DATA ACQUISITION SYSTEMS FOR THE MONITORING OF DELTA THREE-PHASE LOADS AT LOW VOLTAGE

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Abstract **– In the present paper one presents the structure, functionality and conditions imposed to a data acquisition system. Also one presents the specific features of the system utilization, for experimental purposes, for the analysis of a three-phase consumer in delta connection during a distorting regime.**

Keywords: *data acquisition, distorting regime.*

1. INTRODUCTION

The analysis of the electric energy quality is important for a correct operation and can be performed using some data acquisition systems. A data acquisition system (DAS) represents an equipment designed to measure and process some parameters. DAS has 2 main parts: a software part and respectively a hardware part. The hardware part includes sensors, cables and electronic components and the software part contains the collection of programs used for control and analysis [2], [4].

For a physical quantity acquisition transducers must be used to extract information. The electric signal obtained at the transducer output is converted to an electric signal with different parameters (current, voltage, etc.), using conditioning circuits. These can perform various functions: division, amplification, filtering, galvanic isolation, current-voltage conversion, etc.

For the numerical control one must perform the conversion of the analogue signals to some numerical signals accepted by the numerical processing system. The numerical signals are obtained gathering, at specified time moments, the analogue signals values and afterward converting them to numerical values using analog-digital converters (ADC), that represent the basic components of DAS-s.

The numerical processing system can performs over the numerical signals operations like: filtering, representation in the frequency domain, classification, identification. In this way one obtains processed numerical signals that contains information on the physical processes in representations required by applications [1], [6], [7].

2. DAS GENERAL STRUCTURE AND FUNCTIONS

Figure 1 depicts the general structure of a DAS.

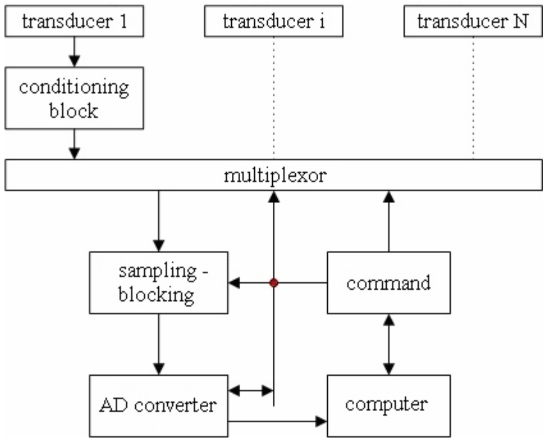

Figure 1: General structure of a DAS.

The systems used for the data acquisition and processing have a variable complexity and are developed, realized and used to perform the following functions:

A. Gathering of information on process

All the quantities submitted to the acquisition process are firstly transformed by the transducers into electric quantities that have parameters accepted by the following stage.

B. Electrical signals conditioning

The electrical signals provided by the transducers are characterized by their waveform, magnitude, frequency, signal's nature (electric current, electric voltage), etc.

The conditioning circuits provide the compatibility between the transducers' output signals and the analogue-numerical converter inputs. The electric signals' conditioning consists in the performing of the following functions: amplification, attenuation, filtering, detection of: RMS, peak or mean values, linearization, mathematic operations (multiplication, summarization, integration, derivation), adaptation to impedance, level detection, multiplexing, etc.

C. Signals sampling, quantification and coding

The information-carrying signals are in most cases analogical. In order to perform a numerical processing of the signals (after their conditioning) one must perform the analogue-numerical conversion, by which one assign a numerical code to the analogue signal (compatible to the computer internal structure). For this aim 3 consecutive operations are required: sampling, quantification and coding. The sampling and recording circuits (SRC) process in a serial manner a signal sample and provides its storage up to the end of the conversion process.

The sampling device converts the input signal $e(t)$, (which has a time continuous evolution) to a sequence of pulses $e^*(t)$. Figure 2 depicts 2 signals, associated to a device that provides a uniform time sampling (the sampling can be considered as a modulation of the pulse magnitude).

