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Implementation of the Improved Slantlet Transform Based Data Compression and Reconstruction Technique Applied to Power Quality Disturbance Signals

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***Abstract*— Wavelets are used to analyze the frequency components of a signal according to a scale. Now-a-days, wavelet transforms have been studied and applied effectively in science and technology fields. One such area of applications of digital signal processing tools is 'Power Quality'. Present paper describes SLT used for compression of different power quality disturbance data. The performance of slantlet transform (SLT) as a novel technique, in terms of compression ratio, percentage of energy retained and mean square error present in the reconstructed signal is assessed. The different power quality events such as voltage sag, swell, harmonics, momentary interruption, voltage flicker and transient oscillation are used to analyze the performance of the new approach.**

***Keywords*— Slantlet transform, power quality, discrete wavelet transform, data compression, reconstruction.**

I. Introduction

The electrical disturbances which affect customer load or power system equipments adversely are known as Power Quality (PQ) events. An increasing number of electricity consumers, including residential consumers utilize end-use devices which are more sensitive to smaller perturbations in the power supply. Electric distribution utilities world-wide are recognizing the increasing voltage sensitivities of many customer devices. The short- term events such as voltage sags or dips lasting a few cycles to a few seconds caused by faults on nearby feeders, sub cycle transients caused by switching power factor corrections capacitors and lightning strikes are termed as typical PQ issues. The performance of the automated equipment, programmable logic controllers, computers and other equipments are very severely affected by such signal disturbances. Electric distribution utilities world-wide are recognizing the increasing voltage sensitivities of many customer devices [2].

The progress of utility deregulation and competition requires greater demand of power quality, increasing the need of more accurate study of power quality events. As a consequence, the events should be recorded at higher sample rates, thereby increasing the amount of data considerably. The volume of recorded data increases significantly, which leads to a high cost both in storing such data and the communication time from the field instruments to a central location for further study [5]. Therefore, the capability of compressing the data Volume is highly desirable [6]. Hence, data compression operation for such data becomes an essential tool.

The slantlet transform is an orthogonal discrete wavelet transform and provides improved time localization than discrete cosine transform and discrete wavelet transform [7]. In the application of wavelet bases to image compression, the time localization and the number of zero moments of the basis are both important [4]. Good time localization properties lead to good representation of edges. The slantlet transform (SLT) is used as a tool in devising an efficient method for compression of different power quality events [3] [1].

II. SLT Based Data Compression and Reconstruction

The data compression of power quality events signals are carried out in the present work using slantlet transform. To obtain a reasonably high compression ratio with low energy loss, a new integrated scheme of data compression using slantlet transform is also adopted. A scheme of data compression and reconstruction using a two-scale slantlet transform filter bank is shown in (Fig. 1). It involves three distinct steps, viz.

- Transformation of input signal using the slantlet transform.
- Thresholding of transformed coefficients.
- Reconstruction of the signal from the threshold coefficients.

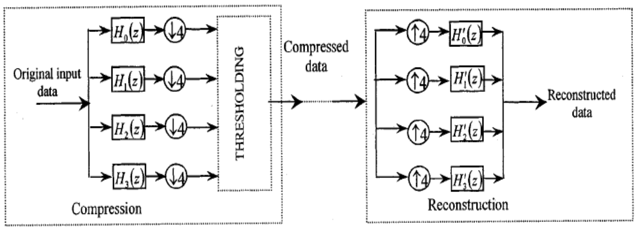

Fig. 1 Two scale SLT based data compression/reconstruction scheme

The first two steps constitute compression operation where as the last step performs the reconstruction operation. The power quality disturbance signal is fed to the two-scale slantlet transform filter bank, where the outputs are down sampled by a factor of four. The transformed coefficients of the slantlet transform are $H_1(z)$, $H_2(z)$, $H_3(z)$ and $H_4(z)$.

