HIGH-VOLTAGE ALTERNATING CURRENT TESTING INSTALLATION

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***Abstract* – The results of the creation of the measuring equipment on the basis of a high-voltage resistive divider from a cast microwire are informed in this article. The design of the voltage divider is described, which includes protective quasi-equipotential shielding of a high-voltage divider branch, allowing to compensate a frequency error of a voltage divider, and the built - in auxiliary devices allow to determine the error of a high-voltage divider and to carry out independent both calibration and checking of installation.**

Keywords*:* high voltage measurement equipment, high voltage divider, glass coated microwire**.**

1. INTRODUCTION

The growth of requirements to quality of the electric power, increase of accuracy of measurements of a high voltage and power is marked now. However circuit technique, constructive and metrological decisions on the initial high-voltage and secondary measuring equipment lag behind existing practical needs. First of all it is connected to complexity of realization of high voltage converters.

The basic requirements of transformation are the next: high accuracy of amplitude transformation factor, absence of a phase error, time stability.

The testing of correctness of functioning and accuracy of measuring converters is necessary to carrying out on a place of their disposition in operating conditions of application.

For this purpose the measuring mobile installations which should have high metrological characteristics serve.

Basically, in most cases, as initial measuring converters of a high voltage in the electric power account circuits, the inductive converters - measuring alternating current transformers (MT) are used, in high voltage measuring testing installations both inductive converters, and voltage converters on the basis of capacitor voltage dividers are used.

The measuring installations on basis of MT have essential overall dimensions and weight [1], have the limited range of working voltages that is caused by necessity of creation certain current loadings of MT for maintenance of its work in a linear mode.

Though MT have enough high accuracy and stability, however the test of their metrological characteristics essentially is complicated, as high-voltage standard measuring instrument of higher class of accuracy or presence of the high-voltage alternating current bridge are necessary for its realization.

The test of such MT on low voltage is not feasible, in connection with of loading voltage nonlinearity of the transfer characteristic.

Capacitor voltage dividers [2] have smaller overall dimensions and weight.

However, high-voltage precision condensers on the basis of various dielectrics used in them, are characterized by dielectric losses and essential dependence of electric capacity on the input voltage. As the result, capacitor voltage dividers have lesser accuracy.

Besides, the electromagnetic shielding of such dividers it is complicated, because of complexity of maintenance of sufficient electric durability and necessity of the account of parasitic capacities on the shield.

As MT, the capacitor voltage dividers have the basic lack - frequency dependence of an input and output impedance.

The certain difficulties are available also in reproduction of division factors expressed by nonintegral numbers, for example with multipliers $\sqrt{3}$.

At the same time for the decision of a problem of scale transformation of the alternating current voltage the resistive voltage dividers can be used.

The known designs of such dividers [3], represent a set of resistive elements, collected in long garlands, for reduction of passage (through) stray capacitance. Such designs are very bulky and nontransportable.

For correct functioning of such dividers it is necessary, that environmental subjects were on enough big distance. The application of such dividers in mobile installations is not obviously possible.

The reduction of overall dimensions of high-voltage measuring converters, the satisfaction to requirements of stability, the independent check, mobility and transportability can be achieved due to resistive voltage dividers on the basis of a microwire in glass isolation [4].

In the scientific research institute "ELIRI" S.A. on the basis of such voltage dividers the alternating current installation DVT-110K intended for checking of high voltage transformers on 110 / √ 3 kV is developed.

2. PRINCIPLE OF ACTION AND THE DESCRIPTION OF THE VOLTAGE DIVIDER AND INSTALLATION

The high-voltage measuring installation is intended for carrying out of MT testing with rated voltage up to 110 / √ 3 kV in operating conditions of application on a place of their disposition. The installation set includes a high-voltage divider, low-voltage dividers, and a comparison measuring device.

2.1. The resistive high voltage divider

The basic metrological part of installation is the high-voltage resistive divider.

The equivalent circuit of a voltage divider is resulted on Fig.1.

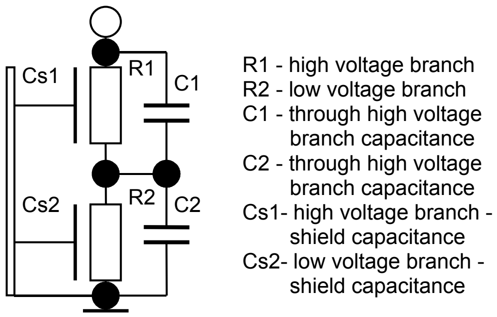


Figure 1: Simple equivalent circuit of high voltage resistive divider

Component of the transfer factor error of a voltage divider on the module (or an error on voltage), caused by through passage capacities C1 and C2, is defined from expression

$$\Delta c = \omega^2 \cdot (R1^2 C1^2 - R2^2 C2^2) \quad (1)$$

where ω - angular frequency.

