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Helima Slimani

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Common Mode and Differential Mode noise of AC/DC LED Driver

Abdelhakim ZEGHOUDI
*Laboratory of Applications of Plasma,
 Electrostatics and Electromagnetic
 Compatibility (APELEC)
 Djillali Liabes University
 of Sidi Bel-Abbès
 Sidi Bel-Abbès, Algeria
 hakooumzeghoudi@gmail.com*

Abdelber BENDAOU
*IEEE Senior member
 Laboratory of Applications of Plasma,
 Electrostatics and Electromagnetic
 Compatibility (APELEC)
 Djillali Liabes University
 of Sidi Bel-Abbès
 Sidi Bel-Abbès, Algeria
 babelber@gmail.com*

Laurent CANALE
*IEEE Senior member
 LAPLACE Laboratory,
 Université de Toulouse,
 CNRS, INPT, UPS,
 Toulouse, France
 laurent.canale@laplace.univ-tlse.fr*

Amar TILMATINE
*IEEE Senior member
 Laboratory of Applications of Plasma,
 Electrostatics and Electromagnetic
 Compatibility (APELEC)
 Djillali Liabes University
 of Sidi Bel-Abbès
 Sidi Bel-Abbès, Algeria
 atilmatine@gmail.com*

Helima SLIMANI
*Laboratory of Applications of Plasma,
 Electrostatics and Electromagnetic
 Compatibility (APELEC)
 University of Tiaret
 Tiaret, Algeria
 slimani.halima@yahoo.fr*

Abstract — Electromagnetic interference (EMI) represents one of the biggest problems facing the production of any electronic device. The impact on the performance of the device caused such unwanted interference must be carefully measured to understand and quantify the electromagnetic compatibility (EMC) of the instrument under test. The electrical power conversions are among the sources of electromagnetic pollution, they provide a low power factor and generate electromagnetic interference (EMI). The white light emitting diode (LED) has attracted a lot of attention from industry and scientific researchers due to its high efficiency, ease of driving, and long life. Nevertheless, LED driver can interfere with the electronic device system due to rapid voltage variation and current. In this paper we simulate some LED driver topology on LTSpice software in order to measure the electromagnetic disturbances using LISN (line impedance stabilizer network) device.

Keywords—LED, Driver, EMC, LISN, Differential Mode, Common Mode, AC/DC PFC.

I. INTRODUCTION

Rectifiers for AC-DC conversion are widely used in many applications, such as LED lighting systems, which result in a non-sinusoidal input current with large harmonic components cause a poor power factor. Thus pollute the network by generating Interference (EMI) causing electromagnetic compatibility problems. Therefore, it is necessary to improve their power factor and mitigate the EMI with respect to the standards [1-3].

Electromagnetic compatibility (EMC) is defined as the ability of an electrical component to work correctly in its own electromagnetic environment without disturbing other electrical equipment or devices present in the same environment its own operation. The tests were conducted in accordance with the European standard EN 55015 shown in

Table I and Fig. 1 for the average and near-peak values [4] and by CISPR 22 in the United States "Limits and methods of measurement of radio waves characteristic of disturbance of electric lighting and equipment" [5-6].

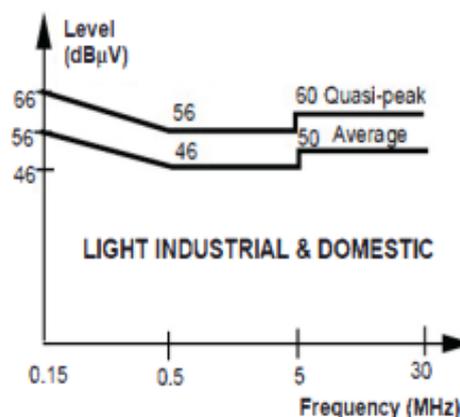


Fig. 1. Permissible interference limits for EN 55015 [5].

