Investigation on Electromagnetic Compactibility Prominence of DC to DC Converters in Electric Vehicle Application

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***Abstract*— Digital Modernization and Digital transformation have become a predominant source of electromagnetic interference (EMI) in today's world. The DC-to-DC Converters market is also expanding due to the emergence of digital market. DC to DC converters produce a lot of EMI and affect the performance of neighbouring sensitive systems. . It is very important to comply with specifications to ensure electromagnetic compatibility (EMC) standards by prioritizing the sustainability and incorporating the social responsibilities for the human well-being. It's really a great challenge to the design engineers to give a best solution to EMI and at the same time producing a cost effective system. During the development of a new system itself at most care need to be taken to prevent EMI. Numerous design methods, simulation tools are available to predict the noise level and provide feasible/reliable solutions to the problems at low cost. In-spite of that, there are some deviations in the end results in reality compare to the simulated values. This research paper focusses on the quick review of Electro Magnetic Interference, EMC standards as well as the comparative analysis of simulated and experimental EMI measurements of a DC-DC converter.**

Keywords— Electromagnetic Interference (EMI), Electromagnetic Compatibility (EMC), DC-DC Converters, LTspice, CE -LISN (Line Impedance Stabilization Network), Common Mode Choke (CMC) coil, wiring harness model.

I. INTRODUCTION

Electric vehicles are gaining worldwide attention for their environmental benefits. Energy conservation is made possible by electric vehicles. DC–DC converter is widely used for a wide range of applications including bio-medical, transportation, telecommunication, computer peripherals, robotic actuators, electrical vehicle, and renewable energy power systems.

Electric vehicles require high power DC-DC converters for power supply. DC-DC converters in electric vehicles are used to boost the fuel cell voltages and to regulate the DC-link voltage when the charger connects the fuel cell. DC-DC converter will generate high electromagnetic interference (EMI) during operation. Electromagnetic interference is becoming a major issue with the operation of electronic equipment and systems. EMI is limited for electric vehicle. Electromagnetic interference is the unfavorable effect of undesired electrical noise transmitted through conduction (through cables or conductors) or radiation (through air). The main source of noise was identified as EMI conducted emission at the subsystem level.

DC to DC converters are gaining popularity in a variety of industries, including automation, motor control and drives, electromobility, electric vehicles, smart grid, renewable energy and power management, and so on, due to their excellent quality, compact size, light weight, dependability, and efficiency. Almost all portable devices contain DC to DC converters. Randomized switching systems have become more popular in recent decades as a result of increased converter efficiency, lower switching noise and harmonics, and improved EMC through EMI reduction.

Electromagnetic compatibility (EMC) has been widely employed to address conducted EMI problems in electronic applications for many years. EMC control is achieved by following proper design procedures, using high-quality components, and testing the equipment. Such conventional practices have been demonstrated to be successful in laboratory tests. Hence it's decided to design and install suitable filter for the electric vehicle. This research paper describes how simulation is used to measure electromagnetic noise which helps to modify the design of a DC-DC converter as well as EMI filters to reduce the Conducted emission (CE) in an Electric vehicle to achieve electromagnetic compatibility based on CISPR 25, EMC standards.

This paper is instructed as follows. Section II presents the EMI and EMC standards available in the market. Section III presents the different case studies of the DC to DC Converter under consideration for EMI analysis. In Section IV presents the comparative analysis. In Section V describes the conclusion of the study. Future work are drawn on the last section.

II. EMI AND EMC STANDARDS

Rising standards of living develops a growing awareness about Electromagnetic Interference (EMI) issues and Electromagnetic Compatibility (EMC) standards among the consumers. The emissions are of two forms: conducted emission and radiated emission. The EMI can never be fully eliminated; however, they can be attenuated to levels, conforming to regulatory limits. Conducted noise has two major contributors. The first result from reflected ripple current and the second is due to the output voltage switching noise. Though, switching converters produce a significant amount of switching noises, they are desired to operate in EMC sensitive applications. The device has to satisfy, not only electrical characteristics, but also EMI regulations like CISPR, IEC, FCC, VDE, European (EN) and Military (MIL) standards etc.

The CISPR 25 standard refers to the "protection of onboard receivers," with conducted noise measured over a frequency range from 150 kHz to 108MHz in specific frequency bands. These frequency ranges are dispersed across the AM broadcast, FM broadcast and mobile service bands. CISPR 25 specifics conducted emission limits for peak (PK), quasi-peak (QP), and average (AVG) signal detectors. This standard applies to all electronic/electrical components intended for use in cars, boats, and internal combustion engines. A good approach for decreasing CE levels has been discovered because the peak and average detectors are below the applicable constraints of the CISPR 25 Standard.

