XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6−11, 2009, Lisbon, Portugal

CALIBRATOR OF ALTERNATIVE VOLTAGE BASED ON THE METHOD OF REPRODUCTION OF VALUE OF DIRECT VOLTAGE

Sergiej Taranow, Yurij Tesyk, Oleh Karasinskij, Stanislava Pronselev

[1]The Institute of Electrodynamics of The National Ukrainian Academy of Science
Kiev-57, 03680, Ukraine, e-mail: pribor@IED.org.ua,
[2,3,4]same coordinates,

Abstract - Passing of exactness from the source of direct voltage to the source of alternative voltage is widely used in measuring technics. Well known method is grounded on the usage of thermoconverter of voltage. There are some drawbacks of this method. The new method of reproduction of alternative voltage value is proposed. It is based on the use of properties of inertia of links of the parallel-resonant circuit for the direct passing of exactness of amplitude of signal from direct voltage source to alternative voltage source. The paper illustrates the mechanism of acting of calibrator of alternative voltage based on proposed method of reproduction

Keywords - error of reproduction, calibration of alternative voltage, thermoconverter.

I.Introduction

The Electric Power Quality Indexes (EPQI) measurement is the part 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, positive symmetrical sequence) may exceed in many times an informative (a negative symmetrical component). That is why accuracy of informative measurers calibration should be on an order higher then accuracy of non-informative parameters measurers calibration.

There are two ways for solution of this problem. The first that is grounded on the known method of calibration by help of thermoconverters, rather expansive and is connected with low reliability. Exactness of this method is limited by metrological characteristics of thermocouple.

The second way is grounded on the usage of new method. It permit to realise direct passing of the accuracy from the direct voltage source to the alternative voltage source. Instruments, created by help of this method, are not expansive, reliable and protected from change of environmental conditions.

II. Mechanism of acting of comparison method and evaluation of it error

The most widespread method of precise reproduction of the value of alternative voltage is a method of passing of the accuracy to the alternative voltage source from the direct voltage source by help of comparison [1]. Conditioned it that accuracy of reproduction of direct current signal value is on an order higher, than of alternative.

The physical principle of this method lies in complete equivalence of energy generated in electrothermal element during passage of direct or alternating current under condition that effective value of alternating current equals to effective value of direct current. This method is based on use of precision thermal converters. In the beginning with the help of thermal electromotive force that occurs on thermal couple output due to its heating by calibrated values of DC source, a preliminary calibration of measuring device scale is carried out. Further the thermal couple is heated from AC source, obtaining the same values of measuring device scale that have been reached during feeding from DC source. Effective values of AC voltage at specific points of the scale equal values of DC voltage.

A flow diagram, given in fig. 1, help to present principle of acting of this method.

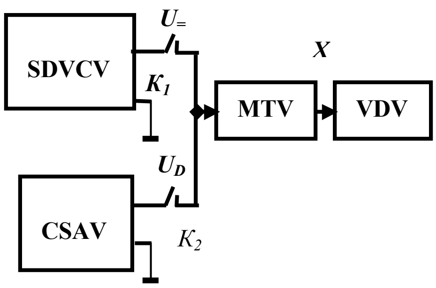

Fig.1. A flow diagram of calibrator grounded on the method of comparison.

It consist of source of direct voltage calibrated value SDVCV, controlled source of alternative voltage CSAV, two switches K1 and K2, measuring thermoconverter of voltage MTV and voltmeter of direct voltage VDV.

Calibration with the help of this device proceeds like the following. At first, when switch K1 is on, the calibrated

ISBN 978-963-88410-0-1 © 2009 IMEKO

value of direct signal $U_=$ comes to the entrance of MTV. The value of direct voltage X, which appears at the output of MTV, fix in MDDV. Then, when switch K1 is off and switch K2 is on, the alternative voltage with an effective value U_D comes to the entrance of MTV. At this time the controlled source of alternative voltage MSAV is regulating until output voltage of MTV will not achive the value, equal to X. As far as equal between itself the effective value of alternative voltage and peak value of direct voltage cause at the output of measuring thermoconverter of voltage the same value of direct voltage X, consider that $U_D = U_=$.

