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Flexibility Equipment of Protection, Control and Measure for Mean and Low Electrical Network in Power Transformation Substations

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Introduction

Classical electromechanical single function relays are used to protect mean and low voltage network and devices against phase to phase, phase-to-ground faults. Other single function relays are used to achieve the auto-reclosing function and several apparatuses to measure voltage, current and active/reactive power. Digital equipment provides an economically alternative for protection, control and measure functions. Additionally, digital technology provides some other advantages that include: improved performance, greater flexibility, reduced wiring, metering of various parameters, disturbance recording, remote communication and automatic self-testing [2].

Developing a multiprocessor structure both hardware and software functions are divided in several blocks, easy to test and offering a high speed processing. Since Digital Signal Processors (DSP) are especially designed for signal processing applications the multiprocessor structure of EPCM includes it. For logic task, serial communication task, user interface microprocessor is used. Additionally, EPCM structure provides microcontroller for frequency supervision and auto-reclosing conditions checking.

Flexibility Protection Functions

To design the equipment the following flexibility protection functions were taken into account, [2]:

- Directional or non-directional over-current flexibility protection instantaneous or definite time characteristic against phase to phase faults;
- Directional or non-directional zero-sequence over-current flexibility protection with definite time or inverse time characteristic against phase to earth faults;
- Negative-sequence over-current flexibility protection with definite time characteristic against phase unbalanced or double phase faults (isolated neutral networks or networks grounded via arc suppression coil);
- Over-current protection with definite time or inverse time characteristic;
- Over/under-voltage protection with definite time characteristics.

Control functions

The following control functions were taken into account:

- Auto-Re-Closing (ARC) function – to restore dead lines or hot lines from hot bus
  - ⇨ two programmable shots;
  - ⇨ internal /external / re-closing initiation signal lines;
  - ⇨ programmable checking of auto-re-closing conditions
- Fault Recorder Function – economically provides valuable engineering information eliminating the need for disturbance recorders:
- Circuit Breaker Failure protection for enhanced substation operational flexibility and reliability;
- Circuit Breaker Monitoring to indicate when circuit breaker maintenance is needed.

Metering

- Measure and display the RMS primary current on each three phase;
- Measure and display the three line-to-line RMS primary voltages;
- Calculate and display of primary complex power, active & reactive power as well as power factor.

Main – Machine Interface

To ensure a friendly man-machine interface the equipment was designed with:

- A two line by 16-characters Liquid Cristal Display (LCD), Fig. 1.
- Local keyboard,
- Serial interface for local or remote communication and connection to SCADA system.

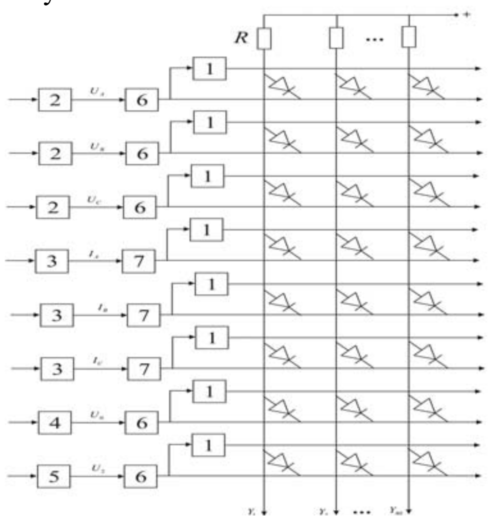

Fig. 1. LCD scheme from realization algorithm diagnostic of faults in electrical network

Self – Checking Functions

The most important self-checking functions included in the equipment are the following:

- Watch dog timer reset;
- Internal RAM check;
- Check sum verification of EPROM;
- DSP to main processor communication failure check;

To achieve the above functions, various parameters of voltage and current signals are estimated using digital signal processing algorithms, Fig.2.