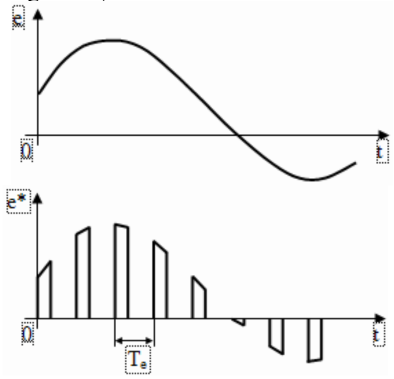

Figure 2: Uniform time signal sampling.

The sampling frequency is determined considering the following:
- the frequency spectrum of the input signals;
- the A/N converter's processing speed;
- the accuracy imposed to the processing process.

D. Communication in DAS

At DAS the numerical information (data, addresses, commands) are transmitted between:
- A/N converters (or memories with small capacity, where the quantized data are stored) and the computation equipment;
- the computation equipment and other equipment placed on the same level or on different hierarchic levels;
- the computation equipment and the peripheral devices for commands from the regulation systems.

The numerical data transfer toward the coordinating computation equipment is generally accomplished by the serial bus RS-232 and especially along the local buses: PCI (32 or 63 bits), ISA (16 bits) or the bus interface GPIB.

E. Data recording, processing and displaying

Through acquisition one can get data that are transmitted to the computation equipment. The data are processed in order to be displayed or to elaborate reports based on the characteristic elements of the signals' analysis.

There is a wide range of software products dedicated to data acquisition, that provides the tools required to data organization, analysis and display [2], [3], [5].

3. CONDITIONS IMPOSED TO A DATA ACQUISITION SYSTEM

A DAS design must meet the conditions imposed by the specific exploiting conditions. In principal these conditions refer to the maximum measurement range, accuracy, resolution, fastness, sampling frequency and time of exploration.

The *maximum measurement range* is defined as the difference between the values m_{max} and m_{min} that can be measured. If m is the quantity to be measured,

$$D_m = m_{max} - m_{min} \qquad (1)$$

The *system accuracy* is expressed through the measurement uncertainty that affects the result, denoted by δM.

This uncertainty can only be estimated. The real value falls inside the range $M \pm \delta M$, M being the result provided by the system.

The *relative error* of a DAS is denoted by ε_p and is defined as:

$$\varepsilon_p = \delta M/(M_{max} - M_{min}) \qquad (2)$$

The *resolution* is defined as the minimum variation Δm of the quantity to be measured that produces a variation ΔM of the measured quantity M. The resolution specifies the number of distinct values that can be assigned to the quantity to be measured along the maximum measuring range.

The *fastness* characterizes the device's capacity to answer to the time variations of the quantity to be measured.

The *sampling frequency* must obey the Nyquist's condition: $F_e \geq 2F_h$ where F_h represents the highest value from the frequencies spectrum of the measurement signal. Practically, the sampling frequency must be much greater than the value yielded by the Nyquist's condition.

A period $T_e = 1/F_e$ elapses between two successive sampling operations performed on the same measuring channel. Along this period one must sample and convert N signals, corresponding to N channels.

The *time of exploring* represents the duration required by a full acquisition along a channel. One can write [2]:

$$Nt_{sc} \leq T_e. \qquad (3)$$

4. DESIGNING OF A DAS FOR THE ANALYSIS OF A DISTORTING REGIME AT A DELTA THREE-PHASE LOAD

A DAS was implemented for the analysis of a three-phase consumer behavior formed by fluorescent lamps serially connected to resistors.

The system is structured as a data acquisition distributed system, containing a module for the level displacement with 8 channels and a system with microcontroller.

The system has 8 inputs, 4 for voltages and respectively 4 for currents. The maximum allowed (a.c.) input voltage is equal to 5V and it is introduced in the level displacement system, that displaces the input signal with 2.5V in order to provide the signals only with positive values. This procedure is necessary because the A/N converter integrated in 80C552 is mono-polar and accepts only positive voltages at the input.

The central unit controls the data acquisition process, their local processing and the transfer to the higher hierarchical level.

The data acquisition process involves the command for the A/N conversions successively, along every analogue input channel.

The local processing is minimal and is determined by the implementation in this equipment of the operating principles of an oscilloperturbograph (recording of electric events).

In the block-diagram depicted by fig. 3 there are presented the input blocks and respectively the blocks used by DAS for the interface with the microcontroller.

