Frequency Variation Impact on Conducted Disturbances Generated by a SEPIC Converter

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Abstract - Static converters consist of active and passive components (inductance, capacitance), and resistors. However, the use of semiconductor components (MOSFET, IGBT, Thyristor, etc...) in switching are generating rapid variations of voltage (d*v*/d*t*) and current (d*i*/d*t*). This leads to electromagnetic conducted disturbances. In this work, the origins of electromagnetic interferences created by Single Ended Primary Inductor Converter (SEPIC) are presented and determined by using simulation under LTspice software. Then, the impact of the switching frequency variation on the output current was studied, and voltage of SEPIC, as well as on the conducted disturbances in two modes : common mode and differential mode in the time domain and frequency domain.

Keywords – SEPIC converter, Electromagnetic interferences, LISN, common mode, differential mode.

I. INTRODUCTION

DC/DC converters are an important part of the conversion chain. They are widely used in battery connections, photovoltaic systems, wind turbines, hybrid systems and automotive applications [1, 2].

The Single Ended Primary Inductor (SEPIC) converter has offered great benefits for power conversion since it can generates a wide range of output voltage. A SEPIC converter is able to operate in a buck-mode or a boost-mode depending on the duty cycle value. In other hand, the input impedance of a SEPIC converter can be changed by regulating the duty cycle. This property makes the SEPIC converter as an excellent candidate for PV applications because it can match the entire (I–V) characteristic curve [3, 4]. The SEPIC converter has been modeled and controlled by different methods as in [5, 6].

SEPIC exchanges energy between inductors and capacitors to convert one voltage to another. The amount of energy exchanged is controlled by S1, which is typically a transistor as MOSFET as shown in Figure 1 [7-9].

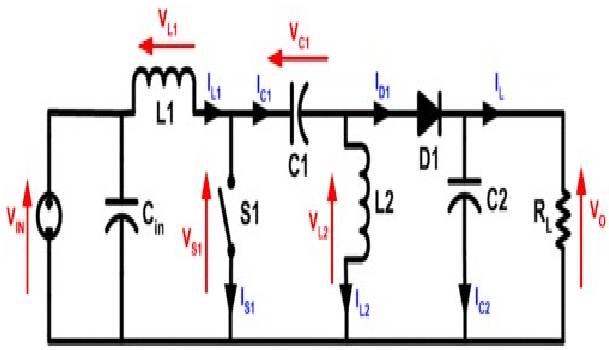

Fig. 1. DC/DC SEPIC Converter [7].

✓ When switch S1 is closed, I_{L1} increases and the current I_{L2} increases in the negative direction. The energy increase the current I_{L1} which comes from the input source. Since S1 is a "*short circuit*" when closed, and the instantaneous voltage V_{C1} is more or less V_{IN}, the voltage V_{L2} is about $-V_{IN}$. Therefore, the capacitor C1 provides energy to increase the current in I_{L2} and thus increase the energy stored in L2. The best way to see is to examine the bias voltages of the circuit in a current continuous state, then close S1.

✓ When the switch S1 is opened, the current I_{C1} even becomes I_{L1} because Inductors cannot have instantaneous current changes. The current I_{L2} continues to flow in the negative direction and reverse never made in direction. From the diagram it can be seen that the negative current I_{L2} is added to the current I_{L1} and it is transferred to the load. From Kirchhoff's law the current shows that $I_{D1}= I_{C1}-I_{L2}$. It can therefore be concluded that, if S1 is open, power is supplied to the load from the two currents of L1 and L2. During the "off" cycle (S1 open) C1 is charged from recharging L1 and L2 during the next "on" cycle (S1 closed) [7-9].

DC/DC converters have generative switching cells of high d*V*/d*t* and d*I*/d*t* slots of smoothing inductances, decoupling capacities and extraneous elements such as parasitic inductances. These variations are responsible for electromagnetic disturbances propagating within the circuit and/or externally [10-15].

