Indian Journal of Electronics and Electrical Engineering (IJEEE)
Vol.2.No.2 2014pp 63-68.
available at: www.goniv.com
Paper Received :15-04-2014
Paper Published:25-04-2014
Paper Reviewed by: 1. John Arhter 2. Hendry Goyal
Editor : Prof. P.Muthukumar

A STUDY ON THE MAGNETIZING INRUSH AND DIFFERENTIAL PROTECTION OF POWER TRANSFORMER

M.Gopila,
Research Scholar,
Asst.Prof/EEE,Sona college of Technology,
Salem,India
greatgee@gmail.com

Dr.I.Gnanambal,
HOD/EEE,
Government college of Engineering,
Salem,India.
ignan1960@gmail.com

ABSTRACT

This paper presents a review on the magnetizing inrush and the faults in a power transformer. In this study the various transformation techniques involved in identifying the abnormalities is proposed. Also the simulation tools like MATLAB, PSCAD, ATP/EMTP are discussed. Analysis of simulation and experimental results show that by varying the parameters like switching angle, and by using the good magnetic material the occurrence of inrush for several dozens of cycles can be reduced. The maloperation of the transformer differential protection during the nonlinear load switching-in mainly results due to the saturation of transformer core and this is termed as ultra saturation phenomenon. Several methods using digital signal processing and artificial intelligent techniques has been proposed.

]***Index Terms***—inrush, power transformer, ultra saturation.

INTRODUCTION

A protection scheme in a power system is designed in such a way to monitor the power system continuously to ensure maximum continuity of electric supply with minimum damage to life and equipment. While designing the protection scheme one has to understand the fault characteristics of all the power system elements.

The modern electrical power system caters the demands to all the electrical apparatus like generator, transformers and the like. In spite of all necessary precautions taken in the design and installation of such systems, they do encounter abnormal conditions or faults. The power transformer is the most important component in a power system network. Any condition that calls for an instantaneous change in flux linkages in a power transformer will cause abnormally large magnetizing currents to flow which leads to mal operation of the relay. This is due to the non linear properties of circuit elements and abrupt changes in the magnetizing voltage.

The magnetizing inrush is experienced whenever there are sudden changes in the system voltage such as sudden recovery of system voltage on clearing of a fault, by energizing an unloaded transformer and occurrence of an external fault. The amplitude of inrush current will be 8-15 times of the rated current and so a detailed analysis of the magnetizing inrush current under various conditions is necessary. Discriminating magnetising inrush currents from internal faults has long been recognised as a very challenging problem to the protection engineers.

In this paper after a careful review on various papers the detailed analysis on the results is presented. The various signal processing techniques along with the latest artificial intelligent techniques is discussed.

INRUSH PHENOMENON

In the case of magnetizing inrush current creating from transformer switching; two major factors affect the peak magnitude value of the magnetizing inrush current [1]. The first one is the energizing time instant, which can be controlled through controlling the time that the circuit breaker is closed and transformer is connected to the system. The inrush current will be larger when energizing time is at the zero crossing point of the transformer voltage. The second factor is the amount of the residual magnetism in the transformer core, which already exists due to previous switching operations of the power transformer. If the polarity of the residual flux is opposite to that of the steady state condition, the peak value of the magnetizing current increases. On the other hand, the residual magnetism can be considered by switching the transformer for several times or the desired remnant magnetism can be set in unenergized transformer with controlled dc current sources in PSCAD/EMT DC simulation model [2]. Several cases of inrush current with variable time switching and different value of residual magnetism have been simulated in [3].The switching time was taken as 0.2 s and figs. 1 and 2 illustrate the correlation coefficients of differential current in the case of an inrush current (without and with residual magnetism respectively).

In [4] the fundamentals of inrush current and the calculations are presented. A single phase transformer is simulated in MATLAB. By varying the switching angle, energizing circuit impedance and remnant flux the characteristics of inrush current is investigated .Remnant flux is the static magnetic field retained by the transformer core when power is removed. Results shows that by increasing switching angle at a positive remnant flux(Br) will decrease the amplitude of inrush current. The difference between inrush and fault is that the inrush current has largest second harmonic content. In this investigation ,largest second harmonic content doesn't appear in the first cycle. For reducing inrush current , an appropriate switching angle by considering remnant flux must be selected.

