Electromagnetic Interferences in Inverter-Fed Induction Motor Drives

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Abstract — The paper deals with the numerical modeling of a pulse-width modulated voltage inverter-fed induction motor drive for the common and differential current modes. The proposed model of the drive respects the influence of the feeding cable described by the lumped or distributed parameters. The theoretical analysis is supplemented by results of relevant simulations and experiments. Evaluated are also the frequency characteristics of selected parts of the system and their contributions to its resultant harmonic spectra.

Keywords: Electromagnetic interferences, IGBT, IGCT, inverter, induction motor, frequency characteristics

I. Introduction

The paper deals with the models of a PWM voltage inverter-fed induction motor drive developed for the common and differential current modes. Both representations of the drive system take into account models of the feeding cable with lumped or distributed parameters. The theoretical analysis is supplemented by results of relevant simulations and experiments carried out on IGBT and IGCT inverters. Evaluated are also the frequency characteristics of selected parts of the system and their contributions to its resultant harmonic spectra.

II. The Basic Models

The basic arrangement of the investigated system is shown in Fig. 1.

A. Induction motor model for high frequencies

The IM is modeled by the developed equivalent circuit consisting of a set of lumped parameters (see Fig. 2) determined by constrained optimization process based on the minimum difference between the calculated and measured frequency characteristics of the circuit.

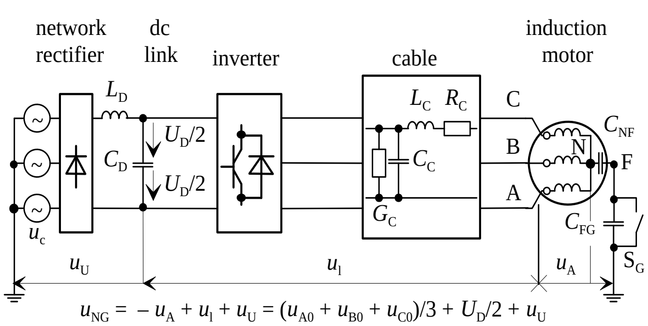

Fig. 1. The investigated drive system with an inverter, cable and IM

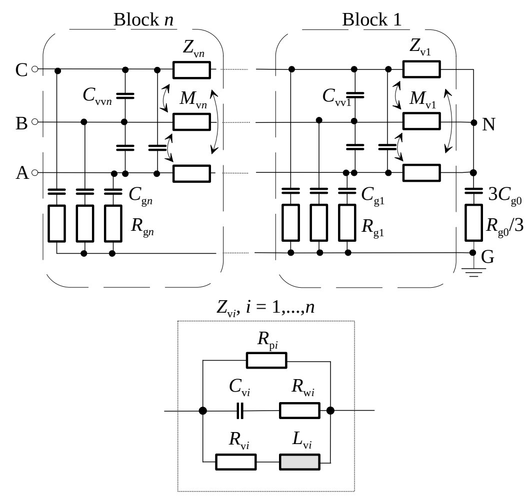

Fig. 2. Possible equivalent circuit of the induction motor

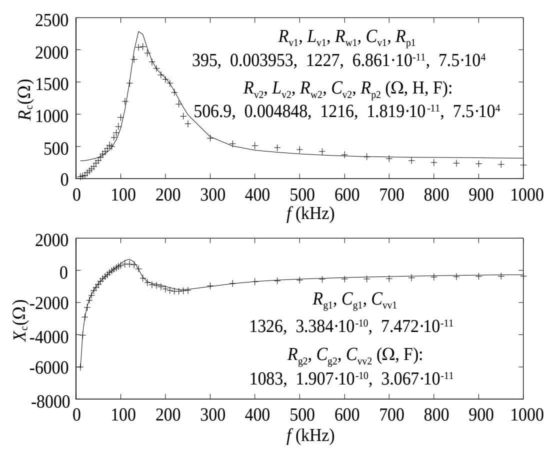

Fig. 3. Real and imaginary parts of the IM impedance in the common mode

Fig. 3 shows both measured points and calculated frequency characteristics of the real $R_c(f)$ and imaginary $X_c(f)$ parts of the IM impedance in the common mode.

