World Journal of Environmental Biosciences
All Rights Reserved WJES © 2014
Available Online at: **www.environmentaljournals.org**

Volume 6, Supplementary: 6-12

ISSN 2277- 8047

A Wavelet Transform Based Discrimination Between Inrush Current And Fault Current in A Power Transformer

Mahdi Mozaffari Legha[1], Seyed Mohammad Hoseeini [2], Mehdi Amiri Domari [3]

[1,2,3]Department of Power Engineering, Institute of Higher Education Javid,Jiroft, Iran.

ABSTRACT

This paper present accurate discrimination between fault current and inrush current in a power transformer. Inrush currents in power transformers are non sinusoidal, high magnitude currents generated due to flux saturation in the core during energization. This paper describes a decision method for discrimination between faults and inrush currents in power transformers using the wavelet transform. It is shown that the features extracted by the wavelet transform have a more distinctive property than those extracted by the fast Fourier transform due to the good time and frequency localization characteristics of the wavelet transform. As a result, by quantifying the extracted features, the decision for distinguishing a fault from an inrush current in different power transformer system can be accurately made. Simulated result show the proposed technique can accurately discriminate between fault current and inrush current in a power Transformer protection.

Keywords: *Inrush Current, Fault Current, Transformer Protection, Wavelet Transform.*

Corresponding author: Mahdi Mozaffari Legha

INTRODUCTION

Transformer protection is critical issue in power system and the issue lies in the accurate and rapid discrimination of inrush current from fault current. Transformers are essential and important elements of power systems. Due to their sizes and varieties, protection approaches of power transformers differ depending on the situation. For small distribution transformers of less than 2 MVA, high rupturing capacity fuse will suffice. Others use over current relays. However, for the larger power transformers, differential protection based on circulating current principle is usually adopted. The differential protection converts the primary and secondary currents to a common base and compares them. The difference between these currents is small during normal operating conditions. The difference is also small for external faults, but is larger than the difference for normal operating conditions. However, during an internal fault in a transformer, the difference becomes significant. The differential protection is then based on matching the primary and secondary current of the transformer for ideal operation. When a transformer is switched off, its core generally retains some residual flux. Later, when the transformer is re-energized, the core is likely to saturate. If the transformer is saturated, the primary windings draw large magnetizing currents from the power system. These results in a large differential current which cause the differential protection relay to operate.

This paper describes a decision method for discrimination between faults and inrush currents in power transformers using the wavelet transform.

1. Wavelets Transformers

Wavelet transform analyses signal at time and frequency simultaneously, because of its localized characteristic of time and frequency and multi-resolution analysis, so wavelet transform is easy for non-stationary signal. (Yang Long and etal ,2011). Continuous wavelet transform is defined as

$$\mathrm{WT}(a,\tau) = \frac{1}{\sqrt{a}} \int f(t)\Psi^{*}\left(\frac{t-\tau}{a}\right)dt$$

$\Psi(t)$ is wavelet mother function ,a is scaling factor, τ is time shift factor. Discrete wavelet transform is defined as

$$\mathrm{WT}\left(a_0^j, k\tau_0\right) = \int f(t)\Psi^{*}{}_{a_0^j,k\tau_0}(t)dt$$

Here j, k is integral, we put a process into power series quantum, and τ is discrete, the continuous wavelet transform become the discrete wavelet, namely

