The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 38, Pages 81-89

IConTES 2025: International Conference on Technology, Engineering and Science

Investigation of Conducted Electromagnetic Disturbances in Power Electronics: A Case Study on DC/DC Choppers

Mohammed Elamine Lahlaci
University Ahmed Zabana of Relizane

Mohamed Miloudi
University Ahmed Zabana of Relizane

Houcine Miloudi
Djillali Liabes University of Sidi Bel Abbes

Mohammed Hamza Bermaki
Djillali Liabes University of Sidi Bel Abbes

Kheira Mendaz
University of Ain Temouchent

Abdelkader Gourbi
University of Oran1 Ahmed Ben Bella

Abstract: Power electronics systems play a key role in modern industrial applications, particularly in motor drives and automation systems. Among the most widely used devices, static converters—especially DC/DC choppers—enable precise control of voltage and power while ensuring high energy efficiency. These converters are essential for adapting voltage levels to the specific needs of loads, thereby providing stable and optimized power supply across various industrial environments. However, these converters are also significant sources of electromagnetic disturbances (EMD), both conducted and radiated, which can compromise the electromagnetic compatibility (EMC) of systems. Conducted common-mode disturbances, in particular, pose a major challenge in industrial settings, where equipment density increases susceptibility to interference. In this context, the present study focuses on the experimental analysis of conducted common-mode EMD generated by a series DC/DC chopper. Accurate measurements are carried out using appropriate instrumentation to characterize waveform shapes, dominant frequencies, and disturbance levels. The aim is to identify operating conditions that exacerbate these emissions and to better understand the underlying mechanisms. To deepen the analysis, machine learning techniques are employed to model the disturbances based on experimental data. The developed predictive models estimate the influence of the chopper's operating parameters on electromagnetic emissions and help propose mitigation strategies through optimized control and design parameters. The results contribute to the development of cleaner converters that meet EMC requirements without compromising electrical performance. This approach enhances the reliability and robustness of power electronics systems in demanding industrial environments.

Keywords: Electromagnetic compatibility EMC, Electromagnetic disturbances EMD, Choppers DC/DC, Conducted common-mode disturbances CM, Machine learning techniques.

Introduction

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

Static converters play a central role in modern power electronics systems (Mohammed et al., 2024; Mohamed et al., 2012; Sara et al., 2023). Their main function is to transform and regulate electrical energy to meet the specific requirements of various industrial applications (Miloudi et al., 2019), including automation (Benhadda et al., 2024), motor drives (Gourbi et al., 2020), renewable energy systems (Naima et al., 2025), and embedded electronics (Zeghoudi et al., 2022). Among these converters, DC/DC choppers are widely used for voltage conversion due to their high efficiency (Mohammed et al., 2024), compactness, and ability to provide precise voltage control (Mohammed et al., 2024). However, the fast-switching operation of these converters generates significant electromagnetic disturbances (EMD), both conducted and radiated (Abdelhakim et al., 2022; Miloudi et al., 2023). These disturbances, often underestimated during the design phase, can severely affect the performance of nearby equipment and compromise the overall electromagnetic compatibility (EMC) of the system (Mohammed et al., 2025; Bermaki et al., 2023). In industrial environments, where numerous electronic devices operate in close proximity, managing such interference is crucial to ensure system reliability, safety, and regulatory compliance (Houcine et al., 2022; Miloudi et al., 2010).

This study focuses specifically on conducted common-mode disturbances generated by a series DC/DC chopper (Lahlaci et al., 2025). The objective is to experimentally characterize these interferences, identify critical operating conditions, and develop effective predictive tools (Zeghoudi et al., 2022). To achieve this, machine learning techniques are incorporated into the methodology (Miloudi et al., 2014). Machine learning offers powerful tools for modeling complex phenomena based on experimental data-especially when traditional analytical approaches become limited. By leveraging these techniques, it becomes possible to predict disturbance levels based on the converter's operating parameters and to propose optimization strategies aimed at reducing electromagnetic impact (Abdelhakim et al., 2022; Miloudi et al., 2025).

This work thus aims to reconcile electrical performance with electromagnetic compatibility requirements, using a combination of experimental analysis and intelligent modeling to improve the design of static converters in demanding industrial settings.

