

THE NEW METHOD OF INTERFERENCE ASSESSMENT IN LOW-VOLTAGE POWER SUPPLY LINES

Beata Palczyńska ⁽¹⁾, Ludwik Spiralski ⁽²⁾, Janusz Turczyński ⁽³⁾

⁽¹⁾ Department of Marine Radio Electronics, Gdynia Maritime Academy, Morska 83, 81-225 Gdynia, Poland
Phone (+48 58) 6289552 e-mail: palbeata@wsm.gdynia.pl

⁽²⁾ Department of Measuring Instrumentation, Technical University of Gdansk, Narutowicza 11/22, 80-952, Poland
Phone: (+48 58) 3471504 e-mail: kapsz@pg.gda.pl

⁽³⁾ Industrial Institute of Electronics, Długa 44-50, 00-241 Warsaw, Poland
Phone (+48 22) 6351247 e-mail: turczyn@pie.edu.pl

Abstract - The paper presents the interference model appearing in the low voltage supply in the form of series connection of equivalent sources: periodic and random. It gives the method to measure interference within low frequencies as well as high frequencies with the use of a typical measuring receiver with frequency change. The application of the measuring receiver makes it possible to limit the band of the analysed high frequency signal to the band equal to the width of intermediate frequency band of the measuring receiver. The receiver, in turn, enables further analogue-digital processing of the signal with an a/c converter of relatively low sampling frequency (of tens of kHz). The proposed method of interference measurement enables a deep analysis of the examined waveforms, especially the distinction of random and periodic components of interference. The paper presents the realisation of the interference measuring system and the exemplary results of the measurements carried out with the system.

Keywords - interference, measurement of electrical quantities, virtual instrument.

1. INTRODUCTION

The so far used models of interference in low voltage supply lines describe the correctly observed phenomena only for the interference of the determined character. The research and measurements, on the contrary, showed in power supply voltage waveforms the appearance of random components of interference beside determined components [1, 2]. Therefore, in reality undesirable periodic waveforms appear inseparably with random waveforms (noises) which affect the results of the measurement of the values accepted in bibliography, that is within the standards, which characterise interference. Neglecting the random interference causes that the measurements of these parameters with the so far used methods contain errors, which are bigger when the participation of the random component of interference is bigger, too.

The paper proposes the method of interference assessment, which allows carrying out a thorough analysis of

the examined waveforms, especially distinguishing the random and periodic components of interference. And as well as both separate and common determination for them the values describing interfering waveforms as e.g. spectral power density, the function of probability density of accepting the instantaneous values.

For this purpose the digital measuring system has been designed, which works in commonly used software LabVIEW [3]. The system uses an a/c converter of relatively low sampling frequency (of tens of kHz) to measure both interference for low frequencies and radioelectrical interference in the band from 150 kHz to 30 MHz. The analogue-digital interference conversion in the wide frequency band was obtained thanks to the application in the measuring path of the high frequency signal the author's method of the measurement performance with the use of a measuring receiver with frequency change.

2. THE INTERFERENCE MODEL IN THE LOW VOLTAGE SUPPLY LINES

The interference model with the distinction of equivalent sources: periodic and random corresponds to the conditions appearing in the real low voltage power supply lines (Fig.1). It requires separating in the observed voltage waveform the random and periodic components of interference. The author's procedure of separating both the components in the voltage power supply waveform consists in adding coherently

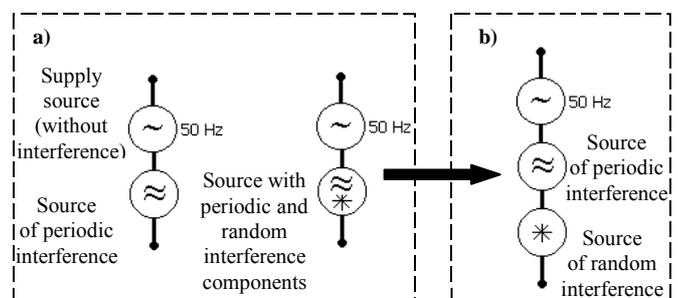


Fig. 1 - Equivalent voltage interference sources in low voltage supply lines
a) basic model heretofore used
b) proposed model (devised by the authors) [4]

the voltage time sections of the length corresponding to the overall multiple of the voltage supply period [4].

