DEVELOPMENT OF DSP TOOLS USING WAVELET TRANSFORM FOR VOLTAGE SAG DISTURBANCE

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Abstract - **Power quality disturbances such as voltage sag, transient, swell and harmonic are serious problem to the power system equipments. The power industry faces a big challenge due to these disturbances. These will cause many problems for influenced loads such as malfunctions, instabilities and short lifetime. Voltage sags are short-durations in RMS voltage due to faults, motor starting and transformer energizing, switching of heavy load, typically caused by a loose connection and the most common power quality disturbance. It can arrive from the utility; however, in most cases, the majority of sags are generated inside a building. This paper proposes an application of Digital Signal Processing (DSP) tools i.e. wavelet analysis to analyze voltage sag in power systems. This method has been used in development of new signal processing method for the complete characterization of voltage sag in power systems as well as a powerful teaching tool in electrical power quality.**

Keywords- Voltage Sag, Wavelet Transforms.

I.   INTRODUCTION

Power quality disturbances such as voltage sag, transient, swell and harmonic are serious problem to the power system equipments. The power industry faces a great challenge due to these disturbances. These will cause many problems for affected loads such as malfunctions, instabilities and short lifetime [1]. Figure 1 shows the power quality disturbance sinusoidal waveform.

Voltage sag is defined as the temporary reduction of RMS voltage between 0.1 to 0.9 p.u. or 10 to 90 percent and with duration from half cycle to 1 minute. Despite of its very short duration, the sag can cause serious problems to a wide range of consumers. Industrial customers which suffer from regular production stoppages due to voltage sag can lead to a tremendous economic losing [1]. A voltage with a 30% drop or more is considered severe.
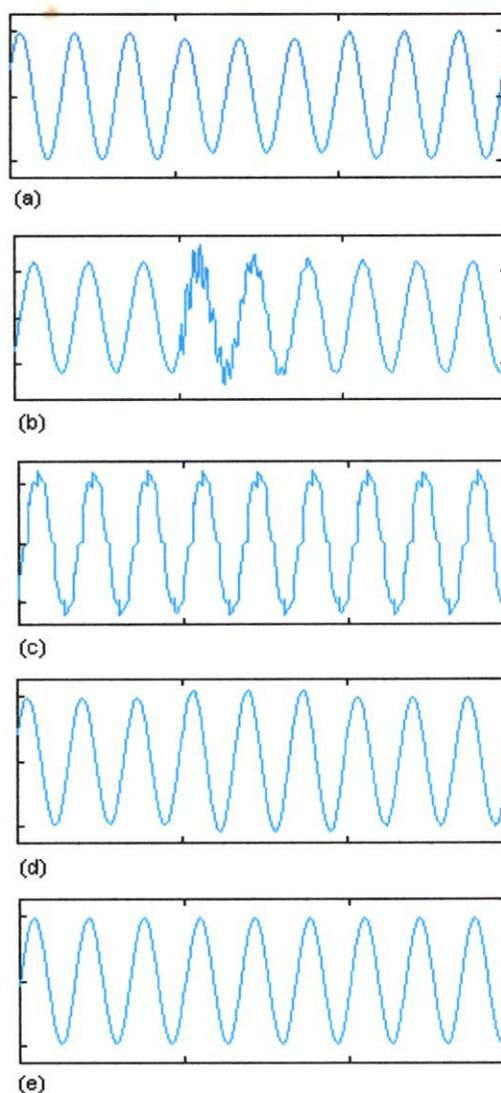

Figure 1: Power Quality Disturbance: (a) voltage sag; (b) capacitor switching; (c) harmonic distortion; (d) voltage swell; (e) load switching
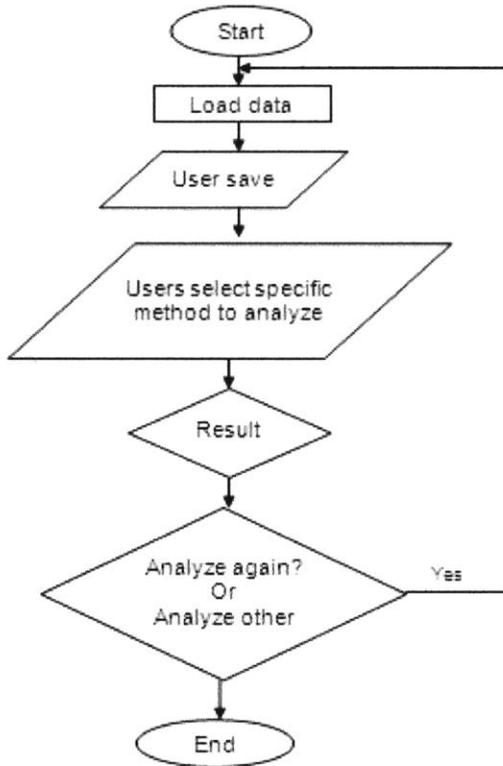
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II. METHODOLOGY