$$\Psi_{a_0^j,k\tau_0}(t) = a_0^{\frac{-j}{2}}\Psi[a_0^{-j}t - k\tau_0]$$

If $a_0 = 2$, $\tau_0 = 1$, this is call as dyadic wavelet. Wavelet transforms are widely used to decompose signals into different frequency components to study each component with a resolution level that matches the scale of the particular component. The multi-resolution technique outperforms the Fourier transform in such a way that both time domain and frequency domain information can be preserved. Wavelet transform performs the optimized sampling. In contrast to the wavelet transform, the windowed Fourier transform over samples the signal under investigation, with respect to the Nyquist sampling criterion. Wavelets decompose and compress signals with good basis systems to reach high efficiency or sparseness. Wavelet analysis provides a new way to look into the intermittent information. A transient signal is broken down into a series of local basis functions called wavelets. Each wavelet is located at a different position on the time axis and is local in the sense that it decays to zero when sufficiently far from its center. Any particular local features of a signal can be identified from the scale and position of the wavelets in which it is decomposed. Wavelets are a powerful tool for presenting local features of a signal. When the size and shape of a wavelet are exactly the same as a section of the signal, the wavelet transform gives a maximum absolute value, a property, which can be used to detect transients in a signal. Thus the wavelet transform can be regarded as a procedure for comparing the similarity of the signal and the chosen wavelet.

Although the waveform analyzed by the continuous wavelet transform is generally a discrete-time sequence, the continuous meaning of the CWT is that the scale and shift values can take on any value. But as the signal has a finite bandwidth and duration, then only a finite range of scales and shifts are meaningful. The CWT can operate at every scale from that of the original signal. Scales are to be chosen by trading off the need for detailed analysis with available computational power. The analysis is much more efficient and just as accurate by using the discrete wavelet transform, where the scales and shifts take on discrete values. The signal f (t) can be represented by the DWT using the coefficients c_{jk}, a_j is the scale coefficient and d_j is the wavelet coefficient (Yang Long and etal ,2011).

$$f(t) = \sum_k \sum_j c_{j,k} 2^{\frac{-j}{2}} \Psi(2^{-j}t - k)$$

$$f(t) = \sum_k \sum_j d_j \Psi_{j,k}(t) + \sum_k a_j \Psi_{j,k}(t)$$

Low pass filter h_k, gives its output known as the approximation or the scale. The filter equation relates the filter and the scale function, or in other words the wavelet. The multi-resolution system satisfies a scaling function, $\varphi_{jk}(t)$ given by: h_k is low-pass decomposition filter; g_k is high-pass decomposition filter. High pass filter g_k, gives its output known as the detail or the wavelet coefficient. This filter equation relates the filter and the wavelet function given by (Mallat ,199; Yang Long and etal ,2011).

$$\varphi(t) = \sqrt{2} \sum_k h_k \varphi(2t - k)$$

$$\psi(t) = \sqrt{2} \sum_k g_k \varphi(2t - k)$$

Simulation and Application

A system with a generator, a three phase transformer and a load has been simulated. A typical 750MVA, 27/420KV, Power transformer is connected between 25KV source at sending end 400 KV transmission line three phase connection diagram are shown in Figure 1. I_{ad} I_{bd} I_{cd} refer to a,b,c three phase differential current through CT secondary side: n1, n2 are the number turn on the low voltage (LV) and high voltage on (HV) the simulation of these power transformer is carried out using MATLAB software which is Shown in Figure 2. In each simulation of the system parameter are varied including the fault type fault position , fault inception angle , remnant flux in power transformer core. and also the effect of CT saturation is also studied (Nayeem and et al, 2013).