Maximum error γ_1 of calibration of alternative voltage value on such method is defined a next formula

$$\gamma_1 = \gamma_{MTV} + \gamma_K + \gamma_= + \gamma_\approx, \qquad (1)$$

where γ_{MTV} is an error of MTV, γ_K – error of calibration of SDVCV, $\gamma_=$ – error, caused by instability of SDVCV, $\gamma_\approx$ – error, caused by instability of CSAV.

If γ_{MTV} is 10ppm, γ_K = 1ppm, $\gamma_=$ = 1ppm, $\gamma_\approx$= 10ppm, a maximum value of error of this method is 22ppm, that does not answer to modern requirements of exactness of reproduction of alternative voltage.

So the method is considered has an error, which is caused by the finite value of error of thermocouple and instability error, caused by unsimultaneous comparison of reproduced and calibrated physical sizes. Manual mode and sluggish-ness of reproduction process significantly prolong the time necessary for the reproduction process.

III. Mechanism of acting of new method and evaluation of its error

An authors are offered the new method of alternative signal reproduction by means of the direct passing of exactness from direct voltage source to alternative voltage source [2]. Development of this method is based on response time of condensers due to which a charge and voltage level fixed by them and obtained from DC source do not change immediately under the load.

Let us consider the proposed method in details with the help of schematic diagram of AC voltage calibrator shown on fig. 2.

It consists of source of direct voltage calibrated value SDVCVwith output voltage $U_=$, four switches Км1- Км4, two condensers C_1, C_2, capacities of which are equal between itself: $C_1 = C_2$, inductance coil L, phaseshifter on 90^0 PS, frequency devider FD, former of impulses FI and invertor I.

It is possible to break up the operation of this device into two cycles which proceed simultaneously: a charge of capacitor C_1 (C_2) up to voltage level $U_=$ and discharge of the capacitor C_2 (C_1) on a parallel-resonant circuit, created by one of capacitors and the inductance coil L. These cycles proceed by help of the switches $Км_1$-$Км_4$.

During the first interval of time switch $Км_1$ connects condenser C_1 to SDVCV, and switch $Км_3$ connects condenser C_2 to the inductance coil L. Condenser C_2 and inductance coil L together create parallel-resonant circuit, in which a free vibrations are caused by charge of capacitor C_2, charged from SDVCV on a previous interval of time. The oscillation of LC_2 - circuit is going on during one period. After that capacitor C_2 is connecting to SDVCV again by help of switch $Км_4$ for proceeding in initial charge. During this time domain the capacitor C_1, charged from SDVCV, is connected to the inductance coil L, that is maintaining the oscillation in circuit during a next period. In future this process is repeating.

Synchronization of this process is provided due to operation of connected in series phaseshifter PS, thanks to which output oscillation U_1 of L C_1 (C_2) circuit displace for 90^0, frequency divider FD, in which output frequency from FS is dividing into 2, impulses former FI, where controling impulses of switches $Км_2$, $Км_4$ are forming, and inverter I, from the output of which control pulses of switches $Км_1$, $Км_3$ appear.

There is only one demand to stability of output voltage of source of direct voltage calibrated value. Other blocks of scheme (Fig.2) are not special as for stability.

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

Following the purpose of achieving low level of THD 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 using active LC - oscillating circuit.

This calibrator is not very expensive, have small dimensions, simple in manufacturing and adjustment.

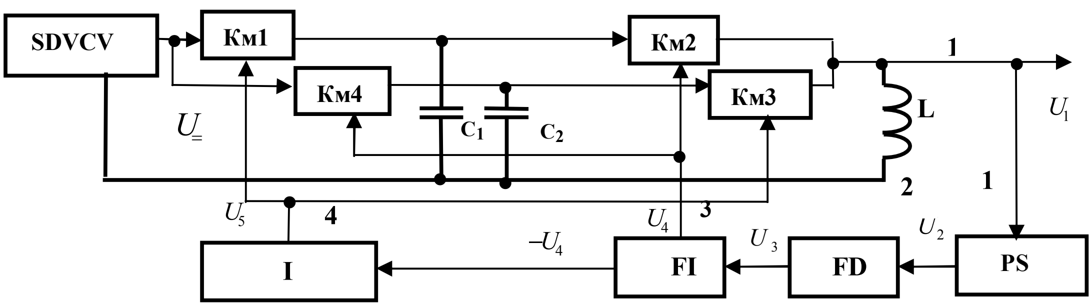

Fig.2. Schematic diagram of AC voltage calibrator based on a proposed method with interval between switching wich is equal to one period of reproduced signal.

