MONITORING OF THE SPECIFIC PARAMETERS OF AN ELECTRIC SYSTEM, BY USING A MICROCONTROLLER EXPERIMENTAL SYSTEM

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Abstract – **The paper deals with experimental monitoring system, developed by the authors, by using a microcontroller within the 8051 family, Dallas DS87C550. The possible functions of the system are related to the acquiring of the six signals specific to the tri-phased equipments, three voltages and three currents.**

Keywords: *monitoring, microcontroller, assembler, user interface.*

1. INTRODUCTION

The modern electric equipments include performing on-line monitoring and diagnosis systems based on microcontrollers. The electrical equipments, being characterised by small time constants and high risk, impose major efforts in order to develop competitive monitoring systems.

This micro-system has two main parts: the acquiring and transfer module and the user interface, developed using the facilities specific to Graphic User Interface(GUI) of Matlab®. The user interface has as aim to establish an on-line link between the acquiring and transfer module and the user.

The possible functions of the system are related to the acquiring of the six signals specific to the tri-phased equipments, three voltages and three currents. The interface displays, at demand, the number of commutations of the equipment, stored in the non volatile serial RAM memory of the acquiring and transfer module.

For the fastest and efficient behaviour to the user's demanded functions, the acquiring and transfer module was programmed in assembler, by using the complex interrupting system of the controller.

2. THE HARDWARE ARCHITECTURE

The hardware part of the monitoring system is centred on the Dallas micro-controller DS87C550. This type of micro-controller is code fully compatible with the 8051 family micro-controllers, being equipped with many integrated peripherals that make it suitable for embedded applications.

More than that, being equipped with the high speed core specific to the Dallas micro-controllers, the performances achieved by the hardware subsystem based on this module make it very suitable for the on-line monitoring of the high speed electrical equipments.

The acquiring and transfer module consists of the blocks: Sources, Controller, Local console, Inputs, Outputs and Serial communication interface.

By the way of three precise voltage regulators, the Sources block supplies the regulated voltages to the micro system.

The Controller block is the core of the module and consists of the controller itself, the full duplex RS485 serial interface, connector to the 7 digits display, digital open collector output, that can be used for commanding a power element (relay), non-volatile serial EEPROM with 32 bytes, for saving adjusting parameters or essential events, 8 micro switches for possible changes of the system's functionality, LED for signalling the state of the system.

The Figure 1 depicts the bloc diagram of the acquiring and transfer module.

In order to integrate the mentioned component in the hardware subsystem of the monitoring structure, specific to the electrical equipments, special transducers must be used.

The system was designed to acquire all the three phase currents and voltages. As current sensors, LEM transducers LTS15-NP are used, special adapted to the integration with the micro-controller.

The voltages are measured by using three precise voltage dividers, built with 1% resistors. These dividers were designed in such manner to obtain, at the rated voltage, a trip by ±0.5 V. The 1% tolerance is quite enough, but more important is the thermal stability. For this reason, for building these dividers were used resistors with identical thermal factor.

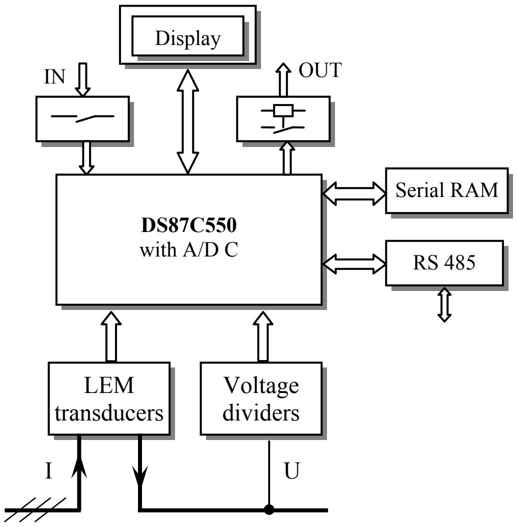

Figure 1: Main structure of the hardware subsystem.

Experimental tests were performed both for calibrating the six transducers and for checking their linearity. The RMS values of the currents and voltages as inputs and the peak values of the corresponding outputs were measured. The dependencies of the output values versus the input ones are plotted in Figure 2 for the voltage transducers and in Figure 3 for the current transducers respectively.

