ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 6, September 2013

Transformer protection using MLE approach

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Abstract: This paper proposed a new wavelet based method to identify inrush currents and to distinguish it from power system faults. The proposed algorithm extracts fault and inrush generated transient signals using DWT. Transient current signals at both sides of a transformer are firstly captured. The wavelet transform is a relatively new and powerful tool in the analysis of power transformer transient phenomena because of its ability to extract information from the transient signals simultaneously in both time and frequency domain. These currents are analyzed by wavelet transform from which the detail coefficient of each phase is derived. In this proposed method, the wavelet transform is firstly applied to decompose the differential current signals of power transformer. The MLE (Maximum Likelihood Estimate) values of each of detail coefficient is calculated and compared with threshold values to detect and identify the type of faults. The extracted information from transient signals is simultaneously in both time and frequency domains. In this study, Daubechies 6 wavelets are used to construct first level filter bank to extract the transients. To discriminate the Inrush current and external faults like Line –Line fault, Line –Ground Fault, 3-Φ Fault using wavelet algorithm. And to prevent protective devices to mal operate for inrush, and external faults.

Index terms: Inrush current, MLE, differential current, fault current.

I. INTRODUCTION

Faults in transformers are relatively infrequent but they cause damage, which are expensive to repair. The fault clearance time greatly affects the extent and costof removal of the damage. Outage of a transformer may upset the power balance in the power system and cause loss of system stability and hence reliability. The correct and effective identification between faults and exciting inrush remains a challenge for protection deployment. In conventional methods of protection, the Fourier transform of the signal is obtained and based on its harmonic spectrum the decision is taken to discriminate fault and non-faulty conditions. But in some conditions, where the fault currents are rich in harmonics, this method will not offer a reliable protection scheme. Hence it is mandatory to look for another reliable scheme of protection. The general practice of protection of power transformer is as follows: Incipient faults below oil level resulting in decomposition of oil, faults between phases and between phase and ground result in abnormal condition. For the protection Buchholz relay that gives alarm signal (gas actuated relay) is generally used. This relay is used for transformers of rating 500kVA and above. This is high-speed high set over current relay but it is too slow and less sensitive. Also there is a scope for the saturation of magnetic circuit. For the protection of transformers of above 5MVA the following protection schemes generally employed are Differential protection, restricted earth fault protection, Over-current protection, Over-fluxing protection, Buchholz relay and sudden pressure relay etc.

II. WAVELET TRANSFORM

The function □ a, b (t) is given by

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right) \ldots\ldots.. (1)$$

The quantity b is the window translation parameter and is a real number; a is the dilation or contraction parameter and is a positive real number. This can be interpreted as follows□ □ □ □-b) by itself is a time-shifted window and is of finite duration. By introducing the factor a as shown in equation (1), the resulting window can be made larger or smaller than the starting window. In the special case where a = 1, it will be the same as the starting window. Because of the large number of possibilities, □ a,b(t) as defined in the equation (1) is called the *mother wavelet.* When equation (1) is replaced in (2) the product x (t), □ □ □ □ □ □ □ □ □ □ □ appears and when it is integrated, we get the continuous wavelet transform which can be viewed as the area under the curve representing this product. Thus the continuous wavelet transform (CWT) can be written as:

$$X_{w(a,b)=}\Psi a,b\,(t)dt = \int_{-\infty}^{\infty} X(t)\,\Psi\left(\frac{t-b}{a}\right)dt..(2)$$

Alternatively, this can be viewed as a measure of the correlation or of the similarity between the signal and the wavelet. In order that □ (t) be acceptable as a mother wavelet it shall:

i) be continuous,
ii) and absolutely integral,
ii) Have a Fourier Transform
iii) for satisfy the conditions

$$\int_{-\infty}^{\infty} \psi(t)dt = 0 \text{ and } \int_{-\infty}^{\infty} (|\psi(w)|^2/|w|)dw < \infty \ldots(3)$$

These simply state that the wavelet transform of a constant term is zero and that the integral shall be bounded.

