A Novel Approach to VFTO Analysis of Power Transformers Including FVL Based on Detailed Model

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***Abstract*-There are two physical models to analyze Very Fast Transient Overvoltage (VFTO) on transformers. These models are multiconductor transmission-line model and Detailed Model. The modeling of windings by the lumped RLCM network (the detailed model) enables the calculation of the currents and voltages using common electrical network analyzing tools (e.g., ATP, Pspice, etc.). In addition, it is possible to consider nonlinearities (e.g., hysteresis, saturation) and frequency dependent effects (e.g., eddy current, dielectric losses). Complex windings can be modeled with several coils, which is not possible for the multi-phase transmission line model. This paper is proposed a complete Detailed Model (DM) that is consisting of Frequency Variable Losses (FVL) and comparison of its results with experimentally results shows that it can be used to analyze the VFTO on transformer easily.**

I. INTRODUCTION

The problem of VFTOs has been widely studied and many publications have appeared on the behavior of the electrical components at high and very high frequencies. Also, several CIGRE working groups and two IEEE working groups (Switchgear Committee and Transformer Committee) that deal with the problem of fast transients addressed the subject and pointed out that it was sometimes difficult to identify specific transformer failures related to fast transients. The short rise time of a surge prompted by a lightning or a switching impulse can cause deterioration in the insulation and ultimately lead to a dielectric breakdown. The severity of this process depends on several factors, such as the frequency at which the transformer is exposed to this type of surge, the system configuration, the specific application of the component etc. Large power transformers are exposed to VFTOs by atmospheric discharges or Gas-Insulated Substation (GIS) switching. Very Fast Transient (VFT) is generated at operations of a disconnecting switch in GIS. It is characterized by a rapid rise time of a few nanoseconds and an oscillating waveform. The oscillating frequency is from a few to several tens of Megahertz and the oscillation lasts several microseconds. Resonance of the voltage oscillation occurs in the transformer winding by application of oscillating waveforms having particular frequencies [1], [2]. Then a simple transformer model at Megahertz frequency is required especially modeling of FVL.

Distribution transformers and motors are exposed to fast surges if they are switched by circuit breakers (CBs). In order to study the propagation of transients, a model is needed which is able to simulate the voltage distribution along the transformer winding. There are two basic physical methods to model VFTO in transformers. These two methods are multiconductor transmission-line model and lumped parameter model called DM [1].

[1] has used multiconductor transmission-line theory to model, simulate and analysis the VFTO on layer type transformer. This method models the transformer such as a distributed element and with using Maxwell equations all frequency behaviors of transformer is considered. But drawback of this model it is not consider saturation and losses such as Hysteresis, eddy and proximity. Instead of this method, DM can consider saturation and losses but disadvantage of this method is that it can not model the behavior of VFTO perfectly due to frequency limit and no model for FVL. In the other hand developing an equivalent lumped parameter model can be a useful challenge and must be done to include the full frequency-dependent core losses [1]. A good candidate for this, is DM of transformer which models every turn (or a group of them called disk) by *RLCM* element.

This paper is proposed a DM that its resistance is modeled as frequency component to model FVL. For verifying the proposed model for VFTO simulation, it is applied on transformer, which is used and tested in [1]. Comparison shows that results of proposed model are near to results in [1].

For modeling the FVL, Foster circuits are selected and with aid of similar methods that considered by [3] and [4], the eddy and proximity losses are modeled. For increasing the accuracy of proposed model, a turn can be modeled by *RLCM* circuit in proposed model.