EMC Measurement and Standards of Conducted EMI.

In practical terms, the LISN ensures consistency and comparability across different measurement setups by standardizing the impedance seen by the equipment under test. This consistency is essential, as the amplitude and spectral characteristics of conducted disturbances can vary significantly depending on the impedance of the power source and the wiring configuration. Additionally, the LISN enables accurate detection of high-frequency noise by diverting these signals toward a spectrum analyzer or EMI receiver, while simultaneously preventing external noise from the power grid from influencing the measurement. Therefore, it plays a critical role in ensuring that electromagnetic compatibility (EMC) assessments of power electronic systems, such as DC/DC converters, are both precise and representative of real-world operating conditions.

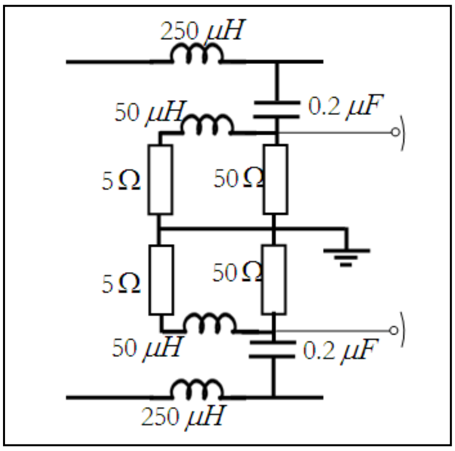

Figure 1. Simplified structure of the LISN

Conducted disturbances often pertain to high-frequency currents circulating within the device. The term high frequency typically encompasses frequencies ranging from 150 kHz to 30 MHz, as this frequency range aligns with the bandwidth regulated by prevailing EMC standards. This current can be dissected into two modes (CM and DM), as depicted in (Figure. 2).

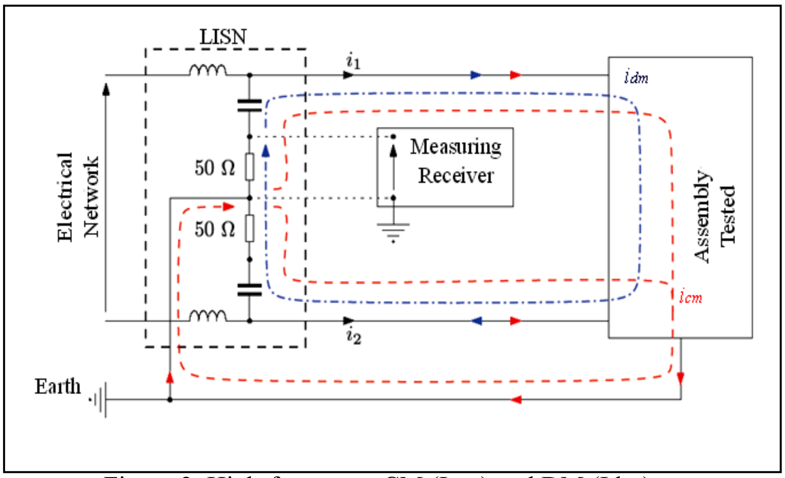

Figure 2. High-frequency CM (Icm) and DM (Idm) currents

Differential Mode (DM) current, denoted as I_{dm}, represents the portion of current that circulates between the power source and the load through the phase and neutral conductors. While this is the intended path for power transmission, high-frequency components superimposed on this current are undesirable and often stem from switching operations. In contrast, Common Mode (CM) current, I_{cm}, flows simultaneously through both conductors and returns via the ground path-typically due to parasitic capacitance between system components and ground. Although not directly involved in power delivery, CM currents can introduce significant high-frequency noise and are particularly sensitive to the layout and grounding scheme of the electrical system. Both DM and CM emissions eventually close their loops through the internal impedances of the power grid, making their behavior-and thus their measurement-highly dependent on the configuration of the surrounding electrical network.

