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Extract of the thesis

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CONTRIBUTIONS IN THE FIELD OF DEVELOPING MONITORING AND CONTROL SYSTEMS FOR THE ELECTRIC EQUIPMENTS

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CONTENT
(condensed)

Key words: *monitoring, SCADA, expert systems, microcontroller, digital processing, assembler programming, interrupts system, user interface*

INTRODUCTION

Taking into account the advances in microelectronics, the thesis is focused on developing monitoring and control systems by using modern microcontrollers. It is organized on five chapters, Introduction, List of the symbols, Conclusions and contributions, Bibliography and nine Annexes.

1. MONITORING SYSTEMS. STATE OF THE ART

In the first chapter, firstly is pointed out the importance and the main functions of the monitoring systems. Due to the technical progresses, we note that more and more intelligence is integrated with the electric equipments, allowing the intelligent monitoring, self evaluation and diagnosis.

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. 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.

Taking into account that the form of the changed data is the digitized one, this chapter presents and analysis (based on different criterions) the main algorithms for processing sampled values. The algorithms are divided in two principal groups: for a single signal and for two signals. In the first group, are presented the algorithms for following the instantaneous values, the slope, the maximum value, the average value, the RMS value. Within the second group, for two monitored signals, can be mentioned the impedance and phase calculus, based on sinusoidal inputs.

The analyzed algorithms were practically used when was realized the user interface of the own experimental system.

2. SUPERVISING AND CONTROL SYSTEMS FOR THE INDUSTRIAL EQUIPMENT

In the second chapter are analysed two types of specialized systems: SCADA and expert. Within two different sections, there are presented the domain of applications, the accomplished functions, the structure and the perspectives.

In what concern the SCADA systems, an important attention was granted to the study of the communication protocols. An example of such serial communication protocol is described, by highlighting the importance and functions of each part of a sent “message”.

It is proposed the integration of the own experimental system as a Remote Terminal Unit (RTU) in a SCADA system. This RTU, should be used for acquiring the six signals (three currents and three voltages) corresponding to the supplying of an electric equipment and the number of commutations.

In the second part of the chapter, the applications domains and the structure of the expert systems are presented. Because the performances of the expert systems are strong influenced by the way how the structures of knowledge are represented, the knowledge representation formalisms are presented further. In the same time, the advantages of using such systems are pointed out.

Finally, it is revealed the possibility of using the manufactured experimental micro system, detailed in §4, within an expert system for the control and command of a process that includes the interpretation, the diagnosis, the monitoring, the prognosis and the restoring, by the acquire and the observation of the six signals characteristic to a tri phased system (three voltages and three currents) and of the number of commutations.

3. TECHNIQUES FOR CONTROLLED COMMUTATIONS

In the third chapter, is developed the methodology for the controlled commutations, taking into account that this solution become a way currently applied in order to reduce the stress caused by the switches. In the present days, there are used more and more specialized controllers for the switching of the shunt capacitor banks, shunt reactor banks, transformers and transmission lines.

The state of the art of the controlled commutation is pointed out, based on the information supplied by five manufacturers that have participated to CIGRE WG13.07.

The modern systems that perform controlled commutation, accomplish functions as the precise determination of the instants for the command of the switchers, in order to reduce the stress and the controlled compensation.

The imposed functions to be realised for controlled compensation, by the way of the microcontrollers, concerning the breakers with independent poles, are: the compensation of the closing time augmentation due to the no operation time; conditional compensation of the closing / opening time due to the environmental temperature, command voltage, hydraulic pressure; adaptive compensation of the closing / opening time versus the long term ageing.

It is proposed the solution of the integration of the experimental micro system, built and detailed in §4, within a modern system that can realize the controlled commutation, by correspondingly adapting the software structure, in order to precisely determine the command instants of the circuit breakers for reducing the commutations stress. This adaptation would take into account the process' parameters, like voltage and current but also the type of commutated load.

