3rd International Conference on Electrical & Computer Engineering
ICECE 2004, 28-30 December 2004, Dhaka, Bangladesh

WAVELET BASED DENOISING FOR ACCURATE IDENTIFICATION OF B-H LOOP OF TRANSFORMER CORE

S. Chatterjee, S. Chakravorti and C. K. Roy

High Tension Laboratory
Department of Electrical Engineering, Jadavpur University, Kolkata-700032, INDIA
E- mail: saibalda@yahoo.com

ABSTRACT

With the advent of digital CRO, the measurements of signals are being done on-site and sometimes on-line also. Achieving acceptable levels of sensitivity during such a measurement of B-H loop characteristics of a transformer often pose a real challenge due to strong coupling of external interferences / noise. In this paper a semi-automatic wavelet-based scheme is proposed to recover voltage and current proportional voltage signals buried in excessive interferences / noise and obtain the B-H loop characteristics of the transformer.

1. INTRODUCTION

B-H loop is an important characteristic in a transformer, which plays an important role during steady state and especially transient conditions. While measuring a B-H loop parameters of a transformer (no load condition), a major bottleneck encountered is the ingress of external interferences (usually of amplitude comparable to the original signals). It directly affects the sensitivity and reliability of the acquired data. Major external interferences encountered during on-site measurements and their sources are [1]:

- Discrete spectral interferences (DSI) from radio transmissions and power line carrier communication systems.
- Stochastic pulse shaped interferences from infrequent switching operations or arcing between adjacent metallic contacts, corona from the power system, which get coupled to the measurement system.
- Other noise sources from components, harmonics from the mains, and interferences from the ground connections, etc.

In most cases, these external interferences can cause false indications thereby reducing the credibility of the measurements. Wavelet analysis is a powerful tool for eliminating noise from the original signal. This paper reports a wavelet based denoising scheme for signals having low signal to noise ratio.

2. WAVELET BASED DENOISING

A wavelet is a small wave, which has its energy concentrated in time, and a tool meant for analysis of transients and non-stationary or time varying signals. Wavelet analysis consists of breaking up of a signal into shifted and scaled version of the mother wavelet. Continuous wavelet transform (CWT) of a signal x(t) Є L^2 (R) is defined as [2]

$$CWT_x^{\psi}(\tau,s)=\frac{1}{\sqrt{|s|}}\int x(t)\psi^*\frac{(t-\tau)}{s}dt$$

where function ψ(t) is the mother wavelet. It is a prototype for generating other window functions, which are dilated or compressed and shifted versions of mother wavelet. T is the shift operator (translation), s is the scaling function and * stands for the complex conjugation.

Open and closed loop noise reduction approaches [3] are normally employed for noise reduction. The wavelet based denoising scheme that is reported in this paper is designed using Matlab Wavelet Toolbox. Denoising of the signal using wavelet employ different parameters. These parameters are wavelet types, threshold type, threshold selection rule applied, level and multiplicative threshold rescaling. The definition and realisation of the WT, its advantages over the FT, wavelet based Denoising procedures, and a range of approaches to thresholding has been reviewed in the literature [4]-

ISBN 984-32-1804-4

[6]. Different types of wavelet used are Daubechius (db), coiflets, symlets, bio-orthogonal and reverse bio-orthogonal. Each type is having different sub-types. However, the scheme in principle is not limited to these wavelet types only. Threshold type can be soft or hard. Threshold selection rule applied are 'rigrsure' using principle of Stein's Unbiased Risk [7], 'heursure' using the heuristic version of the first option, 'sqtwolog' using universal threshold sqrt (2*log (.)), 'minimaxi' using minimax thresholding. Multiplicative threshold rescaling employs 'one' or no rescaling, 'sln' or rescaling using a single estimation of level noise based on first level coefficients and 'mln' or rescaling using level dependent estimation of level noise.

During the implementation of the scheme, selection of two of the above-mentioned parameters, viz. selection of mother wavelet and selection of the number of levels was found to be the significant choice to be made. Direct answer to the first choice is still not available in the literature. With the present status, its choice was based on trial-and-error method and guided by hints published in literature. The choice of level was also based on trial-and-error method and an intelligent guess on the signal to noise ratio.

