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Investigation of non-conventional current and voltage converters characteristics for digital substations

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At present innovative development of electric power industry is aimed at creating a Smart Grid which should have such properties as reliability, flexibility, visibility, self-diagnostics, etc.

One of the key technological aspect of the smart grid is measuring instruments and devices. The development of microprocessor technology opens door for the possibility of using new (non-conventional, low-power) current and voltage converters that were not previously used in power industry and have advantages over electromagnetic current and voltage transformers (no effects of saturation and residual magnetization of magnetic circuits, as well as ferroresonance phenomena, explosion and fire safety , low weight and size indicators). Such converters include the Rogowski coil, shunt, galvanomagnetic sensors, resistive divider and others. However, the operation of these converters under actual conditions (strong electromagnetic fields, wide temperature range), as well as their joint work with secondary devices, especially with intelligent measuring devices, requires further research. It is worth noting that IEC 60044-8 “Instrument transformers. Electronic current transformers” does not include the requirements to non-conventional instrument (primary) converters.

The article will present the results of studies of transient, frequency, thermal and other characteristics of various non- conventional current and voltage converters (including digital transformers), as well as the results of tests of their collaboration with electric power meters and relay protection and automation devices. It will focus on the influence of the electromagnetic fields on the currents and voltages measurement errors using the non-conventional primary converters.

The studies were carried out on the unique scientific installation “Multifunctional test system for the study of primary current and voltage converters, digital substation devices and relay protection and automation devices” at Ivanovo State Power University (Fig. 1). The equipment included into the test system have valid licenses and calibration certificates. The OMICRON CMC 356 hardware-software complex was used as a programmable source of an electrical signal in the frequency range from 0 to 1 kHz. Multimeters Keysight 3458A are designed for high-precision measurement of signals from the reference and verified current converters. Multimeters are controlled from a personal computer (PC) using the EnergoEtalon certified software package. The studies of the thermal characteristics of primary converters were carried out in the heat and cold chamber KTH-74-75 / 180.

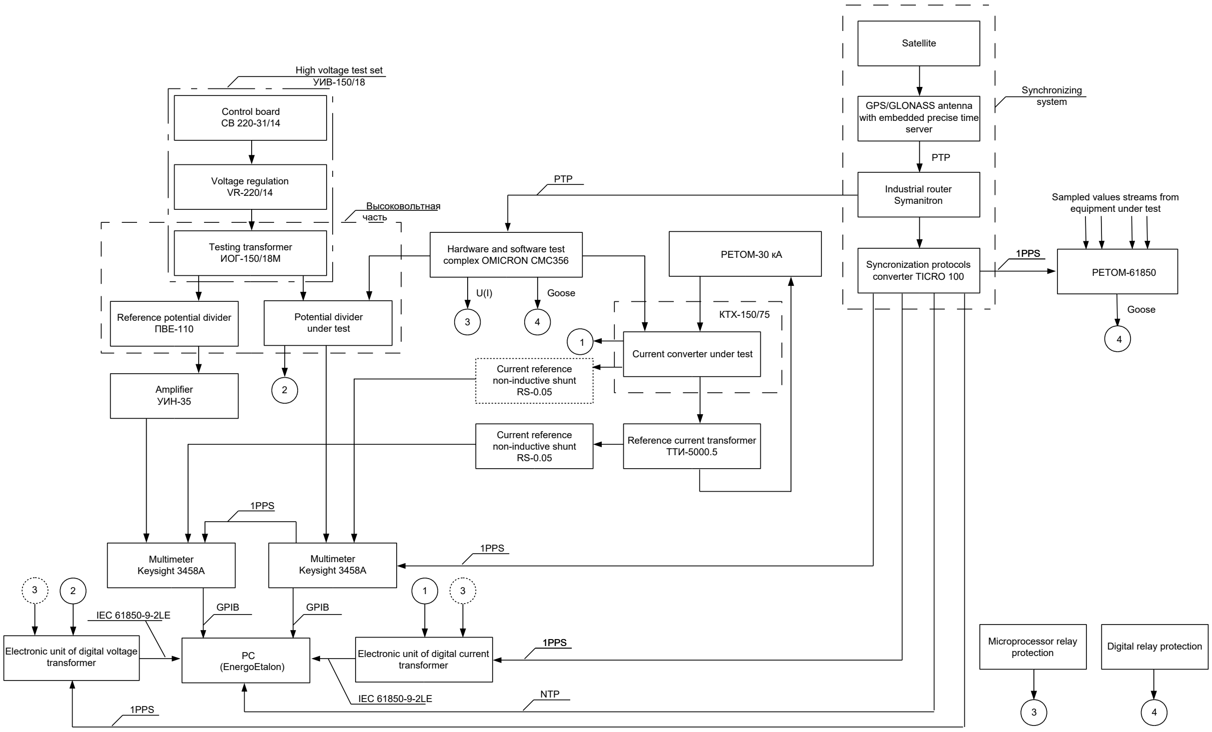


Figure 1 - Structural diagram of a unique scientific installation "Multifunctional test system for the study of primary current and voltage converters, digital substation devices and relay protection and automation devices "

