50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003, pp.137-141

STRUCTURE AND OPERATION OF THE MICROPROCESSOR ANALYZER OF THE ELECTROMAGNETIC COMPATIBILITY OF ELECTRICAL POWER SYSTEMS

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ABSTRACT

After analyzing the characteristics of the already existing analyzers manufactured by the leading companies on the market, the authors of this paper have designed a microprocessor analyzer of the electromagnetic compatibility (EMC) of electrical power systems, having nonsinusoidal and unbalance regime of the voltage and current.

The structure and functional capabilities of the designed analyzer are presented in this paper, fully revealing the operating conditions, the measured magnitudes, types of visualization, and e.t.c.

The newly designed analyzer will contribute to the practical applying of the standards of EMC of electrical power systems, currently in use in our country.

STATUS OF THE PROBLEM OF CHARACTERISTICS CONTROL OF ELECTROMAGNETIC COMPATIBILITY

The basic electromagnetic compatibility (EMC) characteristics which are defined in (БДС EN 61000-40-7; Шидловский и др. 1977; С.Сидеров *и др.* 2003) are:

- Harmonic ratio of current and voltage components;
- Voltage (Current) total harmonic distortion (THD);
- Normalized THD of inductions and capacitors;
- Form factor;
- Crest factor
- Fundamental factor;
- Voltage psofometric coefficient;
- Unbalance factor;
- Voltage deviation and fluctuation;
- Frequency deviation and fluctuation.

The control and the analysis of these parameters are performing by analyzers of various manufacturers. After comparing these analyzers they can be divided into two groups according to their constructional implementation:

- Autonomous – which are developed as a independent measurement units, containing in them all necessary components for working. Companies such as GOSSEN-METRAWATT GMBH and LEM provide those types analyzers.

- Component – or parts of them are implemented as independent devices with standardized inputs and outputs and they can be configuring whole measurement systems with different facilities. Most often a personal computer is used for data processing, visualization and sometimes for supply. As separate units are offered the following:
  - primary transducers (Signal Conditioning);
  - analog-digital transducer (Data Acquisition device) or card for data gathering. There is big variety both of types which offered (PCI, ISA, PCMCIA card extend of personal and portable computers; external devices connected by USB or parallel port to PC) and in technical characteristics;
  - Drivers and Application Software; for personal computer

  Some of the biggest manufacturers of such devices are the following companies: *National Instruments, Hewlett-Packard, Keithley, Computer Boards,* and e.t.c. Personal Engineering 1998

Comparing their functional abilities and technical characteristics it is obvious that their hardware abilities are almost equally, but the application software of the second group offers various functions of research, control and visualization. Both the groups of analyzers have their practical application. The first type is easily portable and can be used by personal in operation, while the second group is suitable for laboratories and research work.

The necessity for permanent supervision of the parameters of EMC is increased to the introduced European standards and the increasing control of their observance and because of the broad application of devices with nonlinear V-A characteristics in industry, interfering the operation of convectional loads and measurement and controlling systems. Usually the problem of application of specialized systems for parameter evaluating of EMC is their high price. Sometimes it is not very easy to use them in industrial conditions.

Bearing in mind all mentioned above the authors aimed at designing an analyzer, which of the one hand is cheap, suitable for practical application, securing necessary precision for EMC control according the standards currently in use. On

the other hand to give an opportunity of further experiments and research work.

THE STRUCTURE OF THE ANALYZER

The block diagram of the system is shown on *Figure 1*. The basic elements of the system are:

Primary transducers

The primary transducers are essential part of each system of measuring and analysis of electric magnitudes. Often the precision and the capability of the whole device depend of them. The measured analog signal is transformed by the primary transducers to levels suitable for further analog-digital transformations.

There are high requirements to the primary transducers.

- To provide the required precision- amplitude and current mistake in given tolerance and minimum self noise.
- To provide vast enough range of the measured values – the levels of voltage in electrical supply systems are standardized and along with this the maximum voltage deviation is set to rate. It will allow the voltage transducers to be produced for constant level of 380 Veff. In the same time the primary current transducers should provide measurement in vast range of values, as with this the use of current transformers should be limited because their precision is guarantied only for low frequencies.