Measurement of three-phase alternating quantities is performed according to following projected scheme that contains 6 (or 8) analogue quantities, processing part for calculation of algorithm on expressions (16) and (17), end medium for result presentation, according to Fig.2. Signal converter is used for amplitude adjustment of signal measuring in the range of A/D convertor. It is composed of measuring transformer of current and (voltage) passive divisor or is composed of linear amplifier, in which way the galvanic detachment of potentially very sensitive microprocessor composition from measuring signal was accomplished.

Law tension filter diminishes amplitudes of higher harmonics (above $1\,kHz$) and it that way reduces error occurred due to spectra overlapping as the result of final frequency of tact (1, 6 kHz).

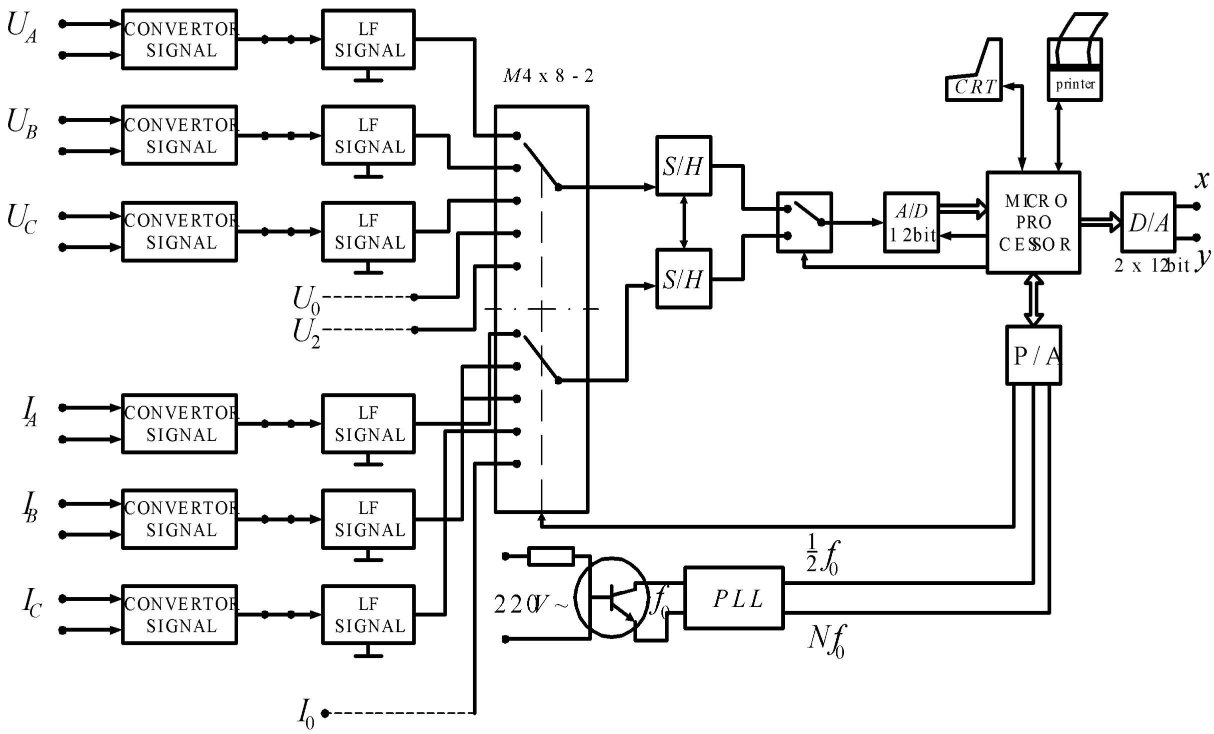

Fig. 2. Presentation of a structure for digitalization and recording of digital results in microprocessor memory

The choice, which one out of four pair signals is ready for digitization, is made by program filled analogue finder (*MAX* 8 – 2). This way enables simultaneous digitalization of chosen digital pair (voltage and current of same phase) with two connections for digitalization and recording (S/H). Second analogue finder-multiplexer (*MUX* 2 – 1) connects to A/D converter, one signal at the time, if A/D is still closed. Converting time of chosen 12 bits A/D converter (for example $AD\,574\,A$) is about 25 μS , and analogue range is within $\pm 10V$. If we take into account finder delay due to transmission time to microprocessor memory, it is possible again to establish digitalization of one signal during the interval 625 μS , if quantization 32 $(1/sec)$ is performed. PLC has the role of frequency range multiplier.