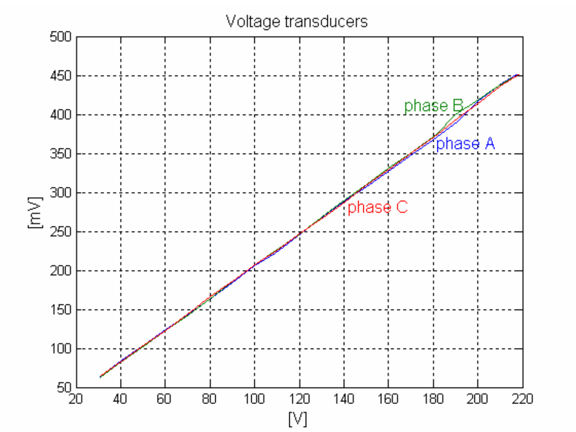

Figure 2: The experimental transfer function of the voltage transducers

We notice the good linearity of all the six transducers. The offset compensation of all six channels is mandatory for obtaining correct measurements. The measured zeros were 2.48V for the voltage transducers and 2.24V for the current ones respectively, far enough by the perfect value of 2.5V.

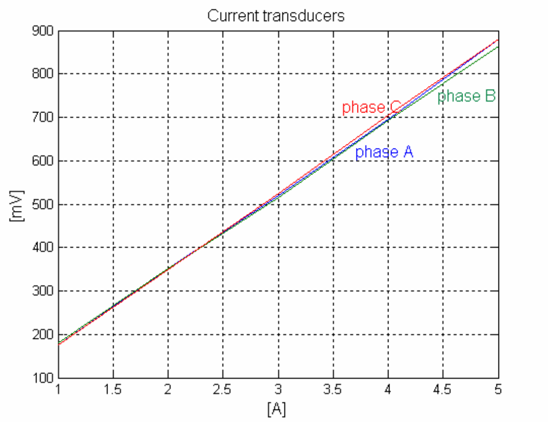

Figure 3: The experimental transfer function of the current transducers

The compensation of the possible offset both of the current transducers and of the resistive dividers is performed a single time, at the system setting, by using the calibration routine. This task is achieved only in local-mode control, by proper configuring the micro switches. The obtained values are stored in the non volatile serial EEPROM RAM. At each start of the system, the values of the offsets are read from the serial non volatile RAM and further used for the correction of the acquired samples.

The same non volatile serial EEPROM RAM is used to store the number of the commutations performed by the installation, available at the user's demand. Due to the importance of the stored values, at start, a short routine checks that the data are not corrupted.

The domain of the possible input signals reaches 830V for the voltages, 8.2A for the current respectively. We mention that in what concern the current domain, it corresponds to the 5A connection of the transducers and can be easily extended to 12.3A or 24.6A with different connections. In order to extend the measure domains, it is also possible to have external voltage and/or current transformers.

Figure 4 depicts the hardware structure of the experimental acquiring and transfer module.

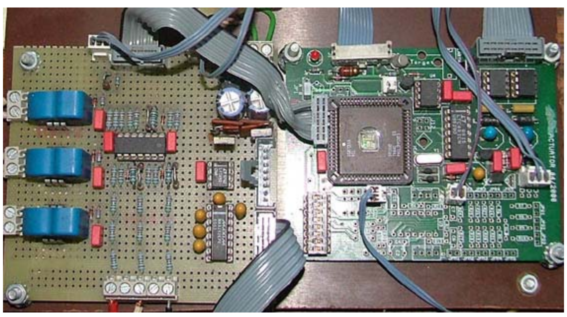

Figure 4: The hardware subsystem

The whole hardware subsystem is fully controlled by a fast serial interface based on the RS 485 protocol.
The sample frequency is fixed, but programmable in the range 175µs÷1ms, depending on the number of channels to be acquired, selected within the user interface and transferred by the way of the serial link.
Being programmed using the assembly language, the whole advancement of the acquisition task is based on using the interruption system of the micro-controller.