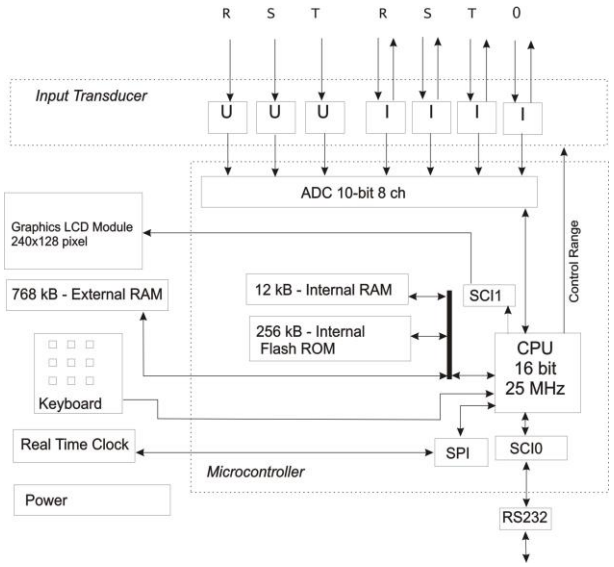

Figure 1. Block diagram of the microprocessor system

- To allow different wiring diagrams – the input transducers should allow measurement of different electrical values in single phase, three phases, DC, symmetrical and asymmetrical electric circuits.
- To provide voltaic diversion between the measurement and the power circuits. That will increase the reliability and the device safety, to give it higher resistance to the inevitable exploitation errors in connecting.
- To be on low price. This condition is often defining in choosing the necessary equipment and scheme design. Dropping down the price would inevitably bring compromise with the other parameters of the system.

Input current transducers: There are three basic methods in current measurement:

- Shunt – basically used for DC (there are shunts for AC with minimum inductance). Their basic faults are their big size and the lack of voltaic diversion between the measurement and the power circuits.

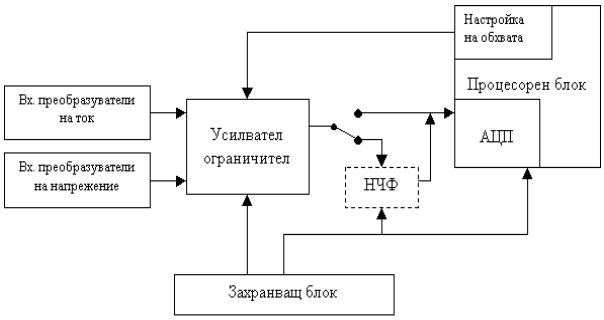

Figure 2. Block diagram primary transducers

- Voltage transformer – the secondary current is proportional to the primary. Usually in digital measurement these transformers work with a small load resistor, which transforms the secondary current to proportional to it voltage. These are the transducers most commonly used for alternating current measurement.
- Devices based on the Hall effect - there are a lot of transducers based on the Hall effect, measuring AC along with DC in very large frequency range.

Most of the manufacturers usually offer the standard transformers and those based on the Hall effect with voltage output 1mV/A, which allows both of them to be used with no change for the rest part of scheme or the algorithm of work.

Input voltage transducers: As a result of the fixed level of the primary voltage cheep active separators are produced. The required precision in certain exploitation conditions could be achieved with high stable resistors. Voltaic diversion is realized with linear optrones use because of providing sufficient precision with drawing down the price.

Amplifier – limiter: Transforms the input signals to levels suitable for ADT of the processor block. The input signal is increased with 2,5V so that the negative half-wave could be transmitted. The amplitude is limited at 5,1V. The precision is increased by the possibility for digital amplification control.

Low-pass filter. The low frequency filter is a-binding part of each system for harmonic analysis. It can be realized like analog, digital or combination of analog and digital and both of the two methods have advantages and disadvantages.
The analog filter limits noise of measured signal before its converting into digital. So it can remove irregular peaks that can't be removed from digital filters. According to highly spread opinion analog filters are suitable for fast systems, where they decrease the signal processing time.

An opportunity for using both types filters is provided.

Microcontroller

The authors looked for following common characteristics by choose of the controller according to the given tasks: good calculate abilities, communicate capabilities (various interfaces); possibility for external addressing according to extended memory; fast enough, multichannel ADC (opportunity for external ADC remain for following development of the analyzer); cheap; enough inputs and outputs with general purpose, often times in electro supply systems performing control function is required and достъпна развойна среда.