The slantlet transform retains most of its input signal energy in some selective coefficients and the magnitudes of the remaining coefficients are insignificant. In view the threshold level is fixed. In the reconstruction process the compressed data are first up sampled by a factor four and then convolved with the synthesis filter coefficients of each channel. These synthesized data are then added together to reconstruct the original power quality signal for the purpose of further analysis and interpretation [1].

To assess the quality of compression, the energy retained in the reconstructed signal and mean square error (MSE) in decibels is used as the performance index. The compression ratio depends on the threshold value selected i.e., the total samples which are retained decides the compression ratio. The energy retained by the reconstructed signal is defined as the ratio of vector norm of the compressed signal to the vector norm of original signal.

$$\%\ \text{Energy retained} = \frac{\text{Vector norm of compressed data}}{\text{Vector norm of original data}} \times 100$$

The mean square error (MSE) in decibels is defined as

$$\text{Mean square error (dB)} = 10\left[\log_{10}\left(\frac{1}{N}\sum_{i=1}^{N}\|x(i)-\hat{x}(i)\|2\right)\right]$$

where, $x(i)$ and $\hat{x}(i)$ are the original signal and the reconstructed signal. In the proposed work a two-level slantlet transform filter bank is chosen considering both the complexity of computation and the quality of compression.

$$\text{Compression ratio} = \frac{\text{Original file size}}{\text{Compressed file size}}$$

Compression ratio is defined as the ratio of original file size to the compressed file size. By choosing a different threshold value, a different compression ratio can be obtained.

III. Simulation Results

A. *Sine Impulse*

The Disturbance containing an impulse at 0.001s generated to demonstrate data compression capability. The ratio between the number of original signal data to the number of data retained after the thresholding is termed as the compression ratio (CR) and in the present case CR 10 is considered. Keeping a lower CR that is at CR 5, the signal is again reconstructed and is observed to be better than at CR 10 (Fig. 2).

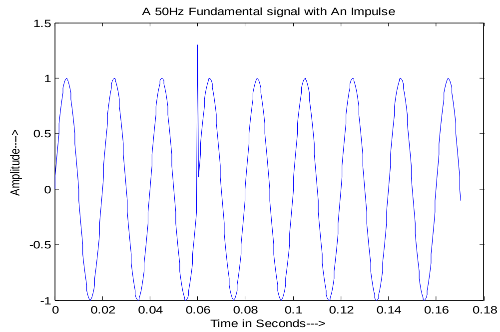

Fig. 2 A 50 Hz fundamental signal with an impulse

B. *Decomposed Sine Impulse Signal*

The signal is decomposed by the SLT into two levels and the corresponding filter outputs are shown in Fig. 3.

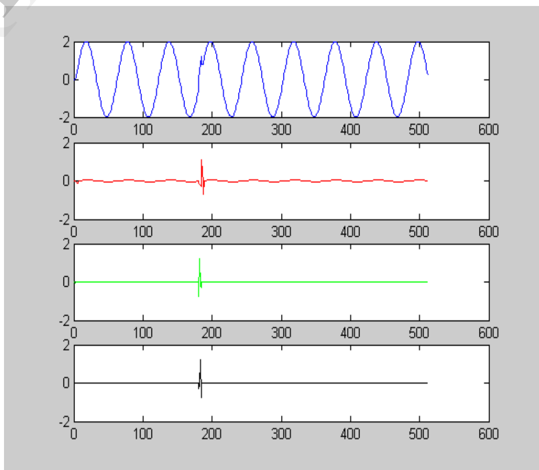

Fig. 3 SLT filter bank output. (a) First filter o/p. (b) Second filter o/p. (c) Third filter o/p. (d) Fourth filter o/p

IV. Data Compression Technique Applied to Power Quality Events

The proposed data compression technique is applied to many PQ issues such as: sag, swell, harmonics, interruption, oscillatory transient and flicker. All the data are generated using the MATLAB code at a sampling rate of 3 kHz. To demonstrate the efficacy of the proposed technique some test cases are presented below. For all simulation study a pure sinusoidal signal of 50 Hz and 1 p.u. amplitude is considered.

