

CONTENTS



List of figures

List of tables

xi

List of symbols

xii

Synopsis

Chapter		Page
1	INTRODUCTION	
1.1	General	1
1.2	Power Quality Phenomena	4
1.3	Power Quality Concerns	6
1.4	Power Quality Solutions	9
1.5	Outline of Thesis	15
2	REVIEW OF DEVELOPMENT	
2.1	Introduction	17
2.2	Converter Configurations	17
2.2.1	Voltage Source Converters (VSCs)	18
2.2.2	VSCs Configurations	19
2.3	Harmonic Elimination Techniques	28
2.4	VSCs for Reactive Power Compensation	32
2.4.1	Scheme-I	32
2.4.2	Scheme-II	35
2.5	Current Control Techniques	35
2.5.1	Indirect Current Control (ICC)	35
2.5.2	Load Current Control (LCC)	36
2.6	Power Semiconductors-General Trends	38
2.6.1	Diodes	40
2.6.2	Thyristors	40
2.6.3	GTOs and IGCTs	40

2.6.4	Transistors	41
2.6.5	Control Electronics	42
2.7	Applications	48
2.7.1	SEQUIN, Texas USA	50
2.7.2	HAGFORS, Sweden	50
2.7.3	TRIER, Germany	51
2.7.4	TORINO, Finland	51
2.7.5	REJSBY HEDE WINDFARM, Denmark	52
2.7.6	East Claydon, UK	53
2.7.7	Shin Shinano, Japan	53
2.7.8	Channel tunnel rail link, between England and France	54
2.8	Conclusion	54
Chapter 3	DESIGN OF DYNAMIC REACTIVE POWER COMPENSATOR	
3.1	Introduction	56
3.2	Reactive Power Compensation	56
3.2.1	Fundamental of Reactive Power Compensation	57
3.2.1.1	Shunt Compensation	59
3.2.1.2	Series Compensation	60
3.3	Traditional Reactive Power Compensation Solutions	60
3.3.1	Fixed Capacitor (FC)	61
3.3.2	Automatic Power Factor Correction (APFC)	62
3.3.3	Thyristor Switched Capacitor (TSC)	63
3.3.4	Thyristor Controlled Reactor (TCR)	64
3.4	Active Converter Based Solution	65
3.5	STATCON	66
3.5.1	Basic Operating Principle of STATCON	66
3.5.2	STATCON : Design details	69
3.5.2.1	Three-Phase STATCON	69
3.5.2.2	Three-Phase STATCON: Vital Design aspects	102

3.5.2.2.1	Power Scheme and Component Selection	102
3.5.2.2.2	Various formulae to be used in the component selection of the converter and their relevance	103
3.5.2.2.3	Converter component selection	105
3.5.2.2.4	Control scheme and list of function in control electronics cards	108
3.5.2.3	Operating sequence of three phase STATCON panel	109
3.5.2.4	Product photographs and field responses	113
3.5.2.5	Single Phase STATCON	115
3.5.2.6	Single Phase STATCON: Vital Design aspects	144
3.5.2.6.1	Power Scheme and Component Selection	144
3.5.2.6.2	Various formulae to be used in the component selection of the converter and their relevance	144
3.5.2.6.3	Converter component selection	147
3.5.2.6.4	Control scheme and list of function in control electronics cards	148
3.5.2.7	Operating sequence of three phase STATCON panel	151
3.5.2.8	Product photographs and field responses	155
3.6	Key Development Aspects of dynamic reactive power compensator	157
3.7	Additional Innovation Highlights	160
3.7.1	Deployment of carrier wave cancellation for harmonic reduction	160
3.7.2	PWM generation (through phase and harmonic compensated sine/cosine table)	164
3.8	Conclusion	166
Chapter 4	DESIGN OF DIGITAL CONTROLS AND EMI-EMC CONSIDERATIONS FOR STATCON INSTALLATIONS IN AUTOMOBILE PLANT AND RAILWAY SUBSTATION	
4.1	Introduction	167
4.2	Design of Digital Controls	167
4.2.1	Solution with 8085/8086 based controller	169
4.2.2	Solution with 8051 based controller	169
4.2.3	Solution with MCS 96 based controller	170
4.2.4	Solution with PC Based controller	171
4.2.5	Solution with 24X based DSP	171
4.2.6	Solution with 24xx based DSP	172