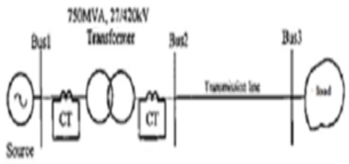

Fig.1. Simulated Power system model

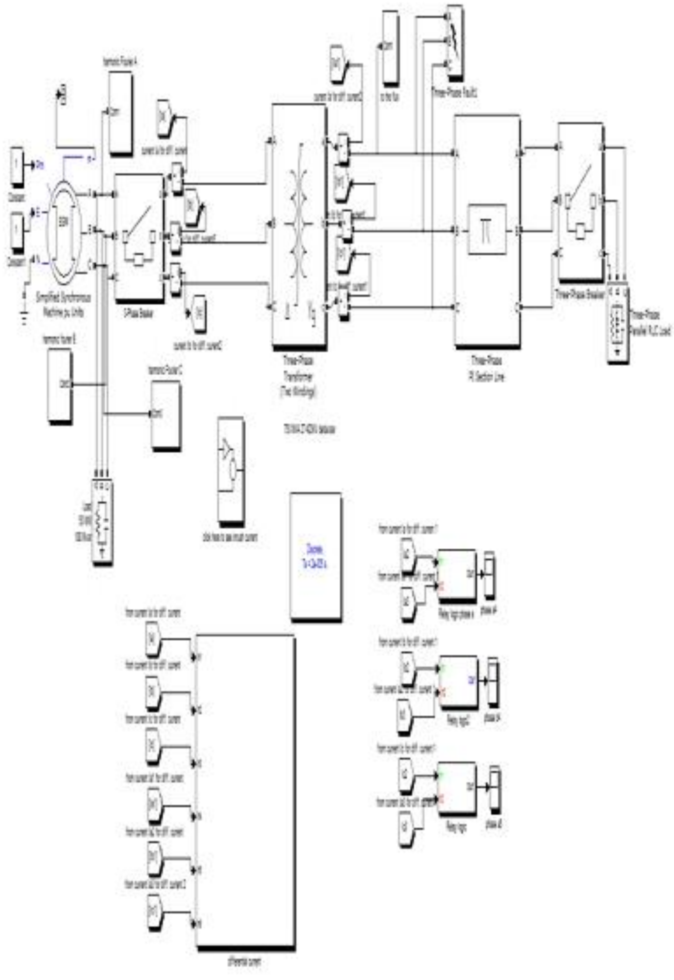

Fig.2. MATLAB model

2. Proposed Protection Algorithm

A Flowchart of the proposed algorithm is seen in Figure 4 [21].

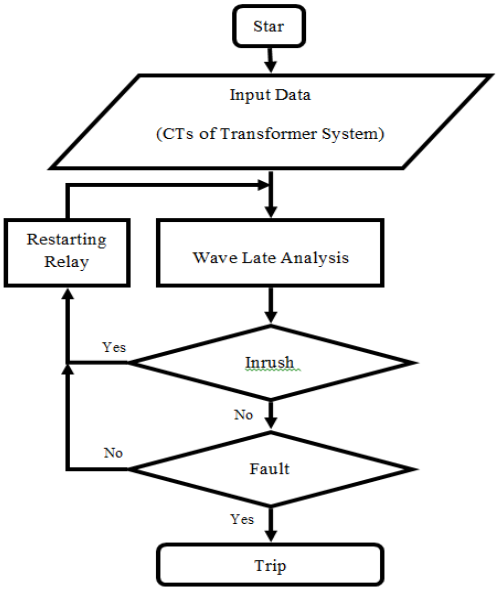

Fig. 4: A flowchart of the proposed algorithm

1. TESTS AND RESULTS

1.1. Case A) Transformer DD

Experimental transformer no-load inrush current and load interterm fault cases, the two sets of waveforms, and a group of normal waveform. Since this article transformer experiment is the presence of harmonic components in the laboratory, during the test, so the experimental results from the waveform is not sinusoidal waveform, but presents the trend of a square wave. Transformer inrush current experimental waveform graph is showed in Figure 5 and scale average for Inrush current waveform is showed in Figure 6 and global wavelet spectrum and significance levels for Inrush current waveform is showed in Figure 7. Transformer Fault Current experimental waveform graph is showed in Figure 8 and scale average for Fault Current waveform is showed in Figure 9 and global wavelet spectrum and significance levels for Fault Current waveform is showed in Figure 10.

