POWER QUALITY ANALYSIS OF UPS USING WAVELET ANALYSIS

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ABSTRACT

Severe power outage condition in Pakistan is on alarming stage. Numerous industries have been moved to other countries while domestic and commercial users have come towards the extensive use of household generators and Uninterruptable Power Supplies (UPS) during load shedding hours. Power quality of UPS output is distorted due to harmonic content; Consequently, ensuring electric power quality has become important to avoid malfunctioning and damage to sensitive equipments. Voltage waveform of UPS has non-stationary frequency behavior nature so their harmonic content cannot be observed through stationary methods such as the Fourier Transform. However they can be better observed through a joint time frequency technique such as wavelet analysis.. The text in this paper has been supported through real time power signal analysis to quantify total harmonic distortion (THD) of UPS output along with its comparative analysis with available utility power i.e. Karachi Electric Supply Company (KESC).The results show that UPS power has significant THD.

Keywords: Power quality, Uninterruptable power Supply harmonics, Wavelet analysis

1. INTRODUCTION

As Pakistan is facing serious power outage issues, many domestic and commercial users have come towards the extensive use of household generators and Uninterruptable Power Supplies (UPS) during load shedding hours to get continuity of operations for their priority loads. Within the past 20 years, the number of nonlinear loads, such as Electronic appliances, Compact florescent lamps, has increased significantly. Low power rating UPS are mostly used by domestic users to operate their non-linear residential loads. Power quality of UPS voltage signal is distorted due to its harmonic contents. Harmonics are generated in KESC power system due to the way UPS draws power for charging its batteries. The harmonics have quite adverse effects on the local appliances as well as the local distribution transformer including neutral overloading(Desmet, Sweertvaegher et al. 2001). The percentage of harmonics in a waveform is measured as THD (Total Harmonic Distortion), the efficiency of the system is decreased with increase in THD. Hence severe effects of harmonics could be avoided through the proper corrective/preventive action (Zhenmei, Wenjun et al. 2003; MA, ZHOU et al. 2009).

The electric power quality has become sensitive issue in particular for Electric Supply Companies (ESC) and their customers. Prior to the control and improvement in electric power quality, reasons and causes of any disturbance in system must be determined (Gaouda, Salama et al. 1999; Zhaojing 2001). Actually there are many parameters which contribute to disturbance of power quality of electrical signal, which is usually defined in terms of the continuity of the supply such as voltage magnitudes, frequency, transients, harmonics etc (Santoso, Powers et al. 1996).In modern age of control and automation of the electrical drives, several power electronic devices are used in conjunction with the basic electrical equipment (Shipp 1979). These controlling devices usually draw non-linear currents from the supply, thereby creating harmonic problem in the whole configuration and thus disturb the power quality of the signal (Santoso, Powers et al. 1994; Bath and Kumra 2008).

Different monitoring devices like disturbance analyzers and harmonic analyzers are available that could monitor and collect sufficient amount of data related to power quality for example THD. However, there are some general problems that normally exist when dealing with these disturbance analyzers such as large data storage, handling of this data, reliability cost of methods, domain problems and could not distinguish between different signals i.e. without artificial intelligence. Therefore computer based techniques are used to deal with such typical problems(Xian and Wang 2005). Waveforms of devices such as UPS have a non- stationary behavior and thus their harmonics could not be detected using stationary methods such as Fourier transform. A joint time frequency method such as wavelet analysis is a better method for non-stationary signal analysis (Pang, Li et al. 2003; Kanitpanyacharoean and Premrudeepreechacharn 2004). It can be used to compute harmonics present in non- stationary signals(González, Bialasiewicz et al. 2008).

In this paper, It is quantified that THD in UPS power is approximately 11.73 times more as compare to KESC. Argument is supported an experiment consisting of data acquisition from both the UPS and utility power outputs is followed by real time signal analysis to quantify the THD of UPS output along with comparative analysis of Karachi Electric Supply Company (KESC) power. A data acquisition system was set up using the NI LABVIEW software and DAQs (Data Acquisition) cards . The acquired data was processed using Wavelet and FFT analysis tools of MATLAB software. The obtained wavelet coefficients were used to quantify THD including wavelet and discontinuity analysis to estimate the share of 3^{rd}, 5^{th}, 7^{th} and 9^{th} harmonics. So the harmonic pollution is discovered, hence the removal methods could be developed to tackle power quality issue.