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TABLE I

PERCENTAGE OF ENERGY RETAINED AND THE MSE IN DB OBTAINEDUSING THE DCT, DWT AND SLT BASED COMPRESSION AND EXPANSION TECHNIQUES FOR ALL THE SIGNALS AT CR = 10

Signal	Energy Retained (1%)			MBS (db)		
	DCT	DWT	SLT	DCT	DWT	SLT
Impulse	88.01	91.13	98.21	-10.67	-13.56	-16.98
Sag	87.81	90.01	98.78	-10.08	-13.04	-17.54
Swell	89.46	91.01	98.61	-11.88	-13.77	-17.95
Harmonics	87.69	90.89	98.19	-11.04	-13.31	-17.68
Momentary Interruption	90.44	91.10	98.70	-12.27	-15.89	-18.79
Oscillatory transient	91.63	90.88	98.11	-12.98	-14.45	-19.07
Voltage Flicker	90.75	91.34	98.75	10.76	-14.74	-19.78

A. Voltage Sag

It is a sudden reaction (10-90 %/) in the voltage magnitude lasting for 0.5 cycles to several seconds. Flow of heavy current associated with the starting of large motor load or the flow of fault currents, switching operation associated with temporary disconnection of supply can cause sag. Magnitude and its duration are responsible for the effect of voltage sag on equipment. To evaluate the performance of the SLT approach a 20% sag case of 3.5 cycles of duration signal is considered. The original and the reconstructed signal obtained through simulation at a CR 10 is shown in Fig. 4, which depicts the accuracy of the approach at reduced data size also.

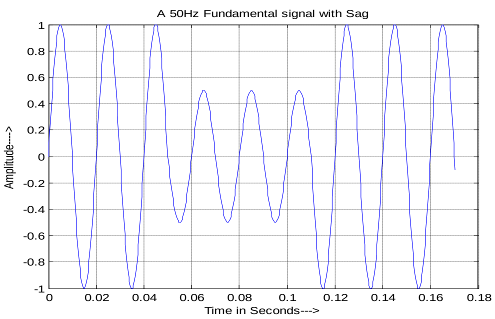

Fig. 4 A 50 Hz fundamental signal with sag.

B. Voltage Swell

It is increase of voltage signal by (10-90%). They usually appear on the sound phases of a power system when heavy motor loads are switched off or where a phase-to-ground fault occurs. The delicate equipment components to premature failure can be stressed by swell. Fig. 5 depicts the waveform of a voltage swell (80%) lasting for three cycles. The corresponding data are used for the decomposition and reconstruction of the disturbance signal using all the three approaches as mentioned earlier.

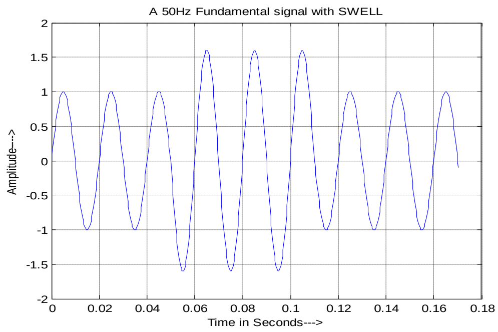

Fig. 5 A 50 Hz fundamental signal with Swell

C. Harmonically distorted signal

The power quality is further degraded as they produce significant amount of different harmonics with the introduction of more power electronic equipment in distribution system. Such harmonic pollution in voltage signal leads to poor performance of converter circuit. A 1 p.u. fundamental voltage signal (50 Hz) distorted by 30% third harmonic and 10% fifth harmonic as shown in Fig. 6