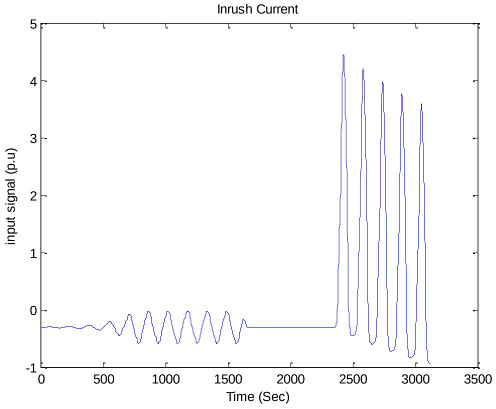

Fig. 5: Inrush current waveform in Primary transformer DD for Phase A

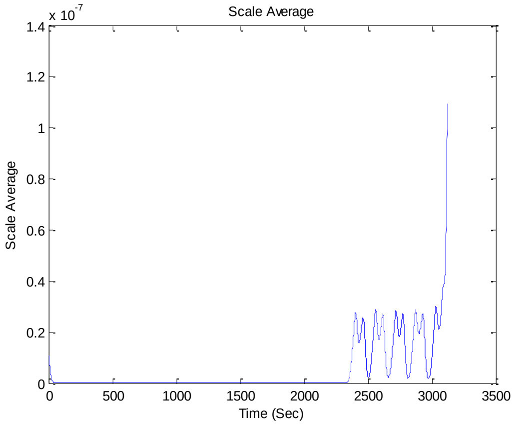

Fig. 6: Scale average for Inrush current waveform in Primary transformer DD for Phase A

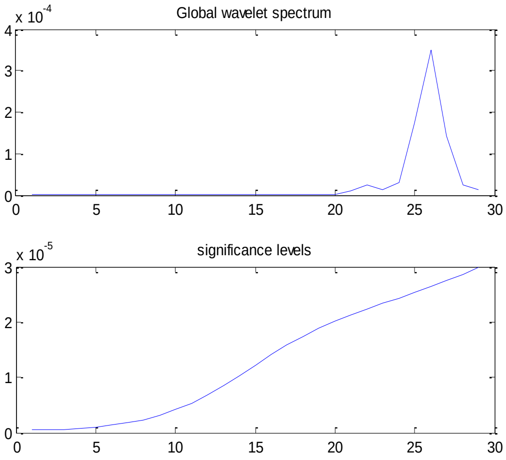

Fig. 7: Global wavelet spectrum and significance levels for Inrush current waveform in transformer DD

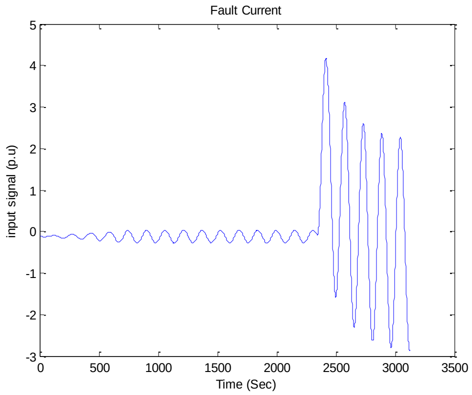

Fig. 8: Fault Current waveform in Primary transformer DD for Phase A

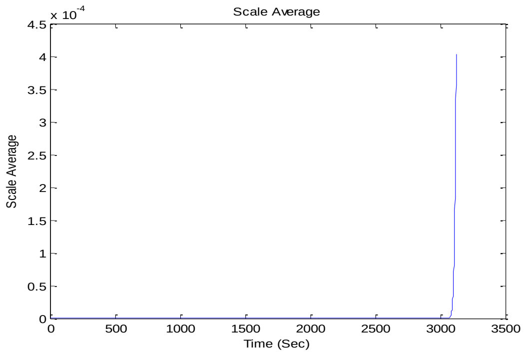

Fig. 9: Scale average for Fault Current waveform in Primary transformer DD for Phase A

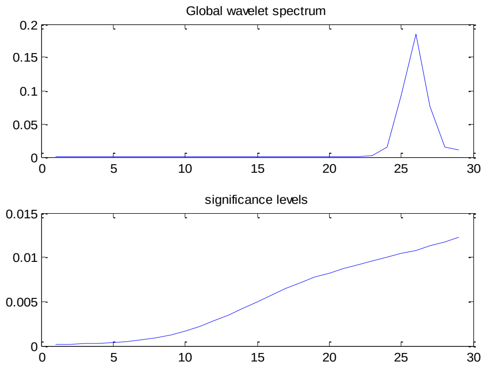

Fig. 10: Global wavelet spectrum and significance levels for Fault Current waveform in transformer DD

