Digital combined instrument transformer for automated electric power supply control systems of mining companies

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Abstract. The present paper discusses ways to solve the problem of enhancing operating efficiency of automated electric power supply control systems of mining companies. According to the authors, one of the ways to solve this problem is intellectualization of the electric power supply control system equipment. To enhance efficiency of electric power supply control and electricity metering, it is proposed to use specially designed digital combined instrument current and voltage transformers. This equipment conforms to IEC 61850 international standard and is adapted for integration into the digital substation structure. Tests were performed to check conformity of an experimental prototype of the digital combined instrument current and voltage transformer with IEC 61850 standard. The test results have shown that the considered equipment meets the requirements of the standard.

1. Introduction
Efficient electric power supply is one of the modern problems of mining companies. This problem engineers and scientists constantly face is typical of all industries. An efficient development of the mining industry is impossible without a complex consideration of energy saving problems [1, 2]. Solution of energy saving problems must be considered in a broad perspective. To save energy in the mining industry, it is necessary to have an efficient production technology [3, 4, 5] and processes of automated electric power supply control and electricity metering [6]. Therefore, the problem of enhancing operating efficiency of automated process control systems is currently vital and will be vital in the future due to the necessity to automate not only the process of production but also its energy saving control.

This line of energy saving is characterized by creation of smart grids featuring higher properties of reliability, controllability and efficiency. It provides for application of digital instrument current and voltage transformers, building of fully automated digital substations, development of new design concepts, equipment, systems and methods to monitor power transmission lines and transformer substations.

2. Research Tasks
Electric power supply systems of mining companies are designed considering further expansion and development prospects for the period of at least 10 years. In modern conditions a set of traditional
functions of the automated process control system of substations, including control of current and voltage consumption at substation buses, the condition of relay protection and automation, telecontrol, the position of switching devices, breakers, disconnecting devices, is insufficient. Adoption of IEC 61850 international standard formed the ground for creation of a new generation of fully digital substations featuring advanced automated process control system functionality.

Main step-down substations included in the power supply system of mining enterprises have various schemes and designs. 35-220 kV open switch gear with an outdoor installation of power transformers and 6-10 kV closed switch gear are generally accepted. However, it should be noted that the voltage of 6 kV is currently rarely used for electric power supply of enterprises. Wiring diagrams of substations are chosen based on the company’s load, number and capacity of power transformers and lines, required level of electric power supply safety, level of short-circuit currents, types of applied electrical equipment and other parameters.

Currently, an adaptive digital combined current and voltage transformer (ADCCVT) has been developed and undergoes tests for application at digital substations [7] (http://limi.ru/). Figure 1 shows a photo of the ADCCVT.

This transformer is meant to measure current and voltage in AC mains with 110 kV voltage class. It ensures accuracy class 0.2 by voltage and 0.2S by current at current measurements within the range of 200 – 2000 A. The ADCCVT consists of an external sensor mounted on the open switch gear and the Merging Unit for integration into the network of the digital substation via IEC-61850-9-2 protocol. Current is measured with the electromagnetic current transformer mounted in the high-voltage part of the sensor. Voltage is measured with the capacitance scaling voltage converter (divider). The data are transmitted between the sensor and the Merging Unit via the fiber-optic link.

Unfortunately, manufacturers of digital substations equipment often incorrectly or in their own way interpret sections of IEC 61850, which describe the model and the structure of data exchange between different intellectual devices [8]. In this connection, there appear divergences in operation of intellectual devices at their integration into a digital substation. Thus, in the course of the tests it was necessary to check the parameters of the transmission to a PC of digital data on real time changes in a format complying with IEC 61850-9-2.

3. Tests
The purpose of the tests was to obtain and visualize data from the ADCCVT. The data flow from the ADCCVT were transferred via the own protocol to the Merging Unit, which, in its turn, transformed
the data into IEC 61850-9-2 and then transmitted them to the PC in accordance with the test scheme. Figure 2 shows the test scheme.

Checking the parameters of the transmission to the PC of digital data on real time in a format complying with IEC 61850-9-2 is preconditioned by the fact that current and voltage measurement results must be transformed into an real time digital flow with the frequency of no less than 4000 Hz in accordance with IEC 60044-8 standard. For application at digital substations, the ADCCVT must comply with IEC 61850, apart from IEC 60044-8. Therefore, metrological data must be transmitted from the Merging Unit in a standard format complying with IEC 61850-9-2.

In the course of the tests the data must be visualized on the PC by means of special Discover software. This software tool is able to visualize information flows of 80 and 256 points/period (50/60 Hz) registered by different communications interfaces of the PC. Figure 3 shows a screenshot of the Discover program.

![Discover program screenshot](image)

**Figure 3.** Window of Discover program in the mode of one data flow of 80 points/period (4000 Hz).

4. Results and Discussion
In the course of the tests the data flow from the external sensor were transformed by means of the Merging Unit into IEC-61850-9-2LE data flow, which contains 4 currents and 4 voltages with a pitch of 80 points per period (for relay protection and automatics) and 256 points per period (for quality monitoring and metering of electricity). IEC-61850-9-2LE data flow was transmitted to the PC and visualized.

This type of tests allows one to consider time delays, potential data losses and to perform equipment pre-setting. In case of a high-precision ADCCVT, time delays for transmission of messages are critical, whereas the measurements are made at the frequency of 12800 Hz. After transmission to the Merging Unit and formation of IEC-61850-9-2LE flow the data transmission rates comprise 4 and 9 Mbit/sec for data flows with the pitch of 80 and 256 points per period, accordingly. It should be considered at determination of the data processing time and delays in network.

It should be noted that currently automated process control systems of substations collect and archive all the incoming data with a minimum possible pitch without information losses. Such data volume is generally excessive, however, the redundancy of information is directly connected with its quality and processability of data processing. It, in its turn, allows to provide online information on the electric power supply system status enabling to recover operability of the system in case of software and hardware failures. In this regard, it is expedient to use universal SCADA-systems, which sometimes have a better functionality and are less expensive as compared to SCADA-systems from equipment manufactures. [9].
The performed research has shown that the current and voltage measurement results are transformed into IEC 61850-9-2 digital flow with the frequency of no less than 4000 Hz. Thus, the requirements of IEC 60044-8 and IEC 61850 [10] to transmission of measurement information are met in the design of the ADCCVT.

5. Conclusion
The performed research allows one to make several conclusions.

• One of the most important problems to be solved in the mining industry is energy saving.
• The mining industry has good prospects in searching for ways to save electric energy.
• One of the ways to solve the energy saving problem in the mining industry is intellectual electricity metering.
• It is expedient to enhance operating efficiency of the automated electric power supply control systems of mining companies by development and implementation of digital instrument current and voltage transformers.
• The requirements of IEC 60044-8 and IEC 61850 to transmission of measurement information are met in the design of the ADCCVT.
• Due to the compliance with the international standards to transmission of measurement information in conjunction with high metrological characteristics, small weight and dimensions, as well as low fire and explosion hazard, the ADCCVT can be used in modern automated electric power supply control systems of mining companies.
• The redundancy of metrological information is necessary for automated process control systems of substations to provide online information on the electric power supply system status.
• To enhance operating efficiency of the automated electric power supply control systems of mining companies it is expedient to use universal SCADA-systems, which sometimes have a better functionality and are less expensive as compared to SCADA-systems from equipment manufactures.

6. References
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