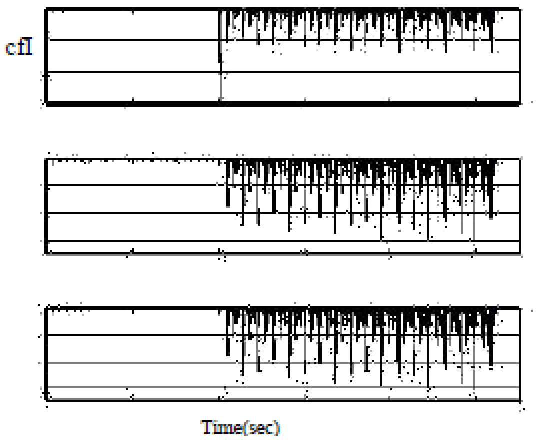

Fig.1 Inrush current without residual magnetism

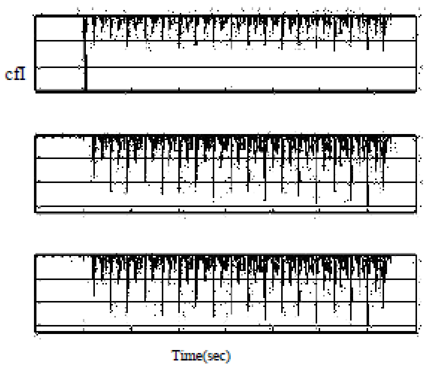

Fig.2 Inrush current with residual magnetism

In [5], analytical expressions for the magnetic fluxes of no-load three-phase transformer is presented that can be used for inrush current calculation. In [6], by analytical solution of two differential equations that governs the behavior of a transformer, the magnetic flux and inrush current are determined. For modeling transformer core including hysteresis, [7] used Jiles-Atherton theory and presented a new algorithm on a sample transformer. In [8], an analytic formula is presented to calculate the peak inrush current of a nonlinear inductor with a series resistor. In [9], a simple model for the transient period of inrush current is presented. In [10] a statistical tool named maximum entropy method (MEM), which seems to provide a reliable and computationally efficient tool for identification inrush currents on two different "C" core materials, SiFe and amorphous is presented.

DIFFERENTIAL PROTECTION

Differential protection is based on the fact that any fault within the power transformer would cause the current entering it, to be different, from that leaving it. Thus a trip signal is given by comparing the two currents if the difference exceeds a predetermined value. In [11] the unusual maloperation of transformer differential protection during the nonlinear load (for example furnace) switched –in to the transformer is investigated. A model is proposed for analyzing the transient course of the non linear load switching-in to the system. The characteristics of saturation of transformer core and non linear load are taken into account and thus the characteristic of inrush waveform is analyzed both numerically and analytically.

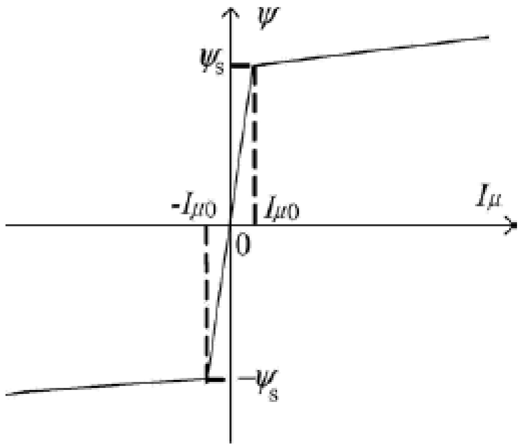

Fig. 3 Simplified saturation characteristic of the transformer core.

Fig.3 shows the saturation characteristic of the transformer core and it varies for different nonlinear loads.The abnormal maloperation in the above case is due to the extreme saturation state that occurs because of the effects between the transformer core and the nonlinear load. Since the saturation degree of the transformer core becomes deeper, the flux linkages stays near the saturation point for several cycles and so the current at the magnetizing branch is relatively high .The second harmonic content is also low and this leads to the maloperation of the differential protection of the power transformer.

The cross-blocking scheme using the dc component [12] is promising to improve the stability of the differential protection. The alternative solutions should be the model-based algorithms [13], [14]. These are independent of the inrush waveform and can operate with high speed. The current difficulty of these schemes is to obtain the accurate transformer parameters else the accuracy of the protection operation will be lowered. However, this problem can be solved by using techniques like the adaptive threshold. In all the differential protection methods the second harmonic restraint method is most widely used in practice for it is simple and easy to perform [15]-[19].