It is realised according to the algorithm shown in Fig. 2 and it requires the introduction of the following input data:

- f_s sampling frequency,
- f_1 basic frequency of the supply net,
- N the multiple of adding the samples sets,
- K the number of one samples set.

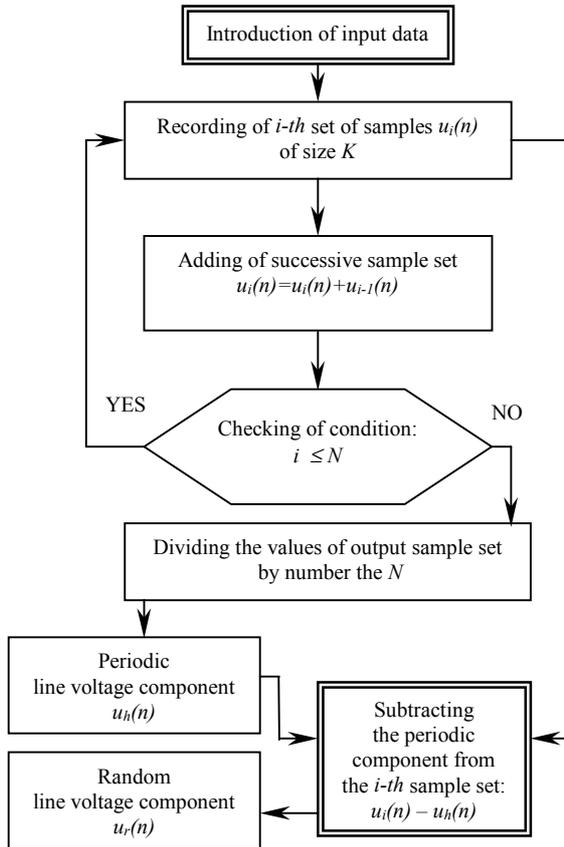


Fig. 2 - Algorithm for separation of periodic and random interference components occurring in the low voltage supply lines

These parameters affect accuracy of the obtained results, distribution of the further spectrum analysis, and also inaccuracy of the estimation of the values connected with the mean square (effective) value, spectral power density of the periodic and random components of power supply voltage.

The periodic component is obtained as a result of coherent addition of N samples sets:

$$u_{mean}(i\Delta t) = \underbrace{\frac{1}{N} \sum_{k=1}^N u_{hk}(i\Delta t)}_{u_h(i\Delta t)} + \underbrace{\frac{1}{N} \sum_{k=1}^N u_{rk}(i\Delta t)}_{u_r(i\Delta t)} \quad (1)$$

where: $u_h(i\Delta t)$ is the averaged periodic component in the supply voltage,

$u_r(i\Delta t)$ is the averaged random component in the supply voltage.

The other part of the equation (1) describes the systematic part of the error (bias error) in the estimation of the instantaneous component of the periodic waveforms in the supply voltage, carried out with the use of coherent addition. For a great number of averages N (in case of an ergodic waveform of the symmetric distribution of the probability of accepting the instantaneous values of voltage), the averaged random component gives the value equal to zero. Then:

$$u_{mean}(i\Delta t) \cong u_h(i\Delta t) \quad (2)$$

Separating the random component $u_r(i\Delta t)$ is performed by subtracting the samples set $u_{mean}(i\Delta t)$, the one resulting from coherent addition, from i -th input samples set $u_i(i\Delta t)$.

3. ACQUISITION OF MEASUREMENT DATA IN HIGH FREQUENCY RANGE

In order to measure digitally the signals in the band of high frequency it is necessary to use an a/c converter of very high sampling speed. The maximum frequency signal occurring in the spectrum, e.g. 30 MHz, requires a converter of sampling frequency over 100 MHz and the memory of great capacity which is necessary to record and store a given fragment of a continuous sampling signal. On the other hand, using the measuring receiver with frequency change in the measuring path of high frequency signal, makes it possible to reduce the bandwidth of the analysed high frequency signal to the band equal to the width B of the intermediate frequency band of the receiver [5]. E.g. for a typical interference meter, within measuring frequencies from 150 kHz to 30 MHz, $B=9$ kHz. Then, after linear detection it is possible to sample a signal of a limited spectrum (called also subsampling), where the required sampling frequency f_s should be at least twice higher than the width of the intermediate frequency band of the receiver [6].

