Development of Portable, Accurate Current-measuring System on the Basis of Rogowski Coil – Actual State

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Abstract: - Contribution deals with the description of advances in the development of portable, accurate current measuring system at low, medium and high voltage potential. It is aimed at the building process of several specialized workplaces, where tests of measuring system's independence from strong electrical and magnetic fields take place, and at experiments, which should be carried out. On the one hand is necessary to verify the evolving measuring system's current transfer-characteristic density, on the other hand the model has to ensure safe in-service operation.

Key-Words: - Rogowski coil, High-voltage, High-current, Portable measuring system.

1 Introduction

Our department, The Department of Electrical Power Engineering of Faculty of Electrical Engineering and Information Technology of Slovak University of Technology in Bratislava cooperates in the research project no. APVV-0546-07 called 'Research and Development of New Precise Current Sensor for High and Very-high Voltage Applications' with other institutes and companies. We are involved mostly in testing of evolving measuring system based on Rogowski coil at various voltage levels and in ensuring the evolving device's operational safety.

The contribution provides a description of progress in workplace building-up process for the needs of testing, and the galvanic separation of measuring and indication units of evolving system as well.

2 Workplaces for testing

In order to solve our particular problem stated in mentioned research project, it was necessary to propose measuring workplace, where it is possible to generate large currents at high voltage potential. In early stages of solution was not possible to obtain a high voltage instrument current transformer, which would serve in its reverse connection as a current source, so we were forced to choose another route. However, over time we obtained an instrument current transformer up to 110 kV, and nowadays we have an instrument current transformer up to 420 kV as well. Building up three experimental workstations we are equipped to provide testing of developing measuring system at all existing voltage levels of distribution and transmission system used in Slovakia. The following subchapters are therefore devoted to different phases of building of necessary workplaces.

2.1 Workplace up to 30 kV

The first solution consists of a current transformer, high voltage cable and a high voltage transformer. The suggested design concept of workplace, more precisely its wiring schematic is shown in Fig.1.

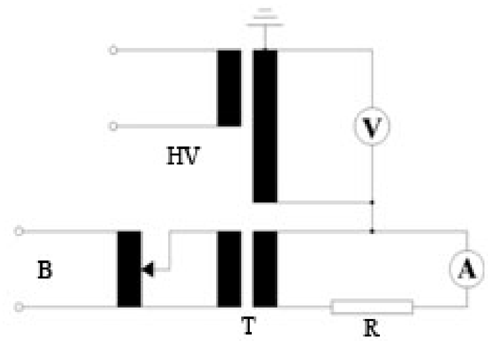

Fig.1 Wiring diagram of workplace up to 30 kV

The current transformer (type Elektrovod Jevišovice TS-24/6) marked T in Fig.1, is supplied by a booster B (type TuR Dresden REOgs 32/380-1M). A short-circuited middle voltage cable (NA2XS(F)2Y 1x300RM/25 - 18/30 kV) was chosen as a secondary winding of the current transformer (R in Fig.1). The reason for this selection is, that the selected cable is insulated by its working insulation (30 kV AC between the cable core and cable shielding, stated by the cable manufacturer) from current transformer. The shielding at one end of the cable is grounded. The second end's shielding is cut, which warrants the voltage-protection of current transformer. Both ends of the skinned core of the cable are connected. At this point is applied high voltage from medium voltage transformer HT (type TuR Dresden GPT 6/12,5). The current loading capacity of shorted circuit is limited by the type of cable used, more precisely by prescribed maximum core temperature. The maximum applicable voltage is defined by the cable insulation type.

The calibration point of designed workplace is the non-insulated core of applied cable. For voltage measurement is used a 30 kV voltage probe with HP 947A multimeter. Fig.2 shows the real connection of devices.

