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Determination of Winding Lumped Parameter Equivalent Circuit by Means of Finite Element Method

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Abstract—In this paper, finite element method is used in order to determine electrical parameters of a machine winding lumped element model. This model allows to study the distribution of the turn-to-turn maximum voltage stress. The suitability of the method is validated by comparison with measurements.

Index Terms—Electrical parameters, equivalent circuit, machine windings, finite element analysis.

I. INTRODUCTION

The new generation of wide gap switching components allows to increase the operating frequency of power converters. Consequently, the motors windings undergo very fast front pulses with high $\frac{dv}{dt}$ imposed by the converter coupled to the cable. The electric fields generated by these high variations can be intense between the wires and can surpass the Partial Discharge Inception Voltage (PDIV). Partial discharges are particularly damaging to the Turn-to-Turn (TT) insulations, leading thus to the deterioration of the electrical insulation system. In order to calculate the dimensions of the latter and to determine the electrical stresses on the TT insulations, the study of the distribution of the TT voltage is a key point. This step can be performed thanks to a lumped parameter model [1], but the determination of those parameter values remains problematic since it is performed experimentally or with empirical data. This is obviously a step that an electrical designer cannot afford. The aim of this communication is to show how to compute those values by means of a Finite Element Analysis (FEA) [2] to provide a highly scalable tool.

II. LUMPED PARAMETER EQUIVALENT CIRCUIT

For each turn of a winding, the lumped parameter equivalent circuit (Fig. 1) includes the turn resistance R_s , representing the Joule losses, the self-inductance L_p , the TT capacitance C_t , the Turn to Ground (TG) capacitance C_m and the TT and TG dielectric losses resistances R_t and R_m respectively. Moreover, in presence of an iron core, the core losses are taken into account through R_p . As previously stated, in this work, the finite element method is used to determine the values of those parameters: the capacitances C_m and C_t can be obtained from an electrostatic computation whereas the resistances R_s and R_p as well as the inductance L_p can be obtained from a magnetodynamic study [2]. The resistances R_t and R_m , as for them, can be determined from a coupled electrokinetic - magnetodynamic computation involving a complex electrical conductivity.

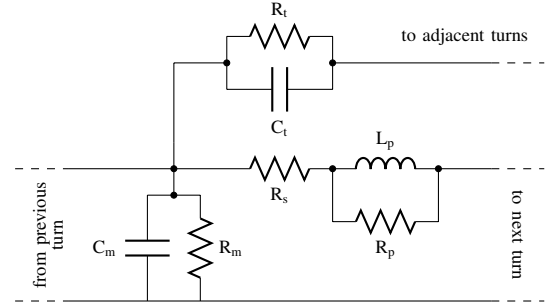


Fig. 1. Lumped parameter equivalent circuit of one turn.

The circuit presented in Fig. 1 has been used to simulate a six-turn winding. The coil is supplied with a voltage step of 300 V, lasting 500 ns and with a rising time of 10 ns. Note that, in this example, R_m , R_t and R_p are taken from the literature. Fig. 2 shows the step response of the winding when the parameters come from measurements and FEA.

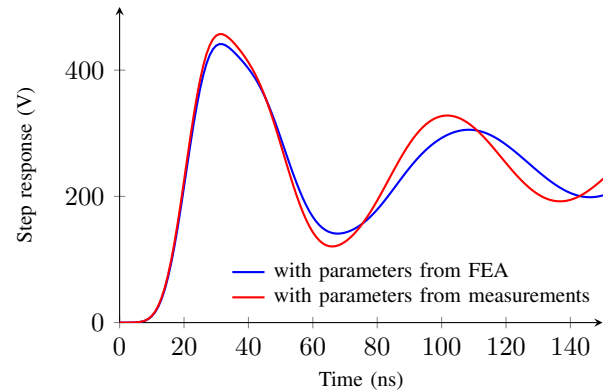


Fig. 2. Measured and simulated voltage at the input of a six-turn winding.

In the extended paper, the formulations used to compute all the parameters of the equivalent circuit will be described.

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