TABLE I. LIMIT OF DISTURBANCE VOLTAGE AT THE TERMINALS OF THE MAINS [5]

Frequency Range	Limits dB(µV)	
	Quasi-peak	Average
150 kHz to 0.5 MHz	66 to 56 ^h	56 to 46 ^h
0.5 MHz to 5 MHz	56	46
5 MHz to 30 MHz	60	50

^h Limit decreases linearly with the logarithm of the frequency in the range 150 kHz to 0.5 MHz

The Conducted Emission "CE" noise of LED lighting mainly comes from its driver [7]. The LED driver contains a

switching circuit that generates common mode and differential mode current [8]. The noise of common mode and differential mode propagate through the driver and become emitted noise in their environment or other interconnected system [5].

The objective of this work is to primarily determine the conducted emissions in common mode and differential mode for the different LED driver topologies, using the simulation on LTspice software. The rest of this document is organized as follows: Section II describes the measurement procedure in common mode (MD) and differential mode (MD) from the line impedance stabilizer network (LISN). In section III the simulation of the diode bridge rectifier with and without passive PFC, next study the AC/DC converter active PFC (PFC boost), the results obtained are discussed, Finally, section V formulates the main conclusions of this work.

II. COMMON AND DIFFERENTIAL MODE

In common mode electronic circuit (CM) and differential mode (DM) determine the amount of energy ratio frequency RF developed and propagated. In the CM field, radio frequency arises on the signal and return the current and propagate in the same direction. The CM field is the main source of RF noise and more difficult to remove. In the DM, RF presents on the signal and return current and flow in the opposite direction [9].

Illustration of CM current propagation (ICM) and DM (IDM) are shown in Fig. 2 and Fig. 3 respectively.

The relations (1) and (2) express the differential mode current and voltage respectively from the currents and voltages of each of the supply phases [10].

$$I_{MC} = I_1 + I_2 \quad (1)$$

$$V_{MC} = \frac{V_1 + V_2}{2} \quad (2)$$

The relations (3) and (4) express the differential mode current and voltage respectively from the currents and voltages of each of the supply phases [10].

$$I_{MD} = \frac{I_1 - I_2}{2} \quad (3)$$

$$V_{MC} = V_1 - V_2 \quad (4)$$

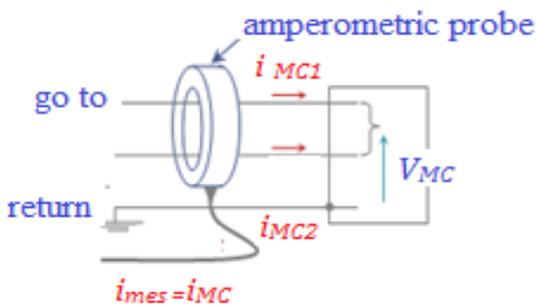


Fig. 2. Common mode current path [10].

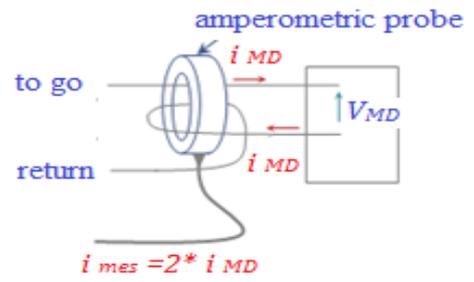


Fig. 3. Differential mode current path [10].

➤ Line impedance stabilization network (LISN)

LISN is an industrial device offered by standards to be placed between the power supply and input of the equipment under test including the load as an interface to make possible the measurement of conducted interferences. Fig. 4 illustrates the LISN placement between source and converter. The LISN should have the following characteristics: meet the measurement requirements.

- 1- Provide a low impedance path to transfer power from the source to the power and load electronic converter.
- 2- Provide a low impedance path from the interference source, (diode bridge rectifier here), to the measurement port.

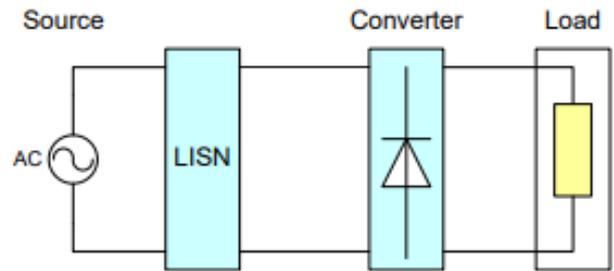


Fig. 4. LISN placement to measure conducted interference [11].

