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METROLOGICAL ASPECTS OF INTER - HARMONIC IDENTIFICATION AND GROUPING IN ELECTRICAL POWER SYSTEMS

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Abstract − The main purpose of this paper is to present some metrological aspects of identification and grouping of harmonics and interharmonics and calculation of total harmonic. The Virtual Instrument for identification of distorted signal spectrum is described and the demonstration may take place at the presentation of the paper at the oral or poster session. We define the total harmonic and interharmonic distortion coefficient and analyse its sensitivity to variation in fundamental and interharmonic frequency and sensitivity to incompleteness of samples for five different cases: rectangular window, triangular, Hanning, Hamming and Blackman windows. The virtual test signal was selected arbitrarily. This signal was processed first by the virtual harmonic analyser, in such a way that all components were identified without any errors, and then the signal was analysed according to the requirements specified in IEC 61000-30-4 draft standard, in which also Harmonic Groups (HG) and Interharmonic Groups (IHG) are defined.

Keywords: Harmonic Group, Interharmonic Group.

1. INTRODUCTION

The quality of electrical power depends on the harmonic contents induced due to the non-linear loads of electrical power users. There are three components of spectrum, which can be classified as follows:

(i) harmonics whose frequencies are integer multiples of fundamental frequency, called harmonics ,
(ii) harmonics whose frequencies are non-integer multiples of fundamental frequency, called interharmonics and
(iii) harmonics non whose frequencies are below the fundamental frequency, referred to as subharmonics.

The presence of harmonics has only disadvantages. One of them is additional electrical power losses caused by the current of harmonics through electrical line. The other, mainly in the form of short picks and spikes, can cause malfunctioning or even braking down of some electronic equipment.

The most commonly known non-linear loads are: electrical furnaces, all electromagnetic devices, power suppliers, frequency converters, switching gears, arc-phenomena based devices and fluorescent lamps. Quite significant contribution to power distortion is due to switching -on and -off of the electrical loads and these devices which need to use electrical power in a pulse way.

Analysis of the problems that arise due to the presence of harmonics is the primary task from measurement point of view and the normalisation in EMC compatibility areas. The character of harmonics, sub- and interharmonics, which are not time invariant, makes it difficult to cope with such unstable and unpredictable frequency. It is very difficult to identify harmonics properly and to choose the antyaliasing filters, and windows (type and width).

2. THE CHALLENGE

Interharmonics and sub-harmonics of the electrical power voltage and current exist nowadays in nearly each branch of all electrical power system. This is due to character of the load. Interharmonics and sub-harmonics influence electrical power quality in a more or less significant way. Evaluation of the flickering effect, which is the result of the presence of sub-harmonics, is quite well characterised but the evaluation of the interharmonics is still not satisfactory.

The flick meters are developed under IEC 61000-4-15 standard. The long term severity and its trend describe sub-harmonics' amplitude and their frequency quite well. The problem is usually with the time of observation.

The evaluation of interharmonics reveals even more problems after more careful analysis even though these problems are not identified by IEC 61000-4-30. The problems are caused by the time variation of interharmonics of electrical power.

3. DEFINITIONS

Interharmonics change their value and frequency in time, very often in a short time, due to the character of their source. This creates a very difficult situation from measurement point of view. The problem is how to choose the type and time of window duration, sampling frequency, and number of samples that should be taken into consideration. The IEC 61000-4-30 draft of standard, which proposes the grouping of harmonics and interharmonics, defines also the length of measurement widow, which allows 5 Hz resolution of harmonics. The proposed Harmonic Groups, HG, and Interharmonic Groups IHG, are in complete agreement with the Total Harmonic Distortion coefficient commonly used for distorted signal characterisation. In this paper we introduce a new term, which is called Total Harmonic & Interharmonic Distortion defined as a root of sum of squares of all HG and IHG minus a square of amplitude of the fundamental harmonic.

$$TH\ \&\ IHD = \sqrt{C^2_{n-200-ms} + C^2_{n+0,5-200-ms} - A_1^2} \qquad (1)$$

where all symbols used have the same meaning as in IEC1000-4-30 standard draft.

The new factor intorduced for easier analysis of sensitivities of the *TH&IHD* coefficient is defined as:

$$TH\ \&\ IHD_{ERROR\_rel} = \frac{TH\ \&\ IHD - TH\ \&\ IHD\_ref}{TH\ \&\ IHD\_ref} \qquad (2)$$

where: $TH\&IHD_{rel}$ corresponds to the ideal conditions of FFT analysis, which means that all components of harmonic and interharmonic were correctly identified.

The arbitrarily chosen test signals were applied at the input of the constructed virtual instrument. The modelled signals, which contain defined sub- higher- and inter- harmonics were used as the non-sinusoidal signals to test proposed algorithm of data analysis. The signals were in a software form, so the real harmonic contents were strictly defined.