Master Processor type 80386 EB, 16 MHz. Processing the Boolean variable received from the DSP and from the slave microcontroller through the 16 bit buffers;

- There are several algorithms such as: **flexibility protection functions algorithm,** auto-re-closing algorithm, breaker failure flexibility protection algorithm etc.
- Initiate tripping signals as well as alarm. These signals are passed trough 8 bit ports to output relays. Microcomputer has 8 – bit microprocessor (6800) with arithmetic process unit (9511) that performs numerical operations on 32 bit numbers. Memory (*RAM*, *EPROM*) serves for recording of variable values and programs for calculation of algorithms. Interaction with comparator and data recording are executed on terminal, printer and analog output (registration on oscilloscope or diagram reading) and on LED or distributive electric network is made by serial asynchronous channel $(RS\,232C)$ *DISPLAY*. Communication with central computer in dispatcher centre of transmission or distributive electric network is made by serial asynchronous channel $(RS\,232C)$.

Digital Signal Processing

The block diagram for digital signal processing consist of:

- LPF-anti-aliasing Low Pass Filter, for example digital filter obtaining inverse components, Fig. 3.
- S&H – sample and hold circuit,
- ADC – analog to digital converter,
- DSP – digital signal processor.

Using a simpling frequency of 1000 Hz (20 samples/ cycle) is possible to achieve:

- Digital filtering to reject high order harmonics;
- An accourate RMS value of current and voltage
- An useful fault recorder function.

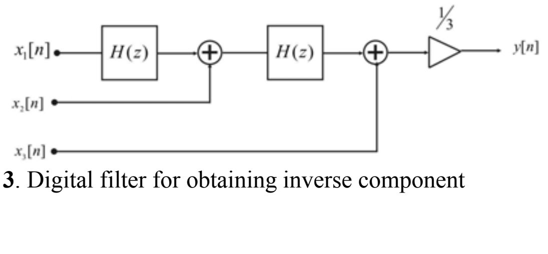

Fig. 3. Digital filter for obtaining inverse component

RMS Value of Current and Voltage

Let us consider a periodic signal y(t) with a period of 2π radians , y(t) = Y sin (wt + φ). The RMS value in discrete form is definited by (1):

$$Y_{RMS\_K} = \sqrt{\frac{1}{N}\sum_{r=0}^{N-1} {y_{k-r}}^2}\ , \qquad (1)$$

where N – 20 samles/cycle; y_k – instantaneuos values of current or voltage. Using the discrete Fourier Transform (DFT) of RMS (Root Mean Square) value in discret form are the following

$$Y_{r-k} = \frac{2}{N}\sum_{r=0}^{N-1} y_{k-r} \cos\frac{2\pi r}{N}, \qquad (2)$$

$$Y_{i-k} = \frac{2}{N}\sum_{r=0}^{N-1} y_{k-r} \sin\frac{2\pi r}{N}. \qquad (3)$$

Phase Angle of the Fundamental Frequency Component

To estimate the phase angle of the fundamental frequency component the same DFT method was used

$$\tan(\varphi) = Y_i / Y_r. \qquad (4)$$

Thus the complex phase-or is:

$$\underline{Y} = Y_r + j\,Y_i. \qquad (5)$$

Positive, Negative and Zero Phase Sequence Components

In case of fault (short-circuit, phase to ground fault, Fig. 4.) the three phase system is no longer a balanced one. Any unbalanced three phase system can be resolved into three balanced three phase systems, the first of which is of positive-phase sequence, the second of negative phase sequence and the zero-phase sequence. These symmetrical components are calculated as follows (for example for current), [1], Fig. 5.

$$\begin{cases} I_1 = (1/3)\,(I_A + a\,I_B + a^2\,I_C),\ F = I, \\ I_2 = (1/3)\,(I_A + a^2\,I_B + a\,I_C),\ a = e^{\,j2\pi/3}, \\ I_0 = (1/3)\,(I_A + I_B + I_C), \end{cases} \qquad (6)$$

where I_A, I_B, I_C, – are computing using (5).

