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IMPROVING THE ACCURACY OF MEASUREMENT OF ELECTRICAL VALUES IN THE NETWORKS OF REGIONAL ENERGY COMPANIES

The article considers the issues of increasing the accuracy and reliability of measurements of electrical quantities in the field of electric power. The high-voltage measuring path consists of current, voltage transformers and measuring devices. It is proposed to use optical current and voltage transformers as measuring transformers. The advantages of using optical transformers and their basic principles of operation are discussed. The significant advantages of these devices are that they work with instantaneous values of currents and voltages. The issue of modernization of the measuring device of the energy consumption parameter indicator, which has been developed at the Department of Electric Power Transmission of National Technical University "Kharkiv Polytechnic Institute" since 2005, is considered. It is shown that the energy consumption parameter indicator is an intelligent system consisting of two subsystems: informational and measuring. The main requirements for the measuring part include the implementation of the functions of control and accounting of electricity in three-phase alternating current networks. In addition, the measuring module must provide indication of controlled parameters, support the functions of setting parameters, receiving information via the EIA-485 interface, and storing the received data. The information part of the measuring device is implemented with support for the ITU-T G.984 standard (including FXS), while the interconnection between the Wide and Local Area Network interfaces must operate in both switch and router modes. The requirements for the technical performance of the energy consumption parameter indicator are presented. The measuring device is controlled in accordance with the standard Optical Network Units Management and Control Interface control protocol according to the ITU-T G.984 recommendation, taking into account the provisions of G.988. The power limitation unit must be built into the energy consumption parameter indicator. The requirements for reliable use of the measuring device are given.

Keywords: optical current transformer; optical voltage transformer; energy consumption parameter indicator; measuring subsystem; information subsystem; interface.

Introduction. Electric energy (EE) has quantitative and qualitative indicators. Qualitative indicators of electric energy ensure the reliability and efficiency of the work of EE consumers. Quantitative indicators - timely payment for consumed EE, which is one of the main factors of sustainable development of the electric power industry. Therefore, specialists pay great attention to the issue of accounting for EE consumption and its quality. Accounting for EE flows is carried out at all stages from production to EE consumption using various information systems (for example, Automated system of commercial accounting of electric power) and EE meters. The issue of reliable accounting for EE flows is of significant national economic and technological importance. Significant assistance in solving these issues is provided by the additional introduction of modern measuring devices for quantitative and qualitative EE indicators. For more than 20 years, the Department of Electric Power Transmission has been developing and implementing an Energy Consumption Parameters Indicator (ECPI, Fig. 1). The general measuring path consists of an ECPI and current transformers (CT) and voltage transformers (VT). The reliability of the obtained results depends on the accuracy (error) of these devices. The article considers an effective means of increasing the accuracy of this measuring path through the use of modern optical technologies in the production of CT and VT, the use of modernized ICPE.

Literature review. Each state pays significant attention to the development of the electric power industry, which is reflected in the main program documents [1–3]. At the same time, serious attention is paid to the development of regulatory documentation in the electric power industry [4, 5]. One of the important and fundamental issues of the electric power industry is the accounting of EE, because it ensures financial stability and sustainable development of the electric power industry. At the state level, the accounting of EE flows is implemented using modern information systems [6]. This leads to a significant digitalization of technological processes and their implementation in the production of EE. As a result, digital substations appear [7, 8]. In addition, to increase the reliability of measuring energy consumption parameters, high-precision measuring devices and means of metrological support are being developed [9, 10]. Modern meters and devices for monitoring the main EE parameters are being introduced for the population and enterprises [11]. Structures and networks of Oblenergo are the last link between the power system of Ukraine and end consumers of EE. For Oblenergo specialists, the population and enterprises, the issue of reliable metering of electric energy is of fundamental importance [12. 13].

Figure 1 – Measurements using ECPI

For networks with a voltage class of 3–110 kV, measurements are carried out using current and voltage transformers and measuring instruments. The errors of measuring instruments are constantly decreasing, while the errors of electromagnetic CT and VT practically do not change and have sufficiently large values [14–16].

Purpose of the article. The article considers the possibility of significantly increasing the accuracy of measurements by introducing optical CT and VT, as well as a modernized ECPI [11]. Modernization of the measuring device consists in creating an intelligent electricity metering device with a built-in optical interface.

Presenting main material. About twenty years ago, leading foreign companies [17, 18] began serial production of fundamentally new high-voltage meters – optical current transformers (OCT) and optical voltage transformers (OVT). These devices are now widely used in high-tech countries of Europe and North America. Due to significant advantages over traditional electromagnetic transformers, interest in optical technologies is growing both in the electric power industry and in the technical industry. Such devices function especially effectively when operating high-voltage power lines [19].

