

TABLE OF CONTENTS

	Page
List of Tables	XII
List of Figures	XIII
Nomenclature	XIX
1 Introduction	1
1.1 Background and Motivation	1
1.1.1 Power Generation in India	1
1.1.2 Pros and Cons of the Renewable Energy Resources	3
1.1.3 Microgrids	4
1.1.4 AC, DC and Hybrid Microgrids	4
1.1.4.1 Need of Multi Outputs Converters in Microgrids.....	7
1.1.4.2 Desired characteristics for Multi Output Converters	8
1.2 Literature Review	12
1.3 Research Gap with Existing Multi Outputs Converters	13
1.4 Objective of the Thesis.....	14
1.5 Organization of the Thesis	16
2 Quasi-Z-Source Series-Parallel Multi-Output Inverters	17
2.1 Introduction	17
2.2 Single-Phase Q-Z Source Series-Parallel Converters with Multi AC Outputs	17
2.2.1 Proposed QSPMO Inverters Schematics	18
2.3 Operation of the Proposed QSPMO Inverter	19
2.3.1 Shoot-Through State	19
2.3.2 Power State	21
2.3.3 DC Boost Factor (B) and AC Voltage Gain.....	24
2.4 AC Power Expression for the Proposed Inverters.....	25
2.4.1 AC Power Expression of the Proposed Parallel Mode Inverters	25
2.4.2 AC Power Expression of the Proposed Series Mode Inverters.....	26
2.5 Voltage and Current Stresses on the Component.....	27
2.6 Design of Passive Components	28

2.6.1	Design of Inductance L_1 and L_2	29
2.6.2	Design of Capacitance C_1 and C_2	30
2.7	PWM Control Technique for the Proposed QSPMO Inverters.....	31
2.8	Controller Design for the Proposed QSPMO Inverters	34
2.9	Verification of the Proposed QSPMO Inverters	35
2.9.1	Verification of Proposed Parallel Mode Inverters	35
2.9.1.1	Steady State Response at Different Reference voltages	37
2.9.1.2	Dynamic Response at Same Reference Voltage	39
2.9.1.3	Dynamic Response at Different Reference Voltage	40
2.9.1.4	Dynamic Response During Boost-Buck Operation at Different Reference voltages	42
2.9.2	Verification of Proposed Series Mode Inverters.....	41
2.9.2.1	Dynamic Response of Series Mode Inverters	44
2.10	Conclusion.....	45

3 Quasi-Z-Source Series-Parallel Multi-Output Inverters Topologies for Three-Phase Microgrid Applications..... 46

3.1	Introduction	46
3.2	Three-Phase QSPMO Inverters Topologies with Regulated Multiple AC Outputs for Microgrid Applications and Three-Phase Residential Load	46
3.2.1	Proposed Three-Phase QSPMO Inverters Circuits	47
3.2.2	Operational Analysis of the Proposed Inverters	48
3.2.2.1	Shoot-through Interval	48
3.2.2.2	Power Interval	50
3.2.3	Variation of AC gain and Boost Factor (B) with Respect to Modulation Index (M) and Shoot-Through Duty Cycle (D)	53-54
3.3	AC Power Expression for the Proposed Three-Phase Inverters.....	54
3.3.1	Parallel Mode Operation of the Proposed Topology	54
3.3.2	Series Mode Operation of the Proposed Topology.....	55
3.4	Switching Stress of the Proposed 3- Φ QSPMO Inverters.....	56
3.5	Pulse Width Modulation for the Proposed Inverters	58
3.6	Controller for the Proposed QSPMO Topologies	60
3.7	Experimental Verification of the Proposed Topologies	61

3.8	Parallel Mode of the Proposed Inverters	62
3.8.1	Steady-State Response of Proposed Parallel Mode Inverters with Equal Reference Voltages	63
3.8.2	Steady-State Response of Proposed Parallel Mode Inverter with Different Reference Voltages	65
3.8.3	PWM Signals of the Proposed Parallel Mode Inverters with Equal Reference	65
3.8.4	Dynamic Response of Proposed Parallel Mode Inverters with the Same Reference Voltages	66
3.8.5	Dynamic Response of Proposed Parallel Mode Inverters with Different Reference Voltages	68
3.9	Series Mode of the Proposed Inverters.....	70
3.9.1	Dynamic Response of Proposed Series Mode Inverters	72
3.10	Efficiency Analysis of the Proposed Inverters	72
3.11	Conclusion.....	74

