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Wavelet Based Analysis Of Power Transients In Different UPS Systems For ICU Applications

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Abstract

Uninterrupted best quality power is required for critical and life safety operations such as intensive care and surgical services. Pure power is necessary for all connected equipments. The main aim of this paper is to record, monitor and analyze the voltage waveforms of different UPS systems during power transients at different load conditions. Wavelet transform is proposed as a fast and effective technique of analyzing transients.

Keywords— Wavelet transform, Uninterruptible power supply, power transients

I. INTRODUCTION

Intensive care offers continuous and specialized patient care and monitoring for various emergency problems. UPS are used to provide uninterrupted power for ICU applications since continuous monitoring is required for patients. Instruments used in ICU are defibrillator, ventilator and infusion pumps.

These equipments develop power disturbances and switching transients. Extensive damage may be produced to these transients. An effective mathematical tool has to be applied for analysis of non-periodic power disturbances. Wavelet transform is an efficient tool for analyzing the voltage waveforms recorded using power quality disturbances[4]. It has the capability of detecting and classifying power disturbances[6].

Generally, a model UPS should provide unremitting power. It should also provide power conditioning for specific applications.

- Regulated output with low THD
- No break or transition time
- High power factor
- High reliability

- High efficiency
- Low EMI
- Electrical isolation
- Low maintenance

Power quality problems are produced due to non-linear loads and unbalanced loads. Specifically, for ICU operations, power disturbances leads to major breakdown. Among all the UPS systems, On-line UPS are suitable for medical applications[1]. The performance of an UPS system is evaluated based on the quality of its output voltage. UPS systems should have good transient response towards sudden changes in the load. THD of the output voltage should also be low.

In this paper, transient response of different UPS systems is compared and the UPS system which performs better is identified. By connecting different loads like defibrillator phonocardiogram (PCG) unit, cautery equipment, sterilizer, etc., to the UPS used in an Intensive Care Unit, the disturbances are recorded in a computer. Analysis of recorded waveforms are done using wavelet transform. Denoising is also proposed in this paper.

II. POWER QUALITY

Complete suppression of transients and harmonics is not feasible. Normally, filters are used to reduce ripples in the output of power converters[9]. The best possible solution to a power quality problem can be achieved by making a particular piece of sensitive equipment less sensitive to power quality variations. The power quality problem can be reduced to a level at which proper operation of the equipment required for specific applications. It is difficult to quantify power quality. If the electrical power is not fitting to the requirements, then there is a deficiency in quality. The technical definition of power is the rate of delivery of energy and is proportional to the product of the voltage and current.

The medical instruments used in an Intensive Care Unit are manufactured to function at sinusoidal voltage of specified frequency(50 Hz) and amplitude. A power quality problem is defined as the notable variation in the frequency, magnitude and purity of waveform**.** Practically the ‘Power Quality’ is the quality of the voltage which is being considered in most cases.

III. WAVELET TRANSFORM

The basic mathematical tool used for signal analysis is Fourier transform. It transforms a signal from time-based one to frequency based one. It converts the signal into sinusoids of different frequency values**.** Fourier transform(FT) is an effective tool for analyzing non-periodic disturbances. But for non-periodic disturbances, Fourier analysis is not suitable because the time information is lost . Therefore, the instant at which the transient has occurred cannot be determined.

To overcome this drawback, Dennis Gabor has proposed a technique called as Short-time fourier transform(STFT) which is known as windowing the signal. This is also a type of Fourier transform which analyzes only small section of the signal. STFT gives the details about the occurrence of a signal event contrasting to FT. However, precise results cannot be obtained by this technique. The main disadvantage of STFT is that the size of window chosen is the same for all frequencies. Once it is chosen, it cannot be changed.

The drawback in STFT can be overcome by using Wavelet analysis. It is also similar to STFT windowing technique. But the size of the window can be changed. Long time intervals can be chosen for low frequency information and shorter regions can be chosen for high frequency information[2]. Time-scale region is used in Wavelet analysis. Wavelet analysis is proposed as a new mathematical tool in analyzing various issues of power engineering[5].

A window function which is dilated and compressed in the time domain for signal x(t) is used by Wavelet transform. When the window length is varied, the resolution can be varied in both the time and frequency domains. To determine the window function, the mother wavelet should be scaled and shifted.

Wavelet transform is categorised as continuous and discrete.