The principle of operation of OCT and OVT is based on a change in the polarization state of the light flux under the influence of an electromagnetic field created by current or voltage. This physical effect has been studied in detail [20] and it determines the design features and advantages of optical transformers in comparison with electromagnetic analogues.

Modern OCT and OVT, as a rule, provide a digital format for representing measured quantities - instantaneous values of current and voltage directly at the metering point. This significantly simplifies analog conversions and increases the accuracy of measurements. All computing functions are performed by a computer system with appropriate software [20, 21]. Moreover, many models also have analog outputs, which ensures universal application, especially in the conditions of the transitional state of the Ukrainian energy sector, where the need for compatibility with traditional measuring devices remains [22, 23]. Thus, in most cases, only two physical quantities are measured today - instantaneous values of current and voltage, while other energy parameters are calculated automatically by software. These include active and reactive power, energy, harmonics and other indicators of electricity quality. The speed of optical transformers is comparable to the computing capabilities of modern microprocessors, which allows for a significant reduction in measurement errors and the implementation of intelligent analysis functions [24, 25]. All this indicates a clear trend towards digitalization of measurement technologies in the energy sector. At the same time, it is worth preserving the technical heritage – support for analog tools, which are still relevant in many measurement systems.

The purpose of the development is to create an intelligent electricity metering device with a built-in optical interface. Such a technical solution is achieved by combining information and technological subsystems. In addition, it is planned to implement services for automated transmission of qualitative and quantitative indicators of consumed electricity from individual metering devices, informing consumers about the volume of electricity used, as well as services belonging to the Smart Home class.

The intelligent electricity metering device is intended for use in scientific research, as well as for technical and commercial accounting of electricity consumption. It can also be integrated into automated information and measuring systems of commercial accounting. Structurally, the device is divided into two functional parts. The measuring part performs the functions of electricity metering and supplies power to the information part. The information part, in turn, provides the exchange of service and external data via an optical, copper or wireless network. The information part is powered from the measuring part via an alternating current network (≈230 V), while the electricity consumption by the information part itself must be taken into account by the measuring module.

To exchange information between the measuring and information parts, in particular to read data on electricity consumption, it is necessary to use the low-speed EIA-485 interface (RS-485 is a standard for the physical level of an asynchronous interface): a four-wire half-duplex line that includes two signal and two power conductors. Saving data on electricity consumption can also be implemented in the memory of the information part.

The data transmission interface must be galvanically isolated. External data output must be implemented through the information part using an optical interface.

The main requirements for the measuring part include the implementation of the functions of monitoring and accounting for electricity in three-phase alternating current networks with a voltage of up to 1000 V, a frequency of 50 Hz at one, two or three tariffs, in compliance with the requirements of interstate standards.

The measuring module must provide the functions of accounting for electric energy and indicating the monitored parameters. In addition, the module must support the functions of setting parameters, receiving information via the EIA-485 interface, as well as storing the received data. The information part of the device is implemented in a version with support for the ITU-T G.984 standard (including FXS), while the internetwork connection between the WAN and LAN interfaces must function in both switch and router modes.

At the same time, the technical performance of the device must meet the following requirements:

- the throughput of unicast traffic routing between WAN and LAN in router, PPPoE or bridge modes must be at least 800 Mbps;
- the processing speed of multicast traffic from WAN to LAN in the specified modes must be at least 128 Mbps (8 streams of 16 Mbps);
- the device must function stably with simultaneous operation of a torrent client in the local network (during testing, 1000 sessions and 200 connections per slot must be supported);

The device is managed in accordance with the standard OMCI management protocol according to the ITU-T G.984 recommendation, taking into account the provisions of G.988. Remote administration is possible via the Web interface (WEB GUI) or Telnet via the WAN port. In addition, the TR-069 protocol is supported.

An intelligent metering device with an optical interface must be controlled using:

- a password-protected web interface;
- the TR-069 protocol;
- OMCI (in versions with ITU-T G.984 implementation).

Passwords for accessing the Web interface and the Internet must be stored in encrypted form, inaccessible in configuration files or when viewing the source code of a web page.

The device must support obtaining IP addresses and static routes to operator resources via the IPoE interface using the CWMP and DHCP protocols. The configuration must be saved after rebooting.

The device must support Wi-Fi wireless data transmission interfaces (standards 802.11b, 802.11g, 802.11n), as well as Z-Wave or ZigBee protocols (at a frequency of 2.4 GHz), implemented as part of the information module to enable the creation of wireless networks.

