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Inrush Blocking Scheme in Transformer Differential Protection

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Abstract

Transformer inrush currents during energization result in mal operation of transformer differential protection, due to the flow of magnetizing current only on the primary / source side of the transformer. A straightforward approach in recognition of inrush currents is proposed here by checking the core cause of this inrush phenomenon i.e. the magnetic saturation of the transformer core. In this method, the pseudocharacteristics were approximated in terms of orthogonal polynomials, and is used to distinguish between inrush currents and fault currents. In this method, the magnetic saturation characteristics of the transformer is modeled by defining pseudocharacteristics, and is obtained over a half cycle data window of the differential current. This data is assessed using certain criteria to detect inrush and fault currents. This method is not reliant on the transformer models and is precise in its output. The propositioned method was tested using delta-wye transformers under both fault and inrush scenarios.

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Keywords: transformer protection; differential protection; inrush current; orthogonal polynomials;

1. Introduction

Transformers are the focal equipment used in power systems, whose reliability and security is of the utmost importance. Differential Protection is the most competent protection for transformer against various faults. This protection works on the principle of differential currents between the primary and the secondary side of the transformer. This protection operates in case of any fault within the transformer zone of protection, and is

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impervious to any external faults. However, energization of a transformer may lead to mal-operation of this type of unit protection, due to the magnetizing inrush phenomenon. Energization of a transformer results in the flow of inrush current through the transformer. Since, this magnetizing inrush currents only flow from the source to the primary side, and no currents flow out of the secondary windings of the transformer, these currents appear as differential currents and this results in erroneous tripping of the transformer.

The prediction of transformer transients, particularly inrush currents has been an active research area ever since this phenomenon was first observed in the early 19^{th} century. This inrush phenomenon, which is generally used in concurrence with energization, can also be prompted by any abrupt change of voltage at the transformer terminals. Such transients include the occurrence / removal of a fault, change of character of fault, out of phase synchronizing, etc. [1]. So, a desensitizing scheme, that is effective only when a transformer is being energized is not an effective counter measure.

The method of harmonic current restraint [2] is the oldest and the most noteworthy work in this field, where harmonic content in the differential current were used as indicators of inrush current and the restraint operation of the differential relay based on them. Although the method is widely used in practice due to its simplicity, the modern development of iron cores with substantial improvement in magnetic characteristics, have increased the probability of failure in this method [3]. Also, as both fault and inrush currents display large amplitudes, it is impossible to differentiate between them just by checking current magnitude.

To improve the efficiency of inrush detection, various intelligence methods and signal processing has been used. Use of different types artificial neural network was proposed in [4,5], but these methods are specific to a particular type of transformer and adds computational requirements to the relay. Different variations of wavelet transforms have in used in differential protection, such as discrete wavelet transform(DWT) [6], wavelet packet transforms (WPT) [7] and boundary wavelet transforms [8]. Although these methods show reasonable performance for fault detection, it has some drawbacks in real-world applications in power system protection, in the form of time delay for real time analysis, failure in case of over damped transients. Correlation analysis and transforms [9,10] has also been used based on the symmetry of current waveform shapes and identification of dead angles. Mathematical morphology, which is signal processing tool, has been proposed for inrush current detection in [11], for analysis of the current data in time domain for symmetry and gradient.

These methods depend on the consequential indicators of inrush current, such as harmonic content, waveform symmetry, etc. The analysis of the underlying cause of inrush currents i.e. magnetic saturation, was taken up in [12], which proposes the modeling of transformer core and its magnetic saturation characteristics, by introducing the concept of pseudoflux and pseudocharacteristics. This paper builds up on that idea

Nomenclature

ϕ_s	Flux
$\phi(t)$	Saturation Characteristics
$i(\varphi)$	Pseudocharacteristic
φ	Pseudoflux
d_j	Polynomial Constants
P_j	Legendre Polynomials
j	Degree of Polynomial
C0	Criterion Zero
C1	Criterion One
C2	Criterion Two
U	Current Energy
FFT	Fast Fourier Transform