$C_{a,b} = (1/\sqrt{|a|}) \int_{-\infty}^{\infty} f(t)\, \Psi((t-b)/a)\, dt$

$\Psi_{a,b}(t) = (1/\sqrt{|a|})\, \Psi((t-b)/a)$

$\Psi(t)$ is the mother wavelet,

'a' = dilation parameter

'b' = translation parameter.

Continuous wavelet transform is not much used in signal analysis since mother wavelet is continuously dilated and translated. To overcome this, 'a' and 'b' parameters are discretized.

$D_{a,b} = (1/\sqrt{a_0^m}) \sum_n S(n)\, \Psi[(k-na_0^m)/a_0^m]$

a_0^m = dilation(scale) parameter

na_0^m = translation (shift) parameter

$a_0=2$ and $b_0=1$.

Thus the wavelet transform is known as dyadic-orthogonal wavelet transform. Low frequency information of a signal is essential. Forward algorithm is used to decompose the signal by computing the wavelet transform and backward algorithm is used to reconstruct the signal by taking inverse transform.

Forward algorithm utilizes the linear filters along with down sampling operations. Linear filters along with up sampling operations are used by backward algorithm. The decomposition of the actual signal leads to breaking of original signal into several low-resolution components. DWT output is represented in a 2D signal in time and frequency divisions. Localisation of transient phenomena and presence of specific frequencies is given by time-frequency grid. Large windows are utilized for low-frequency components and small windows are used for discontinuities.

IV. DISTURBANCE DETECTION

Multi resolution method is efficiently used for detecting the electric disturbances[8].

Since each power quality disturbance is dependent on unique characteristics of wavelet transform co-efficients, it can detect disturbances without any difficulty. Improved time-resolution can be obtained for transients[3]. It is useful in detecting the high frequency disturbance by applying wavelet co-efficients at scale 1.

Selecting an apt mother wavelet enhances accurate detection of power quality disturbances. Low order (db4 and db6) mother wavelets are used for short disturbances. For slow transient disturbances, higher order(db8 and db10) mother wavelets are applied[7]. Mother wavelet greater than 10^{th} order is not mostly used as computational speed is slow.

V. DENOISING

In this paper, an off-line denoising is also proposed based on adaptive wavelet technique. To begin with, the noise level is detected. Then denoising using hard thresholding method is applied to every section of the disturbance with different noise level. Here the main aim of the proposed denoising method is the improvement of signal-to-noise ratio (SNR). Denoising is carried out off-line.

A PCG unit is connected to the output of an UPS and a PCG wave is recorded in a computer. In addition to that, cautery equipment is put into function and therefore a disturbance is developed in the PCG waveform. The most important spatial and frequential features of a regular signal is localized by the wavelet transform in a limited number of wavelet coefficients. The expected noise energy is the same for all coefficients. If the expected noise energy is not too large, noise has the relatively small influence on the important large signal coefficients. Therefore small coefficients should be replaced by zero as they are dominated by noise and carry only a small amount of information. For that, hard thresholding is used and the noise is eliminated.

VI. RESULTS

Tests are done on different UPS systems for different loads. The following waveforms are recorded for all UPS systems with various ICU instruments like defibrillator, sterilizer as loads. The waveforms recorded from UPS1 and 2 are shown in Fig. 1 and Fig. 2 respectively. The recordings from UPS3 is given in Fig. 3

