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Theoretical and Experimental Aspects Concerning Fourier and Wavelet Analysis for Deforming Consumers in Power Network

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Introduction

In recent years, the electrical harmonic pollution is getting more and more serious with the use of nonlinear components in electric and electronic devices. Sever pollution with harmonic in voltages and currents in the electric power system causes degradation of power quality. The presence of harmonics causes, also many inconveniences at the consumer. For eliminated these inconveniences it is necessary the correct identification and measurement of harmonics. The sources of disturbances must be known and controlled. This can be done by first detect, localize and classify different disturbances [8],.

For the study of these problems the Fourier transform give satisfactory results when the signals are periodical. The Fourier transform give the frequency information of the signal, which means that it tell us how much of each frequency exists in the signal, but don't tell us when in time these frequency components exists.

Fourier transform for the stationary and the no stationary signals

The following signal is a stationary signal, because it has frequencies of 50, 100, 150 Hz at any given time instant: $x(t) = \sin(2\pi 50t) + 2\sin(2\pi 100t) + 3\sin(2\pi 150t)$

Of course it is a deformed signal with three harmonics. Fig. 1 shows the signal and its spectral diagram. Contrary to the signal in Fig. 1, the following signal is not stationary:

$$x(t) = \sin(2\pi 50t_1) + 2\sin(2\pi 100t_2) + 3\sin(2\pi 150t_3)\,, \quad (1)$$

where t_1 = 0÷300 ms; t_2 = 300÷600 ms; t_3 = 600÷1000 ms. Fig. 2 plots signal whose frequency constantly changes in time and its spectral diagram. We use Matlab 7 for the plotting of these signals and the spectral diagrams.

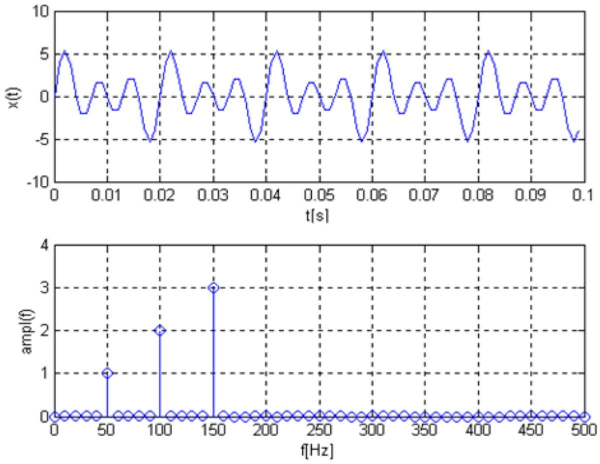

Fig. 1. The stationary signal and its spectral diagram

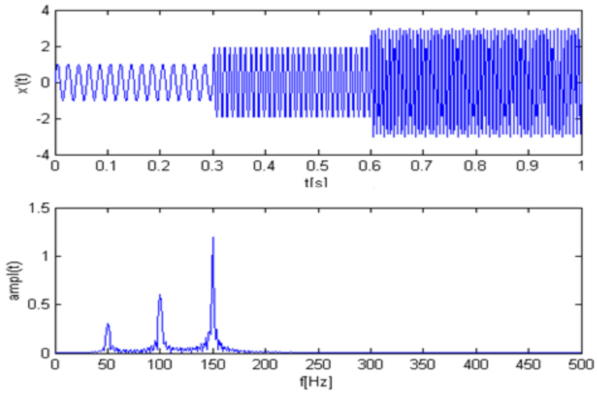

Fig. 2. The non-stationary signal and its spectral diagram

Compare the Fig. 1 with the Fig. 2. The similarity between these two spectrums should be apparent. Both of them show three spectral components at exactly the same frequencies, at 50, 100, 150 Hz (other than the ripples, and the difference in amplitude). Both of the signals involve the same frequency components but the first one has these frequencies at all times, the second one has these frequencies at different intervals. Therefore, Fourier transform is not a suitable technique for the no - stationary signals.

