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TO THE PROBLEM OF MEASUREMENT OF MEAN SQUARE VALUE OF VOLTAGE

The paper present the algorithm of measuring conversion of signal voltage while evaluation of its mean square value (MSV), structural diagram of the device intended for realization of this algorithm of this algorithm is suggested.

Key words: *mean square value of the voltage, constant and variable components, harmonics.*

Introduction

Measuring operation of measured variable electric signal conversion into constant voltage is one of the most common in the domain of electric and radio measurements. Special attention is paid to evaluation of the signals of the random form by the level of mean square value of their voltages, since mean square value is fundamental physical characteristic of the process [1].

Analysis of recent researches and publications

While performing MSV measurements converters both with linear and non – linear conversion functions are used [1]. Advantages and disadvantages of the latter ones are considered in details in [1]. In [2] much attention is paid to consideration and realization of 19 basic structural schemes of MSV converters in the class of elementary functions. However, this number does not comprise all the converters, functioning on the principle of decomposition of various functions into power series. The known method of MSV measurement in [1] is the method of multiple measurement, when variable and constant component is allocated from the module of variable signal *n* times and each of the obtained *n*+1 constant components is raised to square root is extracted from the sum. This result characterizes the magnitude of mean square value of the signal *U*:

$$U = \sqrt{\sum_{i=1}^{n} U_{ni}^2} \, ,$$

where U— mean square value of measured voltage U_x; U_{ni} —value of constant component after *i*-th division.
If $n \to \infty$ the given method provides rather high accuracy of measurements. However, it is characterized by non – sufficient speed expansion of frequency spectrum of measured signal, complex scheme of realization and non – sufficient provision of conversion linearity. Taken together such drawbacks lead to the advent of considerable error due to various forms of sign – variable signal.

These drawbacks are partially eliminated in [1], due to realization of such algorithm:

$$U = \sqrt{U_1^2 + \sum_{i=1}^{n} U_i^2} \approx U_1 + \frac{1}{2U_1} \sum_{i=2}^{n} U_i^2 \, , \tag{1}$$

where U_1— mean square value of the first harmonic of measured signal; $\sum_{i=2}^{n} U_i^2$ — the sum of mean square values squares values.
Squares of highest harmonics of measured signal, beginning from the second.

Realization of the algorithm (1) provides the realization of such operations: allocation of the first harmonic U_1, its transformation into proportional constant voltage, allocation from U_x harmonics with the numbers higher than the numbers of the first harmonic, their square detecting with further large – scale conversion of processed signals and their amplification. Approximate equation (1) is performed when $U_1^2 >> \sum_{i=1}^{n} U_i^2$. If this equation reduces, the methodical error appears due to the difference in the form of measured signals. Besides, transformation error increases as a result of non – complete suppression of the principle harmonic by the filter and while changing the frequency of measured signal it is necessary to evaluate the value of the first harmonic, providing the corresponding restructuring, and technical realization of measuring converter becomes complicated.

Problems set up

Proceeding from the analysis of MSV measurement methods performed the task is to elaborate the algorithm of measured voltage conversion to eliminate the principle drawbacks of existing methods of MSV measurement and propose the structural diagram of the device, realizing such algorithm.

Principle material of the paper

It is well known fact that if a signal is described by sign – variable function of time $U_x(t)$, then the modulus of this function averaged during time T, equals to its constant component U_0:

$$U_0 = \left|\overline{U_x(t)}\right|$$

The difference between the modulus of the function and its average is variable value (variable component) $U_\sim$:

$$U_\sim = \left|U_x(t)\right| - U_0$$

It is obvious thut the square of mean square value of the signal $U_x\,(t)$ can expressed by the sum of squares of constant and variable of components:

$$U^2 = U_0^2 + U_\sim^2,$$

or

$$U = \sqrt{U_0^2 + U_\sim^2} = U_0\sqrt{1 + \frac{U_\sim^2}{U_0^2}} \tag{2}$$

substituting (2) by Newton binominal series and limiting by two first terms of decomposition we obtain:

$$U \approx U_0\left(1 + \frac{1}{2}\frac{U_\sim^2}{U_0^2}\right) = U_0 + \frac{1}{2}\frac{U_\sim^2}{U_0^2} \tag{3}$$

It should be noted, that such mathematical transformation is valid if: $U_\sim^2 << U_0$, and if this inequality weakens, methodical error of measurement will increase.

Structural diagram of the device, intended for realization of the suggested algorithm (3) is shown in Fig 1.

Principle of device operation is the following (Fig 1) by means of the module formator voltage of alternating current of random form U_x is reduced to $\left|U_x(t)\right|$. By means of the blocks of constant component allocation and variable component allocation it is transformed correspondingly as: $\left|U_x(t)\right| = U_0$ и $\left|U_x(t)\right| - \left|\overline{U_x(t)}\right| = U_\sim$.

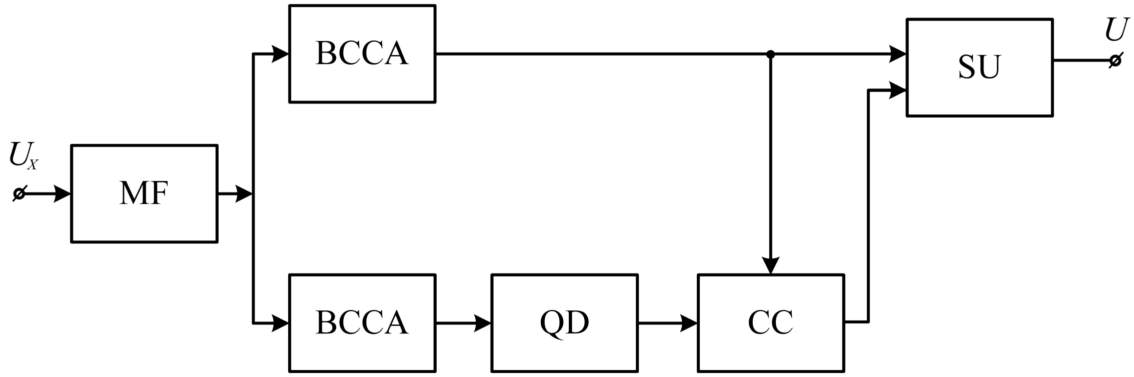

Рис. 1. Structural diagram of the device for realization of the suggested algorithm

Variable component $U_{\sim}$ is detected by means of square detector (SQ) and, using correcting circuit (CC), which provides the division of variable component $U_{\sim}$ into constant component with transmission ratio 1/2, is sent to adding device (AD). Signal of constant component also arrives here. Thus, at the output of Ad we obtain mean square value U of input voltage of alternating current of the random form in accordance with the algorithm.

Analysis of the results obtained

As it follows from the principle of unit operation, signal processing is performed over two products of variable voltage module – constant and variable components, that considerably reduces the requirements to the form of AFC filters, its stability, accuracy, tuning of the filters and, as a result, - increase of accuracy and transformation rate. Due to the lack of complex band filters with adjusting organs and devices of auxiliary indication of frequency and band with, due to the absence of measuring converters of first harmonic voltage, technical realization of the device is simplified. All this allows to use the algorithm (3) in digital measuring devices in real – time scale.

Error, at the expense of application of only linear terms of decomposition series (3), as calculation show is 1, 27 % for sinusoidal signal.

Conclusions

The suggested algorithm of measuring conversion of input signal provides the realization of main requirements, characteristic for MSV evaluation: fact – acting, bandwidth and relatively simple scheme of measuring unit realization – at the same time, providing acceptable for the time being error of measurement.

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