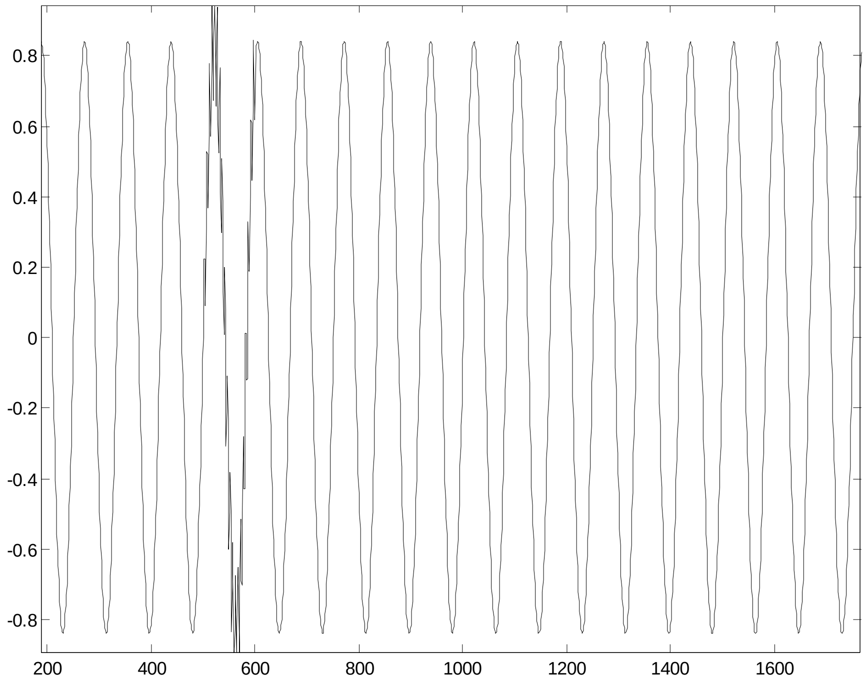

Fig 1. Recordings of UPS1 (a) Oscillatory transient

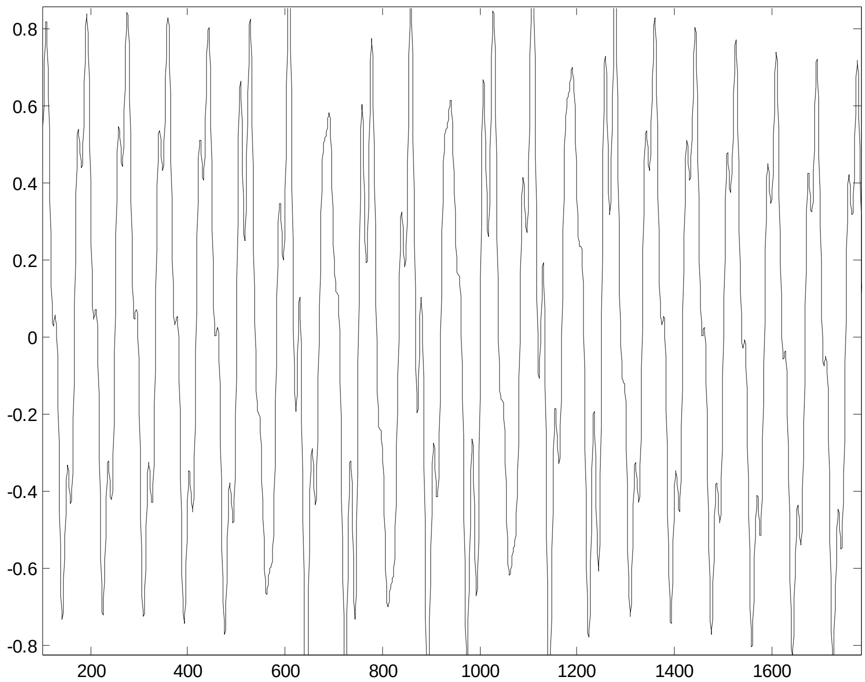

Fig 1(b) Harmonic transient

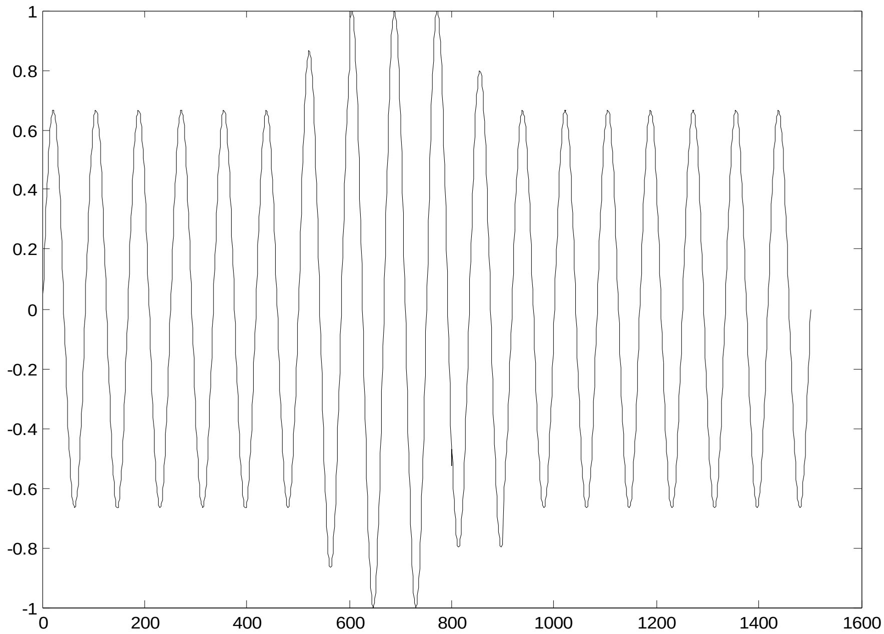

Fig 2. Recordings on UPS2 (a) Swell

