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2018 Paris Session

SC B5 Protection and Automation
PS 2 User experience and current practice
with IEC 61850 process bus

Experience of implementation, testing and operation of digital measuring transformers, merging unit devices, power-system protection and automation devices realizing IEC 61850 process bus for the generator-transformer unit of Nizhegorodskaya HPP

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The Nizhegorodskaya Hydropower Plant (HPP) built in 1948-1962 is the fourth stage of the Volga-Kama Cascade of hydropower plants and, having installed capacity equal to 520 MW, actively participates in daily and weekly regulation of the electric load schedules, in regulation of the daily schedule of voltage levels in checkpoints, in operational and automatic secondary control of frequency and power flows, providing power reserve for emergency situations in 'Unified Energy System of Russia'. 8 hydrogenerators having capacity equal to 65 MW are installed on the hydropower plant, 4 of which are operating in the units equipped with transformers TDC-125000/110/13.8, which produce the power into the 110 kV network, and 4 other of which are operating in the units equipped with the single-phase four-winding transformers 3xODT-53333/220/110 which produce the power into the 110 kV and 220 kV networks.

Elaboration of IEC 61850 process bus for the generator-transformer unit of Nizhegorodskaya HPP began in 2015, when the Unit No. 6 of Nizhegorodskaya HPP was selected by PJSC RusHydro as a pilot facility for testing the technology of the process bus in accordance with the requirements of IEC 61850 standard. The electronic fiber-optical current transformers and the electronic voltage transformers with capacitive divider were installed in the chain of the 110-kV switch of the T-6 power transformer; the flexible electronic fiber-optical current transformers were installed in the main output terminals and in the neutral of the generator No. 6; the merging unit as the digital measuring voltage transducer in the main output terminals and in the neutral of the generator connected to the chains of the 'star' of the voltage transformer of the main outputs and to the branch line of the arc-suppression reactor of the generator's neutral was installed. The IEC 61850-9.2LE process bus and the IEC 61850-8.1 station bus were manufactured in the form of two optical rings having speed equal of 1 Gbit per second, separated at a logical level using Virtual Local Area Network (VLAN) technology.

In order to perform tests and accumulate equipment operation experience with support of IEC 61850, both the process bus and the station bus were organized using equipment from both Russian and foreign manufacturers. The time synchronization system provided synchronization accuracy level equal to no worse than 1 ms for the devices of bay level and of substation level using the methods of mathematical compensation of the packets transfer time in accordance with the standard IEEE 1588 Precision Time Protocol (PTP) and the standard Simple Network Time Protocol 4 (SNTP 4). For the field-level devices, the time synchronization system has provided the required level of accuracy of synchronizing by using the dedicated network of synchronization and of transmitting 1PPS signals (1 pulse per second).

Prior to installation of the equipment on HPP, the factory acceptance tests of digital current transformers and voltage transformers, as well as of the control and protection devices were carried out on the test sites. The electronic fiber-optical current transformers and the electronic voltage transformers (IEC 61850-9.2LE SV80/SV256) underwent factory tests for verification of metrological characteristics; the claimed accuracy classes were confirmed during these tests. Factory tests of control and protection devices were carried out using the RTDS (Real Time Digital Simulator) software and

hardware and other simulators software and hardware (OMICRON CMC 256 plus, RETOM-61850).

The system acceptance tests carried out at the hydropower plant after completion of installation of the equipment included both testing of operation of the system in various operation modes of power equipment, as well as checking in the course of simulating of faults in digital devices. During the tests, problems related to operation of digital measuring transformers as well as problems related to operation of microprocessor protection and automation devices and local area network (LAN) devices were detected. In the course of the test, the following problems were detected: noise in measured currents (both on the side of 13.8 kV and on the side of 110 kV); periodic noises in 110 kV voltages for idling experiments; emissions of the generator neutral current, as well as false alarms of microprocessor power-system protection and automation devices in the event of loss and restoration of synchronization of the electronic unit of the optical measuring transformer; short-term distortion of signals of current in the situation of absence of indicators of 'bad' quality of signals in case of loss of power of the electronic unit of the optical measuring transformer; false alarms of power-system protection and automation devices when emulating a malfunction of the network equipment related to loss of PTP synchronization during the tests of failure of secondary voltage chains.

Analysis of the results of system acceptance tests showed the need to make changes in the composition of equipment organizing the process bus and the station bus of the generator-transformer unit. In 2017, the range of the digital measuring transformers was expanded. Electronic units of digital current transformers and voltage transformers were upgraded in order to eliminate noises and problems in case of loss of power detected during tests. The renewed LAN structure provides physical separation of the process bus and the station bus, the network modules of the measuring transformers' electronics units maintain operation of LANs according to the parallel reservation protocol (PRP). The range of the generator-transformer unit protection and control functions implemented in the power-system protection and automation devices with the support of IEC 61850-9-2LE was expanded.

The report presents the results of the factory acceptance tests and of the system acceptance tests at the hydropower plant, of trial operation and maintenance, which were carried out during 2015-2017 on the operating equipment of the generator-transformer unit of Nizhegorodskaya hydropower plant. The analysis of experience of implementation, testing and operation of digital measuring transformers, merging unit devices and power-system protection and automation devices realizing the IEC 61850-9.2 process bus and the IEC 61850-8.1 station bus is also given. The presented results reflect the unique experience of implementing the requirements of the IEC 61850 standard for elaboration of protection and control systems of generating equipment.