Systems for Monitoring Modes and Disturbances in High-Voltage Transmission Lines

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Abstract: **The article is devoted to the important practical task of using computerized systems of monitoring and control objects of electric power engineering, in which arise problems associated with the effectively identify abnormal situations in high-voltage electrical networks..The effectiveness of applying computerized monitoring systems to control electric power objects is substantiated. The structures and components of control and diagnostics systems for monitoring modes, recognition and authentication of disturbances in high-voltage transmission lines of 6-35 kV are studied. The "Strila" and "Altra's" functions are systematized as the network components of automated remote monitoring and controlling the technological equipment of electric substations. A sequence of operations for the recognition and authentication of load surge, earth fault and starting up powerful electric motors in high-voltage transmission lines is formalized. A structure and components of a microelectronic special-purpose processor protection relay of high-voltage transmission lines are presented.**

Keywords: **high-voltage transmission line, relay protection, disturbance, information monitoring systems, special-purpose processors.**

I. Introduction

One of the main tasks of electricity supply is the maintenance of equipment in an operational condition. Therefore, using new methods for diagnosing the technical condition using specialized microcontrollers and special processors with a high level of digital signal processing is one of the most actual tasks..The successful development of microprocessor and microelectronic technology has created favorable conditions for the development and large-scale replication of automated monitoring distributed computer systems (DCS) to monitor and control distant technological facilities in various industries. The examples of the succesful application of the SCADA systems of this class are the developments made by famous foreign firms and domestic enterprises, for example, Oven, Elektrosvit, Schneider, etc. [1-4]. The DCSs [5-6] designed and developed by Ternopil design bureau (TDB) "Strila" and the Institute of microprocessor control systems of electric power objects (IMCSPEO, Lviv) are being effectively introduced into the electric-power industry. These information systems are multifunctional, and embrace a wide spectrum of functions: monitoring, authentication of and controlling the equipment of 6-35-kV electric substations.

The important condition for permanent expansion of the functional capabilities, improvement of the system characteristics, and perfection of the components is their being equiped with specialized microcontrollers and special-purpose digital signal processors. First of all, it concerns the recognition and authentication of disturbances in high-voltage transmission lines in case of load surge, short-term cable fault, earth fault and starting up powerful electric motors, for example, in the oil and gas industry. The theoretic base of the algorithms for digital signal processing of phase currents and voltages in case of transients and transmission line disturbances in is formed by the image recognition methods, as well as by the statistical, correlational, spectral, and entropy analysis.

II. Automated Remote-Control System (ARCS) "Strila"

The ARCS developed by the TDB "Strila" [5] is designed for remote control, collection of telesignallization and telemetering parameters at 6-35-kV electric substations.

A control point (CP) of the "Strila" telemetry executes previous signal processing of phase voltages and currents, archive registration of digital data, and transmission of coded messages to a distant dispatching point (DP) of the district electric grid (DEG). In addition, the CP receives and executes the commands remotely passed from the DP.

The basic structure of the operative-information complex "Strila", which belongs to the class of the SCADA systems, consists of two remote modules, which are installed at the substation of 35/10 kV, and a server hosted in the offices of dispatching services of DEG and Oblenergo.

The structure of the control point at the 35/10 kV substation is shown in Fig. 1.

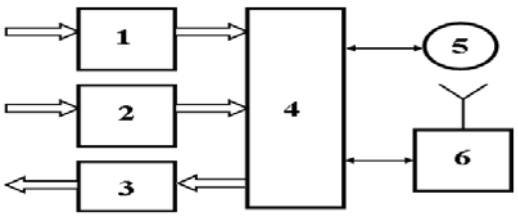

Fig. 1. Structure of CP : *1 - telesignallization module; 2 – telemonitoring module; 3 - telecontrol module; 4 - processor (microcontroller); 5 – operator's keyboard; 6 - radiomodem*

The CP has the following information characteristics:

512 (32x16) discrete inputs (TS);

256 (16x16) analogue inputs (TV);

128 (16x8) control objects (TU);

RS-485 – master interface up to 2000 M;

MEK 870-5-101 – protocol of a code interaction between CP and DP.

While operating, the CP performs a component diagnostics and transmits information to DP. The structure of the "Strila" server equipment at DEG is shown in Fig. 2.