1.2. Case A) Transformer YD

Experimental transformer no-load inrush current and load interterm fault cases, the two sets of waveforms, and a group of normal waveform. Since this article transformer experiment is the presence of harmonic components in the laboratory, during the test, so the experimental results from the waveform is not sinusoidal waveform, but presents the trend of a square wave. Transformer inrush current experimental waveform graph is showed in Figure 11 and scale average for Inrush current waveform is showed in Figure 12 and global wavelet spectrum and significance levels for Inrush current waveform is showed in Figure 13. Transformer Fault Current experimental waveform graph is showed in Figure 14 and scale average for Fault Current waveform is showed in Figure 15 and global wavelet spectrum and significance levels for Fault Current waveform is showed in Figure 16.

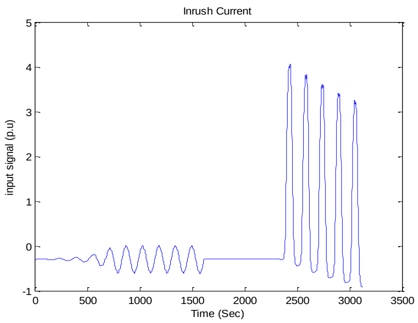

Fig. 11: Inrush current waveform in Primary transformer YD for Phase A

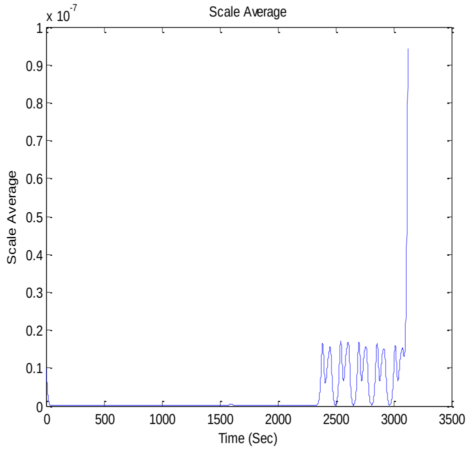

Fig. 12: Scale average for Inrush current waveform in Primary transformer YD for Phase A

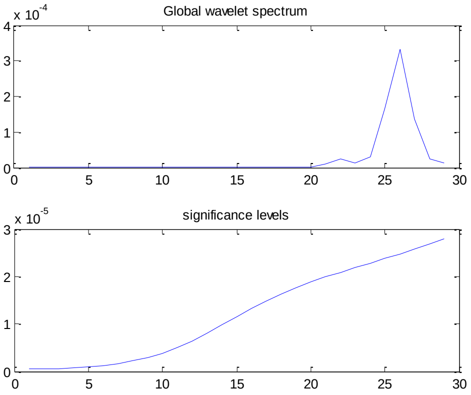

Fig. 13: Global wavelet spectrum and significance levels for Inrush current waveform in transformer YD

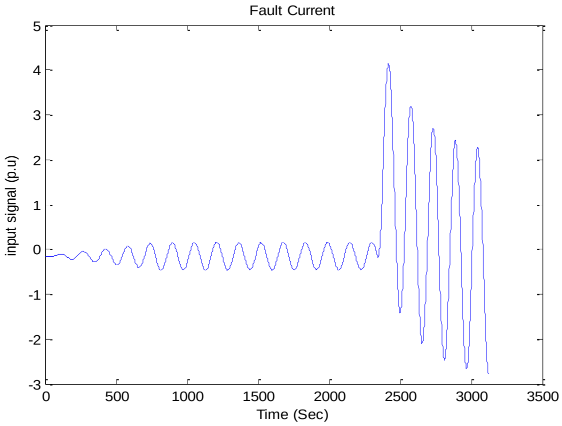

Fig. 14: Fault Current waveform in Primary transformer YD for Phase A

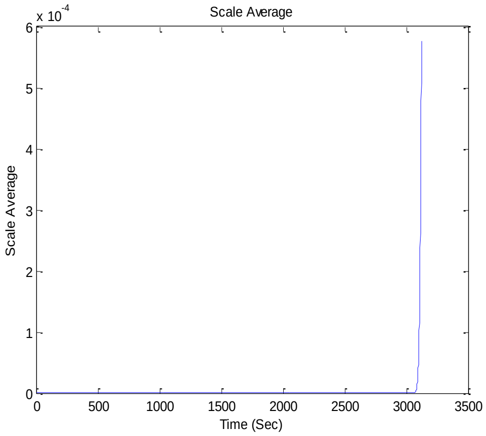

Fig. 15: Scale average for Fault Current waveform in Primary transformer YD for Phase A