Fundamental frequency is 50 Hz, of amplitude of 5 units, and: 92 Hz of amplitude 2 units, 167 Hz of amplitude 2 units and frequencies: 267 Hz, 270 Hz, 273 Hz, 276 Hz, 279 Hz, 282 Hz, 285 Hz, 288 Hz, 291 Hz each of amplitude of 1 unit. This arbitrarily chosen test signal, whose time dependence is presented in Fig. 1, and amplitude spectrum in Fig. 2, was applied at the spectrum analyser. The spectrum analyser based on 200 ms time duration window was used according to the IEC-1000-4-30 recommendation. Fig. 3 depicts the interharmonic content, Fig 4 Inter-Harmonic Grouping, IHG and Harmonic Grouping in Fig 5 was calculated also according to the IEC-1000-4-30 recommendation.

The main goal of this paper is to present the influence of basic harmonic variation. Incompleteness of samples and arbitrarily chosen interharmonic variation affect Total harmonic variation THD calculated based on the IEC-1000-4-30 recommendation. The reference value for THD was considered to be the real value of THD for the test signal. The relative error between as defind by Equ. 2 was calculated as

- variation of IH_{ERROR_rel} vs variation of the fundamental frequency expressed as percentage Table 1 and Fig 6.
- $TH\&IH_{ERROR\_rel}$ vs variation of a single interharmonic frequency expressed as percentage, interharmonic frequency variation expressed as percentage in Table 2. and Fig 7.
- $TH\&IH_{ERROR\_rel}$ vs variation of the percentage of missing samples expressed as percentage

All calculations were performed for five cases of the most commonly used windows: rectangular, triangle, Hanning, Hamming and Blackman.

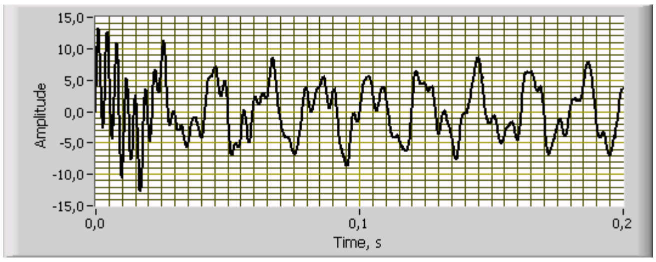

Fig. 1. Arbitrary chosen signal for harmonic and interharmonic examination.

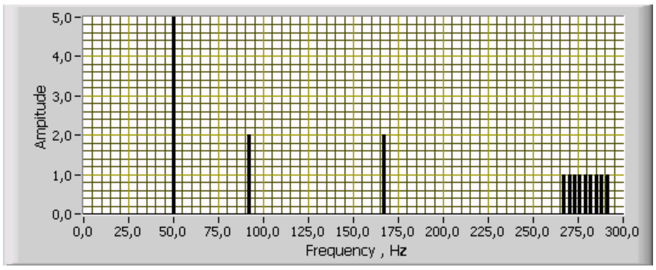

Fig. 2. Harmonics and interharmonics of the arbitrarily chosen signal for f_w=1Hz, f_s=1024 Hz, M=1024

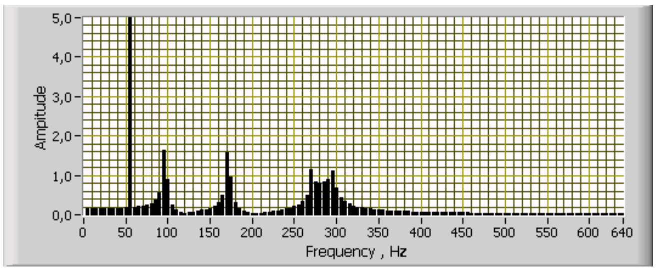

Fig. 3. Spectrum of the signal analysed according to the IEC-1000-4-30 draft (f_w=5 Hz, T_w=200 ms, f_s=5120, M=1024)

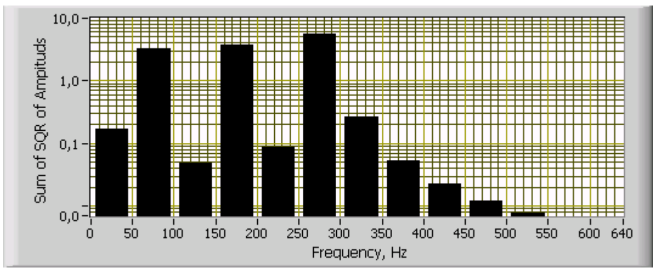

Fig. 4. Interharmonic groups of the signal under consideration in logarithmic scale calculated according to the IEC-1000-4-30 draft

