

List of Figures

Fig 1.1	Shunt Active Filter in Three Phase Power System	2
Fig 1.2	Shunt APF with waveforms	3
Fig 1.3	System Set up: 3- Φ four wire APF	5
Fig 1.4	Four Leg Converter	5
Fig 2.1	Three-leg and Four wire Inverter	9
Fig 2.2	APF with UCI control	10
Fig 2.3	Block Diagram of Voltage Control Loop	11
Fig 2.4	Block Diagram of Current Control Loop	12
Fig 2.5	Basic Shunt Compensation Scheme Using 4-LegVSC	13
Fig 2.6	Switching Vectors of a three-phase four legged Inverter	14
Fig 2.7	Control Circuit: A Three Phase Four Legged APF	15
Fig 2.8	Control Circuit: A Three Phase Four Legged APF	16
Fig 2.9	Industrial Power System	17
Fig 2.10	Experimental System	17
Fig 2.11	Block Diagram of Control Circuit	18
Fig 2.12	Basic Principle of Shunt Passive Filter	19
Fig 2.13	Basic Principle of Shunt Passive Filter	20
Fig 2.14	Circuit Diagram of Combined System	21
Fig 2.15	unified power quality conditioners (UPQC)	22
Fig 2.16	Three-level Module for building Multiconverters	23
Fig 2.17	Main Components of the Four-Stage Multiconverter	24
Fig 2.18	Shunt Active Filter using PWM Techniques	25
Fig 2.19	Shunt APF using the Four-Stage Converter	25
Fig. 2.20	Results from simulation: (a) Source, load and filter currents.	26
	(b) Filter (load) and line voltages. (c) Ultra capacitor voltage.	26
Fig 3.1	Combination of Series Active and Passive Filters	27
Fig 3.2	Hybrid Series Configuration	28
Fig 3.3	Control Diagram of Shunt APF	30
Fig 3.4	Circuit representing DC bus fed by Inverter	31
Fig 3.5	Block Diagram of Hardware setup for DSP Based APF	31
Fig 3.6	Harmonic Compensation circuit with current-fed APF	32

List of Figures

Fig 3.7	Simplified Block diagram of Active Power Compensation Circuit	32
Fig. 3.8	Simplified Block Diagram for the APF Control Algorithm	33
Fig 3.9	Three-Phase Active Power Filter Test Circuit	35
Fig 3.10	Hybrid APF Configuration	37
Fig 3.11	Hybrid APF: Topology & Associated Control Scheme	38
Fig 3.12	Three Phase distribution line Simulator	40
Fig 3.13	Digitally Controlled APF	41
Fig 3.14	Control Block Diagram of APF	42
Fig 3.15	Software Implementation of Automatic Gain Adjustment	42
Fig 3.16	A radial Power Distribution system	44
Fig 3.17	A feeder Arrangement under a fault Condition	45
Fig 3.18	Voltage THD and Compensation Current Calculations	46
Fig 3.19	Communication System	47
Fig 3.20	Cooperative Control in the Host Computer	47
Fig 3.21	Hypothetical Test Setup	48
Fig 3.22	Simplified Laboratory Test Setup	49
Fig 3.23	Hypothetical Test Setup	50
Fig 3.24	Simplified Laboratory Test Setup	50
Fig 3.25	APF Configuration: TWO VSI in Cascade	51
Fig 3.26	Block Diagram of APF Control System	53
Fig 3.27	Power Reference Generator	53
Fig 3.28	Regions of Inverter Output Voltage	54
Fig 3.29	Current Control Scheme	55
Fig 3.30	(a) Harmonic Compensation Circuit with current-fed APF without feedback	56
Fig 3.30	(b) Harmonic Compensation Circuit with current-fed APF with feedback	56
Fig 3.31	Simplified Block Schematic of Current-Fed APF	57
Fig 3.32	Poly phase Interpolator	58
Fig 3.33	Hysteresis Current Controller Algorithm	58
Fig 4.1	Harmonic Current –free ac/dc Power Conversion System	61
Fig 4.2	Control Circuit of Series Active Filter	61
Fig 4.3	Simplified Equivalent Circuit of System	62

