

Contents

1	Introduction	1
1.1	Research Motivation	1
1.2	Problem Statement	2
1.3	Hypotheses	4
1.4	Objectives	4
	1.4.1 General Objective	4
	1.4.2 Specific Objectives	4
1.5	Contributions	5
1.6	Publications	6
	1.6.1 Journal Publications	6
	1.6.2 Conference Publications	6
1.7	Thesis Outline	7
2	Literature Review	8
2.1	Introduction	8
2.2	Impact of the Integration of Distributed Generation on a Distribution Network	9
2.3	Control of Microgrids	11
2.4	Energy Management System	15
	2.4.1 EMS with management of uncertainty	18
2.5	Prediction Interval Modelling	19
2.6	Coordination of Microgrids	21
2.7	Discussion	24
3	Prediction Interval Methodology Based on Fuzzy Numbers	25
3.1	Introduction	25
3.2	Prediction Interval Models Based on Fuzzy Numbers	27
	3.2.1 Fuzzy Prediction Interval Modelling	28
	3.2.2 Neural Network Prediction Interval Modelling	29
3.3	Method for Developing Prediction Interval based on Fuzzy Numbers	31
	3.3.1 Parameters Identification for Prediction Intervals	32
	3.3.2 Solution Method	33
3.4	Experiment and Results	34
	3.4.1 Benchmark	36
	3.4.2 Application for Load Forecasting	39
3.5	Discussion	42

4	Hierarchical Energy Management System for Microgrid Operation	43
4.1	Introduction	43
4.2	Real-time Controller at Microgrid Level	45
4.3	Model Predictive Control for Microgrid Operation	46
4.3.1	Deterministic EMS	47
4.3.2	Robust EMS with Explicit Uncertainty Compensation	48
4.4	Case Study	51
4.4.1	Sizing of Energy Storage System	52
4.4.2	Fuzzy Prediction Interval for Net Power of Microgrid	55
4.4.3	Hierarchical EMS Results	56
4.5	Discussion	61
5	Hierarchical Energy Management System for Microgrid Coordination	62
5.1	Introduction	62
5.2	Model Predictive Control for Microgrid Coordination	63
5.2.1	Deterministic Coordination of Microgrids	64
5.2.2	Robust Coordination of Microgrids with Explicit Uncertainty Compensation	65
5.2.3	Uncertainty Policy	68
5.3	Case Studies	69
5.3.1	Case 1: Two Microgrids with Photovoltaic and Wind Energy	70
5.3.2	Case 2: Three Microgrids with Photovoltaic and Wind Generation including a School Load Profile	74
5.4	Assumed Model Simplifications	79
5.5	Discussion	82
6	Conclusions	83
6.1	Future Work	84
	Appendices	86
A1	Battery Model	87
A2	SoC Estimator	89
A3	Maximum Available Power Estimator	92
	Bibliography	94