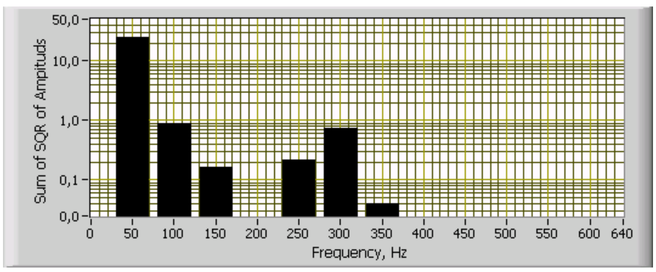

Fig. 5. Harmonic groups of the signal under consideration in logarithmic scale calculated according to the IEC-1000-4-30 draft

TABLE 1. $TH\&IH_{ERROR\_rel}$ vs variation of the fundamental frequency expressed in percentage

frequency		Windowing				
f_1	f_1 in	Rectan -gular	Trian-gle	Hamm -ing	Hann-ing	Black-man
Hz	%	%	%	%	%	%
45.0	-10.0	139.5	-39.0	-27.8	-34.2	-48.4
45.5	-9.0	138.3	-41.8	-31.0	-37.2	-50.5
46.0	-8.0	133.8	-45.1	-34.8	-40.5	-52.7
46.5	-7.0	124.4	-48.9	-39.0	-44.1	-55.0
47.0	-6.0	108.3	-53.0	-43.5	-47.9	-57.3
47.5	-5.0	85.4	-57.2	-48.2	-51.5	-59.4
48.0	-4.0	58.6	-61.2	-52.8	-54.9	-61.3
48.5	-3.0	32.6	-64.7	-56.9	-57.7	-63.0
49.0	-2.0	11.3	-67.4	-60.2	-59.9	-64.2
49.5	-1.0	-2.9	-69.1	-62.2	-61.3	-64.9
50.0	0	-8.6	-69.6	-63.0	-61.8	-65.2
50.5	1.0	-5.2	-69.0	-62.4	-61.3	-64.9
51.0	2.0	6.4	-67.1	-60.5	-59.9	-64.2
51.5	3.0	23.8	-64.3	-57.6	-57.7	-62.9
52.0	4.0	44.3	-60.7	-53.8	-54.8	-61.3
52.5	5.0	66.2	-56.7	-49.3	-51.5	-59.4
53.0	6.0	88.6	-52.5	-44.4	-47.8	-57.2
53.5	7.0	109.8	-48.5	-39.6	-44.1	-55.0
54.0	8.0	126.6	-44.8	-35.0	-40.5	-52.7
54.5	9.0	136.6	-41.7	-31.1	-37.2	-50.5
55.0	10.0	139.9	-39.1	-27.8	-34.2	-48.4

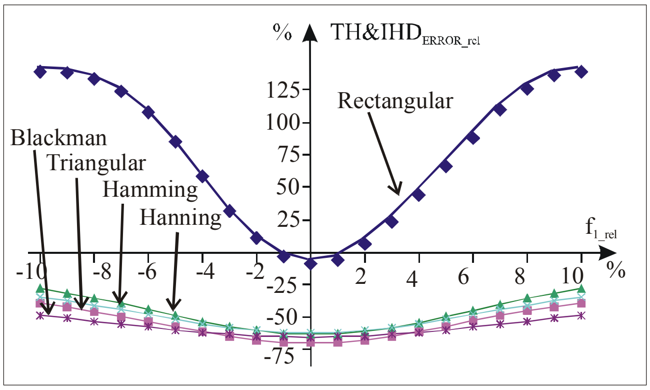

Fig. 6. $TH\&IH_{ERROR\_rel}$ vs. variation of the fundamental frequency expressed in percentage

TABLE 3. TH&IHERROR_rel vs variation of a single interharmonic frequency expressed as percentage, interharmonic frequency variation expressed a percentage

frequency		Windowing				
f_1	f_1 in	Rectan gular	Triangl e	Hamm -ing	Hann-ing	Black-man
Hz	%	%	%	%	%	%
52.0	-43.5	-24.0	-71.0	-64.3	52.0	52.0
56.0	-39.1	-9.0	-79.4	-74.8	56.0	56.0
60.0	-34.8	-8.4	-63.8	-56.7	60.0	60.0
64.0	-30.4	-9.1	-70.9	-63.2	64.0	64.0
68.0	-26.1	-9.6	-69.1	-63.0	68.0	68.0
72.0	-21.7	-8.8	-69.4	-63.0	72.0	72.0
76.0	-17.4	-8.2	-70.1	-63.0	76.0	76.0
80.0	-13.0	-8.3	-69.1	-63.0	80.0	80.0
84.0	-8.7	-9.0	-69.9	-62.9	84.0	84.0
88.0	-4.3	-9.4	-69.5	-62.9	88.0	88.0
92.0	0.0	-8.6	-69.6	-63.0	92.0	92.0
96.0	4.3	-8.1	-69.8	-63.0	96.0	96.0