Power semiconductors, such as transistors used in static converters, inherently generate electromagnetic noise due to their fast switching and the presence of parasitic elements. Despite the fact that industrial environments have historically been more tolerant of such disturbances, the increasing deployment of these technologies in commercial and residential applications necessitates strict adherence to electromagnetic compatibility (EMC) standards. Manufacturers of power supplies and static converters are now required to consider EMC constraints early in the design process. This is especially crucial since power electronics systems are among the most challenging to model and optimize from an EMC perspective.

To ensure standardized testing conditions, regulatory bodies enforce specific EMC measurement procedures, such as those outlined in EN 55022. This standard prescribes a detailed testing protocol to ensure consistency, repeatability, and reliability of conducted emission measurements. Accordingly, the test setup includes components arranged on a reference copper ground plane, with the Equipment Under Test (EUT) electrically isolated to prevent interference from the surrounding environment. A typical block diagram of the test bench configuration is shown in Fig. 4, illustrating compliance with EN 55022 requirements (Figure.3).

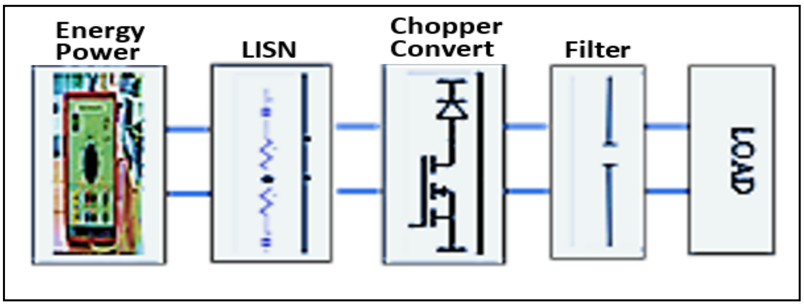

Figure 3. Multi-stage power converter

To compare conducted electromagnetic interference (EMI) in both common mode (CM) and differential mode (DM), an experimental study was conducted using a series DC/DC chopper connected to a resistive load. Two types of power transistors were employed for benchmarking purposes: the IGBT model FGH40N60 and the MOSFET model IRFP4060, each paired with a BYT12 fast recovery diode. The test setup was designed to evaluate the conducted EMI under consistent operating conditions, with the chopper supplying a resistive load at a steady voltage of 24 V (as illustrated in Figure. 4). Key components of the measurement setup included a Line Impedance Stabilization Network (LISN) installed before the chopper to ensure standardized measurement conditions, and a spectrum analyzer used to capture and quantify the conducted disturbances in both CM and DM across various load resistance values.