Short Time FOURIER Transform (STFT) and Wavelet transform

When the time localization of the spectral components is needed, a transform giving the time - frequency representation of the signal is needed [3]. The STFT is a transform of this type. It provides the time – frequency representation. In STFT the signal is divided into small enough segments of the signal can be stationary. For this purpose a 'time – frequency' window is used.

$$STFT_x^{(w)}(t, f) = \int_t [x(t) \cdot w^*(t - t')] \cdot e^{-j2\pi ft} dt . \quad (2)$$

The STFT time window is fixed, however, and this method can be inadequate for accurate analysis of localized transient structures [2]. The problem with the STFT comes from the width of the window function that it uses. Narrow windows give good time resolution but poor frequency resolution. Wide windows give good frequency resolution, but poor time resolution. The problem of resolution of the STFT is a result of choosing a window function, once and for all, and uses that window in the entire analysis.

The Wavelet transform can resolve these problems. Furthermore, the multiresolution signal decomposition allows valuable information to be gained in order to detect and classify different disturbances such as harmonic distortion and short – duration variation. Recently wavelet analysis is proposed in the literature as a new tool for monitoring the deforming state, power system transients and power quality problems [1].

The MRA (multiresolution analysis) analyzes the signal at different frequencies with different resolutions. Every spectral component is not resolved equally as was the case in the STFT.

The Wavelet transform [1] represents the signal as a sum of wavelets at different locations and scales. The wavelet transform can be accomplished in three different ways:

- the continuous wavelet transform (CWT);
- the wavelet series (WS);
- the discrete wavelet transform (DWT).

DWT is used to decompose a discrete signal into different resolution levels. It maps a sequence of numbers into a different sequence of numbers. In MRA, wavelet functions and scaling functions are used as building blocks to decompose and construct the signal at different resolution levels. The wavelet function will generate the detail version of the decomposed signal and the scaling function will generate the approximated version of the decomposed signal. The efficiency of wavelet analysis stems from its fast pyramid algorithm. The algorithm has two faces. The forward algorithm is used to compute [2] the wavelet transform discrete (DWT). The backward algorithm is used to compute the inverse transform (IDWT).

