TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 14, No. 3, June 2015, pp. 381 ~ 387
DOI: 10.11591/telkomnika.v14i3.7849

Wavelet Transforms Based Power Transformer Protection from Magnetic Inrush Current

P. Soundiraraju*, N. Loganathan
K.S.Rangasamy College of Technology, K.S.R Kalvi Nagar, Tiruchengode, Namakkal, Tamilnadu, India
*Corresponding author, e-mail:soundirarajueee@gmail.com

Abstract

The Power transformer is the very essential element in the power systems. For wealthy running operation of power transmission and distribution, the transformer set-up is indispensable. Otherwise, under fault situation the whole transmission system will lead to power loss. The protection is necessary for power transformers i.e. mostly against internal faults and magnetic inrush currents.Exciting magnetic inrush current will tide, when the transformer is operated without keeping load or in the Voltage recovery after the fault being separated. This work suggests developing transient detection techniques using wavelet transform for all these faults. The wavelet transform has a benefit of representation of current and Voltage signals. Empathy of transients is very fast and precise the research proposes to expand a new wavelet method to identify inrush currents to classify it from power system disturbances. The suggested practice extract faults and inrush generated transient signals using wavelet transform process.

Keywords: *inrush current, internal fault, MATLAB, power transformer, wavelet transform.*

1. Introduction

Power transformer is one of the most important elements in the power system. Power transformer professions are as a node to connect two dissimilar voltage levels. Consequently, the continuity of the transformer set-up is of vigorous importance in maintaining the consistency of power system. Various unscheduled preservation, especially replacement of faulty transformer is time consuming and very luxurious. In order to discover faults, high speediness, highly sensitive and reliable protective relays are requisite.

For this purpose, differential protection has been working as the primary protection for most of the power transformers. Differential protection scheme is based on the fact that any fault within electrical equipment would cause the current entering it, to be dissimilar from that leaving it. Hence, we can match the two currents whichever in magnitude or in phase or both and issue a trip output if the variance exceeds a predetermined static value. This practice is very attractive when both the ends of the apparatus are physically nearby each other.

Conventional transformer protection schemes use second harmonic component as the discriminator factor between an inrush and internal fault current [1]. The main disadvantage of this approach is during CT saturation, the second harmonic component could likewise be generated during internal faults and the new low-loss amorphous materials in modern Power transformers may produce low second harmonic content in inrush current [2].

A number of microprocessor based algorithms have been proposed in the ancient [3, 4]. Wavelet techniques have been implemented for consistent protection [5, 6]. Artificial Neural networks have been applied to single phase power transformer protection to discriminate internal faults frommagnetizing inrush currents [7, 8]. However the overhead techniques are based on either time or frequency domain signal and not both time and frequency features of the signal.

In the literature of power transformer protection, the key issue lies in discriminating between transformer magnetizing inrush current and internal fault current. It is natural that relay should be initiated in response to internal fault but not to inrush current or over-excitation/external fault current. Early methods were based on desensitizing or delaying the relay to overcome the transients. These methods are unsatisfactory since the transformer may be exposed for a longunprotected time.

Received March 1, 2015; Revised April 18, 2015; Accepted May 10, 2015

The wavelet transform is a relatively new and powerful tool in the analysis of the power transformer transient phenomenon because of its ability to extract information from the transient signals simultaneously in the time and frequency domain. Recently, the wavelet transforms have been applied to analyse the power system transients, power quality, as well as fault location and detection problems. The wavelet transform for analysing the transient phenomena in a power transformer under conditions of faults and magnetizing inrush currents was presented, and simulated results have shown that it is possible to use certain wavelet components to discriminate between internal faults and magnetizing inrush currents.

2. Magnetic Inrush Current

At the time of transformer energization, a high current will be haggard by the transformer. The specified current is termed transient inrush current is shown in Figure 1 and it may upsurge to ten times the nominal full load current of transformer during process. Transformer magnetic inrush currents can be separated into three types, they are: energization inrush current, recovery inrush current and sympathetic inrush current. The early energization inrush results from reapplication of system Voltage to a transformer which has been formerly de-energized.