All these properties allow to create not only the calibrators of signals but also small sources of the variable calibrated voltage built in a device for the increase of exactness of many measurers.

Time diagrams describing operation of the proposed device are specified on fig. 3.

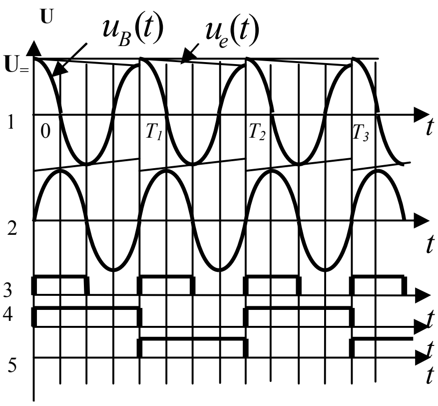

Fig.3. Time diagrams of operation of the calibrator with interval between switching which is equal to one period of reproduced signal.

On a time diagram 1 (fig.3.) output signal of calibrator is shown. On a time diagrams 2, 3, 4 and 5 output signals of FS, frequency divider, puls former FI and inverter I are given respectively.

In the offered method there is a possibility to avoid the application of thermocouple and comparison operation , that allows to present equation (1) in a next kind

$$\gamma_1 = \gamma_K + \gamma_{HC=} . \quad (2)$$

Maximum error γ_1 will decrease significantly and will equal 2 ppm.

As its is clear from fig. 3 (diagram 1) during each period of signal reproduction at the moment of condensers switching amplitude jump occurs caused by the fact that voltage level of charged condenser that is connected to the circuit is higher than voltage level of partially discharged condenser that disconnects from the circuit and connects to SCDCV. This leads to non-linear formations that cause non-accuracy of variable signal amplitude reproduction according to the new method. Signal shown on diagram 1 consists of the main

$$u_в(t) = U_= \sin \omega t , \quad (3)$$

where $u_в(t)$ - momentary value of reproduced signal, $U_=$- initial amplitude of reproduced signal and its bypass curve that represents the following exponential function [3]

$$u_e(t) = U_e e^{-\delta t} , \quad (4)$$

where $u_e(t)$ - exponential function, $\delta = \frac{r}{2L}$ - value inversely proportional to constant of oscillation circuit time, r - loss resistance of oscillation circuit, L - inductance of oscillation circuit.

Function $u_e(t)$ is bypass to function $u_в(t)$ at every interval between switching of commutators Км1-Км4. Under condition of high quality of the circuit the exponential function at time intervals 0 - T_1, T_1- T_2, $T_2 - T_3$ may be represented as powdery function shown on time diagram 6 (fig. 3). This function looks like the following

$$u_в(t) \cong f(\omega t) = \frac{U_e}{2}(1 - \frac{\omega t}{\pi}) ,$$
under condition $0 < \omega t < 2\pi$. (5)

It transformed into Fourier series

$$f(\omega t) = \frac{U_e}{\pi}(\sin \omega t + \frac{\sin 2\omega t}{2} + \frac{\sin 3\omega t}{3} + ...) . \quad (6)$$

From expression (6) it is clear that the series include as harmonic components of the main frequency of reproduced signal, so high-frequency components divisible to this frequency. Of course, these components will cause error of reproduction of effective value of calibrating signal; its absolute value may be represented in the following formula

$$\Delta_в = \frac{U_e}{\pi}\sqrt{f_1^2 + \frac{1}{4}f_2^2 + \frac{1}{9}f_3^2 + ...} , \quad (7)$$

where $f_1, f_2, f_3 ...$ are harmonic components obtained as a result of transformation of the bypass function into Fourier series.

To increase precision of reproduction according to this method it is necessary to reduce amplitude of bypass function. Considering formula (4) we may make a conclusion that amplitude of bypass function $u_e(t)$ and respectively amplitudes of its harmonic components depend on time interval t and constant time of oscillation circuit $1/\delta$. So, one of conditions for reduction of bypass function influence on accuracy of representation of certain value of sinusoid is reduction of loss resistance r of the circuit and increase of inductance L . In other words, it is necessary to increase quality of the circuit. But quality increase due to use of oscillation circuit elements of higher quality and implementation of structural methods provides limited possibilities. That is why it is advisable to use other important way of bypass function influence reduction such as reduction of time interval between the next switching of commutators Км1-Км4.

