Contents

Abstract i

Kurzfassung iii

Acknowledgements v

1 Introduction 1
- 1.1 Motivation . . . 1
- 1.2 Dissertation Goals and Structure . . . 6

2 VISMA Synchronous Machine Model 7
- 2.1 Machine Model Requirements and Implementation History . . . 7
- 2.2 Mathematical Model of the Synchronous Machine . . . 10
- 2.3 Numerical Methods for the Solution of the VISMA Differential Equations . . . 15

3 Mobile VISMA Hardware 19
- 3.1 Experimental Hardware . . . 19
- 3.2 System Architecture . . . 21
- 3.3 Data Acquisition . . . 22
- 3.4 Line Filters . . . 25
- 3.5 Inverter and Driver . . . 27
- 3.6 Applications . . . 29

4 Inverter Modeling and Hysteresis Controller Design 31
- 4.1 Inverter Model . . . 31
- 4.2 Hysteresis Current Controller . . . 34
  - 4.2.1 Verification of the simulation model . . . 37
  - 4.2.2 Tuning of simulation model parameters . . . 41
  - 4.2.3 Asymmetrical hysteresis limit violations . . . 42
- 4.3 Current Tracking Performance . . . 44
  - 4.3.1 Total harmonic distortion . . . 44
  - 4.3.2 Root mean square value of the current . . . 45
  - 4.3.3 Sum of square errors . . . 46
- 4.4 Transfer of Active Power using the Hysteresis Current Controller . . . 46

Dieses Werk ist copyrightgeschützt und darf in keiner Form vervielfältigt werden noch an Dritte weitergegeben werden.
Es gilt nur für den persönlichen Gebrauch.

4.4.1 Feeding power into the grid . . . 47
4.4.2 Drawing power from the grid . . . 53

5 Pulse Width Modulation Controller 59
5.1 Controller Architecture . . . 59
5.2 Controller Development . . . 60
5.2.1 Feedback system design . . . 61
5.2.2 Controller design using a simplified simulation model . . . 68
5.2.3 Simulation model of the PWM-controlled system . . . 75
5.2.4 Deadtime compensation in the PWM Inverter . . . 77
5.3 Testing the PWM Controller . . . 82

6 PWM and Hysteresis Current Controller Performance 85
6.1 Variable Parameters . . . 85
6.2 Step Response . . . 87
6.3 Active Power Transfers . . . 90
6.4 Variable Phase Angle . . . 93
6.5 Harmonics . . . 98
6.6 Summary . . . 103

7 Faults in the Power Network 105
7.1 Power System Faults and Protective Systems . . . 105
7.2 Standards Governing Fault Behavior of Distributed Generators . . . 106
7.3 Grid-Tie Inverter Behavior During Power System Faults . . . 107
7.4 Short-Circuit Tests of the Grid-Tie Inverter . . . 109
7.4.1 Off-grid short-circuit tests . . . 109
7.4.1.1 3-phase balanced phase-to-phase short circuit . . . 111
7.4.1.2 3-phase balanced phase-to-neutral short circuit . . . 115
7.4.2 Online short-circuit tests . . . 118
7.4.2.1 Short-lasting grid fault . . . 118
7.4.2.2 Long-lasting grid fault . . . 121
7.4.3 PWM and hysteresis current controller performance during grid faults . . . 125
7.5 Distant Grid Faults . . . 127
7.6 Reconnection of the VISMA After a Grid Fault . . . 129

8 Conclusions and Outlook 131
8.1 Conclusions . . . 131
8.2 Outlook . . . 132

List of Acronyms 135

Dieses Werk ist copyrightgeschützt und darf in keiner Form vervielfältigt werden noch an Dritte weitergegeben werden.
Es gilt nur für den persönlichen Gebrauch.

A Experimental Setup **137**

B FPGA Base Board **139**

C Connection of Distributed Generators to the Grid – Standards **141**
C.1 Harmonic current limits 141
C.2 Generation facilities connected to the low-voltage distribution network 142

Bibliography **145**

Dieses Werk ist copyrightgeschützt und darf in keiner Form vervielfältigt werden noch an Dritte weitergegeben werden.
Es gilt nur für den persönlichen Gebrauch.