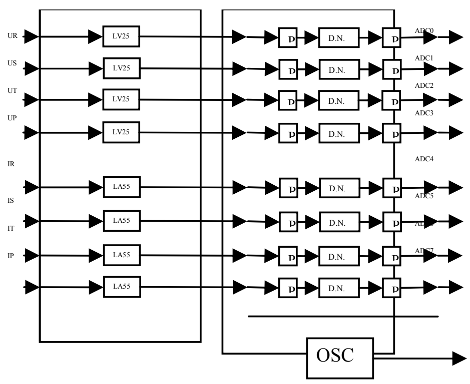

Figure 3: Input block and interface block.

Thus, in the input block, for the 4 voltages, one uses a voltage transducer LV25P in order to bring the voltage level inside a measurable range by the processing unit. This transformer has also a shielding role, removing the interferences from the force side and respectively from the logic side of the DAS, that can alter the measured values accuracy.

For the input currents one uses a current transducer LA55P. When the current flows through it, the voltage drops are picked along the internal resistance of the transducer which is sized so as to obtain voltages that can be measured by the processing unit. The shielding is also provided between the force and respectively logic sides.

At the input block's output there are 8 measurable voltages but, because the processing unit cannot operate over negative values, one must realize a level displacement in order to obtain only positive values. This is the role of the interface block.

In the interface block there is a protection for every input voltage in order to avoid the exceeding voltages along the circuit for the level displacement. This device used for the level displacement is a dedicated circuit built using an operational amplifier LM741. At the output of the device used for the level displacement there is another protection meant to prevent the microcontroller's inputs burning.

The A/N conversion subsystem present at 80C552 consists in an analogue multiplexer with 8 inputs and an A/N converter with sampling, with a resolution of 10 bits, that implements the Successive Approximation principle, for a mono-polar input quantity and an output quantity represented in natural binary code.

The consumer was realized using a three-phase system in a delta connection made of fluorescent lamps serially connected with resistors.

The lamps provide the ballast distorting regime and their parameters are tuned using resistors. They accept a voltage range extended from 190 V (minimum voltage) to 250 V (maximum voltage).

The fluorescent lamps are droved with ballasts having magnetic cores at 50 Hz. They provide low quality light as compared to those with electronic ballasts, resulting in the apparition of harmonic currents in the supplying network.

The resistors are connected so as to provide voltage drops along the fluorescent lamps in 3 stages, in the admitted range of values (fig. 4). During the designing process one considered not only the values of the required resistances but also the power dissipated on them as heat through Joule's effect. As a supplementary measure one uses a radiating support from Aluminum isolated by the wood box through asbestos sheets.

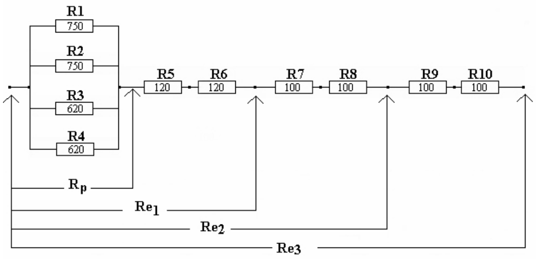

Figure 4: Schematic of the resistances connections.

The resistance equivalent for the parallel connected resistors is:

$$\frac{1}{R_p}=\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}+\frac{1}{R4} \qquad (4)$$

Considering that R1=R2=750 Ω and R3=R4=620 Ω, one obtains: $R_p = 170\ \Omega$.

The equivalent resistances corresponding to the serially connected resistors for three different steps are (see fig. 4):

$$R_{e1} = R_p + R5 + R6 \qquad (5)$$

$$R_{e2} = R_{e1} + R7 + R8 \qquad (6)$$

$$R_{e3} = R_{e2} + R9 + R10 \qquad (7)$$

If $R5 = R6 = 120\ \Omega$, $R7 = R8 = R9 = R10 = 100\ \Omega$, the following values will be obtained:

$$R_{e1} = 410\ \Omega\ ;\ R_{e2} = 610\ \Omega\ ;\ R_{e3} = 810\ \Omega$$

The designed consumer will be delta-connected to a supplying symmetrical system consisting of sine three-phase voltages of 380V a.c.