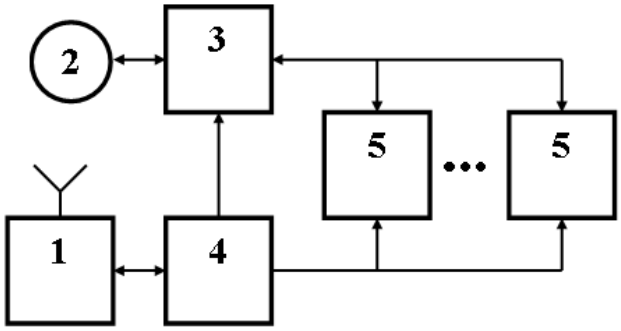

Fig. 2. Structure of server equipment "Strila" *at DEG: 1 - radiomodem; 2 - monitor of dispatch operator; 3 - safety system server; 4 - router; 5 - personal computers*

The DP's server hardware of the complex "Strila" that is located at DEG executes:

3G CDMA EV-DO – safety system software;

IEC 60870-5-101 – computer network protocols;

IEC 60870-5-104 – integration with server equipment of the top-level electricity company CRM "UDS Consulting" (Call-centre) with a direct transfer of information on the position of energy facility switches.

The server system of DEG executes:

- graphic representation of tables of current, voltage and power of connections at the controlled electric substations;

- registration of system events (telecontrol, queries, program states, channel diagnostics, etc.);

- controlling the mimic diagram board, indexation of switch position and alarm system.

The described structure and functionality of the system "Strila" indicate that its level of microelectronic equipment and software meets the world's existing problem-oriented information systems of the SCADA class that are produced by leading foreign firms in the field of electricity.

At the same time, the classic reflection of the states of technological equipment at electric substations in the form of time trends, and tabular representation of digital data on the controlled parameters and processes greatly complicate the interaction of system operators, significantly reduce the speed and effectiveness of their responses to abnormalities of the states of technological facilities both before and at emergency. In addition, the system "Strila", as well as other systems of this class, is not intended to and does not carry out a deep statistical, correlational, spectral and entropy processing of telemetering signals with the possibility of recognition and authentication of disturbances in high-voltage transmission lines at invariant values of phase currents and voltages. For example, in case of load surge and start-up of powerful electric drives, starting phase currents can considerably exceed those of earth-faults at a considerable distance from the substation's switching equipment with certain adjustments of relay protection facilities.

Such functions may be implemented successfully by specialized microelectronic processors on PLIS or by expansion of the problem orientation of application software of the computers embedded in such systems. In addition, the high performance of the special-purpose processors accelerating the signal processing by 1-2 orders of magnitude in comparison with the universal ones used in multifunctional microcontrollers allows the industrial equipment of power systems to be effectively and reliably secured on the intervals of 1-2 periods of industrial frequencies.

III. Control and Diagnostics System "Altra-Mini-Altra"

The system "Altra" developed by IMCSPEO [6] carries out local and distance monitoring of the insulation state of a 6-35 kV electric grid of arbitrary configuration with an insulated or compensated neutral. It performs a continuous real-time monitoring of the state of connections isolation at an electric substation, detection of a damaged area and its localization.

The system "Altra" performs the following functions:

- registration of partial insulation failure of arbitrary duration that provides the insulation state diagnostics of network segments;

- detection of an electric network segment with thinned insulation, remote transfer of information on its mode coordinates to the dispatching point;

- bay disconnection by single- phase earth fault protection, ensuring the appropriate selectivity depending on its kind, duration, category of consumers, features of insulants;

- displaying a network map on the monitor of the dispatching point, authentication of a thinned insulation segment;

- remote control of the substations' switching facilities by using the switchgears equipped with appropriate drives.

The system "Altra-Mini-Altra" is built on the multilevel principle where "Altra" and "Mini-Altra" are the basic blocks. "Altra" is installed at the substations and distribution points of 6-35 kV for the purpose of detection and registration of monophase earth faults. The device is designed for servicing up to 12 connections; the chart of its connections is shown in Fig.3.

Information for the "Altra" device is the phase voltages ua, ub, uc and the value of the voltage of the zero sequence of 3u0, which are obtained from the sectional voltage transformer, as well as currents of zero sequence, which are obtained from current transformers of zero sequence of connections. Overall dimensions of the device are 40x30x22 cm. The device "Altra" can be installed on the facades of standard panels, as well as on its free parts or directly on the walls of the substation building or at the distribution substations. If necessary, to have information about the

position of the switching devices, the device "Altra" is supplemented by a block of control the state of discrete signals.

