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Global noise studies for CMS Tracker upgrade

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ABSTRACT: The characterization of the noise emissions of DC-DC converters at system level is critical to optimize the design of the detector and define rules for the integration strategy. This paper presents the impedance effects on the noise emissions of DC-DC converters at system level. Conducted and radiated noise emissions at the input and at the output from DC-DC converters have been simulated for different types of power network and FEE impedances. System aspects as granularity, stray capacitances of the system and different working conditions of the DC-DC converters are presented too. This study has been carried out using simulation models of noise emissions of DC-DC converters in the real scenario. The results of these studies show important recommendations and criteria to be applied to integrate the DC-DC converters and decrease the system noise level.

KEYWORDS: Particle tracking detectors; Voltage distributions; Detector grounding; Front-end electronics for detector readout

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Contents

1 Introduction

The future generation of the tracker system for the Compact Muon Solenoid (CMS) plans to develop a new power scheme based on switching technology. This scheme includes DC-DC converters to turn the HV into LV to feed the front-end electronics (FEE) within the tracker system. As the switching stage intrinsically generates noise level (in both near and far fields) which is not compatible with the sensitive electronics used in the experiments, a detailed knowledge of this noise is required for the integration of the power supplies.

These powering schemes are also characterised by the presence of high magnetic fields inside the tracker volume. Power supply units must operate reliably under high-energy neutron radiation and fringe magnetic fields. These units must also present high efficiency, isolating galvanically the input and output, and coupling a low amount of noise to the surrounding electronic equipment.

As a result, new designs of FEE search for powering schemes in which DC-DC conversion stages are properly integrated within the sub-detector volume with minimum noise emissions. To achieve so, a study and understanding of the noise nature and its effects on the tracker schemes is required. This involves the development of models and simulations of the interface between electromagnetic noise and the powering structure, in which the effect of the network impedance magnitude is considered to be of utmost importance. Indeed, power network and FEE impedances along with system parameters like converters granularity or stray capacitances must be taken into account in order to achieve a good characterization of noise emissions and to improve the integration strategy.

In this paper, the effect of the network impedances in a DC-DC converter and FEE scheme is studied. The approach includes firstly the modelling of the power network impedance, the identification for the inputs and outputs of the scheme under study and the parameters to be considered

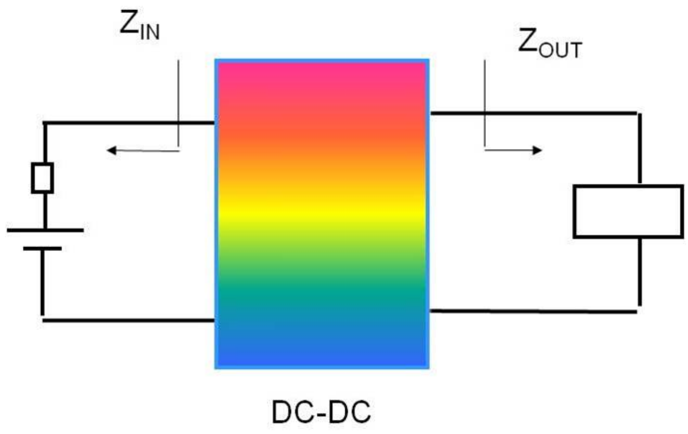


Figure 1. DC-DC conversion layout.

in order to analyse the sensitivity on the noise emissions. Following to this, a set of simulations is performed to obtain the different effects of the network impedance on the noise at system level. The results and concluding findings are aimed at contributing to the definition of design strategies to increase the immunity of the Detector-FEE unit within the tracker upgrade.

2 Power network impedance characterization

2.1 System layout and noise emissions

DC-DC converters emit radiated and conducted noise at the output and input, which can decrease the performance of the FEE. The input and output currents in DC-DC converters contain not only the DC components that contribute to the real power transfer, but also a large amount of harmonic components of the switching frequency. These harmonic components propagates out of the power supply as conducted electromagnetic interference emitted through the input and output cables [1, 2]. The input/output is composed by two conductors (+, -) and a reference and the interference signals can be decomposed into two modes of propagation: Differential mode (DM) and Common mode (CM). The DM noise is the direct result of the fundamental operation of the switching converter, whereas the CM noise often includes parasitic capacitive or inductive coupling.