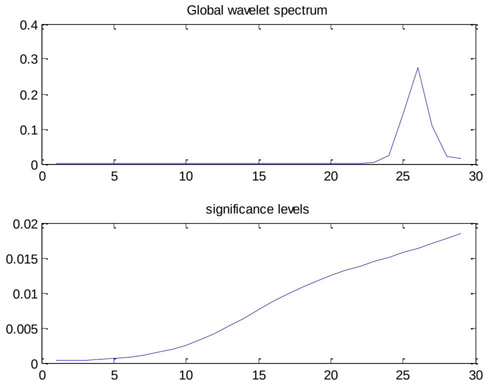

Fig. 16: Global wavelet spectrum and significance levels for Fault Current waveform in transformer YD

1.3. Case A) Transformer YY

Experimental transformer no-load inrush current and load interterm fault cases, the two sets of waveforms, and a group of normal waveform. Since this article transformer experiment is the presence of harmonic components in the laboratory, during the test, so the experimental results from the waveform is not sinusoidal waveform, but presents the trend of a square wave. Transformer inrush current experimental waveform graph is showed in Figure 17 and scale average for Inrush current waveform is showed in Figure 18 and global wavelet spectrum and significance levels for Inrush current waveform is showed in Figure 19. Transformer Fault Current experimental waveform graph is showed in Figure 20 and scale average for Fault Current waveform is showed in Figure 21 and global wavelet spectrum and significance levels for Fault Current waveform is showed in Figure 22.

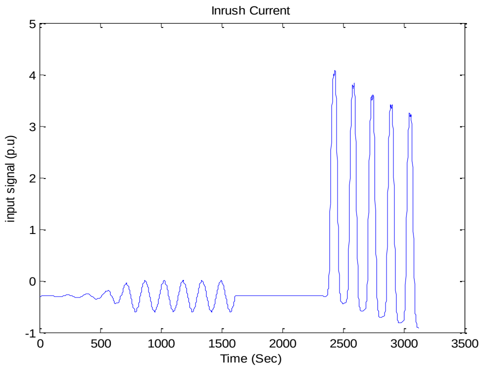

Fig. 17: Inrush current waveform in Primary transformer YY for Phase A

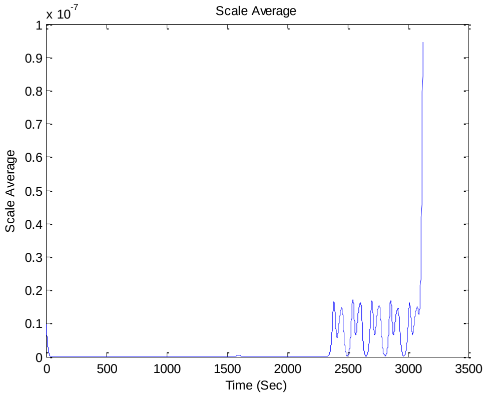

Fig. 18: Scale average for Inrush current waveform in Primary transformer YY for Phase A

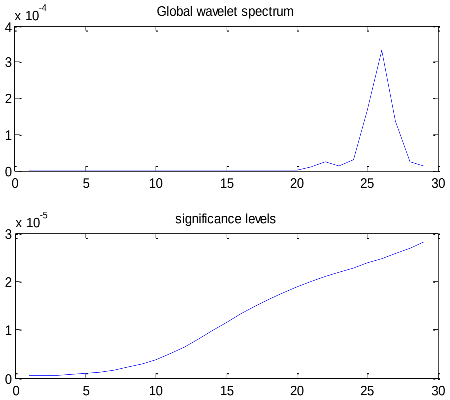

Fig. 19: Global wavelet spectrum and significance levels for Inrush current waveform in transformer YY