Figure 2: Flowchart for analysis using wavelet transforms

In this project, MATLAB software had chosen to use in analyze the voltage events in power system. The Digital Signal Processing tools use to analysis the voltage events in power system is wavelet analysis. There are two method can implement this project where is using simulation of voltage events or analysis from the real voltage events. The tools appear for both methods can select within different signal processing tools for detection and computation of the magnitude and duration of a voltage events. This wavelet analysis is much like a Fourier analysis but it composes a signal into different scale. Figure 2 shows the flowchart for analysis using wavelet transforms.

III. MATLAB WAVELET TOOL BOX

MathWorks DSP solutions enable users to more effectively solve problems encountered in analysis, design implementation and verification of signal processing systems. Wavelet Toolbox software extends the MATLAB technical computing environment with graphical tools and command-line functions for developing wavelet-based algorithms for the analysis, synthesis, denoising, and compression of signals and images. Wavelet analysis provides more precise information about signal data than other signal analysis techniques, such as Fourier.

The Wavelet Toolbox supports the interactive exploration of wavelet properties and applications. It is useful for speech and audio processing, image and video processing, biomedical imaging, and 1-D and 2-D applications in communications and geophysics.

Wavelet methods provide powerful tools for analyzing, encoding, decompressing, reconstructing, and modeling signals and images. They are useful in capturing, identifying, and analyzing local, multiscale, and nonstationary processes, enabling user to explore aspect of data that other analysis techniques miss, such as trend, breakdown points, discontinuities in higher derivatives, and self-similarity. Wavelet toolbox supports a full suite of wavelet analysis and synthesis operations [2].

To analyze the data, firstly the user must save the data in workspace. Then type wavemenu in common window and the wavelet toolbox main menu will appear. For this analysis chose Wavelet 1-D then load the signal from the data had been save in workspace. The user can chose the mother wavelet analysis either Haar, Symmlet, Daubechies, Morlet etc.

IV. WAVELET TRANSFORMS

A. Continuous Wavelet Transform

The continuous wavelet transforms (CWT) where one obtains the surface of the wavelet coefficients, for different values of scaling variable into a function of two continuous variables [3]. The CWT of a signal $x(t)$ with respect to a mother wavelet $g(t)$ is define as:

$$CWT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, g\left(\frac{t-b}{a}\right) dt \quad \text{(Eqn.1)}$$

where a is the scale factor and b is the translation factor and both are continuous variables.

The coefficients of the $CWT(a,b)$ at a specific scale and translation represent how well the original signal $x(t)$ and the specific mother wavelet match. The set of all wavelet coefficients of a particular signal is the wavelet representation of this signal with respect to the wavelet selected.

By considering the mother wavelet as a window function, the scale factor corresponds to the window

size. Narrow-band frequency components of the signal can be analyzed by selecting small scale factors [4]. It should be pointed out that only those functions that have a zero net area can be used as a mother wavelet. This suggests that the transformation kernel of the wavelet transforms is a compactly supported function (localized in time), thereby offering the potential to capture power quality disturbance transitions which normally occur in a short period time [5].

B. Discrete Wavelet Transform

The discrete wavelet (DWT) is used to decompose the original signal into approximation and details at each decomposition level. It maps a sequence of numbers into different sequence of numbers [3]. The DWT is the digital representation of the continuous wavelet transforms, and is define as:

$$DWT(m,k) = \frac{1}{\sqrt{a_0^m}} \sum_n x(n) g\left(\frac{k - nb_0 a_0^m}{a_0^m}\right) dt \quad (Eqn.2)$$

where $g(.)$ is the mother wavelet and the scaling and translation parameters a and b are functions of an integer parameter $m (a=a_o^m$ and $b=nb_o a_o^m)$, and k is an integer that refers to a specific sample in the input signal [4,6].