III. CASE STUDIES

Case 1

The CE -LISN (Line Impedance Stabilization Network) approach as stated in the CISPR 25 standard - Three-LISN and EMC filter are added to the DC-DC converter in LTspice. Fig. 1 shows the schematic diagram of buck boost DC to DC converter connected across the 3 LISN along with EMI filter, which is considered as case 1. The noise measurement is done using FFT analysis and the measured noise for case 1 is shown in Fig. 2. The interference voltage level versus frequency was plotted between 9 KHz and 10 MHz This method was good because of the peak and average detectors below the limit between 500 KHz-2 MHz as compared to the CISPR 25 Standard's equivalent limitations (CE-LISN method).

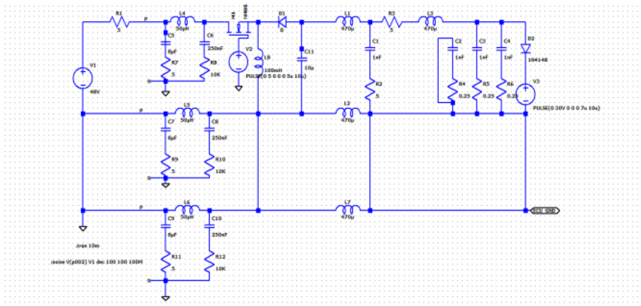

Figure-1 Schematic diagram of 3LISN+EMC Filter

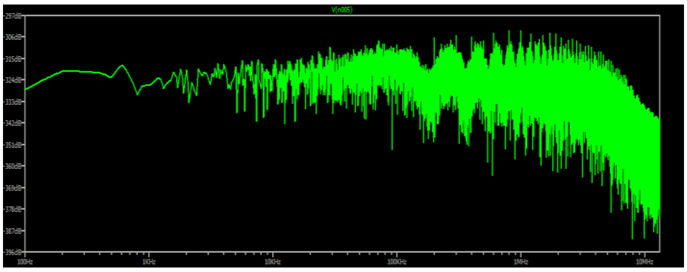

Figure-2 FFT analysis with 3LISN+EMC

Case 2

To suppress common mode noise, common mode choke (CMC) coils are used. CMC is added to the EMC filter which is used to improve the simulation result, here the result has been recorded. The peak and average detectors are below their corresponding limits from the CISPR 25 Standard, a good solution to reduce CE levels is obtained. CMC coils are used to suppress common mode noise. Fig. 3 shows the schematic diagram of buck boost DC to DC converter connected across the CMC filter along with EMI filter, which is considered as case 2. The noise measurement is done using FFT analysis and the measured noise for case 2 is shown in Fig. 4. But the component is being expensive and occupies large area.

