12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25–27, 2002, Zagreb, Croatia

APPLICATION OF TECHNIQUES OF SEPARATING RANDOM AND PERIODIC COMPONENTS IN PROCESS OF LOW-FREQUENCY INTERFERENCE ESTIMATION

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Abstract – The way of evaluation of low frequency interference that enables distinguishing between the periodic and random components of interference is presented. The measurement system is described, most important part of which is designed in the programming environment *LabVIEW National Instruments*. The software implementation of the block of data analysis of the system that realises functions performed by standard interference meters and random signal analysers is presented in details. Exemplary results of experimental research carried out in the industrial low-voltage power supply line obtained by the proposed method of estimation of low frequency interference are presented. These results are compared with the measurements made according to the generally used methods.

Keywords: interference, virtual instruments.

1. INTRODUCTION

The interference models used so far describe the observed phenomena separately as signals either of determined or random character. For instance it is assumed that the process of estimation of interference in the low voltage power supply lines is influenced only by determined periodic interference [1]. In reality the undesirable periodic courses always accompany the random courses (noises), which affect the results of the measurements of the values accepted in bibliography, including the standards, characterising the intensity of interference (for instance the total harmonic distortion coefficient THD).

In the paper the interference model is proposed, in which equivalent sources of periodic and random components of interference are connected in series [2]. As a way of verifying the model a virtual measuring system to measure low frequency interference is designed [3, 4], where the acquisition and the processing of the measuring signal are separated in time. The system consists of two parts: hardware and software, the latter designed in the programming environment *LabVIEW* [5]. In the software part of the system the periodic component is separated from the random one in the measuring signal. Next in the block of processing of the digital data a further analysis is conducted separately for each of the components of interference.

2. SOFTWARE PROCESSING AND ANALYSING DATA

In the software part of the measurement system the measuring data are processed and analysed in the virtual instruments designed in the *LabVIEW* programming environment (Fig. 1). In the measuring signal represented by the sampled data (formerly recorded on a hard disc and archived on CD Rom's) the two components are separated: the periodic from the random. Distinguishing between the periodic and random components of interference is made in the virtual instrument *Separate.vi* (Fig. 2), which requires entering input data:

- sampling frequency f_s,
- basic frequency of periodic interference f_1,
- multiple of adding the sets of samples N,
- number of samples in the set K.

These parameters influence the accuracy of the obtained results, the resolution of a further spectral analysis as well as the inaccuracy of the estimation of the values connected, for example, with the mean square value (effective), the spectrum density of the power of the examined course and its components: periodic and random.

The output data from this virtual instrument are further processed in virtual meters *Periodic.vi* and *Stochast.vi*.

The analysed courses are recorded with the maximum possible sampling frequency f_s of the A/D converter ensuring the possibility for the spectral analysis of the standard parameters characterising periodic interference (for instance the value of the voltage of harmonic components in the power supply line is calculated up to the 40th harmonic).

The analysis of the parameters characterising random interference can be performed separately in a few frequency bands, using a few times the block realising the reduction of data (Fig. 1). Thus, the maximum frequency f_{max} of input courses is reduced to the value of f_{max}/d^n, where d is the coefficient of decimation, n is the number of frequency sub-bands.

