UGC Approved Journal

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 8, August 2017

Inrush Current and Fault Current Discrimination by using Wavelet Transform

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Abstract: 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 internal faults and inrush currents in power transformers using the wavelet transform based feature extraction technique. 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 an internal fault from an inrush current in different power transformer system can be accurately made. The experiment simulation studies have verified that the proposed method is more reliable and simpler, and is suitable for different power transformer systems.

Index Terms: Inrush Current, fault current, wavelet transform; power transformer.

I. INTRODUCTION

As the power industry of our country rapid development, the scale of electric power system expends constantly, and it is higher to demand for the quality of power supply. How to guarantee the quality of power supply, and the safe reliability of electronic power system operation is the key problem of electric power industry department .The power transformer is the very important electrical equipment, whether it operates safely or not, it directly relate to whether the electric power system works continuously and stably or not.

While the power transformer of high capacity is the expensive component, protective devices of good performance and reliable work must be installed according to capacity and significant degree of transformer, and all kind of possible faults and abnormal operating state. The differential protection is the key technology for the power transformer .The power transformer differential protection based on microcontroller collects every phase alternative current, processing it, so it has a powerful processing ability. Its main issues are the distinguishing the internal faults current from the magnetizing inrush current. The protection refuses to trip, when the magnetizing inrush current appears, while the internal fault current takes place, the protection trips fast. It has a higher sensitivity. The wavelet transform has a local property in time domain and frequent domain simultaneously and multi resolution analysis, outstandingly reflects the magnetizing inrush current distortion characteristic, and the internal fault current result is the smooth, small distortion, it identifies inrush from internal fault current.

II. MAGNETIZING CURRENT IN TRANSFORMER

Under normal operation circumstance, the iron core of Transformer works in the unsaturation state, the relative magnetic conductivity is tremendous , and the excitation inductance of winding is also tremendous, so the excitation current is tiny, which is not more than 2%-10% of rated current. When the no-load transformer throws in or voltage recovers after external fault is cleared because of iron core, relative conductivity is nearly 0. Seldom parts of primary side current, most parts are into excitation inrush.

So excitation inrush current only flow into one side of transformer, the amplitude is probably 6-8 times of rated current [2] .And it causes protection equipment error operation. Internal fault is various fault occurring inside of the transformer tank, including the short circuit between the phase winding, single-phase inter-turn short circuit, single-phase ground short circuits, its turn to turn short-circuit problems accounted for a large ratio [3] . Harmful to internal faults, because the high temperature electric arc short-circuit currents will not only damage the winding insulation, burning core, but will also heat insulating materials and decomposition of transformer oil , which will produce large amounts of gas which may cause the transformer tank explosion.

The maximum peak values equal to 8 to 10 times the rated current can occur.

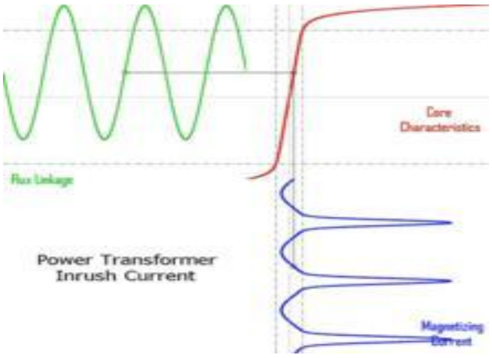

Fig 1. Inrush current waveform

Maximum inrush current can occur if transformer is energized when the voltage wave is passing through zero. At this instant, the current flux should be maximum in highly inductive circuit and in next half wave the flux should change its direction to attain the maximum value. If there is residual flux in transformer, the flux may be in the same or opposite direction. Accordingly the magnetizing current will be less or more, it will saturate the core and increase the magnetizing component further.