To solve this problem authors propose schematic diagram [3] of AC voltage reproduction, shown on fig. 4.

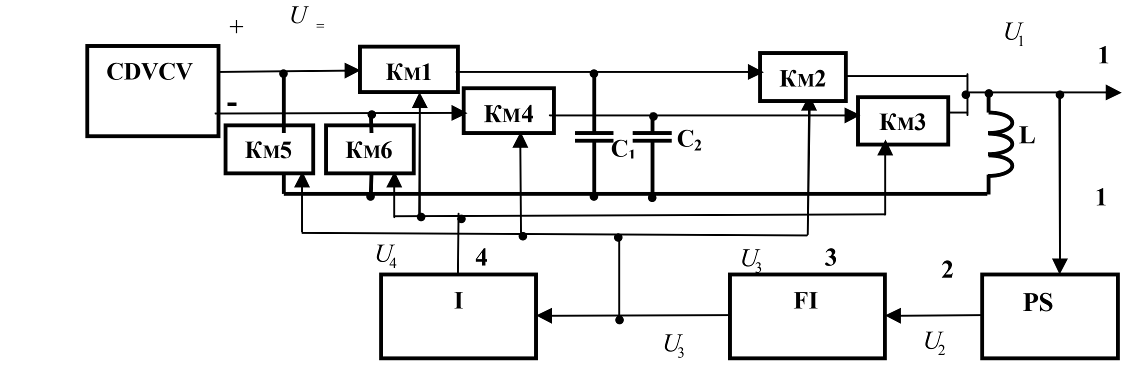

Fig.4. Schematic diagram of AC voltage calibrator based on a proposed method with interval between switching which is equal to half a period of reproduced signal.

The diagram consists of CDVCV which output voltage equals $U_=$, six commutators Км1-Км6, two condensers C_1, C_2 which capacities are equal $C_1 = C_2$, inductance coil L, phase-shifting device (PS) for $\frac{\Pi}{2}$, former of impulses (FI) and inverter (I).

Let us describe operation of this device with the help of time diagram specified on fig. 5.

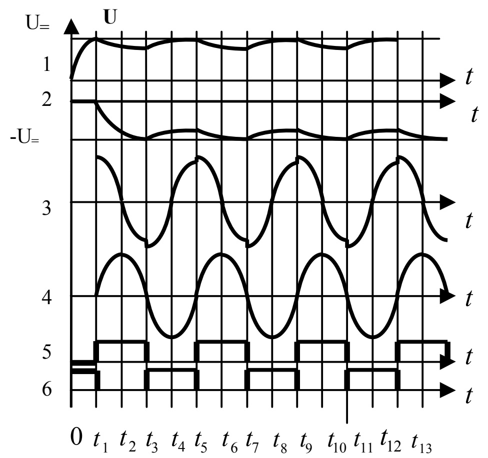

Fig.5. Time diagrams of operation of the calibrator with interval between switching which is equal to half a period of reproduced signal.

On time diagrams 1, 2 charge and discharge processes for condensers C_1, C_2 according to operation cycles of the device are specified. On time diagram 3 – output signal of the device, on time diagram 4 – output signal of phase-shifting device (PS) for $\frac{\Pi}{2}$. On time diagrams 5 and 6 – output signals of former of impulses (FI) and inverter (I).

During time interval 0-t_1 with the help of positive control signal from output of inverter I (diagram 6) commutators Км1, Км3, and Км6 are opened. Due to this condenser C_1 (diagram 1) charges to output level $U_=$ and condenser C_2 connects to inductance coil L. During this period of time commutators Км2, Км4, and Км5 are closed due to zero level of signal (diagram 5) on their control inputs.

During time interval $t_1 - t_3$ with the help of positive control signal from output of pulse former (PF) (diagram 5) commutators Км2, Км4, and Км5 are opened. In this period of time condenser C_2 charges to output level $-U_=$ (diagram 2) and condenser C_1 (diagram 1) connected to inductance coil L discharges on oscillation circuit LC_1. During this period of time commutators Км1, Км3, and Км6 are closed due to zero level of signal (diagram 6) on their control inputs.