Compare with CWT, the DWT is sufficient to decompose and reconstruct most power quality problems. It provides enough information, and offers high reduction in the computational time. The calculation of the DWT is well matched to digital computer [3].

C. Wavelet Families

Wavelet analysis is a powerful signal processing tool especially useful for the analysis of non-stationary signals. Wavelet are short duration oscillating waveforms with zero mean and fast decay to zero amplitude that are dilated and shifted to vary their time-frequency resolution [4]. Providing different frequency resolution while preserving both time and frequency information is the advantage of using wavelet transform.

Wavelet transforms have been proven to be very efficient in signal analysis. The efficiency comes from the reduction in the number of coefficients as the scaling factor increase. The wavelet expansion separates signal components that overlap in both time

and frequency. Wavelet can be designed to fit different applications [3].

The wavelet analysis employs a prototype function called mother wavelet. It is important to observe that the wavelet transform do not have a single set of basis function, but it has an infinite set of possible basis functions (mother wavelet) [7]. This function has a mean of zero and sharply decays in an oscillatory fashion, i.e. it rapidly falls to zero either side of its central path [6]. The wavelet transforms has been used to represent any signal $x(t)$ into a time-frequency spectrum. The basis function of mother wavelet $\psi(t)$, which can be stretched (or compressed) and translated (or shifted) to produce the daughter (or baby) wavelets [8]. Each component is a time domain function at a certain scale. Fast and short transients in the signal are detected at lower scales – corresponding to higher frequencies – whereas slow and long transients are detected at higher scales – corresponding to lower frequencies [7].

There are many types of mother wavelet that can be employed in practice. To choose the best, the attributes of different mother wavelets need to be considered. Figure 3 typifies some of the commonly employed mother wavelets, such as Haar, Symmlet, Daubechies, Morlet etc. Of these Haar and Morlet are classes as orthogonal wheres Symmlet and Daubechies are non-orthogonal.
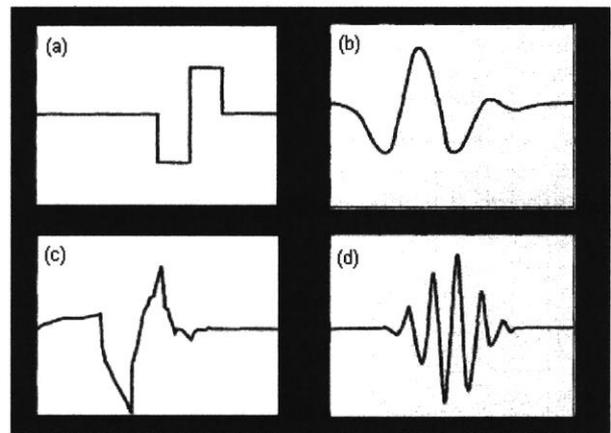

Figure 3: Mother wavelets: (a) Haar; (b) Symmlet; (c) Daubechies; (d) Morlet

A main feature of wavelets is the oscillating and fast decaying behavior that comes along with the location in the time and frequency. Generally, smooth wavelets (such as the Symmlet wavelet) indicate a better frequency resolution than wavelets with sharp steps such as the Haar wavelet, the opposite applies

to time resolution. Another important criterion is a fast computation of the scaled daughter wavelets. In this respect, the orthogonal wavelets calculated recursively have advantages over non-orthogonal wavelets. One of the most widely applied mother wavelets suitable for a wide range of power system applications is the Daubechies wavelet, which is ideally suited for detecting low amplitude, short duration, fast decaying and oscillating type of signals, typical of those encountered in power systems [6].

The wavelet transform can be accomplished in three different ways. There are Continuous Wavelet Transform (CWT), Discrete Wavelet Transform (DWT) and Wavelet Series (WS).

V. RESULTS AND DISCUSSIONS

The data employed in this paper is analyzed using MATLAB Wavelet toolbox software. In general, short wavelet are often more effective than long ones in detecting a signal discontinuity or a fast change. Figure 4 is an original waveform for this analysis.
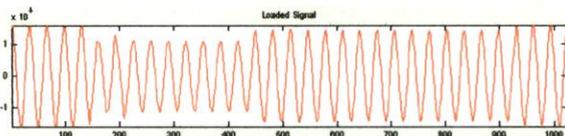

Figure 4: Original waveform as input to wavelet toolbox

Figure 5 is voltage sag analysis using Haar. The Haar wavelet is the simplest possible wavelet. It may be considered to simply pair up input values, storing the difference and passing the sum [9]. This property is suitable for analysis of signal with sudden transitions such as monitoring of tool failure in machine. But in technically, the advantage of the Haar wavelet is not continuous, therefore not differentiable.

