Wavelets for detection of voltage dips and micro interruptions

Zbigniew Leonowicz
Wroclaw University of Technology
Wyb. Wyspianskiego 27
Wroclaw, Poland

***Abstract-* In electrical energy power network, disturbances can cause problems in electronic devices therefore their monitoring is fundamental in Power Quality field both to properly dimension protections and to calculate compensations in case of malfunction of the apparatus. In this paper we address the problem of disturbances estimation by using Wavelets signal processing for detection of short, impulse-like voltage dips and micro-interruptions.**

Index Terms—Power Quality, Wavelets, voltage dips, micro interruptions..

I. Introduction

Electric power quality has became an important part of power systems and electric machines, studied from a wide number of points of view. For this purpose there are many of electric parameters that help to describe the phenomena as a whole are reported in standards. In this context, we consider disturbances as the temporary deviation of the steady state waveform caused by faults of brief duration or by sudden changes in the power system [1]. The disturbances considered by the International Electro-technical Commission include voltage dips, brief interruptions, voltage increases, and impulsive and oscillatory transients [2,3, 4].

The first ones are defined by norms as a sudden reduction (between 10% and 90%) of the nominal voltage, at a given point of electrical system, and lasting from half of the fundamental period to several seconds. The dips with durations of less than half a cycle are regarded as transients. The main characteristics of voltage dips are magnitude and duration, which correspond to the remaining bus voltage during the fault and the required time to clear the fault respectively. A voltage dip may be caused by switching operations associated with temporary disconnection of supply, the flow of heavy current associated with the start of large motor loads or the flow of fault currents or short circuits and earth faults. These last ones can be symmetrical (three phase) or non symmetrical (single-phase to ground, double-phase or double-phase-to-ground). The brief interruptions can be considered as voltage sags with 100% of amplitude. The cause may be a blown fuse or breaker opening and the effect can be an expensive shutdown. For instance, supply interruptions lasting up to few seconds may cost a lot in case of interruption of service or stoppage of machines in a production plant. Costs that can quickly grow up with the plant resetting time that can be very long. The main protection of the customer against such events is the installation of uninterruptible power supplies [1].

Brief voltage increases (swells) are brief increases in r.m.s. voltage that sometimes accompany voltage sags. They appear on the unfaulted phases of a three phases of a three-phase circuit that has developed single-phase short circuit. Swells can upset electric controls and electric motor drives, particularly common adjustable-speed drives, which can trip because of their built-in protective circuitry. Swells may also stress delicate computer components and shorten their life. Possible solutions to limit this problem are, as in the case of sags, the use of uninterruptible power supplies and conditioners [5].

Voltage disturbances shorter than sags or swells are classified as transients and are caused by sudden changes in the power system [5]. According to their duration, transient overvoltages can be divided into switching surge (duration in the range of millisecond), and impulse spike (duration in the range of microseconds). Surges are high-energy pulses arising from power system switching disturbances, either directly or as a result of resonating circuits associated with switching devices. Protection against surges and impulses is normally achieved by surge-diverters and arc-gaps at high voltages and avalanche diodes at low voltages.

In this article we focus the attention on disturbances which will gain more importance in the next future because of the increase of electronic apparatus' that can be particularly sensible to this kind of problems if not adequately protected. In fact there are two important aspects that should be taken into account:

In all cases, in power quality is necessary to detect not only the beginning and end of voltage sag but also to determine the sag depth and the associated phase angle jump.

The performance of wavelet signal processing is tested for analysis of short, impulse signals [8].

II. Applied Wavelet transform analysis

Wavelet transform is a useful tool in signal analysis. Wavelets provides a fast and effective way of analyzing non-stationary voltage and current waveforms and can be applied for precise computation of the beginning of a disturbing event, as shown in this paper. The ability of wavelets to focus on short time intervals for high-frequency components and long intervals for low-frequency components improves the analysis of signals with localized impulses and oscillations, particularly in the presence of a fundamental and low-order harmonic [6].

