Analysis on Behaviour of Wavelet Coefficient during Fault Occurrence in Transformer

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Abstract. The protection system for transformer has play significant role in avoiding severe damage to equipment when disturbance occur and ensure overall system reliability. One of the methodology that widely used in protection scheme and algorithm is discrete wavelet transform. However, characteristic of coefficient under fault condition must be analyzed to ensure its effectiveness. So, this paper proposed study and analysis on wavelet coefficient characteristic when fault occur in transformer in both high- and low-frequency component from discrete wavelet transform. The effect of internal and external fault on wavelet coefficient of both fault and normal phase has been taken into consideration. The fault signal has been simulate using transmission connected to transformer experimental setup on laboratory level that modelled after actual system. The result in term of wavelet coefficient shown a clearly differentiate between wavelet characteristic in both high and low frequency component that can be used to further design and improve detection and classification algorithm that based on discrete wavelet transform methodology in the future.

1. Introduction

Electrical power system has been constantly expanding and getting more complex to keep up with consumption demand due to economic and population growth. It mainly consists of generation, transmission, and distribution system. One of the most vital equipment in power system due is transformer due to its function that can transfer power from one voltage level to another with little power loss in process. This role of transformer enables long distance power transmission from power plant to end-user via transmission line. To ensure reliability of the system, the protection system especially for transformer must be response to disturbance such as fault in system with accurate and fast in order to provide correct response for operator. This can prevent severe damage to transformer and avoid economic cost that result from cost of equipment, operating cost, and loss of opportunity during replacement of damaged transformer.

From the important issue mentioned above algorithm for detect, located and classify disturbance in transformer has been constantly develop and improve. One of the methodology has been widely applied on power system protection is Discrete Wavelet Transform (DWT). The reason is its main attribute that can be used to analyze transient state of the signal [1]. In [2], the internal fault has been modelling using both finite element and further analyze by DWT. The result has shown that fault in primary side does not affect secondary winding, while fault on secondary winding can affects both sides. In [3]-[4], the effect of internal, external fault, inrush current and mechanical defects in
Transformer on protection scheme has been discussed. In addition, classification methodology using DWT and Decision Tree (DT) and Artificial Neural Network (ANN) also been proposed. Another application of DWT on transformer protection is discussed in [5]. The proposed methodology used boundary wavelet coefficient energy that can be used in real-time protection with satisfy performance. The characteristic of wavelet coefficient in case of interturn fault using software simulation has been proposed [6]. In the recent research, only the characteristic of winding to ground fault has been analyze by using experimental setup [7].

From the many research and study that has been reviewed, it has shown that DWT based algorithm has potential to be used in fault diagnosis in transformer with high accuracy and fast response. However, the effect of fault on characteristic, and behavior of wavelet coefficient that will be used to construct those algorithms has little study to cover on. So, this paper proposed study and analysis on wavelet coefficient characteristic when internal (interturn fault) and external fault (fault on transmission line) occurring in transformer in both high and low frequency component. The study characteristic using experimental setup that consist of transmission line connected to transformer. This system has been modelled after actual system part of Thailand’s transmission system. The result and methodology can be used to further improved protection scheme or fault diagnosis algorithm that based on DWT in the future.

2. Wavelet analysis

The internal and external fault signal has been simulated by using transmission line connected to transformer experimental setup that modeled after actual part of Thailand’s transmission system. The wavelet coefficient study process can be illustrated as diagram in Fig. 1. Measurement on both primary and secondary winding has been done in order to obtain current during fault occurrence in both fault phase and normal phase. This signal will be used to calculate differential current. After that DWT will be applied on differential current in order to extract High and Low frequency component from the signal in both fault and normal phase. Coefficient value from high and low frequency component will be used for characteristic analysis under faulty condition.

![Figure 1. Overall diagram of internal and external fault analysis.](imageURL)

Characteristic of discrete wavelet transform under fault condition has been perform in this research by divide case study into internal and external fault case as followed.
In case of internal fault, the case studies are focus on interturn fault due to high possibility of occurrence in transformer. The research has varied width of gap between winding that interturn fault occur from 10% (44V-88V in primary winding and 22V-44V in secondary winding) to 90% (44V-440V primary winding and 220V-440V in secondary winding) with 10% interval in both primary winding and secondary winding in order to evaluate the effect of fault location on coefficient value.

In case of external fault, the case studies are focus on single line to ground fault on transmission line that connected to transformer. The location of fault on transmission line has been varied from 30% to 70% length of transmission line with 10% interval in order to take effect of location in to consideration

3. Result
In case of internal fault, the characteristic of wavelet coefficient in both normal and fault phase can be summarize as shown in Fig. 2. For internal fault on primary winding, the coefficient of low and high frequency component in Fig 2 (a) and (b) respectively, shown that coefficient in fault phase is higher than normal phase significantly in both low and high frequency component. Fault position influences coefficient with coefficient increasing as width of interturn fault increase due to rise in differential current amplitude.

For internal fault on secondary winding, the coefficient of low and high frequency component in Fig.2 (c) and (d) respectively reveal the similar trend when compare with fault on primary winding. However, wavelet coefficient in high frequency component is lower due to fault in secondary winding cause rise in current in both primary and secondary winding. This result in low amplitude for differential current.

![Wavelet Coefficient](image1.png)

![Wavelet Coefficient](image2.png)

![Wavelet Coefficient](image3.png)

![Wavelet Coefficient](image4.png)

Figure 2. Wavelet coefficient on fault and normal phase in case of internal fault.
4. Conclusion
This paper proposed study on wavelet coefficient characteristic in both high and low frequency component when internal and external fault occurring in transformer using experimental setup on laboratory level. The result can be summarize as followed

- For internal fault that occur in transformer, the wavelet coefficient of fault phase is higher than normal phase. However, fault on primary winding has higher coefficient value due to high amplitude differential current. In addition, Fault position has significant impact on coefficient value because width of interturn fault gap has direct effect on amplitude of differential current
- For external fault that occur in transmission line that connected to transformer, the wavelet coefficient in normal and fault phase does not differentiate much with normal phase a little bit higher due to external fault affect amplitude of differential current in fault phase. Fault location on transmission line does not have significant influence on wavelet coefficient.

This characteristic of wavelet coefficient from both internal and external fault in transformer has distinguishing characteristic that can be used to construct protection scheme or fault diagnosis algorithm in the future.

5. References
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