The first stage in the integration studies focus on a better understanding of the impedance characteristics within the power network scheme and its connection to the FEE structure and adjoining components. These impedances define the levels of conducted and radiated noise emitted by the DC-DC power converters at system level. Several proposals concerning system layout can be found, however in terms of impedance they all can be represented with the scheme on figure 1, depicting a DC-DC power system connected to the primary source (input) and the load (output).

Two impedances are outlined: the input impedance (related to the power bus feeding the converter), and the output impedance (corresponding to the electronics fed by the converter). These impedances are analyzed in both differential (DM) and common (CM) modes of noise propagation.

Low DM impedance is found at the input and output of the DC-DC converter because the large amount of capacitors connected to the tracker power network (input) and FEE decoupling

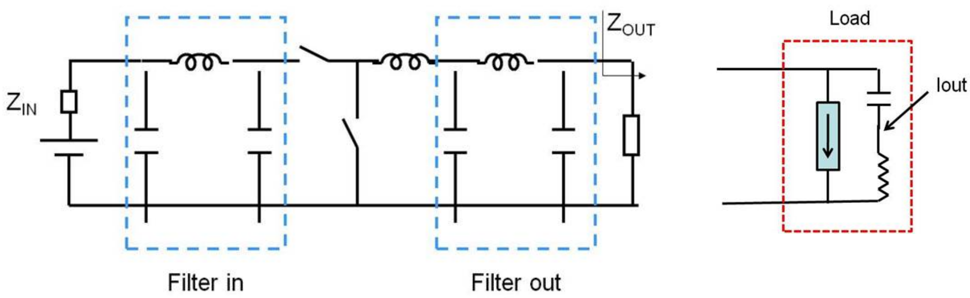


Figure 2. DC-DC converter & load model scheme.

capacitors (output). The characteristic and distribution of these capacitors define this impedance. On the other hand, CM impedance at the input of the converter is defined by the ground connection of the negative line of the power network, whereas the connection between the DC-DC and FEE as well as the parasitic components of the FEE such us the stray capacitance between the DC-DC board and carbon fiber structure, defines the CM impedance at the output.

2.2 DC-DC converter & load model

A model for the DC-DC converter has been developed in PSPICE to study the effect of the impedance on noise emissions in both time and frequency domain. This model is based on DC-DC converters developed by several groups [3, 4]. Figure 2 shows a simplified scheme of the model under study.

The load is modelled as a current source representing the consumption of the converter, in parallel with a resistance-capacitor branch. The simulation model includes all parasitic components associated to the converter and load.

3 Simulation results

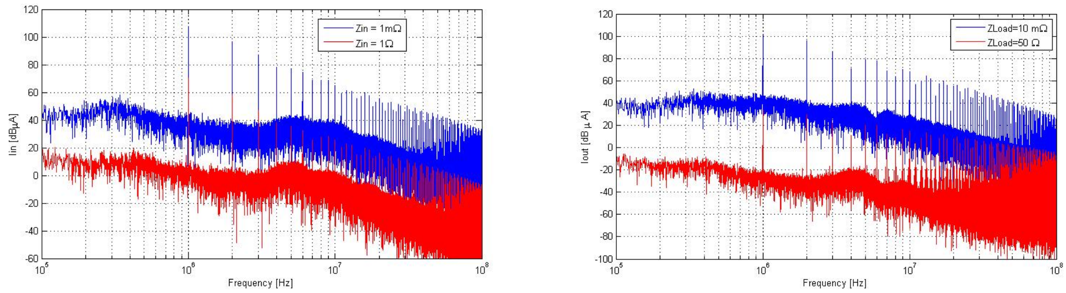
3.1 Effect of input and output impedances

For the input emissions from the DC-DC converter in DM mode, the input impedance play a significant role since the large amount of capacitors connected to the power network makes the impedance lower (in old trackers there can be more than 30 capacitors, resulting in more than 100 μf total capacitance). Figure 3a shows the input DM noise emission for input impedance of 1 mΩ and 1 Ω. The strong effect of the input impedance value can be seen on the spectrum where, keeping the same profile, the levels of emitted noise are significantly higher for the smallest value of impedance.