II. CONDUCTED DISTURBANCES IN POWER ELECTRONICS

In the context of power electronics, the EMC aspects cover the following essential particularities:

The converters are, at the same time:

- Sources due to phenomena linked to the commutations of power switches.

- Victims because their “command-control” card is usually digital or hybrid.

- Self disturbed by the power section.

The external interferences from natural and industrial environments can also occur [16-18].

A simple case of conducted interferences emitted by a converter is presented in Figure 2. In this figure, V_N represents the disruptive voltage of the converter. Z_1 and Z_2 represent the impedances of the noise propagation paths; Z_{C1} is the impedance between the device and the ground. Resistors R_{C1} and R_{C2} represent the load of the noise. These are normalized resistors (50 Ω) in which the parasitic voltages created in the victim are measured.

The differential mode current I_{DM} flows in the loop between two power lines and the common mode current I_{CM} flows in the overall loop, including the power lines and the ground [19, 20].

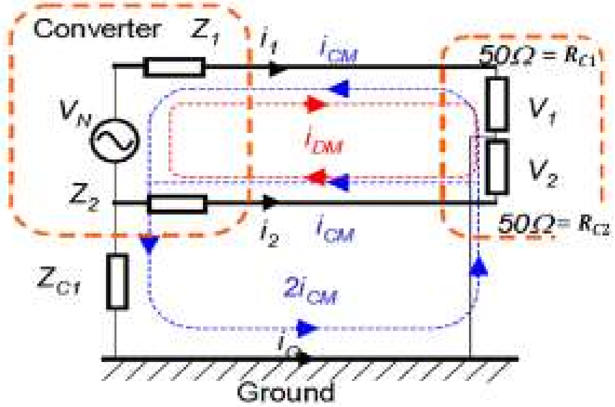

Fig. 2. Pollutions in differential and common modes [19].

This work presents a comparative study on the impact of variation the frequency of switching SEPIC Converter in common and diffeential modes by simulation using Ltspice software.

This paper is organized as follows : in section II, the conducted disturbances in power electronic and two modes of electromagnetic interferences are presented. In section III: the SEPIC converter scheme under Ltspice is presented, then the results are extracted, current and voltage output, common and differential modes with frequency switching is F = 100 kHz in the time and frequency domains. In section IV, the impact of varying the frequency on two modes, keeping the duty cycle at 50% are presented, we chose three frequency: F = 100 kHz, 50 kHz and 20kHz. In section V, the conclusion is drawn from the results of simulation, on the impact of variation of switching MOSFET in the SEPIC converter on conducted disturbances.

III. INTERFERENCES IN SEPIC CONVERTER

In Figure 3, the circuit topology of the SEPIC converter is presented. It consists of two inductances, two capacitors, one MOSFET transistor, one diode, the input voltage source and the load resistance at the output of the converter. The amount of energy exchanged is controlled through switch S1, which is classically a transistor such as a MOSFET, the frequency of switching is F = 100 kHz, and duty cycle at 50%, output voltage is V = 200 V, the load is a resistor R = 40 Ω.

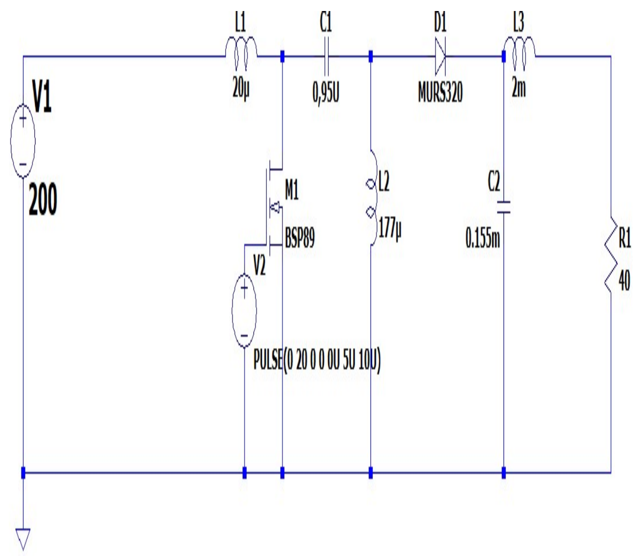

Fig. 3. Diagram of the SEPIC Converter used under Ltspice Software

Figure 4 shows the line impedance stabilizer network (LISN), which must be placed before the converter in order to measure the conducted disturbances in two modes: common mode and differential mode.