By analysing the determinant characteristics of the independent poles circuit breakers, is prospected the possibility of using the experimental conceived and built micro system for other different tasks emphasized above. These would be achieved with a proper programming, by slightly modify the existing software structure.

4. MONITORING MICRO SYSTEM

The forth chapter presents the experimental micro system totally **conceived, designed and built** within the thesis. This micro system has two main parts: the acquiring and transfer module, based on *Dallas DS87C550* microcontroller and the user interface, developed using the facilities specific to *Graphic User Interface* of Matlab®.

In this chapter are extensively presented the two main components. For the acquiring and transfer module are detailed both the hardware structure (§4.1.1.) and the software structure (§4.1.2.), designed to accomplish as fast as possible the proposed functions. In §4.2. is detailed the structure and functions of the user interface.

Starting from the idea that the designed micro system is an experimental one, the purpose was to obtain a highly versatile system. It can be programmed both by the way of a local interface and by the commands received from the user interface. 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. This activity is performed by using a constant, but programmable sampling rate. The results can be displayed both as instantaneous values but as synthetic values too (RMS values, powers, phases). It is possible also to retrieve information concerning the history of the installation.

The designing of the hardware structure of the acquiring and transfer module was performed thinking both to the proposed functionality and to the versatility. In the same time, the software structure was developed by intensively using the facilities and performances of the microcontroller. As was mentioned above, the chosen microcontroller was the *DS87C550* from *Dallas Semiconductors*. This is a fully compatible Intel 8051/8052 microcontroller, but presents important facilities compared both with the basic variants of 8051/8052 and with other 550-type controllers from different manufacturers (Philips).

The Figure 1 depicts the bloc diagram of the acquiring and transfer module. It consists of the blocs: *Sources*, *Controller*, *Local console*, *Inputs*, *Outputs* and *Serial communication line*. The *Sources* bloc is supplied by a double voltage ±9V. By the way of three precise voltage regulators, it supplies the regulated voltages to the micro system. The *Controller* bloc 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.

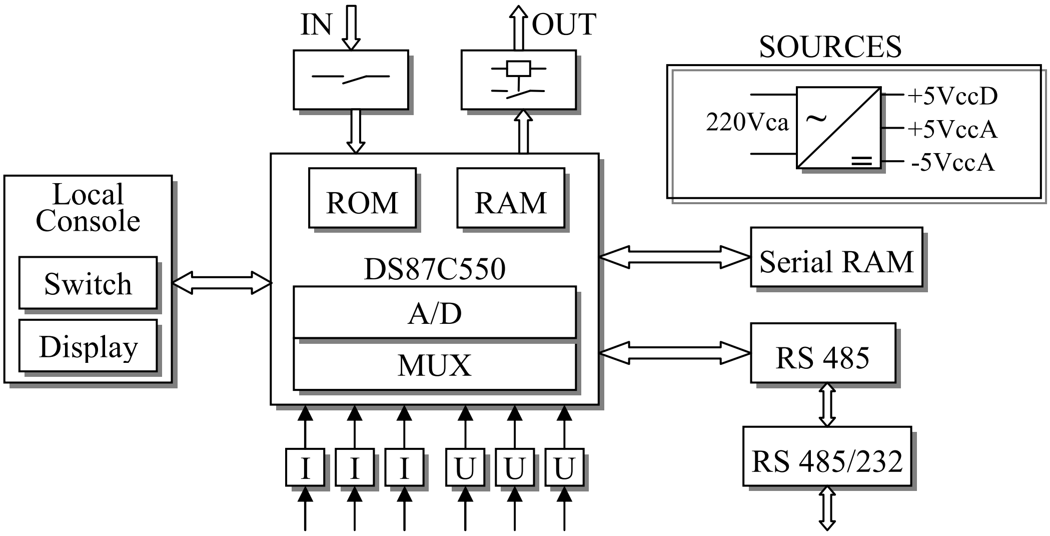


Figure 1 *Bloc diagram of the acquiring and transfer module*

For the measurement of the currents, with galvanic isolation, three current LEM transducers LTS15-NP are used. Concerning these transducers there are two important aspects that must be pointed out, regarding the use in digital systems:

- Supplying voltage is 5 V;
- The output is single polarity, with a 2.5 V offset and ±0.625 V trip, special adapted to the usual 8 bits analog to digital converters.