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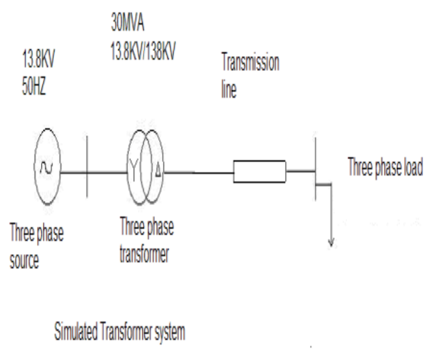
III. MAXIMUM LIKELIHOOD ESTIMATION (MLE)

This description provides a brief introduction to maximum likelihood estimation. It is useful to have a grasp of some of the underlying principles. The concept of likelihood, introduced by Sir R. A. Fisher, is closely related to the more common concept of *probability*. We speak about the probability of observing events. For example, for an unbiased coin, the probability of observing heads is 0.5 for every toss. This is taken to mean that if a coin were tossed a large number of times then we would expect, on average, to find half of the time the coin landed heads, half of the time tails.

There are certain *laws of probability* that allow us to make inferences and predictions based on probabilistic information. For example, the probabilities of different outcomes for a certain event must always add up to 1: if there is a 20% chance of rain today, there must be an 80% chance of no rain. Another very common law is that if two events are independent of one another (that is, they in no way influence each other), then the probability of certain pairs of outcomes will be the product of the two outcomes by themselves: if we toss a coin twice, the probability of getting 2 heads is 0.5 times 0.5 = 0.25.

IV. SINGLE-LINE DIAGRAM OF TYPICAL SYSTEM



V. PROTECTION ALGORITHM

The proposed protection algorithm is summarized as below step by step:

***First Step*:** Acquiring the current and voltage signals obtained from transformer terminals

***Second step*:** Calculating orthogonal basis scale and mother wavelet vectors (V^m_N *and* W^m_N).The coefficient vectors, a^m and d^m, are calculated as below.

$$a^m = \text{(discreet signal)} * V^m_N \;;$$

$$d^m = \text{(discreet signal)} * W^m_N;$$

Approximation and Detail coefficients, *Am* and *Dm*, are calculated as

$$A^m = a^m * V^m_N \;;$$

$$D^m = d^m * W^m_N$$

Third Step: By maximum likelihood estimation(MLE) approach, the detailed coefficients are normalized.

Fourth step: From MLE values we will discriminate whether it is inrush current or not. If yes then restrain relay else go to next step.

Fifth step: From MLE values we will discriminate whether it is fault or not. If it is fault then go to next step.

Sixth step: From MLE values we will discriminate whether the fault is internal or external fault. If it is external fault then restrain relay. Else if it is an internal fault then trip signal is given. In this way the trip signal is given to protective device when only internal fault occurs and mal operation of device is protected.

VI. SIMULATION RESULTS

Case-1:Transformer Energized Without Load with inrush:

Large magnetizing current occurs when a power transformer is energized, the magnitude of this inrush current can be as high as six to eight times of the transformer full load current.The inrush, which occurs on energization, will also depend on the residual magnetism of the core, as well as instantaneous voltage when the transformer is energized. Figure 1 shows the magnetizing inrush current waveforms captured from primary side of a transformer simulated at t=0.2s.

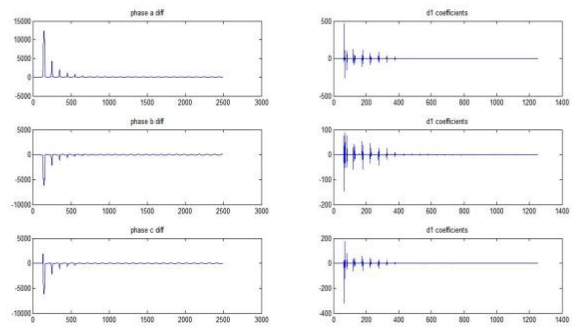


Fig 1 Simulated result for inrush current

The magnetizing inrush current only appears on the primary side of the transformer as seen represents a false differential current, crests a problem to differential protection. The waveform is also apparently distorted; with notable gaps appear over the time intervals of the inrush currents. The sampled current signals of both sides of a transformer are then analyzed using Wavelet Transform. Signals can be decomposed into the fifth level (j=5), and high level coefficients will be extracted.

Case 2: Internal A-G Fault:

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A single phase to ground A-G fault occurs internally on the delta winding at t=0.06s, the WT waveform given in the figure 7.2. The WT is applied to differential current obtained from C.T's at the 40 percent of internal A-phase turn to ground fault.