List of Figures

viii

Fig 4.4	Control System Diagram: first-generation Circuit	63
Fig 4.5	Basic Compensation System	64
Fig 4.6	APF: System Configuration	65
Fig 4.7	Voltage Vector Diagram	66
Fig 4.8	Current Vector Diagram	66
Fig 4.9	Summary of Analysis: Current Controllable region	66
Fig 4.10	Theoretical Optimal Voltage of DC Capacitor	67
Fig 4.11	Resonant turn-off Snubber Topology	69
Fig 4.12	Conventional VS-APF	72
Fig 4.13	Equivalent Block Diagram of q-axis loop Conventional VS-APF	73
Fig 4.14	Block Diagram of Adaptive Algorithm Implemented on VS-APF	74
Fig 4.15	Schematic Diagram of Adaptive Algorithm Implementation	75
Fig 4.16	Calculation of the APF Current Reference	76
Fig 5.1	Three Phase Four Leg Converter	78
Fig 5.2	Feedback PWM Scheme	79
Fig 5.3	Hysteresis Current Controller: Block Diagram	79
Fig 5.4	Typical Analog Implementation: Hysteresis Controller	80
Fig 5.5	Typical Analog Implementation: Driver Circuit	81
Fig 5.6	Shunt Active Filter	81
Fig 5.7	Active Power Filter – Schematic	88
Fig 5.8	Active Power Filter – Actual Wiring Diagram	88
Fig 5.9	Mechanical Specification of APF Power Module Panel	90
Fig 6.1	p-q theory based APF Controller	92
Fig. 6.2	MATLAB Desktop	93
Fig. 6.3	SIMULINK: LIBRARY BROWSER WINDOW	94
Fig 6.4	Dialog Box: SIMULATION PARAMETERS	97
Fig 6.5	WORK SPACE I/O PANE	98
Fig 6.6	Simulation Setup for Control Signal Generation	98
Fig 6.7	SIMULINK subsystem: Power Circuit	99
Fig 6.8	SIMULINK Subsystem: Three Phase – Two Phase Conversion	99
Fig 6.9	SIMULINK Sub System: p-q calculation and Compensating Current Generator	100

List of Figures

ix

Fig 6.10	SIMULINK Sub System: Hysterisis Band controller	101
Fig 6.11	SELECTION of SIMULATION PARAMETER for APF controller	101
Fig 6.12	SIMULATION Responses: Phase A	102
Fig 6.13	SIMULATION Responses: Phase B	102
Fig 6.14	SIMULATION Responses: Phase C	102
Fig. 6.15	Simulation Responses: Power Computations	103
Fig 6.16	Simulation Responses: Load Side Waveforms	103
Fig 6.17	Simulation setup with and without loading	103
Fig 6.18	Simulated Firing Pulses: without Load	103
Fig 6.19	Simulated Firing Pulses for Compensation with load	104
Fig 7.1	Circuit Diagram for Transformation to Orthogonal Coordinate Representation	105
Fig 7.2	Circuit Diagram for Calculation of Instantaneous Power Components	106
Fig 7.3	Circuit Diagram for Orthogonal Compensation Current Calculation	107
Fig 7.4	Circuit Diagram: Orthogonal to Three Phase Coordinates Transformation	108
Fig 7.5	Circuit Diagram: Compensation Current Generator	109
Fig 7.6	Experimental Test Set up	110
Fig 7.7	Power Module with Driver Circuits	110
Fig 8.1	Block Diagram of APF Control Algorithm	111
Fig. 8.2	TMS320C6711 DSK BOARD	112
Fig 8.3	Interfacing daughter Board	113
Fig 8.4	Daughter card Interface Layout on DSP Motherboard	116
Fig 8.5	Daughter card Interface Layout	120
Fig 8.6	INTERFACING ADS8364 WITH 671X	121
Fig 8.7	TLV 2553 EVM BOARD	122
Fig 8.8	ANALOG INTERFACE BLOCK DIAGRAM	123
Fig 8.9	EVM BLOCK DIAGRAM	124
Fig 8.10	5K – 6 K INTERFACE CARD	125
Fig 8.11	SOFTWARE DEVELOPMENT Using MATLAB/SIMULINK	126
Fig 8.12	RTW Code Generation	126
Fig 8.13	TARGET FILE BROWSER	127
Fig 8.14	REAL TIME WORKSHOP PANE	128

