

## AC Standard for Electric Power Quality Indexes Calibrator

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**Abstract** – Transfer measurements from the standard of direct voltage to the standard of alternative voltage is widely used in measurement and instrumentation. Well known method is based on the usage of thermo converter of voltage. There are some drawbacks of this method such as instability of error, hand mode of calibration and inertia of reproduction process. The new method of reproduction AC (AV) value proposed by usage of inertia's properties of links of the parallel-resonance circuit to transfer measurements from the standard of direct current to the standard of alternative current. The paper illustrates the mechanism of action of AC-calibrator based on proposed method of reproduction, where AC signal is coming through L-inductor without its changes.

### I. Introduction

The Electric Power Quality Indexes (EPQI) measurement is the part of the main problem of electric power consumption with parallel estimation of electric power quality and elucidation culprit of change to worse this quality. The problem has many peculiarities in the case of measurement of the following static Electric Power Quality Indexes – the three phase voltage fluctuation, the asymmetry factor, the neutral point shift, the pick-to-pick voltage change. It is necessary to take into account that non-informative parameter (for example, a positive symmetrical sequence) may exceed in many times an informative one a negative symmetrical component. That is why a calibration accuracy of measurement equipment for informative parameters should be rated higher than the calibration accuracy of measurement equipment for non-informative parameters.

There are two ways to solve of this problem. The first one is based on the known method of calibration by thermo converters, rather expensive method with low reliability. The accuracy of this method is limited by metrological characteristics of thermo elements.

The second way is grounded on the usage of new method. It permits to realise the direct transfer measurements from the standard of direct current to the standard of alternative current. The instruments created by this method are not expensive, reliable and protected from environmental conditions changes.

### II. Comparison method mechanism of action and its error estimation.

The most widespread method of precise reproduction of an alternative voltage value is the method of transfer measurements from the standard of direct voltage to the standard of alternative voltage by way of comparison [1]. Requirement for the reproduction of direct current signal value is in 10 times greater than of alternative.

The block diagram of calibrator based on the comparison method consists of standard of direct current SDC, controlled standard of alternative current CSAC, two switches: S1 and S2, shunt R, measuring thermoconverter of voltage MTV and direct voltage voltmeter DVV.

Calibration mechanism of action is following. When switch S1 is “on”-position, the calibrated value of direct signal  $U_{\text{=}}$ , proportional to  $I_{\text{=}}$ ,

$$U_{\text{=}} = I_{\text{=}} r, \quad (1)$$

where  $r$  is a resistance of shunt R, comes to the input of MTV.

The value of direct voltage X, which appears at the output of MTV, is fixing in DVV. Then, when switch S1 is in “off”-position and switch S2 is in “on”-position, the alternative voltage with a root mean square value  $U_{\text{rms}}$ , proportional to  $I_{\text{RMS}}$ ,  $U_{\text{rms}} = I_{\text{RMS}} \cdot r$  comes to the input of MTV. At this time the controlled standard of

alternative current CSAC is controlling until output voltage of MTV achieves the value, which equal to X. When the root mean square value  $U_{rms}$  became equal to maximal value of direct voltage  $U_{\ominus}$  at the output of MTV appears the same value of a direct voltage X. So we can consider that  $U_{rms} = U_{\ominus}$  and  $I_{RMS} = I_{\ominus}$ .

The maximal calibration error of alternative current value of this method is defined by the following formula

$$\gamma_1 = \gamma_{MTV} + \gamma_K + \gamma_{\ominus} + \gamma_{\approx}, \quad (2)$$

where  $\gamma_{MTV}$  is an error of MTV,  $\gamma_K$  – an error of calibration of SDC,  $\gamma_{\ominus}$  – an error caused by instability of SDC,  $\gamma_{\approx}$  – an error, caused by instability of CSAC.

The block diagram in Fig. 1 shows the principle behind this method.

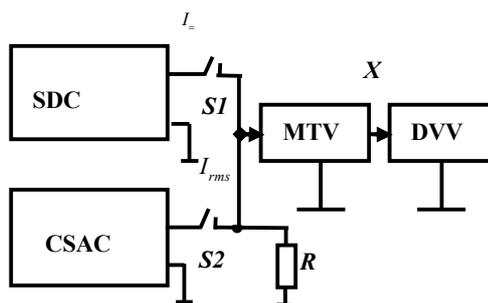


Fig.1. The block diagram of calibrator based on the comparison method

If  $\gamma_{MTV}$  is 10ppm,  $\gamma_K = 1\text{ppm}$ ,  $\gamma_{\ominus} = 1\text{ppm}$ ,  $\gamma_{\approx} = 10\text{ppm}$ , a maximum value of error of this method is 22ppm, which does not satisfied to modern requirements of an accuracy of alternative current reproduction. Up-to-date requirements of accuracy to standards of AC voltage and current achieve 0,001% and higher. Such high accuracy of reproduction of AC signals coursed by the necessity of verification of instruments for measuring of fluctuation of voltage which is 100-300 times less then nominal value of voltage with the error 0,2%.