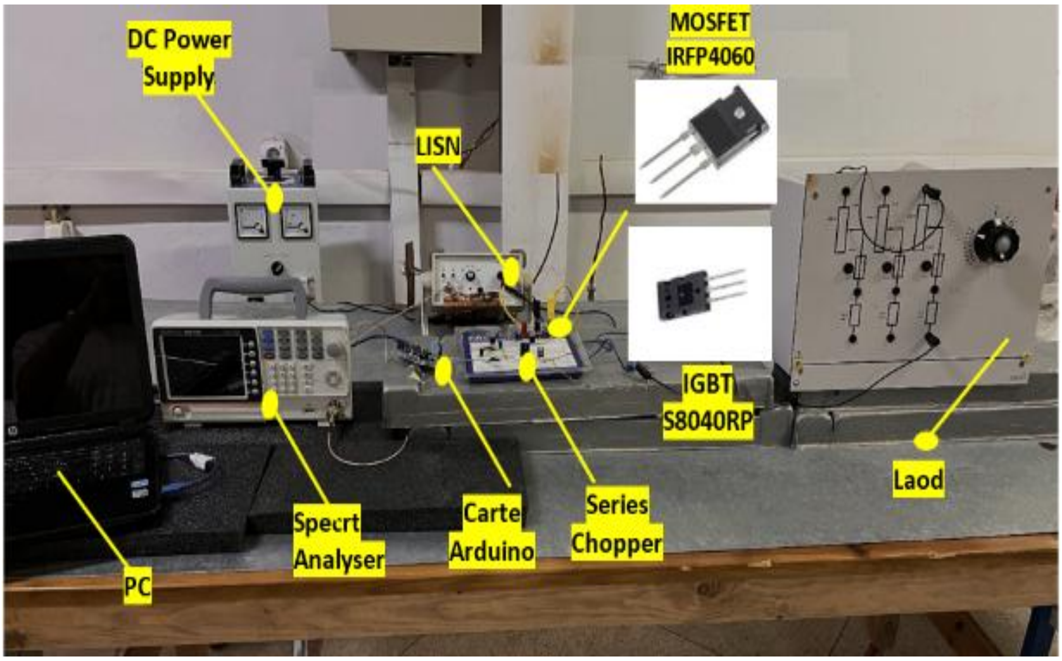

Figure 4. EMC bench for measuring conducted EMI

This study focuses on conducted-mode emissions, which are primarily responsible for the majority of electromagnetic disturbances generated by power electronic converters. Particular attention is given to the distribution of common-mode (CM) currents within the system. These currents originate mainly from capacitive CM coupling mechanisms and propagate through the system by returning via the ground path. This propagation mechanism allows conducted disturbances to affect other components of the installation, often far from the original source. For a thorough analysis of the electromagnetic interference (EMI) produced by the converter, spectral measurements are referenced against the EN 55022 standard, which defines the requirements for conducted emission testing. According to this standard, the frequency range of interest extends from 150 kHz to 30 MHz, and emissions must be quantified at the input of the equipment under test-here, the chopper.

To assess the electromagnetic compatibility (EMC) behavior of the system, a widely used analysis method in power electronics has been applied. The methodology involves first operating the chopper using a MOSFET (IRFP4060) and subsequently repeating the test under identical conditions with an IGBT (FGH40N60). Based on the results, the most appropriate measurement approach and analysis tool will be selected to provide a reliable characterization of the EMI behavior specific to each switching device.

Results and Discussion

Experimental measurements of conducted electromagnetic disturbances were performed on a series buck converter using a MOSFET switch, with different load impedances (50 Ω, 100 Ω, and 200 Ω). The results, presented as magnitude spectra in dBµV, demonstrate that the disturbance levels are strongly dependent on both frequency and the connected load. At low frequencies (100 Hz to 10 kHz) figure 5, the conducted emissions reach high levels before decreasing sharply with increasing frequency. This behavior is attributed to the natural attenuation of switching harmonics and the effect of the circuit's parasitic elements. Beyond 10 kHz, the disturbance levels stabilize around -80 dBµA for the 50 Ω and 100 Ω loads, while the 200 Ω load exhibits a distinct plateau up to 100 kHz. This phenomenon is related to the combined effects of the higher load impedance and the converter's parasitic components, leading to resonance effects at certain frequencies. These results highlight the importance of considering load impedance in the design and sizing of EMC filters to optimize the electromagnetic behavior of switching converters.

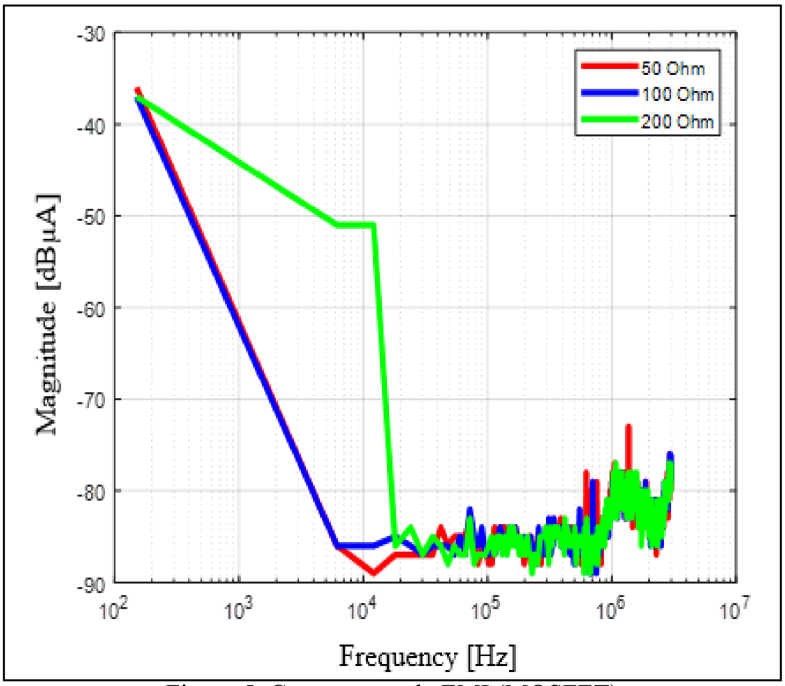

Figure 5. Commun mode EMI (MOSFET)