The variation of the signal level with respect to the frequency at the LISN output is the interference spectrum. The electromagnetic compatibility of a device can be assessed by comparing its interference spectrum with standard limits. The signal level at the LISN output in the frequency range of 10 kHz to 30 MHz or 150 kHz to 30 MHz is a compatibility criterion and should meet the standard limits. In practice, the LISN output is connected to a spectrum analyzer and interference measurements are performed. But for modeling and simulation purposes, the LISN output spectrum must be calculated using appropriate software [11].

The inductance L , by its high value, prevents the current from the equipment under test from returning to the network and channels its passage in the branch comprising C and R . The capacitor C allows to filter the power (LF) and leaves the passage only to the disturbances (HF) towards the measurement impedance R , this impedance is the 50 Ω input of the measurement receiver, which we have represented on figure 5 by a resistor R [12].

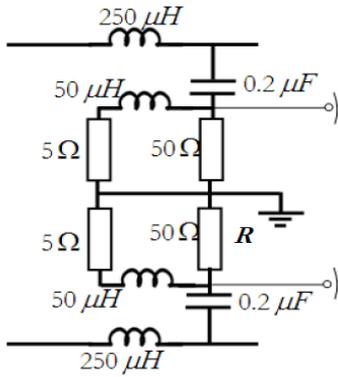


Fig. 5. Simplified structure of the LISN [13].

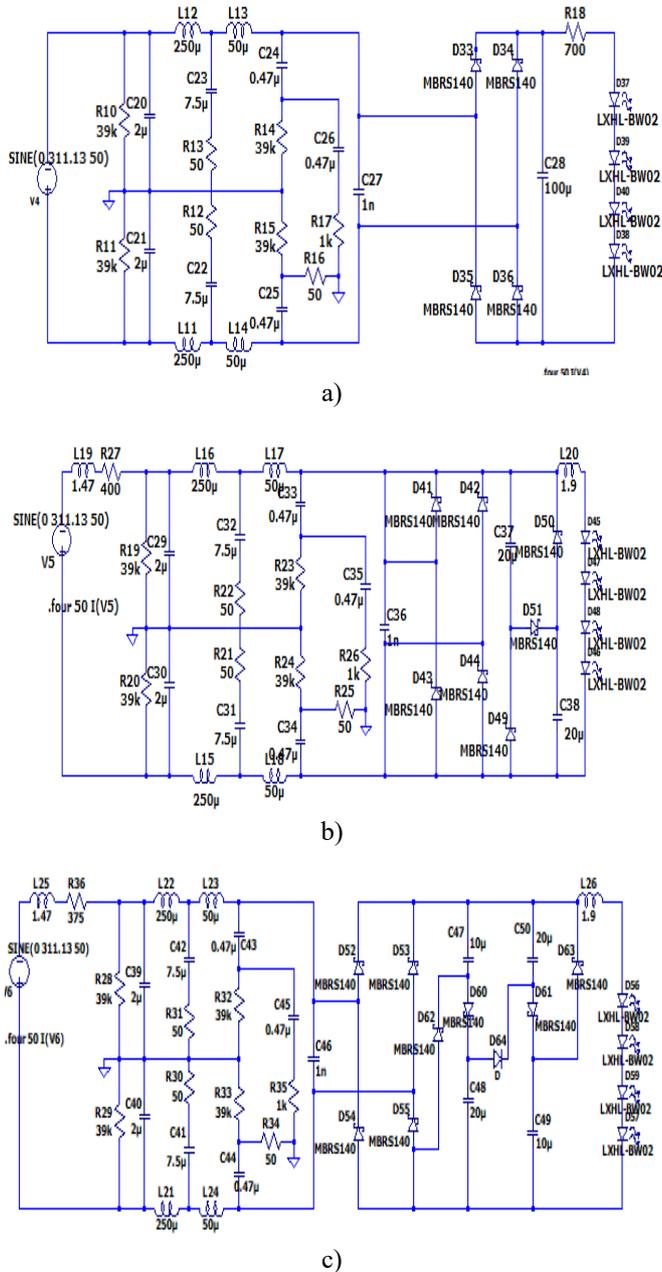


Fig. 6. AC/DC converter with LISN a) without PFC b) valley-fill c) valley-fill with 3 capacitors.