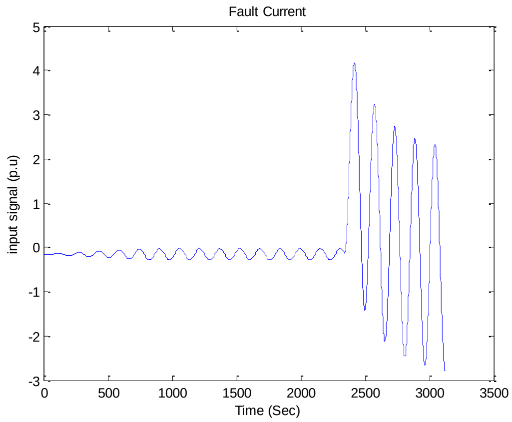

Fig. 20: Fault Current waveform in Primary transformer YY for Phase A

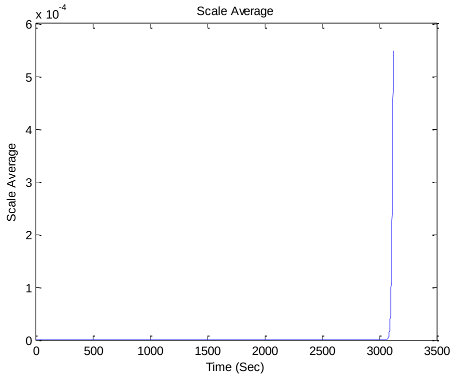

Fig. 21: Scale average for Fault Current waveform in Primary transformer YY for Phase A

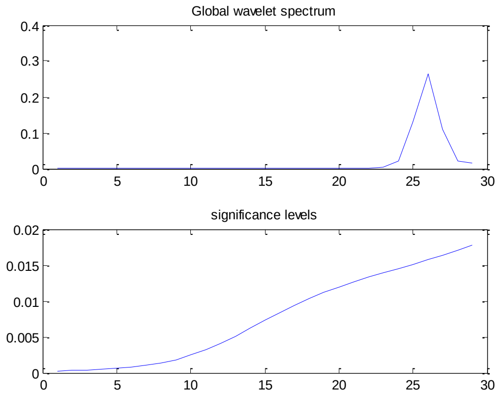

Fig. 22: Global wavelet spectrum and significance levels for Fault Current waveform in transformer YY

Based on proposed analysis In transformer with DD, YY, YD connections, fault current is zero at whole range of sampling and inrush current is fluctuated in Scale average plot; Also In transformer with DD, YY, YD connections, amplitude of fault current is between 0-0.4 in Global wavelet spectrum plot and is between 0-0.02 in significance levels plot, whereas, , amplitude of inrush current is less than fault current

2. CONCLUSIONS

Transformer inrush current and fault current ratio is obvious difference in coefficients which can be used to distinguish the characteristics of magnetizing inrush current. Wavelet transform prominently reflects the distortion characteristics of magnetizing inrush current, which showed mutations in the factor is very large. The fault current in the mutation also affected by the existence of large abnormal features, but the internal short circuit occurs, the current waveform gentle, almost no mutations. The inrush current waveforms show a downward trend over time, while the size of fault current remains same, and dispappear with the fault is removed or the failure is eliminated.