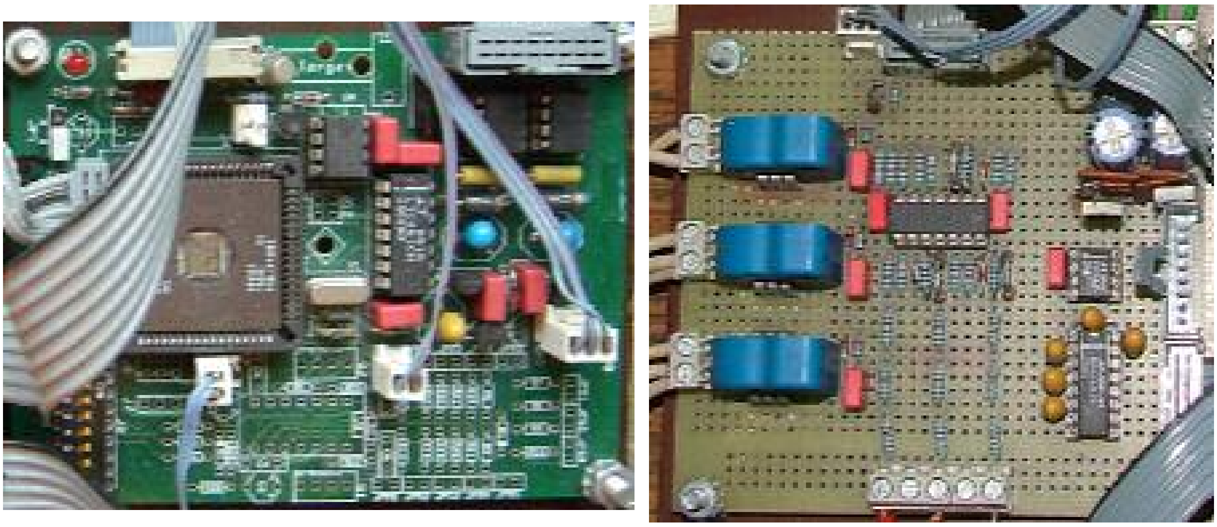
The voltages are measured by using three precise voltage dividers, built with 1% resistors. These dividers were designed in such manner to obtain, at the rated voltage, a trip by ±0.5 V. The 1% tolerance is quite enough, but more important is the thermal stability. For this reason, for building these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

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 offsets' values 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 stored values, at start, a short routine verifies that the data are not corrupted.

The domain of the possible input signals reaches **830V** for the voltages, **8.216A** 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 **12.32A** or **24.65A** with different connections. In order to extend the measure domains, it is also possible to have external voltage and/or current transformers.

Figure 2 depicts the practical circuits of the acquiring and transfer module: bloc *Controller* (a), *Sources* and *Measurement* (b) respectively.



a) b)

Figure 2 *Blocs Controller (a) and Measurement (b)*

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.

Due to the limitations of the internal RAM memory of the microcontroller, 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 175μs sampling period; two channels (phase current and voltage of the same phase) with 350μs sampling period; three channels (phases currents or voltages of the three phases) with 500μs sampling period; six channels (all phases currents and voltages of the three phases) with 1000μs 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.

The software structure of the acquiring and transfer module is organized as the main program (*init1* – Annex 1) and the following routines:

- *i_rec* – Annex 2, the routine that treats the receiving and transmission interruptions of the serial communication port;
- *acq* – Annex 3, the routine that starts the acquisition of the samples, formats and stores the current sample, at each EOC interruption;
- *send* – Annex 4, the routine that sends on serial port the 120 samples;

- *iext* – Annex 5, 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* – Annex 6, 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* – Annex 7, the routine that reads and writes a byte in the non volatile serial RAM, at the generic address updated at call;
- *delay* – Annex 8, the routine that generates the different delays used in the programs.

