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THE PROBLEM OF MEASURING LARGE CURRENTS WITH THE HELP OF CURRENT SENSORS

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ABSTRACT
This study examines the characteristics of current sensors used for the control and monitoring of power supply facilities of industrial enterprises by comparative analysis. High-value currents generated by the industrial power supply system are divided into small volumes. Magneto-galvanic and magneto-modulation current sensors are used to measure large alternating currents, and current transformers are preferred for measuring large alternating currents.
KEYWORDS: ***magneto-galvanic, magneto-modulation, magneto-optical current sensors, magnetic current comparators, current transformers.***

INTRODUCTION
The modern stage of power development is accompanied by an increase in operating voltage and current, which in turn requires the improvement of electrical equipment. In particular, it is planned to use 500-750 kV and 1150-1800 kV power transmission lines for large-capacity transmission. It should also be noted that energy consumption is carried out at constant and alternating currents. For example, in several chemical and metallurgical industries, large currents up to 300 kA are used in transport [1, 2]. At the same time, the use of energy-saving technologies at the modern level of technology is typical.

Improving the accuracy of current measurements plays an important role in the economical and rational use of energy resources, which is associated with the establishment of optimal operating modes of devices and the establishment of a rational option for conducting technological processes.

Obtaining information about large currents is a particular challenge because they cannot be measured directly. This requires the use of intermediate devices - current sensors [2]. The function of the current sensors is to provide information about large currents in a form that is easy to use. It should be noted that the measurement of large currents is not possible without such current sensors.

The accuracy of the information obtained and the level of performance of the assigned tasks are often determined by the error and other characteristics of the current sensors, which determines the relevance of the search for ways to improve such devices. It should also be noted that the current technical solutions in most cases do not give the desired result.

In addition, the improvement of the metrological supply system for the measurement of large alternating and alternating currents is an important task, as a large part of the energy produced in networks using large alternating and alternating currents is consumed. Although the number of current sensors measuring such currents is much larger, this system is far from satisfactory. This problem was caused by the selection of current sensors without taking into account the measured current and voltage scale.

1. Classification of large currents
Due to a large number of controlled and controlled objects, the size of the corresponding currents, it is necessary to define the concept of "large" current. The lower limit of the measured

"large" current can be set based on a zero value that can be measured directly by the ammeters used in practice [1]. In practice, ammeters use additional scale converters to expand the measuring range. The upper limit of such ammeters can be several tens of amperes. On the other hand, the accuracy of the measurement should also be taken into account when setting the lower limit of current converters that measure larger currents. Analysis of existing large current measuring current sensors shows that their bulk of them can measure currents of 10 A and greater with sufficient accuracy [2, 3].

The upper limit of large currents is determined by modern energy advances. The maximum currents occupied by the industry are up to 500 kA at constant current, up to 70 kA at alternating current in the set mode, and up to 700 kA at alternating current [4, 5]. Currents of up to 1000 kA are expected in the future [3].

From the above, it can be seen that the measuring range of large currents is 10-106 A. The task of creating a universal device that can measure current at this scale with the required accuracy is very difficult and practically impossible. Therefore, it is recommended to divide the total scale into smaller ones as shown in the figure below, and for each small-scale, current sensors measuring large currents of one type or another in a design solution should be recommended (Fig. 1) [1].