The consumer structure will allow the subsequent interconnection with the DAS, in order to pick the phase currents and the line voltages.

The assembling schematic is depicted by fig. 5.

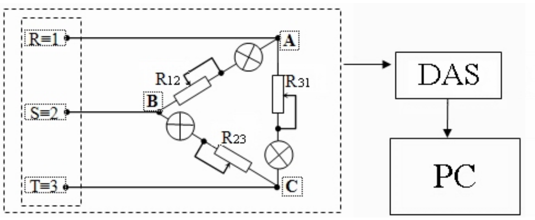

Figure 5: Block schematic of the connections.

The schematic's elements are:

- R_{12}, R_{23}, R_{31} – resistances variable in steps with the values set: 410 Ω, 610 Ω and 810 Ω / 1A that are used with the columns in series;
- DAS used for the current and voltage signals acquisition from the three-phase receiver in delta connection and respectively for the A/N conversion of these signals;
- PC- computer running the software required for the visualization of the quantities submitted to the acquisition process and for their processing.

The above described schematic is depicted by fig. 6.

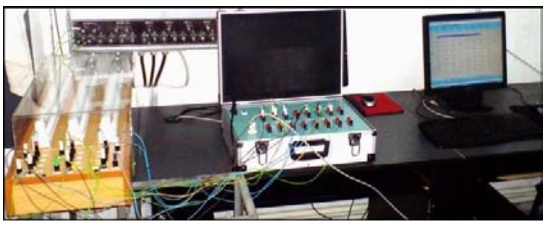

Figure 6: Real connection between DAS and delta three-phase load.

The software integrated to the DAS can provide a harmonic decomposition up to the user-imposed harmonic level. Using a series interface, one can realize the data transfer toward a PC and afterward, through a dedicated software, one can perform a detailed harmonic analysis, considering both national and international standards. For the fundamental harmonic one can also achieve a phase-diagram of voltages and currents.

Over the electric quantities (voltages, currents) one performs a numerical recording and afterward they are transferred to a computer and analyzed using a dedicated software PDM Win, in order to determine the harmonics of the absorbed currents and of the phase voltages.

For the monitoring process one uses 6 channels: 3 for the phase currents and 3 for the phase voltages (from the three-phase supplying source).

The waveforms corresponding to the voltages and currents for the fluorescent lamps, as well as the harmonic levels are presented in the below figures.

Due to the 3 stages of resistances along every phase the number of possible cases is $2^n = 8$ cases.

5. EXPERIMENTAL RESULTS

The significant obtained data are presented in the following:

1. **Case A** (fig. 7): R = 410 Ω along each phase (selectors placed on the terminal B3).

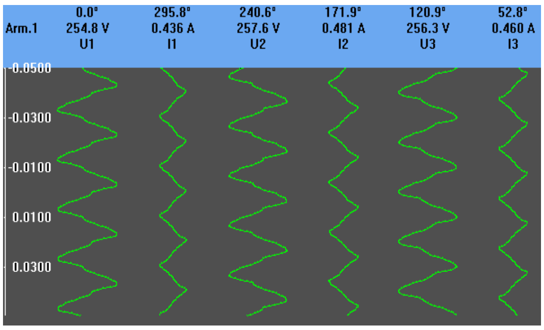

Figure 7: Waveforms for the case A.

The information seen in the software's windows (figures 7-11) is the instantaneous values of the three-phase voltages of the consumer, namely the voltage drops on the fluorescent lamps and the 3 phase currents.

The records made by PDM devices consist of samples. At the loading of a record, the program displays the waveform of the quantities by connecting the points of the corresponding samples.

For each case one can display the phase diagram for voltages and currents, as well as charts for the harmonics level, with the corresponding percent values (fig. 8).

