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MONITORING OF AC TRACTION SUBSTATION EQUIPMENT

The basic results of R&D project on the design of a system for monitoring equipment of traction substations of railway transport implemented in the Institute of Electrodynamics of the NAS of Ukraine are presented. The system is intended for automated monitoring and diagnostics of the condition of electrical equipment and parameters of its operation modes. Ultimately, the system enables enhancing the reliability of Ukrzaliznytsia (UZ) power supply systems and, consequently, the efficiency of railroad traffic management.

Keywords: electrical power equipment, traction substation, emergency operation, automation, monitoring, and diagnostics.

Reliable, efficient, and high-quality railway operation can be ensured by organizing uninterrupted supply of electricity from traction substations (TP), which requires their complex automation and computerization. One of the main directions of this research is the implementation of electrical recording devices at UZ facilities. Their use at traction substations becomes a common practice, significantly improves the working conditions of personnel, and increases the reliability of the equipment due to continuous monitoring of equipment operation and enhanced information support of the system. Technical data of these devices enable addressing many problems associated with the registration of modes of power grid operation, the definition of electrical and time parameters, the detection of damages to power engineering lines and electrical equipment. To ensure reliable operation of railway power grid and to improve traffic safety, in addition to highly reliable registering devices it is necessary to introduce advanced integrated computer systems and technologies for monitoring operation modes, recording and diagnosing the electric equipment of power grids based on registration of pre accident, accident, and post-accident operation modes with reporting the operation status of relay protection and automation systems and transferring the emergency information to all levels of management. Among these objectives, the most important is to monitor the power equipment [1]: power transformers, power switches and grids with different voltage. Thus, the creation of a system for monitoring the condition of railway traction substation equipment (RTSE) is an important and urgent task. The main goal of this system is to provide reliable operation of UZ power supply systems and to improve railway traffic safety.

The traction substation is a power installation designed for transformation and distribution of electricity and reduction of voltage for its transfer to the catenary system for power supply of electric locomotives. There DC and AC traction substations. Hereafter, the research deals with AC traction substations, which number in the UZ structure is about 300. Usually, the distance between them is 50—100 km. Nominal voltage sup-

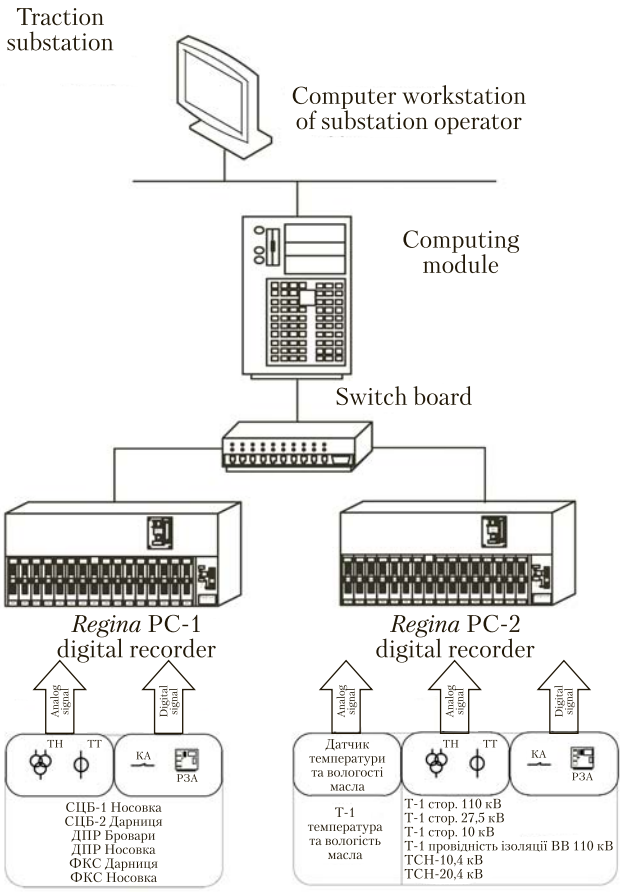

Fig. 1. Structure of system for monitoring of the condition of TS equipment

plied to the catenary system is 27.5 kV. The AC substations are powered from grids with a voltage of 110 or 220 kV. In addition to the rolling stock, other important railway facilities are connected to railway power grids. They are the automation and remote control systems for traffic lights, switches, and communications devices. These facilities operate on voltage of suitable quality supplied by *signaling, centralization, blocking* (SCB) lines with a voltage of 6 or 10 kV fed by substation's own power line. Other less important facilities, such as heating and lighting devices of railway stations and crossings, etc., are fed by "two cables — rail" feeder with a voltage of 27.5 kV or by special power lines with a voltage of 6 or 10 kV.

