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An improved Current Voltage Transferring Device for high current high frequency measurement

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ABSTRACT

This paper represents the characteristics of the improved Current Voltage Transferring Device (CVTD) for high current measurement including lightning impulse currents. The improved CVTD has been developed from the prototype CVTD to provide exceptional characteristics for high current with high frequency measurement. The improved CVTD in h-shaped configuration is made of copper and aluminium. The relationship between input current and output voltages of the new CVTD was investigated with short and long duration lightning impulse currents to establish the empirical formulas. The typical impulse current generator was used to generate 8/20 μs lightning impulse current with the amplitude of 940 A while the impulse generator with crowbar elements was utilized to generate 10/350 μs lightning impulse current with magnitude of 30.2 kA for the experiment. The lightning impulse current measurement characteristics of the CVTD and Rogowski coil were examined. From the experiments, the new improved CVTD shows the superior characteristics to measure the impulse currents with very fast rise time. Besides, nanosecond pulses superimposed on the lightning impulse currents were detected by only the improved CVTD. According to the experiments, there is no doubt that the new improved CVTD is a superior one for high current with high frequency measurement especially lightning impulse currents.

1. Introduction

There are many measuring techniques applied for high current measurements for examples an analog ammeter connecting in series in the test circuit, hall elements measuring electromagnetic field generated from the circuit under test, and a current transformer (CT) measuring the induced voltage generated from a conductor wire in the test circuit. These current measurement techniques are suitable for AC current with power frequencies. Besides, Rogowski coil measuring the induced voltage generated from the test circuit and a special designed low-ohmic resistor connecting in series in the test circuit are usually applied for impulse current measurement [1–4]. The measurement error may occur to some extent when the low-ohmic resistor is applied for impulse current measurement due to the inductive component of such resistor. To overcome this problem, the current measuring by a shunt resistor has been introduced. Shunts can be divided into two types: tubular and wirewound. Tubular coaxial shunts are applied for measurement of high impulse currents. The tubular coaxial shunt resistance is between 0.1 and some 100 mΩ which is required to limit heat dissipation and loading effects on the test circuit. Due to free of a magnetic field within the current-carrying tube, the measurable current bandwidth of the tubular coaxial shunt is quite high. However, its upper frequency limit is determined by skin effect in the inner cylinder involving shunt dimension and material properties. Therefore, higher bandwidth or short risetime tubular coaxial shunts require very thin tubes made of material with high specific resistivity [5–9]. In case of wirewound shunt types, their resistance is in the range of some 50 mΩ–10 Ω. Details of wirewound shunts for measuring fast impulse currents have been well documented in Ref. [7]. In case of current measurement by CT, the induced voltage from external electromagnetic field may enhance the measurement error of this measuring system. Furthermore, the practical skill is needed to operate the CT to avoid the potential problems for the users or the CT itself. Some situations are avoided for example the opening of the secondary circuit of CT. Besides, CT's dimension may quite large and also heavy which can make a big trouble with the installation in the test circuit for measuring a large current. As above mentioned, applying each current measurement technique needs to be considered its limitation especially frequency bandwidth which is very important for high current with

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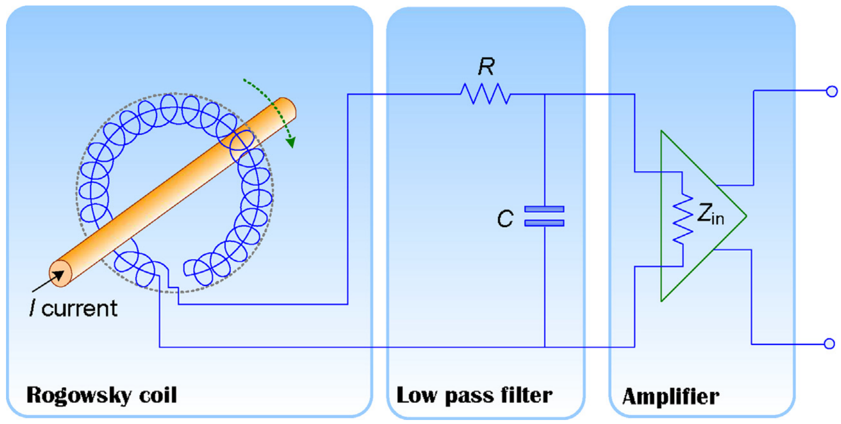

Fig. 1. Schematic diagram of the conventional current measuring method with the Rogowski coil.