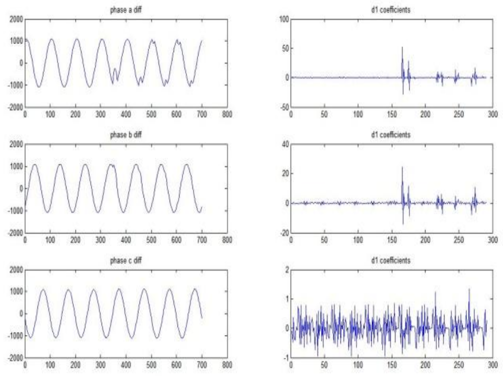

Fig 2 Simulation result for internal A-G fault

Case 3: External A-G Fault:

A single phase to ground A-G fault occurs externally on the star winding at t=0.06s, the WT waveform given in the figure 7.5. We can observe from figure 7.5 a large spike in A phase in D-1 coefficients compared to other phases.

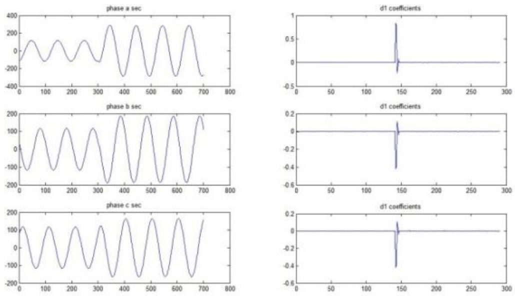

Fig 3 Simulation result for external A-G fault

A. Magnetizing Inrush Condition

At different types of energizing situations, and at rated load conditions and fault conditions have been simulated to assess the efficiency the proposed method.During magnetizing inrush, the MLE values of D coeffecients of each phase are calculated as

Phase **A** = 0.678731 35.22052

Phase **B** = -0.0552 14.99672

Phase **C** = -0.62254 23.19606

The MLE value of the phases A,B,C are very much greater when compared with MLE values of those phases under normal operating conditions. Hence these are inrush currents.

B. Internal Phase To Ground Fault Condition:

During phase to ground fault for different operating conditions on secondary side, the MLE values of D coefficients of each phase are calculated as follows:

Phase **A** differential = 0.058966 **3.833636 (Faulty phase)**

Phase **B** differential = 0.040437 2.26301

Phase **C** differential = 0.0038 1.529334

Phase **A** differential = 0.00055 0.645165

Phase **B** differential = 0.00015 **5.208558 (Faulty phase)**

Phase **C** differential= 0.02139 2.846863

Phase **A** differential = 0.03827 2.372886

Phase **B** differential = 0.01842 1.169528

Phase **C** differential = -0.1718 **4.960936 (Faulty phase)**

We can observe from above values that the MLE values of the corresponding faulty phases for a line to ground fault are very much greater than those of other phases and they are less than 6.

C. External Phase To Ground Fault Condition

During phase to ground fault for different operating conditions on secondary side, the MLE values of D coefficients of each phase are calculated as below:

Phase **A** secondary = 0.007303 0.732426 **(Faulty phase)**
Phase **B** secondary = 0.019251 1.650426
Phase **C** secondary = -0.02654 1.535303
Phase **A** secondary = -0.01522 0.605726
Phase **B** secondary= 0.003976 2.202642 **(Faulty phase)**
Phase **C** secondary = 0.011248 2.547622
Phase **A** secondary = -0.03546 1.291882
Phase **B** secondary = 0.006884 1.150361
Phase **C** secondary = 0.028592 2.119189 **(Faulty phase)**

The MLE values of this type of external line to ground faults are in between 0 and 3.

D. External Phase To Phase Fault Condition

During phase to phase fault for different operating conditions on secondary side, the MLE values of D coefficients of each phase are calculated as below:

Phase **A** secondary = 0.055833 3.286006 **(Faulty phase)**
Phase **B** secondary = -0.07276 7.667847 **(Faulty phase)**
Phase **C** secondary = 0.016937 4.543634

Phase **A** secondary = -0.59641 11.2239
Phase **B** secondary =-0.59842 11.41386 **(Faulty phase)**
Phase **C** secondary = 1.194831 22.61612 **(Faulty phase)**

Phase **A** secondary = -1.14261 22.58597 **(Faulty phase)**
Phase **B** secondary = 0.557009 11.42232
Phase **C** secondary = 0.585611 11.31278 **(Faulty phase)**

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The MLE values of this type of external phase to phase faults are in between 3 and 23. Based on all the above values for different types of faults and inrush current a MATLAB code is generated which discriminates the different faults with inrush.

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BIOGRAPHIES

K. RAMESH received the B. Tech degree in electrical engineering from JNTU KAKINADA in, and the M.Tech from JNTU KAKINADA in 2005. Currently, he is a Assistant professor in BAPATLA ENGINEERING COLLEGE, BAPATLA, where he has been since 2002. His research interests include digital protection of electric power system and electrical machines

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