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Measuring harmonic distortion in electrical power networks – New approach

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ABSTRACT

Standard specification for power network quality diagnostic systems requires synchronization of sampling rate to the network frequency in every 10 s in order to ensure high accuracy of harmonic analysis. The total harmonic distortion (THD) cumulates measurement errors, therefore it is the most sensitive parameter to the frequency synchronization. This paper investigates two main effects putting impact on the THD computation accuracy. The first is the effect of the base clock rate of sampling hardware and the second is the practical deviation of network frequency during the 10 s synchronization period. The relative accuracy of THD calculation is examined in different real practical solutions and different synchronization methods are discussed and assessed. Theoretical proof and practical demonstration are given to show the needs of special synchronization methods in certain measuring circumstances.

1. Introduction

Today and in the future electrical energy is a significant energy source for industrial, community and commercial applications, therefore, its quality and consumption have more and more importance in engineering practice and also in the respective scientific fields. This type of energy looks like usual goods from one side, as its quality and quantity can be determined, but it is a very specific product from the other side since its quantity is more visible than the quality, putting direct effect to the consumption and so to the cost [1]. It is special because the quality depends not only on the power supplier but also on the consumers: non-standard energy cannot be removed from the network and consumers can also disturb each other operation [2,3]. The quality problems have particular importance in the North-East Hungary region, where electronics industry requiring disturbance-free energy sources, suffers from highly contaminated electrical energy, which comes from the nearby significant "old-fashioned" metallurgical industry [4]. Therefore, the University of Miskolc has been dealing with quality determination problems for many decades. Results of the research work summarized in this paper are used in the project for development of a highly reliable system suitable for diagnostics of electrical power network of small and medium enterprises (SMEs). It is developed according to IEC 61000-4-30:2008 standards [5] in order to determine the quality of the energy, sources of the disturbances and efficiency of the energy utilization of the company.

Diagnostics of electrical power networks is a complex task from several aspects. The first aspect is the measurement methods and technology to be used and the second is the reliability and accuracy of data analysis because direct verification of the results is a real problem [6,7]. Standard defines strict rules for measurement methods, techniques and equipment used in power network analysis. In this article the problem of the sampling rate synchronization to the power network's frequency is presented along with new research achievements.

The standard named above requires synchronization of the sample rate to the power network frequency in each 10 s. Industrial measurements in many cases last for several days or weeks, they include 15 signals (for 5 three-phase system, including voltages and currents) to measure, and analysis is performed up to 9 kHz as stated in the standard,

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so the sample rate should be around 20 kHz. In case of performing long term, multichannel, continuous data acquisition on power network with "no data loss" and high sample rate requirement, on-line setting of the sample rate during the measurement needs special hardware and software solutions, like PLL or similar [8]. From the other side our experiments underlined that this synchronization method has accuracy problems. Therefore, different synchronization methods and their accuracy were investigated.

2. Test method

The aim of the standard requirement is obvious: to analyze exactly full periods of the measured signal in order to ensure accurate calculation of root-mean-square value (RMS), moreover frequency harmonics and the total harmonic distortion (THD) [8]. The fragment periods cause appearance of non-existing components around the basic signal's harmonics, while the amplitudes of the real harmonics are decreasing in the spectrum. The THD result in this case will be different from the real value. As the THD includes cumulative measurement and calculation errors, it is the most sensitive parameter from the frequency synchronization point of view. Therefore, relative errors of THD measurement are calculated and presented. There is also another important rule in the standard, defining the time frame for analysis equal to 10 periods of the signal to be measured. It means that the time frame (T_{reg}) used for the analysis is defined as, $T_{reg} = 10/f_{signal0}$ where $f_{signal0}$ is the frequency of the signal measured in each 10 s and used for synchronization. As the theoretical value of $f_{signal0}$ is 50 Hz in Europe, T_{reg} is 0.2 s. This time frame T_{reg} can be set acquiring appropriate number of samples (N_0) by the theoretical sampling frequency (f_{sr0}):

$$T_{reg} = 10/f_{signal0} = N_0/f_{sr0} \quad (1)$$

The sample rate is a whole multiple of the signal frequency in an ideal case:

$$f_{sr0} = k \cdot f_{signal0} \quad (2)$$

where k is a positive whole number, indicating the number of samples acquired during 1 period of the signal to be measured.