Thus, proceeding from specific characteristics of UZ traction substations, the basic equipment to be monitored has been identified as follows.

- Power transformers;
- Measuring transformers;
- Power switches;
- Relay automation;
- Feeders of catenary system with voltage of 27.5 kV;
- *Two cables — rail* lines; and
- *Signaling, centralization, blocking* lines.

While implementing procedures for measuring current, voltage, active and reactive power, and other parameters for process equipment with voltage 10; 27.5; and 110 kV, the readings are input into RTSE for each phase through traditional or electronic [2] current transformers (CT) and voltage transformers (VT). Information from TS, TN, and non-electrical parameters and from the 110 V direct current board (DCB) enters the system without using any intermediate analog transducers. The RTSE data are visualized on the monitor of operator's computerized workstation (see Fig. 1).

The monitoring of power equipment is made automatically under the operating voltage, without any operation involved. The condition of power transformers is assessed by controlling the dissipation factor, capacity, total insulation conduction, unbalance current of high-voltage input insulation; temperature of transformer oils; moisture of transformer oils; and control mechanism operation under voltage.

The condition of voltage measuring transformers is automatically detected while continuously monitoring the operating voltage of each phase (or line voltage) of the low voltage side of the transformer with constant tracking of the ratio between adjacent phases (line voltages). The condition of power switches is determined on the basis of switch commutation life, mechanical durability, and disconnection time.

The automation and relay systems are monitored by a digital recorder through identifying emergency events with further analysis of operation of individual devices. The monitoring of cat-

enary system feeders, two cable — rail lines, and SCB lines involves identifying fault locations through analyzing the data of accidents recorded. This is carried out by digital recorders of subsystem for registration of process parameters and is followed by automatic translation of basic fault parameters to the RTSE database.

The RTS monitoring equipment is located at the TS management board and consists of the following subsystems:

- Digital recorder of process parameters;
- Processing, analysis, and visualization of data;
- RTSE communication components;
- Time synchronization.

The subsystem of digital parameter recording shall register the primary data from the sources, store and do their primary processing in order to prepare them for further use in the subsystem for processing, analysis, and visualization of RTSE monitoring system data.

The subsystem is a source of information on technical parameters of main equipment. On the basis of this information, deviations from the normal operation of RTSE are identified and assessed. The subsystem registers the information by recording instantaneous readings of analog and digital values and stores them in the database. The following processes and parameters are to be recorded: normal operation of the main equipment; electromagnetic transition processes associated with disturbances in the 27.5 kV catenary system, two cable — rail lines, and SCB lines; changes in the position of switching devices; actuation of relay protection and automation; other parameters of the main equipment used for monitoring.

The subsystem for processing, analysis, and visualization of data is designed for continuous processing and real-time analysis of primary data coming from the digital recorder of process parameters. This subsystem implements basic functions and algorithms for TS equipment monitoring and visualizes RTSE performance.

The subsystem is based on a computing module dealing with processing the incoming signals, setting the RTSE, receiving the primary data, working with RTSE database, processing, analyzing, and delivering the data for visualization at operator's computerized workstation, etc. While processing the information, scaling operations (calculation of real physical values in nominal units taking into consideration the CT and VT transformation ratios, etc.) are performed; the design values (active and reactive power, cos φ, frequency, dielectric loss tangent, admittance, etc.) are calculated; the warning and emergency settings are compared; time markers (signal excess/diminution as compared with the settings) are assigned.

A specialized software has been designed for the organization of subsystem operations. The structure of this software includes:

- Program for receiving and processing emergency information (Comport.exe);
- Emergency information analysis program (Qu. exe);
- Setting for data on a particular object (Rgsetw. exe).

General view of the substation dialog window for receiving and processing the emergency information Comport.exe is showed in Fig. 2. The above software enables setting and adjusting the parameters of recording the normal operation and running the digital recorder; receiving and processing accident files; controlling the operation of the subsystem and its individual recorders; composing arrays of emergency information; composing libraries form of accidents; organizing procedures for direct access to any part of oscillograph pattern for its detailed consideration; measuring instantaneous and real values of analog signals in any part of the pattern, displaying the readings, and determining the angles between sinusoidal values. In addition, it makes it possible to perform harmonic analysis of analog signals and to represent arbitrary number of charts linked to the same time. Also, the system can find the fault locations in the case of short circuits on the power line, estimate the residual life of high-voltage switches, automatically generate information on the results of accident registration, and transmit this information to the senior management.