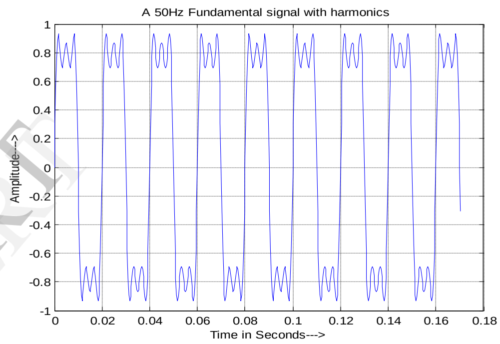

Fig. 6 A 50 Hz fundamental signal with third and fifth harmonics

D. Momentary Interruption

Voltage sags with 100% amplitude which are mainly due to the short circuit faults being cleared by the protection are called Interruptions. The performance of glass and computer industries is greatly influenced by supply interruption for few cycles. For evaluating the performance of the SLT based compression technique a voltage signal interrupted for three cycles is shown in Fig. 6.

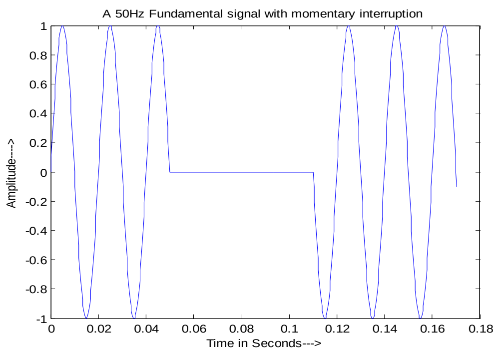

Fig. 6 A 50 Hz fundamental signal with Momentary interruption

E. Oscillatory transient

Signals which are shorter than sags and swells which have oscillatory characteristics and are found during capacitor bank switching. An oscillatory transient signal is shown in Fig. 7, which persists for 5ms only.

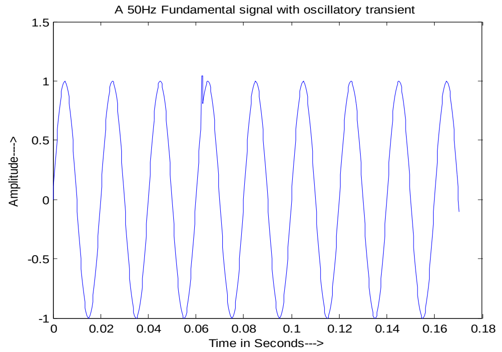

Fig. 7 A 50 Hz fundamental signal oscillatory transient

F. Voltage Flicker

Slow (0.5-30 Hz) modulation of the voltage magnitude is known as voltage flicker. Cyclic and acyclic loads with temporal variation or sudden starting of large induction motors can cause voltage flicker. The amplitude of a sinusoidal voltage signal (1 p.u., 50 Hz) is modulated by a low frequency component of 0.05 p.u., 5 Hz and is shown in Fig. 8.

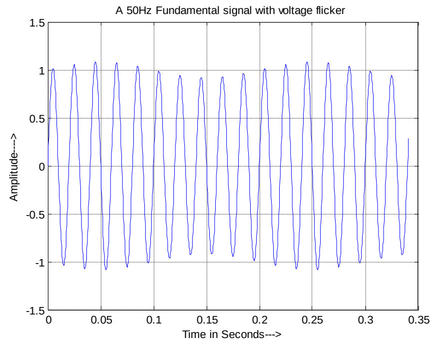

Fig. 8 A 50 Hz fundamental signal with Voltage Flicker

V. Conclusions

In this paper the SLT has been applied for compression of data pertaining to the PQ events. The compression performance of the new is assessed through computer simulation and the results are compared with the DCT and the DWT approaches. It is, in general, observed that the accuracy of the reconstruction of the proposed SLT method is better than that the DCT and DWT. Exhaustive computer simulation results on different PQ signals indicate this trend. Thus it is, in general, concluded that the SLT based compression technique yields better performance compared to both the DCT and DWT.

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