For the correct comparison of the non-conventional primary converters the research was carried out to the sensors of the same rated primary currents and voltages. The technical characteristics of the researched sensors will be presented in the report.

Rogowski coil is one of the researched non-conventional primary converters. The studies were carried out to the following types of this converter:

- Rogowski coil with one-piece construction;
- Rogowski coil with split-core construction;
- Rogowski coils of the types above with the usage of the digital integrator.

The results of the research of Rogowski coil with one-piece construction and the rated primary current of 600 A are presented below.

Figures 2-5 show the results of the study of the frequency, thermal and transient characteristics of Rogowski coil. The presented characteristics of Rogowski coil demonstrate high accuracy and linearity in the studied frequency range and the possibility of using them both for protection purposes and electricity metering purposes.

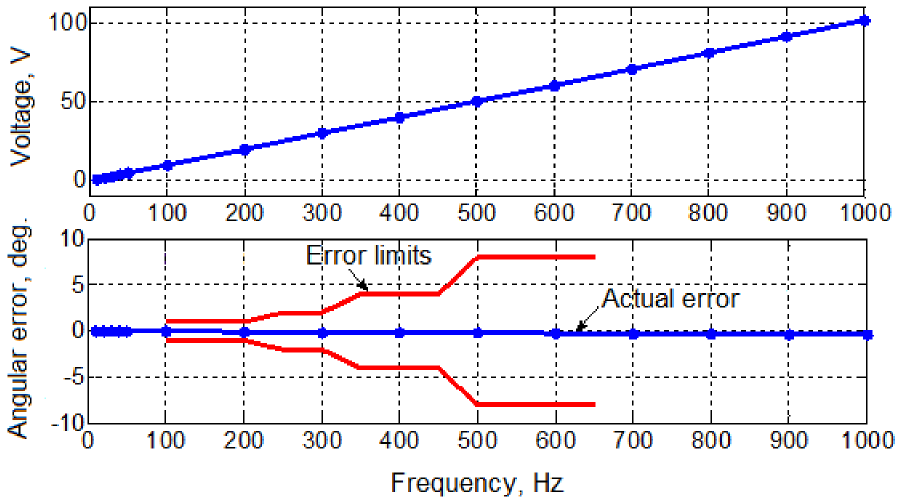


Figure 2 - Amplitude-frequency and phase-frequency characteristics of Rogowski coil without integrating with indication of the limits of error for electricity metering (accuracy class 0.1) in accordance with Standart IEC 60044-8-2010

