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COMPARATIVE ANALYSIS OF MODERN CURRENT CONVERTERS

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ABSTRACT

The article studies the problems of alternating and direct currents. Existing and widely spread types of great current converter meters are analyzed. Advantages of magneto-galvanic and magneto-modulating converters of great direct currents are explained as for as transformers for metering for great alternating currents. The ways of improving the construction of such devices are also shown here.

KEYWORDS: ***Large unchanging current, a large alternating current, Measurement Scale, magneto galvanic converters, magnetic modulation converters, electromechanical converters, magnetic resonance converters, current transformers.***

1. INTRODUCTION

At the current stage of energy development, when electrical appliances and power tools are widely used, accurate measurement of current strength is important in ensuring high reliability and safety of industrial systems and networks.

As an example, consider the measurement of large currents in electrified rail transport: traction generators. Locomotive and electric locomotive motors, traction substation transformers and converters (samplers), power transmission lines, consumers and separate elements of electrified railway power supply system (27.5 and 6 kV inputs, 6 kV distribution device feeders, contact network, maintenance points, SCBS (signalling, centralization, blocking systems), TCR (two-conductor-rails), compensating devices, bus connectors, chargers together with control and management of battery operating modes; testing, manufacture and consumption of electrical equipment and devices in the process of managing tasks such as accounting for the electricity being done, there is a need for large AC and AC converters.

1.1 Classification of measured currents by value.

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 current converters that measure large currents shows that the bulk of them can measure currents of 10A and larger with sufficient accuracy [2]. The series Z-source network, an expansion of the popular concept of the Z-source dc link, was originally proposed for boosting the output voltage of power electronic inverters. In this paper, that idea is extended on a three-phase indirect matrix converter. The converter is based on the ultrasparse matrix topology characterized by the minimum number of semiconductor switches [26].

The upper limit of large currents is determined by modern energy advances. The maximum currents taken by the industry are up to 500 kA in AC, up to 70 kA in the built-in alternating current, and up to 700 kA in the alternating current [3]. Currents of up to 1000 kA are expected in the future [4].

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

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very difficult and practically impossible. It is therefore recommended that the total scale be divided into the following small scales: Relatively small currents (10-102 A), large currents (102-104A), very large currents (104-105A), very large currents (105 A and greater) and for each small scale a large current meter of this or that type and design solution should be recommended [4]. Many modern power conversion systems require a bidirectional energy transfer capability as a central part of their system operation [12]. AC and DC power transfer paradigms clashed with each other in the early days of the electric power system. [14, 23]. Two types of DC-DC converters are compared [22, 27].

1.2 Types of large current measuring converters.

Due to the purpose of changing large currents, different requirements are placed on the accuracy characteristics of large current measuring transducers. 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. Voltage Source Converter based High Voltage Direct Current (VSC HVDC) technology is used more and more in modern power systems [14, 15]. To achieve an adequate reserve of reliability, large current measuring transducers with 2-3 times higher accuracy are used in these cases. Voltage Source Converters (VSC) are becoming more common in modern High Voltage DC (HVDC) transmission systems [16]. 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 converters. Large current measuring transducers 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 current. The second peculiarity is that it requires very high precision. Therefore, from large current meters for laboratory and scientific research to electrotechnical devices, instruments for measuring (verification) work form a nomenclature for testing for various purposes. Microminiature electromechanical inertial sensors are created with electrostatic converters which possess high adaptability to manufacture [30, 31, 32].

There are some peculiarities of measuring large currents [1, 7]. One of them is a very strong precise chain and depends on their geometric dimensions. The conductors in such chains are solid stationary tires or tire packages that are rigidly mounted. Separation of conductors from this is labour-intensive and impossible to do in the right place and time. Accordingly, one of the requirements is the separation of large current measuring transducers. The next peculiarity of large current circuits is the continuity of the power supply system. In AC and DC power lines (up to 750-1500V), the main requirement at the outputs of transformers and generators is to provide galvanic separation between measuring and power circuits [8, 29].

Large DC sources typically use symbolic, semiconductor, or thyristor AC-to-AC converters. In this case, large alternating currents are obtained not from one, but several units connected in parallel to the total load. In most cases, these currents are measured, i.e. separately from each unit, and from their sum secondary signals of the converters are formed [7].

In measuring and controlling large currents, the main purpose of changing a large current value is through a measuring transducer, which is usually a change in electrical (current, voltage) magnitude to a second physical quantity. The measured magnitude value is proportional to the large current and is convenient to transfer to measuring or control and monitoring systems, the scale of change and other technical characteristics are coordinated with the output characteristics of the measuring transducer.