The DM noise output emissions from the DC-DC converter are also defined by the impedance connected at the output (filter and load). Figure 3b depicts the results with 10 mΩ and 50 Ωsghere again a strong impact on the DM noise emission spectra at system level is observed.

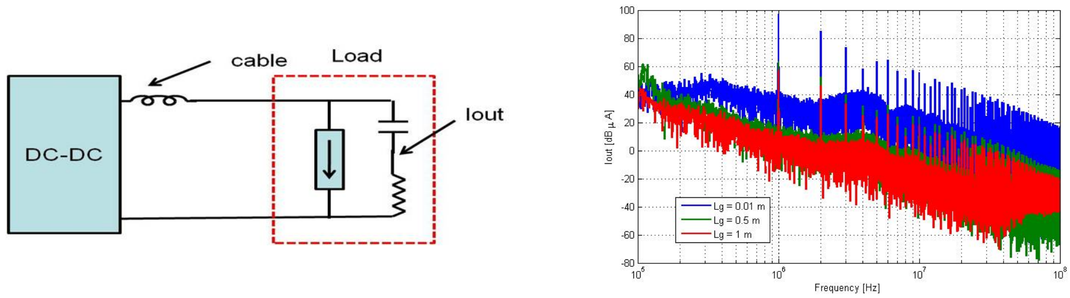
3.2 Influence of cable length

The DC-DC converter is expected to be connected to the FEE via short cables (figure 4a). Different cable lengths (Lg =10 cm, 0.5m and 1m) have been evaluated in the model to account for this effect,



(a) (b)

Figure 3. DM noise emissions at input (a) and output (b) with different impedances.



(a) (b)

Figure 4. DC-DC, cable and FEE simulation model (a) and DM noise output emissions for different cable length - Lg (b).

which is reflected on the DM noise emissions (figure 4b). In the three cases, the values for output load and impedance are fixed (Iout=3A, Zout=10 mΩ). The reference inductance value for the cable is chosen from old tracker systems as 0.5 mH/m. Figure shows that the profile of the spectra remains similar, but shifted upwards as the cable length decreases.

3.3 Effect of granularity

The granularity of the conversion stage refers to the output current as well as the number of DC-DC converters connected to the same bus. In this case, different topologies have been simulated to study its effect on the DM noise spectra. Figure 5a shows the input emissions when the output current is 1 A or 5 A. In the same way, the input emission spectra is obtained for 1 and 4 DC-DC converters connected in parallel (synchronized switching frequency) as shown in figure 5b. In all the cases the input and output impedances have been set to 10 mΩ.

3.4 CM noise emission at system level: stray capacitances

The system layout of DC-DC converter topology may include cooling blocks close to the DC-DC, a frame support made of carbon fiber or inductor shields. These elements may contribute to the appearance of stray capacitance phenomena which in turns leads to CM noise emissions. These emissions may also be defined by the transitions in the switching stage, which depend on