Factors influencing the magnitude and duration of magnetizing current inrush are:
1. Size of transformer: as size of transformer increases, the inrush current also increases.
2. Type of magnetic material in the core: if the core is made up of material having good permeability then the inrush current automatically decreases.
3. Residual flux of transformer before switching in: presence of residual flux also increases the magnetizing current.
4. Instant of switching: if the transformer is switched on at the instant when the voltage wave is passing through zero value, then the magnetizing inrush current at that inrush will be maximum.

The inrush current of a transformer can be as high as 5-10 times the rated transformer current. This current appears only on one side of the transformer and is not reflected on the other side of the transformer. This causes an imbalance of the currents appearing at the transformer differential relay. This imbalance will be seen as a differential current and will cause the differential relay to trip. Since an inrush condition is not a fault condition, the operation of a differential relay during an inrush condition must be prevented.

III. TYPES OF FAULTS

Faults can be classified as through faults and internal faults. A through fault is located outside the protection zone of the transformer. The unit protection of the transformer should not operate for through faults. The transformer must be disconnected when such faults occur only when the faults are not cleared by other relays in pre-specified time. Internal faults can be phase-to-phase and phase-to ground faults. These internal faults can be classified into two groups.

Group I: Electrical faults that cause immediate damage but are generally detectable by unbalance of current or voltage. Amongst them are the following:
- Phase-to-earth fault
- Phase-to-phase fault
- Short circuit between turns of high-voltage or low-voltage windings
- Faults to earth on a tertiary winding or short circuit between turns of a tertiary winding

Group II: These include incipient faults, which are initially minor but cause substantial damage if they are not detected and taken care of. These faults cannot be detected by monitoring currents or voltages at the terminals of the transformer. Incipient faults include the following:
- A poor electrical connection between conductors
- A core fault which causes arcing in oil
- Coolant failure, which causes rise of temperature
- Bad load sharing between transformers in parallel, which can cause overheating due to circulating currents

For a group I fault, the transformer should be isolated as quickly as possible after the occurrence of the fault. The group II faults, though not serious in the incipient stage, may cause major faults in the course of time. Incipient faults should be cleared soon after they are detected.

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IV. WAVELET TRANSFORM THEORY AND SIMULATION

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.

V. MODEL DIAGRAM AND MAIN PARAMETERS

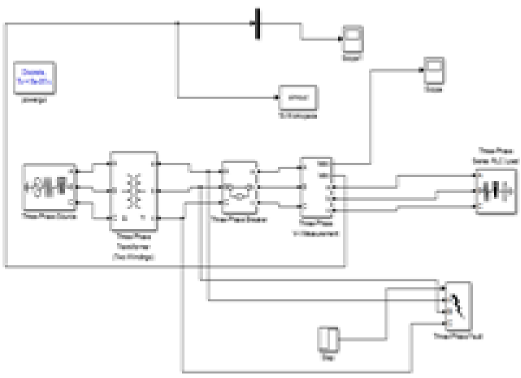

Fig 3 shows MATLAB Simulink diagram

Main Parameters of the system:
Three phase voltage source phase to phase rms value: 525kv
Frequency: 50Hz
Transformer nominal power: 500MV
Primary winding: 500KV
Secondary winding: 250KV
Load active power 60 KV

VI. SIMULATION ANALYSIS

Because the mother function is not unique, the same question has different result with different wavelet mother function. So we introduce several mother functions. Haar function is simple, symmetry and orthogonal compactly supported bases, Haar function is not continuous, its defects are bad smooth. When Haar function represents continuous signal, there is the smooth. B spline function is continuous, symmetry and linear phase and good smooth, but B spline function is not ortho normal compactly supported bases. Daubechies function is continuous, orthogonal compactly supported bases, but it is not symmetry itself. Although Daubechies function is continuous, but is smooth is not better. The N is great, the smooth is good, but it has great deal of data, so the speed is slow. Coiflet function is a wavelet function were constructed by Daubechies, it content coifN(1,2,3,4,5) series, It features dual orthogonally, compact support of, support for a length of 6N- l, approximately symmetrical, the anishing. Moments of wavelet function is 2N, the anishing moments of Scaling function is 2N-1, and its filter length is 6N.