3. PROGRAMMING ARCHITECTURE

For the fastest and efficient behaviour to the user's demanded functions, the acquiring and transfer module was programmed in assembler, by using the complex interrupting system of the controller [3].
The tasks performed by the main program are depicted in Figure 5.
At the first operation, a calibration procedure is called, that determines and stores in a non-volatile serial RAM, the channels' offsets, used further for the samples correction.
Due to the limitations of the internal RAM memory of the micro-controller, the acquisition strategy was fixed to get all the time 120 samples within 20 ms. Depending on the option of the user, the following types of acquisitions can be performed: one channel (phase voltage or current) with 175 µs sampling period; two channels (phase current and voltage of the same phase) with 350 µs sampling period; three channels (phases currents or voltages of the three phases) with 500 µs sampling period; six channels (all phases currents and voltages of the three phases) with 1 ms sampling period. The equidistance between the acquired data packages is achieved by a proper programming of one Timer of the controller, which will generate an interruption at specified intervals. Immediately after the acquisition of the first sample, the transmission routine is started and consequently, the acquisition and the transmission work in parallel, on the same bank of data.
By using the interruption system of the micro-controller, the code, written in assembly, is quite compact and efficient. The whole acquisition process is started by the serial port interruption that receives a command generated by the user interface (on-line). Depending on the structure of the channels to be acquired, the sampling period is programmed within a Timer, in order to have equidistant samples. At each Timer interruption, all the programmed channels are sampled consecutively, based on the EOC interrupt.
The software structure of the acquiring and transfer module is organized as the main program (init1) and the more routines:

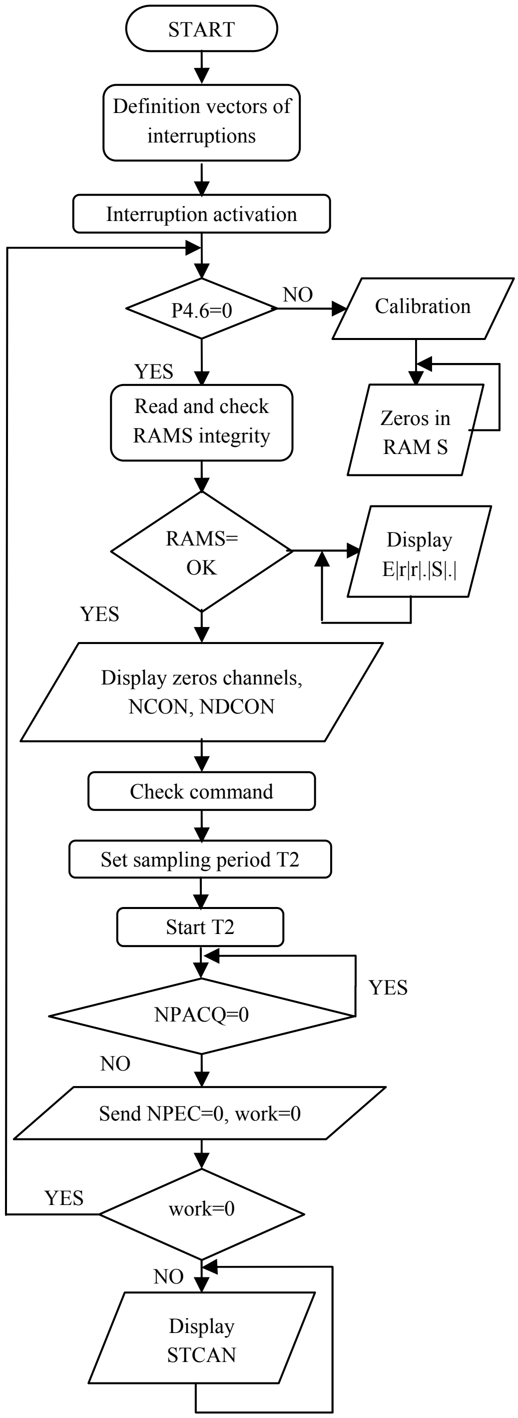

Figure 5: The flowchart of the main

i_rec – the routine that treats the receiving and transmission interruptions of the serial communication port;
acq – the routine that starts the acquisition of the samples, formats and stores the current sample, at each EOC interruption;
send – the routine that sends on serial port the 120 samples;

iext – the routine activated by the external interrupts that increments the number of switches-on or switches-off, stored then in the non volatile serial RAM;
calibru – the routine that performs, at the very first start up, the measurement of the zeros of all the six channels, then stores them in the non volatile serial RAM and resets the number of commutations of the equipment;
rw_rams – the routine that reads and writes a byte in the non volatile serial RAM, at the generic address updated at call;
delay – the routine that generates the different delays used in the programs.