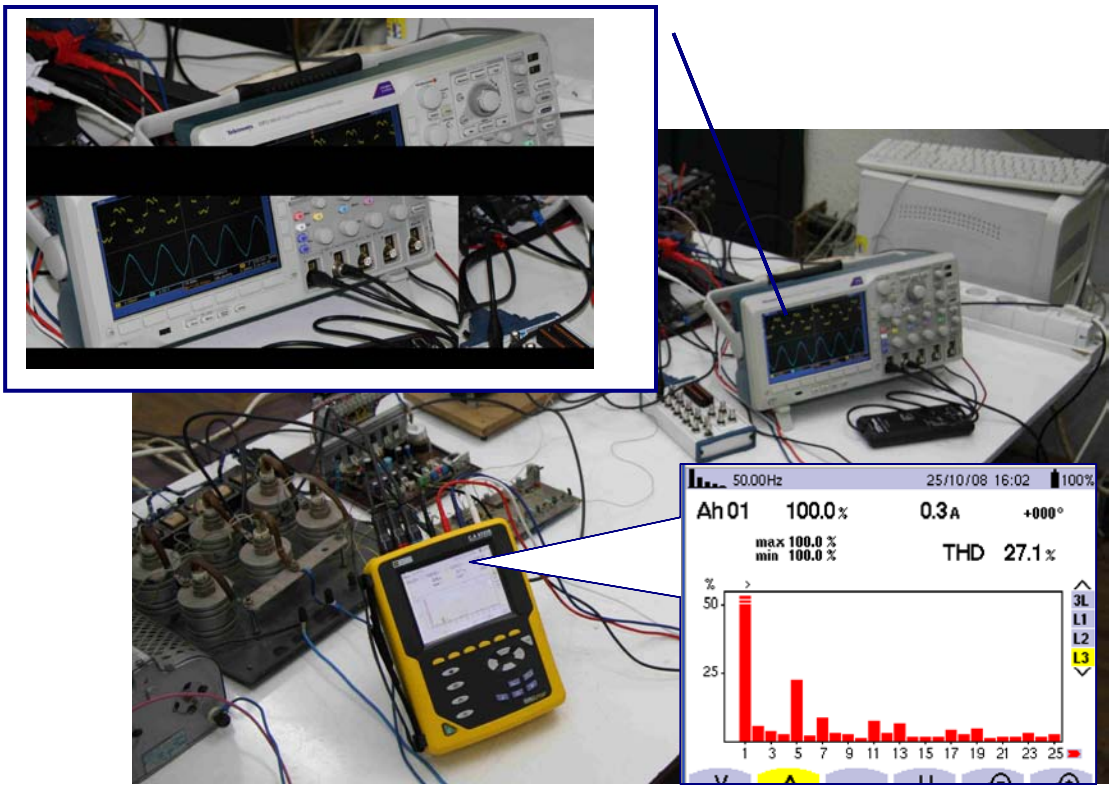

Fig. 3. The experimental arrangement

Applications

The three-phase rectifiers represent 60% from the deforming consumers in the electric power systems. The most used static three-phase power converter is the rectifier in bridge with 6 pulses [4]. The current harmonic spectrum depends by the light angle of the static three-phase power converter and the transformer connection [5,6].

For study of the current harmonic spectrum we make an experimental arrangement with this type of power converter, illustrates in Fig. 3.

The analysis of harmonic distortions is realized with Power Quality Analyzer C.A. 8332B from Chauvin Arnoux and a virtual instrument (Fig. 4) implemented in LabVIEW 8.

For data acquisition of the voltage and the current in different work case of rectifier (different light angle and different transformer connection) we use the PCI6251 board acquisition from National Instruments.

All data was saved in format text in the PC. With the help of virtual instrument we can select what work condition is analyzed.

The current is the more deformed than the voltage. It is clear from the Fig. 3 that the most important harmonic is the 5-th harmonic.

The virtual instrument gives approaching results with the same obtained with the power quality analyzer. This instrument permits to select the different type of deforming consumer. The virtual instrument read from a file text the acquired data of the consumers. The harmonics are (in percent by fundamental) dependent on normalized frequencies. We can see that the THD is bigger than the normalized value [7, 11].

