

# Contents

<b>1</b>	<b><i>Introduction</i></b>	<b>1</b>
1.1	<i>Motivation</i>	2
1.2	<i>Contributions</i>	4
1.3	<i>Related work</i>	10
1.4	<i>Publications</i>	16
1.5	<i>Outline</i>	17
<b>2</b>	<b><i>Problem statement</i></b>	<b>19</b>
2.1	<i>Microgrid concept</i>	19
2.2	<i>Hierarchical control of MGs</i>	21
2.3	<i>Requirements for operation control</i>	23
2.4	<i>Summary</i>	28
<b>3</b>	<b><i>Preliminaries</i></b>	<b>29</b>
3.1	<i>Notation</i>	29
3.2	<i>Model predictive control</i>	31
3.3	<i>Optimization theory</i>	33
3.4	<i>Power transmission</i>	38
3.5	<i>Summary</i>	45

4	<i>Microgrid model</i>	47
4.1	<i>Introduction</i>	49
4.2	<i>Assumptions</i>	50
4.3	<i>Load</i>	52
4.4	<i>Conventional generators</i>	53
4.5	<i>Renewable generators</i>	54
4.6	<i>Storage units</i>	55
4.7	<i>Transmission network</i>	57
4.8	<i>Power sharing</i>	62
4.9	<i>Overall model</i>	66
4.10	<i>Summary</i>	69
5	<i>Model predictive control formulation</i>	71
5.1	<i>Model variables</i>	71
5.2	<i>Cost function</i>	72
5.3	<i>Problem formulation</i>	75
5.4	<i>Example</i>	77
5.5	<i>Summary</i>	78
6	<i>Forecast</i>	79
6.1	<i>Preliminaries</i>	80
6.2	<i>ARIMA forecasting</i>	83
6.3	<i>Load</i>	85
6.4	<i>Wind turbine</i>	86
6.5	<i>Photovoltaic power plant</i>	89
6.6	<i>Summary</i>	91

7	<i>Certainty equivalence MPC</i>	93
7.1	<i>Model variables</i>	93
7.2	<i>MPC problem formulation</i>	94
7.3	<i>Example</i>	95
7.4	<i>Summary</i>	97
8	<i>Minimax MPC</i>	99
8.1	<i>Introduction</i>	100
8.2	<i>Model variables</i>	103
8.3	<i>Cost function</i>	113
8.4	<i>MPC problem formulation</i>	114
8.5	<i>Example</i>	115
8.6	<i>Summary</i>	116
9	<i>Scenario trees</i>	119
9.1	<i>Formal description</i>	119
9.2	<i>Model variables</i>	123
9.3	<i>Generation from forecast scenarios</i>	131
9.4	<i>Summary</i>	138
10	<i>Risk-neutral stochastic MPC</i>	139
10.1	<i>Expectation</i>	140
10.2	<i>MPC problem formulation</i>	142
10.3	<i>Example</i>	145
10.4	<i>Summary</i>	146
11	<i>Risk-averse MPC</i>	149
11.1	<i>Measuring risk</i>	150

11.2	<i>MPC problem formulation</i>	156
11.3	<i>Example</i>	163
11.4	<i>Summary</i>	165
12	<i>Case study</i>	167
12.1	<i>Simulation setup</i>	168
12.2	<i>Simulation with simple MG</i>	172
12.3	<i>Simulation with extended MG</i>	186
12.4	<i>Summary</i>	195
13	<i>Conclusion</i>	197
13.1	<i>Summary</i>	197
13.2	<i>Future research directions</i>	200
A	<i>Simulation results with extended MG</i>	205
	<i>Bibliography</i>	209
	<i>List of Figures</i>	239
	<i>List of Tables</i>	243
	<i>Abbreviations</i>	245
	<i>Nomenclature</i>	247
	<i>Index</i>	251