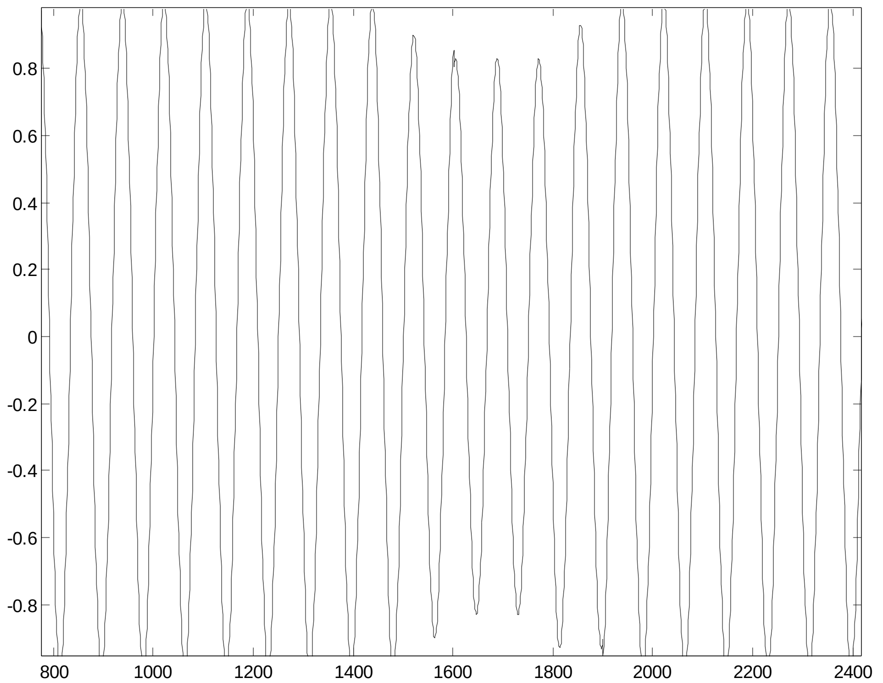

Fig 2(b) Sag

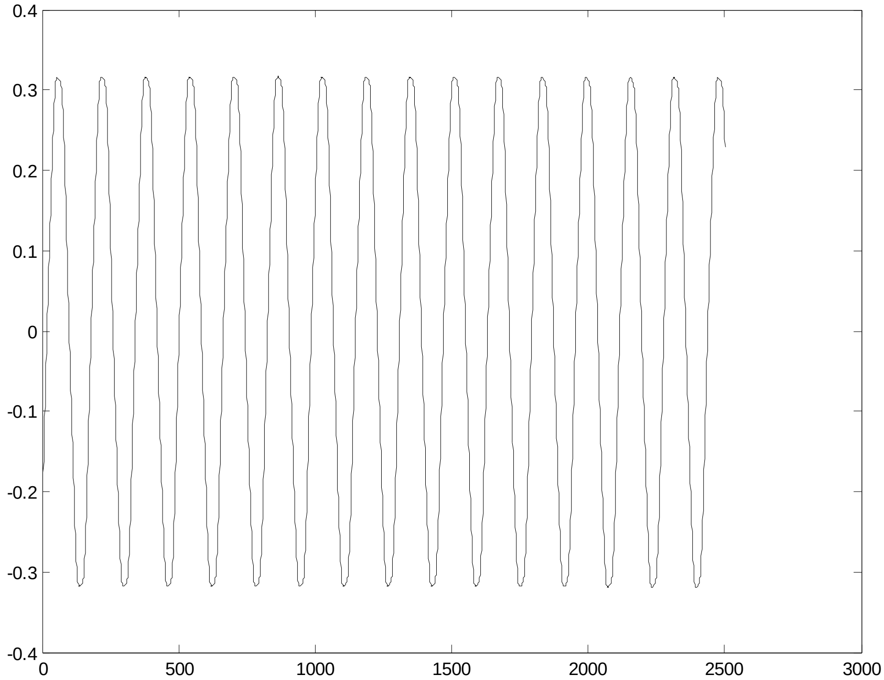

Fig 3. Recordings of UPS3

From the above results, we conclude that the UPS3 has the better performance compared to the other two UPS systems.