$$f_s \geq 2B \quad (3)$$

Simultaneously, because of the effect of R - multiple duplication of spectrum, the minimum sampling frequency f_{smin} , which allows avoiding the aliasing effect, can be expressed by the formula [6]:

$$f_{smin} = \frac{2f_{int} + B}{R} \quad (4)$$

where: f_{int} - intermediate frequency of the receiver,
 R - the total number of duplications, such that:

$$R \leq \frac{f_{int} + \frac{B}{2}}{B} \leq R + 1$$

When the typical interference meter $f_{int}=2,1$ MHz is used within the measuring frequency range of the meter from 150 kHz to 30 MHz and the width of the meter band $B=9$ kHz, the total number of duplications $R=233$; thus $f_{smin}=18,06$ kHz.

The proposed method of acquisition of the measuring data representing high frequency interference enables the use of an a/c converter of a relatively low sampling frequency.

The intermediate frequency band of the receiver determines the width of the analysed band.

4. MEASURING SYSTEM

In the elaborated measuring system it is possible to distinguish two parts: hardware and software (Fig. 3) [7].

In the hardware the input signal is preliminarily conditioned (damping, the separation of the signal in the supply 50Hz), and then depending on the frequency range it is further processed in two separate measuring paths. The low-frequency signal after low-pass filtration (antialiasing) is processed directly in the converter a/c. Whereas, the high frequency signal is put to the typical measuring receiver with frequency change (interference meter), which enables transferring the successive bands of the analysed high frequency signal to the range of low frequencies. The signal from the intermediate frequency output is taken to the band amplifier of the constant amplification around the intermediate frequency f_{int} and of the bandwidth equal to the intermediate frequency bandwidth B of the measuring receiver. The function of the amplifier is to intensify the signal to the level appropriate for linear work of the detector. On the detector output we obtain the signal of the spectrum

limited to the width B of the intermediate frequency band. The window discriminator steered by the constant component obtained during detection is included in the detector feedback loop in order to correct linearity of the detector characteristics. Then, the signal is sampled in an a/c converter and stored in the computer memory. The presented system makes it possible to measure continuously the signal in the high frequency band for the successive measuring frequencies separated from one another by the bandwidth B . The digital signal is next processed by the off-line method in the computer processor in the software LabVIEW.

In the system software in the measuring signal two components are separated: periodic and random. Then, in the processing and digital data analysis block a further separate analysis is performed for both interference components. The virtual instruments designed in the software LabVIEW fulfil the functions of the periodic interference standard meters, as well as of the random signal analysers. In case of the measurement of a high frequency signal during the digital procession it is necessary to take into account the influence of the shape of frequency characteristics $H(\omega)$ of the interference meter and the intermediate frequency bandwidth B of the meter on the measurement result.