III. SIMULATION AND RESULT

A. Bridge AC/DC converter with and without PFC passive

Single-phase diode bridge rectifiers have been used in industrial applications. Sample of such equipment, including 220 V line source, LISN, AC/DC converter and LEDs lamps type LXHL-BW02 under LTSPICE software. Fig. 6 shows AC/DC LED driver with and without passive power factor correction (PPFC).

Simulated passive power factor correction is conventional valley-fill (Fig. 6(b)) and valley-fill with 3 capacitors (Fig. 6(c)). The input voltage and output current were measured (Fig. 7), then the electromagnetic disturbances localized on the LISN in common mode (Figs.8 and 9), and differential and total mode (Figs 10, 11 and 12).

Fig. 7 shows the current circulating in the LED lamps for the 3 types of AC/DC converter and the supply voltage, we notice a concordance between the 3 straightened.

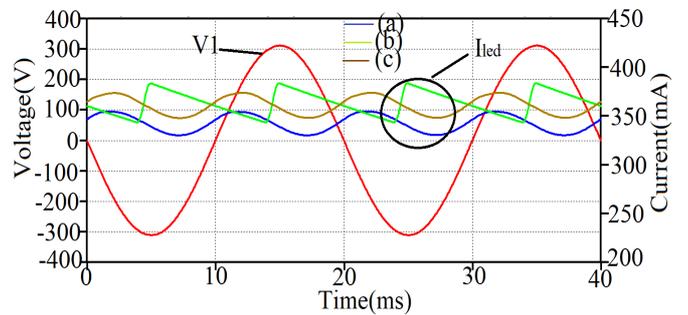


Fig. 7. Current flows in the LED lamps.

❖ Differential mode

Fig. 8 shows the temporary response of electromagnetic disturbances in differential mode.

We note that a significant noise created in case (a) until 350 mA due to Electronic righting and filtering component, while the two cases (b) and (c) that present a very significant reduction in the amplitudes of noise CE around 50 mA, so the passive power factor correction method by the valley-fill and valley-fill 03 techniques plays another role, this role is reduced emissions conducted in differential mode.

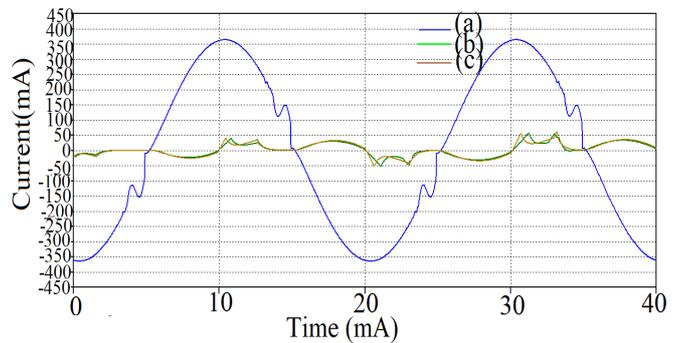


Fig. 8. Temporary response of differential disturbances.

Fig. 9 shows the frequency response of electromagnetic disturbances in differential mode.

We notice the very intense harmonics in base frequency as a result of the non-linear load in case (a). Therefore an oscillatory phenomenon of a high frequency appears, on the

other hand in the two cases (b), (c) with the passive valley-fill PFC technique, the base frequency of harmonics decreases and the oscillatory phenomenon reduced to high frequency, The power factor correction is done by reducing the low frequency harmonics.