 DOI 10.17148/IJIREEICE.2017.5811

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Selected mother wavelet function of the signal function has great influence on the results of wavelet transform, although there have been some of the best domestic and foreign-based selection method, but the lack of system specification method of selecting the best wavelet basis that is optimal for different problems can choose the generating Function of different applications to achieve the best results. This simulation program by comparing results of various

Wavelet transforms, the paper selects coif5 wavelet function. We use the MATLAB Simulink [5][6] to carry out simulation analysis for the excitation inrush and the internal fault. The wavelet transform simulation analysis result about inrush current and internal fault in transformers is indicated in the below figures: the wavelet transform of magnetizing is seeing in Fig.4, the wavelet transform of internal fault current is seeing in Fig 5.

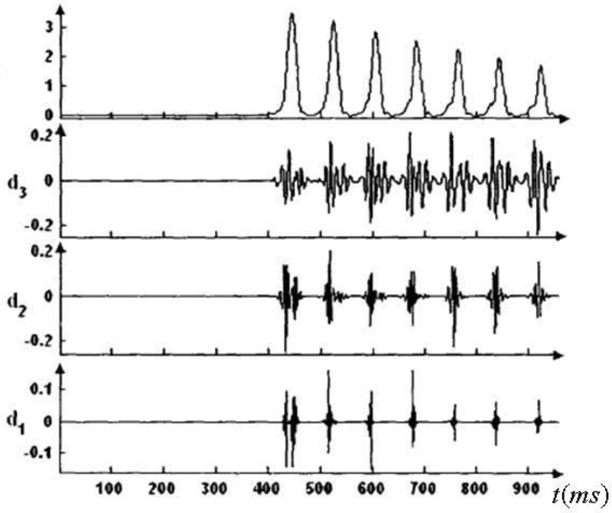

Fig 4 the wavelet transform of magnetizing inrush

The inrush current waveforms show a downward trend over time, while the size of fault current remains same, and disappear with the fault is removed or the failure is eliminated. Magnetizing inrush current of the wavelet transform results are very significant, its coefficient is attenuated. Thus, you can extract the inrush current is different from the characteristics of the internal fault current, that is no longer an internal fault mutation, after the inrush current during each cycle there are mutations, which is also proposed new ideas.

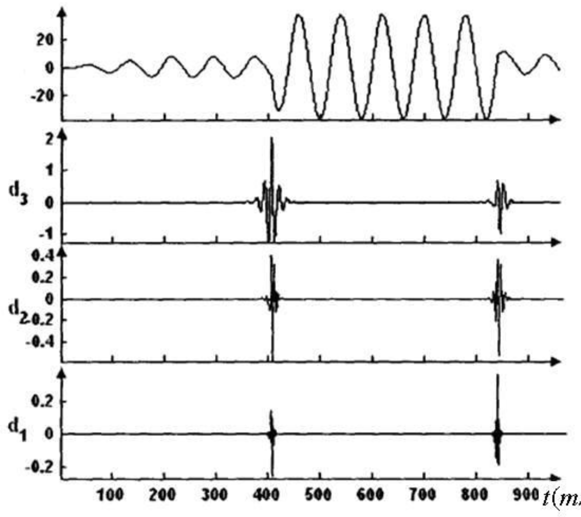

Fig 5 the wavelet transform of internal fault current

VII.CONCLUSION

Wavelet transform prominently reflects the distortion Characteristics of magnetizing inrush current, which showed mutations in the factor is very large. The internal fault current in the mutation also affected by the existence of a large

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abnormal features, but the internal short circuit occurs, the current waveform gentle, almost no mutations. Transformer inrush current and internal fault current ratio is obvious difference in coefficients which can be used to distinguish the characteristics of magnetizing inrush current.

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