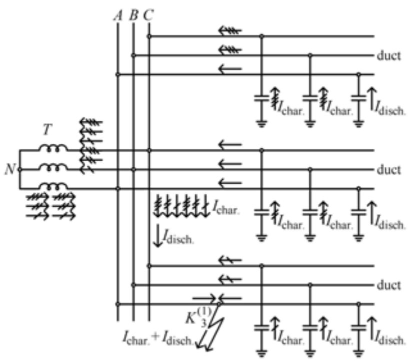

Fig. 4. Electrical network scheme in mono – phase earth fault

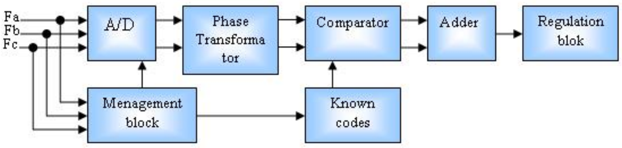

Fig. 5. Block diagram of the system for measurement of symmetrical components

Active - Real and Reactive power

A method to calculate real and reactive power is to use complex phase-ors of voltage and current obtained by (5) and firsts calculate the complex power [1]

$$\underline{S} = P + j\,Q = \underline{V}_A\,\underline{I}_A^* + \underline{V}_B\,\underline{I}_B^* + \underline{V}_C\,\underline{I}_C^* \qquad (7)$$

and separate the real part and the imaginary part of $\underline{S}$. The total power in a three phase system is the sum of the individual power in each phase. The power factor (PF) is computed as fallows [1]

$$PF = P / V\ P^2 + Q^2. \qquad (8)$$

The Hardware Development of EPCM

The block diagram of estimation and detection of the signal from earth short circuits it is shown Fig. 6. The block diagram of EPCM is shown in Figure 7.

The voltage and current signals, real phase and symmetrical components are isolated and scaled using voltage transformers (VTs, Fig. 7, block 2,4,5) and current transformers (CTs, Fig. 7, block 3.). These transformers are based on the principle of magnetic field compensation or zero-magnetic flux method (feedback system) offering a wide rang of measurement, high overload capability [7], good dynamic performances, good sensitivity and response time batter than 1μs, (di/dt) correctly followed over 50A/μs.

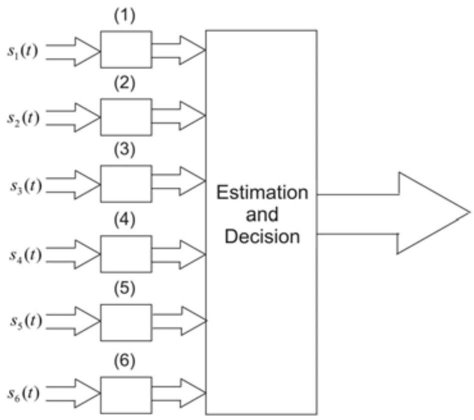

Fig. 6. Block diagram of estimation and detection of the signals from earth short circuits.

The analog signals are then passed through a low pass filter (Figure 7. block 6.) to prevent `Alias` phenomena. The filtered analog signals are then multiplexed by using of analog multiplexer and passed of the analog to digital converter (DC). The digital bit pattern output from the DC is then passed to the Digital Signal Processor (DSP).

