Research on modeling and conduction disturbance simulation of secondary power system in a device

Xu Ding\textsuperscript{1,2}, Zhi-Yong Yu\textsuperscript{1} and Rui Jin\textsuperscript{1}

\textsuperscript{1}Department of Information and Communication Engineering, Xi’an Research Institute of High Technology, Xian 710025, China
\textsuperscript{2}Beijing Institute of Remote Sensing Technology, Beijing 100854, China

Abstract. To find electromagnetic interference (EMI) and other problems in the secondary power supply system design quickly and effectively, simulations are carried out under the Saber simulation software platform. The DC/DC converter model with complete performance and electromagnetic characteristics is established by combining parametric modeling with Mast language. By using the method of macro modeling, the hall current sensor and power supply filter model are established respectively based on the function, schematic diagram of the components. Also the simulation of the component model and the whole secondary power supply system are carried out. The simulation results show that the proposed model satisfies the functional requirements of the system and has high accuracy. At the same time, due to the ripple characteristics in the DC/DC converter modeling, it can be used as a conducted interference model to simulate the power bus conducted emission CE102 project under the condition that the simulated load is full, which provides a useful reference for the electromagnetic interference suppression of the system.

1. Introduction

The working condition of the seeker is complicated, the integration is high, and the sub-systems are affected by each other, which makes the electromagnetic compatibility requirement very high. The secondary power supply system is the key power supply part of the seeker. Its power bus is unstable, and DC / DC converter in the DC conversion can easily introduce or form a variety of interference noise \cite{1}. The problem of electromagnetic interference in the secondary power system (conducted interference, radiation interference) is directly related to whether the sub-system on the seeker can work normally and through the corresponding index test.

For the secondary power system performance testing and electromagnetic interference analysis, at present, testing after forming the product is the main mean, which results many of the improvements cannot be added to the design. If you can build a simulation model with the electromagnetic characteristics and complete function of the secondary power supply system, you can use the model instead of the actual system to analyze its performance \cite{2}, but also can be used as the conduction interference model, to analyze the electromagnetic interference generated by the system and predict the actual test results and timely detection of problems, improve the design.

In this paper, Saber software is used to build the simulation model of the secondary power supply system. The key link is to model the domestic components of the system and use the method of parametric modeling and Mast language to establish DC / DC converter Model. Finally, the system model is simulated with full load and the results show that the electromagnetic characteristics of the system, which has certain guiding significance for passing CE102 \cite{3} project and the improvement of electromagnetic compatibility.
2. Introduction of the system

The secondary power supply system consists of a DC / DC converter, a Hall current sensor, a power supply filter and different types of load. The secondary power supply system should have the following functions: the Hall current sensor samples the input current of the power supply circuit, and converts it into voltage output to achieve the primary power input monitoring function; different types of DC / DC converter +28 V regulator input into 5V, 15V and 8V regulator output to supply different loads, but also with short circuit protection and other functions; EMI filter constitutes an input filter circuit, suppresses the input crosstalk, while preventing electromagnetic interference generated by DC / DC converter module coupled to power supply. The model block diagram shown in Figure 1:

![Block diagram of secondary power system](image)

Figure 1. Secondary power system model block diagram

3. Component modeling

3.1 DC / DC converter Modeling

DC / DC converter is the core components to achieve secondary power supply function, in addition to the completion of the basic DC / DC conversion, but also should have the secondary power supply system requirements of the voltage input protection, short circuit protection and other functions [4]. How to establish a DC / DC converter model with full function and characteristic parameters conforming to the specification and reflecting its ripple characteristics has always been the focus and difficulty of component modeling. In this paper, using parametric modeling and Mast language combination method to model it based on Saber software dcdc_1_os template. The main steps are as follows:

1. Put the nominal input / output parameters (voutnom, vinnom), input characteristic parameters (input), output characteristic parameters and transient inputs specified in the component data sheet into the dcdc_1_os template.