Multi resolution analysis for oscillatory transient is shown as an example. The signal is separated into low and high frequency components using DWT for three levels. Finally, the signal is reconstructed without a transient using IDWT.

Approximation coefficients are shown in Fig 4 and detail coefficients are shown in Fig 5. The reconstructed signal is given in Fig 6.

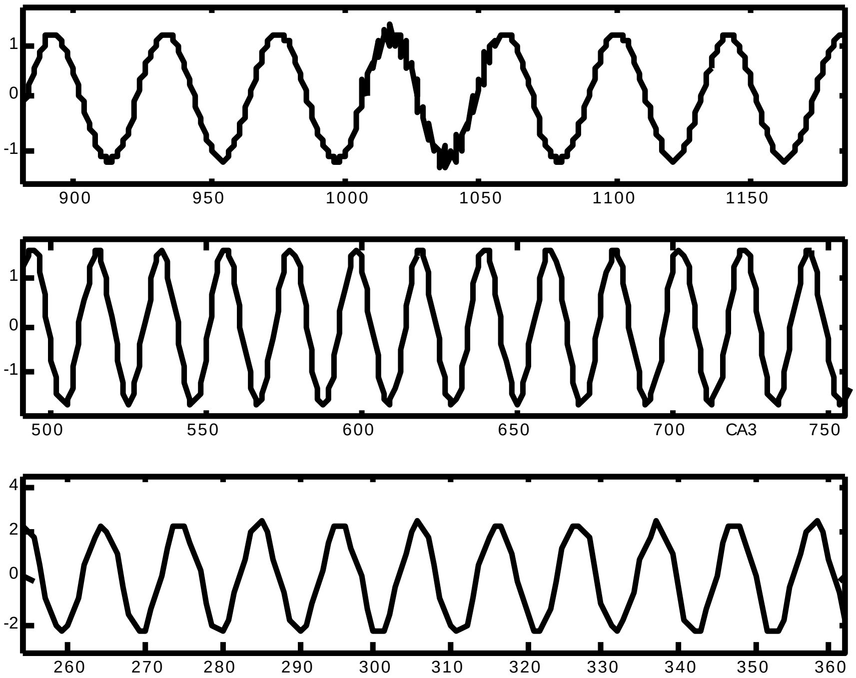

Fig 4. Approximation co-efficients (CA1, CA2, CA3)

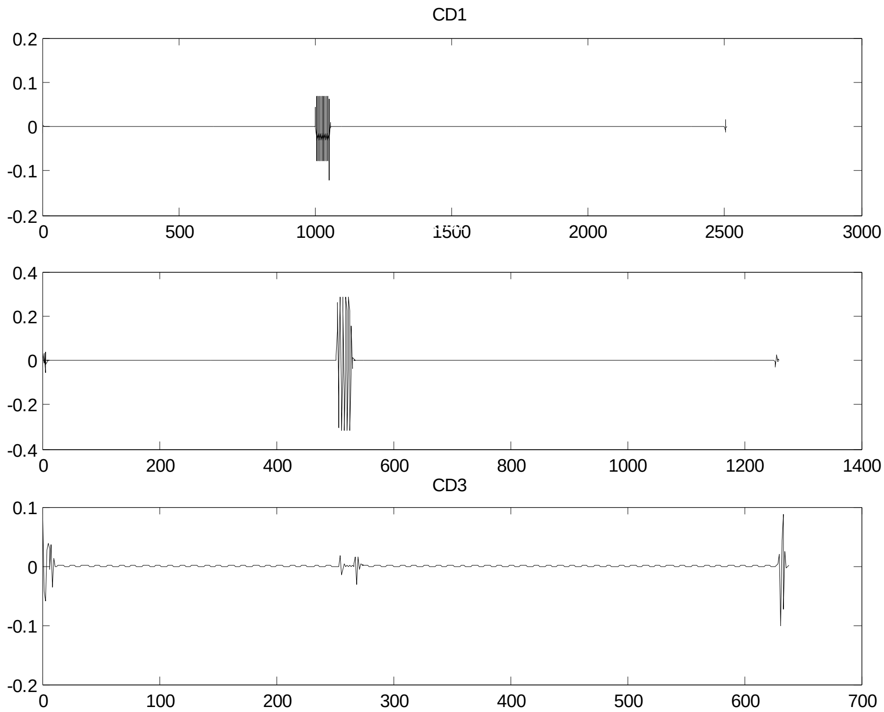

Fig 5. Detail coefficients(CD1, CD2 and CD3)