In a subsequent set of measurements, the same experimental protocol was applied to a series buck converter using an IGBT as the switching device Figure 6. The disturbance spectra obtained under identical load conditions exhibit a similar global trend, with high emission levels at low frequencies followed by a sharp decrease beyond 10 kHz. However, it is observed that the influence of load impedance on the EMI levels becomes less significant in the IGBT case, particularly in the mid-frequency range. Unlike the previous results, where the 200 Ω load introduced a noticeable plateau up to 100 kHz, the disturbance levels for all load impedances remain closely aligned with the IGBT. Additionally, a slight rise in disturbance levels is detected beyond 500 kHz, reflecting the inherent switching characteristics of the IGBT, such as slower transitions and higher parasitic capacitance compared to the MOSFET. These findings further emphasize the impact of the switch's dynamic behavior on the distribution of conducted disturbances across the frequency spectrum.

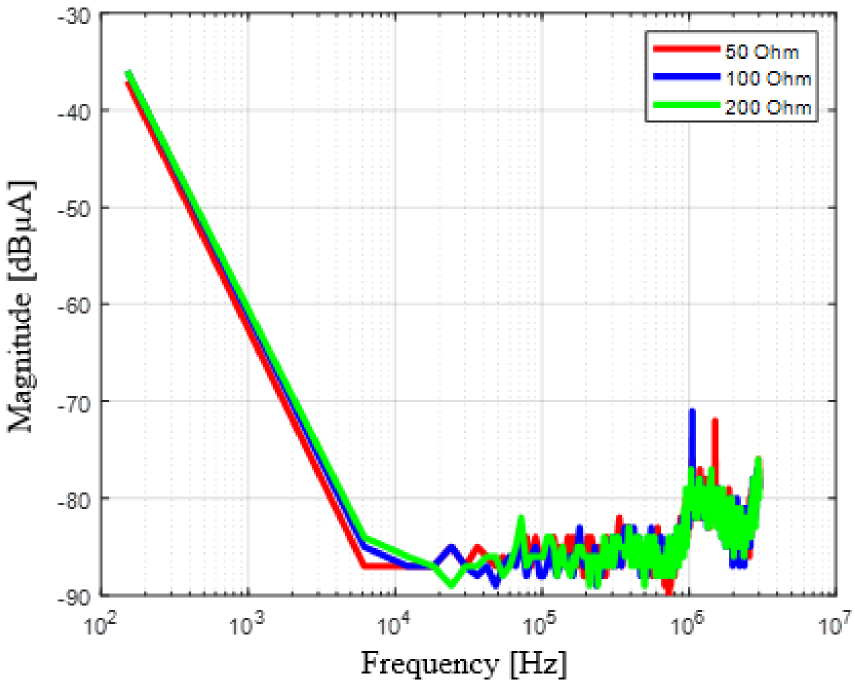

Figure 6. Common mode EMI IGBT

In the second part of this study, we focus on the integration of machine learning techniques to analyze and interpret the experimental data obtained from common-mode conducted EMI measurements. While classical approaches provide valuable insights into spectral characteristics, they often fall short when it comes to modeling complex, nonlinear relationships between operating parameters and disturbance levels. The goal of this section is to develop predictive models capable of estimating the level of conducted emissions based on various input features, such as load resistance, switching frequency, and the type of semiconductor switch used (MOSFET or IGBT). By training algorithms on the acquired measurement data, it becomes possible to identify hidden patterns, assess the influence of different variables, and ultimately optimize the converter's design for improved electromagnetic compatibility (EMC). This data-driven approach offers a powerful complement to conventional analysis methods, particularly in contexts where physical modeling is either too complex or insufficiently accurate. The selected machine learning models will be evaluated based on their predictive accuracy and interpretability, providing engineers with practical tools for EMI mitigation during the early stages of power converter development.

