Conducted Emissions Generated by a Variable Speed Drive System

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Abstract – The variable drive systems are constantly changing in particular to increase their efficiency and compactness. However, the advanced process technology isn't without problems of electromagnetic compatibility (environmental disturbances and self-interference). In a variable speed drive is the switching cell that generates the electromagnetic disturbances, switching current does cause differential mode, and switching voltage generates HF common mode currents that we find in the parasitic components. The direct objective of this paper is to understand the simulation of the conducted emission level. The study focuses on the selected spectral estimation electromagnetic disturbance generated by variable drive systems to the network using Impedance Stabilization Network Line (LISN).

Keywords – Conducted Emissions, Common Mode, Electromagnetic Compatibility, Variable Speed Drive System, Switch.

I. INTRODUCTION

Variable speed drive systems, which are now being established in many tertiary sectors, we can enumerate a few applications integrating variable speed devices, such as industrial fields. This type of converter is constantly evolving in particular to increase their efficiency and their compactness. However, the progress of technological processes is not without posing some problems of electromagnetic compatibility (environmental disturbances and self-disturbance) [1-3].

In this paper, we enter the rather complex field of electromagnetic compatibility (EMC) of power electronic structures. This field is poorly mastered because until now, it has remained confined to specialized fields (space, military, broadcasting). The various paragraphs, therefore, describe the generalities and particularities of static converters from the point of view of electromagnetic compatibility (EMC). Thus, this work develops the way of understanding the modeling of the switching cell in the light of EMC considerations, keeping in mind that the analysis of the EMC problem in power electronics, is always linked to the basic building block, in power electronics, that is the switching cell [4-6].

In this work, we are interested in quantifying electromagnetic disturbances (Fig. 1). We take as support the European standard EN55022, the aim of which is to understand the various phenomena causing electromagnetic pollution of the variable speed drive. We will therefore study and develop common-mode models. We focused on the common-mode component, commonly believed to be primarily responsible for the problems encountered.

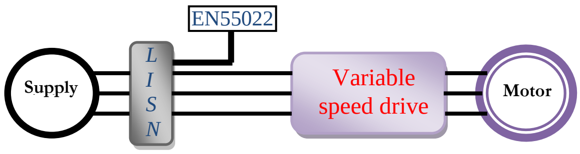

Fig. 1. Schematic diagram of EM pollution measurement

II. EMC PROBLEM IN THE SPEED DRIVERS

The increase in power and switching speed means that static converters create increasingly large conducted and radiated disturbances. These appear to be conducted in symmetrical and asymmetrical mode and radiated in electric and magnetic fields. They come mainly from the opening or closing of the semiconductor switches that make up the inverter [7-12]. The latter can be both a source of disturbance and also a victim. The means of propagation being, its printed circuit tracks, and their connections. These behave like antennas radiating electric and magnetic fields.

In the case of a variable speed drive, the switching of the semiconductor power components used in the variable speed drives of asynchronous motors is the main source of the conducted electromagnetic disturbances. The rapid variations in voltage (dv / dt) and current (di / dt) at the output of the converter cause the appearance of common mode and differential mode currents [13-15].

III. EMC MODELING APPROACH

In our case, the prediction of the conducted emissions generated by a variable speed drive system is based on the linearization of the structure. The proposed method is based on a matrix approach, the objective of which is to determine the spectrum of signals directly in the frequency domain. This method requires knowing, for a given structure, and identifying:

- the main disturbance generation mechanisms;
- all the critical propagation paths and the victim.

Indeed, the generators of the disturbances are constituted by the switching cell, the latter is replaced by sources of voltages and currents to form an equivalent EMC diagram. Each mode of propagation is replaced by an equivalent source:

- The common mode is modeled by a voltage source;
- The differential mode is modeled by a current source.

The propagation paths are formed by the passive components, the converter tracks, the parasitic capacitances, the diode bridge, the machine, and its power cable (Fig. 2). The victim is the LISN on the power side, and each subsystem must be modeled as a variable impedance as a function of frequency [5-12].

The spectral estimates are referred to as standard EN 55022, the standard for measuring radio interference in information processing equipment. This standard, specifying the high-frequency levels of conducted emissions applicable to residential, commercial, and light industrial areas. The specifications of the standards relating to conducted disturbances in the radio frequency band (150 kHz - 30 MHz) fall into two categories.

The first referred to as Class A, defines the emission level for devices intended for the industrial sector. The second, and certainly not the least, is reserved for the domestic and hospital sector: it is Class B. The levels are given on a logarithmic scale in dBµV.