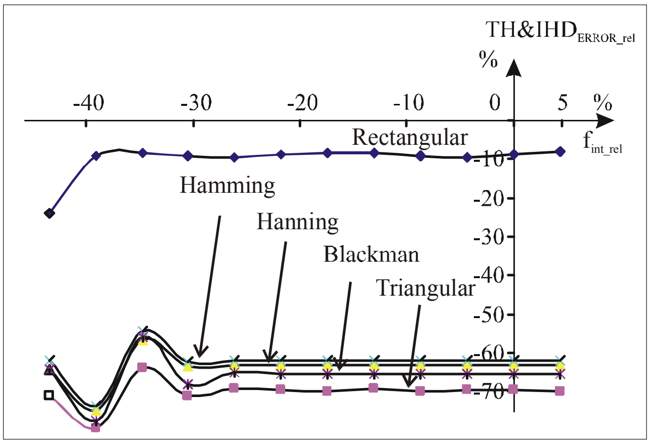

Fig. 7. $TH\&IH_{ERROR\_rel}$ vs. variation of single interharmonic frequency expressed in percentage, interharmonic frequency variation expressed in percentage.

TABLE 3.TH&IHERROR_rel vs variation of percentage of missing samples expressed as percentage

frequency		Windowing				
f_1	f_1 in	Rectan -gular	Trian-gle	Hamm -ing	Hann-ing	Black-man
Hz	%	%	%	%	%	%
964	-5.86	-5.3	-68.7	-62.6	-61.8	-65.7
970	-5.27	-5.6	-68.7	-62.6	-61.8	-65.6
976	-4.69	-5.3	-68.8	-62.6	-61.8	-65.6
982	-4.10	-4.8	-68.8	-62.6	-61.8	-65.5
988	-3.52	-5.2	-68.9	-62.6	-61.7	-65.5
994	-2.93	-6.2	-69.1	-62.7	-61.7	-65.4
1000	-2.34	-7.2	-69.2	-62.8	-61.7	-65.4
1006	-1.76	-8.4	-69.3	-63.0	-61.7	-65.3
1012	-1.17	-9.3	-69.4	-63.0	-61.7	-65.3
1018	-0.59	-9.5	-69.6	-63.0	-61.8	-65.2
1024	0.00	-8.6	-69.6	-63.0	-61.8	-65.2
1030	0.59	19.9	-66.3	-59.8	-62.3	-69.5
1036	1.17	20.0	-66.1	-59.6	-62.1	-69.3
1042	1.76	20.1	-65.9	-59.4	-61.9	-69.1
1048	2.34	20.6	-65.7	-59.2	-61.7	-68.9
1054	2.93	21.3	-65.5	-58.9	-61.5	-68.8
1060	3.52	22.2	-65.4	-58.7	-61.2	-68.6
1066	4.10	22.7	-65.2	-58.5	-61.0	-68.4
1072	4.69	22.7	-65.0	-58.3	-60.8	-68.3
1078	5.27	23.0	-64.9	-58.0	-60.6	-68.1
1084	5.86	23.1	-64.7	-57.8	-60.4	-67.9

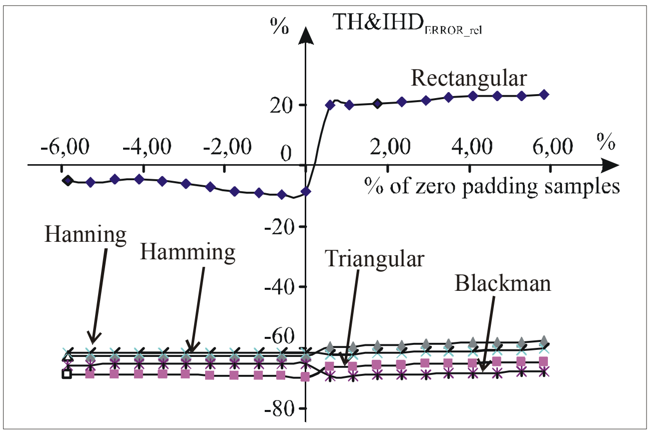

Fig. 8. $TH\&IH_{ERROR\_rel}$ vs. variation of the percentage of missing samples expressed as percentage

4. CONCLUSIONS

A rectangular window is most adequate but also most sensitive to variations of tested parameters. By applying the windows, the sensitivity is reduced significantly, but a displacement is observed. The displacement has a systematic character, hence it may be corrected.

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