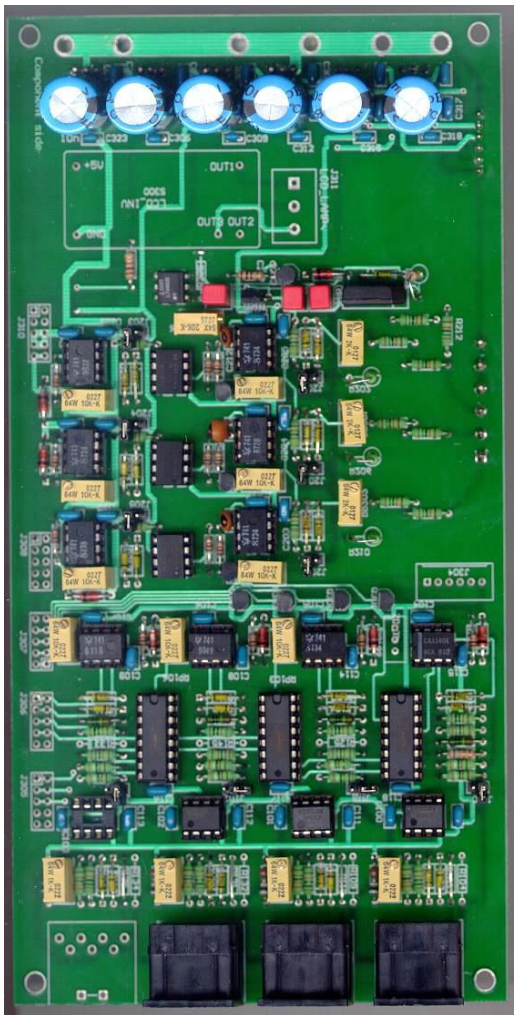

Figure 3. Primary transducers - PCB

These are the reasons why we use 16-bit processor of *Motorola* with the following characteristics:

- 25 MHz bus operations at 5V for 40 nsec minimum instruction cycles time and C optimized architecture produce extremely compact code.
- Dedicated serial debug interface, on-chip breakpoints and read/write memory and registers while running at full speed.
- Integrated 256 K Flash EEPROM. Programming, reading and erasing with 5V trough debug interface.
- Two 8-channel A/D transducers 7 μsec, 10-bit single conversion time and scan mode available.
- 8-channel 16-bit with input capture, output compare and pulse accumulator 16-bit modulus down counter.
- 8-bit or 16-bit pulse-wide modulation.
- Asynchronous communication between the MCU and a terminal, computer or a network of microcontrollers (SCI)
- High-speed synchronous communication between multiple MCUs or between MCU and serial peripherals (SPI).
- Inter IC bus (I2C).
- Modules implementing the CAN 2.0 (Controller Area Network) A/B protocol.

We don't use all the capabilities of the single chip computer, because they are not necessary for our tasks and the other will be used in the future development of the system. The first serial communicational interface (SCI0) is used for connection with graphic LCD for control of the visualization. The second (SCI1) is used for connection of the analyzer with PC by RS232. This allows controlling the analyzer by the PC; transfer all the data from analyzer to PC for storing, processing and analysis. The serial peripheral interface (SPI0) is used for communication with real clock timer (RTC) build into analyzer. One of the inputs of the timer module is used for measuring of the voltage frequency.

Memory

This passage concerns both Random access memory RAM for variables and data used in the programs, and the memory for the program codes (ROM) Solving such problems usually engages a good deal of memory because a lot of data is being processed and stored. As the controller memory is insufficient in this case external RAM is added.

Keyboard

It is used for choosing and setting-up of different operation modes of the measuring system, for controlling of visualization of results, for input of parameters and e.t.c.

Module for visualization

It consists of graphic LCD with resolution 240/128 and controllers.

Supply unit and battery

They provide for all necessary supply voltages of the separate system elements and allow saving of operation memory content when there isn't external supply (for example when transporting measuring device).

Communication unit (RS232)

It is used for connection with PC, which allows us to foresee opportunities for additional processing of measured data by our software, for preparation of data for using by other standard analysis application, for control of the measuring process and more detail various visualization of results.

Real time clock (RTC)

It is used to register date and time of each measurement and control the implementation of set in advance operations by analyzer according to defined timetable.

Functional abilities and operation modes

On the basis of measured voltages and currents the analyzer calculate the active, reactive and apparent power, energies and other magnitudes connected with qualitative and quantitative parameters of electric power. When the voltage values are less than 400 V, connecting to the voltage inputs of

the device are direct while to the current inputs - by ampere clamps. Additional options such as digital outputs and PC interface are also provided.