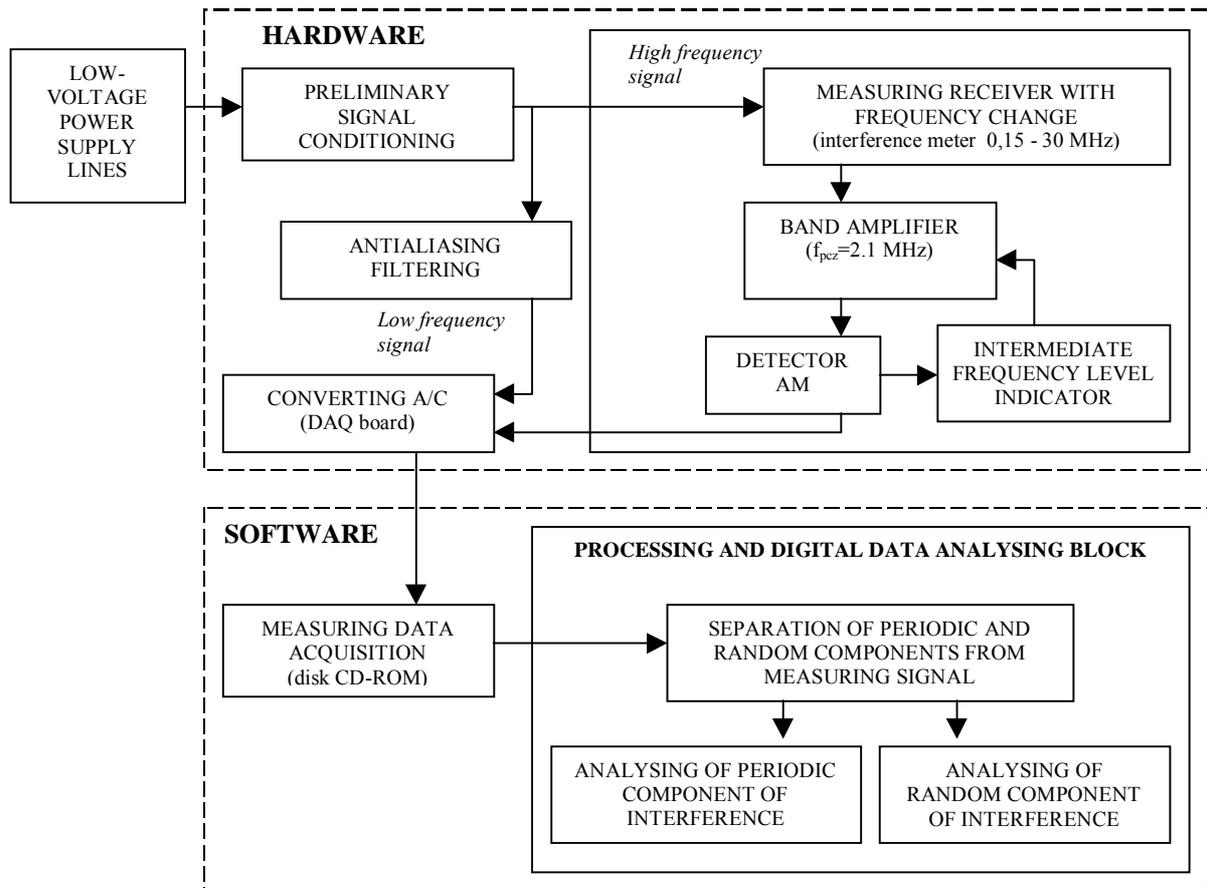


Fig. 3 – Block diagram of the digital system for measuring the interference with the distinction of the random and periodic components

5. EXEMPLARY MEASUREMENTS RESULTS

The presented system was used to measure the interference occurring in the low voltage supply lines. For instance, it was possible to present the measurements results of the interference introduced to the low voltage supply by the pulse generator. It was also possible to record voltage waveforms for the measuring frequency 1,82 MHz with the use of a typical interference meter (Fig. 4a). After the application of the presented procedure we obtained the periodic (Fig. 4b) and the random (Fig. 4c) components.

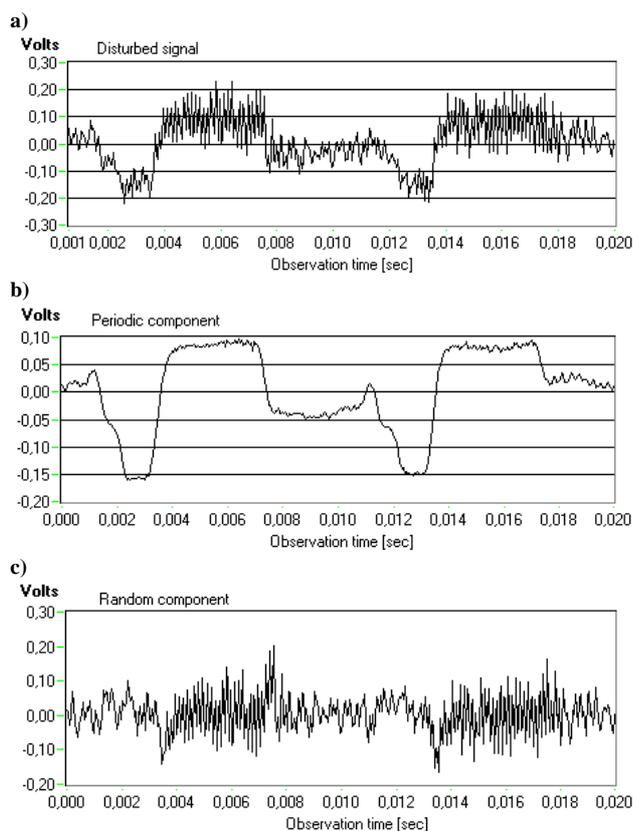


Fig. 4 – Time waveforms of voltage interference produced in the power supply lines by pulse generator (a), periodic component (b), random component (c).

