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Calculation of internal overvoltages using a wide band transformer model based on limited information about transformer design

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Abstract

Specific insulation coordination studies might require an accurate modeling of power transformers. This is the case for instance when transfers of fast front overvoltages from the high voltage side to the low voltage side of a transformer are involved. Modeling accurately the transformer's electromagnetic behavior for the frequency range of fast front overvoltages requires special care. There are numerous existing transformer models which are intended to model the wide band transformer's behavior. However, many of them are too complex or require confidential information about the transformer design. This makes them not suitable for power engineering applications.

In this paper a wide band transformer model based on limited information about the transformer design and compatible with an electromagnetic transients program is presented. Then, its application on calculating internal overvoltages distribution along transformer windings, taking into account different conditions on the outer transformer terminals, is shown for lightning impulse.

1. Introduction

Transformer outages can sometimes happen due to dielectric failures inside the transformer caused by lightning or switching operations (fast and very fast front overvoltages) [1]–[3]. Consequently, internal overvoltages distribution along transformer's windings in the case of high frequency overvoltages are of interest to power utility

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engineers. However, even though many transformer models for high frequency exist today, because of the lack of data and the complexity of these transformer models it is not always possible to accurately represent transformer's high frequency electromagnetic behavior. With the introduction of the Grey Box transformer models it becomes possible to make a model detailed enough, usable for power utility engineers, without having access to the detailed transformer design data.

This paper first presents a wide band transformer model based on limited information about the transformer design and compatible with an electromagnetic transients program [4]. Then, its application on calculating the internal overvoltages distribution along the transformer windings, taking into account different conditions on outer transformer terminals, is shown for a lightning impulse. Finally, a method to detect the resonant frequencies of a transformer winding is explained.

2. Wide band transformer model based on limited information about transformer design

In this paragraph a wide band transformer model is presented. The model is based on finite element calculations, rational approximation and derived from limited information about the transformer geometry. It can be classified as a Grey Box model [1]. The model can be used to simulate external overvoltages as well as internal overvoltages that might occur in the transformer. That said, it can be separated into two successive steps: first step related to the calculation of external overvoltages and the second step devoted to the calculation of internal overvoltages. Because of the specificities of the model interaction with the electromagnetic transient software program (EMTP-RV), it is more efficient to have only external transformer terminals represented in EMTP-RV. Note that the voltages that occur on these terminals depend on the electromagnetic interaction between the power network and the transformer [1]. Once the values of voltages at the external terminals are known, it is possible to calculate the internal distribution of overvoltages taking into account the current power network configuration. A similar approach for interfacing with EMT-type programs has been already proposed in [5] on the example of the Black Box model.

2.1. Parameters determination

The model presented in this paper is based on a lumped *RLCG* equivalent network and a segmentation of the transformer geometry. Similar models can be found in [6]–[8]. In this model the parameter values are calculated from the transformer geometry and properties of the materials. Each *RLCG* element represents a physical part (segment, some authors refer to them as "electrical elements" [9]) of the transformer's winding. See Fig. 1 for the example of a *RLCG* network which represents one phase of a two windings transformer represented with only one segment per winding.
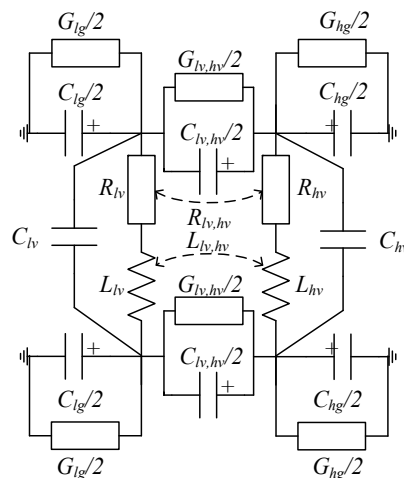

Fig. 1. *RLCG* network for one phase of a two winding transformer.