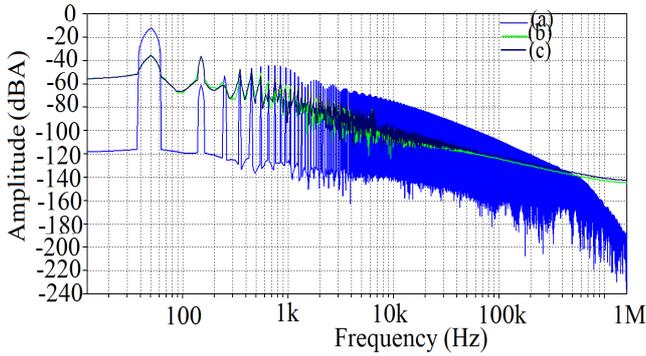


Fig. 9. Spectrum of localized differential mode disturbances on the LISN.

❖ Common Mode

Figs. 10 and 11 present the temporary and frequency electromagnetic disturbances in common mode for the types that we studied. We notice that the topology (c) valley-fill with 3 capacitors the amplitudes of noise very low while the case (a) which presents a noise peak about 280 mA (Fig. 10) and case (b). In Fig. 11 which shows the frequency electromagnetic disturbances, the noise in common mode for 3 cases less intense than the differential mode (Fig. 9).

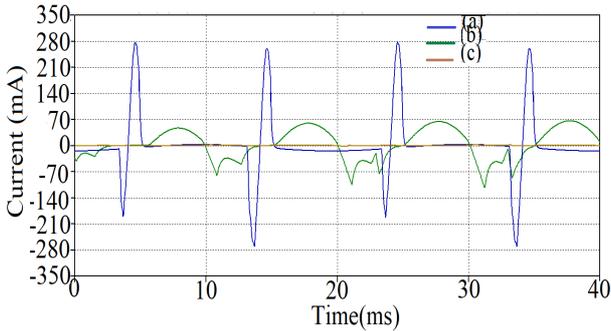


Fig. 10. Temporary response of the differential disturbances.

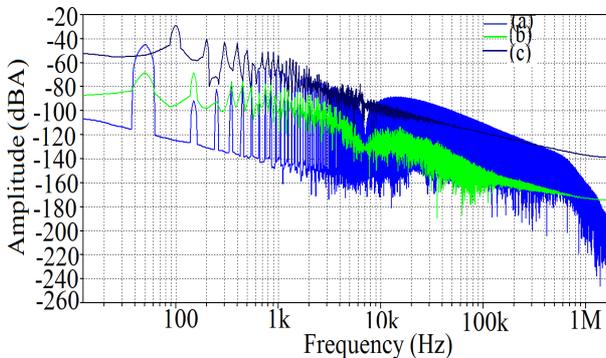


Fig. 11. Spectrum of common mode disturbances located on the LISN.

Fig. 12 shows the spectrum of total localized disturbances on the LISN, we observe the oscillatory phenomenon reduced in the very important frequencies for cases (b) and (c) against the case (a).

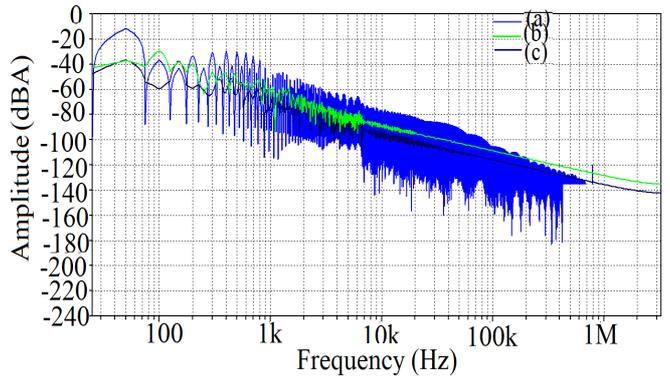


Fig. 12. Spectrum of total localized disturbances on the LISN.

B. Bridge AC/DC converter PFC ACTIVE

In this part we simulated an AC/DC converter PFC boost using LTspice software with the LISN replaced between the source and the converter, the RMS supply voltage is 220 V, the control period of MOSFET type IRF1503 is 40 μ s with the switching frequency is equal $f_0 = 25$ kHz and a diode type 1N5819 as shown in figure 13. We measured the voltage, the line current and the voltage at the output of AC/DC converters and the voltage at the terminals of the electronic switch, also the conducted emissions from the LED's driver.