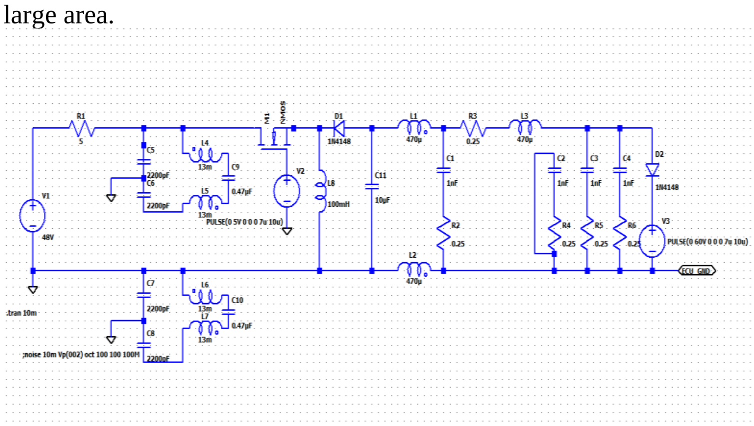

Figure-3 Schematic diagram of CMC Filter

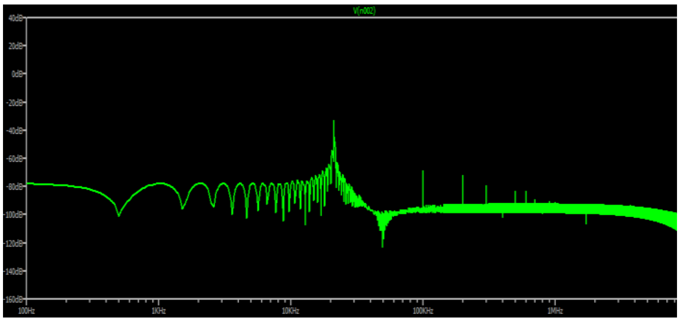

Figure-4 FFT analysis with CMC of 470 µF

Case 3

CST Microwave Studio tool, a wiring harness model is exported for use in LTspice. A DC-DC converter is designed with an input of 48V. The load is simulated now using R=272 mΩ, L=0.8 µH and C2=C3=100 pF. In order to improve the CE test, an extra low voltage (LV) ground has been added to the schematic. To simulate a connection between the ECU (Electronic Control Unit) and LV ground, these components were used C=60µF in series with L=0.166nH and R=0.75MΩ. The result has been recorded. Fig. 5 shows the schematic diagram of buck boost DC to DC converter connected across wiring harness with GND LV along with EMI filter, which is considered as case 3. The noise measurement is done using FFT analysis and the measured noise for case 3 is shown in Fig. 6. A good solution to reduce CE is obtained.

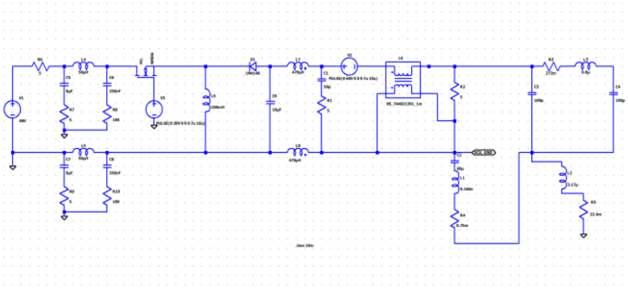

Figure-5 Schematic diagram of wiring harness with GND LV

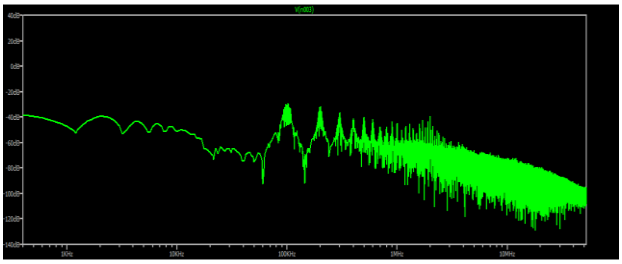

Figure-6 FFT analysis with wiring harness

IV. RESULTS AND DISCUSSION

Comparing all the three cases it is clear from the table 1 by using wiring harness, the noise has been reduced. In case of using 3 LISN, the noise has increased. Since there are lots of parasitic components involved, the size of 3LISN model has also been increased. In the EMI study, the system components were given varied weights, and certain noise sources did not play a substantial part in the CM noise flow Based on the impedances and noise analysis of the EMI equivalent circuit, the system could not fulfil the CISPR-25 standard without EMI filter improvement and the installation of extra components.

CMC reduces the CE level to a great extent but CMC also occupies a large area in PCB board and it is also expensive. In the future work CM noise reduction mechanism could be verified experimentally and this research will also contribute to development of noise reduction method. The results of this study support to keep the buck boost converter's emissions to a minimum. It's important to note that each system and power converter requires distinct EMI reduction methodologies and EMI filter optimization, and that improved performance and efficiency necessitates a balance between filter size and additional components.

Methods	**Frequency Band 9KHz-10-MHz**	**Peak (dBµV)**
Case 1- 3LISN	**8.4KHz**	**-327**
Case 2- CMC	**16KHz**	**-98**
Case 3- Wiring harness	**10.9KHz**	**-30**

Table 1: Comparison of three cases

V. CONCLUSION

The conducted emission from Buck Boost DC to DC power converter has been analyzed through LTspice simulation. An overview of buck boost converter topologies and EMI /EMC standards were also presented in this paper. When comparing the results, it is clear that the simulated values shows interference in the low frequency range i.e near the switching frequency (9 kHz to around 10 MHz).According to data, under the CISPR-25 standard, no single solution can reduce EMI noise. Combining all of the methods into a system and inserting the required values for the new components in the appropriate locations in the circuit is a very effective technique for achieving the standard limitations. So care must be taken while designing the circuit by considering the parasitic values of the circuit components in order to fulfil the EMC regulations.

V. FUTURE WORK

In the future work, balanced windings should be ensured as much as possible in the design phase to avoid the CMC problems. More switching noise sources and parasites need to be analyzed and modeled. To find the smallest commercial components that meet noise attenuation, stability and efficiency requirements while guaranteeing effective filter damping. The results of numerical simulations will be confirmed by experimental observations in future studies, and the mathematical model will be refined and improved

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