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

1. The 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 variable does not play the role of the output magnitude as the voltage obtained at the output. The state in which a large current meter 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, a large current measuring transducer is distinguished as follows: Induction (current transformer), magnetic modulation (alternating current transformers), magneto-current comparators, magneto-galvanic, magneto-resonance, magneto-optic, electromechanical. In modern railways coaches, the electrical separation between the high voltage side and the auxiliary types of equipment on the consumer side is realized by means of heavy and bulky 50 Hz transformers [13].

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1.3 Negative and positive properties of a large current measuring converter.

A comparative analysis of the basic characteristics of large current measuring transducers above [1 ÷ 8] showed that each resistive measuring transducer does not require an additional supply source invariant to the external magnetic field and ferromagnetic mass, but they cannot be used in high voltage circuits. They require chain breakage and have a large dynamic error. The electromechanical large current measuring transducer is simple in design, highly reliable, autonomous and universal in application, however, the presence of moving parts and additional errors limit their widespread use [10, 11]. The advantage of a magnetic-modulation large current meter 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 of the mass index when measuring very, very large currents. Magnetic current comparators are more accurate, sensitive, and capable of converting very large currents than other large current measuring transducers. Autoclaving the current into the circuit requires protection of the core from foreign fields and has great inertia. Although the magneto-resonance meter is a large AC meter with the highest accuracy, the need to disconnect the circuit during installation, the need for a strictly evenly distributed magnetic field, the large threshold of sensitivity limits their scope of application. The peculiarity of the magnetic-galvanic large current measuring transducer is that it has relatively high sensitivity and high speed. Disadvantages: Constructive and technological complexity, as well as the instability of the characteristics. The compactness and lightness of the parts that 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, a complex design, and the dependence of the current on the polarization angle is not the same. Alternating current transformers are widely used in various sectors of the economy and 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 AC 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.

1.4 Application of large current measuring transducers depending on the current value.

Because of the above, the selection and use of this or that type of large current measuring transducers should take into account the specifics of the object and the purpose of their application. Boost and Buck-Boost PFC converter faces very high THD and poor PF in open loop control [24, 25]. Comparing the metering converters used in our opinion and practice in the management and control of power supply equipment in the national economy and electric transport, the results of the analysis are promising to use magneto-galvanic and magneto-modulation measuring converters and AC transformers in large AC transformers (Table 1).

Purpose of application	Management and control	Inspection of measuring instruments	Testing of electrical equipment	Laboratory and scientific research	Electricity accounting	Extremely high voltage devices
Relatively small currents (10-102A)	Magneto-galvanic, current transformers	Magnetic current comparators	Resistive, current transformers	Magnetic resonance, current transformers	Resistive, current transformers	Magneto-optic
large currents (102-104A)	Electromechanical current transformer	Magnetic current comparators	Magnetic resonance, current transformers	Magnetic resonance, current transformers	Current transformer, AC transformer	Remote current transformer
Very large currents (10 / 4-10 / 5A)	Magneto-galvanic, current transformers	Magnetic current comparators	Magneto-galvanic, current transformers	Current transformer, AC transformer	Alternating current transformer, magnetic current comparator	-
Extreme currents (105A and greater)	Magneto-optic	Magneto-optic	Magneto-optic	Induction	Magnetic current comparator	-

Table 1. Purposes of application of large current measuring converters.

1.5 Application of large current meters depending on mains voltage.

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

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 Compensation type: ± 5, ... ± 1200 A with a logical output of 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 2. 1 kV rated voltage.

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, Hz	50,60			
Secondary chain galvanic bonding	Electromagnet			
Secondary circuit output parameters	1A 5A			
Price	High			

Table 3. 6-35 kV Nominal voltage.

Description	Current transformers	Resistive	Magneto-galvanic	Magneto-optic
Operating temperature range, °C	-60-+55			-50-+60
Nominal 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	Electromagnet			Absolutely
Price	High			High

Table 4. 110-750 kV Nominal voltage table.

CONCLUSION

The most common measuring meter in the management and control system of power supply facilities of the national economy and electric transport is a current transformer. It operates over a wide range of temperatures and rated currents, has sufficient accuracy for practical application, and can operate over a wide range of rated voltages. Current transformers provide secondary circuit galvanic separation [4]. The main drawback is that the secondary winding is not allowed to separate, as this creates an emergency due to overvoltage and overheating. A resistive measuring transducer can be used in low-voltage variable and fixed circuits. They are simple to perform, have high measurement accuracy, but have galvanic contacts, which limits their field of application.

The analysis shows that a magneto-galvanic measuring transducer is now widely used to measure alternating and alternating currents. Disadvantages: temperature dependence, small nominal voltage range compared to current transformers, magneto-optic current transformers are used in most cases to measure very large currents. The future development of large current measuring transducers should be focused on the creation of large-scale measuring transducers that change 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. The SC converter is evidently a promising candidate for future high power density integrated DC-DC converters [17].

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