Fig. 14 shows the voltage and the current of the line, we notice that the voltage is a sinus signal and the current an approximate sinusoidal signal due to the correction of active power factor.

Figs. 15 and 16 show the voltage at the terminals of the MOSFET and the output of converter. From the two figures we notice that the voltage to the terminal of MOSFET is a rectified square signal, when we zoom in corresponding to the interval of time of the switching, a periodic oscillatory phenomenon is visible. This phenomenon is similar to the switching frequency of MOSFET. It is due to the abrupt switching of the switches and the effect of the inductances of connection and the passive components of the converter.

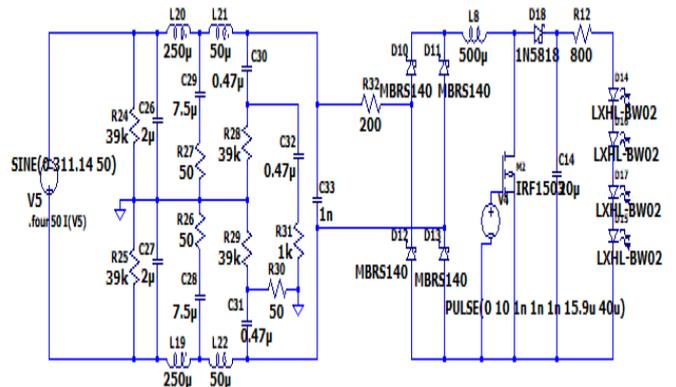


Fig. 13. AC/DC converter PFC BOOST for LED driver .

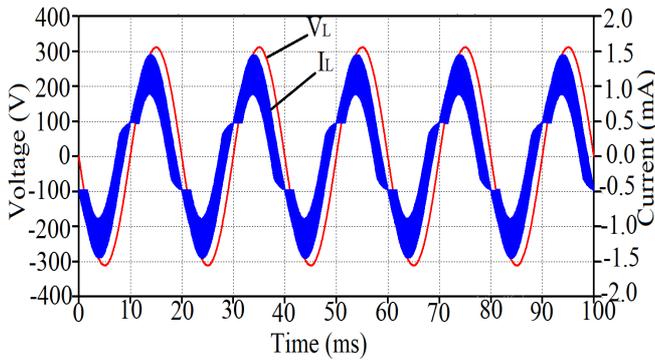


Fig. 14. Line current and voltage of the line.

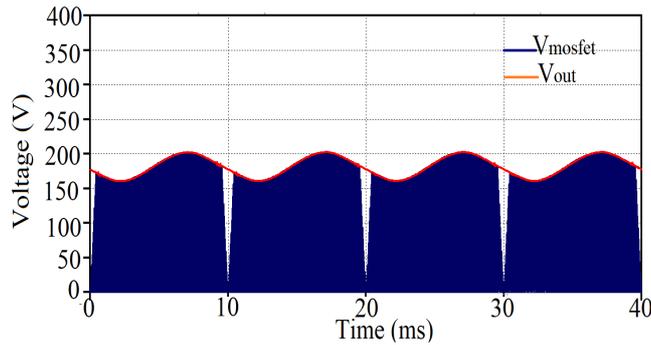


Fig. 15. Voltage at the output of AC/DC converter PFC boost and at the terminals MOSFET.

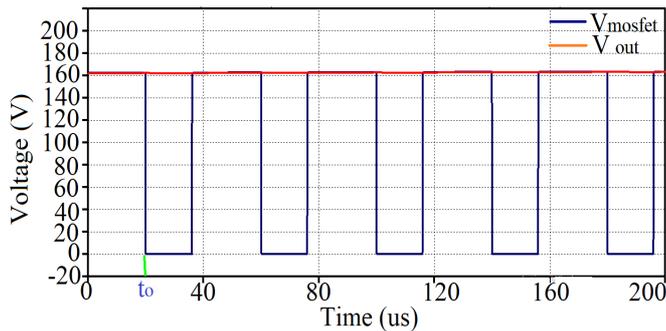


Fig. 16. Zoom of the voltage at the output of AC/DC converter PFC boost and at the MOSFET terminals

