Reduction of Electromagnetic Interference Cuk Converter for Aircraft Application

Agalya V and Sumathi S

Dept. of EEE, Maherndra Engineering College (Autonomous), Mallasamudram, Tamilnadu, India.

ARTICLE INFO

ABSTRACT

A significant increase of the electrical equipment in modern aircrafts is leading to an increase in the demand for electrical power. The usual electrical power distribution in aircraft applications is done via a three-phase 415 V_{ac} grid. A new trend of DC distribution is emerging employing a 270 V_{dc} grid. With the advancement in the power semiconductor devices and power transformers, DC-DC converters are designed with frequency ranging up to MHZ range. Increase in the switching frequency along with the sudden change in the current di/dt or voltage dv/dt generates higher order harmonics which leads to Electro Magnetic Interference (EMI). EMI noise creates malfunctioning of the circuit and also leads to miscommunication within the system and sometimes leads to device failure. Which is an undesirable condition as far as airline is considered. Hence the reduction of EMI noise is of uttermost important. This paper focus on the reduction of EMI using passive filter along with modified PWM carrier modulation technique. A circuit model for the prediction of conducted emissions due to DC/DC converters in an aircraft black box system is proposed and corresponding attenuation method is been analyzed.

I.Introduction

One of the major challenge in the development of power efficient converters depends mainly on minimization of EMI. In recent years, EMI considerations have become more important, because the EMC regulations have become more stringent.

The power density can be reduced by having small size passive/energy storage components like inductors, capacitors, and transformer. Small sized passive components can be obtained by increasing the switching frequency. With the advancement in the power semiconductor switches and the development of PCB power transformers, it is possible to design a small sized, power efficient Dc-Dc converters in MHZ range[1]-[4]. The increased switching frequency range along with the change in current or change in voltage results in generation of harmonics in the devices which results in Electro Magnetic Interference.

The EMI produced in the DC-DC converters is prolonged and it ranges from operating frequency to Several MHZ. EMI occurs by coupling between circuit element through the action of either a magnetic field or an electric field. EMI can be divided in to radiate and conducted EMI.

The conducted EMI is generated due to switching action of semiconductor devices [5]. Electronic converters such as rectifiers and inverters tend to generate high frequency current harmonics at their input and voltage related interference at their output. The voltage related interference may disturb operation of communication and control system in the proximity of converter [6]. High frequency current harmonics of substantial amplitude which are injected back into voltage source can interfere with operation of nearby equipment [7]. The conducted EMI is regulated in the frequency range of 150 kHz to 30 MHz.

This work mainly concentrated on the conducted EMI and its minimization technique. The conducted EMI is generated due to switching action of semiconductor devices. Converters tend to generate high frequency current harmonics at their input and voltage related interference at their output. The voltage related interference causes disturbance in the operation of communication and control system. High frequency current harmonics of high amplitude which are injected back in to voltage source can interfere with the operation of nearby equipment.

Various standards that specify the limit on conducted EMI include CISPR, FCC, IEC, VDE, and military standards [8]. Some principle standards for EMI are given in [9]. The conducted EMI is regulated in the frequency range of 150 kHZ to 30 MHZ.

II. Cuk Converter

Cuk chopper circuit, as the buck-boost series converter, can be viewed by boost and buck series application. Cuk converter was introduced by Dr. Slobodan Cuk from the United States California Institute of Technology. In Cuk converter the control of the IGBT1 is simple and capacitor facilitates the flow of energy between input and output, which helps to reduce the size, increase the power density and buck-boost voltage can be achieved as well. The circuit structure is showed in Fig. 1.
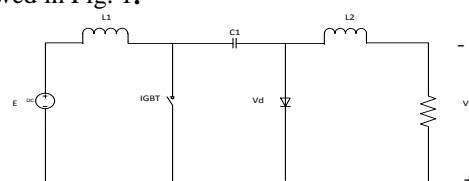

Figure 1. Simulation model of CUK Converter

Tele:
E-mail addresses: agalya.vetri@gmail.com

Cuk chopper circuit, shown in Fig. 1, is different from the buck-boost chopper circuit. Cuk chopper circuit has the following advantages [10]

- It has the same inductance in the input and the output.
- Its input and output currents are continuous.
- The ripples of the input and output currents can be reduced as well.