The procedure of separating both components was realised for 50 averages

Another example of the efficiency of the elaborated method of separating periodic and random components is Fig. 5, which illustrates low frequency interference introduced into the industrial supply line as a result of the work of very big loads.

6. CONCLUSIONS

At present the authors continue work on the problems connected with interference measurement techniques. The work concerns especially the modification of the sets of preliminary conditioning of the signal with the emphasis on

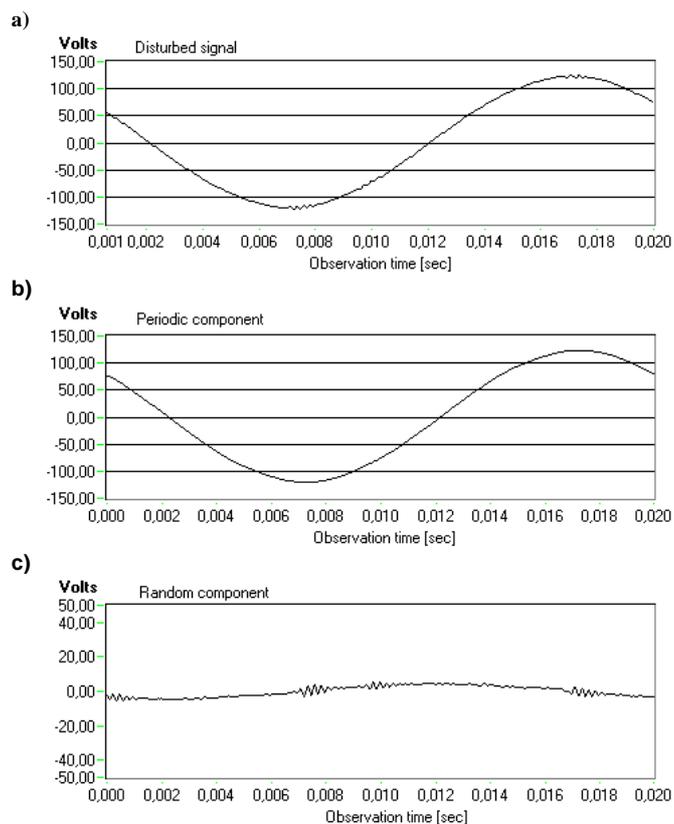


Fig. 5 - Time waveforms of interference voltage in the industrial net supplying a rolling mill (a), periodic (b) and random component (c).

The procedure of separating both components was realised for 50 averages

increasing the sensitivity of the measuring system for the low frequency measurement as well as experimental research on the verification of the interference model, particularly on the determination of the parameters values characterising the random component of the interference of both low and high frequencies. Another subject, not touched in the paper, is a detailed frequency analysis – separate for the periodic and random components.

In the authors' opinion the presented method of interference measurement distinguishing both components, more adequate to the real conditions in comparison with the so far used method, enables the use of more effective methods of interference reduction.

REFERENCES

- [1] B. Pałczyńska, T. Tarasiuk, "Method of measurement of voltage properties on bus bars of ship's main switchboard – tools and preliminary results", *Polish Maritime Research*, no.2 (24), June 2000, vol.7, Shipbuilding&Shipping Ltd., pp.9-12.
- [2] R. C. Dugan, M. F. McGranaghan, H. W. Beaty, *Electrical Power System Quality*, McGraw-Hill, New York 1996.
- [3] LabVIEW Analysis VI Reference Manual, National Instruments, 1994.
- [4] B. Pałczyńska, L. Spiralski, J. Turczyński, "The measurement of random component disturbances in low voltage power supply lines", *Letters of Industrial Institute of Electronics*, Issue no. 142/2000, (in Polish).

- [5] L. Spiralski, A. Konczakowska, B. Pałczyńska, J. Turczyński, "Digital measurement of high frequency interference with use of standard measuring receiver with frequency change", *Metrology and Measurement Systems*, Quarterly of Polish Academy of Sciences, in press.
- [6] C. Marven, G. Ewers, *A simple approach to digital processing*, John Wiley&Sons Inc., 1996.
- [7] B. Pałczyńska, L. Spiralski, A. Konczakowska, "Measurement system of interference in low frequency range in low-voltage power supply 50 Hz", in *Proc. of IMEKO World Congress*, Vienna 2000, vol. IV, pp.259-264