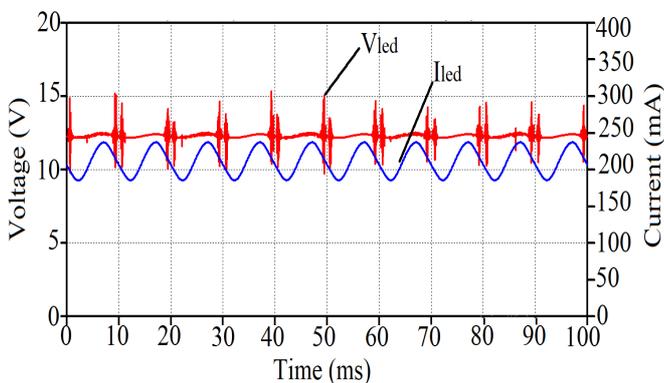


Fig. 17. current and voltage at the terminals LEDs lamps.

Fig. 17 shows the voltage and current at the terminals of the LED lamps. We can see the ripple of the current and the voltage but with the noise due to the effect of passive components .

❖ Common and differential mode

The figures 18 and 19 present the electromagnetic disturbances localized on LISN temporary and frequential in common mode and differential mode respectively. We notice that the electromagnetic disturbances in differential mode more intense compared to common mode as well as the rapid variation of the voltage across the equivalent resistance of the LISN. It appears the oscillatory forms of disturbances during switching of the MOSFET. Also we observe the resonance frequencies which presents peaks of disturbance are after 25 kHz, they are going to be minimized towards the high frequencies.

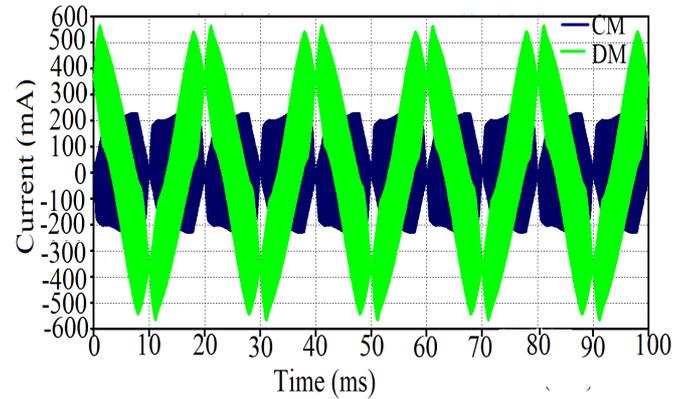


Fig. 18. Temporary response to common and differential disturbances.

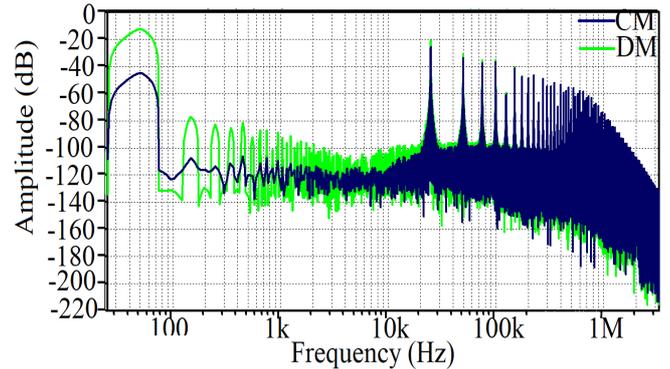


Fig. 19. Spectrum of localized disturbances on the LISN.

IV. CONCLUSION

Static converters are sources of electromagnetic pollution due to the rapid variation of voltage and current depending on the switching time of electronic switches as well as passive components.

In this paper, we studied AC/DC converters with and without active or passive power factor correction for LED lamps with LISN in the time and frequency domain, in order to measure the conducted emissions in common mode and in differential mode, using LTspice software. The results show that controlled and uncontrolled switches are responsible for the electromagnetic disturbances. In order to reduce the noise, EMC filters must be added to the input of the studied converter.

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