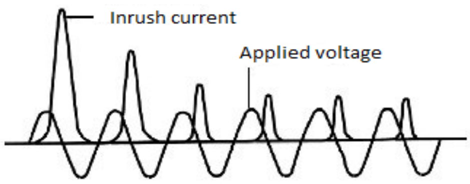

Figure 1. Magnetic Inrush Current

The second recovery inrush occurs when transformer voltage is restored after having been reduced by a nearby short circuit on power system. The third sympathetic inrush current can arise when two or extra transformers are operated in parallel. The level of the transformer inrush current is a function of numerous factors, such as the switching angle of the terminal voltage, the residual flux of the core, the power system impedance, the transformer design and others. Holcomb [9] suggests an improved analytical equation for the inrush.

$$i(t)=\frac{\sqrt{2U}}{\sqrt{R_w^2+\omega^2\cdot L_{air-core}^2}}\left(\sin(\omega t-\varphi)\times -e^{\frac{R_w}{L_{air-core}}(t-t_0)}\sin(\omega t-\varphi)\right) \quad (1)$$

Where,

$$\varphi=\tan^{-1}\frac{\omega.L_{air-core}}{R_w} \quad (2)$$

Where U is the applied voltage; $R^2{}_W$ is the winding resistance; $L^2{}_{air-core}$ is the air-core inductance of winding; and is the time when the core begins to saturate$(B\ (t) > B_s)$.

2.1. Causes of Inrush Current

The main sources of transient inrush current are as moment of switching, residual flux. Transformer is highly inductive in nature. As fig.1 after the transformer are energized at its positive peak value of instant voltage i.e. at 90° at this instant the rate of current and flux are zero. In order for the transformer to make an opposing Voltage drop to balance against this applied source Voltage, a magnetic flux of rapidly swelling value must be produced. The inrush current interrupts whole power system. It mainly influences on protection system, transformer, equipments coupled to system and increases power quality issues [2, 4, 7].

2.2. Effects of Inrush Current

The inrush current affects entire power system. It mostly disturbs on transformer, protection system, equipments connected to system and upsurges power quality issues [4, 7].

As the inrush current increases the temperature increases by the theory of influence of bad temperature. As a result the temperature of bushings and the windings upturns [7]. The short circuit of transformer is always less than inrush current [4]. Thus inrush current reasons malfunction of protective system [1]. As transformer gets isolated due to effect on protection system there is disruption of system.The attendance of harmonic content in inrush current cause's incorrect analysis with medical equipments. It also affects to heat increase of the system [1].

3. Proposed Method- Wavelet Transform

The wavelet transform is a novel and powerful tool which can extract information from the transient signals simultaneously in both the time and frequency domains unlike Fourier Transformwhich can only give the information in the frequency domain. Wavelet transforms have been widely used for analyzing the transient phenomena in a Power transformer for differentiating internal fault currents from inrush currents [9-10].

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k] \cdot g[2n - k] \quad (3)$$

Where x is the signal in discrete time function, the sequence is denoted by x[n]. n is an integer, g[n] is the impulse response of the low pass filter and y[n] is the output of the filter.

$$y_{low}[n] = (x * g)[n] = \sum_{k}^{\infty} x[k] \cdot g[2n - k] \quad (4)$$

3.1. Flowchart of the Proposed Algorithm

The flowchart of the suggested algorithm is shown in Figure 2 and is explained in following steps.

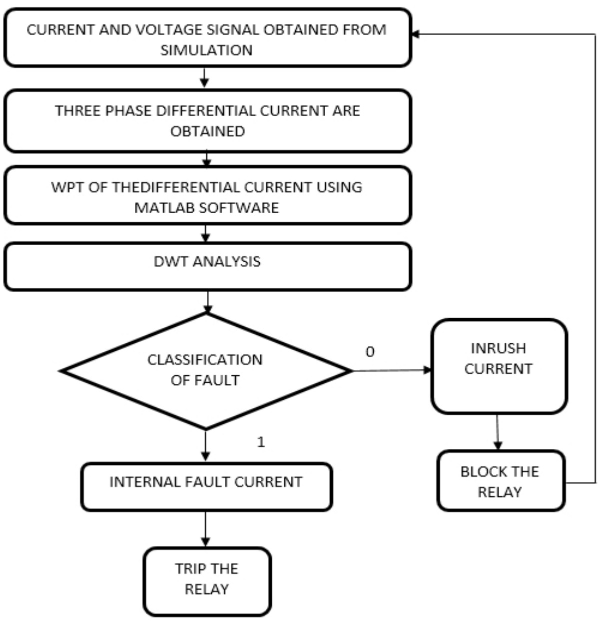

Figure 2. Flowchart of proposed algorithm

Step 1: The current and Voltage signals are attained from the three phase transformer using MATLAB software for dissimilar kinds of fault and inrush currents.
Step 2: The differential currents of the power transformer are calculated.
Step 3: Three phase differential currents of wavelet transform are acquired by means of MATLAB software.
Step 4: The DWT investigation of the differential current is studied.
Step 5: The detail coefficients of the signal are obtained.
Step 6: Nature of the transient barbs in the DWT analysis and the value of the Detail coefficients and spectral energy decides whether the current is an inrush or internal fault current.
Step 7: The d1 coefficients of different fault and inrush currents are fed and trained.
Step 8: Wavelet based relay discriminates internal fault current from inrush current.