The **user interface** has as aim to establish an *on-line* link between the acquiring and transfer module and the user. It must be able, on one hand, to generate and to send the commands to the module and on the other hand, to receive, to process and to display the requested data. One of the concerns was to obtain an easy to use, ergonomic and easy to read interface. As developing medium, *Graphic User Interface* (GUI) of Matlab® was chosen.

The created interface was conceived in such way to be intuitive and easy to use. In the same time, more inter-blockings were inserted, in order to avoid the transmission of wrong commands, keeping always the high versatility of the module's programming.

The user interface is launched within Matlab®, with the command ***inter***. Consequently, the application (Annex 9) is initiated that will open the window depicted in Figure 3.

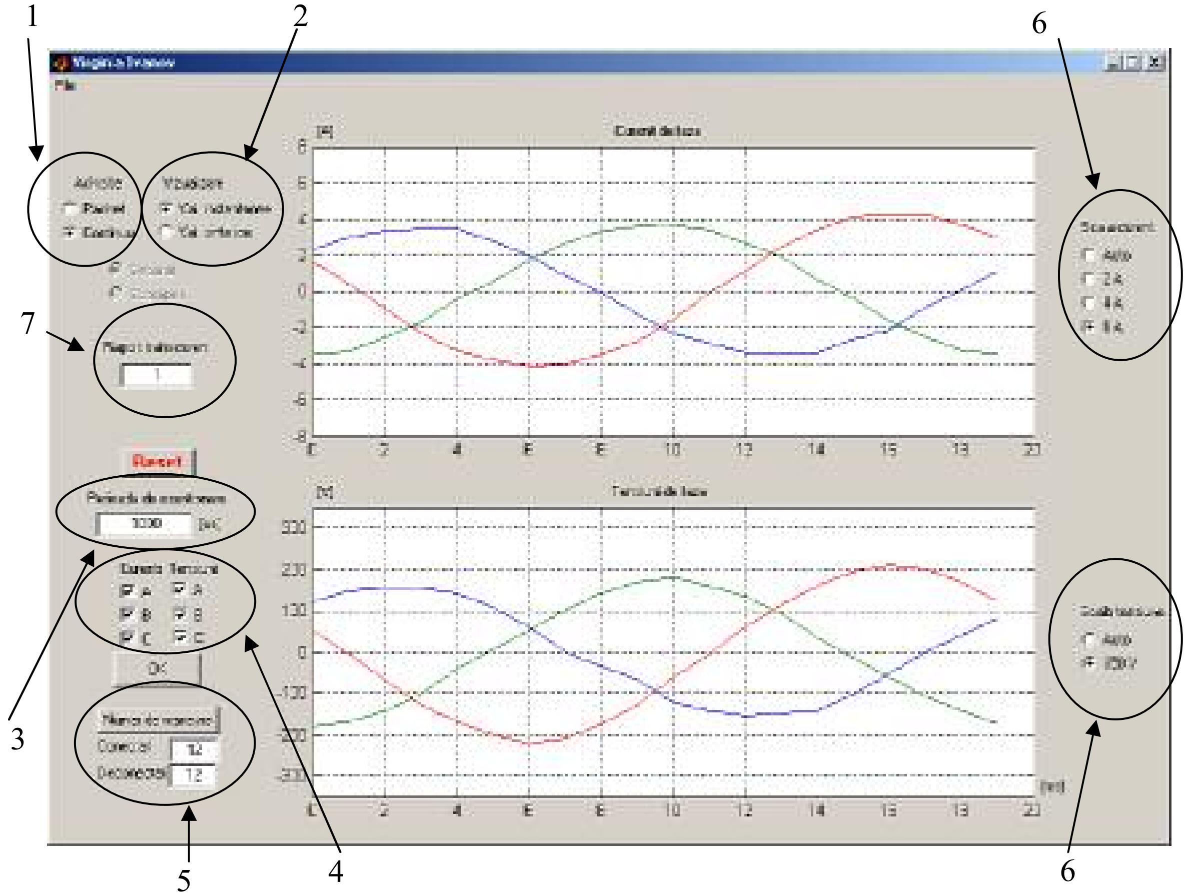


Figure 3 *User interface window*

The rated current of the employed current transducers is 5A. If we have to monitor equipments whose rated current I_N is much greater, it is necessary to use external current transformers having the ratio $I_N/5$. The user interface offer the possibility to specify the value of the ratio of the external current transformers and takes into account then this value when scaling the axes. For a correct displaying of the values, at the start-up of the application, the user must specify the value of the ratio of the external current transformers (zone 7). The default value of the ratio is 1 (without external transformers).

Then, the displaying type is selected from the buttons within the zone „Vizualizare": instantaneous or synthetics values (zone 2).

If the continuous acquisition is preferred, with the buttons within the zone „Achiziție", the default selection of type „Pachet" that corresponds to one period acquisition (zone 1).

Then, the channels to be acquired and displayed are selected. In the same time, the value of the sampling period is updated automatically, depending on the number of selected channels (zone 3).

Depending on the user's demand, can be displayed on one hand, the instantaneous values of the signals (currents or voltages) on one, two, three or all the six channels, or on the other hand, the synthetic values (RMS values, powers, phases) on a selected phase or on all the three (zone 4).

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 (zone 5).

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 (zone 6).

5. EXPERIMENTAL TESTS

The correctness of the acquisition and processing algorithms that use the acquired values obtained with the experimental micro system is confirmed within the Chapter 5. The results obtain ed with the experimental micro-system are compared with the information found with an industrial measurement equipment, the Fluke 196 power scope, for two types of loads, one pure resistive and other with reactive nature.

The assembly of the experimental results prove the fidelity of the displayed monitored signals and the accuracy of the synthetic values computes based on the samples obtained with the built micro system.

Figure 4 depicts some results obtained with the experimental micro system, for the reactive nature load. For comparing, the captures of the scope screen are plotted in Figure 5, both instantaneous and synthetic values being displayed.