B. Feeding cable model

The voltage and current distributions in a system consisting of n conductors are described by the following set of equations

$$\frac{\partial[\boldsymbol{u}]}{\partial x} = -[\boldsymbol{R}'][\boldsymbol{i}] - [\boldsymbol{L}']\frac{\partial[\boldsymbol{i}]}{\partial t}$$
$$\frac{\partial[\boldsymbol{i}]}{\partial x} = -[\boldsymbol{G}'][\boldsymbol{u}] - [\boldsymbol{C}']\frac{\partial[\boldsymbol{u}]}{\partial t} \qquad (1)$$

III. Simulations and Measurements on Induction Motor Drive

A great amount of simulations and measurements have been carried out for confirmation of the validity of the models and provide a deeper view into the effects. The responses obtained on this model well correspond with the responses captured on the real drive system.

Fig. 4 compares the calculated (the number of the Fourier expansion terms being 500) and measured transient common mode current responses in a system with the feeding cable of length 10 m and IM.

Fig. 5 shows the common mode interference spectra detected at the measurement point at the LISN and expressed in the double logarithmic representation. Three characteristics are depicted, namely for only the inverter in operation, the IGBT inverter with the feeding cable and for the inverter feeding the IM through the cable. By comparing the interference spectra for different lengths of the cable and different parts of the system we can evaluate impacts of these individual subsystems of the drive.

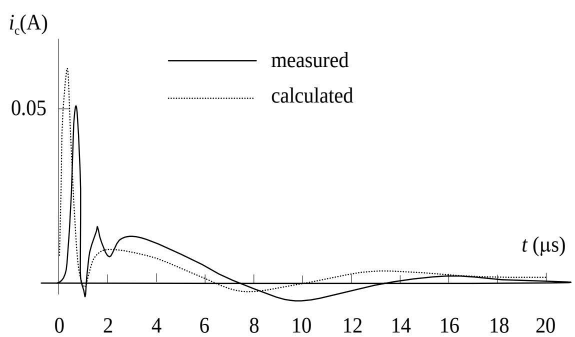

Fig. 4. Calculated and measured current response in the common mode (system with the feeding cable of length 10 m and IM)

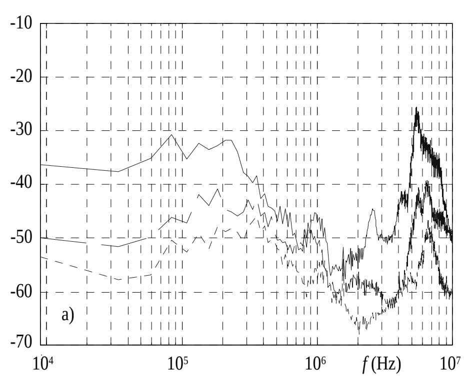

Fig. 5. Common mode interference spectra for $l_c = 2\,\mathrm{m}$

We have also proven experimentally that the voltage front edges at both the IGBT and IGCT inverters have similar steep slopes and, although the switching times at the IGCT-based inverters are longer than those at the IGBT inverters, these inverters will produce also similar overvoltage phenomena.

We have found the results and experience referred so far very useful at the development and testing of some drives of vehicles for city mass transport from the point of view of EMI. In addition to conducted high frequency parasitic currents also radiated EMI produced by the drives of vehicles (tramways and trolleybuses) were calculated and measured.

Fig. 6 present an example of results gained when modeling magnetic field inside and outside the trolleybus TR21. Computation of the magnetic field was performed by the professional FEM-based program QUICKFIELD. Results were compared with values measured and those given by standards.

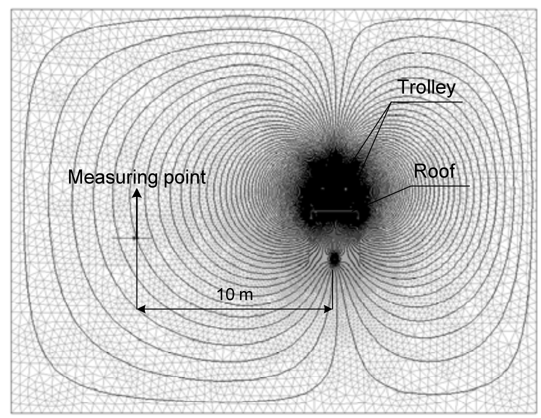

Fig. 6. Contours of calculated intensity of magnetic field inside and outside trolleybus TR21

IV. Conclusions

The equivalent models of the feeding cable as well as the IM suitable for the determination of stray current disturbances in the common and differential modes have been suggested. The frequency characteristics of selected parts of the system and their contributions to the resultant harmonic spectra have been evaluated as well.

The responses obtained on this model well correspond with the responses captured on the real drive system.

The paper summarizes also practical knowledge gained from the employment of these switching devices in vehicles of city mass transportation.

V. References

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