So this method has an error, which is caused by the finite value of error of thermoelement and instability error, caused by non simultaneous comparison of reproduced and calibrated physical quantities. The drawbacks of this method are the hand mode of calibration and inertia of reproduction process.

### III. Proposed new calibration method mechanism of action and estimation of its error

Proposed new method of alternative signal reproduction is based on the direct transfer measurements from the standard of direct current to the standard of alternative current [2]. Development of this method is due to the property of inertia, where a level  $I_{\ominus}$  of direct current of SDC is fixed in inductors and does not change instantly after the act of loading.

Let us consider in detail the proposed method through block diagram of alternative current calibrator, which is presented in Fig.2.

Block diagram consists of standard of direct current SDC with output current  $I_{\ominus}$ , four switches S1- S4, two inductors L1, L2, which are equal :  $L1 = L2$ , variable capacitor C1, a frequency divider FD, a precise current transformer CT, an amplifier-limiter AL and an inverter I. The SDC is established the standard value of calibrated current stable in two inductors L1, L2.

It is possible to divide the operation of this device by two cycles, which take place simultaneously: an establishing by SDC in inductor L1 the current level  $I_{\ominus}$  and free oscilations of parallel-resonance circuit, created by inductor L2 and variable capacitor C1. These cycles take place by the switches S1-S4. During the first interval of time operate switch S1, which coupled the L1 and SDC, and switch S3, which is coupled inductor L2 and the capacitor variable C1. Both inductor L2 and variable capacitor C1 are created at the same time parallel-resonance circuit, in which free oscilation is caused by current  $I_{\ominus}$  of inductor L2 established of SDC on a

previous interval of time. The oscillation of L2C1 - circuit is going on during one period of reproduced signal. After that inductor L2 is coupled to SDC

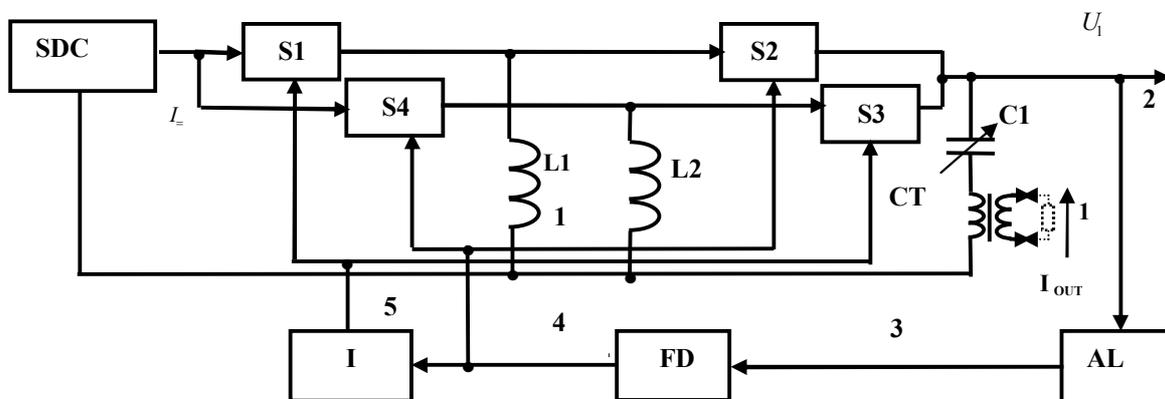


Fig.2. Block diagram of alternative current calibrator based on the proposed method

again by switch S4 for proceeding in initial current  $I_0$ . During this time the L1, which is charged from SDC, is coupled to the C1, that is maintaining the oscillations in circuit during a next period. This process is repeating (Fig.3).

Synchronization of this process is provided due to operation of consistently united amplifier-limiter AL, where controlling impulses are forming, frequency divider FD, in which initial frequency of output signal of AL is divided by 2 and controlling impulses of switches S2, S4 are forming, and the inverter I, where are controlling impulses of switches S1, S3 are forming too. There is no phase-shifter as in AV-calibrator [3], therefore current and voltage signals are shifted in 90 degrees in LC- oscillating circuit.

The accuracy of direct current DC is coming in order through L1, L2 - inductors is determined only by class of SDC. But to obtain high accuracy of reproduction AC through calibrated value of DC it is necessary to hold the following condition:  $r_{SDC} \gg r_l$ , where  $r_l$  - resistance of copper of inductor L1(L2),  $r_{SDC}$  - output resistance of SDC.

