

The problem of “spectrum leakage” in the measurement of harmonics

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Abstract. The paper presents the results of a simulation research showing the problem of "spectrum leakage" in harmonic measurements. At the beginning, the paper discusses issues related to the need to analyze the power quality and the phenomenon of "spectrum leakage". Subsequently, for the test signals, measurement of harmonics in accordance with the applicable standard, was performed. During the simulation research, the frequency of the tested signal was changed in the range of acceptable deviations of the frequency of the voltage in the power grid determined by the appropriate standard. The harmonic measurement error was determined, with the known spectrum of test signals. Metrological interpretation of the obtained results, and formulations of conclusions were presented in the paper.

1 Introduction

The intensive development of the provision of power supply services has resulted in the fact that pursuant to the Act [1], which refers to the Regulation of the Minister of Economy [2], there is a requirement that the power distributor guarantees the certain quality of power.

The basic values determining the quality of supplied power are inter alia:

- voltage harmonics u_n , where n is the harmonic order,
- THD_U voltage total distortion factor.

These two parameters determine deformation of the power supplied. They are currently particularly important due to the large number of electronic power loads in the power grid. According to standard [3], these parameters are calculated for a time equal to $10T$, where T is the nominal fundamental period of the voltage in the power grid. In practice, period T is not constant, which results in the phenomenon of "spectrum leakage", causing the incorrect evaluation of power quality.

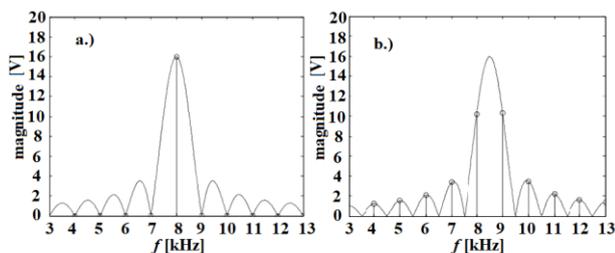


Fig. 1. The example of the convolution of spectrum of sinusoidal signal with frequency a.) 8 kHz or b.) 8.5 kHz and spectrum of rectangular measurement window with length 1 ms, where in case b.) measuring window is not total multiple of the period of sinusoidal signal - "spectrum leakage" [4].

The detailed discussion of the phenomenon of "spectrum leakage" is presented in [5]. In short, if the length of measurement window is not total multiple of the period of the analyzed signal, then result in a "spectrum leakage", as shown in Fig. 1.

2 Numerical simulation research

To analyze the impact of "spectral leakage" on the measurement error of harmonics, two test signals were selected, i.e., the sinusoidal and the triangular signal.

For the simulation study of the quality of the elimination "spectrum leakage", three measurement windows were selected:

- Blackman, characterized by high damping,
- Blackman-Harris, characterized by high dynamics,
- Flat top, recreating the accurate value of the fundamental harmonic,

and compared with the rectangular measurement window and the subgrouping determined by the standard [3].

The studies were performed for the following frequency values of test signals:

- 47 Hz and 52 Hz, which are the acceptable limit deviation of the frequency of the voltage in the power grid, defined by the standard [6],
- 49.9 Hz and 50.1 Hz, which are limit typical deviation of the frequency of the voltage in the power grid [7],
- 50 Hz, which is nominal value.

To evaluation of the effect of "spectral leakage" on the measurement error of harmonics an unsigned relative error δ , described by equation [8]:

$$\delta = \frac{|U_a - U_F|}{U_F} \cdot 100\%, \quad (1)$$

where: U_a is the rms value of the harmonic from the simulation, and U_F is the rms value of the harmonic

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obtained from the expansion of the function in the Fourier series.

The results of the calculated errors of the fundamental harmonic measurement for a sinusoidal signal with an amplitude of $230\sqrt{2}$ V are shown in Fig. 2.

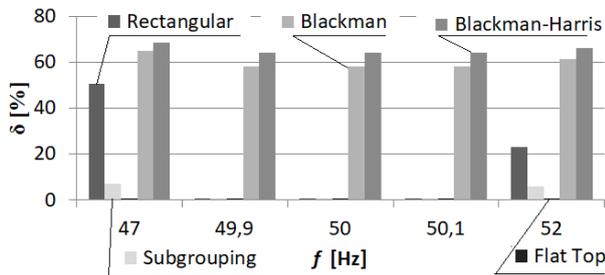


Fig. 2. Distribution of relative error of the fundamental harmonic for the sinusoidal test signal.

Based on the results of the simulation for a triangular signal with an amplitude of $230\sqrt{3}$ V, the characteristics of error for individual harmonics at the frequency of the signal respectively: 47 Hz (Fig. 3), 49.9 Hz (Fig. 4), 50 Hz (Fig. 5), 50.1 Hz (Fig. 6) and 52 Hz (Fig. 7).