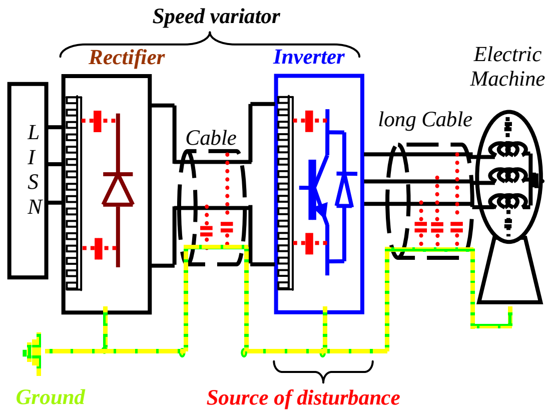

Fig. 2. Common mode couplings within the variable speed drive system

IV. IDENTIFICATION OF EQUIVALENT VOLTAGE GENERATOR

The voltage supplied by the inverter is responsible for disturbances, this voltage source is defined in the frequency domain. The conducted disturbances estimated using the matrix approach are strongly dependent on the sources that we have just mentioned.

The diagram shown in figure 3, integrates the three voltage generators as well as the propagation paths defined by the load (motor + cable). It can be seen that the three arms of the inverter constitute the main sources of disturbance of this structure. More precisely, these sources are modeled by three voltage harmonic generators.

The scheme is however based on the assumption of the symmetry of the inverter from the point of view of common-mode propagation paths, and that the common-mode currents are the most dominant [7-10].

The common-mode voltage of each phase is given by the following formula:

$$V_{CM_i} = Z_{eq} I_{CM_i} + \frac{Z_{eq}}{2} I_{CM_i} \quad (1)$$

The single source of common-mode V_{CM} is then equivalent to the average of the three generators initially dissociated.

$$I_{CM} = \frac{V_{CM}}{\frac{Z_{eq}}{2} + \frac{Z_{eq}}{3}} \quad (2)$$

The common-mode current is due to variations in the common-mode voltage generated by the inverter.

The three-phase inverter, shown schematically in figure 3, generates chopping voltages between the three output phases and the midpoint of the DC bus (point O, active in this example).

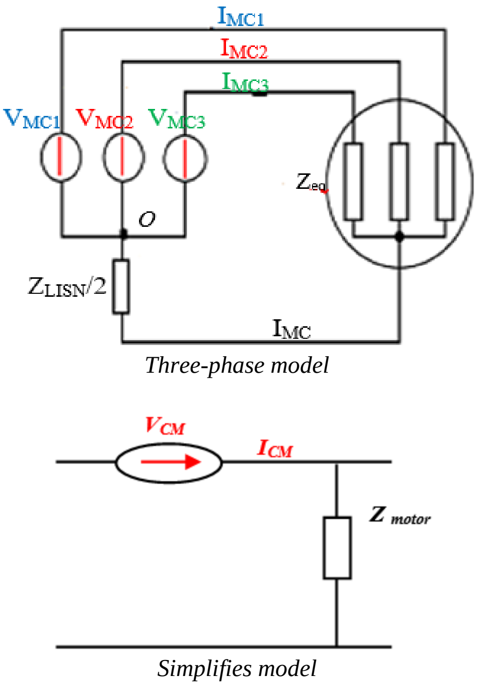

Fig. 3. Equivalent diagram of the three-phase common-mode model

According to these notations, the common-mode voltage (V_{CM}) allows the sum of the voltages of the three phases at the output of the inverter.

$$V_{CM} = \frac{V_1 + V_2 + V_3}{3} \quad (3)$$

V. MODELING OF THE EM DISTURBANCE MEASUREMENT RECEIVER

The LISN (made up of resistance, inductance, and capacitance: RLC), fulfills four essential functions:

- it authorizes the passage of power to the device under test;

- it does not let through the HF currents coming from the sector;

- the measuring device freezes the network impedance in a certain frequency range to ensure the reproducibility of the tests;

- it channels the disturbances from the converter to a measurement location.

Figure 4 represents a simplified structure of the LISN in common-mode, the frequency behavior of which is quite satisfactory. It makes it possible to reduce the size of the simulated circuits while preserving the dynamics of the electrical quantities.