REFERENCES

1. Dessaint,Le-huy,Sybille.A Power System Simulation Tool Based on SIMULINK.IEEE Trans. Ind. Electron. Vol.46, Dec. 1999, pp.1252-1254
2. F. M. Cao and P. P. Su, "The Application of Wavelet transform in Transformer's Differential Protection," Electric Power, Vol. 31, No. 11, 1998, pp. 21-24.
3. J. A. Sykes and L. F. Morrison, "A Proposed Method of Harmonic Restraint Differential Protection of Transformers by Digital Computer," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-91, pp. 1266-1273. doi:10.1109/TPAS.1972.293485
4. Karady , Amarth , McCulla. Improved Technique for Fault Detection Sensitivity on Transform Impulse Test. Proceedings of the IEEE Power Engineering Society Transmission and Distribution Conference, Seattle, United States, 2004, pp. 1239-1243
5. L. M. Peilin, R.K. Aggarwal, A Novel, Approach to the Classication of the Transient Phenomena in Power Transformers Using Combined Wavelet Transform and Neural Network, IEEE Transactions on Power Delivery, Vol. 16, No. 4, October, 2002.
6. M. Fancisco, A.A. Jose, Wavelet Based ANN Approach For Transmission Line Protection, IEEE Power Engineering Review, 2003.
7. M. Habib, M.A. Marin", A Comparative Analysis of Digital Relaying Algorithms for Deferential Protection of Three Phase Transformers, IEEE Transactions on Power Systems, Vol. 3. No. 3, August 1988.
8. M. Vannucci, P.J. Brown, T. Fearn, A Decision Theoretical Approach to Wavelet Regression on Curves With a High Number of Regressors. Journal of Statistical Planning and Inference, 112(1-2), 195-212, 2003
9. M.A. Rahman, B. Jeyasurya", A State-of-The-Art Review of Transformer Protection Algorithms, IEEE Transactions on Power Delivery, Vol. 3, No. 2, April 1988.
10. M.A. Rahman, B. So, M. R. Zaman, M.A. Hoque", Testing of Algorithms for A Stand-Alone Digital Relay for Power Transformers, IEEE Transactions on Power Delivery, Vol. 13, No. 2, April 1998.
11. M.Misiti, Y.Misti, G. Oppenheim,J.M.Poggy. Wavelet Toolbox User's Guide.The Math Works,1996
12. Mallat. A Wavelet Tour of Signal Processing,Second Edition,Academic Press, 1999
13. Mallat. A Wavelet Tour of Signal Processing,Second Edition,Academic Press, 1999

14. Mohammad Nayeem A Tahasildar & S. L. Shaikh'' A Novel Technique for Power Transformer Protection based on Combined Wavelet Transformer and Neural Network''; International Journal of Advanced Electrical and Electronics Engineering, (IJAEEE), Volume-2, Issue-4, 2013, pp: 2278-8948.
15. Moises Gomez-Morte,Denise W.Nicoletti. A Wavelet-based Differential Transformer Protection. IEEE Transactions on Power Delivery, Vol. 4, No. 4, October 1999, pp. 1351-1358
16. Okan OZG ONENEL, Guven ONBILGIN, Cagr KOCAMAN.'' Transformer Protection Using the Wavelet Transform''. Power Turk J Elec Engin, TUBITAK 2005, VOL.13, NO.1,pp: 119-135;
17. S. H. Jiao, W. S. Liu, J. F. Liu, Z. H. Zhang and Q. X. Yang, "A New Principle of Discrimination between Inrrush Current and Fault Current of Transformer Based on Wavelet," Proceedings of the CSEE, Jul. 1999, pp. 1-5.
18. T. Y. Li, Y. Zhao and N. Li, "A New Method for Power Quality Detection Based on HHT," Proceedings of the Csee, Vol. 25, No. 17, 2005, pp. 52-56
19. Xiangning Lin, Pei Liu, Shijie Cheng. A Wavelet Transform Based Scheme for Power Transformer Inrush Idenification. Power Engineering Society Winter Meeting , 2002 IEEE , Vol. 3, pp.1862-1867
20. Y.W. Seng, Q. Wang, A. Wavelet Based Method to Discriminate Between Inrush Current and Internal Fault, Power System Technology, 2000. Proceedings. PowerCon 2000. International Conference on, Volume: 2, 4-7 Dec. 2000, Page(s): 927 -931 vol. 2.
21. Yang Long, Ning Jingdong; "A Wavelet Transform Based Discrimination Between Internal Faults and Inrush Currents in Power Transformers"; 2011 IEEE; pp: 4240-4244
22. Z. Ke, J. Jie and T. Q. Zhang, "Distinguishing Magnetizing Inrush Based on Characteristic of Equivalent Instantaneous Inductance," Power System Protection and Control, 2010, pp. 12-16