As shown in figure 6 is an analysis using Symmlet wavelet. General characteristic of Symlet is compactly supported wavelets with least asymmetry and highest number of vanishing moments for a given support width. Associated scaling filters are near linear-phase filtersThe Symmlet are nearly symmetrical wavelet proposed by Daubechies as modifications to the db family. It is smooth wavelets indicate a batter frequency resolution than Haar.
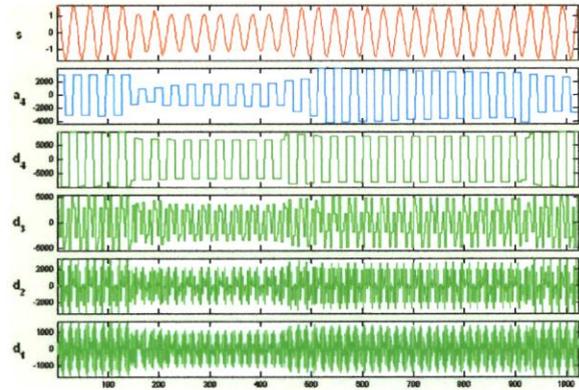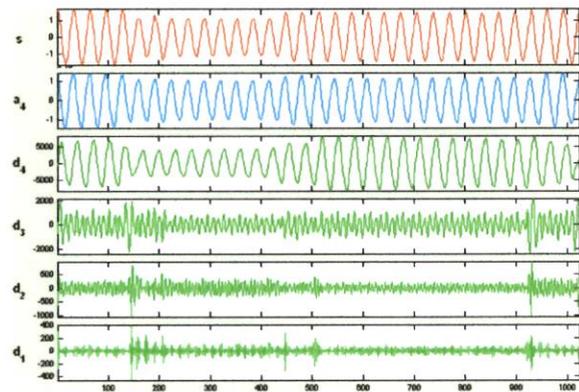

Figure 5: Haar wavelet.

Figure 6: Symmlet wavelet.

In Figure 7 shows the wavelet performed with db4 at 2 levels applied to voltage sag. In the figure, the horizontal axis is marked for index of sample points, while the vertical axis is for magnitude with time 10^4. The d1 and d2 components have low coefficients and can reveal the sag beginning and end. The decomposition clearly evidences that occur at the end and in the middle of the sag. The large drastic variations indicate that the event has occurred at between 150th, 459th and 950th.

The results here reported are obtained through the db4 wavelet, but other wavelet (for example db2, db6) can be chosen as well leading to very similar result. For instance, db2 is to sharp for this application, where it is considered particularly suited for analyzing faster transients like spike.
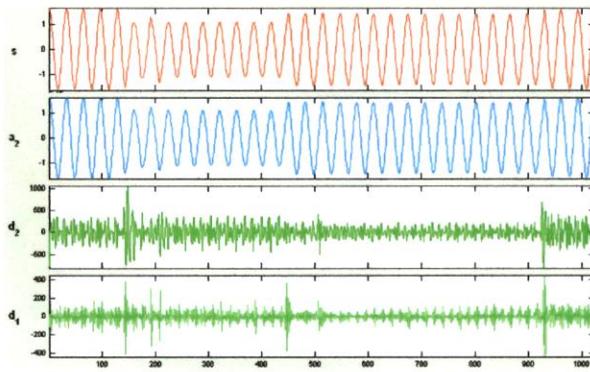
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Figure 7: Wavelet perform with db4 at level 2

VI.   CONCLUSION

This paper presents for analysis of voltage sag using digital signal processing tools specific to wavelet transforms. The analysis of real voltage sag, showing the tools box helped to detected the sag and can chose either Haar, Symmlet, Daubechies, Morlet etc. For the user that do not have background in software engineering can using this application for voltage sag analysis. In the future, it is possible to programming in MATLAB Graphical User Interface (GUI) and analyzing other power disturbance such as voltage swells, starting of induction motor etc.

VII.   ACKNOWLEDGMENT

VIII.   REFERENCES

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