WAVELET TRANSFORMS

In conventional Fourier analysis the information about the frequencies of the signal are present whereas all clues about the time at which these frequencies appear are lost. Continuous Wavelet analysis removes this lacuna of Fourier analysis and gives information about the frequencies and the times at which they appear. Discrete Wavelet transform is a discrete implementation of the continuous one. Recently a number of Wavelet based approaches for data compression and recognition of faults or inrush current is used.

In [20] a decision making logic method for discrimination between internal faults and inrush currents in power transformers using the wavelet transform based feature extraction technique is described. The wavelet transform Technique is applied to decompose the differential current signals through the CTs secondary side into a series of wavelet components. 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 localisation characteristics of the wavelet transform. As a result, by quantifying the extracted features, the decision for distinguishing an internal fault from an inrush current in different power transformer systems can be accurately made and the proposed method is more reliable and simpler, and is suitable for different power transformer systems.

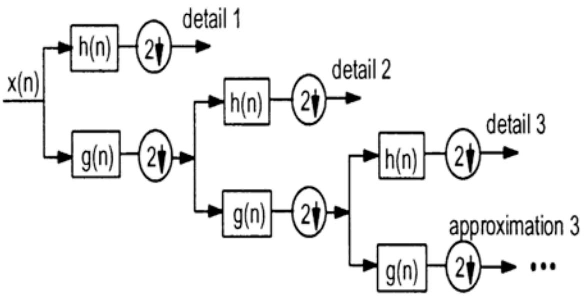

Fig. 4 Implementation of DWT

In fig 4. X(n) is the original signal and h(n) and g(n) are low pass and high pass filters respectively. Techniques [20–22] based on wavelet transform for transformer protection used the detailed and approximate coefficients in respective frequency band to distinguish between inrush current and faults in power transformer. To further enhance the performance, a wavelet packet based scheme for power transformer protection [23] has been proposed. Wavelet transform, due to its natural ability in adjusting the width of the mother wavelet frequencies [24,25], is more appropriate than other methods of frequency domain such as Fourier window for analyzing transient states. The DWT can process a signal by decomposing it into an approximate and a detail by crossing through low-pass and high-pass filters. The approximate is decomposed to obtain the information of the next level and the process continues. Moreover, the practical implementation of DWT is very simple. Therefore, the DWT is widely used to distinguish between the transient phenomena in the power transformer differential protection. In [26] a new approach of discrimination between inrush current and internal fault currents is proposed based on wavelet packet transform (WPT).The selection of optimal mother wavelet and the optimal number of level of resolution is carried out using the minimum description length (MDL) criteria. The proposed approach is tested for signal tripping using data collected from a simulink model of power three phase transformer for different cases that included inrush, internal fault currents and external fault currents. The simulated results clearly show that the proposed approach facilitates the accurate discrimination between inrush and fault Currents in differential transformer protection.

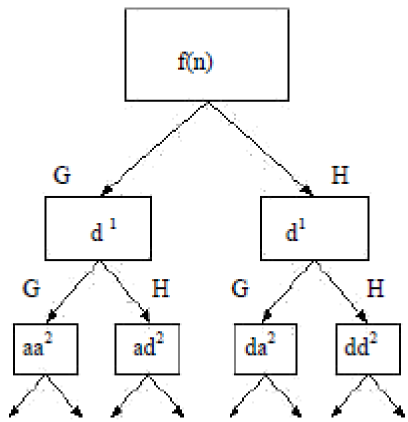

Fig.5 Implementation of WPT

NOVEL ALGORITHM

Many algorithms are under research to discriminate magnetizing inrush with the fault. A novel methodology for transformer differential protection, based on wave shape recognition of the discriminating criterion extracted of the instantaneous differential currents is proposed in [27]. The diagnosis criterion is based on median absolute deviation (MAD) of wavelet coefficients over a specified frequency band. The work on power transformer protection has included many approaches, among these approaches: artificial neural networks (ANN) [28–30], flux and voltage restraints [31], Fuzzy logic [32–34] and Neuro-Fuzzy approach [35, 36]. In [37] a new algorithm for discriminating different transient phenomena is presented based on energy vector. The algorithm combines advantages of wavelet transform and PNN. The wavelet transform has been used for decomposition of signals, which breaks up the time domain in to low frequency and high frequency. Using parseval's theorem energy and standard deviation features are extracted for different operating conditions. The signals generated using MATLAB are polluted with noise SNR 20 db. The PNN was trained with features extracted without noise in the signal but tested with signal having 20db noise. The discrimination was satisfactory even in the presence of noise. The flowchart for the proposed MAD and PNN algorithm is shown in fig.6 and fig.7.