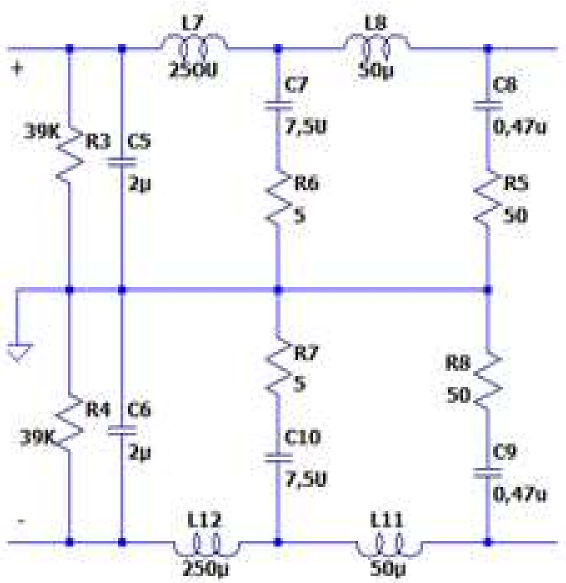

Fig. 4. Line impedance stabilizer network (LISN).

Figure 5 shows the time variation of the control signal of the MOSFET transistor with a duty cycle is equal to 50% of different switching frequencies: F =100 kHz, 50 kHz and 20 kHz.

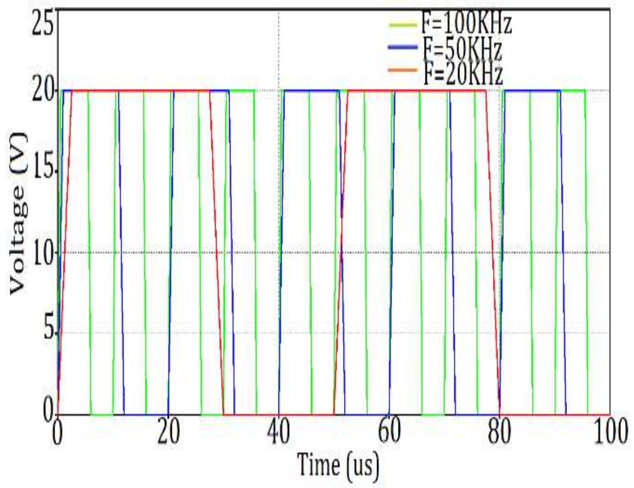

Fig. 5. Control signal of the SEPIC MOSFET.

Figure 6 presents the Frequency variation of control voltage applied on the MOSFET of SEPIC converter, where we can see the peak of each step present the control frequency, then minimization towards high frequencies.

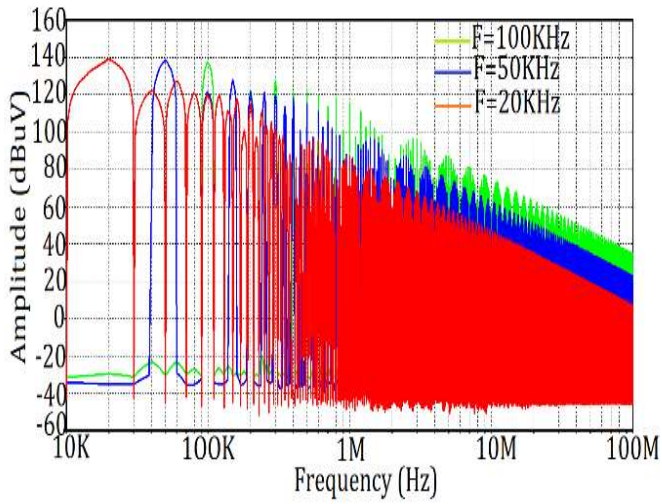

Fig. 6. Frequency variation of control voltage applied on the MOSFET.