2. According to the DC / DC converter ripple characteristics, with Mast language for the original template to add ripple function, and according to the actual situation to set its switching frequency range, internal capacitance, resistance and other devices, as shown in Figure 2 (a). After adding the ripple function, the property block diagram shown in Figure 2 (b), setting the parameters ripplepeak, ripplefreq value.
3.2 Hall current sensor modeling
In the secondary load system, the Hall current sensor acts as a current sensing element to convert the primary input current value into a voltage output to detect the input current. The Hall current sensor (HDC10A) used here measures the current range from 0 to 10A and operates from ±12V~±15V. It can transmit the current of an arbitrary waveform in a certain frequency band without distortion. It is built using the Saber software macro modeling method, the model is shown in Figure 3.

3.3 Power filter modeling
The power supply filter (passive EMI filter) in the secondary power system has a different nature, which can suppress the interference of the primary power supply and reduce the high frequency reflected noise [5] of the DC/DC converter coupled into the power supply line. To meet the requirements of CE102 (Power Line Conduction Emission) in GJB151B-2013, and reduce the adverse impact of other sub-systems. Typical power supply filter contains common mode interference and differential mode interference in two parts of the suppression circuit.

Figure 4 for the passive filter circuit principle circuit. Lx is equivalent to the differential mode choke and with the differential mode working capacitance Cx constitute the differential mode suppression circuit together. The parallel grounded capacitance Cy acts as a bypass for common mode noise, can effectively suppress common mode interference [6]. In the design of the power supply filter
in Figure 5, according to the circuit schematic, the common mode interference is mainly considered, and because the secondary power supply circuit has multiple grounds in design, the differential mode interference suppression uses only one filter capacitor. As the missile environment limits the filter size, only two-stage common-mode filter circuit is used.

![Figure 4. Passive filter circuit schematic diagram](image)

![Figure 5. Power filter model](image)

4. Simulation results and analysis

4.1 DC / DC converter simulation and analysis
Using a rated power of 25W 28V / 5V DC / DC converter to verify the functional characteristics of the DC / DC converter model from the following aspects:

1. Input and output characteristics. The input voltage in Figure 6 (a) is linearly increasing from 0-60V. From the output waveform, it can be seen that the turn-on voltage vinon = 15.913, turn-off voltage vinoff = 50.09V, which meets the input DC voltage: 16 ~ 50V requirement, DC / DC converter has input voltage protection function. When the converter turning on, the output voltage stabilizes at 5V and the output current stabilizes at 5A.

2. Output voltage ripple characteristics. Figure 6 (b) ripple waveform consistent with the actual test, peak-to-peak value is about 33.2mV, less than the data manual 50mV requirement, the output voltage has a high accuracy.

3. Short circuit protection characteristics. In the simulation experiment process experiment, the load of the converter is gradually reduced to simulate the output short circuit. Figure 6 (c) shows that the converter in the event of a short circuit, when the output current increasing, the converter output current reaches the maximum value of 7.09A and no longer increases, the converter starts the output protection function, the voltage value is gradually reduced to 0.
Figure 6. DC/DC converter model characteristics simulation

4.2 Simulation and analysis of electromagnetic interference in system

The power bus voltage and output voltage by the impact of load fluctuations is small, when the system working properly. The simulation of the secondary power supply system is only under the condition that the load is fully loaded or the seeker is working properly [7], the equivalent resistance of the load is calculated from the rated power of the loads of the receiver, frequency synthesizer, and the actual measured shunt current.

When the load is fully loaded, the current on the secondary power supply system bus and the feedback from the Hall current sensor are shown in Figure 7. It can be seen that the Hall current sensor can reflect the change of the power bus current value accurately, thus verifying the correctness of the Hall current sensor model. However, due to the existence of a delay in the feedback, it can not reflect the surge current [8] on the power supply bus shown in Figure 7. Surge current will affect the normal working of the power system, resulting in great electromagnetic interference, often adding transient suppressors before the power system to overcome the power bus fluctuations, reduce the surge current amplitude and electromagnetic interference level, to improve its electromagnetic compatibility.
Secondary power supply system of three forward output voltage ripple and its spectrum shown in Figure 8, the ripple amplitude is less than 40mV, in line with actual requirements. The simulation results show the electromagnetic characteristics of the secondary power supply system. It can be clearly seen from the spectrum that the frequency of the ripple noise generated by the DC / DC converter with output voltage of +8 V, +5 V + 15 V is 800kHz, 600kHz, 400kHz, which coincides with the switching frequency of the actual set converter.