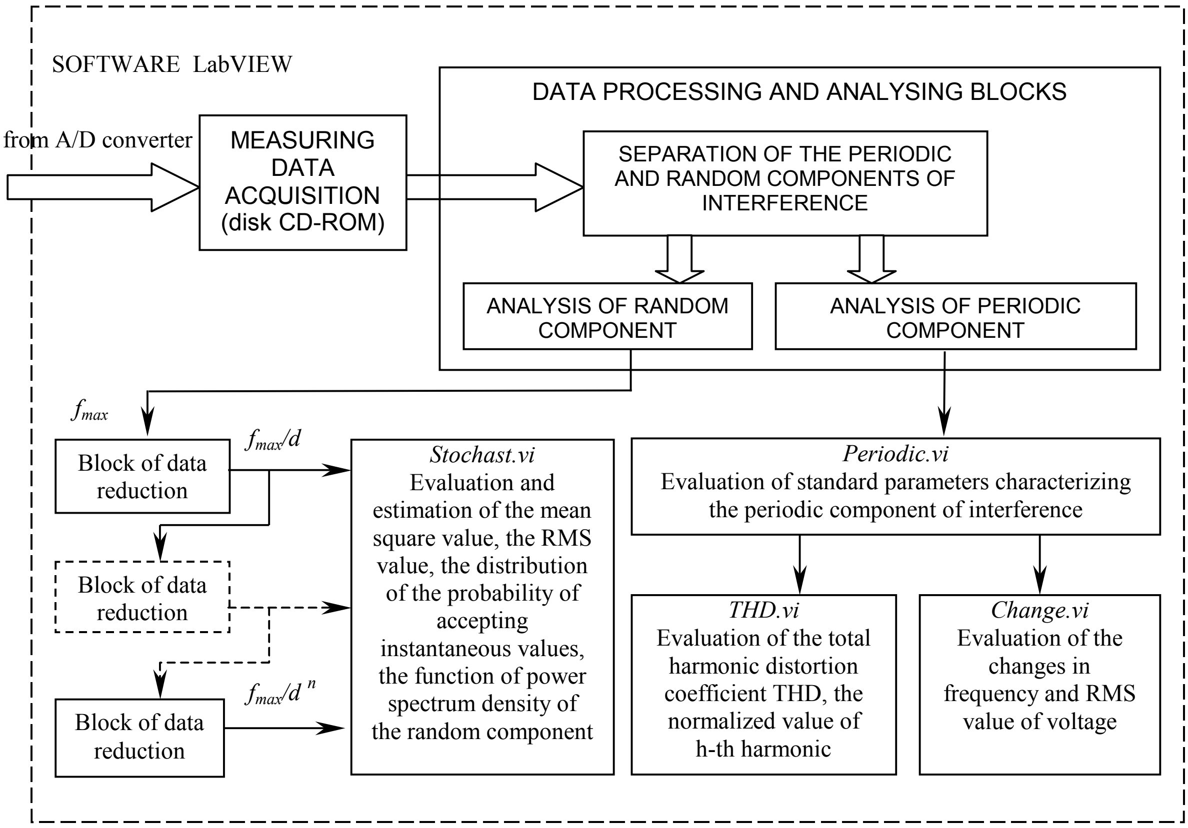

Fig. 1. Software part of system - data processing and analysing blocks

2.1. The method of determining the standard factors of periodic interference

The virtual interference meters are designed to measure standard parameters characterising the periodic component of interference (*THD.vi, Change.vi*) (Fig. 3). In the virtual instrument *Periodic.vi* the following input data are entered:

- the number of averaging the spectral density of power Q,
- the kind of data window used w(i),
- number of samples in the set K,
- order of harmonics h.

The evaluation of the standard parameters characterising the periodic component of interference is made with the use of DFT (Discrete Fourier Transform). The spectral density of power $G_x(f)$ is calculated from the dependence [3]:

$$G_x(k,q) = \frac{2\Delta t}{K\Delta f_w}\left|X_k\right|^2 \quad (1)$$

where: $k=0,1,..,K-1$ - k-th value *of* DTF, Δf_w – equivalent noise band of the applied window, $q=1,2,..,Q$.

The components of the discrete Fourier transform X_k are determined from the equation [3]:

$$X_k = \sum_{i=0}^{K-1} u'_h(i\Delta t)\exp(-j\frac{2\pi ki}{K}) \quad (2)$$

after earlier multiplying the set of samples by the set of window parameters *w(i)*.

$$u'_h(i\Delta t)=u_h(i\Delta t) \times w(i) \quad (3)$$

On the basis of the distribution of frequency spectrum the value of voltage and the localisation of successive spectral lines are determined. Thus, for a given period of time it is possible to evaluate the frequency of the basic and successive harmonic components as well as the RMS value of the basic and successive harmonics. This way enables the calculation of: the total harmonic distortion coefficient THD and the normalised value of voltage of the h-th harmonic (with respect to the basic harmonic).

In order to determine short-termed changes in frequency and the effective voltage of the power supply line the temporary voltage and frequency values x(i) are recorded for the observation time $K\Delta t$, where Δt is the sampling period. The virtual instrument *Change.vi* determines the basic statistical parameters for the frequency and the effective voltage as well as the maximal changes of these values in the determined time interval.

2.2. The method of determining the values characterising random interference

Random signal analysers enable the evaluation of: estimators of the mean square value and RMS value of the signal, and the distribution of the probability of accepting the instantaneous values of voltage and the power spectrum density. In the virtual instrument *Stochast.vi* the following input data are entered (Fig. 4):

- number of samples in the set K,

- the number of averaging Q,
- the number of quantisation intervals m.

