

Energy-based Control in HVAC Systems in Commercial Buildings to Optimize the Building Energy Performance

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Signature of the Supervisor(s):

Date:

Prof. Sisil Kumarawadu

Prof. Chandima Dedduwa Pathirana

Abstract

The severity of the emerging environmental problems and the criticality of a future energy crisis with associated socio-economic quandaries are becoming strengthen along with the inevitable growth of energy demand due to the ever-increasing population and urbanization. Inspired by this, many state-of-the-art and efficient engineering advancements under demand side management are being conceptualized, developed, and examined via worldwide research for several years.

As one of the largest global energy consumers, buildings, and their Heating, Ventilating and Air Conditioning (HVAC) systems acquire substantial attention regarding optimal and efficient energy management. Nevertheless, longer computational time, complicated implementation, deficient occupants' thermal comfort and productivity, and limited practicability and feasibility of most of the approaches that have been proposed, have demotivated the industry applications even though they offer consequential designing and operating advancements to the system. Therefore, the expected building energy performance can be further extended by unraveling these encountered disputes with novel energy saving strategies.

This research concentrates on energy optimal operation of HVAC systems by addressing secondary chilled water pumping system, temperature setpoint management, cooling water system, and temperature controllers in Air Handling Unit (AHU). Three different innovative energy saving strategies to determine the optimal number of chilled water pumps to be operated with their optimal speed, optimal zone temperature setpoint schedule, and optimal cooling water flow rate with a setpoint of the chilled water supply temperature have been proposed along with the consideration of system constraints, safety, occupant thermal comfort, and satisfaction. In addition, a novel temperature controller that can be utilized in AHU has been introduced and the performance in comparison with available controllers has been studied. Simulation results obtained via the case studies authenticate the effectiveness of the introduced approaches and encourage the functioning of these strategies in real engineering systems due to the inherent simplicity, robustness, and less computational complexity.

Keywords- Chilled Water System, Energy Optimization, HVAC, Parallel Pumps, Variable Speed, Dijkstra, Energy Management, Optimal Setpoint, Productivity, Thermal Comfort, Cooling Water System, AHU, Elliot Function, Temperature Control

DEDICATION

*To my family,
for always loving and supporting me...*

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CONTENTS

Declaration	i
Abstract	ii
Dedication	iii
Acknowledgments	iv
Table of Contents	viii
List of Figures	xiii
List of Tables	xiv
List of Abbreviations	xv
1 Introduction	1
1.1 Background	2
1.2 Problem Statement	4
1.3 Research Objectives	6
1.4 Thesis Overview	7

2	Literature Review	9
2.1	Heating, Ventilating and Air Conditioning Systems	9
2.1.1	Overview	9
2.1.2	Central Plants	9
2.1.3	Main Components	11
2.2	Chilled Water Pumping Systems and Energy Saving	13
2.3	Indoor Temperature Setpoint Management, Thermal Comfort and Energy Saving	17
2.4	Cooling Water System and Energy Saving	21
2.5	Temperature Controllers in Air Handling Unit	24
3	Novel Energy Saving Strategy for HVAC Secondary Chilled Wa- ter Pumps	27
3.1	Mathematical Modeling of the Chilled Water Pumping System . .	27
3.2	Methodology	33
3.2.1	Definition of the Constraints	33
3.2.2	Problem Statement	34
3.2.3	Proposed Algorithm	35
3.3	Simulation Results	35
3.3.1	Case Study I: Validating Parallel and Variable Speed Pumps	35
3.3.2	Case Study II: Comparing the Proposed Method with Con- ventional Methods	40

3.3.3	Case Study III: Comparing the Proposed Method with Intelligent Methods	43
4	Zone Temperature Management Strategy for Optimal Energy and Cost Saving with Guaranteed Thermal Comfort	47
4.1	Methodology	47
4.1.1	Mathematical Background	48
4.1.2	Definition of the Constraints	49
4.1.3	Problem Statement	50
4.2	Proposed Strategy	51
4.3	Case Study	54
4.3.1	Room Temperature, Outdoor Temperature, and Supply Air Temperature	55
4.3.2	Supply Air Temperature and Temperature Setpoint	55
4.3.3	Power and Temperature Setpoint	57
4.4	Simulation Results and Comparison	57
5	Novel Energy Saving Scheme for HVAC Cooling Water System	66
5.1	Methodology	66
5.1.1	System Model	66
5.1.2	Problem Formulation	69
5.1.3	Algorithm Development	70

5.2	Simulation Results and Comparison	72
6	Modified Elliot Function Based Temperature Controller for AHU	76
6.1	System Model	76
6.2	Different Control Methods	79
6.2.1	PD Controller	79
6.2.2	Fuzzy Logic Controller	79
6.2.3	Sigmoid Function Based Controller	83
6.2.4	Proposed Controller	83
6.3	Simulation Results and Comparison	87
7	Conclusions	91
7.1	Integration with Building Management Systems	93
7.2	Limitations	95
7.3	Recommendations for Future Developments	96
	List of Publications	98
	Bibliography	112

LIST OF FIGURES

1.1	Significance of Demand Side Energy Management	1
1.2	Share of Total U.S. Energy Consumption by End-use Sectors, 2018 [4]	2
1.3	U.S. Total Energy Consumption by End-use Sector, 1950 - 2018 [4]	3
1.4	Electricity Use in U.S. Commercial Buildings by Major End Uses, 2012 [4]	3
1.5	Share of Major Energy Sources Used in U.S. Commercial Buildings, 2012 [4]	4
2.1	Schematic of a Central HVAC System with a Water Cooled Chiller [20]	12
2.2	Importance of Optimal Temperature Setpoints	18
2.3	Schematic Diagram of the AHU Temperature Control	25
3.1	Schematic Diagram of the Considered Chilled Water System [102]	28
3.2	Proposed Control System for Controlling Room Temperature . . .	29
3.3	Pump Curve for Parallel Operation	30
3.4	Flow Chart for the Proposed Algorithm	36
3.5	Required Flow Variation for 12 Time Slots	38

