

Contents

Nomenclature	iii
List of figures	xv
List of tables	xix
1 Introduction	1
1.1 Future Smart Home	1
1.2 Demand Response on Smart Grid	3
2 Control Development for Air Source Heat Pump System	5
2.1 Research Initiative	5
2.2 State-of-the-Art Technologies	7
2.2.1 General Control and Automation Methodologies for Heating, Ventilating and Air Conditioning Systems	7
2.2.2 Investigation of System Modeling Approaches	8
2.2.3 Investigation of Optimization Approaches	10
2.2.4 The Rapid Control Prototyping Technology	11
2.3 Solution Proposal	13
3 Target System Description	15
3.1 System Architecture	15
3.2 The Target Residential Building	18
3.2.1 The Building Physics	18
3.2.2 The Heat Distribution System	20
3.3 The Target Heat Pump System	25
3.3.1 The Working Principle	25
3.3.2 The Selection of the Modulation Method	26
3.3.3 The Coefficient of Performance Characteristics	29
3.4 The Target Domestic Hot Water Tank	31
4 Self-Adaptive Modeling Approach	33
4.1 The Self-Adaptive Building Model	33
4.1.1 The Recursive Finite Difference Building Model	34

4.1.2	The Artificial Neural Network Building Model	41
4.2	The Self-Adaptive Stratified Tank Model	44
4.3	The Reduced Air Source Heat Pump Model	51
4.4	Model Validation	52
4.4.1	Validation of the Reduced Building Model	52
4.4.2	Validation of the Reduced Air Source Heat Pump Model	54
4.4.3	Validation of the Reduced Domestic Hot Water Tank Model	55
5	Active Thermal Management Strategy	57
5.1	The Model Calling Procedure	57
5.2	Problem Formulation for Optimal Modulation	61
5.3	The Modulation Solver for Heat Mode Control	64
5.4	Demand-Actuated Tank Management	73
5.4.1	Statistical Modeling of the Domestic Hot Water Consumption	73
5.4.2	Energy Storage Estimation for Stratified Tank Unit	76
5.4.3	The Active Tank Charging Principle	79
5.5	The Extension to Heat+Tank Bi-Mode Control	81
6	Dynamic Test Approach for Home Energy System	83
6.1	The Validation Platform	83
6.2	The Emulation System	87
6.2.1	The Hydraulic Emulation Interface	87
6.2.2	The Thermal Emulation Interface	91
6.2.3	The Domestic Hot Water Load Emulation	94
6.3	The Integration of Software Prototype	97
7	Validation Results	101
7.1	General Test Scenario	101
7.2	Heat Mode Control Validation	103
7.3	Tank Mode Control Validation	109
7.4	Heat+Tank Bi-Mode Control Validation	114
8	Conclusion and Outlook	119
Appendix		121
A.1	Thermal Characteristics of the Target Single-Family House	121
A.2	The Target Heat Pump Characteristics	124
A.3	The Applied Domestic Hot Water Consumption Profile	125
A.4	The Applied Parameter Configurations for Validation Purpose	126
Bibliography		129