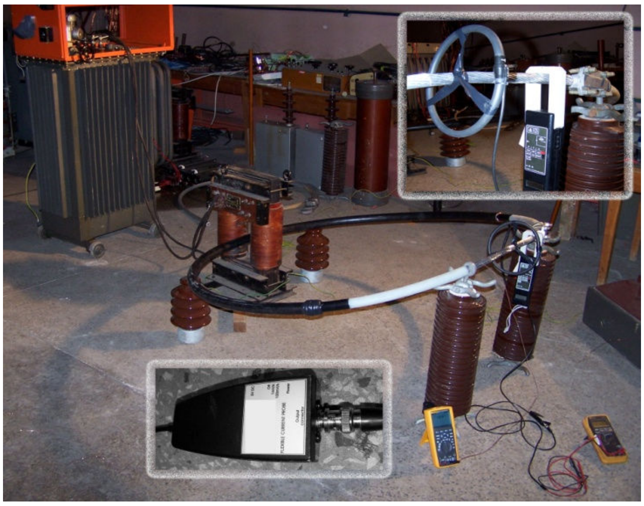

Fig.2 The real arrangement of workplace up to 30 kV

The ammeter clamp and the current sensor cable, a flexible inductive coil, are shown in the upper detail of Fig.2. The lower detail shows the electronic box of evolving precision flexible AC current probe based on Rogowski coil.

To demonstrate the functionality of the research equipment according to its current range a series of comparative measurements were accomplished by using ammeter clamp simultaneously with the developing measuring system based on Rogowski coil. The applied current range was chosen by respecting the short-time current loading capacity of selected circuit, and the maximum ranges of measuring devices. A maximum current value achieved during these test did not exceed 2kA. The temperature of cable core was continually controlled by a digital thermometer to ensure, that the maximum allowed overload temperature was not exceeded.

2.2 Workplace up to 110 kV

Upon obtaining the current instrument transformer up to 110 kV, all requirements were met to the construction of another workplace. Since the High Voltage Laboratory of our department has the necessary test transformers and as well as calibrated measuring system up to 300 kV it enabled to build up next workplace captured in Fig.3. From the available sources the transformer type PEOJ 100/200A up to 200 kV was used.

Fig.3 The real arrangement of workplace up to 110 kV

As shown in Fig.3, the instrument current transformer is reversely connected, supplied from low voltage side, and high voltage terminals are shorted using an AlFe line wire. Subsequently the value of 300 A was experimentally determined as the maximum current without any damage of instrument current transformer.

2.2 Workplace up to 400 kV

The final stage is the design of a workplace up to 400 kV. As a current source a reversely connected 420 kV instrument current transformer is used. The high voltage terminals of instrument transformer are shorted by an AlFe line wire. The most complex workplace can carry up to 500 A without any damage of used instrument current transformer. The only suitable voltage source available at our laboratory is the transformer cascade FPEO 1200/600 AB / K in conjunction with a calibrated 800 kV measuring system.

3 Performed experiments

As the first of a series of experiments performed were carried out the invariance measurements using the current characteristics of the reference instrument. These experiments were made at workplace no.1 up to 30 kV. The tested current range was chosen with respect to the maximum short-term overload capacity of selected scheme. During measurements the maximum temperature of the cable core did not exceed the value indicated by the manufacturer. The difference in currents measured by both systems did not exceed the value of 2 %, which is the accuracy class of used Clamp ammeter.

Further verification measurements were carried out to determine the influence of position of current probe on its accuracy. In core of medium voltage cable at workplace up to 30 kV flowed a constant current of 500 A. To eliminate the influence of cable core warming-up on its impedance and then on measured current the measurement was started after a period of two hours. The dependence measurements of current on the angle between the plane of the current probe and the plane perpendicular to the axis of the cable core took place. Measurements were performed in the range of angles of -70º to 70º with 10º steps. The zero angle was the case when the current probe plane was perpendicular to the vertical axis plane of the cable core. The relative differences in measured current values were in tolerance provided by the current probe manufacturer, but it is clear that the measurement probe is characterized by the largest relative error in case, when the connection of current probe is in touch with the cable core. This fact was proved for various arrangements. The real equipment arrangement during these tests is shown in Fig.4.