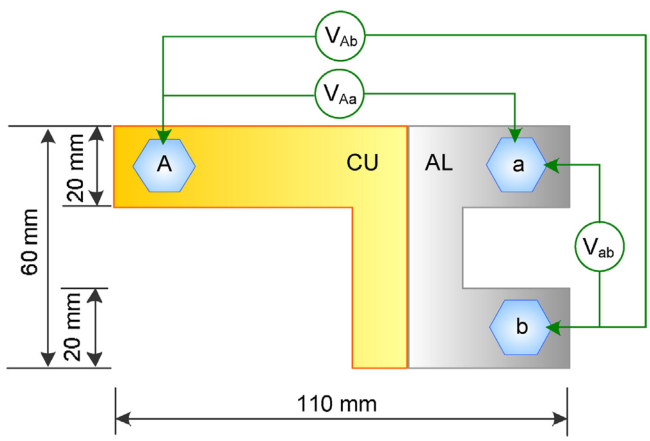

Fig. 2. The improved CVTD for high current measurement.

high frequency measurements in high voltage field. Many efforts have been devoted for developing high current with high frequency measurement techniques for high voltage engineering applications and researches in order to deeply understand the breakdown mechanism of the lightning discharges and switching discharges, plasma phenomena and so on. However, there is mostly no progress on developing the high current and high frequency measuring devices. Therefore, the prototype CVTD has been developed continuously for these proposes by the authors [10,11].

Focusing on the conventional Rogowski coil circuit as shown in Fig. 1, it composes three parts as the Rogowski coil, a low pass filter, and an amplifier respectively. Each part has a frequency band affecting the high frequency current measurement. Currently, maximum frequency is limited as a few MHz for application in high voltage field. However, some electrical components or circuits such as PCB (Printed Circuit Board) utilized in such field can properly operate above the mentioned frequency.

2. The improved Current Voltage Transferring Device

An improved Current Voltage Transferring Device (CVTD) for high current with high frequency measurement was developed from the prototype as reported in Refs. [10,11]. The improved CVTD consists of two different metals (aluminium and copper) forming to be a small letter "h" with the specified dimension as depicted in Fig. 2. Aluminium to copper joints have been widely used for over 40 years in a variety of applications such as in heat exchangers, power plants, electrical transmission lines (i.e. busbars) and so on because of their unique properties. Copper has superior electrical and thermal conductivity while aluminium provides average electrical and thermal conductivity, low density and a stable oxide layer [12,13]. Besides, the interface layer of the aluminium to copper joint should provide sufficient resistance; consequently, the voltage across the junction layer should sufficiently large to be measured when the current flows through the CVTD. It is reported that the resistivity at the aluminium to copper interface might up to 7 times compared to copper's resistivity [12]. The thickness of the CVTD is 8 mm. This CVTD can measure AC current up to 600 A for 1 minute which provides the maximum output voltage of 20 mA. Besides, it is expected to measure the impulse current with the maximum amplitude of 60 kA. The designed thickness of the CVTD is related to the maximum measurable current amplitude. Considering the CVTD configuration, the h shaped CVTD is the optimized dimension adapted from the comb shaped CVTD as reported in Ref. [10]. The improved CVTD dimension requires small size as possible for installation in the narrow space.

The improved CVTD has three terminals by which two terminals, terminal (A) and terminal (b), are used as the input terminal and the output terminal connecting in series in a DC testing circuit, so the measuring current flows through the different materials of the CVTD. Besides, the terminal (b) is used as the common terminal for the voltage measurement. The output voltage is the voltage across the input terminal (A) with the common terminal (b), V_{Ab}, and the remaining terminal (a) with the common terminal (b), V_{ab}, including the voltage across the input terminal (A) and the remaining terminal (a), V_{Aa}, which are measured and transferred to be the input current at the end. The output voltages obtained from V_{Ab}, V_{Aa} and V_{ab} should be different due to the interface characteristics between copper and aluminium. For impulse current measurement, terminal (a) and terminal (A) are connected in series in the impulse current measurement test circuit. The voltages across each terminal are measured.

3. Test experiments and test results

3.1. Direct current measurement by the new improved CVTD

To characterize the new designed CVTD, the DC current, *I*, generated from a controllable DC power source (max. 8 V, 12 A) was controlled and measured by the DC ammeter (type: moving coil, class 0.5) while the voltages (V_{Ab}, V_{ab} and V_{Aa}) were measured as shown in Fig. 3. The relationship between the input current, *I*, and the output voltages were calculated with a commercial software. The experiment was performed in short time to avoid the raising temperature of the connecting wire. Furthermore, the connecting wires and the CVTD connections were tightened due to reducing contact resistance problem. The output voltages were measured