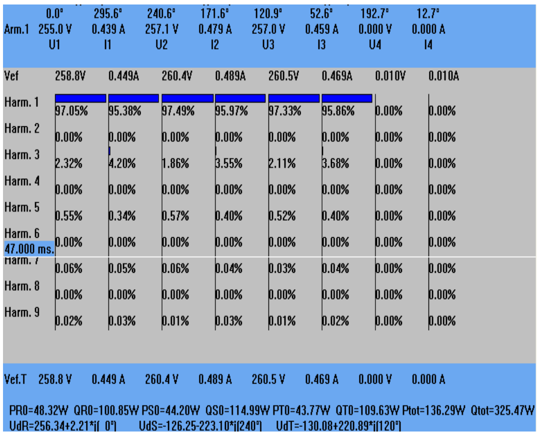

Figure 8: Harmonic analysis for the first 10 harmonics

For the analyzed case the RMS values of the voltage drops on the fluorescent lamps were: $U_{12\ lamp}$=258.8 V; $U_{23\ lamp}$=260.4 V; $U_{31\ lamp}$=260.5 V whilst the values of the fundamental harmonics on each phase were:
$U^{(1)}_{12\ lamp}$=255 V; $U^{(1)}_{23\ lamp}$=257.1 V; $U^{(1)}_{31\ lamp}$=257 V.
The voltages' analysis revealed the following weights of the 3-rd harmonic reported to the fundamental harmonic: 2.32% for the phase 12; 1.86% for the phase 23; 2.11% for the phase 31.
The RMS values of the phase currents were: $I_{12_{RMS}}$=0.449A; $I_{23_{RMS}}$=0.489A; $I_{31_{RMS}}$ =0.469A whilst the values of fundamental harmonics were: $I^{(1)}_{12}$=0.439A; $I^{(1)}_{23_{RMS}}$=0.479 A; $I^{(1)}_{31}$ =0.459A.
The most significant harmonic for the phase currents was the 3-rd harmonic, whose weights were:
$I^{(3)}_{12_{\%}}$=4.2%; $I^{(3)}_{23_{\%}}$=3.55%; $I^{(3)}_{31_{\%}}$=3.69%.
One can also notice harmonics of 5-th order in the waveforms of both voltages and currents.

2. **Case B** (fig. 9): R = 810 Ω on the phase R, 610Ω on the phase S and 410 Ω on the phase T

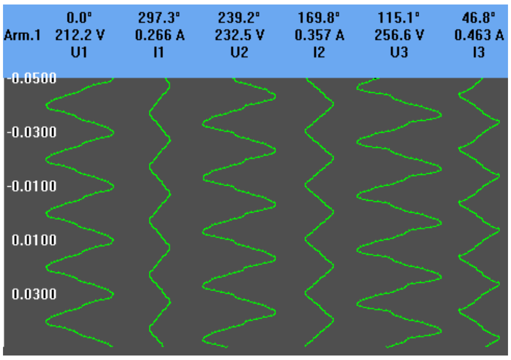

Figure 9: Waveforms for the case B.

If the delta receiver is unbalanced, the following RMS values were recorded for the phase voltages:
$U_{12_{RMS}}$=213.4V; $U_{23_{RMS}}$=234.6V; $U_{31_{RMS}}$ =259.7 V

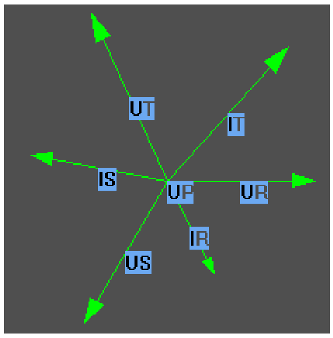

Figure 10: Phase diagram of voltages and currents for the 1-st harmonic

whilst the values of the fundamental harmonics were: $U^{(1)}_{12}$ =211.7 V; $U^{(1)}_{23}$=232.7 V; $U^{(1)}_{31}$=256.1V.
The RMS values of the phase currents were: $I_{12_{RMS}}$=0.268A; $I_{23_{RMS}}$=0.360A; $I_{31_{RMS}}$ =0.475A whilst the values of fundamental harmonics were: $I^{(1)}_{12}$=0.266A; $I^{(1)}_{23_{RMS}}$=0.357 A; $I^{(1)}_{31}$ =0.465A.
The most significant harmonic for the phase currents was the 3-rd harmonic, whose weights were:
$I^{(3)}_{12_{\%}}$=1.11%; $I^{(3)}_{23_{\%}}$=1.45%; $I^{(3)}_{31_{\%}}$ =3.79%.
Because the RMS values of the currents and of the fundamental harmonic present significant differences, a part of the 3-rd harmonic currents that flows through phases penetrates the supplying network and have negative influences both over the line conductors and respectively over other consumers [3].