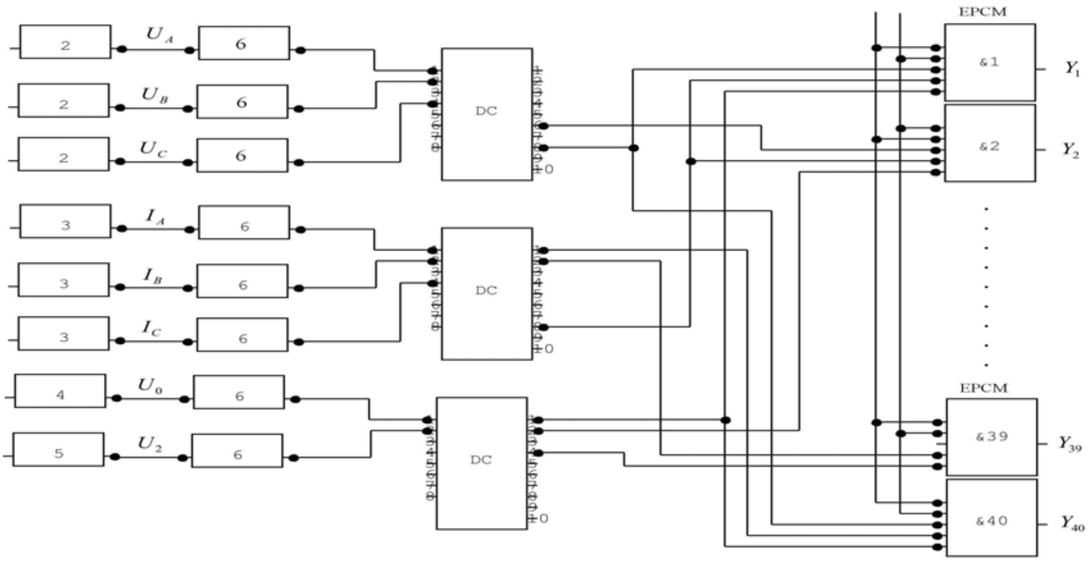

Fig. 7. Realization with using digital signal processing algorithms and equipment EPCM

The Software Development of EPCM

This section presents in brief the most important algorithm used for filtering an flexibility protection functions. Digital Filtering algorithm are based one the discrete Fourier transform and on the general method for designing a FIR filter as shown in [6]. Applying this algorithm for a 1000Hz sampling frequency, figure 8 presents the frequency response of the filter and an example of a voltage filtering where: x_k = input value (before filtering), y_k = output value (output filtered voltage. Similar to above presented algorithm the frequency response characteristics are obtained for a third and fifth harmonics.

