

Contents

Part I Monograph

1	Introduction	3
1.1	State-of-the-Art for Wind Power Generation.	3
1.2	Development of Wind Power Technologies	5
1.2.1	Evolution of Wind Turbine Concepts	5
1.2.2	Evolution of Power Electronics for Wind Turbines	8
1.3	Emerging Challenges for Wind Power Converter	8
1.3.1	More Grid Supports	8
1.3.2	Higher Reliability.	11
1.3.3	Special Cost Considerations.	13
1.3.4	Formulation of Overall Requirements	14
1.4	Scopes of the Book.	15
	References.	16
2	Promising Topologies and Power Devices for Wind Power Converter	19
2.1	Promising Converter Topologies	19
2.1.1	Traditional Two-Level Converters	19
2.1.2	Multilevel Converters	21
2.1.3	Multi-cell Converters	23
2.2	Potential Power Semiconductor Devices	26
2.3	Summary	27
	References.	27
3	Criteria and Tools for Evaluating Wind Power Converter	31
3.1	Importance of Thermal Stress in Wind Power Converter	31
3.1.1	Thermal Stress Versus Reliability.	32
3.1.2	Thermal Stress Versus Cost.	34

3.2	Classification and Approach for the Thermal Stress Analysis	37
3.2.1	Classification of Thermal Stress in Wind Power Converter	37
3.2.2	Methods and Models for Stress Analysis.	38
3.3	Summary.	42
	References.	42
4	Thermal Stress of 10-MW Wind Power Converter Under Normal Operation	45
4.1	Requirements and Conditions Under Normal Operation	45
4.2	Stress of Converter Imposed by Wind Speeds	47
4.2.1	Thermal Stress Under Steady-State Wind Speeds	47
4.2.2	Thermal Stress Under Wind Speed Variations	50
4.3	Stress of Converter Imposed by Grid Codes.	51
4.3.1	Converter Efficiency Considering Reactive Power Demands by Grid Codes	51
4.3.2	Thermal Stress Considering Reactive Power Demands by Grid Codes	53
4.4	A Thermal Control Method Utilizing Reactive Power	55
4.4.1	Control Idea and Diagram	55
4.4.2	Idea to Overcome the Reactive Power Limits	56
4.4.3	Thermal Stress Considering Extended Q Ranges in Paralleled Converters	57
4.4.4	Thermal Control Results	57
4.5	Summary.	60
	References.	61
5	Stress Analysis of 3L-NPC Wind Power Converter Under Fault Condition	63
5.1	Requirements and Conditions Under Fault Operation.	63
5.2	Stress Analysis of Converter Under LVRT.	67
5.2.1	Electrical Behaviors	67
5.2.2	Thermal Behaviors.	70
5.3	Thermal Redistributed Modulations Under LVRT.	71
5.3.1	Basic Idea.	71
5.3.2	A Group of Modulation Methods.	74
5.3.3	Loss and Thermal Improvements	77
5.3.4	Neutral Point Potential Control and Total Harmonic Distortion.	79

5.4	New Power Control Methods Under Unbalanced AC Source	80
5.4.1	Applicable Conditions and Control Structure	81
5.4.2	Control Ideas and Methods	82
5.5	Summary	91
	References	92
6	Conclusions and Future Works	95
6.1	Conclusions	95
6.2	Proposals for Future Research Topics	97
7	Appendix	99
7.1	Used Models for Analysis	99
7.1.1	Wind Speed Generator	99
7.1.2	Wind Turbine Model	99
7.1.3	Generator Model	101
7.1.4	Parameter for Thermal Impedance of Used IGCT	101
7.2	Experimental Setup	103
 Part II Specially Selected Topics		
8	The Impacts of Power Switching Devices to the Thermal Performances of 10 MW Wind Power NPC Converter	107
8.1	Wind Power Converter for Case Study	107
8.2	Thermal-Related Characteristics of Different Power Switching Devices	108
8.2.1	Switching Loss	109
8.2.2	Conduction Voltage and Loss	110
8.2.3	Thermal Resistance	112
8.3	Thermal Analysis of Different Device Solutions	112
8.3.1	Normal Operation	113
8.3.2	Low-Voltage-Ride-Through Operation	115
8.3.3	Wind Gust Operation	120
8.3.4	Summary of Thermal Performances Under Different Operation Modes	121
8.4	Conclusions	121
	References	122
9	Reliability-Cost Models for the Power Switching Devices of Wind Power Converters	123
9.1	Loss Model with Chip Number Information	124
9.2	Thermal Impedance Model with Chip Number Information	129

9.3	Analytical Solution of Junction Temperature with Chip Number Information	133
9.4	Conclusions	137
	References.	138
10	Electro-Thermal Model of Power Semiconductors Dedicated for Both Case and Junction Temperature Estimation	139
10.1	Conclusion.	143
	References.	143
11	Reactive Power Influence on the Thermal Cycling of Multi-MW Wind Power Inverter	145
11.1	Effect of Reactive Power in Case of Single Converter.	146
11.2	Effect of Reactive Power in Case of Paralleled Converters.	152
11.3	Conclusions	157
	References.	157
12	Thermal Loading of Several Multilevel Converter Topologies for 10 MW Wind Turbines Under Low Voltage Ride Through.	159
12.1	Promising Topologies and Basic Design	159
12.2	Operation Status Under Balanced LVRT	161
12.3	Loss Distribution Under Balanced LVRT.	164
12.4	Thermal Distribution Under Balanced LVRT	166
12.5	Unbalanced LVRT	171
12.6	Conclusion.	179
13	Another Groups of Thermal Optimized Modulation Methods of Three-Level Neutral-Point-Clamped Inverter Under Low Voltage Ride Through.	181
13.1	Basic Principles	181
13.2	Neutral Point Potential Control Method	183
13.3	Loss and Thermal Performances	185
13.4	Conclusions	187
14	Limits of the Power Controllability of Three-Phase Converter with Unbalanced AC Source	189
14.1	Conclusion.	196

<http://www.springer.com/978-3-319-21247-0>

Power Electronics for the Next Generation Wind Turbine
System

Ma, K.

2015, XIV, 196 p. 188 illus., 177 illus. in color.,

Hardcover

ISBN: 978-3-319-21247-0