4. USER INTERFACE

As medium for the development of the user interface, the Graphic User Interface (GUI) of Matlab® was chosen.
It allows the bi-directional communication with the hardware subsystem. Thus, on one hand, based on the channels chosen within the interface, it sends the proper command to the hardware subsystem which configures the proper sampling period. On the other hand, the user interface receives the sampled data and reconstitutes the signals on each sampled channel.
The interface was designed in a user-friendly manner, avoiding the programming mistakes.
As the number of acquired signals could be only one (one phase current or voltage), two (the phase current and voltage on the same phase), three (all thee phase currents or voltages), or six (all the phase currents and voltages), the interface assures the interlocking for a correct selection of the channels (Figure 6, highlight 1).

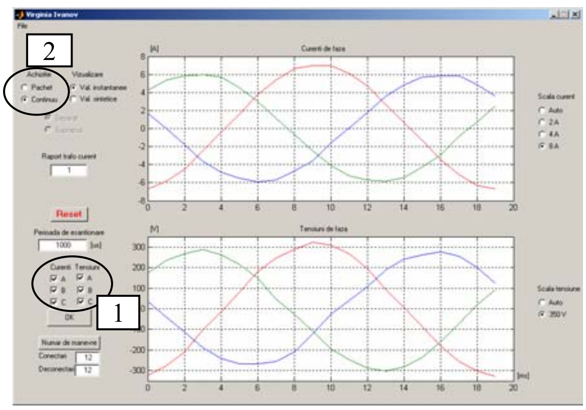

Figure 6: Interlocking of the selected channels

Depending on the structure of the selected channels, the sampling period is displayed, the value being further used for plotting the signals or for their processing.
In order to adapt the range of the rated power of the monitored equipments, external current transformers could be used, the user interface being able to adapt the scale of the plotting windows accordingly.
The interface allows the programming of two types of acquisitions: continuous, when the selected structure of channels is displayed continuously, or packet by packet, when each acquisition must be confirmed by the user (Figure 6, highlight 2).
If two channels are selected to be displayed as instantaneous values, the buttons for the selection of the type of representation become active. From here, can be selected the representation in different axes or in the same axes, with the automatic adaptation of the scales, in order to be easily readable. For the option of representation in different axes, the buttons for selecting the scales of the two systems become active.
The interface displays, at demand, the number of commutations of the equipment, stored in the non volatile serial RAM memory of the acquiring and transfer module.
No matter of the acquisition type, the displaying method could be as a plot versus the time or a calculus of the synthetic values: rms values of the phase currents and voltages, the angle between the two signals of the same phase, the active and reactive powers on each phase.

5. EXPERIMENTALS RESULTS

The described hardware subsystem and user interface were used to monitor two types of loads: a resistive one and a high inductive one.
In the following, some results will be presented.
Figure 7 depicts the acquired signals for a pure resistive load, when all six channels were selected with continuous acquisition and Figure 8 presents synthetic values obtained with the micro-system.

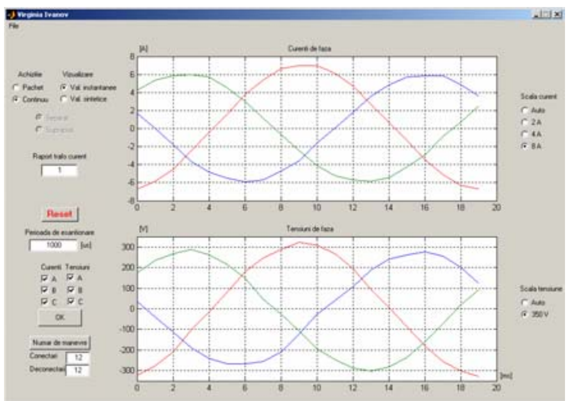

Figure 7: Experimental results with resistive load

Figure 8: Synthetic values of a resistive load

The synthetic values are computed based on the instantaneous values sampled on one period by using the following expressions:

- rms values:

$$U = \sqrt{\frac{1}{N \cdot \Delta t} \cdot \sum_{k=1}^{N} u_k^2 \cdot \Delta t} \qquad (1)$$

- the angle between the two signals of the same phase is computed by using the Gilcrest-Rockefeller algorithm that computes the phase angle depending on three successive sampled values [2]:

$$\varphi = \mathrm{arctg}\frac{\omega \cdot \Delta t}{2}\frac{u_3 - u_1}{u_3 - 2u_2 + u_1} - \\ - \mathrm{arctg}\frac{\omega \cdot \Delta t}{2}\frac{i_3 - i_1}{i_3 - 2i_2 + i_1} \qquad (2)$$

Figure 9 depicts the instantaneous values and Figure 10 presents synthetic values obtained with the micro-system for the phase A of an inductive load.