2. POWER QUALITY ANALYSIS FROM DIFFERENT PERSPECTIVE

2.1 Wavelet analysis

The Fourier transform resolves a signal into a sum of sine’s and cosines, similar to Fourier transform the wavelet analysis resolves a signal into a sum of scaled versions of wavelets. The wavelet is a function that has an average value of zero and unlike the sine or cosine function its limited in time. The wavelet shape might be irregular and asymmetric to detect sharp changes in a signal as opposed to the continuous and uniform sinusoids.

We could do local analysis through this wavelet technique. This means that no matter how small the discontinuity or a distortion in a waveform, it could be detected in the wavelet transform through this technique(Basu and Basu 2007). Wavelet is suitable for applications related to power engineering and where time varying frequencies are concerned. MORLET and MEYER wavelets could be used for harmonic analysis due to their maximum resemblance to sinusoidal and are able to explain the amplitude information as shown in figure 1.

2.1.1 Continuous wavelet transform

Continuous wavelet transform (CWT) is defined as the integration over time of signal multiplied by the scaled and shifted versions of the wavelet functions. Mathematically, the signal is multiplied by scaled versions of the wavelet function denoted by $'\varphi'$. The wavelet is a function of scale and position as shown in equation ‘A’ (Heydt and Galli 1997).

$$C(s,p) = \int_{-\infty}^{\infty} f(t)\varphi(s,p)dt$$ -- Eq. (A)

Here s= scale & p=position

The CWT is continuous because the scale and the position variables are continuous in nature, the signal could be stretched or shifted to any amount. But this kind of data is not suitable for the computers for processing because the computers require discrete data. Hence the Discrete

Wavelet transform (DWT) is employed which takes discrete values of the position and shifting variables and hence yields lesser amount of data(Gaouda, Salama et al. 1999).

This result in a decomposition of the signal into constituent wavelet of different scales and positions just like the Fourier Transform decomposes the signal into sinusoids of differing frequencies as shown in figure 2.

2.1.2. Data acquisition

Due to the various dynamic features and hardware support such as interfacing with NI DAQ Card, LabVIEW software could be the optimum choice for data acquisition process in this analysis. Since we were primarily concerned with the high voltage signals of the range from 200-300 V, we required a DAQ device with this voltage handling capability. The NI 1125 DAQ accompanied with its 1327 module could provide this capability. So this solved our problem of acquiring high fidelity UPS and KESC signals.

2.1.3 Design and process

The acquisition starts with the designing of the Virtual instrument which further consists of the front panel and the block diagram on the LabVIEW as shown in figure3. While Wavelet analysis carried out on MATLAB as shown in block diagram represented by figure 4.

For mathematical analysis, the UPS and KESC Voltage signals (acquired from labVIEW) were exported to MATLAB as shown in figure5, which is a prime tool for Signal Processing due to high computation capability easy User Interface and Coding.This is done to make use of the fantastic advantages offered by the MATLAB Wavelet toolbox. So in essence we have employed Lab VIEW for acquiring the data and MATLAB for the actual analysis purposes.

2.2 Discontinuity analysis

The power of the wavelet transform is that it could be used to detect any high frequency variations in the signals with great ease. A discontinuity or a sharp rise or fall could be identified with this analysis. Power signal could be decomposed into its various wavelet coefficients as shown in figure 6. Observations on the first wavelet coefficients show variations at the instant of around 150^{th} sample which means that some sort of sharp discontinuity was occurred at this point as shown in figure 7,While from naked eye, the original signal was being seen without discontinuity. The subsequent coefficients could reveal the further details of this discontinuity. This is the power of the wavelet analysis over Fourier analysis that it not only tells about the frequency but also tells the exact location in time that frequency component are occuring.