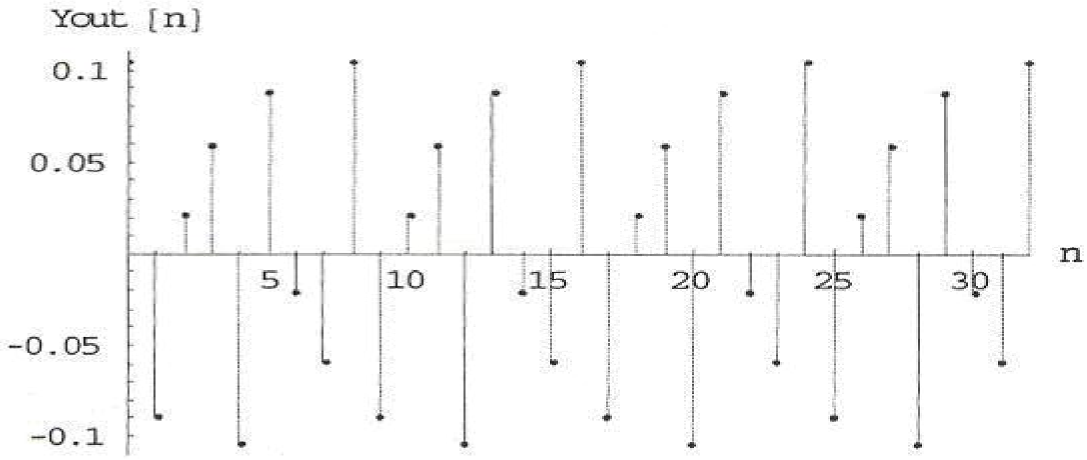

Fig. 8. Output signal with 3. harmonics

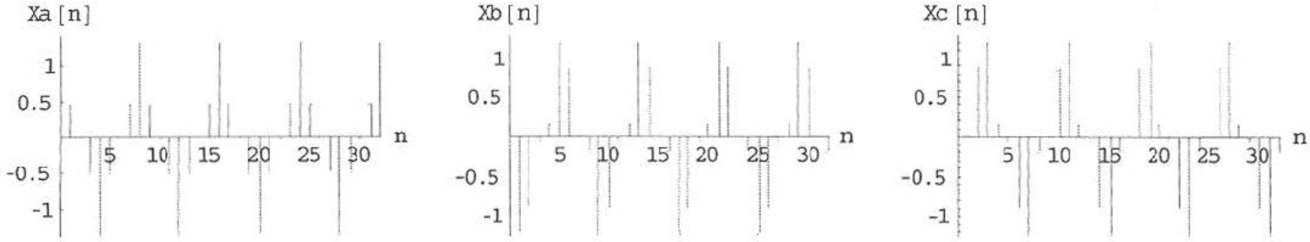

Fig. 9. Forms input signal in sistem acquisition

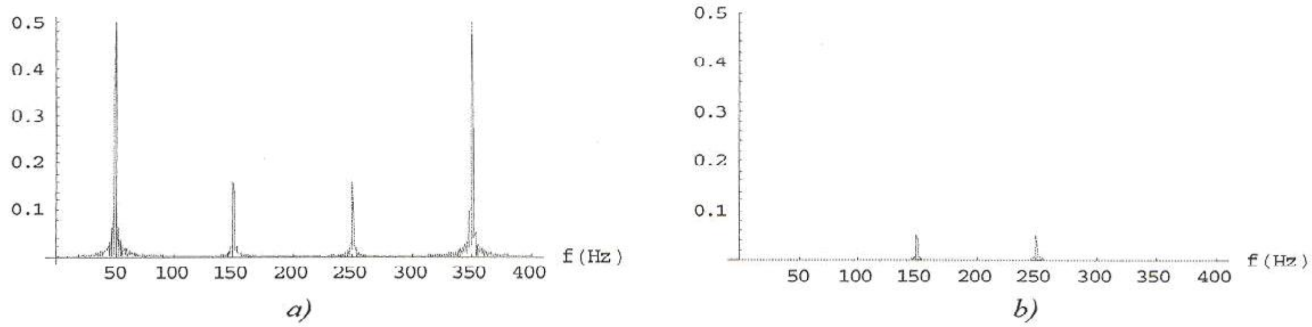

Fig. 10. Spectar input (a) and output signals (b) in normal work, with out faults

Conclusions

The presentation tried to explain the way in which an integrated equipment for protection, control measure and communication for mean and low voltage networks is to be realized using a hardware based on multiprocessor techniques and several algorithm to obtain the desired functions. Including three-phase over-current flexibility protection directional on non-directional with definite or inverse characteristics, ground directional over-current protection with definite or inverse time characteristics, auto-re-closing function and metering, the equipment is adequate to protect mean and low voltage feeders and other apparatus. Further testing of the equipment, including real conditions, is to be done to confirm or not the correct design of EPCM.

