Simulation of Conducted Emissions from Power Converters Using Leading Switching Technologies

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***Abstract*— This paper presents a comparative study between the commonly used switches (IGBT, MOSFET, SiC and GaN) for power inverters of electric vehicles. A 400V, three-phase inverter system simulation test is implemented using LTspice and the conducted emissions are compared to variant CISPR standards and switching frequencies in order to show the possible interferences with the other car equipment.**

Keywords—Conducted emissions, electric vehicle, IGBT, MOSFET, power converter, wide-bandgap switches.

I. System Structure

The model simulation in focus contains a battery system, a line impedance stabilization network (LISN) based on CISPR 25, a DC-link capacitor for voltage stabilization and a 3-phase, 400 V inverter. To make the model accurate to reality the circuit parasitics are included such as the board track inductance, passive and active component parasitics. In this study, the emissions related to the use of insulated-gate bipolar transistors (IGBTs), metal–oxide–semiconductor field-effect transistors (MOSFETs), Silicon Carbide (SiC) and Gallium Nitride (GaN) transistors are analyzed in order to provide a comprehensive understanding to the possible interference.

II. System Parameters and Results

All the used switches have the same gate driver – supplied at 15 V – and a snubber, except for the IGBT, which had convergence issues during the simulation with a snubber. The modulation signal used in this study is sinusoidal PWM with two switching frequencies of 24 kHz and 100 kHz presenting two case studies while the output frequency is 400 Hz.

The transistors‘ SPICE simulation files were chosen as level 1 models (the stray capacitance and inter-electrode capacitance parasitics are included in the switch model). This would make the LTspice model not so complicated and yet accurate. Fast Fourier transformation is used for all the emission analyses. For the first case study, the inverter differential mode emissions are obtained while the switches operate at 24 kHz and the results are presented in Fig. 1. The high bandwidth emissions (150 kHz – 30 MHz) are compared with the limits of CISPR 11 class A and CISPR 25.

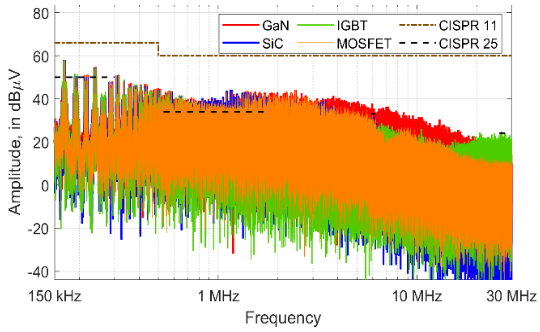

Fig. 1. Emissions of the four switches at 24 kHz and bandwidth 150 kHz–30 MHz compared with CISPR 11 and CISPR 25 limits.

For the second case study, a 100 kHz switching frequency is applied and the emissions are also compared to CISPR standards, as shown in Fig. 2. The low bandwidth emissions (9 – 150 kHz) are also obtained, but not displayed here.

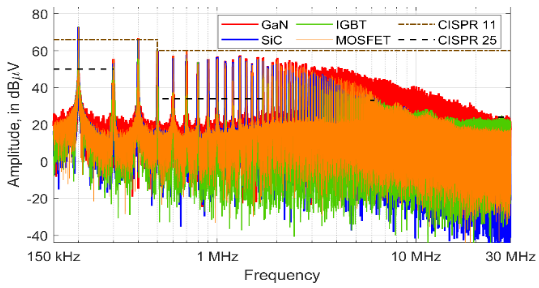

Fig. 2. Emissions of the four switches at 100 kHz and bandwidth 150 kHz–30 MHz compared with CISPR 11 and CISPR 25 limits.

III. Conclusion

This case study shows the prediction of conducted emissions by SPICE simulations and the possible interference in electrical vehicles under the influence of the utilization of each switch type. The emissions at high-frequency bandwidth require mitigation in order to evade any interference with the peripheral vehicle equipment and are highly dependent on the switching frequency.

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