Component of the transfer factor error of a voltage divider, caused by capacities Cs1 and Cs2 between a resistive brunches and the metal shield of a divider, is defined from expression

$$\Delta cs = -k_1 \omega^2 \cdot (R1^2 Cs1^2 - R2^2 Cs2^2) \quad (2)$$

where k_1 - the factor of influence of capacity on an error of the module, dependent on design data.

In the voltage divider R1>>R2, R1Cs1>>R2Cs2

and then, from expressions (1) and (2), it is possible to receive expressions for a voltage and a phase error of a divider, caused by constructive capacities:

$$\Delta_{UC} = (\omega R1C1)^2 - (\omega R2C2)^2 - k_1(\omega R1Cs1)^2 \quad (3)$$

$$\Delta_{\varphi C} = \omega R1C1 - \omega R2C2 - k_2 \omega R1Cs1 \quad (4)$$

where k_2 - factor of influence of capacity on the angular error, dependent on design data.

From expressions (3) and (4) follows, that compensation of a voltage and a phase error can be achieved, if a condition satisfied:

$$(\omega R1C1)^2 - k_1(\omega R1Cs1)^2 \geq 0 \quad (5)$$

$$\omega R1C1 - k_2 \omega R1Cs1 \geq 0 \quad (6)$$

By regulation of capacity C2 is achieving compensation of the voltage error or the angular error. It is established, that $k_2 \approx 6$ and at $Cs2 \approx 6 \cdot C1$ there is compensation of an angular error of the voltage divider.

Researches have shown, that compensation of a voltage error occurs at other parities of sizes of capacity on the shield and through passage capacity.

The theoretical value of factor k_1 is in limits from 2 up to 5 depending on the equivalent circuit and the accepted model of calculation.

Therefore to achieve simultaneous compensation of a voltage error and an angular error in the simple voltage shielded divider it is not possible.

Besides in such voltage divider the performance of conditions (5,6) is connected to substantial growth of the sizes of the shield as the size of capacity of a high-voltage brunch of a divider on the shield has big enough size.

For reduction of capacity between the high-voltage brunch of a divider and the shield and simultaneously decisions of a problem of compensation of a voltage error of a divider as on the module and an angular error, the additional resistive shield [5] located between a measuring high-voltage brunch of a voltage divider and the metal shield is entered.

The equivalent circuit of a voltage divider with the resistive shield is submitted on Fig. 2.

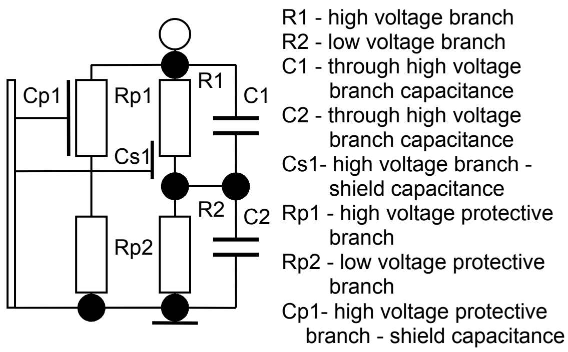


Figure 2: Equivalent circuit of high voltage resistance divider with protective resistive shield

The input circuit of the high-voltage resistive shield (the top part of resistor Rp1) is connected to the input circuit of a measuring brunch, and at the output

circuit of the high-voltage resistive shield the potential, equal to output potential of a measuring output brunch (R2) of a voltage divider, is applied.
The compensation of the voltage error and simultaneously on a phase error is achieved by creation of non-uniform distribution of potential along the resistive screen.
For this purpose high-voltage measuring and resistive shield brunches of a voltage divider are executed from 6 high-voltage cylindrical resistive elements, and the measuring brunch is inside a protective brunch, as shown in fig. 3.

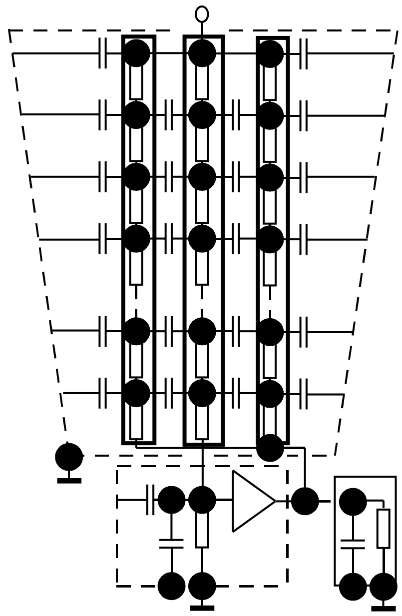


Figure 3: Full equivalent circuit of high voltage resistance divider with protective resistive shield