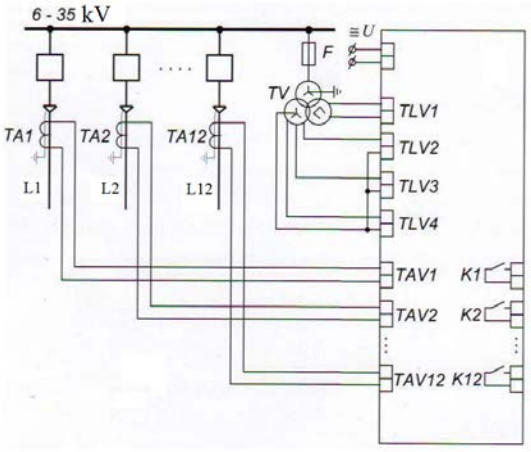

Fig. 3. Chart of connections and the "Altra" linking-up: *TA – current transformer; TV – voltage transformer; L1 – L12 – connection lines; F – base fuse; K1 – K12 – switching facility*

The block diagram of the "Altra" concentrator is shown in Fig. 4.

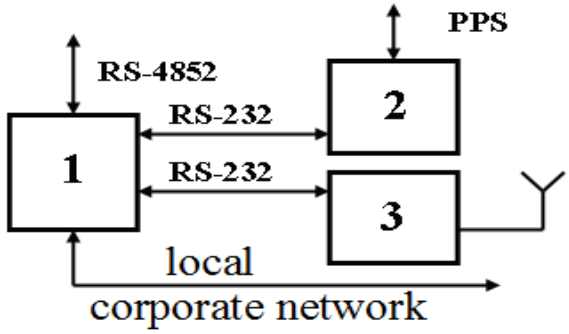

Fig. 4. Block diagram of the concentrator of the system "Altra": *1 – embedded computer; 2 – synchronization marks reciver; 3 – GSM-modem*

"Altra" responds to the earthing of a connection phase. At any duration of the phase earthing, the date and time of the event when an insulation breakdown, and effective current of zero-phase sequence are detected can be seen on the "Altra's" display. Digital graphs of all mode coordinates are recorded in the power independent memory. The position of switching equipment is monitored by a block intended for monitoring the state of discrete signals. For the selective detection of a network segment with thinned insulation, the substations without voltage control are equipped with "Mini-Altra" devices (Fig. 5).

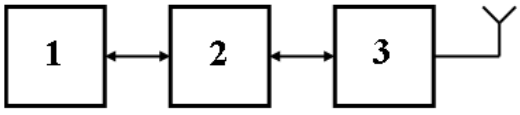

Fig. 5. Block diagram "Mini-Altra": *1 – processor; 2 – switching module; 3 – GSM-modem*

This device controls the current of a zero sequence of substation connections (8 connections). The detection of a thinned insolation segment of the network with partly voltage control at separate substations takes place on the basis of information received both from "Altra" and "Mini-Altra". Therefore, these devices are provided with 1 ms timing according to GPS–technology.

The data collection functions are performed by the concentrator based on the embedded computer.

The block diagram of data collection executed by the information system "Altra" is shown in Fig. 6.

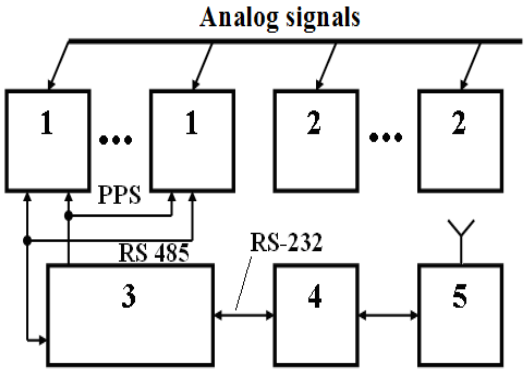

Fig. 6. Block diagram of data collection on the basis of the concentrator: *1 – Altra; 2 – Mini-Altra; 3 – concentrator; 4 – operator's workstation; 5 – GSM-modem*

The improvement of the "Altra's" software and hardware, and the expansion of its functional capabilities is realized by reequipping the system with special-purpose processor protection relay of high-voltage transmission lines, whose structure is shown in Fig. 7 [6-9]. This is done on the basis of theoretical and experimental studies of transient processes in the transmission lines in case of charges and short circuits.