3.2. Implementation of Wavelet Transform

The Wavelet transform has been used to investigate the transients in the power transformers. The data obtained from the simulations are given to the wavelet transform for compute DWT coefficients of the signals. DWT analysis of filter is shown in the Figure 3. There are many categories of wavelets such as Daubechies, Haar, Coiflet and symmlet wavelets. In this paper, as we are interested in sensing and analyzing small amplitude, little duration, fast oscillating and decaying type of high frequency current signals.

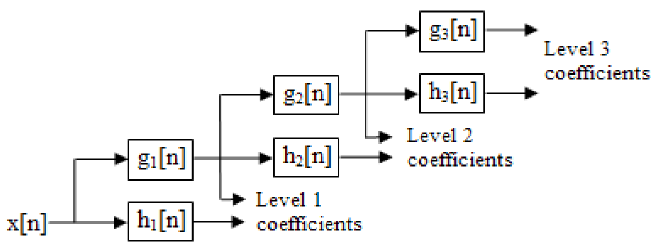

Figure 3. Block diagram of filter analysis

Daubechies wavelet of type 6 (DB6) suited well to this type of high frequency current. Consequently DB6 was used as the mother wavelet. Wavelet decomposition is completed on the signal and the DWT coefficients of level 1of the signal are attained.

3.3. Wavelet Transform of Inrush Current

The magnetizing inrush current under steady state operating circumstance is only 1-2% of the transformer rated current. However when the primary of an unloaded transformer is energized, the primary windings of the transformer enticements a huge magnetizing current is ten times greater than the rated current. Due to the deliberate attenuation of this current, it may take around 10 cycles to settle down. This current pretexts like a fault current to the differential relay and the relay maloperates.

4. Simulation Results

Differential currents have different behaviours below fault and inrush current situations. From the time when the magnetizing inrush current corresponds to the transformer core saturation, the inrush current has a conical shape (non-sinusoidal); in other words inrush current at the switching time increases very slowly; as time passes, its slope rises. However, when a fault arises, the differential current angle increases comparing to the opening of the inrushcurrent. Consequently these topographies could be used as the basis of discerning the faults from the inrush current. Essentially two principles are used in practice:

1) The differential current instigated from faults begins withupper slope and then its slope diminutions. But differential current initiated from inrush current begins with a low slope and then its slope increases.

2) A higher slope in the time domain shows that there are higher frequencies in the frequency domain.

Based on the above principles, it is likely that the amplitude of the high frequency components at the initial time has swelling trend in inrush current. It means that their amplitudes increase from a low value to a high value. The differential current owing to the inrush current at t = 50 ms and the resultant frequency (D1–D5) from WT are presented in Figure 5. The overhead features at frequency (up to 4 kHz) level D3 are clearly noticeable.It is also likely that the amplitude of high frequencies (D1–D5) at the initial instants of time has a reducing trend following internalfaults. Wherever the differential current due to the ABC–G internal fault at t = 50 ms and frequency levels from the WT are demonstrated.