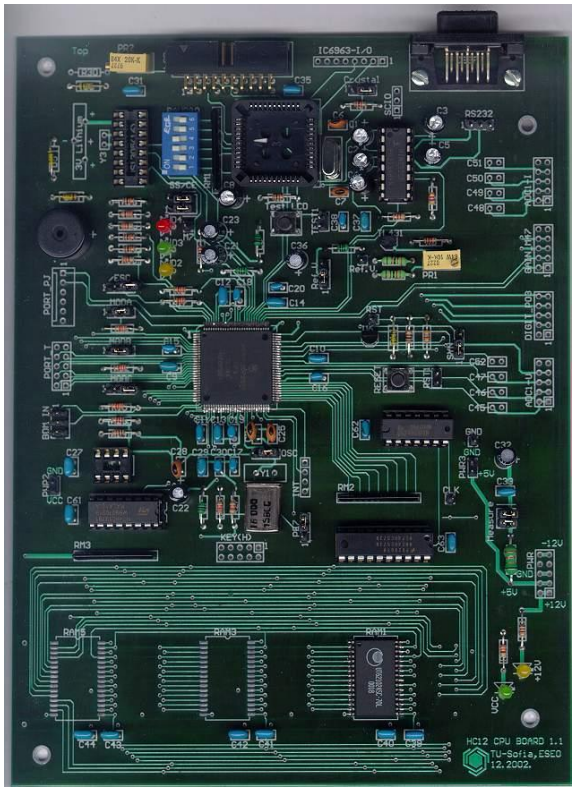

Figure 4. Microprocessor system - PCB

Operation modes and measured magnitudes: The analyzer has several operation modes, which are chosen by the user. The following modes and options are offered:

- *Measurement* – under this mode on the basis of the measured values of voltage and current the following basic electric magnitudes of each phase are calculated:
  - Effective value of voltage - Urms and current - Irms;
  - Maximum values of voltage - U_m and current - I_m;
  - Active power – P;
  - Reactive power – Q;
  - Apparent power – S;
  - Power factor;
  - Frequency of voltage – f_1 (phase 1);
  - Deviation of voltage frequency;
  - Deviation of voltage.

- *Harmonic analysis* – under this mode on the basis of Fast Fourier Transform (FFT) harmonic analyses of voltage and current is carried out up to 50 th harmonic. The following values of each phase and each harmonic can be visualized:
-
  - R.m.s. values of voltage and current for each harmonic in named and relative units (harmonic coefficient);
  - Initial phases of harmonics;
  - Voltage and current THD;
  - Form factor;
  - Fundamental factor;
  - Active, reactive, apparent and deformation powers;

  Information can be shown in tables or charts.

- *Transient processes* – on the basis of the discrete values of voltage and current for given time interval fluctuation of voltage and peak value of the current is calculated. The curves of voltage and current are visualized by phases. There are three possibilities to start of the measuring – manually (from button in the front panel) or automatically in preliminary adjusted time.

- *Statistics* – under this mode for given time interval the measured magnitudes are stored into the memory or sent to PC (see measuring mode). After that some statistic parameters of stored information are calculated.

- *Energy* – under this mode the analyzer operates like electric meter. It calculates active and reactive power. There is a possibility to adjusts time zones according to prices of energy, to input the prices currently in use and to calculate and visualize the amount due. The visualization includes displaying of active and reactive power by phases and as a whole in tables or load timetable.

- *Compensation of reactive loads* – on the basis of measured magnitudes calculation of necessary capacitor banks for specific nodes of electro supplying system is provided for.

- *Unbalance* - under this mode the characteristics connected with unbalance in three - phase systems are analyzed and calculate.

- *Test and Set-Up* – this option is for testing and setting up of some characteristics and functions of the analyzer like:
  - Transformation coefficients of power and current transformers (if there are any connected);
  - Calibration of primary transducers;
  - Setting of real time clock;
  - Setting and testing of communication with PC;
  - Determination of sequence of phase connection. It includes vector diagram visualization on the display.

Figure 5. Common view of Analyzer

It is important to be marked out that because of complexity and variety of the solved theoretical ant practical problems we have to elaborate many of the set tasks and algorithms. This will make our system very useful for both practical application

and for continuation and extension of research in the field of electromagnetic compatibility in electric power systems.

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Recommended for publication by Department of Electrical Engineering, Faculty of Mining Electromechanics