To further analyze the conducted EMI behavior of the series buck converter with an IGBT switch, figure 7 a nonlinear regression model was applied to the measured common-mode disturbance levels. The experimental data, represented by blue markers, were fitted using a nonlinear curve (in red) to predict the overall EMI trend across the frequency spectrum. The predicted curve successfully captures the general shape of the disturbance spectrum, with a sharp attenuation observed from 100 Hz to 10 kHz, followed by relatively stable levels in the mid-frequency range. Although minor discrepancies appear at higher frequencies, particularly beyond 500 kHz, the model effectively follows the primary trends of the measured data. These results suggest that nonlinear regression techniques can provide valuable insight into the frequency behavior of conducted EMI and serve as a useful tool for estimating disturbance levels in power electronic systems, especially for common-mode emissions where parasitic effects and switching dynamics play a significant role.

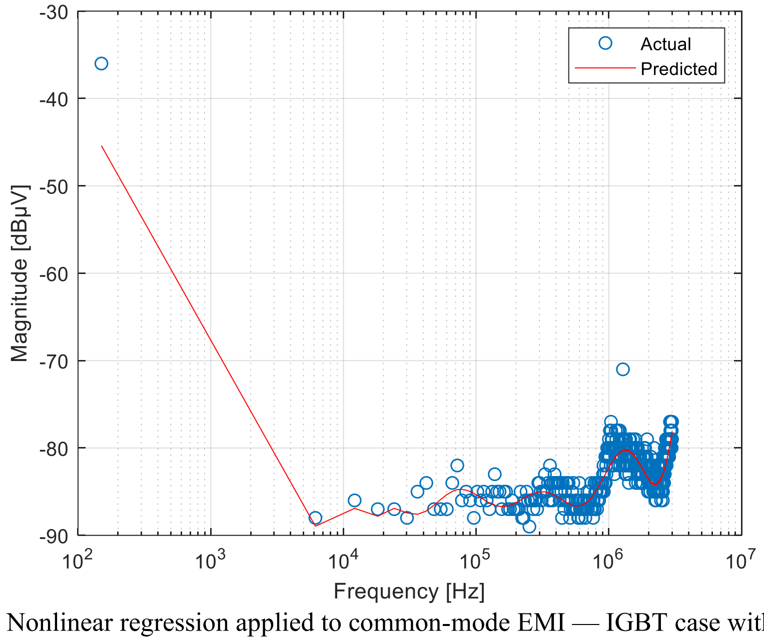

Figure 7. Nonlinear regression applied to common-mode EMI — IGBT case with 50 Ω load

In contrast, when the same nonlinear regression model is applied to the MOSFET-based converter under identical load conditions (50 Ω), the fit is less accurate, particularly in the low-frequency region (below 1 kHz), where the model significantly underestimates the measured EMI levels. While the predicted curve captures the overall trend in the mid-to-high frequency bands, it fails to represent certain spectral details, especially the initial steep drop and the slight ripples observed around the MHz range. This discrepancy may be attributed to the faster switching characteristics of the MOSFET, which generate more pronounced high-frequency transients and a more complex spectral signature. As a result, the EMI profile becomes harder to approximate using standard nonlinear regression, which may require additional terms or alternative modeling strategies to handle the rapid variations effectively.

Overall, these results indicate that while the modeling approach performs adequately for both devices, its accuracy is more sensitive to the dynamic behavior of the switching element, with the MOSFET case posing a greater challenge in terms of low-frequency prediction and spectral ripple tracking