3. EXAMPLARY RESULTS OF EXPERIMENTAL RESEARCH

A number of computer simulations were made, in which the random component is added to the periodic component. The periodic component consists of a sum of sinusoidal signals - these are harmonics (the experimental research proved that such a type of periodic interference dominates in the low frequency power supply lines). The random component has the Gauss distribution of the probability of accepting the instantaneous values of voltage and the RMS value of voltage being 1% of the basic harmonic component (on the basis of theoretical analyses it can be assumed that the sum of the random courses coming from a number of independent receivers have normal distribution, according to the central limitary theorem). The operation of coherent addition is performed on the periodic course with a noise

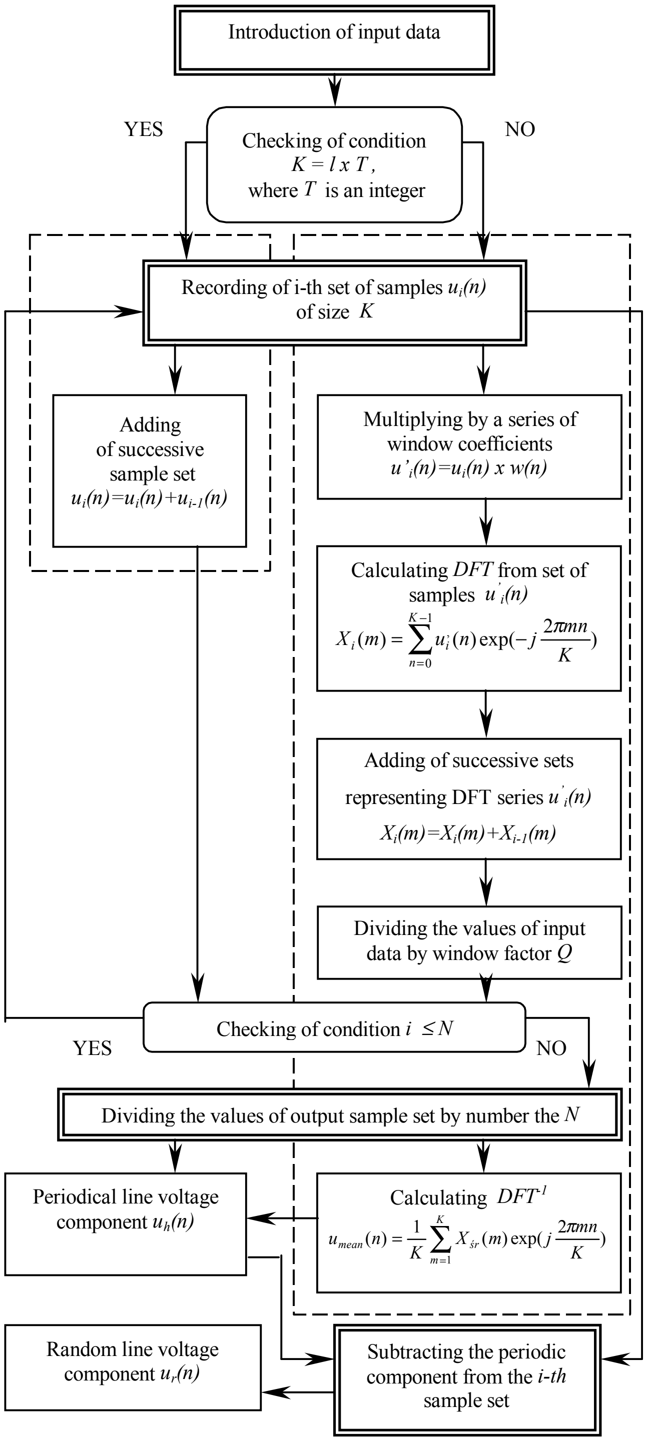

Fig. 2. Algorithm for separation of periodic and random interference components occurring in the low voltage lines