3. EXPERIMENTAL SETUP AND DATA ACQUISITION

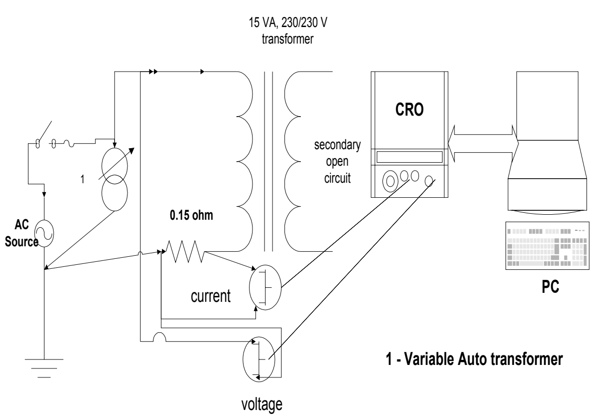

Fig. 1 Schematic of Experimental setup

Fig. 1 shows the schematic diagram of the experimental set up. The digital CRO used was YUKOGAWA make DL1720 with the *Waveform Viewer* software for acquiring data, displaying, analysing, and storing it in PC through USB. The sampling rate was chosen such that the recorded signals correspond to minimum four power frequency cycles with a record length of 1002 samples. It should be noted that the B-H loop has to be formed from the voltage and current signals with the approximation that the voltage signal represents the flux or flux density (B) with a phase difference of around 90^{o} and the current signal representing H. The denoising tool adopted is basically an offline technique.

4. RESULTS & DISCUSSION

The recorded voltage and current signals were normalised and processed with the denoising tool. The salient features of data processing and results obtained for each signal are discussed below. It is worthwhile to mention that various combinations of the parameters of the tool were tried to obtain the optimum choice. The optimum result has only been discussed here (with normalised signal).

Both the noisy voltage and current signals were processed through the wavelet based denoising tool. It can be observed from Fig. 2 that the noise level present in the voltage signal is quite low in comparison to the original signal whereas it is of significant level in the current signal.

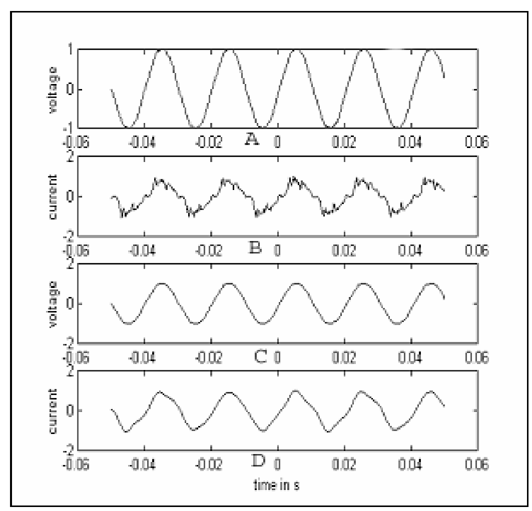

Fig. 2 Noisy (A & B) and denoised (C & D) voltage and current signal

The parameters used for the optimum results of the respective signals are given in Table 1.

Table1. *Optimum values of denoising parameters*

Type of signal	Wavelet name	Threshold type	Level	Thres-hold selection rule	Multiplicative thres hold rescaling
voltage	Db10	soft	2	sqtwolog	one
current	Sym8	soft	5	rigrsure	one

It was also observed that the denoising of the voltage signal only leads to insignificant improvement in the B-H loop but cumulated with the denoising of the current signal leads to considerable improvement (Fig. 3).