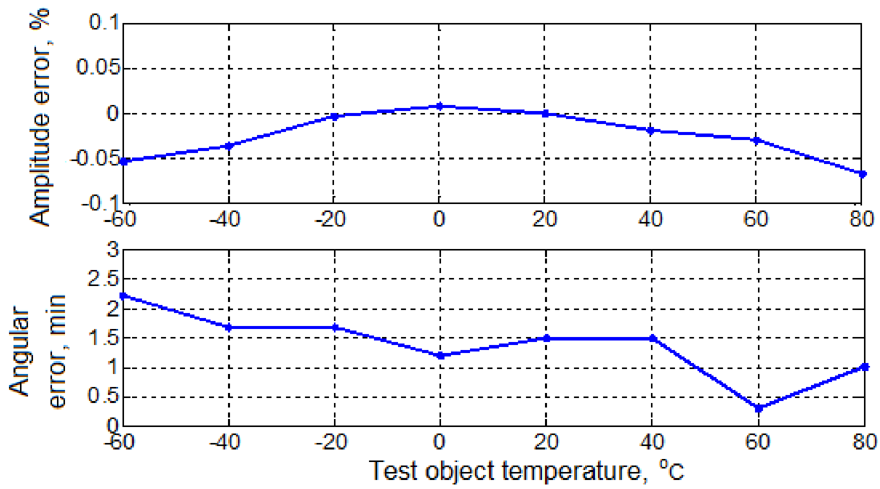
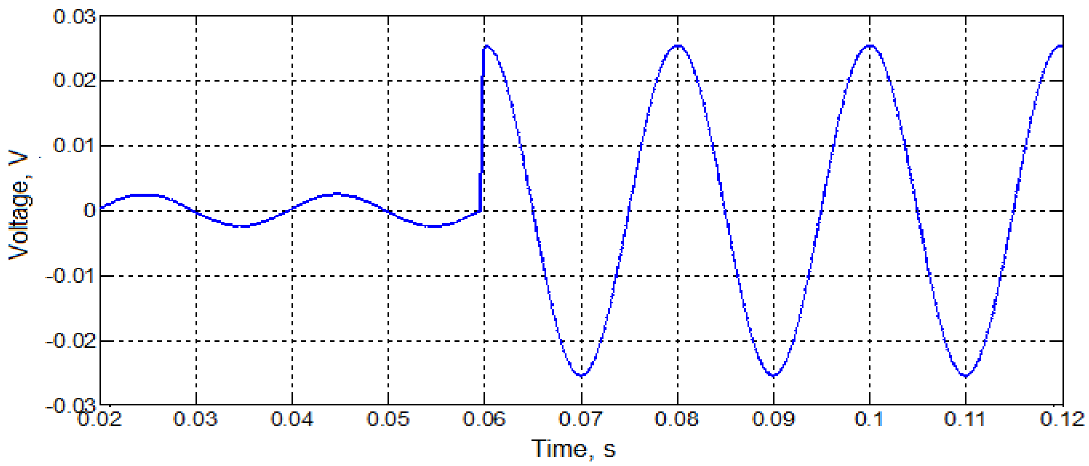
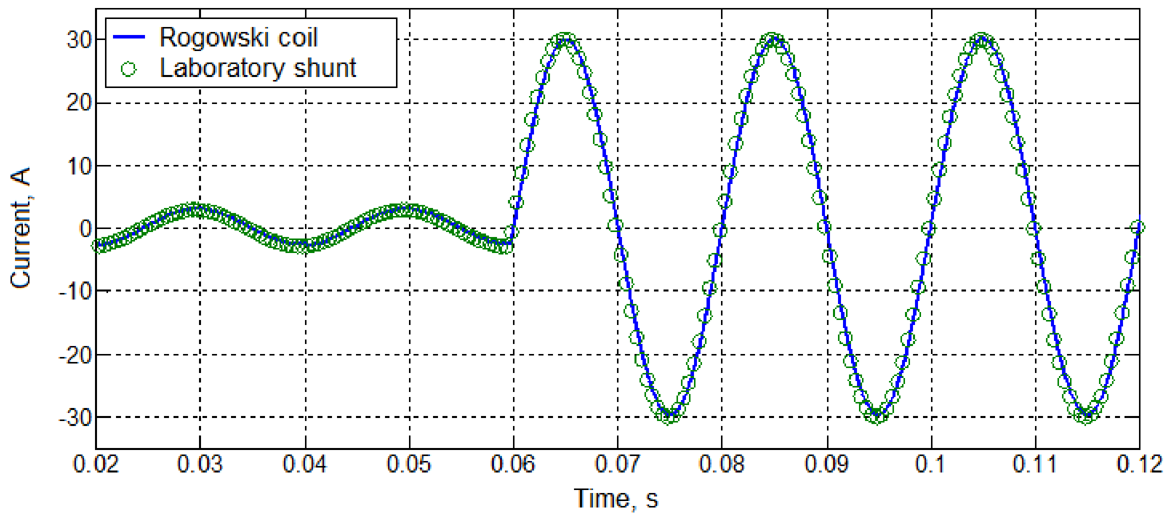


Figure 3 - Dependences of the amplitude and angular errors of the Rogowski coil on the temperature



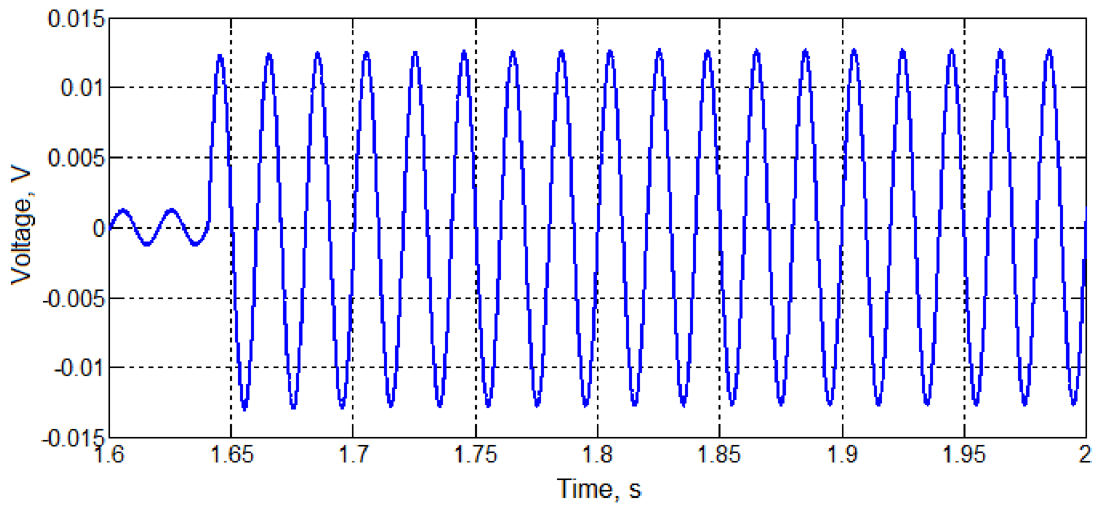
a)