The continuous *Wavelet Transform* (WT) of a signal $x(t)$ is defined as

$$X_{a,b} = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} x(t)\psi(\frac{t-b}{a})dt \qquad (1)$$

where $\psi(t)$ is the mother wavelet, and other wavelets

$$\psi_{a,b}(t) = \left(\frac{1}{\sqrt{a}}\right)\psi\left(\frac{t-b}{a}\right)dt \qquad (2)$$

are its dilated and translated versions, where a and b are the dilation parameter and translation parameter respectively, $a \in R^{+} - \{0\}$, $b \in R$ [7,8].

The discrete WT (DWT), instead of CWT, is used in practice [23]. Calculations are made for chosen subset of scales and positions. This scheme is conducted by using filters and computing the so called *approximations and details.* The *approximations (A)* are the high-scale, low frequency components of the signal. The *details (D)* are the low-scale, high-frequency components. The DWT coefficients are computed using the equation

$$X_{a,b} = X_{j,k} = \sum_{n \in Z} x[n] g_{j,k}[n] \qquad (3)$$

where $a = 2^{j}$, $b = k2^{j}$, $j \in N$, $k \in Z$.

The wavelet filter g plays the role of ψ [6]. The choice of mother wavelet is different for each problem at hand and can have a significant effect on the results obtained. Orthogonal wavelets ensure that the signal can be reconstructed from its transform coefficients .

As wavelet the *symlets* function was used. The symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the “db” family - orthogonal wavelets characterized by a maximal number of vanishing moments for some given support (Fig. 1). Dips detection was realized through tracking values of *details (D)* representing higher frequencies in the signal. High value indicated dip. In contrary to other presented method this approach did not use the amplitude parameter of the main component, but was therefore prone to noise and other high frequency disturbances.

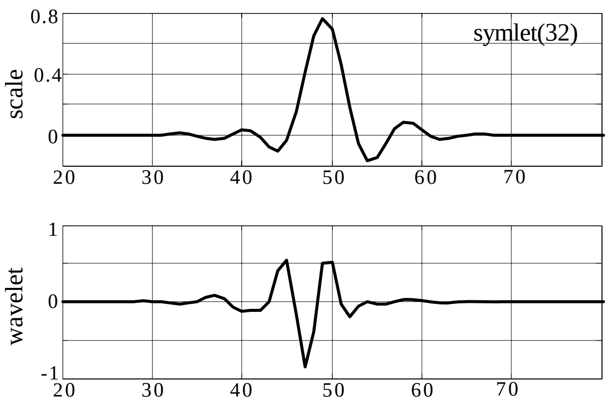

Figure. 1. Scale and wavelet symlets function for 32 coefficients

Figure 2 shows the behaviour of the wavelet decomposition of the sinusoidal waveform distorted by one voltage dip. The decomposition was made using the Daubechies 6 wavelet at the D2 level.

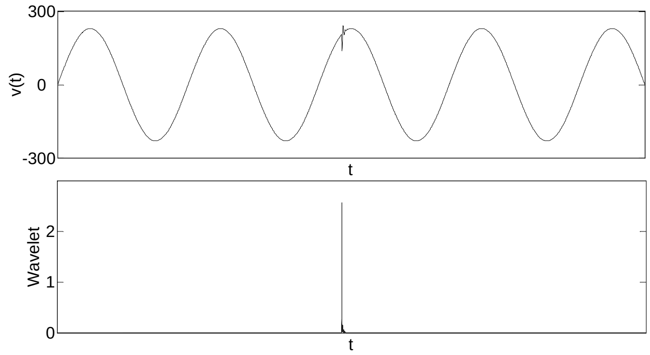

Figure 2. Wavelet decomposition (lower plot) of the sinusoidal waveform (upper plot) distorted by one voltage dip.

III. INVESTIGATIONS, DISCUSSION AND CONCLUSIONS

For experimental testing the performance of the algorithms, we used a synthesized signal realized by MATLAB able to generating voltage dips of different magnitudes.