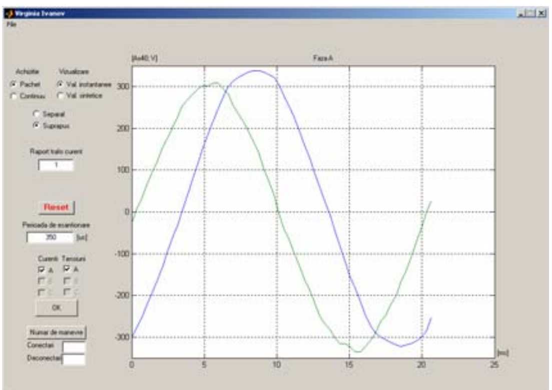

Figure 9: Instantaneous values for the phase A of an inductive load

The results obtained with the experimental micro-system are compared with the information found with a industrial measurement equipment, the Fluke 196 power scope.

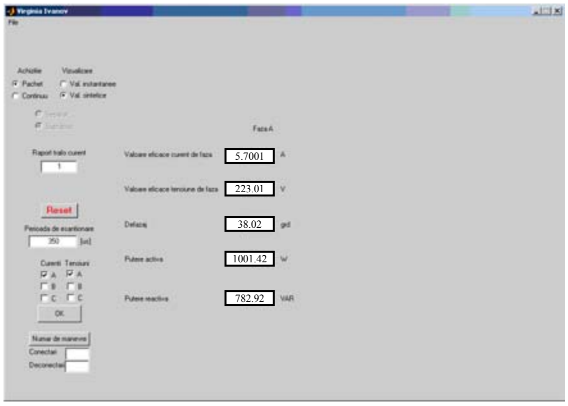

Figure 10: Synthetic values for the phase A of an inductive load

Figure 11 and Figure 12 contains the plots of the screen of the scope.

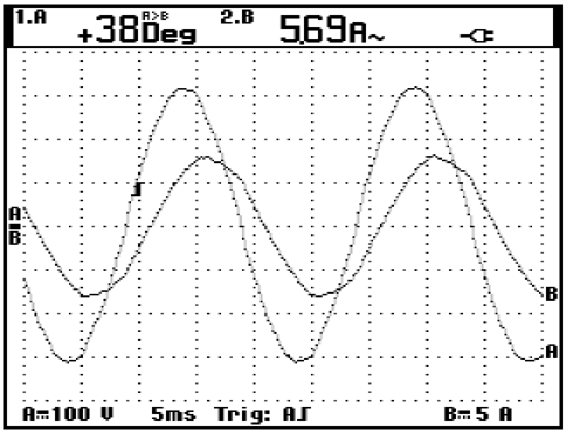

Figure 11: Fluke 196 plots, the instantaneous values

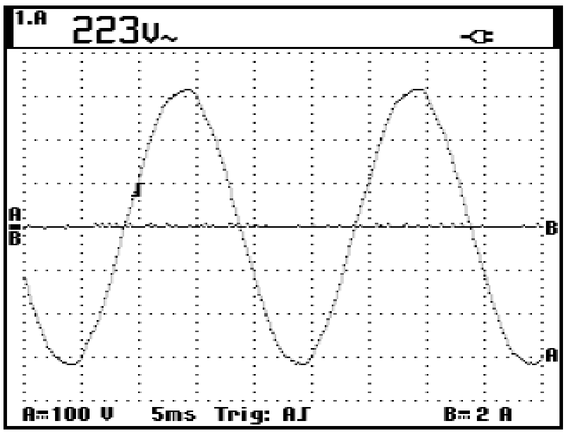

Figure 12: Fluke 196 plots, the synthetic values

It can be noticed the high similitude of the values obtained with the two measurement systems [1].

6. CONCLUSIONS

It is described the main structure of a monitoring system that is mainly composed of two parts: the field systems and the central unit. The field systems are generally dedicated to a certain part of the equipment and consist of specialized sensors, transducers, adapters and signal conditioners that acquire information about the monitored process, digitized it and store in a local computer. Due to the small time constants and high risk specific to the considered applications, the whole structure was designed in order to respond fast and efficient to the specified demands.
The last communicates with the central unit by the way of a serial protocol. The central unit processes the information and can send the main data to the hierarchal superior level.
The experimental results, compared with the indications of classical measurement devices confirm the correctness, both of the micro-controller programming and of the algorithms specific to the user interface.

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