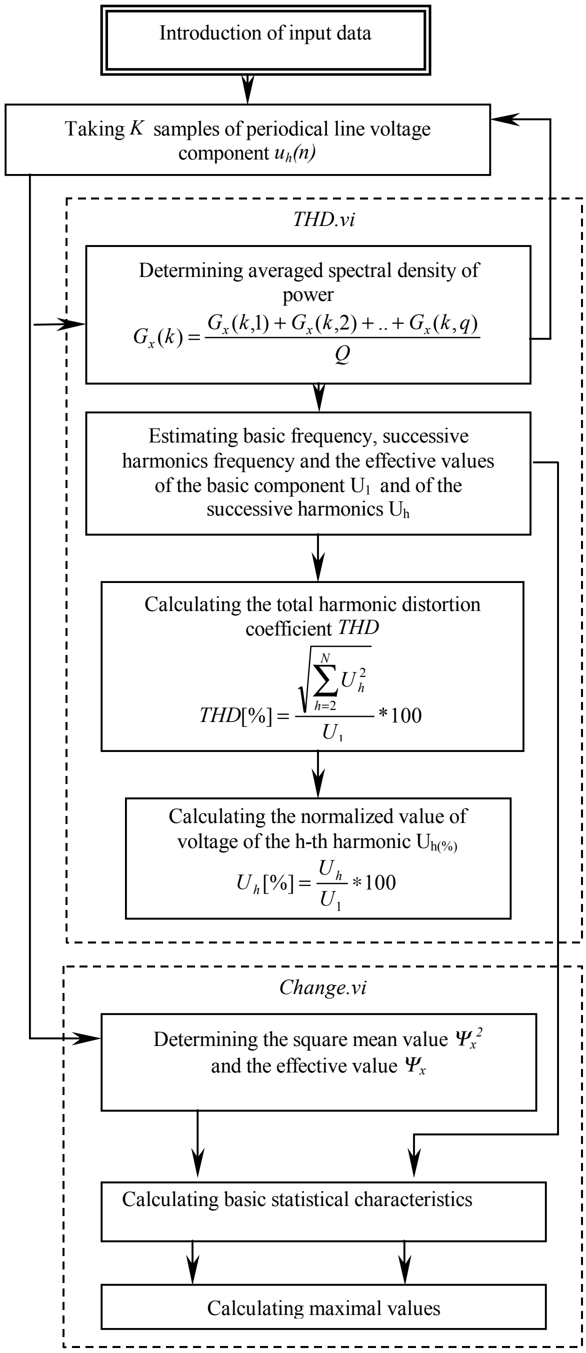

Fig. 3. Algorithm to determine standard values characterising periodic interference in the virtual instrument *Periodic.vi*

