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A computational tool to assist the analysis of the transformer behavior related to lightning

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ABSTRACT

This paper proposes the application of computational intelligence techniques to assist complex problems concerning lightning in transformers. In order to estimate the currents related to lightning in a transformer, a neural tool is presented. ATP has generated the training vectors. The input variables used in Artificial Neural Networks (ANN) were the wave front time, the wave tail time, the voltage variation rate and the output variable is the maximum current in the secondary of the transformer. These parameters can define the behavior and severity of lightning. Based on these concepts and from the results obtained, it can be verified that the overvoltages at the secondary of transformer are also affected by the discharge waveform in a similar way to the primary side. By using the tool developed, the high voltage process in the distribution transformers can be mapped and estimated with more precision aiding the transformer project process, minimizing empirics and evaluation errors, and contributing to minimize the failure rate of transformers.

1. Introduction

Due to increasing concerns about the quality in the energy service, the researchers have concentrated efforts to study overvoltages caused by lightning on low-voltage lines. One of these phenomena that have been deeply investigated is related to surges transferred from medium voltage line to the secondary of the distribution transformers. This way, the accurate identification of eventual failures on transformers due to lightning turns out to be indispensable to reduce the number of burnt transformers.

Transformer failures can result from lightning surges on the transformer secondary side. Lightning strikes to structures served by the transformer can introduce lightning currents into the secondary of the transformer. Lightning currents flowing on the secondary circuit or the power system neutral can be introduced into the secondary of the transformer. The transformer primary side is protected with a lightning arrester. The secondary of the transformer has no surge protection, and the failure rate could be explained by secondary surges. Besides, the insulation strength of transformer insulation can be expected to decrease with age.

As the transformer ages, the protective margin of the lightning arrester decreases. Given a moderate severity lightning strike, the transformer can fail from reduced insulation strength that can happen due to manufacturing tolerances, water contamination of the transformer oil, air bubbles in the winding, mishandling during shipping and warehousing that causes damage. A strike of moderate severity could be expected to cause failure of a transformer whose insulation strength has been decreased by damage [1,2].

Impulse test techniques about high voltage tests on transformers have been developed to detect failures, such as internal perforations on transformers caused by overvoltages. The lightning representations are made starting from waveforms obtained through impulsive voltage tests [3–7]. These techniques have been improved constantly, researches using power spectral density and wavelets analysis on fault detection sensitivity [8], or using Artificial Neural Networks in order to recognize fault patterns [9] have shown good results.

The great obstacle to detecting these perforations in experimental tests, in addition to the difficulty of acquiring experimental basis, have led us to adopt computational models to simulate the behavior of distribution transformers in high frequencies caused by lightning. This kind of approach allows an electromagnetic transient simulation under different conditions of atmospheric overvoltages [10]. Current methods to evaluate the voltage behavior transferred to the secondary of the transformer are still empiric. At this point, it is possible to proceed with an assessment more quantitative than qualitative [11,12].

In order to obtain a better performance of the supplied energy quality, several researches showed that the variation of secondary interlacement, the use of arresters, the format changes in the insulation system or changes in the ground resistance can all mitigate voltage surges transferred to the secondary of the transformer and thus to the consumer [5,13–15].

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