Simulation Optimization and improvement of conducted emission for DC/DC converter in electric vehicle

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Abstract. Based on the simulation of conducted emission noise voltage of electric vehicle DC/DC converter, this paper uses a co-simulation analysis method with HFSS-Simplorer, to predict the optimization and improvement impacts by adding magnetic core into the full 3D model, or changing the value of lumped capacitor in the simulation circuit. According to the difference of the simulation results, the effectiveness of improvement can be determined quickly, it provides an important support for the location and rectification of component level electromagnetic interference problem of conducted emission in DC/DC converter.

1. Introduction
Aiming at the electromagnetic compatibility (EMC) performance of conducted emission (CE) of DC/DC converter in electric vehicle (EV), at present, the product engineers are all producing the product samples and testing them, if they failed, they will change and repeat the test until it passes. But using the co-simulation analysis method can quickly predict the results and find the best solution by comparing the simulation results of various improvements, which can reduce the difficulties of product rectification.

2. Initial simulation results
After the calculation of the co-simulation circuit, the result of CE voltage method of DC/DC converter are obtained. The full 3D model of DC/DC converter is shown in Figure 1, and the simulation result is shown in Figure 2, Compared with the limit requirement in the standard, it is found that in the almost full frequency band, the simulation result (the blue curve) beyond the limits (the red one), and rectification should be taken.
Figure 2. Simulation result without rectification

Under the current simulation condition, the near E field of the DC/DC converter 3D model is shown in Figure 3. There is no obvious strong area of E field around the core transformer and the magnetic inductor, so the shield can’t be added, and mainly consider adding the filter capacitor and magnetic core at the output.

Figure 3. The near E field of DC/DC converter 3D model without rectification

3. Improvements

3.1. Add the filter capacitor at the output of the simulation circuit
It is well known that adding a filter capacitor at the output of the DC/DC converter circuit can suppress the CE noise voltage from the experiences, but it is not clear how much capacitor to add and the effect of the suppression. As shown in the co-simulation circuit in Figure 4, the blue part is the filter capacitor, which can be changed to the different capacitance easily and the results are shown from Figure 5 to Figure 7.
Figure 4. The full co-simulation circuit of CE voltage method of DC/DC converter in EV

Figure 5. Output frequency-domain noise voltage curve with 4nF filter capacitor

Figure 6. Output frequency-domain noise voltage curve with 10uF filter capacitor
Figure 7. Output frequency-domain noise voltage curve with 100uF filter capacitor

From Figure 5 to Figure 7, the effect can be shown clearly that high frequency CE noise voltage can be suppressed about 30dB by adding 4nF capacitor, the CE noise voltage in the whole frequency band can be suppressed about 40dB by adding 10uF capacitor or more.

3.2. Add the core in the full 3D simulation model

Another way to suppress the CE noise voltage is adding the magnetic core on the output busbar in the full 3D model of DC/DC converter. The grey part is the magnetic core and the orange parts are the input/output busbars, as shown in Figure 8.

Figure 8. The full 3D model of the DC/DC converter with/no magnetic core

Figure 9. The output frequency-domain voltage curve of DC/DC converter with/no magnetic core
From Figure 9, the blue curve is the output frequency-domain voltage curve of DC/DC converter with magnetic core and the red one is without magnetic core. It is found that the CE noise voltage can be suppressed about 10dB by adding magnetic core on the output busbar in the full 3D model.

4. Conclusion
The co-simulation analysis method with HFSS-Simplorer can not only accurately predict the CE performance of DC/DC converter in EV, but also can carry out various improvement and quickly predict the effect of them. The CE noise voltage of high frequency band can be suppressed about 30dB by adding 4nF capacitor, the CE noise voltage in the whole frequency band can be suppressed about 40dB by adding 10uF capacitor or more. And also the CE noise voltage can be suppressed about 10dB in the whole frequency band by adding the magnetic core on the output busbar in the full 3D model.

To sum up, by modifying the 3D model or changing the parameters in the CE co-simulation circuit of DC/DC converter, the effect of each improvement can be predicted accurately, it is very convenient, fast and accurate. It can significantly shorten the product development cycle, especially suitable for the early stage of product development and rectification process.

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