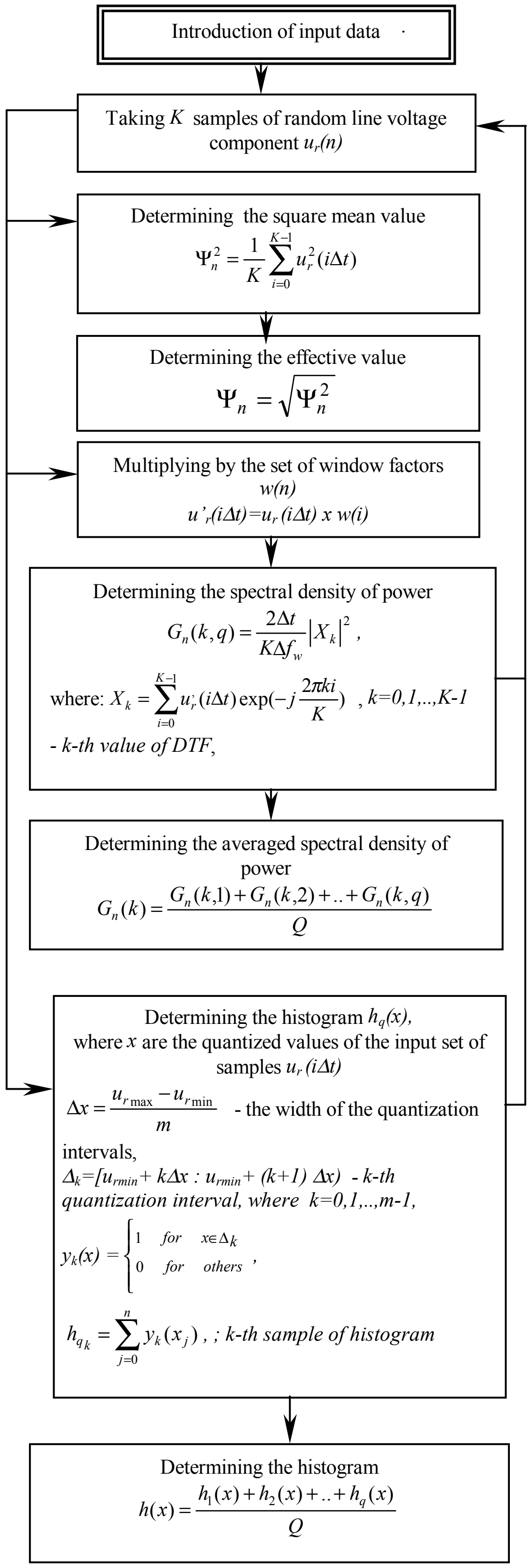

Fig. 4. Algorithm to determine values characterising random interference

component, which enabled distinguishing components. The relative error of estimation of the instantaneous value representing the periodic component is less than 1% in the simulations. Next, exemplary results of experimental research, which was done in the industrial power supply line using the presented method of evaluation of low frequency interference are showed. After the application of the presented procedure of separating two components of interference in the industrial supply line (Fig. 5a) (the procedure of separating both components was realised for 50 averages) we obtained the periodic (Fig. 5b) and the random (Fig. 5c) components. For both components a further analysis was carried out according to the presented algorithms. As a result of the spectral analysis for the periodic component the harmonic distortion coefficient THD was determined. Moreover, with the use of the designed virtual instrument *THD.vi* , THD was calculated for the course of the power supply line voltage which contains both components (Fig. 6).

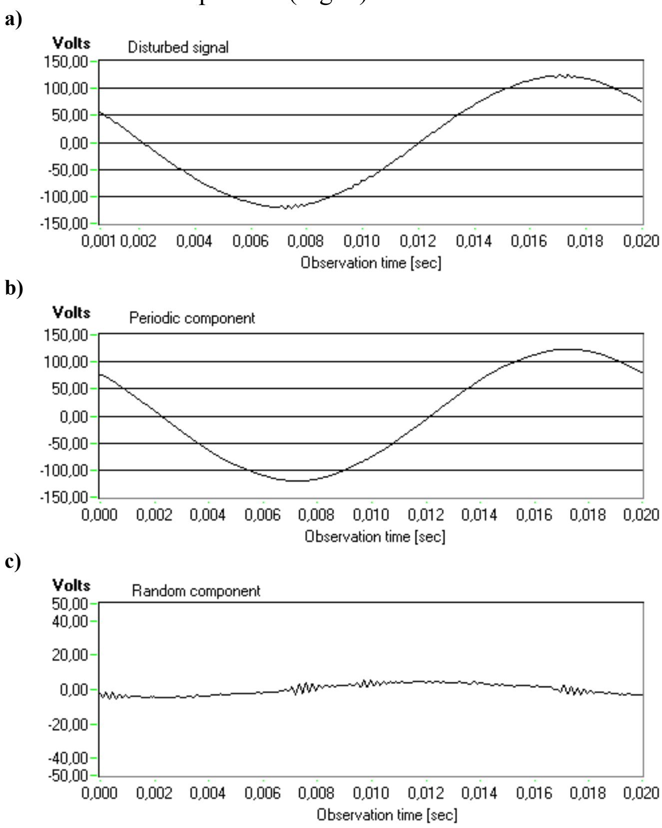

Fig. 5. Time waveforms of interference voltage in the industrial net supplying a rolling mill (a), periodic (b) and random component (c)

The observed differences between the two values indicate that there is a great influence of a random component, not yet taken into account in the analyses, on the results of the standard measurement of the coefficient THD, which characterises low frequency periodic interference in the supply voltage.

The conducted spectral analysis of a periodic component in the four measuring bands (Tab. 1) showed the presence of random interference especially as far as the range of very low frequencies below 50Hz (Fig. 7) were concerned. It was confirmed by the results of measuring the voltage fluctuations causing flickering of the light, whose source is random interference of very low frequency, and which are caused by the work of receivers with sudden change of

