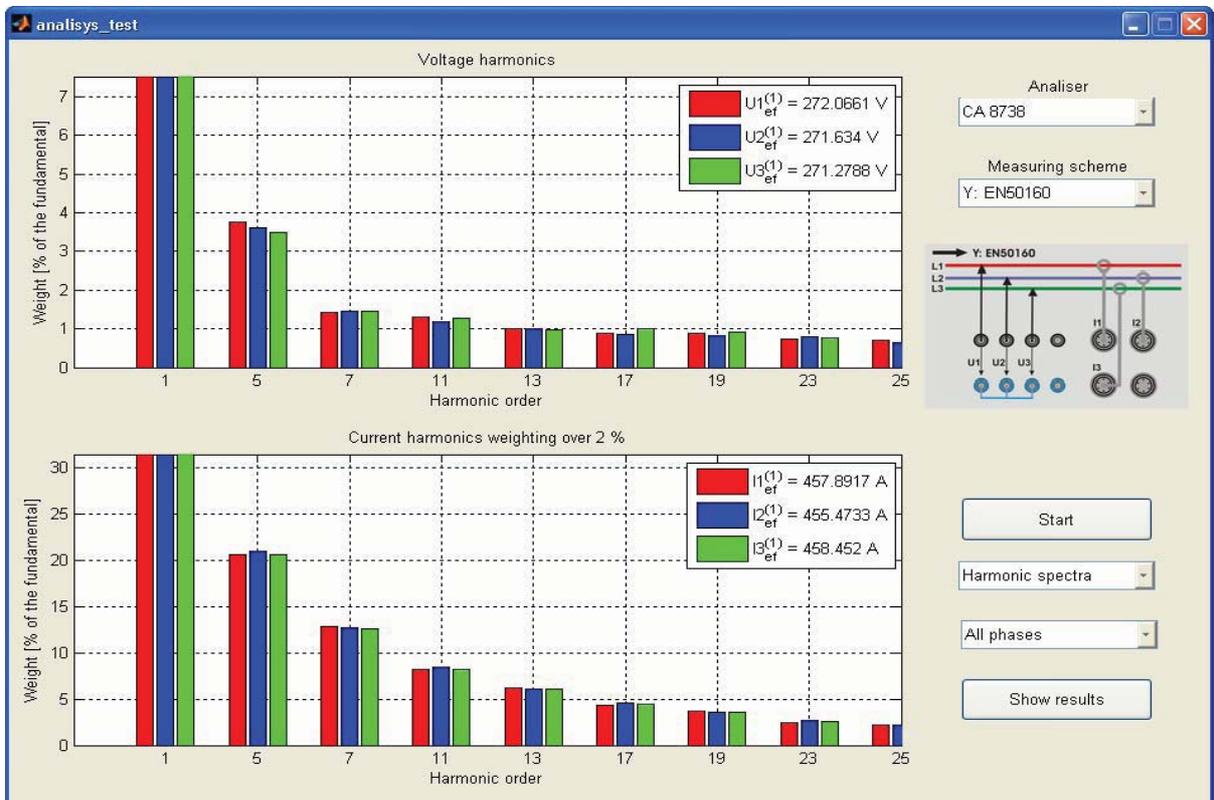


Figure 6. Harmonic spectrum of voltages and currents with weights higher than 2%.

In the results document file one can find the following power quality parameters used for diagnosis:

- harmonic spectrum of active powers, along with the indication of the direction of power circulation corresponding to every harmonic component and percentage weight of the total active power;
- effective values of all the monitored quantities, computed by means of all the harmonic components until the correspondent Nyquist frequency order;
- the deforming residues of all the quantities measured;
- total factors of harmonic distortion;
- peak values;
- apparent power, active power, reactive power and deforming power transferred trough the measuring point, as well as the global power factor;
- the fundamental frequency.

## 5. CONCLUSIONS

The paper presents a program with GUI used for the processing of numerical data acquired during power quality measurements at a rectifying station used for the urban transportation system, using a data acquisition system of type CA 8352.

The program provides complete information required for the adoption of optim measures for the quality parameters improving, through compensation and filtering in order to provide the conformity with the EU norms. It can be adapted to the specific features of the system in the test points owing to its flexibility and to the possibility of improvement.

A major advantage of the program consists in the unitary mode of treating the data acquired from various types of analyzers.

The program is easy to use owing to the friendly interface, accessible to an operator whose level of knowledge on the acquired data gathering and power quality parameters monitoring is medium.

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