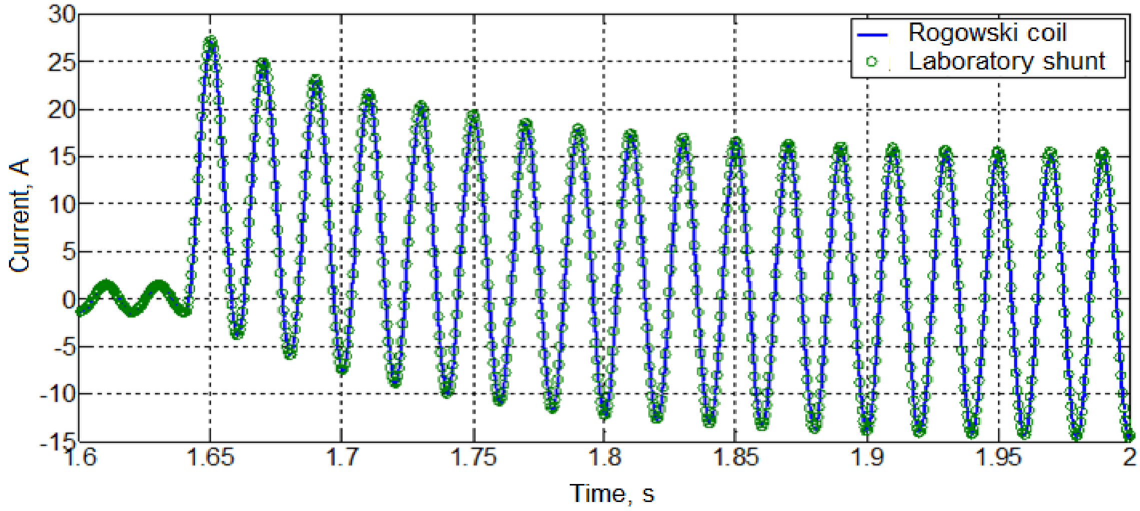
b)

Figure 4 - The signal of the Rogowski coil with an increase in the primary current of 10 times:

a - before integration; b - after integration and reduction to the primary current



a)



b)

Figure 5 - The signal of the Rogowski coil at the primary current with the aperiodic component:
a - before integration; b - after integration and reduction to the primary current

The characteristics of the Rogowski coil are influenced by the following factors:
- position of Rogowski coil relative to the conductor;
- external electromagnetic field;
- aging of materials;
- mechanical loads.

Performed studies of one-piece and split-core design of Rogowski coils with different diameters allowed us to draw the following conclusions:

1. When the conductor is displaced, the split-core Rogowski coils have larger conversion error compared to the one-piece core due to the absence of turns in the connector area.

2. When the conductor is displaced to the split of Rogowski coil, the conversion errors increase more as compared to the other side.

3. With the same current conductor displacement, the current conversion error is less for the Rogowski coils of larger diameter. It should be noted that the larger the diameter of the Ro-gowski coil, the lower its output signal, all other parameters being the same. The level of noise is also higher.

4. The inclination of the Rogowski coil relative to the conductor has a smaller effect on the current conversion error compared to the current conductor offset. The errors of current conversion of shielded Rogowski coil with a large number of turns did not exceed the limits of the accuracy class even at a 45 tilt angle. However, the errors of current conversion of other structures at the specified angle of inclination reached 1%.

Similarly, the report will review and analyze the characteristics of a small-sized current transformer with magnetic conductors of electrical and amorphous steel, galvanomagnetic sensors, shunt and resistive voltage divider.

The report will also present the results of trial operation of digital transformers with non-conventional primary converters at substations in the central and northern parts of the Russian Federation.

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