Figure 7 shows the voltage at the terminals of the Resistor R, where it is noticed that a voltage stability with the increase of this last with the increase of the frequency of switching the MOSFET.

Figure 8 presents the current circulates in the load, where it is observed so the current increases with the increase of the frequency of signal, of control the MOSFET. For exemple for F = 100 kHz, the current is 1,2 A and the voltage is 50V, therefore a power of 60 W, with the reduction of the frequency, the power also decreases.

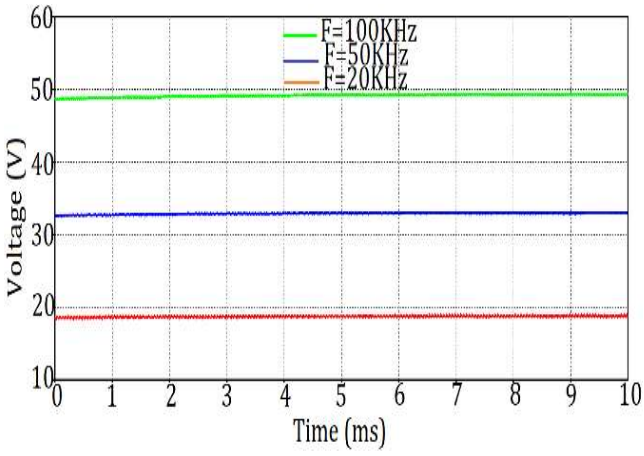

Fig. 7. Voltage at the output of SEPIC converter.

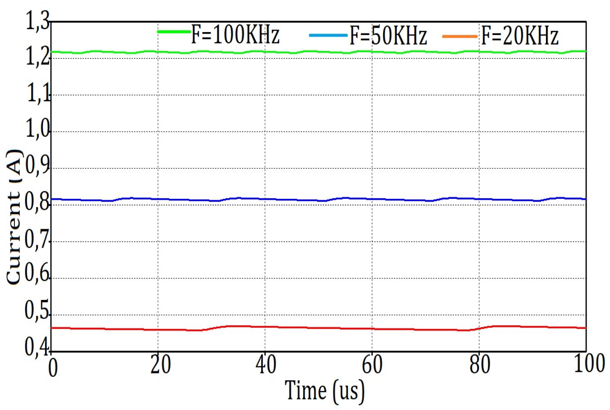

Fig. 8. Current flows through the load.

Figure 9 presents the conducted disturbances in common and differential modes in the temporal range, where we notice that the noise in the differential mode is greater than the common mode, with a peak up to -5.5 V, while the common mode is of about -3.6V.

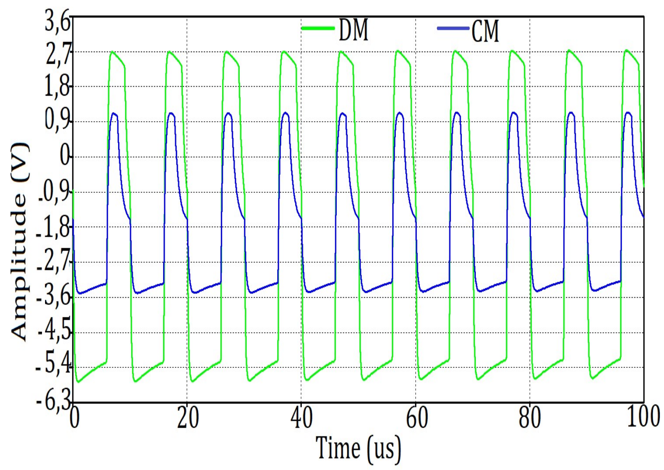

Fig. 9. Common and differential modes voltage in time domain.