The introduction of the resistive shield has allowed to reduce considerably size of capacity Cs1 between a measuring brunch of a voltage divider and the external shield, and to satisfy requirements (5,6).
The creation of non-uniform distribution of potential along a resistor shield is achieved by selection of value of resistance of resistive elements of the shield under the certain law.
The given way of shielding, is possible to name quasi - equipotential shielding as, actually, there is no full conformity of voltage distribution along the length of a measuring and protective brunches of a voltage divider, the equality of potentials it is present only in the top (input) and bottom (output) circuit of a divider.
Some additional compensation of a frequency error of a voltage divider it is created also due to the cone-shaped form of the conducting external shield.

The effect of action of the protective shield can be estimated on value of the capacity C2 at which there is compensation of an error (see Table 1).

Presence of a protective shield	Capacity of a high-voltage brunch, C1, [pF]	Capacity of a low-voltage brunch, C2, [pF]
No	16,9	18000
Yes	0,05-0,15	50-150

Table 1: Equivalent values of constructive capacities.

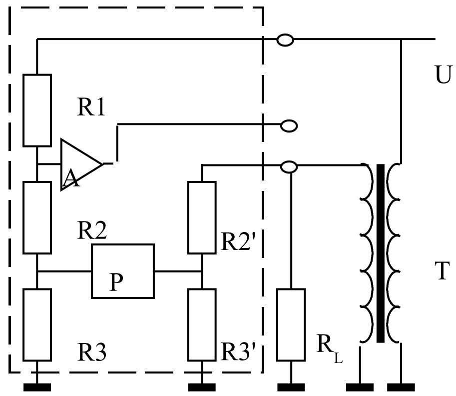
Apparently from experiments and tab. 1 the introduction of shield considerably reduces equivalent through passage capacity of a measuring shoulder of a voltage divider.

2.2. Measuring installation

The appearance of installation is submitted on fig. 4.

Figure 4: Installation DVT-110K

The principle of action of installation is based on a method of voltage comparison of the input voltage of the test transformer and the input standard voltage of the installation.
The equivalent circuit of the test transformer T with the help of installation is submitted on Fig. 5.



R1-R3 - high voltage divider of the installation
R2'- R3' - subsidiary low voltage divider
R_L - resistance load
A - high voltage repeater,
P - comparator
U - input voltage (10-80 kV)

Figure 5: Testing circuit of HV transformers

The output voltage of the transformer T is compared on value and on phase shift angle to an standard output voltage of a high-voltage divider (R1-R3) with the help of the comparison device P of the installation.
The output voltage of transformer T enters to an auxiliary low-voltage divider (R2'-R3) and is compared with the voltage of the standard voltage divider (R2-R3).
The principle of work of the comparison device of the installation P consists in time discretization and analog-digital conversion of measured voltage with fine resolution that allows to carry out testing measuring transformer with the necessary accuracy.
High-voltage divider (R1-R3) together with the high-voltage repeater (A) form the simulator of the high-voltage standard transformer.
Auxiliary and standard low-voltage dividers can be adjusted (calibrated) both on a voltage, and on a phase shift angle with identical accuracy that allows:
- to eliminate a relative voltage and phase shift error of an auxiliary and standard low-voltage divider at testing transformers;
- to carry out test of the error and calibration of the division factor of the high-voltage divider and of phase shift by the method of comparison with an standard low-voltage divider;
- to carry out test of the error and calibration of the simulator of the standard transformer formed by the standard high-voltage divider and the high-voltage repeater A, direct during checking transformers.

Thus the measuring installation allows to carry out the calibration of the standard high-voltage divider at operation, and also provides testing transformers in a range of working voltages from 20 up to 80 kV.

Technical characteristics of the installation:
- the working voltage is 10-80kV at an alternating current at frequency 50 Hz,
- the division factor of a high-voltage divider - 1100,
- the voltage error measurement - 0.05%,
- the difference of phases error measurement - 3min,
- the range of working temperatures is 10-40 ºC
- the overall dimensions are 450x450x1100 mm
- weight is 50 kg.

3. CONCLUSIONS

The action of protective resistive shielding of a high-voltage divider is considered.
At observance the certain conditions compensation of an angular error and an error on a voltage of a divider is possible.
The high-voltage divider of an alternating current and measuring installation with high metrological characteristics is created.
The installation allows to carry out testing of high-voltage dividers and measuring transformers in a range of entrance voltages from 10 up to 80 kV at an alternating current of industrial frequency.

4. ACKNOWLEDGEMENTS

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