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Analysis of External Insulation of Optic- Fiber 35 KV Current Transformer

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ANALYSIS OF EXTERNAL INSULATION OF OPTIC- FIBER 35 KV CURRENT TRANSFORMER

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The work represents the information of both traditional electromagnetic and new domestic and foreign versions in the field of high-voltage optoelectronic microprocessor current and 35 kilovolt potential transformers with different principles of operation. The current status of electrical power station systems is discussed in this article. An analysis of high-voltage measuring current transformers is carried out. A comparison of the main parameters, between conventional transformers and optic-fiber is made. It is proved that optic-fiber transformers eliminate the disadvantages of traditional transformers. The further implementation of optic-fiber current transformers in the electric power industry is analyzed.

Key words: optoelectronic transformers, optoelectronic sensors, Faraday's effect, high voltage.

Introduction. Current transformers (CT) are designed for reducing alternating current to controlled level in proportion to the corresponding original values. They provide halvanic isolation of measuring devices, counters, relays, etc. from the high-voltage (HV) circuit. Principle of their operation is based on the electromagnetic induction law.

Digital (microprocessor) systems of relay protection, automation, automatic control, measurement and dispatching systems are modern trends in the world power industry, along with the existing traditional systems of relay protection, emergency control, measurement and metering at power plants and substations, And this situation leads to an increase in the load on CT and, as a result, to a deterioration in the accuracy class of CT.

Grechukhin V.N. [1] analyzed the economic conditions for the functioning of power energy enterprises and energy systems in his work "Electronic current and voltage transformers". According to this work, it is necessary to increase the accuracy of electricity monitoring signals. Digital metering systems can achieve it, but, the insufficient accuracy class of conventional CTs is a barrier on this path.

World leading companies' designers strive to develop CTs of a higher accuracy class (better than accuracy class 0,2S and 0,2) with greater load capacity. Satisfying these requirements will inevitably lead either to an increase in weight and size indicators (larger amount of electrotechnical steel, copper and other high-cost materials), which is undesirable under the conditions of current economy situation. The identified problems have led to more intensive use of insulation, and according to international normative documents, this question remains open and relevant.

On the modern stage of the HV technology development conventional transformers have reached the limit of their capabilities and can hardly meet new requirements and tendencies, such as digitalization, safeness, and compactness.

Search for an alternative technical solution measuring current and voltage of high voltage electric power plants started a long time ago both in our country and abroad.

These researches have become more relevant considering the intensive process of introducing microprocessors into control systems, measurement, relay protection, emergency control at substations.

Optic-Fiber Current Transformer (OFCT) is next-generation transformers. In our country many transformers are approaching deadline of service life. Implementation of the modern technologies makes senseless replacing the old current transformers (CT) with the similar new ones, as they can be hardly paired with digital communication methods.

Aim of the work. Analysis of materials and shapes used in external insulation design, in terms of optimal protection of optical sensors from natural phenomena and breakdowns.

Current and voltage transformers. Advantages and disadvantages. Among the requirements for high-voltage current and voltage transformers, the main ones can be singled out:

• electrical safety of personnel and secondary circuits of all systems on the control panel of the station or substation, i.e. ensuring high-voltage isolation between the primary and secondary circuits of CT and VT;

• accuracy of measurement of primary current and voltage

These requirements determine the construction features of the CT and VT.

The economic conditions for the functioning of energy enterprises necessitates to increase the accuracy of electricity metering.

The magnetic system of traditional transformers results in such flaws, as phenomena of saturation, hysteresis, resonance, residual magnetization, as well as large weight and dimensions. To surpass these drawbacks the OFCT was developed.

To the main advantages of this transformers Khairulin I. and Pashali D. in their work "Fiber optic components transformers as modern electrical and complex systems" [2] includes the following:

• Fast installation;

• Small size and weight;

• Multi-function: metering & protection in one device;

• Self - monitoring;

• Simplifies substation or feeder design by allowing a simple template design for multiple applications;

• High precision control and metering of electricity;

• Transmission without distortion of all information in short circuit modes, including aperiodic SC current component;

• Digital communications;

• OFCTs have analog and digital outputs, and, therefore, compatible with existing secondary circuits as well as with advanced information systems;

• Spark-, explosion- proof;

• Versatility in production;

• Lower operating costs;

• Economic viability.

Research of OFCT is ongoing in order to accomplish the following tasks:

• improve accuracy;

• improve in temperature and time stability;

• suppress the vibration sensitivity;

• ensure the transformation of the aperiodic component of the short-circuit current;

• create more cost-effective technology of the current sensor.