4.3	Physical Design based on MCS-96 Controller	172
4.4	Physical Controller Design upgrade with 24x DSP	174
4.5	New generation Digital Core devices	175
4.6	Latest offerings: Texas 28xx DSP	180
4.6.1	Details of TMS320F2812 PWM Generator	180
4.7	Salient features of embedded software of digital controller for single and three-phase STATCON panels	182
4.8	STATCON installation for spot welding applications	184
4.8.1	Details of Spot welding System solution	184
4.8.2	600 kVAR dynamic compensation system per transformer	185
4.8.3	Control implementation	187
4.8.4	Compensation waveforms	187
4.8.5	Dynamic response of STATCON Compensator	188
4.8.6	Summary of performance	189
4.9	Installation for railway substation application	190
4.9.1	Scenario before installation	191
4.9.2	DRPC installation	193
4.9.3	Performance improvement in railway TSS	194
4.9.4	Summary of TSS STATCON installation	198
4.10	EMI-EMC Considerations	199
4.10.1	Care in Power Stack and Gate drive integration	199
4.10.2	Care in Control Hardware and Software design	200
4.10.3	Care for signal conditioning and Analog section	201
4.10.4	Care in PCB design stage	202
4.10.5	Care at the Product Engineering level	203
4.10.6	Care at the installation level	204
4.11	Conclusion	206
Chapter 5	NOVEL CONCEPT OF RPC WITH ACTIVE POWER BALANCING	
5.1	Introduction	207
5.2	Need for load KW balancing	207

	5.3	Concept of Reactive Power compensation with load KW balancing	208
	5.3.1	Basic equation for load KW Balancing	209
	5.3.2	Steps for basic control function	210
	5.3.3	Basic Simulation Model	211
	5.3.4	MATLAB Model	212
	5.3.5	Simulation results	214
	5.3.6	Summary	219
	5.4	Conclusion	219
Chapter 6		NOVEL CONCEPT OF STATCON IN MULTIPLEXED MODE	
	6.1	Introduction	220
	6.2	Need for STATCON multiplexer	220
	6.3	Concept of STATCON multiplexer	221
	6.3.1	MATLAB Model	222
	6.3.2	Fuzzy Algorithms	225
	6.3.2.1	Fuzzy definitions (membership functions)	225
	6.3.2.2	Fuzzy system block diagram	229
	6.3.3	Simulation results	229
	6.3.3.1	Fuzzy system	229
	6.3.3.2	Compensation performance	230
	6.3.4	DSP Based Hardware setup	231
	6.3.5	Summary	235
	6.4	Conclusion	235
Chapter 7		NOVEL CONCEPT OF WINDOW OPERATED STATCON	
	7.1	Introduction	236
	7.2	Need for economical reactive power compensation solution	236
	7.3	Concept of window operated STATCON	237
	7.4	MATLAB Model	240
	7.5	Steps for basic logic control function	241

	7.6	Simulation results	242
	7.7	Experimental setup	243
	7.8	Experimental results	245
	7.9	Conclusion	246
Chapter 8		NOVEL CONCEPT OF ELECTRONIC TRANSFORMER	
	8.1	Introduction	247
	8.2	Need for Electronic transformer	247
	8.3	Concept of Electronic transformer	247
	8.4	Modeling and simulation	250
	8.4.1	Input Line side Rectifier stage	250
	8.4.2	Output Inverter	251
	8.4.3	Buck converter section	251
	8.4.4	Buck converter simulations	251
	8.4.5	Open loop control for Buck converters	253
	8.4.6	Closed Loop Control – Current Feedback for BUCK Converter	254
	8.4.7	Closed Loop Control – Voltage Feedback for BUCK Converter	255
	8.4.8	Closed Loop Control – Voltage Feedback for BUCK Converter with PI controller with Rectifier and Capacitor used at input side	256
	8.4.9	Closed Loop Control – Voltage Feedback for BUCK Converter with PID controller	257
	8.4.10	Closed Loop Control for BUCK Converter with voltage feedback and PID controller with Rectifier and Filter Capacitor used at input side	261
	8.4.11	Closed Loop Control for BUCK Converter with voltage feedback and current feedback (Advanced current control)	262
	8.5	Summary	263
	8.6	Conclusion	264
Chapter 9		NOVEL CONCEPT FOR VOLTAGE COMPENSATION	
	9.1	Introduction	265
	9.2	Need for Voltage Dip-Rise compensator	265
	9.3	Concept of Novel Voltage Dip and Rise compensation	266

	9.4	Modeling and Simulation	266
	9.4.1	MATLAB Simulation results	268
	9.5	Experimental Setup and Results	270
	9.6	Summary	281
	9.7	Conclusion	283
Chapter	10	CONCLUSIONS	
	10.1	General	284
	10.2	Overall Conclusion	284
	10.3	Suggestion for Future work	287
		List of Papers published	288
		References	290