Figure 10 shows the frequency response of the disturbances driven in common mode and differential mode of the SEPIC converter. We see that the MOSFET switching frequencies, cause peak disturbances that do not meet the CISPR 22 Class B (quasi-peak) limits in the range of 150 kHz to 30 MHz, due to the MOSFET. The maximum noise amplitude up to 120 dBµV at the frequency of 200 kHz exceeds the limit CISPR22 (average standard) in differential mode. In the case of common mode, the peak is lower than in differential mode and exceeds the limit of the CISPR22 Class B standard. The peak is equal 114 dBµV at frequency 200 kHz.

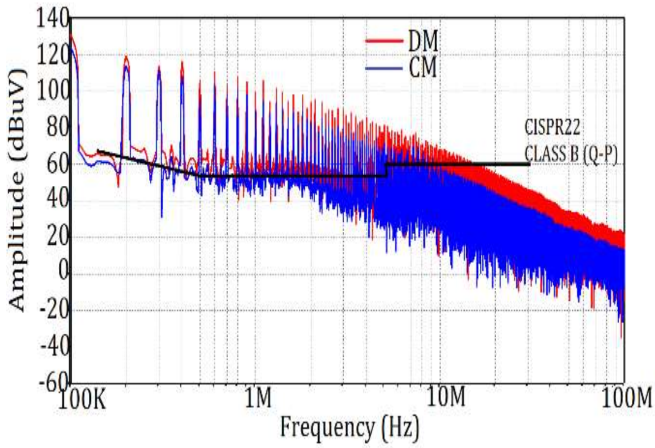

Fig. 10. Common and differential modes voltage in frequency domain.

IV. Impact of Variation of the Switching Frequency

Figures 11 and 12 show the electromagnetic disturbance of the common mode currents in the time and frequency domains as a function of the variation of the switching frequency of the MOSFET, fixing the duty cycle at 50%.

From the results obtained in Figure 11, we notice that with the increase of the frequency, the oscillatory phenomenon increases with very important peaks compared to the basic frequencies, as indicated in Figure 11. For Figure 12 in the frequency domain, we observe the disturbances increases with the increase of the switching frequency with very big gains in the range of frequency 100 kHz to 1 MHz, then a minimization the emissions for all the boxes of towards the high frequencies.

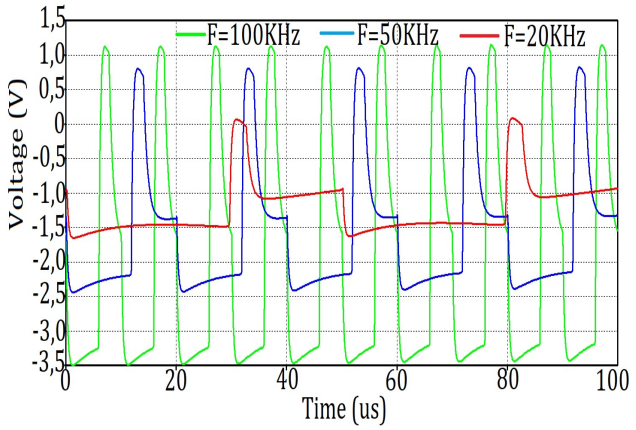

Fig. 11. Temporal response of the common mode voltage as function of switching frequency variation of the MOSFET for duty cycle 50%.

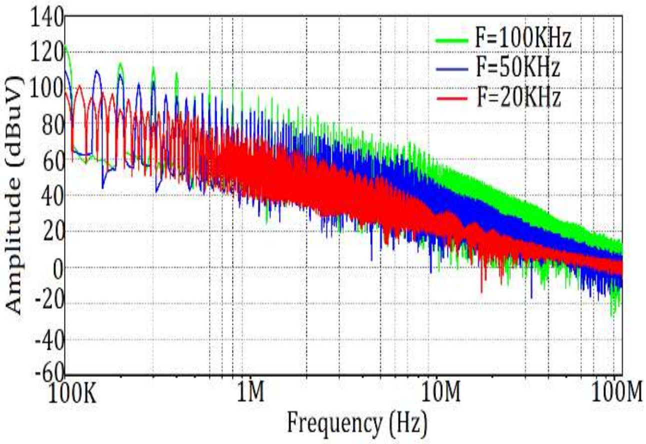

Fig. 12. Frequency response of the common mode voltage as function of switching frequency variation of the MOSFET for duty cycle 50%.