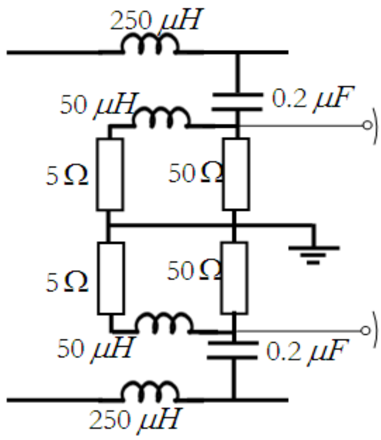

Fig. 4. Equivalent diagram of the three-phase common-mode model

Figure 5 shows the LISN impedance characteristic (amplitude and phase). We see that the characteristic impedance of the LISN has a capacitive impedance in LF, and a rather inductive impedance in HF.

The LISN, within the normative framework, is used for the standard measurement of conducted disturbances in the frequency range 150 kHz - 30 MHz, it is characterized by its impedance standardized by the CISPR.

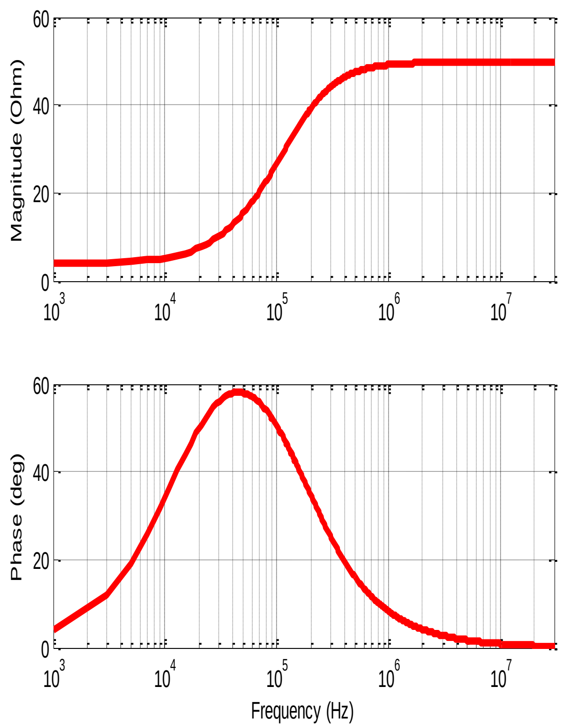

Fig. 5. LISN common-mode impedance

VI. CONDUCTED EMISSION

Figure 6, clearly shows the appearance of the common-mode voltage spectrum, the level is higher than the class B standard (according to the standard EN 55022 - class A) over a large part of the frequency range (150 kHz – 1 MHz), which is partly due to the absence of the filter in the structure. Also, we notice that there is a very clear improvement in the result for frequencies above 1 MHz.

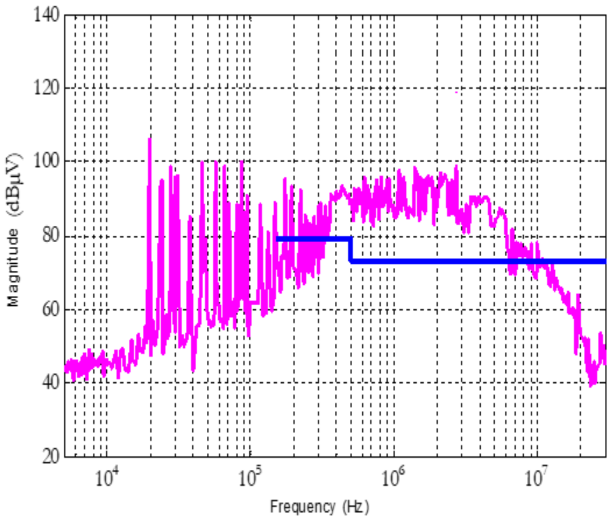

Fig. 6. Common-mode voltage

Figure 7 shows the common-mode current spectrum in the LISN, the level is given on a logarithmic scale in dBµA.

For higher currents, a cooling system is sometimes necessary. If it is connected to the system earth for safety reasons, parasitic capacitive couplings appear and are liable to cause common mode currents. The most damaging parasitic capacitive couplings are generally associated with potentials which can change suddenly.

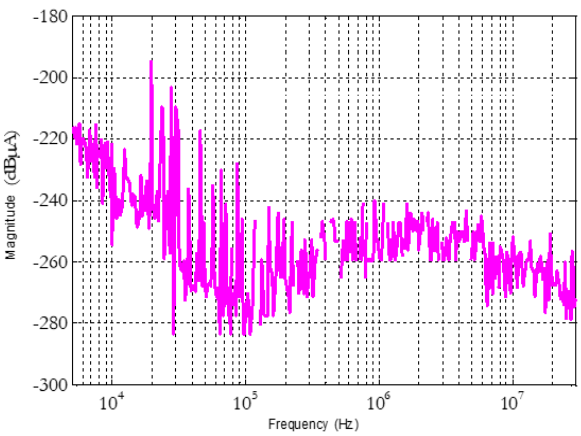

Fig. 7. Common-mode curant

VII. CONCLUSION

The approach proposed in this work is to replace the switching cell with equivalent generators. These generators represent the power signals within this cell, and generate, directly or indirectly, the differential mode and common mode currents, and present all of the critical and victim propagation paths by their equivalent impedances. It allows us to estimate common-mode conducted electromagnetic disturbances in a speed variation system directly and only in the frequency domain.

The level of electromagnetic disturbances generated by the variable speed drive to the network (common-mode voltage spectrum of the LISN) is greater than the template resulting from the driving standard: class B, although it remains critical compared to the imposed level by the standard even though the chosen model is simple.

VIII. REFERENCES

[1] H. Miloudi, A. Bendaoud, M. Miloudi, Analyse et prédiction des perturbations électromagnétiques conduite générées par un onduleur triphasé alimentant un moteur asynchrone, *Proc. 3rd international conference on electrical engeneering, ICEE'09, Alger, 2009.*

[2] N. Idir, J.J. Franchaud, R. Bausière, Evaluation and Reduction of Common Mode Currents in Adjustable Speed Drives, *Proc. conference PCIM Europe, Nürnberg, Germany, 2003, 279-284.*

[3] X. Huang, E. Pepa, J. S. Lai, S. Chen, T. W. Three-Phase Inverter Differential Mode EMI Modeling and Prediction in Frequency Domain, *IEEE IAS'03, 3, 2003, 2048 – 2055.*

[4] Chaiyan Jettanasen, *Modélisation par Approche Quadripolaire des Courants de Mode Commun dans les Associations Convertisseurs-Machines en Aéronautique ; Optimisation du Filtrage,* doctoral diss., university of Lyon, 2008.

[5] C. Chen, Characterization of Power Electronics EMI Emission, *IEEE Electromagnetic Compatibility, 2, 2003, 553 – 557*.

[6] Qian Liu Wang, F., Conducted EMI Noise Prediction and Characterization for Multi-phase-leg Converters Based on Modular-Terminal-Behavioral (MTB) Equivalent EMI Noise Source Model, *Proc. Power Electronics Specialists Conference. PESC '06. 37th IEEE, 2006.*

[7] Bertrand Revol, *Modélisation et Optimisation des Performances CEM d'une Association Variateur de Vitesse-Machine Synchrone,* doctoral diss., university of Grenoble, 2003.

[8] K. Karanun, W. Khan-ngern, S. Nitta, Conducted EMI Circuits Modeling During Transient Phenomena on Three Phase Full-Bridge PWM Inverters. *Proc. EMC'04 Sendai, 2004.*

[9] Revol, B; Roudet, J; Schanen, J.L; Loizelet, EMI Study of a Three Phase Inverter-Fed Motor Drives, *Proc.Conference Record of the IEEE, 2004, 2657 - 2664.*

[10] G. Grandi, D. Casadei, U. Reggiani, Common and Differential-Mode HF Current Components in AC Motors Supplied by Voltage Source Inverters, *IEEE Trans. on Power Elect, 19(1), 2004.*

[11] Adam Kempski, EMI Noise Splitting Into Common And Differential Modes In PWM Inverter Drive System, *Proc. 4th International Workshop Compatibility in Power Electronics - CPE 2005.*

[12] K. S. Kostov, A. Niinikoski, J. Kyyrä, and T. Suntio, Prediction of the conducted EMI from DCDC switched mode power converters, *Proc. 11th International Power Electronics and Motion Control Conference, 2004.*

[13] Mohamed Miloudi, Houcine Miloudi, Abdelber Bendaoud, Mohammed Adnan Salhi, Ahmad N. Al–Omari, Experimental Characterization of the High–Frequency Isolating Power Transformer, *Journal of Electrical Engineering and Computer Science, 86 (4), 2019, 211–218.*

[14] Mohamed Miloudi, Abdelber Bendaoud, Houcine Miloudi, Common and Differential Modes of Conducted Electromagnetic Interference in Switching Power Converters, *Revue Roum. Sci. Techn. 62 (3), 2017, 246–251.*

[15] Houcine Miloudi, Mohamed Miloudi, Abdelber Bendaoud, A Method for Modeling a Common–Mode Impedance for the AC Motor, *Journal of Electrical Engineering and Computer Science 84 (5), 2017, 241–246.*