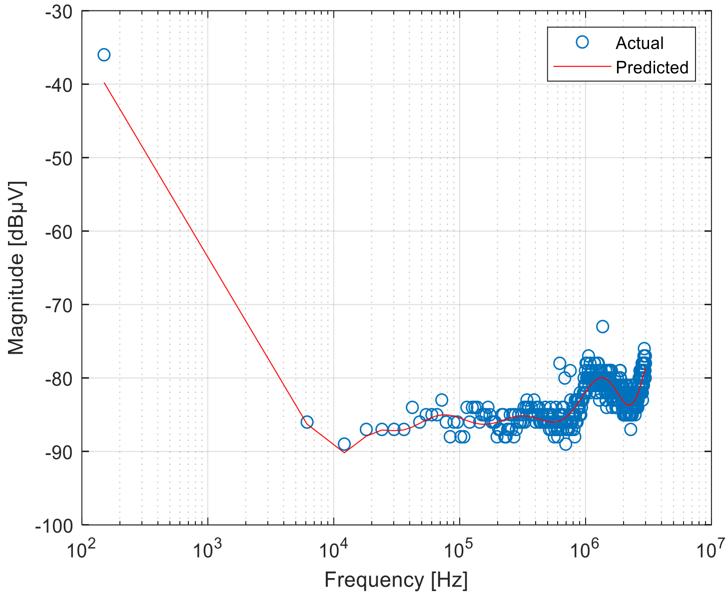

Figure 8. Nonlinear regression applied to common-mode EMI — MOSFET case with 50 Ω load

Conclusion

This study provided a comprehensive analysis of common-mode conducted electromagnetic disturbances in a series buck converter using both MOSFET and IGBT switching devices under various resistive load conditions. The experimental measurements revealed the strong influence of load impedance and switch type on the spectral distribution of EMI, particularly at low and mid frequencies. While MOSFET-based configurations exhibited more pronounced variations and resonant effects, the IGBT demonstrated a more consistent EMI profile across different load conditions.

To complement the experimental observations, a nonlinear regression model was applied to the measured data to evaluate its capacity to predict the overall EMI behavior. The model proved capable of capturing the global spectral trends, especially for the IGBT case, although some limitations were noted in accurately modeling the low-frequency emissions in the MOSFET configuration.

These findings highlight the dual importance of empirical measurement and data-driven modeling in understanding and controlling conducted EMI in power converters. Nonlinear regression emerges as a promising analytical tool for estimating disturbance levels, offering insights that can guide the design of effective EMI mitigation strategies and improve electromagnetic compatibility in future converter architectures.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Funding

* This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements or Notes

* This article was presented as a poster presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Türkiye on November 12-15, 2025.

References

Benhadda, N., Bendaoud, A., Miloudi, M., Benazza, B., & Belhenini, S. (2020). Buck converter common-mode emission with the frequency approach. *International Journal of Electronics and Electrical Engineering Systems, 3*(1), 24-28.

Bermaki, M. H., Miloudi, H., Miloudi, M., Gourbi, A., & Bendaoud, A. (2023). High-frequency differential mode modeling of universal motor's windings. *International Journal of Electrical and Electronics Research, 11*, 1057-1064.

Ghalem, S., Bendaoud, A., Miloudi, H., Bermaki, M. H., Miloudi, M., & Zeghoudi, A. (2023). Prediction of conducted disturbances generated by a DC/DC converter. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics, 26*, 299-305.

Gourbi, A., Miloudi, M., Miloudi, H., & Bermaki, M. H. (2024). Comparative analysis of differential-mode ımpedance in single-phase ınduction motors. *WSEAS Transactions on Circuits and Systems.*

Lahlaci, M. E. A., Miloudi, M., Miloudi, H., Bendaoud, A., Bermaki, M. H., Gourbi, A., & Hakmi, Y. (2025). Analysis of common-mode and differential-mode noise in DC motors with variable speed drives. *International Journal of Advanced Natural Sciences and Engineering Researches, 9*(1).

Lahlaci, M. E., Miloudi, M., & Miloudi, H. (2024). Experimental electromagnetic compatibility of conducted electromagnetic interferences from an IGBT and a MOSFET in the power supply. *Electrical Engineering & Electromechanics, 2024*(3), 3-7.

Lahlaci, M. E., Miloudi, M., Miloudi, H., Gourbi, A., Bermaki, M. H., Mankour, M., & Mostefa, A. (2025). Comparative research in common and differential modes of EMI propensity in series and parallel chopper drives for DC motors. *Przegląd Elektrotechniczny, 101*(7).