Figures 13 and 14 indicate the temporal and frequency response of the disturbances of the voltage in differential mode for the various frequencies. By fixing the duty cycle of 50 %, one notices in the temporal domain an oscillatory phenomenon with peaks of current, this phenomenon can be explained by the fast variation of switching the MOSFET which causes a variation of voltage and current very fast according to time. For Figure 14 which presents the frequency domain, we notice that the peak of disturbances increases with the increase of switching frequency, so a minimization of these noises towards the high frequencies.

It is concluded that the conducted disturbances in the differential mode are very large compared to the common mode, as well as the increase in frequency, the disturbances are increased with significant peaks. which exceeds the standards CISPR22 Class B.

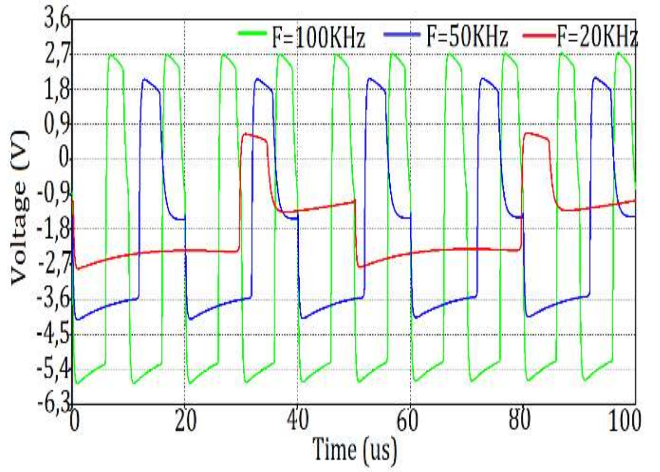

Fig. 13. Temporal response of the differential mode voltage as function of switching frequency variation of the MOSFET for duty cycle 50%.

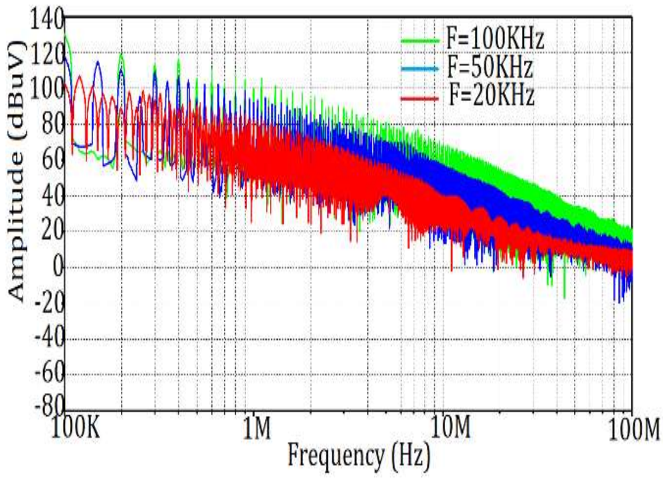

Fig. 14. Frequency response of the differential mode voltage as function of switching frequency variation of the MOSFET for duty cycle 50%.

V. CONCLUSION

This paper presents a comparative study of the impact of the switching frequency variation of the MOSFET by fixing the duty cycle, in the temporal and frequency domains in order to measure the electromagnetic disturbances in common mode and in differential mode. First of all, we started to study a SEPIC Converter and their operating principle, then we determine the conducted electromagnetic disturbances, then the effect of variation of the switching frequency of the MOSFET on the two modes. We have taken the following frequencies with constant duty cycle is equal to 50% : F = 100 kHz, F = 50 kHz and F = 20 kHz, where it is concluded that the electromagnetic noise exceeds the standard of limit CIPR22 Class B, and these disturbances increase with the increase of the frequency of MOSFET control.

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