

Contents

1	Introduction	1
1.1	Power Quality Issues	1
1.2	Standards of Power Quality Issues	3
1.3	Development of Hybrid Active Power Filter	3
1.3.1	HAPF Topology 1–Series APF and Shunt PPF	5
1.3.2	HAPF Topology 2–Shunt APF and Shunt PPF	6
1.3.3	HAPF Topology 3–APF in Series with Shunt PPF	7
1.4	Research Objectives	8
1.4.1	Circuit Configuration of a Three-Phase Four-Wire Center-Split HAPF	10
1.4.2	Conventional and Proposed Compensating Current Generation Method for HAPF	13
1.4.3	Limitations of Conventional Three-Phase HAPF	17
1.5	Organization of the Book	17
	References	19
2	Analysis of HAPF in Harmonic Resonances Prevention and Compensation Capabilities	23
2.1	Introduction	23
2.2	HAPF Single-Phase Harmonic Circuit Model	24
2.2.1	HAPF Single-Phase Harmonic Circuit Model Due to I_{Lxh} Only	24
2.2.2	HAPF Single-Phase Harmonic Circuit Model Due to V_{sxh} Only	26
2.3	Investigation of HAPF Steady-State Compensating Performances	27
2.3.1	HAPF Capability to Prevent Parallel Resonance	28
2.3.2	HAPF Capability to Prevent Series Resonance	29
2.3.3	HAPF Capability to Improve Filtering Performances	32
2.3.4	HAPF Capability to Enhance System Robustness	33
2.4	Summary	36
	References	37

3	Nonlinearity and Linearization of Hysteresis PWM Study and Analysis for HAPF	39
3.1	Introduction	39
3.2	Modeling of a Three-Phase Four-Wire Center-Split HAPF and APF	40
3.2.1	Circuit Configuration of a Three-Phase Four-Wire Center-Split HAPF and APF	40
3.2.2	Mathematical Modeling of a Three-Phase Four-Wire Center-Split HAPF and APF	42
3.3	Hysteresis PWM Control for HAPF	43
3.3.1	Nonlinearity of HAPF Inverter Current Slope	43
3.3.2	Single-Phase Simulation and Experimental Results for HAPF Inverter Current Slope Linearization Analysis	44
3.3.3	Summary for Determining Quasi-Linear Limit T_{limit} and Linear Limit T_{linear}	50
3.4	HAPF Linearization Study Verification Under Three-Phase Four-Wire Power Quality Compensator Application	50
3.4.1	Determination of Final Sampling Time T_{final} and Hysteresis Band H_{final}	51
3.4.2	Simulation and Experimental Verifications for HAPF Linearization Study Under Three-Phase Four-Wire Power Quality Compensator Application	51
3.4.3	Simulation Results	52
3.4.4	Experimental Results	55
3.5	Summary	58
	References	60
4	Adaptive DC-Link Voltage Control Technique for HAPF in Reactive Power Compensation	61
4.1	Introduction	61
4.2	Single-Phase Fundamental Equivalent Circuit Model of HAPF	62
4.3	HAPF Required Minimum DC-Link Voltage with Respect to Loading Reactive Power	65
4.3.1	Full-Compensation by Coupling Passive Part	66
4.3.2	Under-Compensation by Coupling Passive Part	66
4.3.3	Over-Compensation by Coupling Passive Part	66
4.4	Adaptive DC-link Voltage Controller for A Three-Phase Four-Wire HAPF	68
4.4.1	Instantaneous Power Compensation Control Block	68
4.4.2	Adaptive DC-Link Voltage Control Block	68
4.4.3	Final Reference Compensating Current and PWM Control Block	71

4.5	Simulation and Experimental Verifications of the Adaptive DC-Link Voltage Controller for the Three-Phase Four-Wire HAPF.	71
4.5.1	Under-Compensation by Coupling Passive Part Situation ($L_{c1} = 6 \text{ mH}$, $C_{c1} = 140 \text{ }\mu\text{F}$)	73
4.5.2	Over-Compensation by Coupling Passive Part Situation ($L_{c1} = 6 \text{ mH}$, $C_{c1} = 190 \text{ }\mu\text{F}$)	74
4.5.3	Comparison Between Fixed and Adaptive DC-Link Voltage Control	80
4.6	Summary	84
	References	84
5	Minimum Inverter Capacity Design for HAPF	87
5.1	Introduction	87
5.2	Mathematical Modeling of A Three-Phase Four-Wire Center-Split HAPF in D-Q-0 Coordinate	89
5.2.1	Equivalent Circuit Models of a Three-Phase Four-Wire HAPF in D-Q-0 Coordinate	89
5.2.2	Coupling Part Filtering Characteristics Analysis of the HAPF without or with Coupling Neutral Inductor	90
5.2.3	Resonant Frequency Selection for Coupling LC without or with Coupling Neutral Inductor	92
5.3	Minimum Inverter Capacity Analysis of A Three-Phase Four-Wire Center-Split HAPF.	93
5.4	Simulation and Experimental Verifications for Inverter Capacity Reduction Analysis of the Three-Phase Four-Wire HAPF with Coupling Neutral Inductor.	98
5.4.1	Simulation Results	99
5.4.2	Experimental Results.	103
5.5	Summary	109
	References	109
6	Design and Performance of A 220 V 10 kVA Adaptive Low DC-Link Voltage Controlled HAPF with a Coupling Neutral Inductor Experimental System	111
6.1	Introduction	111
6.2	Adaptive DC-Link Voltage Controller for A HAPF without and with L_{cn}	112
6.2.1	Instantaneous Power Compensation Control Block	115
6.2.2	Proposed Adaptive DC-Link Voltage Control Block	115
6.2.3	Final Reference Compensating Current and PWM Control Block.	120

6.3 A 220 V 10kVA Three-Phase Four-Wire Center-Split
HAPF Experimental Prototype 121

6.3.1 System Configuration of Three-Phase Four-Wire
Center-Split HAPF 121

6.3.2 Experimental Testing Loads 122

6.3.3 Design of PPF Part of HAPF 122

6.3.4 Design of APF Part of HAPF 124

6.3.5 General Design Procedures for Adaptive DC-Link
Voltage Controlled HAPF with L_{cn} 130

6.4 Experimental Verifications of A 220 V 10 KVA Low Adaptive
DC-Link Voltage-Controlled HAPF with L_{cn}
Experimental Prototype 131

6.4.1 Power Quality Data of the Experimental Loadings 132

6.4.2 Experimental Results of Conventional Fixed DC-Link
Voltage-Controlled HAPF 132

6.4.3 Experimental Results of Adaptive DC-Link
Voltage-Controlled HAPF 136

6.4.4 Experimental Results of Adaptive DC-Link
Voltage-Controlled HAPF with L_{cn} 138

6.4.5 Comparison 139

6.5 Summary 143

References 144

7 Conclusions and Prospective for Future Work 145

7.1 Conclusions 145

7.2 Perspectives for Future Work 146

Appendix 147

Biography of Authors 157