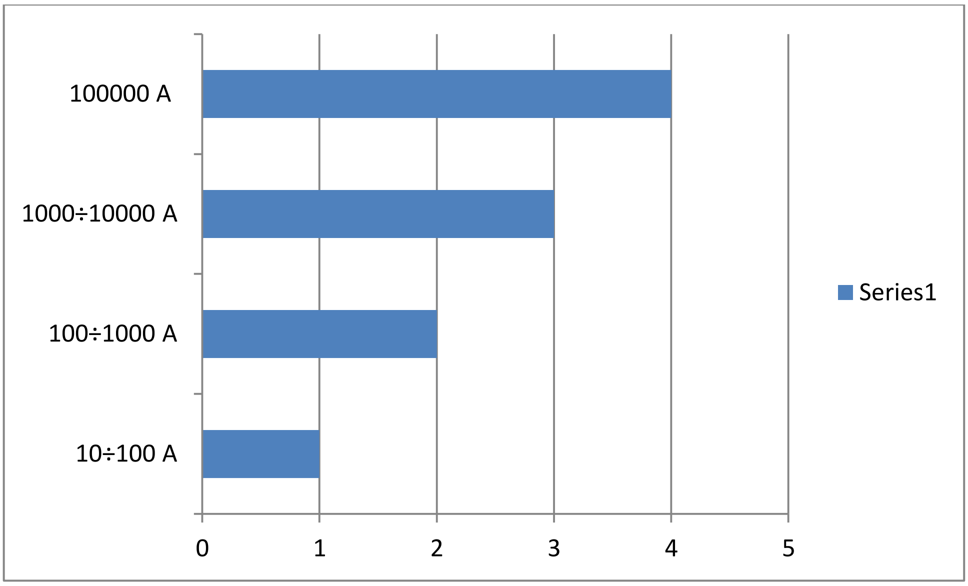

Figure 1. The scale of measured currents.
1 - Relatively small currents (10-102 A); 2 - large currents (102-104A); 3 - very large currents (104-105A); 4 - very large currents (105 A and greater).

2. Types of measuring transducers.

Owing to the purpose of changing large currents, different requirements are placed on the accuracy characteristics of current sensors measuring large currents. For example, if the device requires high reliability and stability of characteristics to change large currents when used for control and management systems, the extreme precision required for typical test devices is not required. Extremely high accuracy of modification will be needed to test new products - electric machines, apparatus and more. To achieve an adequate reserve of reliability, large current measuring sensors with 2-3 times higher accuracy are used in these cases. We know that large currents and high-voltage scale transformations into an electricity metering system include the tasks of multiplying them and integrating them over time [6]. To achieve high accuracy of the final result, it is necessary to reduce the errors of all components of the error, including current and voltage sensors. Large current flow sensors designed for laboratory and scientific research differ in purpose from the devices discussed above. Correspondingly, their technical characteristics and constructive performance differ [1]. They differ primarily in the wide range of alternating currents. The second feature is that it requires very high precision. Therefore, large current measuring meters for laboratory and scientific research form the nomenclature for electro technical devices, and instruments for measuring (verification) work for various purposes.

There are some peculiarities in measuring large currents [1, 7]. One of them is a very strong precise chain and depends on their geometric dimensions. For current sensors, such chains are rigidly mounted massive stationary tires or tire packs. Therefore, the installation of current sensors requires a lot of work to disconnect the current conductors and it is not possible to do it at the right place and time. Accordingly, one of the requirements is to prepare a separator of current sensors that measure large currents. The next feature of large current circuits is the continuity of the power supply system. The main requirement in AC and AC (up to 750-1500V) power lines, transformer and generator outputs is to provide galvanic separation between measuring and power circuits [3].

Large alternating current sources typically use acoustic, semiconductor, or thyristor alternating current sensors. In this case, large alternating currents are obtained not from a single, but several aggregates connected in parallel to the total load. In most cases, these currents are measured separately, ie separately from each unit, and from their sum secondary signals of current sensors are formed [7].

The measurement and control of large currents are carried out using a measuring current sensor, the main purpose of which is to change the value of a large current to a second physical quantity, usually an electrical (current, voltage) magnitude by nature. The measured magnitude value is proportional to the large current and is convenient to transmit to measuring or control and monitoring systems, the scale of change and other technical characteristics are coordinated with the output characteristics of the measuring current sensor.

It is known [1] that there are two views (principle) of the physical nature of current in current sensors measuring large currents:

1. Occurrence of potential difference in alternating current flowing resistance terminals;

2. The formation of a magnetic field in the space around the conductor is used by the law of complete current.

In the latter case, the magnetic field is often an intermediate magnitude, and in the first case, the measuring current sensor does not play the role of the output magnitude as the voltage obtained at the output. The state in which the current sensor measuring large currents is used in the first principle is called resistive, and the state in which the second principle is implemented is called electromagnetic because the current is used in one form or another. Depending on the conversion of the magnetic field to the output signal, the current sensor measuring large currents differs as follows: Induction (current transformer), magneto-modulation (alternating current transformers), magnetic current comparators, magneto-galvanic, magneto-resonance, magneto-optic, electromechanical.