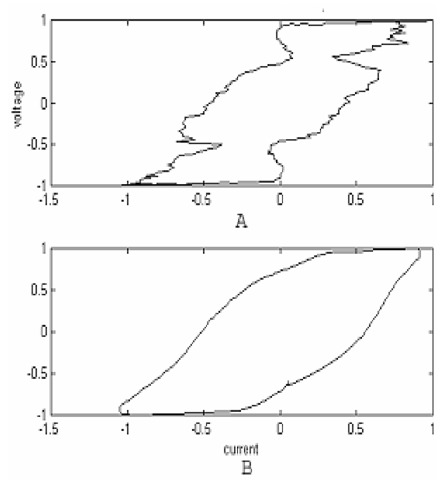

Fig. 3 Noisy (A) and denoised(B) BH loop

In addition, the FFT of the respective signals (Fig. 4) show a considerable decrease in the noise of range 300 Hz and above (specially in the. FFT of the voltage signal (both noisy and denoised) shows that it contains only a 50 Hz component, as there are no other significant frequencies present in the spectrum. On the other hand the FFT of the noisy current signal shows frequency components of 650 Hz or higher.) current signal

But the FFT of denoised current signal shows the most significant frequency component at 50 Hz (fundamental) and one more frequency component at 150 Hz i.e. 3rd harmonics, which is expected in the no-load current of a transformer supplied with a sinusoidal voltage and a non-linear magnetisation curve.

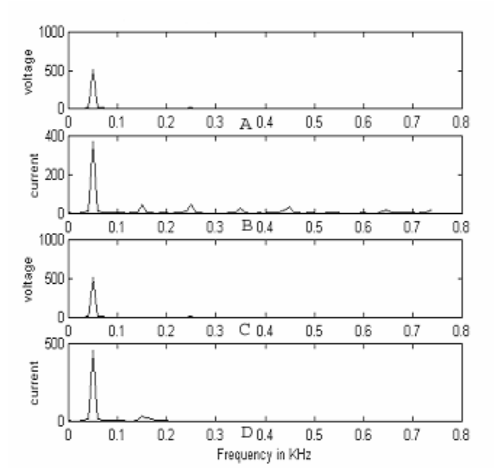

Fig. 4 FFT of noisy (A & B) and denoised (C & D) signals

5. CONCLUSIONS

Reliability of the voltage and current signals gathered on-line and the application of the denoising tool is strongly influenced by external interferences. This paper presents results of such denoising for extracting the voltage and current signals buried in high level of noise and interferences. Further, the hardware method involved in filtering out the noise and interferences is often expensive, cumbersome and time consuming. Therefore, the method proposed is quite efficient especially in areas of unknown sources of noise.

6. ACKNOWLEDGEMENT

S. Chakravorti expressed thanks to All India Council for Technical Education for the support provided by the project “Advanced Techniques for Condition Monitoring and Life Prediction of Power Transformer” grant no. 8022/RID/NPROJ/RPS-18/2003-04, awarded to him at the High Tension Laboratory, Electrical Engineering Department, Jadavpur University.

7. REFERENCES

1. L. Satish & B. Nazneen, “Wavelet-Based Denoising of Partial Discharge Signals Buried in Excessive Noise & Interference”, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 10, No.2, pp. 354-367, 2003.

2. R. K. Young, Wavelet Theory and its Applications, Pennsylvania State University, Kluwer Academic Publishers, 1993.

3. I. Shim, J.J. Shoragan, and W.H. Siew, “ Digital signal processing applied to the detection of partial discharge: An overview,” IEEE Electrical Insulation Mag., vol. 16, no. 3, pp 6-12, 2000.

4. I. Shim, J.J. Shoragan, and W.H. Siew, “ Detection of PD utilising digital signal processing methods, part 3: Open loop noise reduction,” IEEE Electrical Insulation Mag., vol. 17, no. 1, pp 6-13, 2001.

5. X. Ma, C. Zhao, & I.J. Kemp, “Investigation into the use of wavelet theory for partial discharge pulse extraction in electrically noisy environments”, IEEE Electrical Insulation Magazine, Vol.18, No. 2, pp 37 – 45, 2002.

6. J. Ramirez-Nino,, S. Rivera-Castaneda, V.R. Garcia-Colon, and V.M. Castano, “Analysis of partial discharges in insulating materials through the wavelet transform,” in Computational Materials Science, vol. 9, pp 379-388, 1998.

7. M. Misti, Y. Misti, G. Oppenheim, and J. Poggi, “Wavelet toolbox manual – User’s guide,” The Math Works Inc., USA, 1996.