Principle of operation. The Faraday effect was the first magneto-optical effect to be proposed and demonstrated in fiber current sensors. Fig. 1 shows a schematic configuration of the Faraday rotation. When a light beam passes through an optic medium in a magnetic field, its polarization vector is rotated in proportion to the field. The Verdet constant V relates the line integral of the magnetic field B to the rotation of the polarization plane of a linearly polarized, according to the equation [3–4]:

$$\varphi = V \oint B\, dl \qquad (1)$$

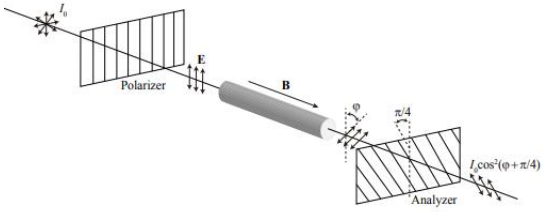

Figure 1 - Faraday effect

Design features. As the OFCT operation principle is based on the magneto-optical Faraday effect, as in Fig. 2, these transformers are free from a magnetic system and its shortcomings.

It follows that the design assumes a simplified execution of external and internal insulation, because the fiber-optic cable is made of dielectric material and transformer overall dimensions are much less. And opto-electronics can be remote from the operating OFCT to a distance up to 1 km, without signal distortion.

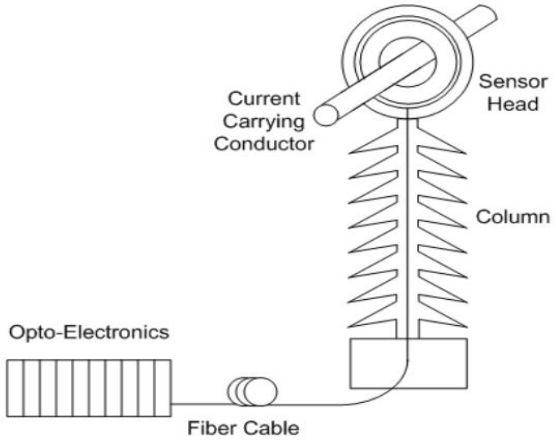

Figure 2 – Common view of optical current transformer.

Another advantage of these transformers is that the current measuring element can be made in different modifications, as it [4]. Some examples can be seen at the Fig. 3.

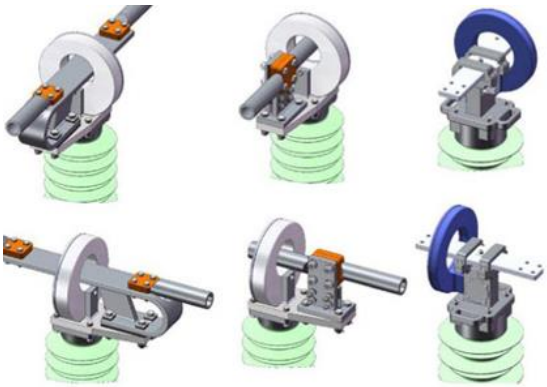

Figure 3 – Different types of optic current sensors.

The drawback of this installation is that the opto-electronics requires external low-power energy source (50W) for their operation.

There are many analogues of optical current sensors. Abramenkova I. and Korneev I. analyzed the product characteristics of leading manufacturers by sensor's main parameters in their work [5]. The result of their work is represented below in the table.

Table 1 - Comparative characteristics of fiber optic current sensors of various companies

Characteristic	Nxt Phase	Field Metrics	ABB	Airak
Rated current, kA	0,1-100	0,6-20	1-3,5	0,003 -30
Rated voltage, kV	69-750	11-36	75-800	3,6-36
Accuracy, %	0,25	0,2	0,2	1
Frequency bandwith, Hz	0,01-6000	5000	10000	5000
Mass,kg	49 -65	5 - 15	50 - 186	0.029 - 0.6

As a result, OFCT can be represented as an adaptable system for any equipment: old-fashioned analog

output for substations with old complementary equipment and digital output for modern digital substations.

Insulation analysis. Insulators are one of the most important elements of the equipment of electric networks. Uninterrupted operation of the networks and the quality of supplied electricity directly depend on the quality of the used insulators, their reliability and type.

In terms of design the main point of the OFCT is their low weight and fast installation procedure. Polymer type insulators have the same advantages in comparison with other types. Moreover, some of their drawbacks are overlapping with OFCT design. To improve insulator strength, if it is necessary, fiberglass reinforcement plate can be placed in body of insulator. To reduce hygroscopicity, such insulators are coated externally with waterproof varnishes.

So, all these factors make polymer insulator the best choice for OFCT design.

