Digital substation implementation: testing and commissioning of automated control system and relay protection with IEC 61850-8-1 and 9-2 on Nizhny Novgorod hydro power plant

In 2011 leading Russian developers in electrical energy industry – LLC «EnergyindustryAutomatization» (hereinafter referred to as «EPSA», http://www.epsa-spb.ru/), EKRA Research and Production Enterprise Ltd (hereinafter referred to as «EKRA», http://www.ekra.ru/), CJSC «Profotech» (hereinafter referred to as «Profotech», http://www.profotech.ru/) and JSC «Scientific and Technical Center of Unified Power System» (hereinafter referred to as «STC UPS», https://www.ntcees.ru/) signed general agreement to organize strategic collaboration in order to combine scientific, technical, engineering and commercial efforts for creating a digital substation in Russian Federation. As a result, there was designed a software and hardware, including optical current and potential transformers (Profotech), relay protection terminals (EKRA) and multifunctional controllers NPT, SCADA NPT Expert and CAD system for digital substations SCADA Studio (EPSA).

Functional tests and tests in increased traffic load had been successfully accomplished on test bench of STC UPS by the end of 2011. A prototype of digital substation was presented on «Russian Electrical Grid – 2011» exhibition.

In order to assess innovative technologies and detect their advantages and disadvantages Russian hydroelectric power company JSC «RusHydro» (hereinafter referred to as «RusHydro», http://www.rushydro.ru/) began a pilot project of creating digital substation on Nizhny Novgorod hydro power plant. This plant is the forth step of Volga-Kamsk hydroelectric power chain. It includes eight hydroelectric units of 520 MW each and supplies a row of industrial facilities and residential areas of Nizhny Novgorod region. Within the scope of the pilot project it was supposed to use concepts of digital substation for generator-transformer unit's automated control system.

In 2013, a contract was signed for Research and Technological Development on creating recommendations for implementation of unconventional optical current and potential transformers. EPSA as a general contractor arranged equipment delivery and, in association with partners, accomplished all of the activities on commissioning of software and hardware, entirely based on Russian solutions (Figure 1). STC UPS provided a test bench and played role of scientific expert.