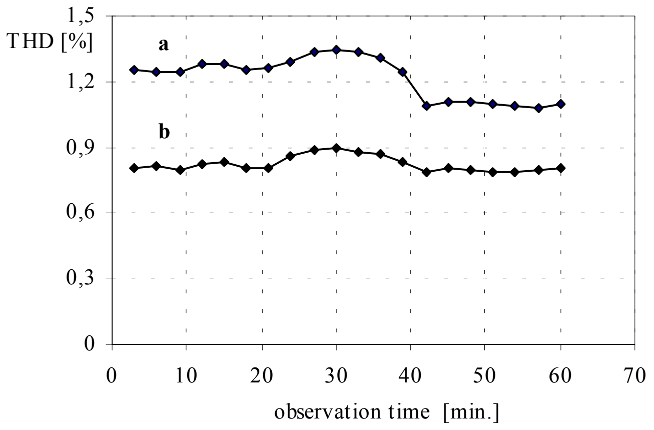

Fig. 6. Values for the total harmonic distortion coefficient THD in the voltage of the power line supplying a rolling mill determined:

a) on the basis of the analysis of the measured course
b) according to the definition of THD (taking into account a periodic component only)

loads, supplied by this power (Fig. 8). The big changes of the effective error values (Tab. 1) result first of all from the fact that the constant sampling time was accepted in the frequency analysis. A greater accuracy within very low frequencies can be obtained by increasing this time.

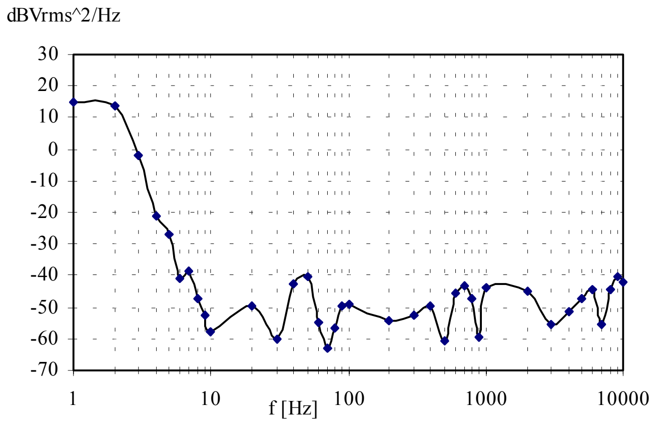

Fig. 7. The power spectral density of random component of the interference in the voltage of the line supplying a rolling mill

TABLE 1. Resolution and effective error of the measurement of the power spectral density of the random component of the interference in the voltage of the line supplying a rolling mill

Measuring Bands	Resolution Δf [Hz]	Effective Error ε [%]
1 Hz – 10 Hz	1	10
10 Hz – 100 Hz	10	3,2
100 Hz – 1 kHz	100	1
1 kHz – 10 kHz	1000	0,32

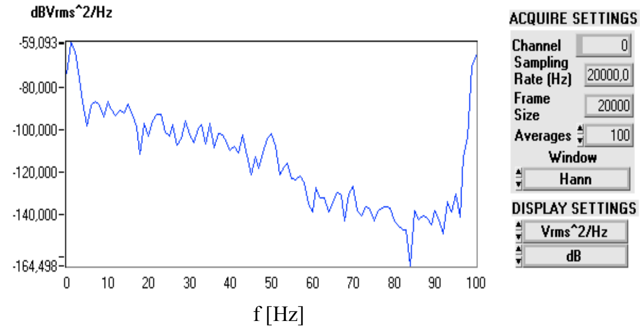

Fig. 8. The power spectral density of the signal from the exit of the envelope demodulator of the flickermeter, on whose entrance the voltage course from the power line supplying a rolling mill was given – the panel of the virtual instrument [4] (Δf=1Hz, ε=10%)

4. FINAL REMARKS

In the technique of making measurements of interference it is necessary to ascribe a priori certain features to the analysed course. The problem is connected with determining both detailed data essential to measure a definite parameter or characteristics, as well as the factors deciding about the inaccuracy of the measurement. The inaccuracy of these data in respect to their real values is the source of a subjective error– the error of classification. In order to reduce this error the new concept of a method measuring low voltage interference was proposed. This methodology allows differentiating periodic and random components in the analysed course of interference.

The results of the measurements showed that it is possible to increase the accuracy of the measured values, characterising undesirable periodic courses. For instance, while measuring THD with the standard methods it is often possible, especially for their small values, to overstate considerably their level, because the measured effective values contain not only periodic, but also a random component.

The effective increase of the accuracy of the measurements results of the values determining low frequency interference can be thus produced elaborating the measuring software using the algorithms which take into account the specificity of the features of the measured values (occurrence of random and determined components), the conditions connected with the devices and the selected statistical and probabilistic methods in the process of digital measurements of low frequency interference.

The very important thing is, however, the proper evaluation of the obtained results of the measurements, which is connected with the analysis of the whole measuring course, which depends on the configuration of the hardware part of the measuring system, and also its software (algorithms of signal processing).

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