Miloudi, H., Bendaoud, A., & Miloudi, M. (2014). Réduction des perturbations électromagnétiques conduites dans la machine asynchrone (Reduction of conducted electromagnetic disturbances in the asynchronous machine). *Mediterranean Journal of Modeling and Simulation, 2*(1), 8–15.

Miloudi, H., Bendaoud, A., Miloudi, M., Gourbi, A., & Slimani, H. (2010). Common mode conducted electromagnetic interference in inverter-fed-AC-motor. *Electrical and Electronics Engineers Review*, 271-275.

Miloudi, H., Miloudi, M., Ardjoun, S. A. E. M., Nour, A. A., & Mahariq, I. (2025). Experimental investigation of conducted electromagnetic interference differential-mode performance in various split-phase induction motors designs. *Results in Engineering, 25*, 103456.

Miloudi, H., Miloudi, M., Bermaki, M. H., Gourbi, A., & Bendaoud, A. (2023). Optimization of EMC filter for a variable speed drive system in electric aircraft. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics, 26*, 264-269.

Miloudi, H., Miloudi, M., Gourbi, A., Bermaki, M. H., Bendaoud, A., & Zeghoudi, A. (2022). A high-frequency modeling of AC motor in a frequency range from 40 Hz to 110 MHz. *Electrical Engineering & Electromechanics, 2022*(6), 3-7.

Miloudi, M., Bendaoud, A., Miloudi, H., Nemmich, S., & Okli, M. (2012). Characterization of conducted electromagnetic interference (EMI) generated by switch mode power supply (SMPS). *The 7th International Conference on Electrical Engineering*.

Miloudi, M., Miloudi, H., Bendaoud, A., Salhi, M. A., & Al-Omari, A. N. (2019). Experimental characterization of the high-frequency isolating power transformer. *Journal of Electrical Engineering and Computer Science, 86*(4), 211-218.

Miloudi, N., Bendaoud, A., Miloudi, M., Miloudi, H., Gourbi, A., & Bermaki, M. H. (2025). Characterizing radiated electromagnetic interference from a power converter for improved electromagnetic compatibility. *WSEAS Transactions on Circuits and Systems, 24*.

Zeghoudi, A., Bendaoud, A., Slimani, H., Miloudi, H., Miloudi, M., & Chikhi, N. (2022). Experimental measurement of common and differential modes for variable speed drive DC motor. *2022 19th International Multi-Conference on Systems, Signals & Devices (SSD)*, 607-611.

Zeghoudi, A., Bendaoud, A., Slimani, H., Miloudi, M., Miloudi, H., & Canale, L. (2022). Experimental measurements of near magnetic field by different probe for AC/DC LED driver. *2022 IEEE International Conference on Environment and Electrical Engineering and 2022 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe)*, 1-5.

Zeghoudi, A., Bendaoud, A., Tilmatine, A., Miloudi, M., Miloudi, H., & Canale, L. (2022). Experimental measurement of harmonic distortion and electromagnetic interferences for LED lamps. *2022 IEEE Industry Applications Society Annual Meeting (IAS)*, 1-7.

Author(s) Information

Mohammed El-Amine Lahlaci
University Ahmed Zabana of Relizane, APELEC, Algeria
Contact e-mail: *lahlaciamine@gmail.com*

Mohamed Miloudi
University Ahmed Zabana of Relizane, APELEC, Algeria

Houcine Miloudi
Djillali Liabés University of Sidi Bel Abbés, APELEC, Sidi Bel-Abbès, Algeria

Mohammed Hamza Bermaki
Djillali Liabés University of Sidi Bel Abbés, APELEC, Sidi Bel-Abbès, Algeria

Kheira Mendaz
University of Ain Temouchent (Belhadj Bouchaib Ain Temouchent University), Algeria

Abdelkader Gourbi
University of Oran1 Ahmed Ben Bella, APELEC, ISTA, Oran, Algeria

To cite this article:

Lahlaci, M. E.., Miloudi, M., Miloudi, H., Bermaki, M. H., Mendaz, K., & Gourbi, A. (2025). Investigation of conducted electromagnetic disturbances in power electronics: A case study on DC/DC choppers. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM)*, *38*, 81–89.