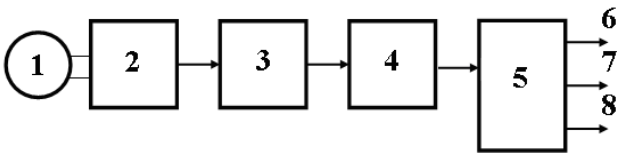

Fig. 7. Block diagram of a special-purpose processor device of relay protection: *1 - current transformer; 2 – two half period rectifier; 3 - analogue-to-digital converter; 4 – digital correlator; 5 – squarer; 6, 7, 8 - load surge signals, earth fault and starting up a powerful electric motor, respectively*

The basis of the structural solution of this device is the task of improving the protection relay of high-voltage transmission lines by introducing a current rectifier, an analogue-to-digital converter, a logic element "Excluding OR", and a shift register. This makes it possible to recognize charges and short circuits in the transmission line, regardless of the absolute values of current growth in one of the phases.

The main advantages of the proposed relay protection device for high-voltage transmission lines are: advanced functionality; high speed recognition of charges and short circuits at intervals of one - two periods of industrial frequency; simplified algorithm of microelectronic implementation of the device; possibility of realization on a FPGA crystal; reduced cost of the device and the possibility of mass replication and implementation at high-voltage

substations; increased reliability and ability to work in a wide range of temperatures.

The device operation based on the method of integral-difference processing of phase currents in case of disturbances in high-voltage transmission lines developed by IMCSPEF in collaboration with the Department of specialized computer systems of Ternopil National Economic University [8,10].

Figure 8 shows an example of a change in the characteristics of digital graphs of a phase current at load surge (1), earth-faults (2) and starting up powerful electric drives (3).

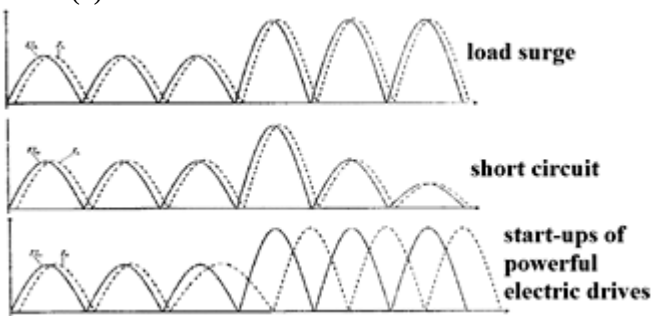

Fig. 8. Examples of disturbances in high-voltage transmission lines.

The results of computer modeling and identification of classified load surge (perturbations) in transmission lines are shown in Fig. 9, namely, integral characteristics of the modular differences in the squares of instantaneous current values of working and output currents, in the case of three-phase drives (the start of powerful electric motors). In particular, starting the powerful asynchronous motors, and long-term start-ups are shown in Fig.9.

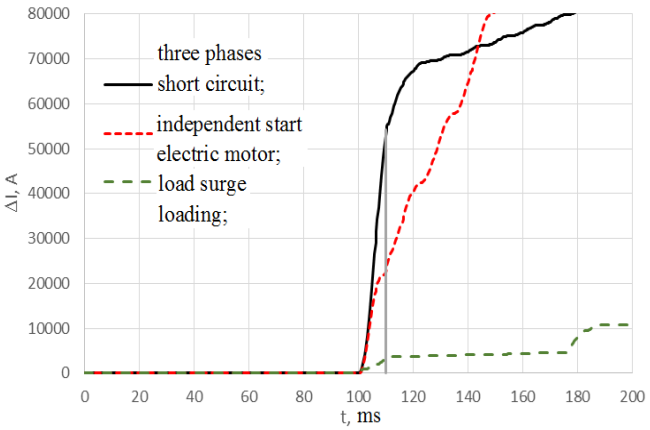

Fig. 9. Results of computer simulation of disturbances in transmission lines.

Fig. 9 shows that after the first period it is possible to judge which of the modes refers to a state of emergency and which is not. As the rapid linear change in the integral characteristics of the modular differences in the squares of instantaneous current values occurs during the first half period, it is possible to recognize the emergency mode even during the half-period industrial frequency.

IV. Conclusion

The actuality and effectiveness of applying computerized systems of monitoring and control of electric power engineering objects is outlined. The functions and basic modules of the structures of "Strila" and "Altra" are systematized. The necessity of expanding functional capabilities of the systems of such class by using microelectronic special-purpose processors with a deep level processing of digital graphs of phase currents on the basis of statistical, cross-correlation, spectral and entropy analyses is substantiated.

The structure of the relay protection device based on the microelectronic special-purpose processor was designed and the results of computer simulation of the proposed integral-difference method of the correlation signal processing in case of disturbances in high-voltage transmission lines are presented. Such devices can widely be used both as the components of computerized systems for monitoring and control of the electric substations equipment and autonomous specialized protection relays. The control and diagnostic monitoring systems allow to effectively identifying abnormal situations in high-voltage electrical networks.

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