We do not need internal insulation, as the fiber cable is dielectric, the OFCT insulation economical advantage is already proved. So, lets focus on the external insulation parameters.

To increase the economic effect, it is possible to design the insulator with the alternate rib length, as in Fig.4. Such approach saves costs for the insulator production.

Figure 4 – Example of alternate rib length on the polymer insulator

The calculations and analysis of external insulation was carried out according to the well-known methods of Afanasiev V.V. [6] with implementation of other 'know-how' methods. According to these methodologies the corresponding software was developed. The results of the calculations can be seen at the Fig.5 and Fig.6.

The followed marks, according to the ГОСТ 1516.2[7], corresponds to three levels of insulation category:

'А' – low pollution level,

'Б' – moderate pollution level,

'В' – high pollution level.

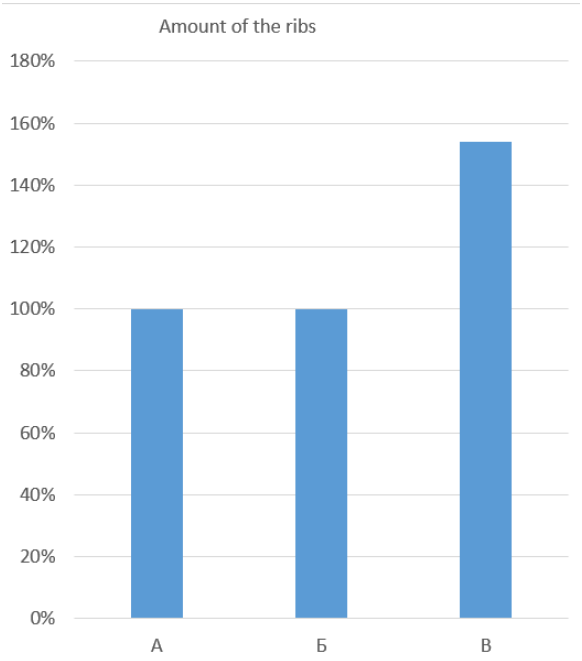

Figure 5 – Polymer insulator ribs amount dependency from the category of insulation.

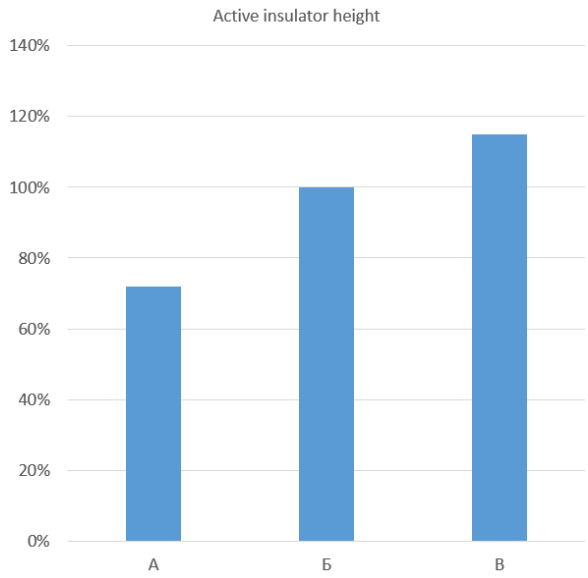

Figure 6 – Polymer insulator active height dependency from the category of insulation

Conclusion. The external insulation of OFCT 35kV is researched for 3 contamination types of insulation. The results of the work represented in the diagrams above.

The further research intention is to develop more economically effective optic current sensor.

It is obvious, that the development of digital current transformers and their use together with microprocessor-based measurement devices at substations with the prospect of a transition to a "digital" substation, where all information flows are circulated and processed in digital form is a promising area of research.

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АНАЛІЗ ЗОВНІШНЬОЇ ІЗОЛЯЦІЇ ОПТО-ВОЛОКОННОГО ТРАНСФОРМАТОРА СТРУМУ 35 КВ

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Робота представляє інформацію щодо як традиційних електромагнітних трансформаторів, так і нових вітчизняних та зарубіжних, в області високовольтних оптоелектронних мікропроцесорів та 35 кіловольтних трансформаторів основаних на різних принципах. Поточний стан систем електростанцій обговорюється в цій статті. Проведено аналіз високовольтних вимірювальних трансформаторів струму. Зроблено порівняння основних параметрів між звичайними трансформаторами та оптико-волоконними. Показано, що оптичні волоконні трансформатори усувають недоліки традиційних трансформаторів. Проаналізовано подальше впровадження оптико-волоконних трансформаторів струму в електроенергетиці.

Ключові слова: оптоелектронні трансформатори, оптоелектронні датчики, ефект Фарадея.

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