2.3 Harmonic Analysis

The wavelet analysis could also be used to estimate the amount of harmonics present in a non-stationary signal with accuracy. Obtained coefficients were transferred to the wavelet toolbox and wavelet analysis was carried out to calculate the harmonics in the time varying waveform.

2.3.1 Harmonic Analysis of the KESC Signal

Harmonic analysis was conducted on MATLAB through wavelet coefficients of KESC signal to quantify the percentage of each harmonics present in KESC signal. THD in KESC signal were found to be 3.0874% due to the presence of following harmonics as shown in figure 6.

h_3 = 2.5382%

h_5 = 1.4458%

h_7 = 0.9945%

h_9 = 0.0995%

THD = 3.0874%

Here h_3, h_5, h_7, h_9 represent the percentage contribution of the 3rd, 5th, 7th and 9th harmonics respectively.

2.3.2 Harmonic Analysis of the UPS Signal

UPS output signal, acquired using LabVIEW, was transferred to the MATLAB wavelet toolbox to obtained wavelet coefficients as shown in figure 8. Similarly harmonic analysis was carried out on UPS output signal as carried out on KESC signal. THD of UPS output signal were found to be 36.2239% due to the presence of following harmonics.

h_3 = 31.1733%

h_5 = 16.0252%

h_7 =8.4375%

h_9 =3.5206%

THD =36.2239%

The above is the MATLAB output of the program after running our analysis of the wavelet coefficients. Where h_3, h_5, h_7, h_9 represent the percentage contribution of the 3rd, 5th, 7th and 9th harmonics respectively and the represents the total harmonic distortion of the UPS signal.

3. RESULTS AND DISCUSSION

Wavelet analysis on two signals i.e. the KESC and UPS signals show that how the wavelet analysis could accurately locate variations components such as discontinuities. THD in KESC signal were found to be 3.08% whereas for the UPS signal it was 36.22%. Hence THD in UPS signal is 11.73 times more as compare to KESC power. Hence different frequency groups are obtained in the computation process with reference to fundamental wavelet to detect different types of Power Quality disturbances. Squared waveform UPS was used in this analysis which shows that significant amount of harmonics in UPS output signal may cause malfunctioning of various electrical equipment. If we switch towards the use of sinusoidal waveform UPS or stepped sinusoidal, then this percentage of total harmonic distortion could be reduced. The addition of a filter in UPS inverter to reduce multiple frequency harmonics present in it, will be very useful to improve the power quality of UPS.

These results can be utilized to find out the efficiency of different UPS and real time signal analysis of various non-stationary signals in terms of the event’s time at which the disturbance occurred in the system. Immediate attention is required towards power quality of UPS to avoid distortion and disturbance in electrical power system. Furthermore this analysis could be carried out for more UPS available in market o estimate the THD for approximate number of UPSs in Pakistan. Harmonic filtration and other work related to UPS signal is left for future consideration.

4. CONCLUSION

Use of different scaling and approximate coefficients could make easier detection of disturbance in power quality. Computational outcome in this paper have exposed that wavelet transform is an appropriate tool to examine power quality distortion, when time-frequency information is required at the same time. When wavelet analysis was applied to the KESC signal, it showed that discontinuity was occurred around the 150th sample which was hard to detect with the naked eye, however wavelet coefficients locate it very clearly. Finally we applied the analysis techniques to calculate harmonics in the two signals.

5. ACKNOWLEDGEMENT

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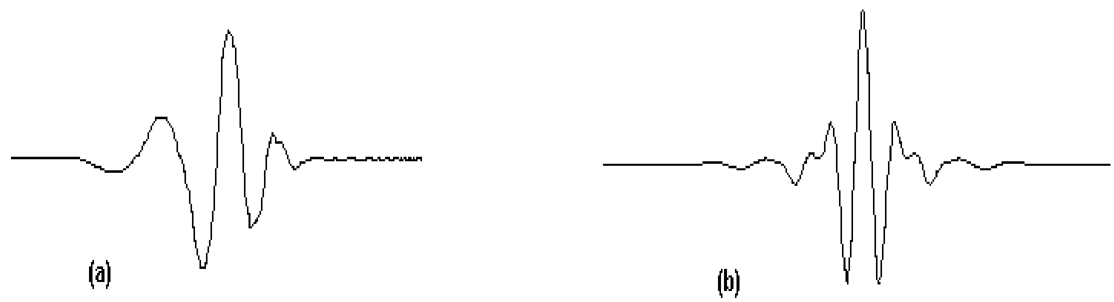