3. **Case C** (fig. 11): R = 810 Ω on all phases

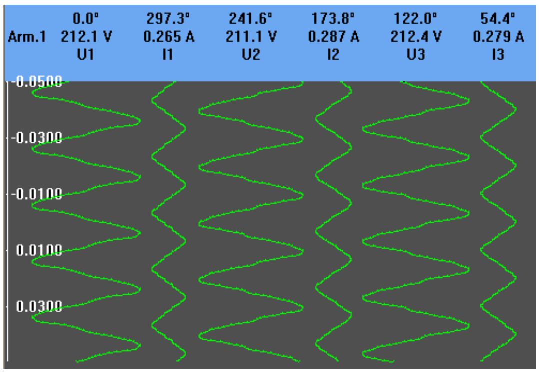

Figure 11: Waveforms for the case C.

In this case one can notice that when the resistances placed on phases have greater values, the voltage drops across the fluorescent lamps were lower, but their values still fired the lamps. The RMS values of the voltages were:
$U_{12_{RMS}}$=213.4V; $U_{23_{RMS}}$=211.7V; $U_{31_{RMS}}$ =213.5V
The voltage harmonics' weights were not significant. As for the phase currents, one could also notice small

values of the high harmonics, but the phase currents still make possible the lamps firing and a stabilization of the emitted light after a longer period.

6. CONCLUSIONS

The fast progress of the digital sampling technologies with respect to the measurement of the parameters in the three-phase circuits made possible the separation between the fundamental quantities and the harmonic quantities, emphasizing the supplementary harmonics that present disadvantages for consumers [5].

In this paper one presented the structure, the functions and the conditions imposed to a DAS as well as the modality of using it for experiments, when such a system is used to perform an analysis of the distorting regime of a three-phase consumer in delta connection. As one could see from the obtained experimental data, the fluorescent lamps introduced high-order harmonics with the highest value equal to 4.2 % for currents (the 3-rd harmonic) in the case A, the 3-rd phase, where the currents had the highest values ad respectively equal to 3.2 % for voltages, on the same phase. This harmonic level is placed within the limit of 5%, where no problems occur.

But the presence of the superior harmonics in the currents waveforms for a unbalanced consumer allows the penetration of those harmonics in the supplying network with drawbacks over the line conductors and other consumers from the system (as presented in the case B). The presence of some balanced three-phase distorting consumers distort the phase currents and the more significant is the linear consumer, the lower is the superior harmonics weights. On the other hand, a lower supplying voltage at the fluorescent lamps terminals reduces their lighting (useful) effect.

In conclusion, making a generalization for practice cases, one can say that the presence of distorting consumers along with the unbalanced feature of a receiver cause problems both to the supplying network and respectively to the consumers connected to the system.

References

[1] Nicolae, P.M.,*" Calitatea energiei electrice în sistemele electroenergetice"*, Editura Tehnică, Bucureşti 1998.

[2] Dobriceanu, M., – *„Sisteme de achizite si microprocesoare"*, Editura Universitaria., Craiova 2003.

[3] Nicolae, P.M., Nicolae, I.D., Stănescu, D. G. – *„Inregistrari si prelucrari numerice ale regimului deformant datorat unui consumator trifazat nesinusoidal"*, SNET 2008

[4] http://www.ttiedu.com/courses.html - Digital Data aquisition.

[5] Nicolae, P.M., „*Distorting and Unbalanced Working Regimes – A Possible Diagnosis Method"*, Revue Roumaine des Sciences Techiques, Serie Electrotecnique et Energetique, no. 1/2007, Bucharest.

[6] Nicolae, P.M., Vlăduț, G., Mandache, L. „*New Strategies for Waveforms Analysis Using FFT*" , IEEE International Conference on Automation, Quality and Testing, Robotics AQTR 2008

[7] Nicolae, P.M., Nicolae, I.D., Stănescu, D. G. *"Practical and Theoretical Aspects on Current Conditioning Boards Used for PEBB Converter Control*" , IEEE International Conference on Automation, Quality and Testing, Robotics AQTR 2008