References

1. **Bjelić S.** Uvod u srednjenaponske mreže i niskonaponske instalacije, SVEN Niš. – 2007. ISBN 978-909183-7, Cobiss SR-ID 134502668
2. **Popovic G.** ,The Felexibility of protection equipment for communication, informatic and monitoring systems in objects. Work version of masters tese, Faculty of technical science, Kosovska Mitrovica. – 2008.
3. **Popovic G., Bjelic S.** One Solution For Protection Of Telecomunication Device Electric Power Supply System // TELFOR Internationale Conference, Belgrade. – 2008.
4. **Mladenovic V., Nilsen C.** System control and monitoring using human machine interface // IEEE COM SOC Chapter Serbia & Montenegro, Belgrade, Serbia&Montenegro, PU#1. 5. – 2005.
5. **Mladenovic V., Bjelic S.** Measuring of nonsymmetrical components in power energy networks // The IASTED International Conference on Power, Energy, and Applications PEA(2006), September 11-13, 2006, Gaborone, Botswana, ID#506-047.
6. **Bjelic S., Mladenovic V.** Algorithm of measurment – information system to make diagnosis faults in electrical networks, 14th Telecommunications forum, TELFOR 2006., IEEE COM SOC Chapter Serbia & Montenegro, Belgrade, Serbia 21, 22 and 23. November 2006 (in Serbian), PEL#7.6

7. **Bjelic S., Popovic G.** Protection and control devices in TELECOM Kosovska Mitrovica, PES 2007, 3-5 September, Nis, EM circuits&systems, pes2007@elfak.ni.ac.yu Proceedings of extended abstract, 08. EM ciruits&systems 08-05. – P. 143–145.
8. **Bjelić S., Mladenović V.** Algorithms and Possible Methods of Emergency Control Electrical Network, RS2.3. Session 2: Applications of NNs 2: Power Control, NEUREL Belgrade. – 2008.
9. **Bjelic S., Markovic N., Jaksic U.** Multi-sliced-level type phase-comparison carrier relaying system for multiter-minal lines, TELFOR Internationale Conference, November 2008, Belgrade.

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A digital devices designed to achieve protective functions as control and measure function for low electrical network and devices is described in the paper. The equipment includes protection functions for isolated neutral networks or networks grounded via a resistor or via an arc suppression coil as well as control and measurement functions. The device takes advantage of digital signal processing and multiprocessor techniques to obtain improved performance. In addition to improved performance, the equipment also provides self-checking functions, a user friendly man-machine communication and serial interfaces for to SCADA systems. Ill. 10, bibl. 9 (in English; summaries in English, Russian and Lithuanian).

С. Бјелич, Г. Попович. Гибкость оборудования защиты, контроля и оценки работы сетей среднего и низкого электрического напряжения // Электроника и электротехника. – Каунас: Технология, 2009. – № 4(92). – С. 27–32.

Описаны цифровые устройства, предназначенные для обеспечения защиты контроля и измерения состояний электрических сетей и устройств среднего и низкого напряжения. Оборудование включает в себя функции защиты сетей изолированной нейтралью или сетей, заземленных через резистор или дуговые катушки погашения, а также функции контроля и измерения. Устройство использует цифровую обработку сигналов и многопроцессорные технологии, обеспечивающие получение повышенной производительности. В дополнение к повышению производительности оборудования, также имеются возможности самостоятельной проверки функций, человеко-машинного общения и применения серийных интерфейсов для систем SCADA. Ил. 10, библ. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

S. Bjelić, G. Popović. Žemos įtampos elektros tinklų galios pastočių įrangos apsaugos, kontrolės ir matavimo lankstumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 4(92). – P. 27–32.

Išanalizuoti skaitmeniniai įtaisai, skirti apsaugos funkcijoms, kaip kontrolės ir matavimo funkcijoms žemos įtampos elektros tinkluose ir įrenginiuose, užtikrinti. Įranga atlieka izoliuotų neįžemintų tinklų ar tinklų, įžemintų per rezistorių arba per lankines slopinimo rites, apsaugos kontrolės ir matavimo funkcijas. Produktyvumui didinti taikomos skaitmeninio signalo apdorojimo ir multi-procesoriaus technologijos. Be to, siekiant padidinti įrangos produktyvumą, atliekamos savidiagnostikos funkcijos, diegiami vartotojiški žmogaus ir mašinos ryšiai ir SCADA sistemų sąsajos. Il. 10, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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