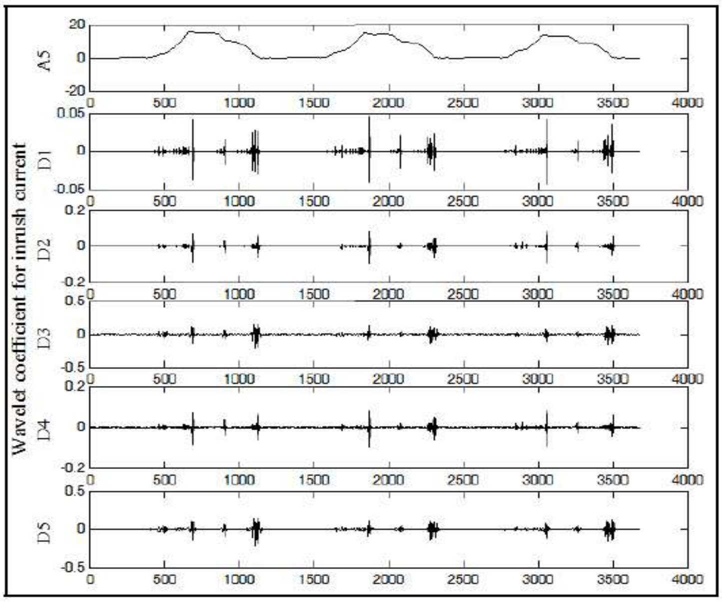

Figure 4. Wavelet coefficient for inrush current within frequency of 4 kHz

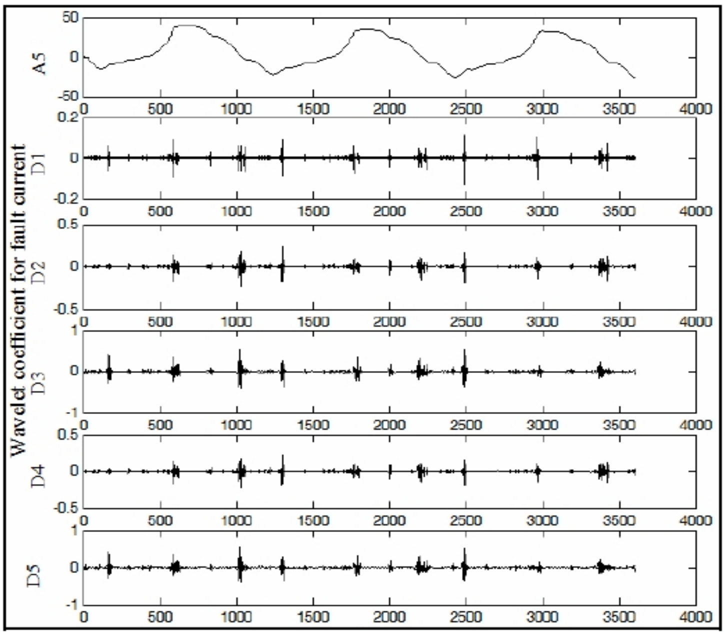

Figure 5. Wavelet coefficient for fault current within 4 KHz

Analyzing profoundly the first two coefficients D1and D2 yields a beneficial tool of discrimination between the two dissimilar cases of inrush and fault current. Figure 4 presents the shapes of D1 and D2 components (first 50 elements) for the different cases of inrush and internal fault conditions. Figure 5 dowries the first four elements of the wavelet components D1 and D2 which shows minor deviation between the two deliberated cases. It is clear that it is difficult to discriminate between the inrush current and the internal fault founded on the D1, D2 coefficients values only however if D1, D2 coefficients can be drawn against the time and which presents the first four elements of the wavelet components D1 and D2 versus time.

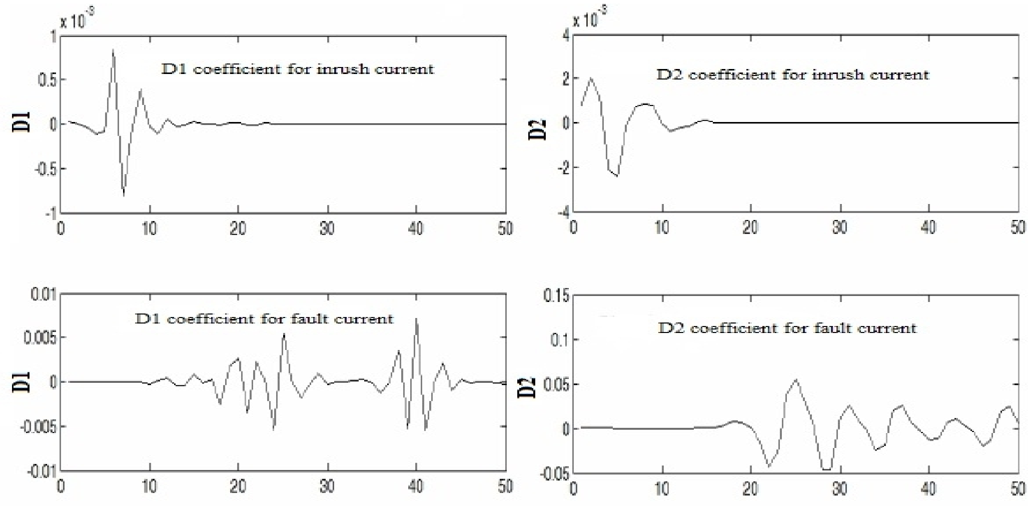

Figure 6. D1and D2 wavelet coefficients for the two cases within frequency of 50 Hz

Figure 6 dowries the first four elements of the wavelet components D1 and D2 which shows minor deviation between the two deliberated cases.It is clear from the above figures that the values of D1, D2coefficients occur in a small time for internal fault condition compared to its time in case of inrush current state.