Fig 1. Comparison between (a) Daubechies-10 Wavelet and (b) Meyer Wavelet

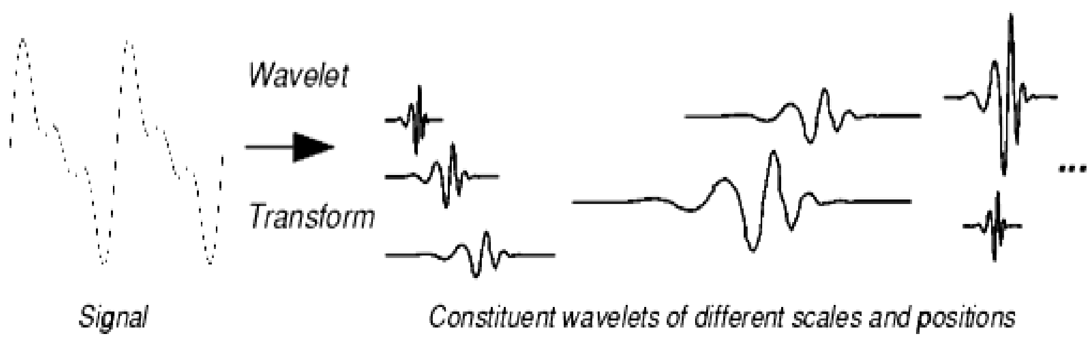

Fig 2. Wavelet transform from signal to Decomposition of the original wave