A modern approach is put forward for discrimination of L-G fault and inrush current in power transformer using Support Vector Machine (SVM). The main features of SVM are:The upper bound on the generalization error does not depend on the dimension of the space and the error bound is minimized by maximizing the margin g. In [38] a modern method for discrimination between magnetic inrush and L-G fault in power transformer using SVM has been proposed. The method is done based on current signature verification. This method is more effective for modern transformers with high harmonic components in internal fault current. The results obtained on simulated data of a three phase two winding Y-Y connected transformer showed that SVM classifier outperforms greatly in discrimination between magnetic inrush and L-G fault currents.

A new method for digital protection of power transformers using Clarke's transform and fuzzy logic is presented in [39].This technique is fast and reliable for digital protection of transformer.

CONCLUSION

This paper presented an overview of magnetizing inrush current that occurs in the power transformer. The maloperation of the differential protection is due to the ultra saturation state which is a real physical phenomenon and it possibly occurs in the power system. The Wavelet Transform which is a reliable and computationally efficient tool for distinguishing between the inrush currents and fault currents is also discussed. The latest algorithms like Support vector machine, fuzzy systems and PNN are also presented with the corresponding flowchart.

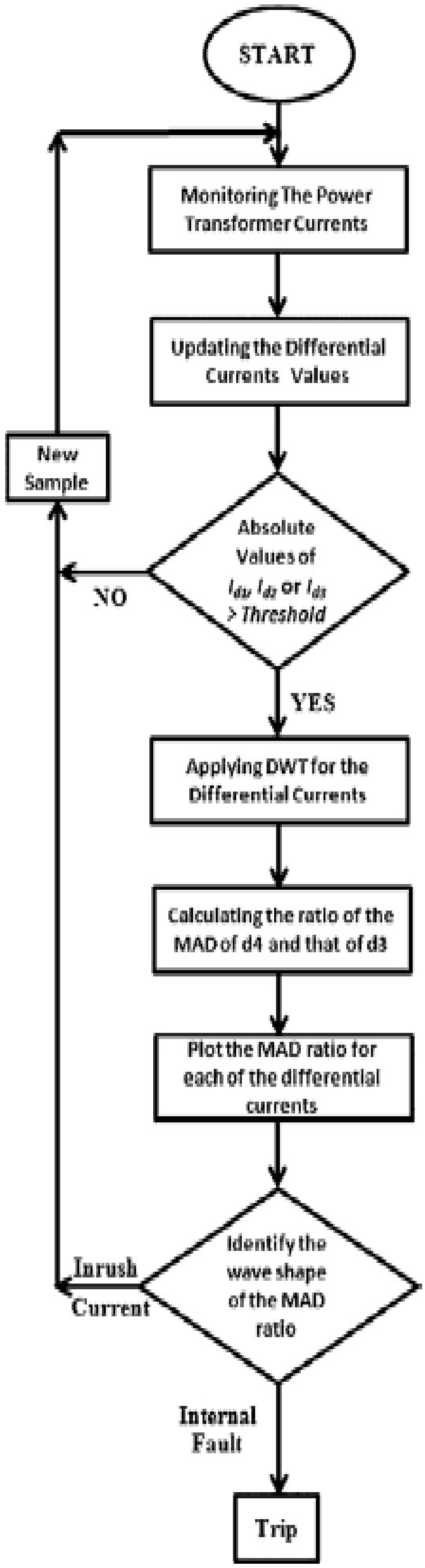

Fig.6 Flowchart of the MAD algorithm

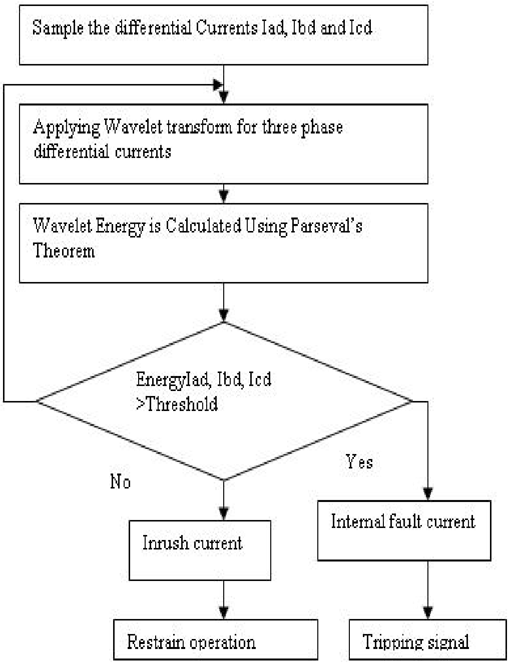

Fig.7 Flowchart of the PNN algorithm

REFERENCES

HossumEldin AA, Refaey MA., "A novel algorithm for discrimination between inrush current and internal faults in power transformer differential protection based on discrete wavelet transform". Electr Power Syst Res 2011; 81(1):19–24.

Woodford D, "Introduction to PSCAD V3".Winnipeg,MB,Canada:Manitoba HVDC Research Centre Inc.;2001.January.

M. Rasoulpoor, M. Banejad, "A correlation based method for discrimination between inrush and short circuit currents in differential protection of power transformer using Discrete Wavelet Transform: Theory, simulation and experimental validation", Electrical Power and Energy Systems 51 (2013) 168–177.

M.Jamali,M.Mirzaie,S.Asghar Gholamian , "Calculation and analysis of transformer inrush current based on parameters of transformer and operating conditions",Electronics and Electrical