5. Conclusion

The results clearly show that the proposed Wavelet combined neural network relay accurately distinguishes internal fault and magnetizing inrush currents in three phase transformers. The ANN effectively distinguishes and gives trip signal within 1/8th of cycle which is considered to be very fast. The relay also provides high sensitivity for internal fault currents and high stability for inrush currents.The classification ability of the ANN in combination with advanced signal processing technique opens the door for smart relays for power transformer protection with very less operating time and with desirable accuracy. The results clearly showed that the proposed Wavelet combined neural network relay accurately distinguishes internal fault and magnetizing inrush currents in three phase transformers. The ANN effectively distinguishes and gives trip signal within 1/8th of cycle which is considered to be very fast. The relay also provides high sensitivity for internal fault currents and high stability for inrush currents.

Acknowledgements

The authors would like to thankMs. K. M. Priyadharshini**,** Mr. S. Manoj Arun, PG scholar, K.S.R.C.T for their contributions in the development of the power transformer protection for MATLAB simulations. And also we would like to thank Mr. C. Srinivasan, Assistant Professor, Department of Electrical and Electronics Engineering, K.S.R.C.T for their support and cooperation in developing the system.

References

[1] Jawad Faiz, S Lotfi-Fard. A Novel wavelet – based algorithm for discrimination of internal faults for magnetizing inrush currents in power transformers. *IEEE Trans. On power delivery*. 2006; 21(3): 543-549.
[2] Kasztenny B Rosolowski E, Saha MM, Hillstrom B. *A self-organizing fuzzy logic based protective relay - an application to power transformer protection*. IEEE PES'96 Summer Meeting in Denver. 1996.
[3] Liu P, Malik OP, Chen D, Hope. Study of non-operation for internal faults of second-harmonic restraint differential protection of power transformers. *Transactions of the Engineering and Operating Division of the Canadian Electrical Association*.1989; 28(3): 1-23.
[4] PL Mao, RK Aggarwal. A novel approach to the classification of the transient phenomena in power transformers using combined wavelet transform and neural network. *IEEE Transactions on Power Delivery*. 2001; 16(4): 655-660.
[5] M Nagpal, MS Sachdev, Kao Ning, LM Wedephol. *Using a neural network for transformer protection*. IEEE Proc. Oh EMPD Int.conference. 1995; 2(3): 674-679.
[6] Okan Ozgonenel, Guven Onbilgin, Cagrikocaman. Wavelet based transformer protection. *IEEE Melecon*. 2004; 3(5): 11-16.
[7] Okan Ozgonenel. Wavelet based ANN approach for transformer protection*. International journal of computational intelligence*. 2005; 2(3): 31-39.
[8] MA Rahman, Jeyasurya. A state-of the- art review of transformer protection algorithms. *IEEE Trans. Power Delivery*. 1998; 3(4): 534-544.
[9] TS Sidhu, MS Sachdev. On line identification of magnetizing inrush and internal faults in three phase transformers. *IEEE Trans. Power Del*. 1992; 7(4), 1885-1890.
[10] S Sudha, Dr A Ebenezer Jeyakumar. Wavelet based relaying for power transformer protection. *Gests International Transaction on computer Science and Engineering*. 2007; 38(4):12-16.
[11] JS Thorp, AG Phadke. A microprocessor based three phase transformer differential relay. *IEEE Transaction on Power apparatus and Systems*. 1982; 10(3): 426-432.
[12] Wiszniewski A, Kasztenny B. A multicriteria transformer differential relay based on fuzzy logic. *IEEE Trans. On Power Delivery*. 1995; 10(4): 1786-1792.
[13] Yuxue Wang, Huazhong, Xianggen Yin, Xianggen, Yin Zhenxing Li. Phase current differential protection for transformers in wyedelta mode*. TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(6): 1280-1286.
[14] MR Zaman, MA Rahman. Experimental testing of the artificial neural network based protection of power transformers. *IEEE Trans.On Power Delivery*. 1998; 13(2): 510-517.
[15] ZHOU Bin, YING Liming, Yonggang, ZHU. Differential Protection for Distributed Micro Grid Based on Agent*. TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(5): 2634-2640.