3. Characteristics of current sensors measuring large currents.

A comparative analysis of the main characteristics of large current measuring sensors given above [1 ÷ 10] showed that each resistive measuring current sensor is invariant to the external magnetic field and ferromagnetic mass, no additional supply source is required, but they cannot be used in high voltage circuits. They require chain breakage and have a large dynamic error. Resistive measuring current sensors are affected by various physical quantities: electrical, magnetic, mechanical, thermal, light magnitudes, as well as lead to work instability and errors. Their mass is large, small reliability, limited to multidimensional [3]. The electromechanical large current measuring current sensor is simple to implement, highly reliable, autonomous and universal in application, while the presence of moving parts and additional errors limit their widespread use [6]. In particular, part of the converted energy is released in the form of heat. The advantage of a current sensor that measures magneto-modulation large currents is that it can be used in high voltage lines and the output power is significantly larger. The disadvantages can be described as follows: the effect of an external magnetic field has a large, relatively large inertia in the mass index when measuring very, very large currents [8, 9]. Magnetic current comparators are more accurate, sensitive, and capable of converting extremely large currents than other large current measuring sensors. Autocorrelation of the current in the circuit requires the introduction of protection of the core from foreign fields and has large inertia. However, the construction is very complex. Although magnetoresonance meter current sensors are large alternating current meters with the highest accuracy, the need to disconnect the circuit during installation requires a strictly evenly distributed magnetic field, a large threshold of sensitivity limits their scope of application. The uniqueness of magneto-galvanic large current measuring current sensors is that they have a relatively high sensitivity and high speed. Disadvantages: Constructive and technological complexity, as well as the instability of the characteristics [9, 10].

The compactness and lightness of the parts, which can be used in high-voltage lines and devices, show that magneto-optical measuring transducers are promising in measuring large currents. However, their disadvantage is that they have a relatively small sensitivity, complex structure, and the fact that the current depends on the polarity angle is not the same [11]. Alternating current transformers are widely used in various sectors of the economy and in the control and management systems of power supply devices of electrified transport systems. They have high metrological characteristics, high reliability, overload capacity, simplicity of service and large output capacity. The disadvantages of alternating current transformers are the influence of the external magnetic field, the decrease in the metrological characteristics of the transient processes of work, the lack of ways to adjust the magnitude of the change.

4. Application of large current measuring sensors depending on the measured current value.

To select and use current sensors that measure large currents, it is necessary to take into account the

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specificity of the object and the purpose of their use (Table 2).

Description	Current transformers	Resistive	Magneto-galvanic	Magneto optic
Operating temperature range, ° C	-45 -+50	Not applicable	Not applicable	Not applicable
Rated voltage, kV	10			
Nominal current, A	5;10;15;20;30;40;50; 75;80;100;150;200; 300;400;600;800; 1000;1500;2000; 3000;4000;5000;6000			
Accuracy class	0,25;0,5,5;0,5			
Weight, kg	20 to 90			
Working frequency	50,60			
Secondary chain galvanic bonding	Electromagnetic			
Secondary circuit output parameters	1A 5A			
Price	High			

2 Table. 6-35 kV Nominal voltage.

In our opinion, comparing current sensors used in practice for various sectors of the economy, including electrified transport power supply system, the results of the analysis suggest the use of magneto-galvanic and magneto-modulation current sensors measure large alternating currents, current transformers to measure large alternating currents (Fig. 2).

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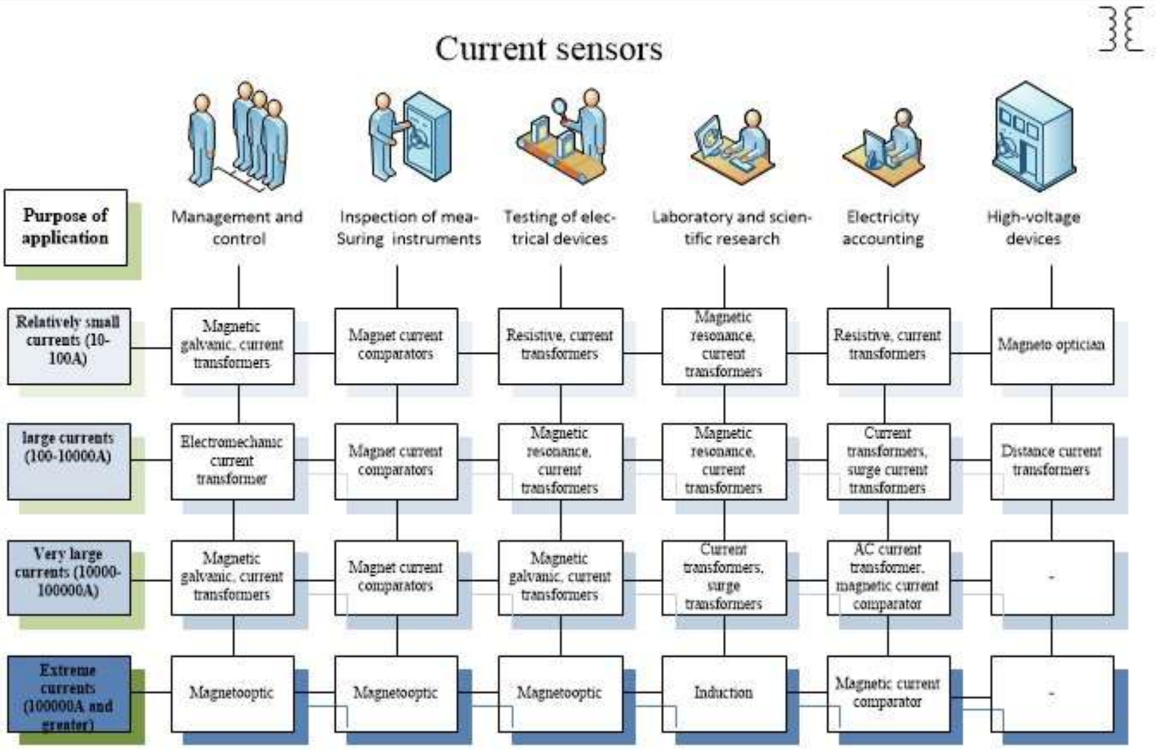