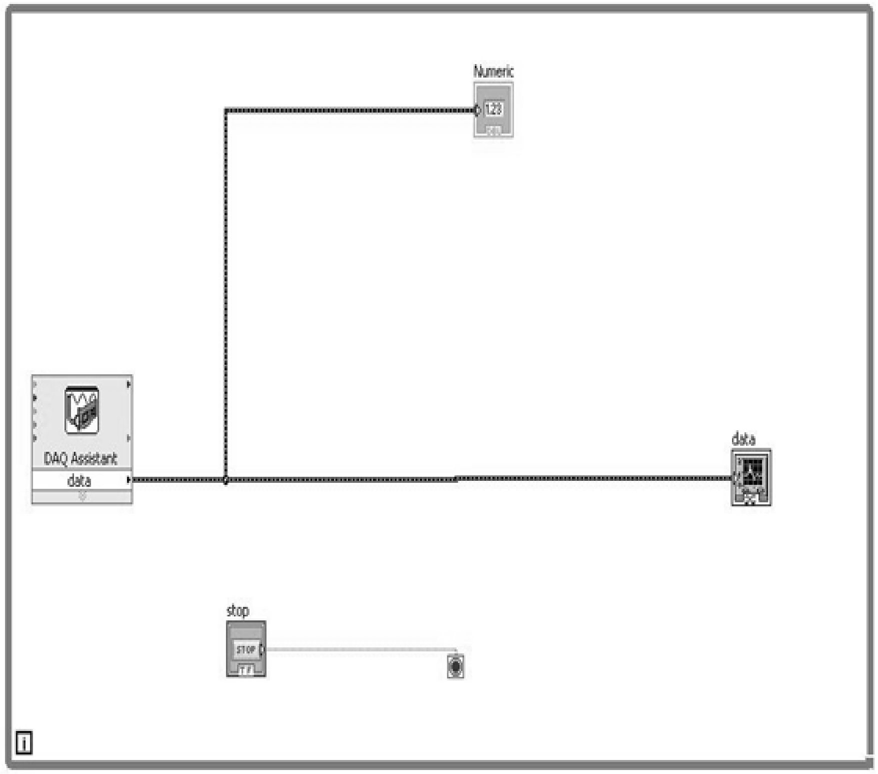

Fig 3. LabVIEW Interface for DAQ Process

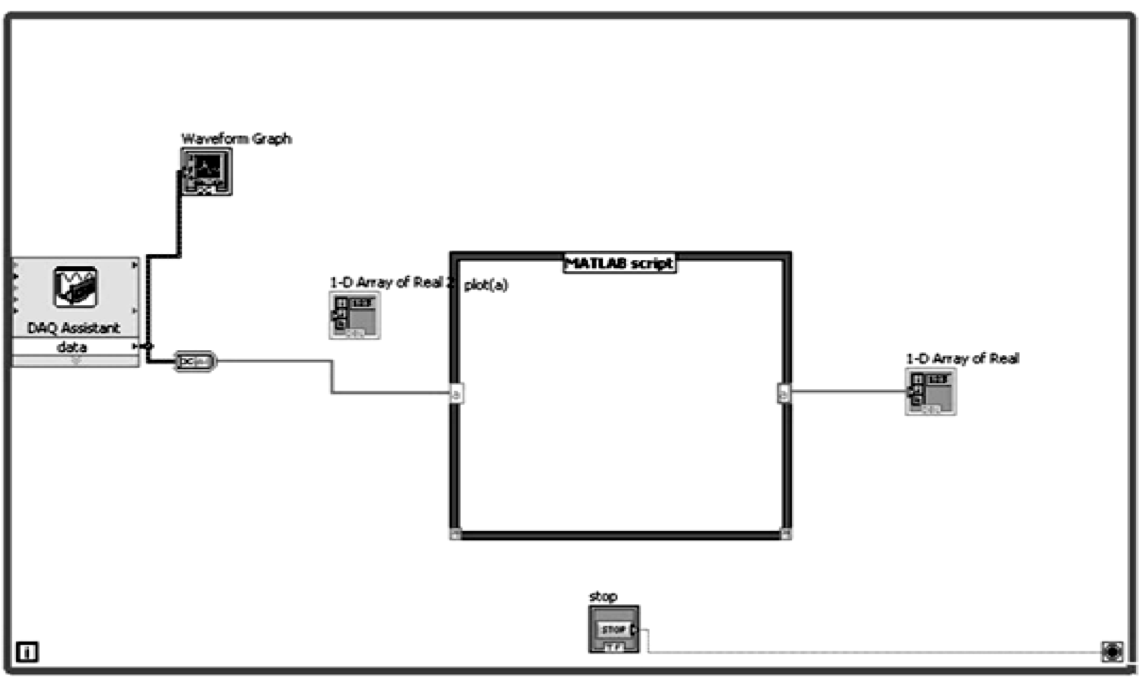

Fig 4. Export to MATLAB