There is only one demand to stability of the output current generator of direct current calibrated value. There is not high requirement to stability of other parts of block diagram of Fig.2.

Another advantage of the proposed method is a low THD level of the reproduced variable signal, which we can get due to free oscillations of LC-circuit.

Following the purpose of achieving low THD level of output signal of calibrator, it is necessary to provide high quality of LC - oscillating circuit. It should be at the level of 100 or higher. Such a quality can be provided by usage an active LC - oscillating circuit.

This calibrator is not very expensive, have small dimensions, simple in manufacturing and adjustment. All these properties allow to create not only the calibrators of signals but also small generators of the variable calibrated current built in a device for the increase accuracy of many measurers.

The time diagrams, which describe the proposed calibrator's operations are shown on Fig.3.

On the time diagram (Fig.3.) 1 - an output signal I of calibrator in LC- oscillating circuit, 2- an output voltage of LC- oscillating circuit, 3 - an output signal of amplifier-limiter AL, 4 - an output signal of frequency divider FD and a former impulses FI, 5- an output signals of inverter I.

It is possible to avoid the application of thermoelement and comparison operation, that allows to present the equation (2) as a following

$$\gamma_1 = \gamma_K + \gamma_{HC=}, \quad (3)$$

and to decrease the maximal value of the error to 2ppm. This is a theoretical value of error, which permits to achieve proposed method. The researchers of experimental model of AC calibrator, manufactured by proposed method, shows that there are many practical problems, caused by the non-ideal characteristics of switches S1-S4 and inductors L1, L2. So at the frequency 500 Hz instability of output current is 0,005% and error of

alternative current reproduction is 0,005%. But at the frequency 50 Hz which established by variable capacitor C1 instability of output current is 0,02% and error of alternative current reproduction is 0,02%.

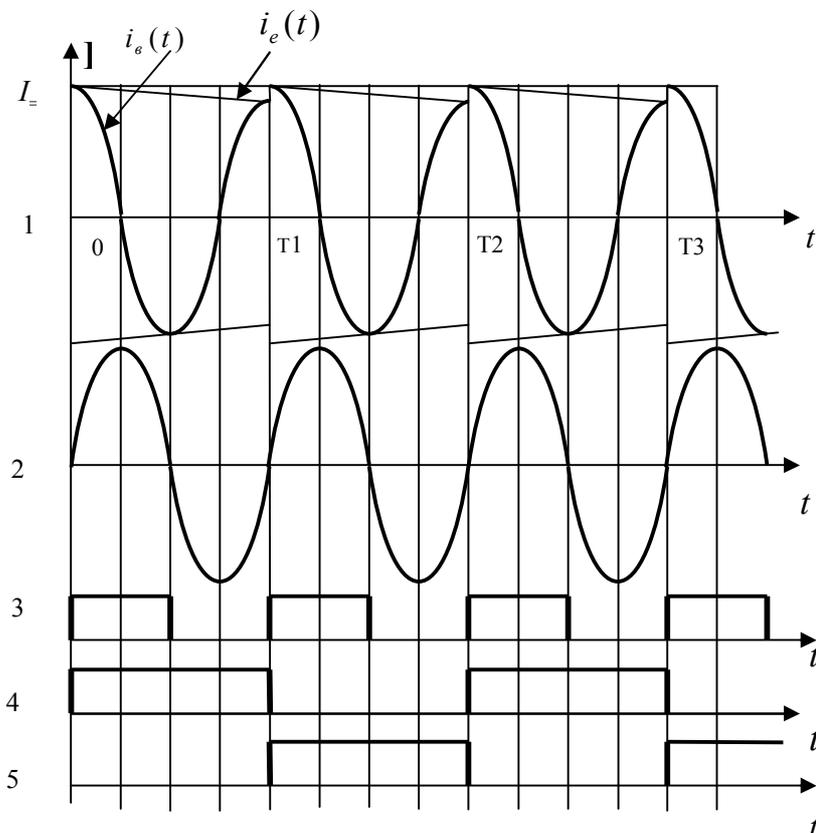


Fig.3. Time diagrams, which describe operation of the proposed calibrator

#### IV. Conclusions

The analysis of proposed calibrator shows that direct transfer measurements from the standard of direct current to the standard of alternative current provides higher accuracy. There is no thermoelement with its inertia and its error in the scheme. The created model of AC calibrator has next parameters: output current range is 0,001 – 5,0 A, output frequency range – 40-500 Hz, instability of output current – 0,02%, error of alternative current reproduction - 0,02%, a setting time – 0,04s. The calibrator was used for development and implementation into serial production instruments for measurements electric power quality indexes: positive, negative and zero symmetrical sequences of three phase current system.

#### References

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