
Contents

Preface	ix
1 Introduction	1
1.1 Background	1
1.1.1 Trends in electrical power systems	1
1.1.2 Role of power electronics	3
1.1.3 Control of power electronic systems	5
1.2 Periodic control of power converters	10
1.2.1 Basic control problem for power converters	11
1.2.2 Internal model principle (IMP)	12
1.2.3 Internal model principle-based periodic control	15
1.2.4 Periodic control of power converters	17
1.3 What is in this book	19
References	20
2 Fundamental periodic control	27
Abstract	27
2.1 Repetitive control (RC)	27
2.1.1 Internal model of any periodic signal	27
2.1.2 Classic RC scheme	28
2.1.3 Digital RC system and design	30
2.1.4 Two alternative RC schemes	37
2.2 Multiple resonant control (MRSC)	39
2.2.1 Internal models of harmonics	39
2.2.2 MRSC scheme	40
2.2.3 Digital MRSC system and design	41
2.2.4 RSC – Generalized integrator for sinusoidal signals	43
2.3 Discrete Fourier transform (DFT)-based RC	45
2.3.1 DFT-based internal model of interested harmonics	45
2.3.2 DFT-based RC scheme	47
2.3.3 DFT-based RC system and design	48
2.3.4 Modified DFT-based RC scheme	49
2.4 Basis function	50
2.5 Summary	53
References	54

3	Advanced periodic control for power harmonics mitigation	59
	Abstract	59
3.1	Parallel structure repetitive control (PSRC)	59
3.1.1	Complex internal model of selective harmonics	60
3.1.2	Parallel structure RC	61
3.1.3	Digital PSRC system and design	65
3.2	Selective harmonic control (SHC)	71
3.2.1	Real internal model of selective harmonics	71
3.2.2	Selective harmonic control	73
3.2.3	Digital SHC system and design	74
3.3	Optimal harmonic control (OHC)	79
3.3.1	Optimal harmonic control	79
3.3.2	Digital OHC system and design	80
3.4	Summary	81
	References	83
4	Periodic control of power converters	87
	Abstract	87
4.1	Periodic control (PC) of CVCF single-phase PWM inverters	87
4.1.1	Background	87
4.1.2	Modeling and control of single-phase PWM inverters	88
4.1.3	Experimental validation	93
4.1.4	Conclusion	106
4.2	PC of CVCF single-phase high-frequency link (HFL) inverters	108
4.2.1	Background	108
4.2.2	Modeling and control of single-phase HFL inverters	109
4.2.3	Experimental validation	111
4.2.4	Conclusion	113
4.3	PC of CVCF three-phase PWM inverters	114
4.3.1	Background	114
4.3.2	Modeling and control of CVCF three-phase PWM inverters	116
4.3.3	Experimental validation	118
4.3.4	Conclusion	122
4.4	PC of grid-connected single-phase photovoltaic (PV) inverters	123
4.4.1	Background	123
4.4.2	Modeling and control of grid-connected single-phase PV inverters	124
4.4.3	Experimental validation	127
4.4.4	Conclusion	130
4.5	PC of grid-connected single-phase HFL rectifiers	131
4.5.1	Background	131
4.5.2	Modeling and control of grid-connected single-phase “Cycloconverter” HFL rectifiers	132
4.5.3	Experimental validation	135
4.5.4	Conclusion	138

4.6	PC of grid-connected three-phase PWM inverters	138
4.6.1	Background	138
4.6.2	Modeling and control of grid-connected three-phase PWM inverters	139
4.6.3	Experimental validation	141
4.6.4	Conclusion	146
4.7	Summary	147
	References	147
5	Frequency-adaptive periodic control	153
	Abstract	153
5.1	Frequency-adaptive fundamental periodic control	154
5.1.1	Resonant control (RSC)	154
5.1.2	Direct frequency-adaptive RSC	155
5.1.3	Delay-based classic repetitive control (CRC)	157
5.1.4	Frequency-adaptive CRC with a fixed sampling rate	158
5.1.5	Frequency-adaptive CRC system and design	162
5.2	Frequency-adaptive advanced periodic control	163
5.2.1	Frequency-adaptive parallel structure repetitive control (PSRC)	163
5.2.2	Frequency-adaptive selective harmonic control (SHC)	165
5.2.3	Frequency-adaptive optimal harmonic control (OHC)	166
5.3	Frequency-adaptive discrete Fourier transform-based RC	167
5.4	Fractional-order phase-lead compensator	172
5.5	Summary	174
	References	175
6	Frequency-adaptive periodic control of power converters	181
	Abstract	181
6.1	Frequency-adaptive periodic control (FAPC) of programmable AC power sources	181
6.1.1	Background	181
6.1.2	Modeling and control of three-phase PWM inverters	182
6.1.3	Experimental validation	184
6.1.4	Conclusion	188
6.2	FAPC of grid-connected PV inverters	189
6.2.1	Background	189
6.2.2	Modeling and control of grid-connected PV inverters	190
6.2.3	Experimental validation	192
6.2.4	Conclusion	198
6.3	FAPC of shunt active power filters	199
6.3.1	Background	199
6.3.2	Modeling and control of shunt active power filters	200
6.3.3	Experimental validation	204
6.3.4	Conclusion	209
6.4	Summary	209
	References	209

7 Continuing developments of periodic control	215
Abstract	215
7.1 Periodic control for multi-period signals	215
7.1.1 Digital multi-period repetitive control	215
7.1.2 Multi-period resonant control	218
7.1.3 Frequency-adaptive periodic control for multi-period signals	219
7.2 Periodic signal filtering	220
7.2.1 Notch and comb filters	221
7.2.2 Digital notch and comb filters	227
7.2.3 Discrete Fourier transform-based comb filter	228
7.2.4 Frequency-adaptive notch and comb filters	229
7.2.5 Periodic signal filtering for grid-connected converters	233
7.3 Summary	240
References	240
Index	245