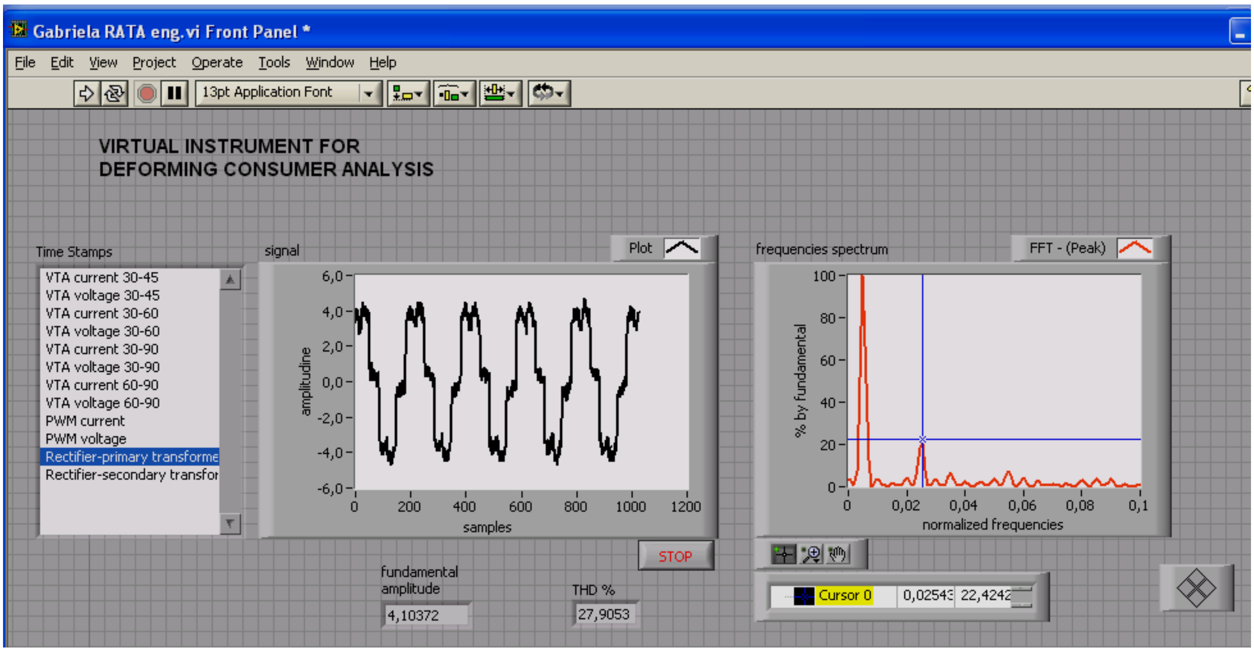

Fig. 4. The virtual instrument

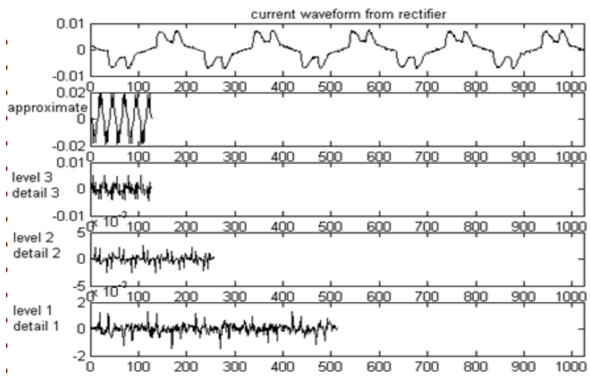

Fig. 5. The decomposition of current distorted signal in three-detailed version and one approximated

Also we make a comparative study between the Fourier transform and Wavelet transform. For this we read the data in the text format with Matlab7 and we make a program with these data. Using scaled and translation version of the wavelet and scaling functions, the distorted signal is decomposed to three-detailed version and one approximated like in Fig. 5.

Fig. 6 shows the reconstruct of the approximation and detail coefficients and Fig. 7 shows the reconstruction signal. It is clear from the Fig. that the initial signal and reconstructed signal are identical.