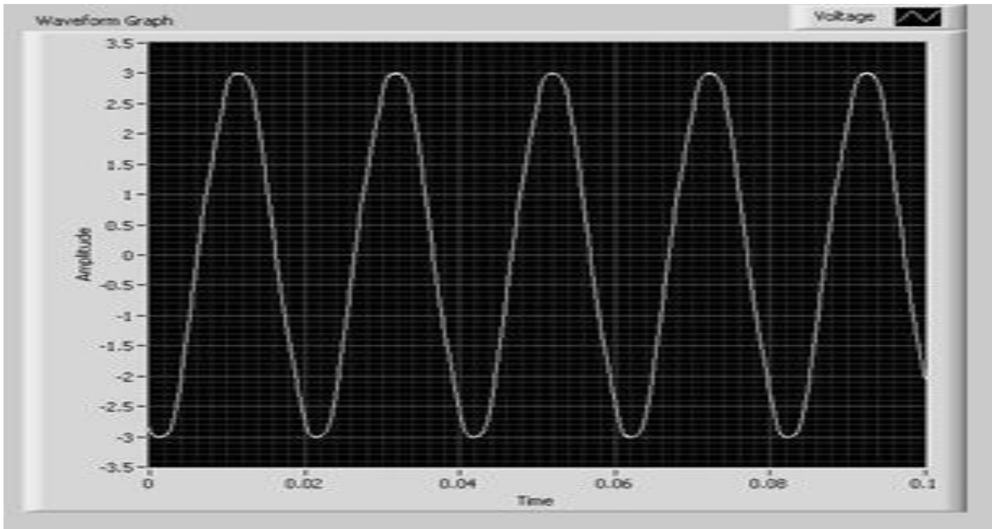

Fig 5. Display of Signal on LabVIEW

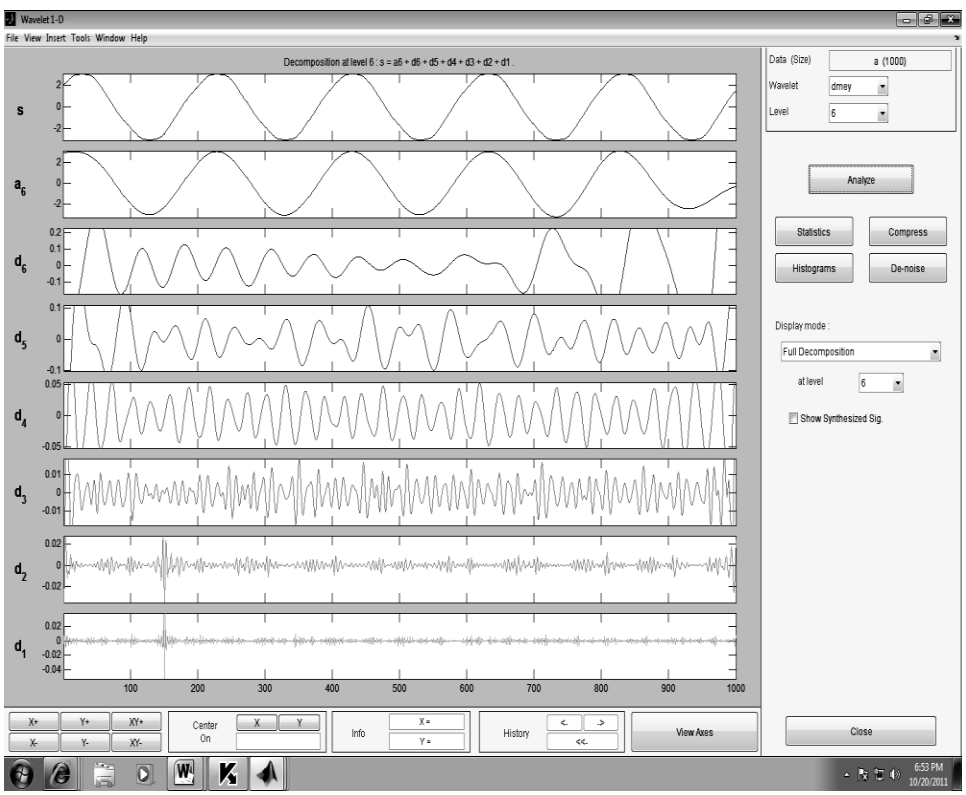

Fig 6. Wavelet Decomposition of the KESC Signal

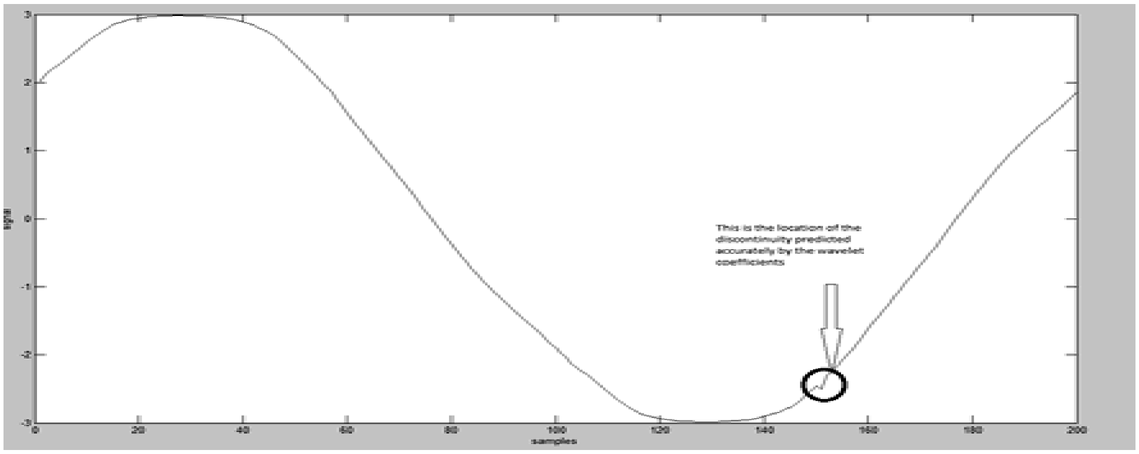