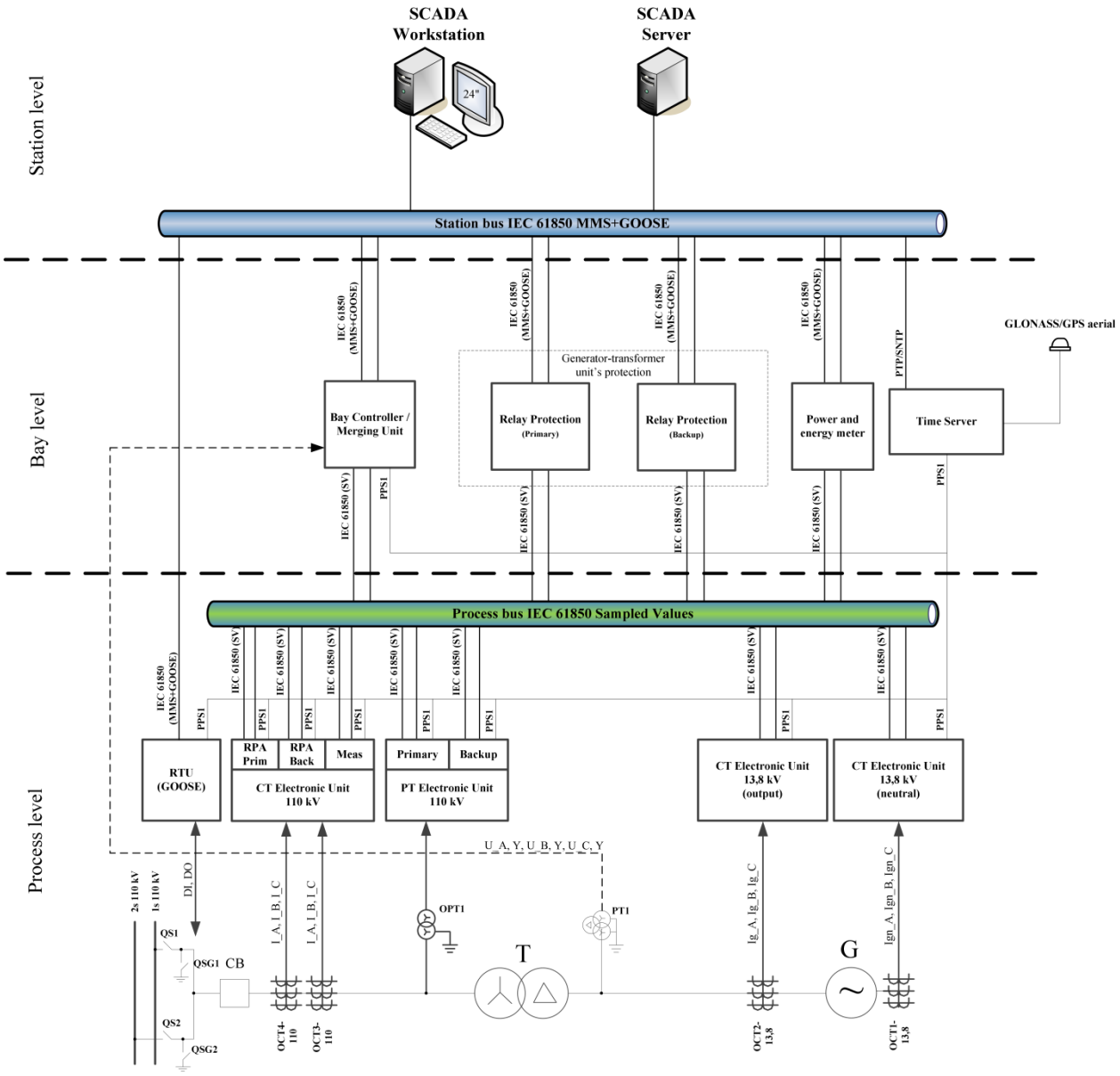

Figure 1 – Structure

Optical current transformers have been installed on 110 kV side of power transformer (Figure 3) and on 13,8 kV side in generator neutral and in generator outputs (Figure 2).

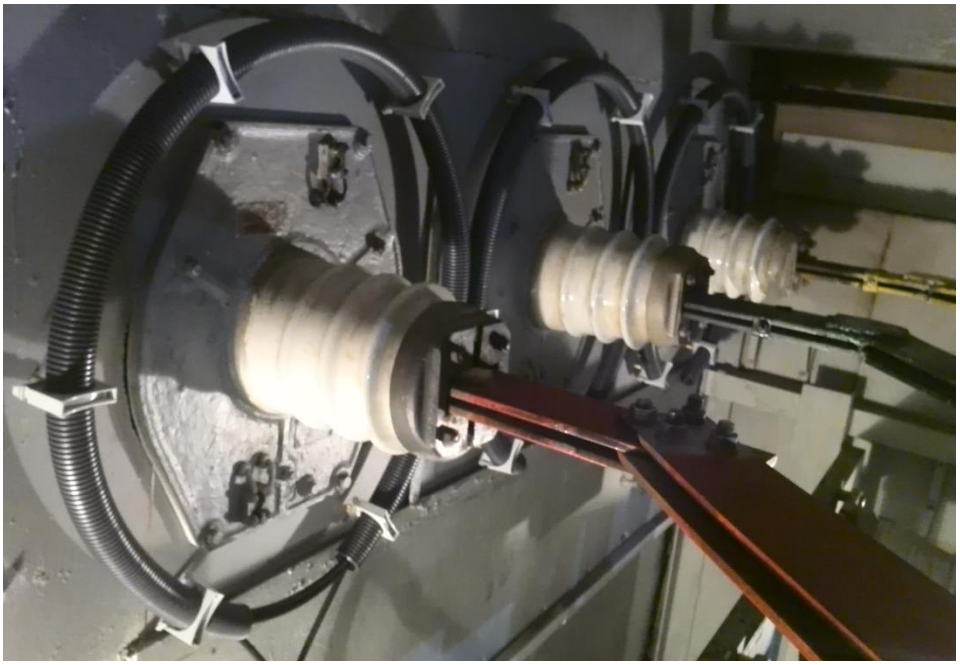

Figure 2 – Flexible OCT 13,8 kV

Optical potential transformers have been installed on 110 kV side of power transformer (Figure 3).