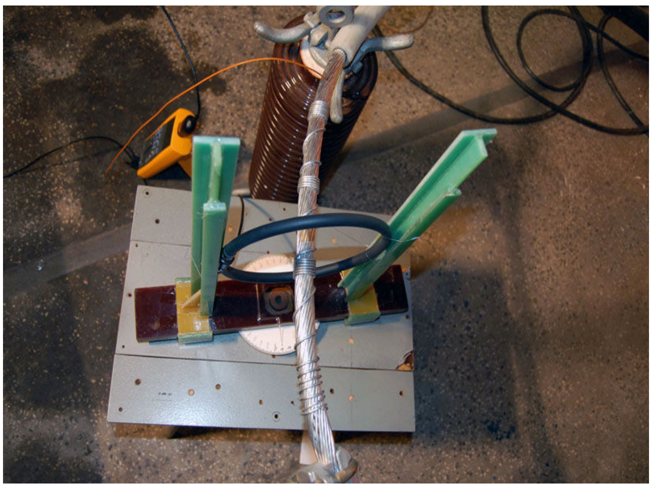

Fig.4 Position influence measurements

Next a series of test followed at different voltage levels. The precise current probe manufacturer claimed 600 V maximum applicable voltage in contact with non-insulated live parts. In order to apply a higher potential, the probe had to be taken away from the surface of the cable. In this case the maximum value of the voltage could rise to the level of 3kV. As the results show, no influence of applied voltage was obtained in range of 0 to 3 kV on measured current.

To increase the maximum allowed in-service voltage a galvanic separation between measuring and indication or evaluation units is necessary. The selected solution is the usage of two optical cables, when one of them is used to supply the media converter and the electronics, and the other one assures data communication. Usage of regular, on-the-market available optical cables is decided. The problem is that the producer of mentioned optical cables does not state the recommended intensity of electric field, where these cables are able to operate properly. Deploying a research in this field provided valuable information about the selected optical cables. Primarily was decided to verify the simplest arrangement of two equally long optical cables with their terminals on (shown in Fig. 5).

Before providing withstand test by applied AC high-voltage, the insulation resistance measurement took place by using the MEGGER S1-1052 insulation tester. The resistance evaluated by applied 10 kV DC was more than 500 GΩ. Breakdown voltage of 1m long optical cable pair was determined by 5 measurements to be 360 kV in relation to the earth under normal atmospheric conditions. Insulation resistance measurements ended with the same result as those carried out before withstand testing. This fact proves that either within the cable or on the surface of selected optical cable no conductive path was formed.

Specimen was during withstanding testing damaged at their terminal sides.

Fig.5 Withstand voltage tests

4 Planned tests

As soon as the manufacturer of developing accurate current probe based on Rogowski coil finishes the galvanic separation of current probe and the evaluation device, and finishes the applicator prototype, a series of tests and measurement is planned at low, medium and high voltage level in laboratory conditions and in real operation conditions as well. Mentioned tasks can be summarized as follows:

- verification of the transfer function for higher harmonics, reducing, respectively. excluding the interference from power source using programmable power source,
- using multifunction cards to workplace control and to measure needed electrical and non-electrical quantities, and subsequent visualization of measured data,
- verification of galvanically separated measuring system at higher voltage levels,
- comparison of the measurement system developed with commercially available alternative measurement systems.

5 Conclusion

The main aim of the designed workplace is to enable to performing of necessary tests at the evolving measuring system by applied high current and voltage simultaneously. It is also important to develop a galvanic separation between components of measurement system at high-voltage level and at the ground potential, which enables its operational safety. Attention is also given to the future problem-solving approach of presented research.

Acknowledgement

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