For evaluating the performance of the method many test signals has been used with different THD and SNR. The THD used are 5.7%, 11.2% and 22.4%. These values were obtained using for each of the first 24 harmonics half of the norm limits, the norm limits, and the double of norm limits [9].

For each of the three THD has been created three signals with a different SNR: 100dB, 80dB and 60dB. The added noise is white Gaussian.

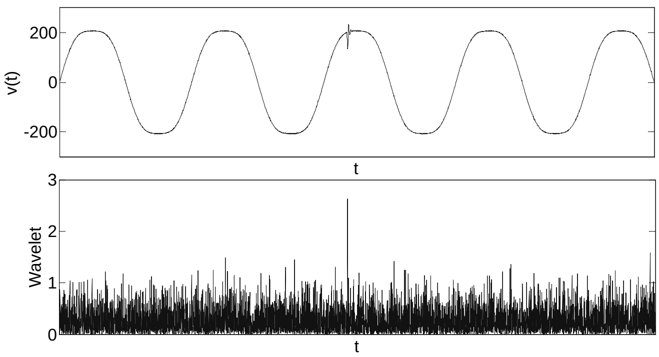

Figure 3. Wavelet decomposition (lower plot) of the sinusoidal waveform with harmonics (upper plot) distorted by one voltage dip.

Higher order frequency components present in the signal deteriorated the detection ability of the method. Two wavelets with significantly different lengths have been used; *Symlet* (length of the filter 32 samples) and *Daub 6* (length of the filter 6 samples).

In the nine test signals 100 dips have been added, one for each period in randomly position. In Tables I and II are reported the percentage of detected dips for 35V and 100V dips of respectively 15% and 43% of nominal voltage.

TABLE I

DETECTION ACCURACY OF 35V DIPS

THD \ SNR	100 dB	80 dB	60 dB
5.7 %	100 %	45 %	12 %
11.2 %	100 %	45 %	17 %
22.4 %	100 %	33 %	14 %

TABLE II

DETECTION ACCURACY OF 100V DIPS

THD \ SNR	100 dB	80 dB	60 dB
5.7 %	100 %	100 %	70 %
11.2 %	100 %	100 %	67 %
22.4 %	100 %	100 %	62 %

The wavelet approach ensures good performance in presence of high THD, but the percentage of detected dips is strongly reduced for high noise level.

REFERENCES

[1] J. Arrillaga, N.R. Watson, S. Chen, Power System Quality Assessment, John Wiley & Sons, 2000, ISBN 0 471 98865 0.

[2] IEC 61000-2-1: 1990, Electromagnetic Compatibility (EMC), Part 2: Environment, Section 1: Description of the Environment – for Low-Frequency Conducted Disturbances and Signalling in Public Power Supply Systems.

[3] IEC 61000-2-2: 1990, Electromagnetic Compatibility (EMC), Part 2: Environment, Section 2: Compatibility Levels for Low-Frequency Conducted Disturbances and Signalling in Public Power Supply Systems.

[4] IEEE c62.41: 1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

[5] UIE-DWG-2-92-D, UIE Guide to Measurements of Voltage Dips and Short Interruptions Occurring in Industrial Installations.

[6] S. Santoso, E.J. Powers, W.M. Grady, P. Hofmann: " Power Quality Assesment via Wavelet Transform Analysis," IEEE Transactions on Power Delivery, 11(2), pp. 924-930.

[7] M. Misiti, Y. Misity, G. Oppenheim, J-M. Poggi, "Wavelet Toolbox User's Guide, MathWorks", 1996.

[8] H. Amaris, C. Alvarez, M. Alonso, D. Florez, T. Lobos, P. Janik, J. Rezmer, Z. Waclawek: "Application of advanced signal processing methods for accurate detection of voltage dips," 13th International Conference on Harmonics and Quality of Power. ICHQP 2008, Wollongong, Australia, 28th September-1st October 2008, 6p.

[9] CEI EN 50160 Power Quality Application Guide: Voltage Characteristic in Public Distribution System.