Figure 2. Selection of current sensors according to the scope of currents and purposes of use.

5. Selection of current sensors measuring large currents according to the object voltage

When we studied the application of large current measuring transducers depending on the current value above, we saw that the following four types are used: resistive, galvanic magneto, current transformer, and magneto-optic current sensors. Consider these current sensors for three classes of voltage (low to 1kV, medium 6-35 kV, high 110-750kV) (Tab. 1, 3).

Description	Current transformers	Resistive	Magneto-galvanic	Magneto - optic
Operating temperature range, ° C	-45 - +60	-40-+60	-40-+150	Not applicable
Rated voltage, kV	To 0.66 kV	To 1 kV	To 6 kV	
Nominal current, A	5; 10; 15; 20; 30; 40; 50; 75; 80; 100; 150; 200; 300; 400; 600; 800; 1000; 1500; 2000; 3000; 4000; 5000; 6000 15000; 25000	0,3; 0,5; 0,75; 1; 1,5; 1; 1,55; 4; 5; 6; 7,5; 10; 15; 20; 30; 50; 75; 100; 150; 200; 300; 500; 600; 1000; 1500; 2500; 4000; 6000; 7500; 10000; 15000	Open type: ±57,... ,±950 type of compensation: ±5, ... ±1200 A logical output 0,5; 3,5; 5,0; 7,0; 10; and 54 A	
Shelf life, years	30	15	20	
Working frequency	50, 60 Hz	500 kHz	Open type: 100 kHz, compensation system 1 MHz	
Galvanic dependence	Electromagnetic	No	Absolute	
Price	High	Low	Medium / high	

Accuracy class	0,2; 0,2S;0,5S,1	0,2; 0,05; 0,1; 0,2; 0,5	0,1 to 0,8	
Weight, kg	0,5 to 150	0,1 to 35	To 1 kg	

Table 1. 1 kV rated voltage.

Description	**Current transformers**	**103**	**Magneto-galvanic**	**Magneto optic**
Operating temperature range, ° C	-60-+55			-50-+60
Rated voltage, kV	110-750			110-750
Nominal current, A	100;150;200;150; 300;400;500;600; 750; 800;1000;1200 1250;1500;1600;2000 2500;3000;3500;4000; 5000;6000;8000;9000; 10000;12000;15000;18000			100-500000
Accuracy class	0,2;05			0,2
Weight, kg	450-7500			40 kg to 400 kg
Use	30			30
Secondary chain galvanic bonding	Electromagnetic			Absolutely
Price	High			High

Table 3. 110-750 kV Nominal voltage table.

CONCLUSION

1. The most common current sensor in the system of control and monitoring of power supply facilities in the national economy and electrified transport AC is a current transformer. The current transformer operates over a wide range of temperature and rated current has sufficient accuracy for practical use, and can operate over a wide range of rated voltage. Current transformers provide secondary circuit galvanic separation [4]. The main drawback is that the secondary winding is not allowed to separate from the load, as this condition causes an emergency due to overvoltage and overheating. Resistive current sensors can be used in low-voltage alternating and fixed circuits. It is simple to perform, has high measurement accuracy, but its galvanic contact with the primary current circuit limits their areas of use.
2. The analysis shows that magneto-galvanic current sensors are widely used today to measure alternating and non-alternating currents. Disadvantages: temperature dependence, small nominal voltage range compared to current transformers. Magneto-optical current sensors are often used to measure very large currents. The future development of large current measuring sensors should be focused on the creation of large-scale measuring current sensors that convert large currents on a large scale, have high measurement sensitivity at relatively small currents, provide stable characteristics and high metrological characteristics in transient processes in power supply systems.
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COMPETING INTERESTS

The authors declare that they have no competing interests.

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