List of Figures

x

Fig 8.15	CODE DEVELOPMENT FLOW	130
Fig 8.16	SIMPLIFIED CCSSTUDIO DEVELOPMENT FLOW	131
Fig 8.17	BUILDS OPTIONS: DIALOG BOX	131
Fig 8.18	PROJECT CREATION WINDOW	132
Fig 8.19	CCSSTUDIO IDE BASIC WINDOW	132
Fig 8.20	ADD FILES TO PROJECT DIALOG BOX	133
Fig 8.21	TOOLBAR SHOWING BUILD OPTION	133
Fig 8.22	Block library for DSK C6711	136
Fig 8.23	CCS Project Creation	138
Fig 8.24	DCP Start Screen	139
Fig 8.25	Data Converter Selection	139
Fig 8.26	Select TLV2553 Converter and ADD to DCP	140
Fig 8.27	DSP Page	141
Fig 8.28	GUI of the TLV 2553	141
Fig 8.29	Files Page	142
Fig 8.30	Code Generation	142
Fig 8.31	SETTING PROGRAM PARAMETERS	144
Fig 8.32	REAL TIME WORKSHOP PANE	144
Fig 8.33	SYSTEM TARGET FILE BROWSER	145
Fig 8.34	C SOURCE CODE	146
Fig 8.35	ASSEMBLY LANGUAGE CODE	146
Fig 8.36	Simulation Parameters: Dialog Box	147
Fig. 8.37	Target File Browser	148
Fig 8.38	CCS WINDOW: activefilter_dsp1.pjt	149
Fig 8.39	SCHEMATIC OF ACTIVE POWER FILTER	150
Fig 8.40	System Setup: High Resolution	150
Fig 8.41	System Setup: Low Resolution	151
Fig 8.42	SIMULINK model	151
Fig 8.43	System Flowchart: APF Controller	152
Fig 8.44	FIRING PULSES: Without Load	153
Fig 8.45	FIRING PULSES: with load (for compensation)	153

List of Figures

xi

D- I Transformed Waveforms (Two Phase: 2 ϕ)	204
Fig D-1.1: v_{α} and i_{α}	
Fig D-1.2: v_{β} and i_{β}	
D-2 Power components	205
Fig D-2.1 p_{ac} AND p (Active Power)	
Fig D-2.2: q_{ac} AND q (REACTIVE POWER)	
D-3 Compensating Reference Currents (2 ϕ)	206
Fig D-3.1 $i_{c\alpha}$ and $i_{c\beta}$ (α and β Phase)	
D-4 Compensating Reference Currents (3 ϕ)	206
Fig D-4.1 i_{ca} and i_{cb} (Phase-A and Phase-B)	
Fig D-4.2: i_{ca} and i_{cc} (Phase-A and Phase-c)	
D-5 Source Voltage and Load Currents (3 ϕ)	207
Fig D-5.1: Phase A	
Fig D-5.2: Phase B	
Fig D-5.3: Phase C	
D-6 Source Voltage and Compensating Currents (3 ϕ)	208
Fig D-6.1: PHASE-A	
Fig D-6.2: PHASE B	
D-7 Source Current and Source Voltage (3 ϕ)	209
Fig D-7.1: PHASE-A	
Fig D-7.2: PHASE-B	
Fig D-7.3: PHASE-C	
D-8 v_{ce} and Compensating Current	210
Fig D-8.1: UPPER IGBT PHASE- A	
Fig D-8.2: V_{ce} and COMPENSATING CURRENT	
D-9 Gate Pulse and Compensating Current	211
Fig D-9.1; UPPER IGBT A-PHASE	
Fig D-9.2: LOWER IGBT A-PHASE	
Fig D-9.3: UPPER IGBT: Phase-A (Zoomed)	