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

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(198081T)

Degree of Master of Philosophy

Department of Electrical Engineering

University of Moratuwa

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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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Sandali Rukshila Walgama

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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