III. Simulation Analysis of Cuk Converter

The Cuk chopper circuit model is shown in Fig. 2. The parameters are as follow: The inductance is L1=L2=2.35mH, the power E is 100V, the resistance load R is 10 Ω, the filter capacitor C is 100 μF, the inductance L1 is 0.35mH, and the switching frequency of the IGBT1 is 200kHZ
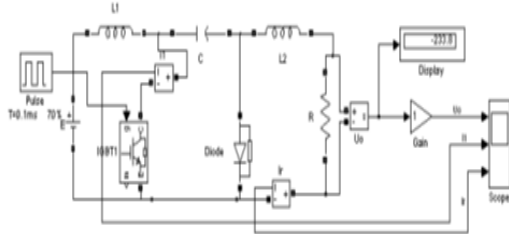

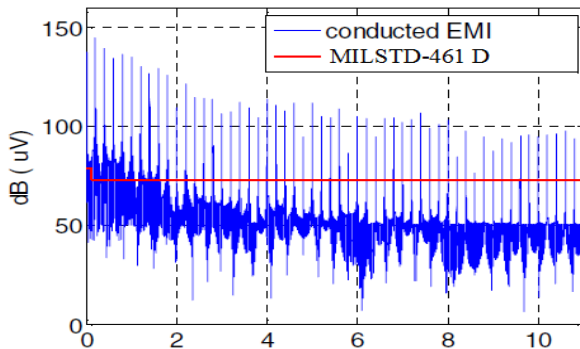**Figure 2. CUK converter simulation model**

Figure 3. Spectrum analyzer waveform

Figure 3 shows the output voltage waveform and spectrum analyzer output waveform. The spectrum analyzer waveform infer that there exist a conducted EMI noise of the order of 142 dB(μv).

IV. Design of Filter

The actual size of the filter depends on the design approach. It also depends on the layout and placement of components used in the filter. The performance of the filter is effected by the mutual couplings of the passive component used in the circuit. However, in general, the size of the filter is expected to decrease with increasing cutoff frequency.

The filter parameters are calculated according to following expressions [1]

$$f_c = f_{SW} \cdot 10^{\frac{ATT}{40}} \qquad (1)$$

Where: Att is the required attenuation
     fC is the cutoff frequency
     fSW is switching frequency

The relationship between the inductance and capacitance of the filter with filter cutoff frequency is given as

$$L = \frac{R_L \cdot \zeta}{\pi \cdot f_C}$$

follows   (2)

$$C = \frac{1}{(2\pi f_C)^2 L}$$

(3)

Where R_L the noise load resistor and ζ is is the damping factor. The damping factor describes the gain at corner frequency as well as time response of the filter. Its value for many actual EMI filters is selected between 0.707 and 1. It is obvious that the values of inductors and capacitors depend on cutoff frequency of the converter. Hence, the converter with higher switching frequency requires smaller EMI filter.

Carrier modulation technique using sine wave as the carrier is employed in this paper. Gate pulse of 200 kHz is generated by comparing the sine wave and constant and is given as switching frequency to the IGBT switch.

The EMI compliance testing is done using a LISN. Essentially, LISN ensures that equipment under test receives the proper dc voltage and current levels and also sees controlled impedance for the ripple frequencies of interest [6]. It performs following functions [10]:

- Attenuates the external interference signal present on main power supply to avoid them interfering from measurements.
- Couples the signals from main port of the equipment under test to the measuring apparatus

The EMI plot after the application of filter along with carrier modulation technique is shown in Figure 5(b) and corresponding output voltage waveform is shown in Figure 5(a). Gate signal for 200 kHz generated using carrier modulation technique is shown in Figure 5(c).