Figure 3 - OCT and OPT 110 kV

Experimental-industrial specimen of software and hardware consisted of:

- cabinet of RTU based on controller NPT microRTU by EPSA (Figure 4);
- cabinet of bay controllers based on controller NPT BAY by EPSA (Figure 5);
- cabinet of relay protection based on terminals by EKRA (Figure 6);
- cabinet of SCADA server by EPSA.

Figure 4 – Cabinet of RTU

Figure 5 – Cabinet of bay controllers

Figure 6 – Cabinet of relay protection EKRA 200

The pilot project envisaged commissioning and functioning of new equipment together with conventional equipment that had already been on the plant.

Basic concepts are listed below.

Discrete signals are gathered on process level by microRTU and delivered via station bus on bay level using GOOSE-messages.

As voltage on 13,8 kV level changes, analog measurements proceed to Merging Unit, which physically combined with bay controller NPT Bay. There measurements are digitized and delivered on process level as Sampled Values. Other measurements are carried out by optical current transformers and optical potential transformers directly. Signals from the transformers proceed to CT or PT Electronic Units and then go to process level as Sampled Values. Thus, devices of bay level complete only tasks of information digital processing and control operations. They don't need to do analog-to-digital conversion.

Time synchronization system includes software and hardware, providing precise time reception of signals from an external GPS / GLONASS source and maintaining an accurate clock rate in case of GPS / GLONASS failure. System is based on time server Meinberg M400 / PTP and PPS Meinberg SDU / TTL / FO signal distribution device. These devices have been installed on distribution board of outdoor switchgear 110 kV in the cabinet of station level.

Process bus and station bus are designed as a single optical ring, 1 Gbit / s. Separation between them is performed using VLAN technology. This logical separation of networks provides increased reliability of the LAN.

The equipment, which has been installed as part of the project contributes to the reliability and safety of optical current and potential transformers, reduces cost of cabling secondary circuits and improves the electromagnetic compatibility of relay protection and automation systems and their secondary circuits due to the transition to optical communications.

In addition to these advantages and benefits, an innovative solution has allowed to formulate new questions to modern technology automation of power generation facilities and to identify their development potential.

In 2015 experimental-industrial specimen was expanded by adding three cabinets (Figure 7):

- cabinet of relay protection based on terminals by Research Centre «Bresler» (http://www.ic-bresler.ru/);
- cabinet of relay protection based on terminals by ABB;
- cabinet of relay protection based on terminal by Alstom Grid.

Figure 7 – Cabinets of relay protection (left to right: Bresler, ABB, Alstom Grid)

In October, 2015 commissioning tests were carried out on the plant.

Among the results were the following:

- tests have proved compatibility of devices by 7 vendors including Russian and foreign ones;
- tests have confirmed IEC 61850 standard compliance for all the devices;
- all the devices have been integrated into SCADA NPT Expert and have been monitored via MMS reports and fault records;
- relay protection and automation equipment have performed all the functions similarly to the conventional ones;
- tests have showed necessity of physical LAN separation into process bus and station bus. The process bus should support redundancy with zero recovery time (PRP);
- tests have revealed some features in equipment operation that require analysis.

In the nearest future it is planned to:

- put hardware and software into a trial operation to ensure constant monitoring of the equipment and accumulate work statistics;
- integrate the specimen in automated system for commercial measurement of power consumption;
- wholly separate station and process buses;
- apply centralized digital recorder of GOOSE messages and SV streams which has been tested during commissioning tests;
- install optical potential transformer on 13.8 kV side;

- implement malfunction diagnostic of all generator-transformer unit’s digital equipment and transmit its data into SCADA NPT Expert.

Mounted on Nizhny Novgorod HPP innovative complex is the first industrial implementation of digital substation technology on hydropower facilities in Russia. New approaches and procedures to be included in the technical policy of JSC «RusHydro» will be developed on the basis of empirically obtained data.