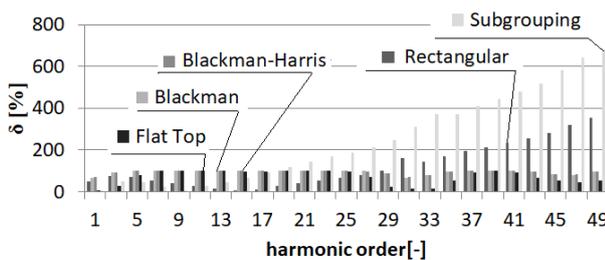


Fig. 3. Distribution of relative error of odd harmonics for the triangular test signal (47 Hz).

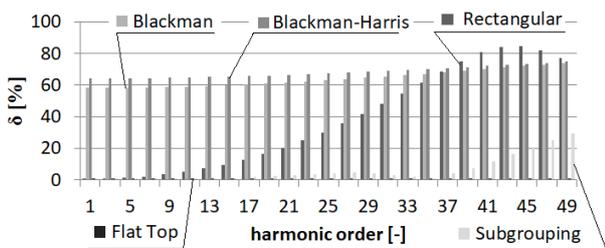


Fig. 4. Distribution of relative error of odd harmonics for the triangular test signal (49.9 Hz).

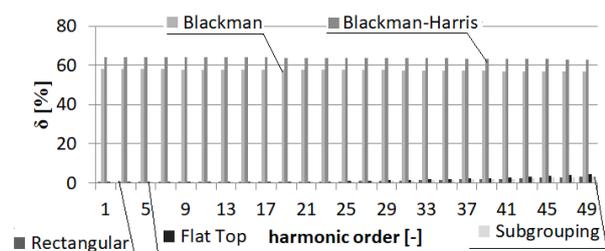


Fig. 5. Distribution of relative error of odd harmonics for the triangular test signal (50 Hz).

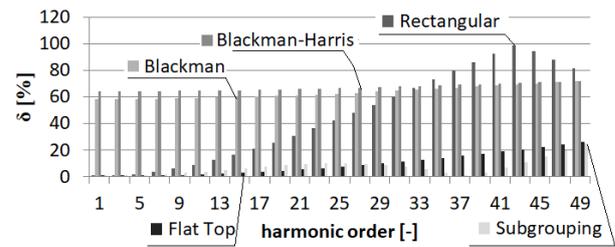


Fig. 6. Distribution of relative error of odd harmonics for the triangular test signal (50.1 Hz).

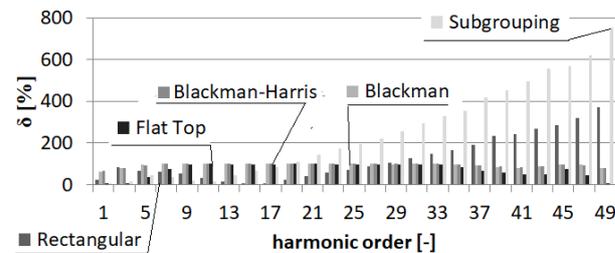


Fig. 7. Distribution of relative error of odd harmonics for the triangular test signal (52 Hz).

3 Conclusions

Performed simulation research allows to formulate the following conclusions.

- The phenomenon of "spectrum leakage" is dangerous for measurement of higher harmonics. In addition, the fundamental harmonic, used to calculate other indicators of power quality, is distorted. Ultimately, an unjustified financial burden on the consumer may occur.
- The subgroup method enables satisfactory reduction of the effects of "spectrum leakage" only for typical frequency deviations of the voltage in the power grid.
- The Flat Top window allows reducing the error of measuring the harmonics for the whole range of acceptable changes and enables accurate recreation of the fundamental harmonic.
- Other analyzed measurement windows do not have properties that support the measurement of harmonics.

References

1. The Act of 10th of April 1997 Energy Law
2. Decree of Ministry of Economy on detailed conditions of power system operation, 2007
3. IEC Std. 61000-4-7: (EMC) – Part 4-7
4. P. Kuwalek, PUT Academic Journals. Electrical Engineering., 63-74, **97** (2019)
5. P. Kuwalek, *The Problem of "Leakage Spectrum" in the Process of Power Quality Evaluation*, M.Sc. Thesis (Poznan 2018)
6. EN Std. 50160 – Voltage Characteristic in Public Distribution Systems
7. B. Schäfer, Nature Energy, 119–126, **2** (2018)
8. P. Kuwalek, P. Otomanski, *Proc. of the 11th Int. Conf. on Measurement*, 15-18 (Smolenice, 2017)