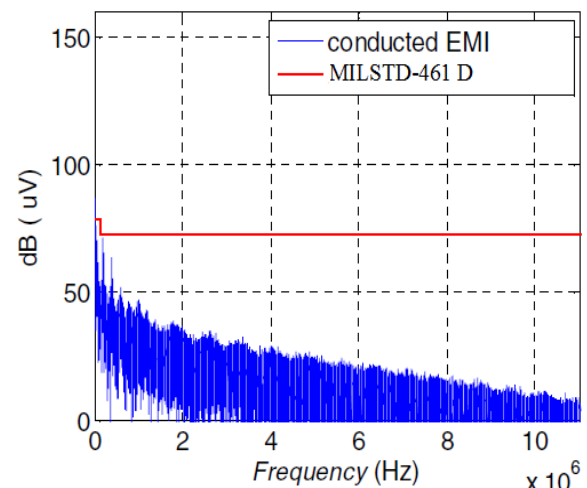**Figure 5(a). Output voltage waveform**

Figure 5(b). Spectrum analyzer output

Frequency spectrum analysis of the same Cuk converter and output voltage by employing passive filter and modified carrier modulation technique infer that the Emi noise has been reduced below 80 dB(μv) and the output ripples also gets reduced
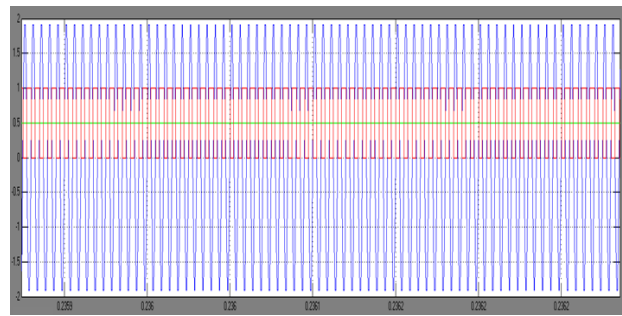
Figure 5(c). Gate signal of 200 Khz

Table 1. Comparison of result

Parameter	EMI standard	Without filter	With filter
Magnitude of EMI noise [dB(μv)]	80	142	70

V. Conclusion

The consequences on implementation of a line filter along with carrier modulation technique for suppressing conducted EMI on CUK converters are investigated. The conducted EMI is estimated for both models and the results for both the converts are analyzed.

References

[1] A.Majid, H.B.Kotte, J.Saleem, R.Ambatipudi, S.Haller, K.Bertilsson, "High Frequency Half-Bridge Converter using Multilayered Coreless Printed Circuit Board Step-Down Power Transformer", 8th Internal Conference on Power Electronics-ICPE 2011 at Jeju South Korea (May28-June 03 2011)

[2] Hari Babu Kotte, "High Speed (MHz) Switch Mode Power Supplies (SMPS) using Multilayered Coreless PCB Transformer technology Passive gate drive circuit using Coreless Printed Circuit Board (PCB) Signal Transformer", Licentiate Thesis 62, Mid Sweden University, ISSN: 1652-8948, ISBN: 978-91-86694-41-8

[3] Radhika Ambatipudi, "Multilayered Coreless Printed Circuit Board (PCB) Step-down Transformers for High Frequency Switch Mode Power Supplies (SMPS)", Licentiate Thesis 61, Mid Sweden University, ISSN: 1652-8948, ISBN: 978-91-86694-40-1.

[4] Hari Babu Kotte, radhika Ambatipudi and kent Bertilsson, "High Speed Series Resonant Converter (SRC) Using Multilayered Printed Circuit Board Step-Down Power Transformer", Holland Conference.

[5] Tim William, "EMC for Product Designers" 4th edition ISBN–13: 978-0-75-068170-4).

[6] Electronics Handbook: Devices, Circuits, and Applications by M. H.Rashid.

[7] Richard Lee Ozenbaugh, Timothy M. Pullen "EMI Filter Design",Second Edition.

[8] N. Mohan, T. Undeland, and W. P. Robbins, Power Electronics. NewYork: Wiley, 1995.

[9] Tim William, "The circuit Designer's companion", Second Edition.

[10] Bob Mammano and Bruce carsten, "Understanding and Optimizing Electromagnetic Compatibility in Switchmode Power Supplies", Texas Instruments Post Office Box 655303 Dallas, Texas 75265.

[11] Chris Likely, "Achieving EMC for DC-DC Converters" http://www.complianceclub.com/archive/old_archive/021132.htm (last accessed February28, 2011)