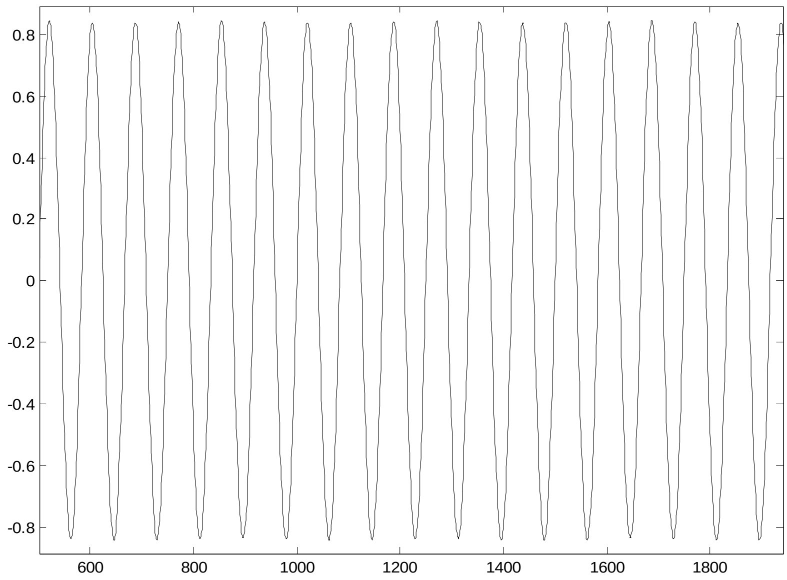

Fig 6. Reconstructed signal

Denoising:

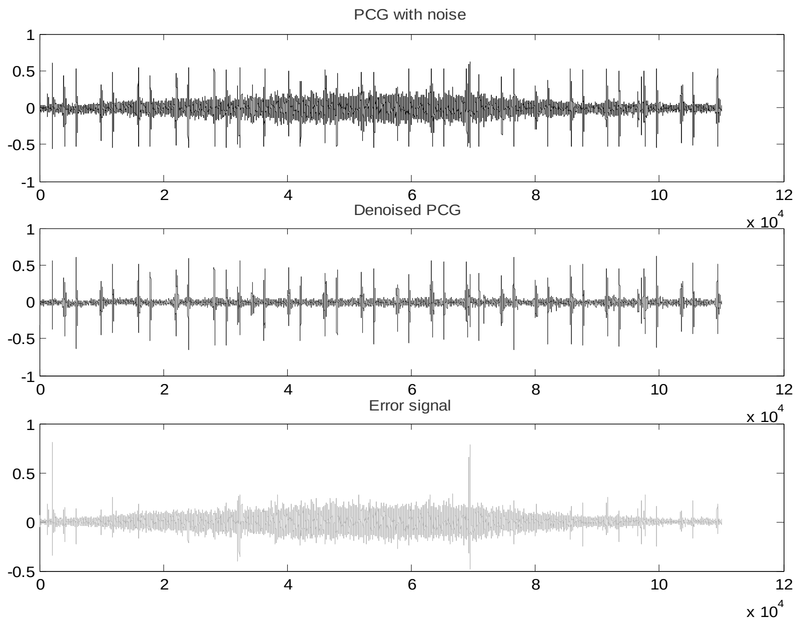

Fig 7. Denoised signal

Denoising of a PCG signal is shown in Fig 7. Initially, the noise level is detected and hard thresholding technique is applied and the denoised signal is obtained. Noise present in the signal is also shown.

IV. CONCLUSION

In this paper, the wavelet transform is used as a new component to detect and eliminate power quality disturbances. From this analysis, UPS of better performance is also found. 4th and 8th order Daubechies mother wavelets are chosen that are familiar to the fundamental waveform.

The wavelet analysis is performed from the high frequency component which has the information of time domain and hence detection of disturbances is very fast. The details of occurrence of a transient can also be easily obtained.

The main conclusion of this paper is that it is possible to use wavelet transform to detect power quality problems. Using that the transient response of different UPS systems is evaluated and their performances are compared.

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