3.6	Frequency Variations with Proposed Algorithm	38
3.7	Energy Consumption of the Pumps at Each Time Slot	39
3.8	Total Energy Consumption Comparison for Different Strategies	39
3.9	Required Water Flow Variation	41
3.10	Number of Operating Pumps with and without the Proposed Algorithm	41
3.11	Frequency Variation of the Pumps with and without the Proposed Algorithm	42
3.12	Energy Consumption of the Pumps with and without the Proposed Algorithm	42
3.13	Accumulated Energy Consumption of the Pumps with and without the Proposed Algorithm	43
3.14	Required Flow Variation for 10 Time Slots	44
3.15	Optimal Number of Operating Pumps Determined by the proposed and PSO Methods	44
3.16	Optimal Speed Ratio of Operating Pumps Determined by the proposed and PSO Methods	45
3.17	Power Consumption of the Pumps at Each Time Slot	45
3.18	Accumulated Energy Consumption of the Pumps at Each Time Slot	46
4.1	Flow Chart for the Proposed Strategy	51
4.2	Schematic Diagram of the AHU	55

4.3	Relationship between Room Temperature, Outdoor Temperature, and Supply Air Temperature	56
4.4	Relationship between Supply Air Temperature and Setpoint Temperature	56
4.5	Relationship between Temperature Setpoint and Power Consumption	57
4.6	Outdoor Temperature at Each Time Slot	58
4.7	Selected Temperature Setpoints at Each Time Slot with and without the Algorithm	59
4.8	Power Consumption at Each Time Slot with and without the Algorithm	60
4.9	Energy Usage at Each Time Slot with and without the Algorithm	60
4.10	Accumulated Energy Usage at Each Time Slot with and without the Algorithm	61
4.11	RTP of Electricity and Cost for Electricity at Each Time Slot with and without the Algorithm	61
4.12	Accumulated Cost for Electricity at Each Time Slot with and without the Algorithm	62
4.13	Indoor Temperature at Each Time Slot with and without the Algorithm	63
4.14	PMV at Each Time Slot with and without the Algorithm	63
4.15	PPD at Each Time Slot with and without the Algorithm	64
4.16	RP at Each Time Slot with and without the Algorithm	64

5.1	Cooling Water System	67
5.2	Flow Chart for the Proposed Algorithm	71
5.3	Hourly Cooling Load Variation through the Year	72
5.4	Outdoor Wet Bulb (WB) and Ambient Temperature (DB) Variation through the Year	73
5.5	Optimal Hourly Water Flow through the Year for the Proposed and Water Flow Control Methods	73
5.6	Optimal Hourly Chilled Water Supply Temperature through the Year for the Proposed and Water Flow Control Methods	74
5.7	Hourly Power Consumption through the Year for the Proposed and Water Flow Control Methods	74
5.8	Accumulated Power Consumption through the Year for the Proposed and Water Flow Control Methods	75
6.1	System Model with PD Controller	78
6.2	Membership Functions for (a) Error (b) Derivative of Error (c) Output	80
6.3	3-D Surface of the Variables	81
6.4	System Model with FL Controller	82
6.5	System Model with Symmetric Sigmoid Function Based Controller	84
6.6	Characteristic Curves for Symmetric Sigmoid, Elliot, and Modified Elliot Functions	85
6.7	System Model with the Proposed Controller	86

6.8	Step Response of (a) PD Controller (b) FL Controller (c) Sym- metric Sigmoid Function Based Controller (d) Modified Elliot Function Based Controller	87
6.8	Step Response of (a) PD Controller (b) FL Controller (c) Sym- metric Sigmoid Function Based Controller (d) Modified Elliot Function Based Controller (cont.)	88
7.1	Integration of Developed Systems with the BAS	95

LIST OF TABLES

2.1	Main Processes in HVAC Systems [19]	10
2.2	Advantages and Disadvantages of a Central Plant [19,21]	11
3.1	Selecting Pumps	37
4.1	Summary of Total Energy, Total Cost of Energy and Average RP for the Month	65
6.1	Fuzzy Rules Designed for the Controller	81
6.2	Performance Comparison of Different Controllers	90

LIST OF ABBREVIATIONS

AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation Systems
BEP	Best Efficiency Point
BMS	Building Management Systems
CAV	Constant Air Volume
COP	Coefficient of Performance
CW	Cooling Water (Condenser Water)
FCM	Fuzzy Cognitive Map
FCU	Fan Coil Unit
FL	Fuzzy Logic
GA	Genetic Algorithm
HSS	Hydronic System Solutions
HVAC	Heating, Ventilating and Air Conditioning
ISO	International Organization for Standardization
MDP	Markov Decision Process
MIMO	Multiple-Input and Multiple-Output
MINLP	Mixed Integer Non-Linear Programming
MPC	Model Predictive Control
NN	Neural Network
OPC	Open Platform Communications
PD	Proportional Derivative
PID	Proportion Integration Differentiation

PMV	Predicted Mean Vote
PPD	Predicted Percentage Dissatisfied
PSO	Particle Swarm Optimization
RP	Relative Productivity
RTP	Real Time Pricing
SQL	Structured Query Language
TCP	Transmission Control Protocol
U.S.	United States
VAV	Variable Air Volume
VFD	Variable Frequency Drives