[1] Wang Y., Abdulsalam S. G., Xu W. " Analytical formula to estimate the maximum inrush current", IEEE Trans. Power Delivery. April, 2008. Vol. 23. No. 2. P. 1266–1268.

[2] Chen S. D., Lin R. L. "Magnetizing inrush model of transformers based on structure parameters", IEEE Trans. Power Delivery. July, 2005. Vol. 20. No. 3. P. 1947– 1954.

Okan Ozgonenel,caner Akuner, "A study on magnetizing inrush current of different core materials".

Hanli weng and Xiangning Lin, "Studies on the unusual Maloperation of transformer Differential protection during the Nonlinear load switch-in", IEEE Trans on power delivery,Vol.24,No.4,October 2009.

A. Guzman, S. Zocholl, G. Benmouyal, and H. J. Altuve, "A current-based solution for transformer differential protection—Part II:Description and evaluation," *IEEE Trans. Power Del.*, vol. 17, no. 4,pp. 886–893, Oct. 2002.

T. S. Sidhu and M. S. Sachdev, "On line identification of magnetizing inrush and internal faults in three phase transformer," *IEEE Trans. Power Del.*, vol. 7, no. 4, pp. 1885–1891, Oct. 1992.

K. Inagaki *et al.*, "Digital protection method for power transformer based on an equivalent circuit composed of inverse inductance," *IEEE Trans.Power Del.*, vol. 3, no. 4, pp. 1501–1510, Oct. 1988.

Yuan Yubo, Lu Yuping, Li Cheng, et al. "The Characteristic Analysis of Three Phase Transformer Inrush and the Discussion of Second Harmonic Restrained Method Using Phase Angle and Amplitude". *Proceedings of the CSEE*. 2006; 26(19):23-28.

[3] Hu Yufeng, Chen Deshu, Yin Xianggen, et al. "The comparison of several harmonic-restrain algorithms used in microprocessor-based transformer relay". *Relay*. 2000; 28(7):41-44.

[4] Chen Fufeng, Qian Guoming and Song Guobing, "Study on Traveling-wave Differential Protection for Series Compensated Line". *Proceedings of CSEE*. 2009; 29(28): 89-94.

[5] Zheng Tao, Cao Zhihui. "Scheme for Second Harmonic Block of Magnetizing Inrush Current in Transformers Based on Fuzzy Logic". *Automation of Electric Power Systems*. 2009; 33(2):61-65.

Lv Zhen, Yue Wei, Liu Pei. "The simultion of scheme of second harmonic restraint for power transfomer. *Relay*. 2003; 31(6): 69-72

Mao PL, Aggarwal RK. "A wavelet transform based decision making logic method for discrimination between internal faults and inrush currents in power transformers". Inte J Elec Power 2000;22(6):389–95.

Sedighi A-R, Haghifam M-R. "Detection of inrush current in distribution transformer using wavelet transform". Inte J Elec Power 2005;27(5-6):361–70.

