



DEVELOPMENT OF ENERGY CENTRE COOLING PLANT

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
in partial fulfilment of the requirements for the
Degree of Master of Science

by
MAHINDA GALLAGE

Supervised by: Professor Lanka Udawatta

Department of Electrical Engineering
University of Moratuwa, Sri Lanka

2009

93946



Abstract

This work study reviews the conceptual development of optimization strategies of an Energy Centre based on operational task of daily thermal load contours and interaction of weather profiles of the environment in the selected area of the project. The weather profile analysis was primarily done by the interactive plotting of temperature/humidity sensor data against historical data. Gray Model was also employed in order to predict much accurate data patterns in the fuzzy areas of weather prediction process. However, by introduction of genetic algorithm on the historical samples would able to predict the anticipated weather profile more accurately and thereby the thermal load required for the future trend on the following day. The current thermal energy storage (TES) technologies and their applications using the traditionally available methods are the common practice of any ice storage design in the industry; however in this analysis dedicated low freezing media (Glycol) is used to chill the common chilled media (water) and also the chilled media is used as storage medium with phase change. Latent heat storage on the other hand, is a young and developing technology which has found considerable interest in recent times due to its operational advantages of smaller temperature swing, smaller size and lower weight per unit of storage capacity. Design methodology and its prime results of simulation show the effectiveness of the proposed solution for an Energy Centre for efficient operation.

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

Mahinda Gallage



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

I endorse the declaration by the candidate.

UOM Verified Signature

Professor Lanka Udawatta

Acknowledgement

Thanks are due first to my supervisor, Professor Lanka Udawatta for his great insights, perspectives, guidance and sense of humor. I have been battling with my health for at least a year prior to the final date of submission of this assignment. I strongly believe that if not for his great support on literature collection and putting them in the right track and continuous supervision of my work, I would not have made this possible and my heartfelt thanks goes to his sincere thoughts towards me and of understanding my actual situation.

My special thanks go to both Dr. J.P. Karunadasa, Head of the Department, Electrical Engineering and Dr. Chandima Pathirana, Coordinator Department of Industrial Automation, who helped me in numerous ways at the stage of submitting this project.

My sincere thanks go to the officers in the Post Graduate Office, Faculty of Engineering, and University of Moratuwa, Sri Lanka for helping in various ways to clarify the things related to my academic work in time with excellent cooperation and guidance. Sincere gratitude is also extended to the people who serve in the Department of Electrical Engineering office.

I also extend my sincere gratitude to my wife, who encouraged me to complete the relevant write up without exception of difficulties, which we have gone through during the last few years. Also, equally, sincere thanks go to my mother in law Dr. Mrs. S. Samarasekara, whose hospitality towards me during my short stay in Sri Lanka.

It is not fair if I do not write few words about Mrs. Himali Wanigasekara, who took her own interest of proof reading and editing the language at the last minute, before this report went for printing. I should thanks to her for completing it timely manner without any hesitation.

Finally, I should thank many individuals, friends and colleagues who have not been mentioned here personally in making this educational process a success. I could not have made it without their support.

List of Figures

Figures	Page
1.1 Flow Chart for Project teams Assignment and their functions	2
1.2 Flow Chart for the Research Objectives	7
1.3 Control Procedure and Research Objective	12
1.4 Thermal Load Contour of the Selected Environment (Garden)	13
2.1 Chilled Water Plant Simplified Schematic on the Selected Project	22
3.1 Glycol Flow through the Circuit when Chiller Priority Mode	32
3.2 Glycol Flow through the Circuit when Ice Priority Mode	37
3.3 Glycol Flow through the Circuit when Peak Load Mode	40
3.4 Glycol Flow through the Circuit when Ice Build Mode	44
3.5 Glycol Flow through the Circuit when Ice Build Plus Cooling Mode	48
4.1 Glycol Sub system Interface with the main Chw System	52
4.2 Glycol Chiller Plant Control with Different Sub Systems	54
4.3 CPCS Architecture	56
5.1 Thermal Load Contour of the Building and its Distribution from Primary Production Cycle	62
5.2 Peak Load Matching with Ice Produced	64
5.3 Typical Load Sharing in the Winter Season	67



List of Tables

Table	Page
2.1 Chiller Performance Data for Different Glycol Leaving Temperature and Different Ambient Conditions	26
2.2 Chiller Performance for Different Ambient Conditions for the same Chilled Water Leaving and Same Delta T	26
6.1 Tactical Control Procedure	74
6.2 Strategic Control Procedure	75