In the case of full load, CE102 (power line conduction emission) simulation experiment is carried out on the secondary power supply system model with real electromagnetic characteristics and conductive coupling path. Using Saber simulation software, after the time domain transient analysis of the model, the conduction voltage waveform of each node is obtained, and the waveform of the power supply bus in the frequency range of 10kHz ~ 10MHz is obtained by FFT processing. It is worth noting that in the FFT transformation process, we must set reasonable simulation start and end time steps, select the correct ripple period, otherwise it will cause the simulation spectrum distortion.

The red polyline in Figure 9 is the CE102 limit, the upper red spectrum is the pre-improved spectrum, and the lower black spectrum is the spectrum after adding the power supply filter. In the process of setting switching frequency, only 800kHz, 600kHz, 400kHz were selected. It can be seen from the spectrum that the electromagnetic interference signal on the power bus contains the same frequency Reflection noise and its harmonics as these three switching frequency produced by DC / DC

**Figure 7.** Power bus current and feedback voltage waveform

**Figure 8.** System forward output voltage ripple and voltage spectrum
converter, making its spectrum similar to the comb spectrum, there are about 200 kHz intervals between the signals. It can be seen that switching frequency and its harmonics are the main interference components of the secondary power supply system, and this interference can’t be completely eliminated [9]. Therefore, in the process of secondary power supply design, taking into account the switching frequency settings is necessary, so as to avoid the system operating frequency and receiver and other sensitive equipment, the receiving frequency range, making the normal operation of the system is not affected.

Figure 9. Power system bus CE102 simulation spectrum

5. Conclusion
The model of the secondary power system is constructed by using the modeling method described above, and the spectrum obtained by the model simulation has high similarity with the spectrum of the actual CE102 test. The secondary power supply model can be used as the conduction interference model to analyze electromagnetic interference of system. After adding the designed power supply filter, the level of the interfering signal is reduced by about 15dBμV compared to the non-filter, which provides a reference for the seeker to pass the CE102 index test.

References
[1] LU Hong-min, YU Zhi-yong, LI Wan-yu. 2010. Engineering Electromagnetic Compatibility[M]. Xi’an: Xidian University Press.
[2] LIU Yun-sheng, CHEN Hua-qing. 2008. A framework of multidiscipline system-level simulation evaluation for marine propulsion system argumentation[J]. Computer Simulation, 25(6) 4-6.
[3] GJB151B. 2013. National Military Standard of the People's Republic of China[S]. Beijing: General Armament Department of the People's Liberation Army.
[4] YAN Qun-min. 2012. The Modeling and simulate research on airborne secondary electric power system[J]. Fire Control &Command Control, 37(5) 175-178.
[5] FAN Zhi-yu. 1997. Power line Conduction interference suppression[J]. Electronics Optics & Control, 2(1) 14-19.
[6] ZHENG Min-qi. 2014. A study of component modeling and WCA technique in power supply circuit[D]. Xi’an: Xidian University.
[7] WANG Xue-zhou, ZHANG Xiao-bin, PAN Di. 2013. Modeling and simulation of aircraft tree-stage synchronous generator[J]. Computer Simulation, 30(4) 59-63.
[8] WANG Xiao-peng, YU Dong-jing, QI Xin-da. 2011. Application of DC/DC converter in secondary power for spacecraft[J]. Chin. J. Space Sci, 31(6) 814-820.
[9] TAO Chen-bin. 2008. A research on inhibition technology of common mode EMI in switch mode power system[D]. Tianjin: Tianjin University.