During time interval $t_3 - t_5$ with the help of positive control signal from output of inverter I (diagram 6) commutators Км1, Км3, and Км6 are opened again, condenser C_1 (diagram 1) charges to output level $U_=$ and condenser C_2 (diagram 2) connected to inductance coil L discharges on oscillation circuit LC_2. During this period of time commutators Км2, Км4, and Км5 are closed again due to zero level of signal (diagram 5) on their control inputs.

Further this process will be repeated continuously in automatic mode.

As it is clear from diagram 3 time period $t_1 - t_3$ equals half of oscillation period of LC_1–circuit. During this period of time there is zero transfer of oscillations from positive value of sinusoid to negative value. During period of time $t_3 - t_5$ there is zero transfer of oscillations of LC_2 – circuit from negative value of sinusoid to positive value. These oscillations are transmitted to phase-shifting device (PS) for $\frac{\Pi}{2}$, on the output of which a sinusoid occurs that is shown on time diagram 4 (fig. 5). This signal is reinforced and limited in PF on the output of which we obtain a signal that is transmitted to controls of commutators Км2, Км4, and Км5 and to the input of inverter I (ref. time diagram 5 on fig. 5). At the same time control signal for Км1, Км3, Км6 occurs on inverter output (ref. time diagram 6 on fig. 5). That is how synchronization of the device proceeds.

As far as oscillating process of LC–circuit that includes of one of condensers (C_1 or C_2) connected to the circuit and inductance coil L proceeds only half of a period, discharge of each of them proceeds only partially (during time intervals $t_1 - t_3$, $t_5 - t_7$, $t_9 - t_{11}$ for condenser C_1 and during time intervals $t_3 - t_5$, $t_7 - t_9$, $t_{11} - t_{13}$ for condenser C_2) to support free oscillations. During time interval $t_3 - t_5$, $t_7 - t_9$, $t_{11} - t_{13}$ condenser C_1 and during time interval $t_1 - t_3$, $t_5 - t_7$, $t_9 - t_{11}$ condenser C_2 charge from CDVCV to levels $U_=$ and $-U_=$, respectively. This promotes reduction of amplitude jumps of sinusoidal signal at the moments of commutators switching t_1,t_3, t_5,t_7, t_9,t_{11} , etc. In order to reduce time interval, during which condensers connected to oscillation circuit discharge, up to the half of period of output signal, the commutators Км5 and Км6 were introduced. They provide positive charge of condenser C_1 by commutation of positive output of CDVCV to the first output of condenser C_1 and by commutation of negative output of CDVCV to the second output of condenser C_1 during time intervals $t_3 - t_5$, $t_7 - t_9$, $t_{11} - t_{13}$, and vice versa, they provide negative charge of condenser C_2 by commutation of negative output of CDVCV to the first output of condenser C_2 and by commutation of positive output of CDVCV to the second output of condenser C_2 during time intervals $t_1 - t_3$, $t_5 - t_7$, $t_9 - t_{11}$.

Thanks to use of the proposed device time of discharge of condenser C1 (C_2) of oscillation circuit is reduced doubly and this allows doubly reduction of error of AC voltage reproduction.

Comparison of proposed method with known technical solution shows that the calibrating device for AC voltage on the basis of new method is most precise, because it provides direct transmission of precision from source of direct current calibrated voltage to source of alternating current voltage.

Significant advantage of the proposed method is possibility of manufacturing of compact source of reference voltage that may be located directly in measuring device.

IV. Conclusions

The created model of AC voltage calibrator has next parameters: output voltage range is 0,1 – 5,0 V, output frequency range – 40-500 Hz, instability of output voltage – 0,02%, error of alternative voltage 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 voltage system.

References

[1] Bezikovich A.Ya., Shapiro E.Z. Measuring of electric power in the sound range of frequencies. - L.: Energy. Leningr. otd-nie, 1980.-168 pages.

[2] Patent of Ukraine 27031, G01r21/06. Method of calibration of variable voltage size/ Tesik Yu.F.- Publ. 10.10.2007, bul. 16. – 8 pages.

[3] Patent of Ukraine 37410, G01r21/00. A device for calibration of variable voltage size/ Tesik Yu.F.- Publ. 25.11.2008, bul. 22. – 8 pages.