Valsan Simi P, Swarup KS. "Wavelet based transformer protection using high frequency power directional signals". Electr Pow Syst Res 2008;78(4):547–58.

Eissa MM. "A novel digital directional transformer protection technique based on wavelet packet". IEEE T Power Deliver 2005;20(3):1830–6.

C.H. Kim, R. Agganrval, "Wavelet transforms in power systems – Part 1: Generalintroduction to the wavelet transforms", IEEE Power Engineering Journal 14 (2)(2000) 81–87.[16]

C.H. Kim, R. Agganrval, "Wavelet transforms in power systems—Part 2: Exam-ples of application to actual power system transients", IEEE Power EngineeringJournal 15 (4) (2000) 193–202.

[6] Adel A. Obed, Majed A. Alwan and Waad N. Taboor, "A Wavelet Packet Transform-Based Technique for the Discrimination of Inrush Currents from Faults in Three-Phase Transformer", Journal of Basrah Researches ((Sciences)) Volume 37. Number 4 A / 15 August ((2011)) 1-14.

[7] A.A. Hossam Eldin, M.A. Refaey, "A novel algorithm for discrimination between inrush current and internal faults in power transformer differential protection based on discrete wavelet transform," Electric Power Systems Research 81 (2011) 19–24.

[8] Y.-P. Lu, L.L. Lai, L.-D. Hua, "New artificial neural network based magnetizing inrush detection in digital differential protection for large transformer," Proceedings of the Fourth International Conference on Machine Learning and Cybernetics, Guangzhou, August 18–21, 2005, pp. 441–447.

[9] M. Geethanjali, S.M.R. Slochanal, R. Bhavan, "A novel approach for power transformer protection based upon combined wavelet transform and neural networks (WNN)", 7th Internal Power Engineering Conference (IPEC), November–December 2005, pp. 1–6.

[10] M. Tripathy, R.P. Maheshwari, H.K. Verma, "Probabilistic neural-network-based protection of power transformer", IET Electric Power Applications 1 (5) (2007) 793–798.

[11] S.A. Saleh, M.A. Rahman, Modeling and protection of three-phase power transformer using wavelet packet transform, IEEE Transactions on Power Delivery 20 (April (2)) (2005) 1273–1282.

[12] M. Delshad, S.M.Mosavian-nasab, B. Fani, A new method for improved of power transformer protection using fuzzy logic, in: Proceeding of International Conference on Electrical Machines and Systems, Seoul, Korea, October 8–11, 2007,pp. 1279–1282.

[13] E.M. Tag Eldin, A new algorithm for the classification of different transient phenomena in power transformers combining wavelet transforms and fuzzy logic, in: Proceedings of the 46th IEEE International Midwest Symposium Circuits and Systems (MWSCAS), vol. 3, December 27–30, 2003, pp. 1116–1121.

[14] M. Shin, C. Park, J. Kim, Fuzzy logic-based relaying for large power transformer protection, IEEE Transactions on Power Delivery 18 (3) (July 2003) 718–723.

[15] H. Khorashadi-Zadeh, Fuzzy-neuro approach to differential protection for power transformer, IEEE TENCON 3 (November) (2004) 279–282.

[16] M. Delshad, B. Fani, "A new method for discriminating between internal faults and inrush current conditions in power transformers based on neuro fuzzy", in:POWERENG 2007, Setubal, Portugal, April 12–14, 2007, pp. 731–735.

[17] S. Sendilkumar, B. L. Mathur, and Joseph Henry, "Differential protection for power transformer using wavelet transform and PNN," World Academy of Science, Engineering and Technology 39 2010.

[18] V. Thamarai Selvi and V. Malathi, "A classification approach using SVM to detect magnetic inrush in power transformers", International Journal of Innovation and Applied Studies ISSN 2028-9324 Vol. 3 No. 3 July 2013, pp. 693-700.

[19] Daniel Barbosa, Ulisses Chemin Netto, "Power transformer differential protection based on clarke's transform and fuzzy systems," IEEE Transactions On Power Delivery, Vol. 26, No. 2, April 2011.

[20] Javad Faiz and S. Lotfi-Fard, "A Novel Wavelet based algorithm for discrimination of internal faults from magnetizing inrush currents in Power Transformer", IEEE Trans. on Power Delivery, 21, 2006, 1989-1996.