The basic requirement is, of course, to have accurate determination of the network frequency, for which several scientific solutions exist [9]. In practical implementation of this simple theory we face two main problems. The first is the practical setting of the sample rate, and the second is the frequency change of the power network during the 10 s period, i.e. between the two synchronization moments.

In order to perform reliable and accurate investigation of the problems described above, a special test signal was generated (see Figs. 1 and 2), and sampling on different circumstances was simulated. As the practical power network voltage signals include mostly odd harmonics, the test signal has 50 Hz base frequency and 100 V amplitude, and it includes 20 odd harmonics up to 2050 Hz with amplitude of 10 V each. This is an unusual in practice waveform with 44.721% THD, but it serves as a tractable and reliable test signal for determination of THD and RMS calculation accuracy. This basic test signal is varied in frequency and disturbed during experiments. The frequency range of the diagnostics should be between 42.5 and 57.5 Hz by the standard, therefore, base frequency of the test signal was changed in this range during experiments. As the standard requires 10 periods of the signal for analysis, and the harmonics determination up to 9 kHz, sampling was simulated in 0.2 s time frame and on two different basic sample rates, one is 6400 Hz, and the other is 20,000 Hz.

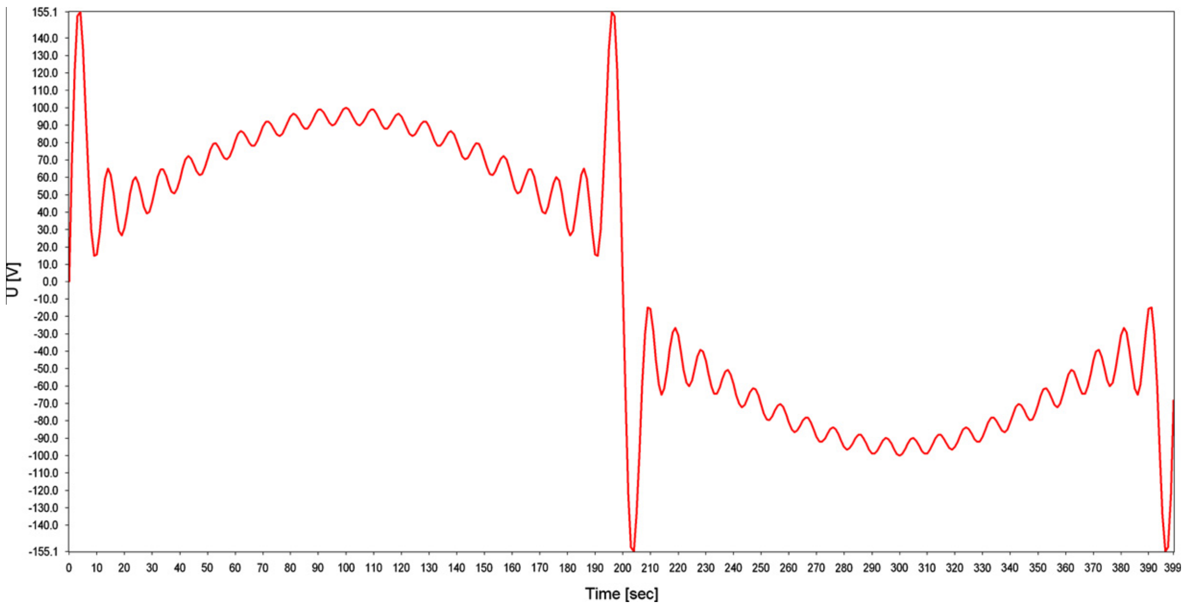

Fig. 1. Time function of the test signal generated for analysis of THD measurement accuracy.