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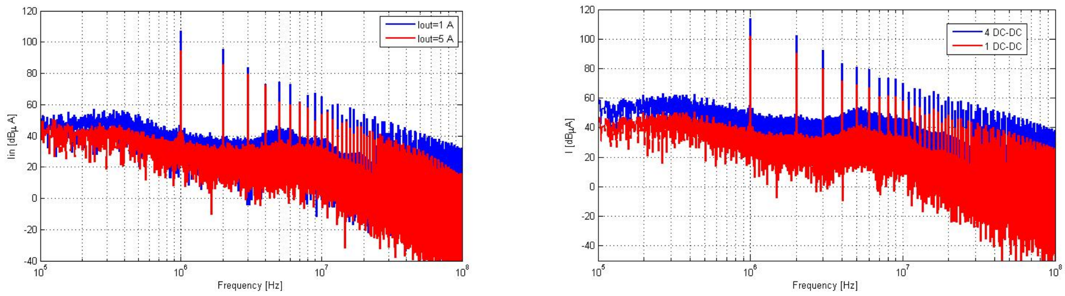
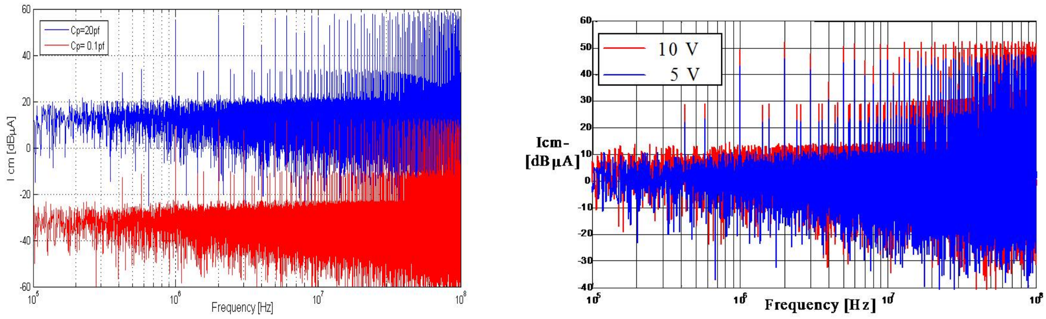


(a) (b)

Figure 5. DM noise input emissions for different output currents (a) and number of DC-DC (b).



(a) (b)

Figure 6. CM noise emissions for different stray capacitances (a) and input voltages (b).

the input voltage in the bus. These parameters are included in the modelling scheme to study the CM emissions.

Though the value of the stray capacitance is difficult to define, several values have been used ranging from 0.1 pf to 20 pf. The result is shown on figure 6a for these two values.

Comparing figure 6a with the DM spectra, a different profile is found for the CM emission. In this case, the noise does not decrease with the frequency, but it remains at similar levels, which results in a higher ability of CM phenomena to radiate at high frequencies. A similar effect is observed in figure 6b, where different input voltages are chosen (5 V and 10 V bus voltage).

4 Conclusions

The results obtained in this approach have revealed a strong effect of input/output impedances as well as system granularity on the DM emission noise. In frequency scope, a significant difference in the current levels has been observed, remarking the important role the impedance plays in the noise emission at system level. Simulations of CM noise transmission have also shown an important effect of stray capacitances and input bus voltage.

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References

[1] F. Arteche and C. Rivetta, *EM immunity studies for front-end electronics in high-energy physics experiments*, in the proceedings of the *EMC Europe* 2004*, International Symposium on Electromagnetic Compatibility*, September 6–10, Eindhoven, The Netherlands.

[2] F. Arteche, C. Rivetta and F. Szonsco, *Electromagnetic Compatibility Plan for the CMS Detector at CERN*, in the proceedings of the 15th *International Zurich Symposium & Technical Exhibition on Electromagnetic Compatibility*, February 18–20, Zurich, Switzerland (2003).

[3] K. Klein et Al., *Experimental studies towards a DC-DC conversion powering scheme for the CMS Silicon Strip Tracker at SLHC*, in the proceedings of the *Topical Workshop on Electronics for Particle Physics (TWEPP*2009*)*, September 21–25, Paris, France (2009).

[4] G. Blanchot et al., *System integration issues of DC to DC converters in the SLHC Trackers for the SLHC*, in the proceedings of the *Topical Workshop on Electronics for Particle Physics (TWEPP*2009*)*, September 21–25, Paris, France (2009).

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