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Measurements for validation of manufacturer's white-box transformer models

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Abstract

The transformer manufacturers make use of electromagnetic transient calculations by detailed white-box models to ensure that the transformer will withstand the lightning impulse test during the factory acceptance test. In principle, such models could be used in general electromagnetic transient simulation of overvoltages in the system. One of the objectives of CIGRE JWG A2/C4.52 is to assess the accuracy of the manufacturer's white-box models in the context of general transient overvoltages that can occur in the system. As part of this activity, extensive measurements have been performed on two three-winding transformers: one three-phase unit and one single-phase unit. The measurements involved voltage transfer between external terminals and from external terminals to three points in the regulating winding. The measurements were performed with alternative points of voltage excitation, grounding conditions and alternative tap settings, giving 64 cases for each transformer. Some admittance measurements were also performed. This paper gives an overview of the measurements that were performed, the measurement procedure, and some initial results. The voltage transfer measurements were mostly performed in the frequency domain and transferred to the time domain via rational function approximation and recursive convolutions. That way, voltage transfer functions have been generated for well-defined excitations, e.g. the standard 1.2/50 μs voltage wave. In addition, initial results for black-box modeling of the three-phase unit is shown. The measurements are currently being used within CIGRE JWG A2/C4.52 for benchmarking of white-box models.

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Keywords: Transformer; model; white-box, black-box; grey-box; measurement; overvoltages; electromagnetic transients

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1. Introduction

This paper is presented on behalf of CIGRE JWG A2/C4.52 "High-frequency transformer and reactor models for network studies". One of the pursued objectives of the JWG is to make the detailed white-box models [1]-[8] used by transformer manufacturers available for use in general electromagnetic transient simulations. This would permit calculation of the transient interaction between the transformer and the system, giving the overvoltages on the transformer terminals. In principle, overvoltages inside the transformer windings could be calculated as well. The need for such model is high since the currently applied high-frequency transformer models for system studies are primitive [2], often being just one or a few lumped capacitors whose values are in any case not well known.

As the white-box models are primarily targeted at calculating the voltage response due to the standard lightning impulse test voltage (1.2/50 μs), their accuracy for use in general transients studies remains to be clarified. It was already observed in a previous WG (JWG A2/C4.39) that the calculation programs by manufacturers give quite different results when applied to the same geometry [9]. One example of such comparison is given in Fig. 1 which shows the node-ground voltage at one internal point inside the transformer when a lightning impulse voltage is applied to an external terminal. It is clear that the simulation by the various contributors differ substantially regarding the frequency components and their damping. These deviations are particularly worrisome if the model is to be used in simulations involving resonant overvoltages as the natural frequencies must then be quite accurate to obtain reliable results.

In order to validate the various white-box models and their parameter determination, it is necessary to compare simulations against measurements on a complete transformer whose geometry is known in detail. Such combination of measurements and detailed geometry description has not been available. In A2/C4.52, WEG Transformers Mexico therefore offered to release the detailed design information of one three-phase unit and one single-phase-unit. Measurements of transient waveforms were performed by the WG on the two transformers to permit direct comparison between white-box simulations and measurements. This paper gives an overview of the measurements that were performed and the adopted measurement principles. The possible use of such measurements for modeling purposes is also discussed.

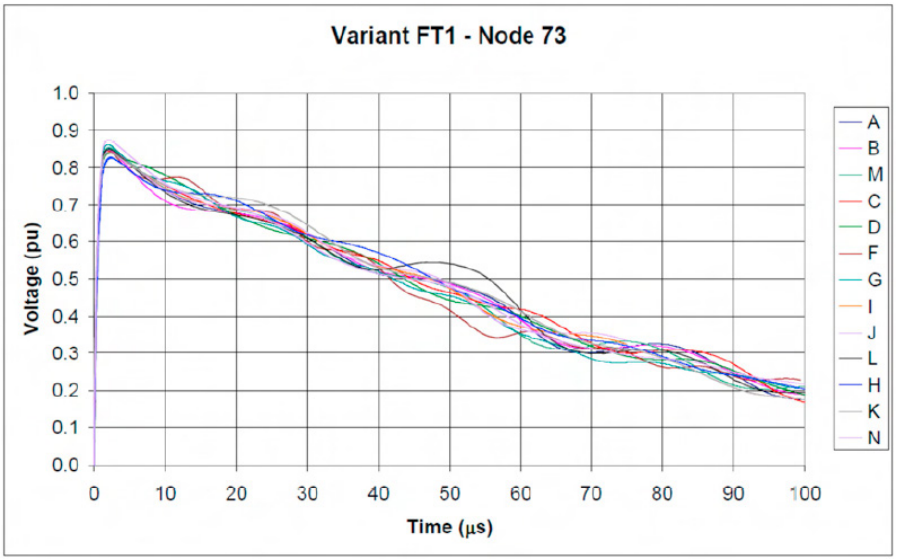

Fig. 1. Comparison of calculation results for the "Fictitious Transformer 1" [9].