Fig 7. Zoomed view of the signal showing a discontinuity at around 150th sample.

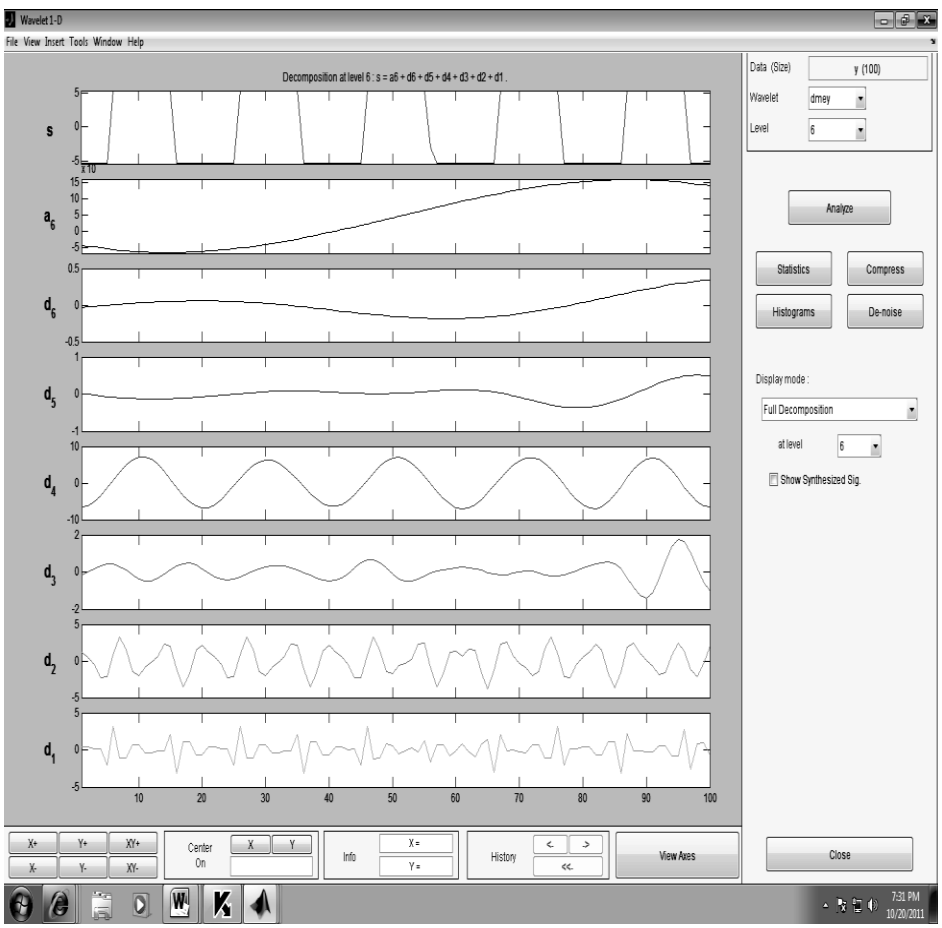

Fig 8. Harmonics Coefficients of the UPS Signal