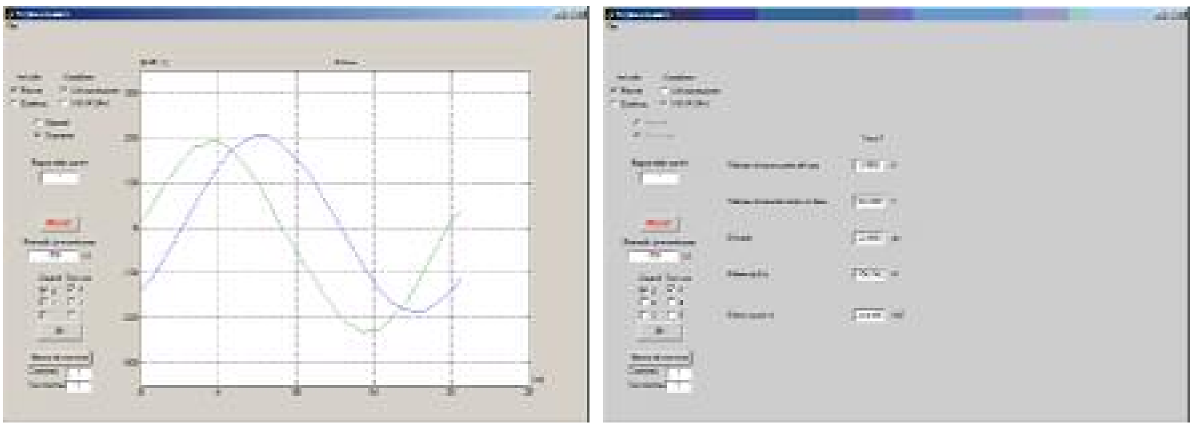


Figure 4 *Results obtained with the experimental micro system*

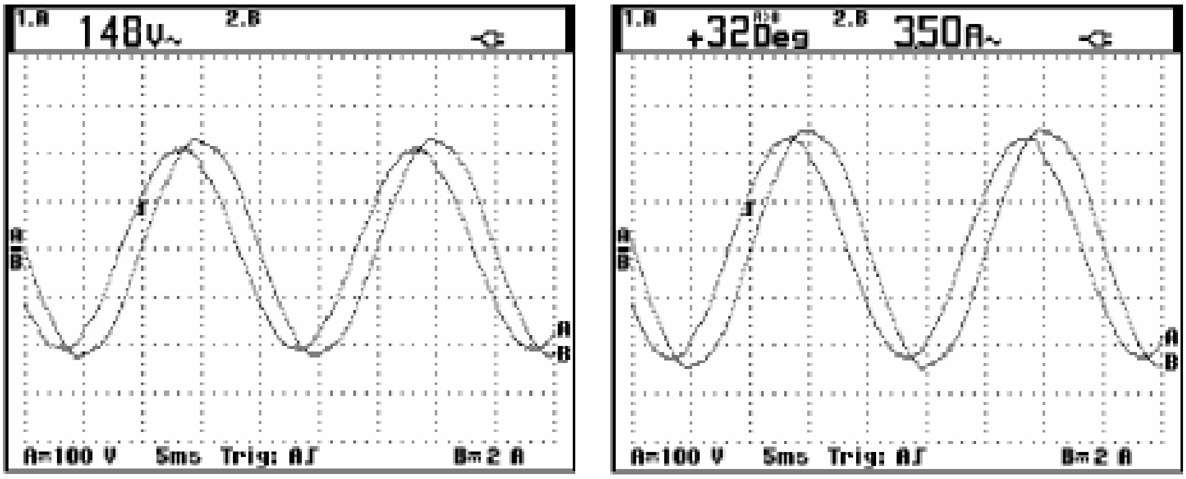


***Figure 5** Experimental results obtained with Fluke 196 power scope*

6. CONCLUSIONS AND CONTRIBUTIONS

The Chapter 6, titled „" highlights that the accomplishments described in the thesis represent a step forward within the studied area. The thesis has brought out a systematic analysis of the monitoring systems for the electric equipments and further presents an experimental micro system, fully conceived, designed and tested by the author, whose main favourable arguments are the versatility, the precision, the friendly user interface and the last but not the least, the attractive price.

Among the original contributions, as most important can be mentioned:

♦ conceiving, manufacturing and testing of an economic and versatile module for acquiring and transferring of sampled data, used for monitoring the six instantaneous values specific to a three phased system and for storing the history of the installation operation;

♦ creation of the operation algorithm for the acquisition and transfer module, pointing out in the same time the opportunity to choose the operation manner, depending on the user's option;

♦ conceiving of the software structure of the acquisition and transfer module, and programming in assembler by using the complex interrupts system of the microcontroller used;

♦ all the software components stand for original attainments of the author, conceived and tested based on algorithms specific to the 8 bits microcontrollers;

♦ conceiving, building and testing the user interface that accomplishes the on-line communication with the acquisition and transfer module, in an ergonomic and easy to use manner;

♦ creation and testing the routines programs for computing the synthetic values (RMS values, powers, phases) of the acquired signals, by using numeric algorithms signalled by the literature;

♦ testing the experimental built micro system for different loads of the monitored equipment;

♦ the comparative evaluation of the experimental results obtained with the built micro system, with the ones furnished by an industrial, performant digital measuring system.

The thesis opens new researching perspectives in the field of technological advancement of the monitoring systems, legitimated by the increasing of them complexity, combined with the necessity of obtaining high efficiency, maximum operation security, without significantly increase the price of the product.

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