4 Diode Assisted Switched LC Quasi-Z-Source Series-Parallel Hybrid Converters with Multi AC and Single DC Outputs

.....		76
4.1	Introduction	76
4.2	Proposed QSPHCs with Single-Phase with Multiple AC and Single DC outputs....	77
4.3	Circuit Operation.....	78
4.3.1	Shoot-Through (ST) Interval	78
4.3.2	Power Interval	81
4.3.3	DC Voltage Gain.....	83
4.3.4	Derivation of AC Voltage Gain	84
4.4	Mathematical Expression for AC and DC Power	85
4.4.1	AC and DC Power for the Parallel Version Converters.....	85
4.4.2	AC and DC Power for the Series Version Converters	86
4.5	Voltage and Current Stresses	87
4.6	Passive Components Design	88
4.7	Hybrid Pulse Width Modulation (HPWM) Technique	90
4.8	Close-Loop Implementation for the Proposed Converters.....	92

4.9	Verification of the Proposed Converters	92
4.9.1	Simulation of the Proposed Parallel Version Converter (Dual AC with Single Boost DC Outputs Simultaneously)	93
4.9.1.1	Steady-State Results at Same Reference AC Voltage ($V_{ref} = 125$ V)	94
4.9.1.2	Steady-State Results at Different Reference Voltage (V_{ref})	95
4.9.1.3	Dynamic Results at Same Reference Voltage ($V_{dcref} = 380$ and $V_{ref} = 125$ V)	97
4.9.1.4	Dynamic Results with Different Reference Voltage ($V_{ref1} = 125$ and $V_{ref2} = 100$ V)	99
4.9.1.5	Dynamic Results with Buck-Boost and Different Frequencies Operation.....	100
4.9.2	Simulation of the Proposed Series Version of QSPHCs (Dual AC with Single Boost DC Outputs Simultaneously)	101
4.9.2.1	Dynamic Response of Series Version by Changing the Reference Voltage (V_{ref})	103
4.10	Conclusion.....	103

5 Three-Phase Multi AC Quasi-Z-Source Series-Parallel Hybrid Converter Topologies for Microgrid Application . 105

5.1	Introduction	105
5.2	Proposed Series Parallel Topologies	106
5.3	Operating Principle, Circuit Analysis and Boost Factor of the Proposed QSPHC Topologies.....	108
5.3.1	Shoot-Through State	108
5.3.2	Non-Shoot-Through State	110
5.4	AC and DC Power Expression for the Proposed Topologies.....	113
5.4.1	Proposed Parallel Version Topologies	113
5.4.2	Proposed Series Version Topologies	114
5.5	Voltage/Current Stresses of the Components and Cost Analysis of the Proposed QSPHC Topologies	115
5.6	Comparative Analysis amongst Existing Topologies and Proposed QSPHC Topologies.....	117
5.7	Control Strategy for the Proposed Topologies	119
5.7.1	Hybrid PWM Technique for the Proposed Topologies	119

5.7.2	Closed loop Control Strategy for the Proposed Topologies	121
5.7.3	PWM Signals and Operation of the Proposed Topologies with Multiple Units for Different Voltages and Frequencies	122
5.8	Verification of the Proposed QSPHC Topologies.....	123
5.8.1	Verification of Proposed Parallel Version Converters (Regulated Dual AC and Single DC Outputs)	125
5.8.1.1	Steady-State Results of the Proposed Parallel Version Converters	125
5.8.1.2	Dynamic Response of the Proposed Parallel Version Converters	130
5.8.1.3	Dynamic Response of the Proposed Parallel Version Converters with Different AC Reference Voltages	132
5.8.2	Verification of Proposed Series Version Converters (Regulated Dual AC and Single DC Outputs)	133
5.8.2.1	Steady State Result of the Proposed Series Version Converters.....	133
5.8.3	Efficiency and Power Loss Analysis of the Proposed Topologies	135
5.9	Conclusion.....	140
6	Conclusion and Future Scope.....	141
6.1	Conclusion.....	141
6.2	Future Scope of the Proposed Work	143
	Bibliography	145-153
	List of Publications	154

LIST OF TABLES

TABLES	Page No.
1.1 Pros and cons of different renewable energy resources	3-4
2.1 Voltage stress of each components in different intervals	28
2.2 Current stress of each components in different intervals	28
2.3 List of parameters with their attributes	35
3.1 Voltage stress of each components in different intervals	57
3.2 Current stress of each components in different intervals	57
3.3 List of parameters with their values	62
4.1 Voltage and current stresses of the components.....	88
4.2 List of parameters with their attributes	93
5.1 Voltage and current stresses of the proposed topologies.....	115
5.2 Cost of two single unit individual converters.....	117
5.3 Cost of proposed converters with two units	117
5.4 Comparison among previously reported and proposed topologies	118-119
5.5 Components list of the proposed topologies	124
5.6 Efficiency of the various hybrid converters	139