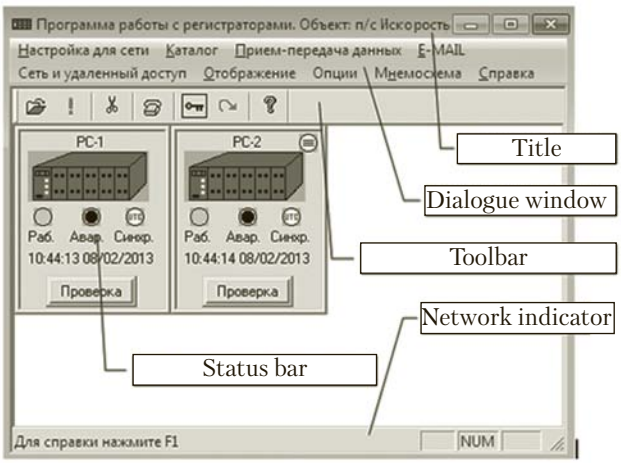

Fig. 2. Dialogue window

Fig. 3. Cabinet of the monitoring system near the TS switch panel

The RTSE component communication subsystem provides data transfer between the subsystems. Standard hardware and software of local computing networks with transport protocols TCP/IP are used as basic equipment of the subsystem.

The time synchronization subsystem is based on the principle of bringing digital timers of local registrars in line with the signals from the GPS satellite system. This ensures certainty in the timing of events recorded by various subsystems and enables the formation of a single time in the RTSE. The discrepancy in time of accident recorded by different subsystems is less than 100 microseconds. The time synchronization of RTSE elements is automatically controlled by the time synchronization subsystem cyclically, at least, one per 10 minutes.

The RTSE is powered by two independent sources:

- the main supply with voltage of 220 V, with a frequency of ~ 50 Hz;
- Backup supply with voltage of 110 V.

As a result of the research, the technical documentation have been prepared and a prototype of RTSE has been manufactured. This prototype has the following basic functions:

- Monitoring and diagnostics of main process equipment and tracking of changes in operational parameters;
- Operational analysis of emergency situations;
- Warning of possible equipment failures;
- Determination of equipment residual service life on the basis of diagnostic data;
- Forecasting of the equipment residual service life;
- Identification of fault locations on the lines of electrified railways.

The Table contains general technical data of the RTSE prototype.

Description	Value
Weight, kg, maximum	180
Dimensions (H × W × L), mm	2200 × 800 × 600
Input voltage, V	
AC	220 ± 20%
DC	110 ± 20%
Frequency, Hz	50 ± 2%
Input power, W, maximum	200

The RTSE prototype is operating at the *Iskorost* traction substation of South-West Railways (Fig. 3), where it has been tested in accordance with designed program and method. The test results show that the system is ready to be commercialized.

Hence, within the framework of R&D project, in accordance with the requirements of applicable regulations, a system for monitoring the condition of AC traction substation equipment has been designed, which enables raising effectiveness, reliability, and safety of traction substation operation and railway traffic management.

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МОНІТОРИНГ ОБЛАДНАННЯ ТЯГОВИХ ПІДСТАНЦІЙ ЗМІННОГО СТРУМУ

Представлено основні результати виконання Інститутом електродинаміки НАН України науково-технічного проекту зі створення системи моніторингу стану обладнання тягових підстанцій залізничного транспорту. Система реалізує автоматизовані процедури з моніторингу і діагностування стану основного електротехнічного обладнання, визначення параметрів режимів його роботи. В кінцевому результаті система дає можливість підвищити надійність роботи систем електропостачання Укрзалізниці та, відповідно, системи організації руху на залізниці.

Ключові слова: електроенергетичне обладнання, тягова підстанція, аварійний режим, автоматизація, моніторинг, діагностика.

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МОНИТОРИНГ ОБОРУДОВАНИЯ ТЯГОВЫХ ПОДСТАНЦИЙ ПЕРЕМЕННОГО ТОКА

Представлены основные результаты выполнения Институтом электродинамики НАН Украины научно-технического проекта по созданию системы мониторинга состояния оборудования тяговых подстанций железнодорожного транспорта. Система выполняет автоматизированные процедуры мониторинга и диагностирования состояния основного электротехнического оборудования, определение параметров режимов его работы. В конечном итоге система позволяет повысить надежность работы систем электроснабжения «Укрзалізниці» и, соответственно, системы организации движения на железной дороге.

Ключевые слова: электроэнергетическое оборудование, тяговая подстанция, аварийный режим, автоматизация, мониторинг, диагностика.

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