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Abbreviations and Symbols

Acronym	Definition
BMS	Building Management System
TCP/IP	Transmission Control Protocol/Internet Protocol
TES	Thermal Energy Storage
CWP, ChW	The Chilled Water Plant .Chilled water
BACnet IP	Building Automation Control Network protocol over the Internet protocole
ITES	Ice Thermal Energy Storage
COP	Co-efficient of Performance
CPCS	Chilled plant Control System
GCPCS	Glycol Chiller plant Control System
HXCS	Heat Exchanger Control System
VFD, VSD	Variable Frequency Drive , Variable Speed Drive
MS, TP	Master – Slave/ Token – Passing
ANN	Artificial Neural Network
θ	Ambient temperature in °C (Air in temperature of cond.)
λ	Coefficient of Performance: 1/Efficiency
τ	Glycol supply temperature °C (Evaporator to the system)
τ_c	Chilled water temperature of the system °C
ψ, ϕ, μ	Polynomial functional constants (Curve)
ψ	Chiller part load ration (PLR)
$f(\lambda, \theta, \tau)$	Thermal(cooling) capacity by the Chiller operation with λ COP, θ ambient and the τ refrigerant temperature
$f(\lambda, \theta, \tau)$	Thermal(cooling) capacity by the Ice storage with λ efficiency, θ ambient and the τ refrigerant temperature
$P(\theta, \phi)$	Thermal(cooling) capacity of the Base load chilled water
$f_o(\gamma, \theta, \tau, \phi)$	Objective function of Total Cooling of the Energy Centre
Open Protocol	Standard Convention for Communications available to all to develop compliant devices that can talk to each other consistently and coherently

Contents

Declaration	ii
Abstract	iii
Dedication	iv
Acknowledgement	v
List of Figures	vi
List of Tables	vii
List of Abbreviations and Symbols	viii
Chapters	
1. Introduction	1
1.1 Background of the Project	1
1.2 Objectives of the Research	6
1.2.1 The objectives of energy optimized control	6
1.2.1.1 Objective No.1	6
1.2.1.2 Objective No.2	7
1.2.1.2.1 Energy Objective function for Optimization	8
1.3 Chapter Summary	9
1.4 Load Profile and Thermal Contour of the Garden	13
1.5 Thermal Energy storages (TES)	14
1.6 Glycol and Chw Chiller Operation	15
1.7 Chiller Plant Control System	16
1.8 Tactical and Strategic Controls	17
1.9 Mathematical modeling of Energy Equation	17
2. Concept Development for Cooling System	20
2.1 Summary of Concept Development	20
2.2 General System Description	21
2.3 ITES System Description	23
2.3.1 Base Load Chillers	23
2.3.2 Glycol Heat Exchanger	24
2.3.3 Ice Storage	24
2.3.4 Glycol Chiller	25
2.4 Sequencing the ITES Modules	27
2.4.1 Adding the ITES Modules	27
2.4.2 Subtracting the ITES Modules	27
3. System Control Modes	28
3.1 System Control Modes of Operation	28
3.1.1 Base Load Chiller (Operation Only)	28
3.1.1.1 Control Sequence	29

3.1.2 Chiller Priority (Base Load Chiller + Mid Temp Glycol Chiller Cooling)	31
3.1.2.1 Control Sequence	33
3.1.2.2 Sequence of operation of Glycol chillers on Chiller Priority Mode	34
3.1.2.3 Shut down of Chiller Priority operation	35
3.1.3 Ice Priority (Base Load Chiller + Ice Cooling)	36
3.1.3.1 Control Sequence	38
3.1.4 Peak Load (Base Load Chiller + High Temp Glycol Chiller + Ice Cooling)	39
3.1.4.1 Control Sequence	41
3.1.4.1.1 Control Procedures	42
3.1.5 Ice Build (Base Load Chiller + Ice Build only)	43
3.1.5.1 Ice Build Cycle	43
3.1.5.2 Control Sequence	45
3.1.5.3 Start Up Procedure	46
3.1.5.4 Shut down Procedure	47
3.1.6 Ice Build Plus Cooling (Base Load Chiller + Low Temp Glycol Chiller)	47
3.1.6.1 Control Sequence	49
3.1.6.2 Start Up Procedure	49
3.1.6.3 Mode Exit Procedure	50
4. Control Strategies for Sub System	51
4.1 System Control Strategies for Sub Systems	51
4.1.1 Control of Heat Exchanger Mixing Valve	53
4.1.2 Control of Heat Exchanger Circulation Pumps	53
4.1.3 Glycol and Chilled water heat exchanger freeze protection	53
4.1.4 Control of Ice Storage flow and bypass valves	54
4.1.5 Control of Glycol Chillers and Shunt Pumps	55
4.1.6 CPCS Architecture and Subroutines	56
5. Analysis of Seasonal Demand Profile	61
5.1 Typical Seasonal Demand Profile	61
5.2 Typical Summer Profile:	65
5.3 Typical Winter Profile	66
5.4 Load Profile Prediction Methodologies	68
5.5 Load profile prediction using software	69
5.6 Daily operations with some of the potential optimum conditions	71
5.6.1 Cooling Load exceeds Maximum Chiller Capacity	71
5.6.2 Extreme Peak Load	71
5.6.3 Post-Peak Load Operation	72



6. Results and Analysis	73
6.1 Analysis and Conclusion	73
6.2 Additional System Design Considerations	75
References	77
Appendix	79
Appendix A ITES Mechanical Schematics	79



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk