

# Table of Contents

<b>Chapter 1. Phenomena of Perturbation in Electrical Systems</b> . . . . .	1
1.1. Electromagnetic perturbations in energy systems. . . . .	1
1.1.1. Introduction . . . . .	1
1.2. Power grid harmonics . . . . .	6
1.2.1 Presentation . . . . .	6
1.2.2. Characterization of the quality of electrical energy. . . . .	8
1.2.3. Relevant standards for harmonic emissions . . . . .	10
1.2.4. Classification of appliances . . . . .	11
1.2.5. The limits of harmonic currents . . . . .	12
1.2.6. Examples of observations of harmonic currents. . . . .	15
1.2.7. Fluorescent lighting scenario . . . . .	16
1.2.8. Practical scenario of the improvement of the total harmonic distortion generated by a variable-frequency drive . . . . .	20
1.2.9. Converter with sinusoidal absorption . . . . .	24
1.3. Common-mode and differential-mode conducted perturbations. . . . .	29
1.3.1. Common mode and differential mode. . . . .	30
1.3.2. Crosstalk . . . . .	41
1.4. Measuring electromagnetic perturbations . . . . .	44
1.4.1. The line impedance stabilization network. . . . .	44
1.4.2. Current sensors . . . . .	46

1.4.3. Antennae . . . . .	53
1.4.4. Spectrum analyzer. . . . .	65
1.5. The standards . . . . .	72
1.6. Bibliography . . . . .	73
<b>Chapter 2. Fundamental Principles . . . . .</b>	<b>75</b>
2.1. Sources of noise: the switching cell and its control . . .	75
2.1.1. Origin of conducted and radiated perturbations in static converters . . . . .	76
2.2. Modeling. . . . .	77
2.2.1. Simple model of the switching cell . . . . .	77
2.2.2. More complex model of the switching cell. . . . .	82
2.3. Characterization of coupling functions and parasitic elements . . . . .	86
2.3.1. Passive components and differential-mode effects . . . . .	86
2.3.2. Invisible parasitic elements and common-mode effects . . . . .	89
2.3.3. Parasitic effects contributing to undesirable couplings. . . . .	91
2.4. Electromagnetic compatibility study of a practical scenario: the Buck chopper . . . . .	103
2.4.1. Description of the case study . . . . .	104
2.4.2. Influence of the design parameters of the converter . . . . .	109
2.4.3. Influence of technological parameters and control . . . . .	111
2.4.4. Other sources of switching noise . . . . .	112
2.4.5. Other switching modes: soft switching, advantages and constraints . . . . .	113
2.5. EMC study of an insulated DC-DC fly back power supply. . . . .	114
2.5.1. Description of the device. . . . .	114
2.5.2. Creation of the circuit model . . . . .	117
2.5.3. Analysis of switchings in the structure . . . . .	121
2.5.4. Electric simulation of the complete structure . . . .	123

2.6. Corrected exercise number 1: conducted perturbations of a step-up chopper . . . . .	127
2.7. Answers with comments . . . . .	130
2.8. Bibliography . . . . .	141
<b>Chapter 3. EMC of Complex Electrical Energy</b>	
<b>Conversion Systems: Electromagnetic Actuators . . . . .</b>	<b>143</b>
3.1. How to define a complex system? . . . . .	143
3.2. Qualitative study . . . . .	145
3.2.1. Description of the conversion chain . . . . .	145
3.2.2. Reminder of the standards . . . . .	147
3.2.3. Propagation methods . . . . .	149
3.3. Modeling in frequency domain . . . . .	152
3.3.1. Linearization of the switching cell . . . . .	152
3.3.2. Modeling of the perturbation sources . . . . .	157
3.4. Frequency-based representation of an inverter . . . . .	173
3.4.1. Equivalent common-mode source – simplified diagram . . . . .	173
3.4.2. Differential-mode influence . . . . .	176
3.4.3. Proposed frequency-based diagram . . . . .	178
3.5. Modeling of the cables and motors . . . . .	179
3.5.1. Estimation of the primary parameters of the power cables . . . . .	179
3.5.2. High-frequency model of an asynchronous machine . . . . .	185
3.6. Connection of the cable and the motor . . . . .	196
3.6.1. Total impedance read by the variable-speed drive . . . . .	196
3.6.2. Measuring the total common-mode impedance . . . . .	197
3.7. Results . . . . .	198
3.7.1. Time-based simulation and frequency-based simulation . . . . .	198
3.7.2. Measurement versus simulation . . . . .	200
3.8. Passing from the time domain to the frequency domain: circuit simulations . . . . .	201
3.9. Conclusion . . . . .	204
3.10. Bibliography . . . . .	205

<b>Chapter 4. Concrete Study of Solutions for the Reduction of Electromagnetic Perturbations . . . . .</b>	<b>207</b>
4.1. Concrete study of solutions for the reduction of electromagnetic perturbations. . . . .	207
4.1.1. Introduction . . . . .	207
4.2. Filtering conducted emissions: analysis and conceptual design of common-mode filters . . . . .	212
4.2.1. Introduction . . . . .	212
4.2.2. Description of a common-mode filter . . . . .	214
4.3. Case study: determining a common-mode filter for a variable-speed drive . . . . .	221
4.3.1. Equivalent model of the drive . . . . .	221
4.3.2. Filter simulated using perfect components. . . . .	223
4.3.3. Effect of the parasitic elements of components . . . . .	226
4.4. Design and optimization components. . . . .	230
4.4.1. Study of capacitors . . . . .	230
4.4.2. Study of the common-mode toric inductance . . . . .	232
4.4.3. Results . . . . .	237
4.5. Conclusion . . . . .	239
4.5.1. Corrected exercise: filtering the conducted perturbations of a step-up chopper . . . . .	239
4.6. Shielding . . . . .	248
4.6.1. Introduction . . . . .	248
4.6.2. Breakdown of shielding effects. . . . .	249
4.6.3. Materials . . . . .	252
4.6.4. Wave impedance . . . . .	257
4.6.5. Expression of attenuations . . . . .	264
4.6.6. Global attenuation: case study. . . . .	269
4.6.7. Shielding issues for magnetic fields in low frequency . . . . .	273
4.7. Conclusion . . . . .	275
4.8. Bibliography . . . . .	276
<b>Index . . . . .</b>	<b>279</b>