The device must have a built-in power limitation unit that controls the level of active or total load power in a single-phase or three-phase network. This functional unit is located in the measuring part of the device. The threshold value for disconnecting the load is set remotely from a higher control level via the information module. The power is turned off automatically when the set threshold of consumed power is exceeded with the possibility of setting the shutdown delay. The function of automatic re-switching or granting permission for manual switching on by the subscriber using a button in the measuring module with setting the intervals or number of such switching on during the day is also provided. In addition, an authorized employee of the energy supply organization must have the ability to remotely switch on/off the load via the information module in manual mode. In the load limitation mode, independent power supply of the information part is provided, with mandatory accounting of its energy consumption by the measuring module.

The reliability of the device must meet the following indicators:

• time between failures for the measuring part – at least 150,000 hours, for the information part – at least 90,000 hours;

• inter-verification interval of the measuring part – 15 years.

A comparative analysis of various modifications of the measuring device is given in Table 1.

Table 1 - Comparative analysis of measuring devices

Device parameters	ECPI-1 (2005)	ECPI-3 (2020)
Phase voltages, V	70–280	30–300
Linear voltages, V	70–560	30–600
Phase currents, A	10–800	1–900
Frequency, Hz	30–70	10–75
Power, kW	10–360	1–360
Summary current error, %	1.5–2.5	0.5
Error of power, %	2.5	0.5
Cost, UAH	2500	5000

Conclusions. The work proposes measures to increase the accuracy of measurements of electrical quantities in networks with a voltage of 3-110 kV. This concerns the replacement of electromagnetic current and voltage transformers with optical ones. From the point of view of measurement errors, OCT and OVT have significant advantages. The use of optical devices requires the modernization of the measuring device – ECPI. In the general case, this concerns the adaptation of the information and measuring subsystems to work in the conditions of the new measuring path. In addition, the issue of modernization of other ECPI blocks (control unit, information display unit, etc.) is considered. Modernization of ECPI should not significantly affect its final cost. By the way, this issue should also be taken into account when choosing optical measuring devices. In conclusion, we would like to emphasize the following. Unfortunately, today not all regional energy companies of Ukraine are able to implement the considered measuring path. This is due to the need for systematic and simultaneous reconstruction of their electrical networks (for example, simultaneous operation of analog and digital devices in relay protection and automation systems is practically impossible). In addition, a significant number of our regional energy companies have a difficult material and financial situation. Taking into account the significant prospects and interest of both scientists and technological workers in the issues under consideration, the scientific and technical community continues to actively work on the issues under consideration.

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ПІДВИЩЕННЯ ТОЧНОСТІ ВИМІРІВ ЕЛЕКТРИЧНИХ ВЕЛИЧИН У МЕРЕЖАХ ОБЛЕНЕРГО

У статті розглянуті питання підвищення точності та достовірності вимірів електричних величин в галузі електроенергетики. Високовольтний вимірювальний тракт складається з трансформаторів струму, напруги та вимірювальних приладів. Запропоновано, в якості вимірювальних трансформаторів використовувати оптичні трансформатори струму та напруги. Розглянуті переваги використання оптичних трансформаторів, та їх основні принципи функціонування. Суттєвими перевагами цих пристроїв є те що вони працюють з миттєвими значеннями струмів та напруг. Розглянуто питання модернізації вимірювального пристрою індикатора параметрів енергоспоживання, що розробляється на кафедрі передачі електричної енергії Національного технічного університету «Харківський політехнічний інститут»з 2005 року. Показано, що індикатор параметрів енергоспоживання являє собою інтелектуальну систему, що складається з двох підсистем інформаційної та вимірювальної. Основні вимоги до вимірювальної частини передбачають реалізацію функцій контролю та обліку електроенергії у трифазних мережах змінного струму. Крім того, вимірювальний модуль повинен забезпечувати індикацію контрольованих параметрів, підтримувати функції задання параметрів, приймання інформації через інтерфейс EIA-485, а також зберігання отриманих даних. Інформаційна частина вимірювального приладу реалізується з підтримкою стандарту ITU-T G.984 (включаючи FXS), при цьому міжмережеве з'єднання між WAN та LAN інтерфейсами має функціонувати як у режимі комутатора, так і маршрутизатора. Представлено вимоги до технічної продуктивності індикатора параметрів енергоспоживання. Керування вимірювальним пристроєм здійснюється відповідно до стандартного протоколу управління OMCI згідно з рекомендацією ITU-T G.984, з урахуванням положень G.988. В індикатор параметрів енергоспоживання повинен бути вмонтований блок обмеження потужності. Приведено вимоги до надійного використання вимірювального пристрою.

Ключові слова: оптичний трансформатор струму; оптичний трансформатор напруги; індикатор параметрів енергоспоживання; вимірювальна підсистема; інформаційна підсистема; інтерфейс.