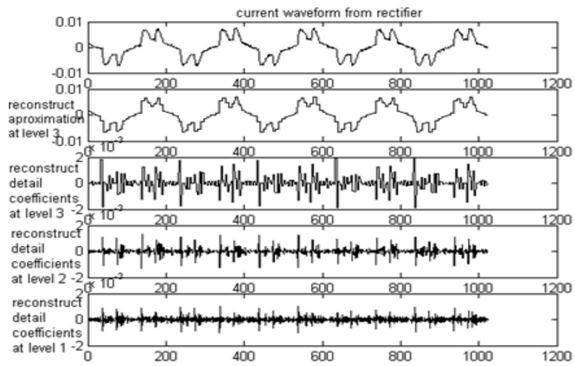

Fig. 6. The reconstruct of the approximation and detail coefficients

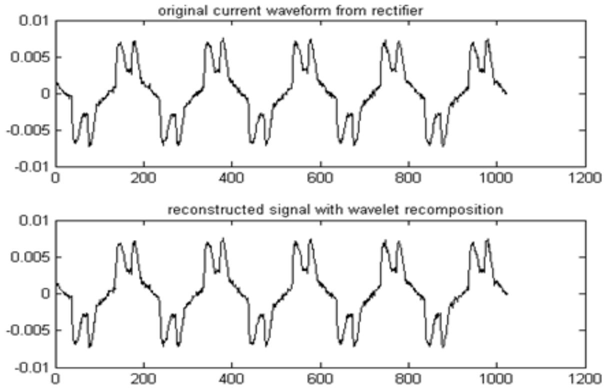

Fig. 7. The reconstruction signal

Conclusions

The paper presents the Fourier transform and Wavelet transform from the study of deforming consumers. Using the MRA decomposition technique we can decompose the distorted signal into different resolution levels. With MRA we extract important information from the analyzed distorted signal. The virtual instrument realized for different consumers give approaching results with that obtained with the power quality analyzer. The most important current harmonic by the rectifier in bridge is the 5-th harmonic. We can reduce this harmonic through transformer winding connection.

Acknowledgment

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This paper presents the application of Fourier and Wavelet transforms in analysis of the deforming consumers. Fourier transform is probably the most popular transform being use in the analysis of the deforming state, but it is not the only one. The Wavelet transform is introduced as a powerful tool for monitoring the deforming state. We present a comparative study between the Fourier transform and Wavelet transform. It is presents a multiresolution signal decomposition technique in analysis of the deforming signals from the three-phase rectifier with thyristors. Also we illustrate a virtual instrument for Fourier analysis of some deforming consumers Data acquisition, display and analysis are making with the PCI 6251 board acquisition, the digital oscilloscope DPO 3014 and power quality analyzer C.A. 8332 B. Ill. 7, bibl. 12 (in English; abstracts in English, Russian and Lithuanian).

Г. Рата, М. Рата, К. Филоте, К. Стругару. Теоретические и экспериментальные аспекты анализов Фурье и Вавелет для деформированных потребителей электрической сети // Электроника и электротехника. – Каунас: Технология, 2010. – № 1(97). – С. 62–66.

Эта программа представляет аппликации трансформированных Фурье и Вавелет в анализе деформирующих потребителей. Трансформированная Фурье однозначно самая популярная трансформированная в деформирующем анализе, но не единственная. Трансформированная Вавелет была введена как мощный математический инструмент для анализа деформирующего режима. В этой письменной работе показана техника многорезолюционного разложения деформированных сигналов, происходящих от трехфазного выпрямителя с тиристорами. Также показан виртуальный инструмент, который делает анализ Фурье для нескольких типов деформированных потребителей. Сбор данных, их афиширование и их анализ реализуются с помощью пластины для приобретения (PCI 6251), с помощью цифрового осциллоскопа (DPO 3014) и с помощью анализатора для качества электроэнергии C.A. 8332 B. Ил. 7, библ. 12 (на английском языке; рефераты на английском, русском и литовском яз.).

G. Raţă, M. Raţă, C. Filote, C. Strugaru. Furjė ir Vaveleto analizės teoriniai ir eksperimentiniai aspektai, susiję su vartotojų defektais elektros galios tinkluose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(97). – P. 62–66.

Apžvelgtos Furjė ir Vaveleto transformacijos, analizuojančios vartotojų defektus elektros galios tinkluose. Viena iš populiariausių transformacijų, skirtų deformacijos būsenai nusakyti, yra Furjė transformacija, tačiau ne vienintelė. Vaveleto transformacija apibūdinama kaip galingas įrankis gebantis stebėti ir nusakyti deformacijos būseną. Pateikiama Furjė ir Vaveleto transformacijų lyginamoji analizė. Tai iliustruojama analizuojant deformuotus signalus tiristoriniame trijų fazių lygintuve taikant daugiaraiškio signalo skaidymą. Duomenų surinkimas, vaizdavimas ir analizė atliekama su PCI 6251 (National Instruments) plokšte, skaitmeniniu osciloskopu DPO 3014 (Tektronix) ir galios kokybės analizatoriumi C.A. 8332 B (Chauvin Arnoux). Il. 7, bibl. 12 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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