UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF SIMULATION PROGRAM FOR THERMAL ENERGY STORAGE INTEGRATED DISTRICT COOLING SYSTEM

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

I would like to record my deepest appreciation to my parents Hj. Abd. Salam Hj. Mohd. Zain and Hjh. Noor Aini Mohamed for their infinitive support. To my loving wife, Sharifah Intan Khursiah Syed Husin, for her encouragement and getting through my disposition during the whole writing process. My lovely kids, Qurratul Ain and Aminatul Adilah for the laughter that enlighten the family. Also, to my big family members who are always there for me.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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Chairman: **Associate Professor Megat Hamdan Megat Ahmad, Ph.D.**

Faculty: **Faculty of Engineering**

Awareness on the environment and significant benefit to the customer has lead to the growth of Thermal Energy Storage (TES) application in Malaysia. Most of them are implemented in medium to large chilled water manufacturing facility that cooled multiple buildings in a widespread area or integrated in a District Cooling System (DCS). For encapsulated ice method, the difference in the amount of ice supplied to supplement the chilled water generated during peak hours plays major role in ascertaining the result of electricity bill savings and therefore, payback period. Based on actual implementation in Cyberjaya, Selangor, a simple simulation program of TES integrated DCS is created to study the impact on the electricity bill savings,

conventional system. Varying the percentage of ice supply, application to cooling capacity of 500 RT, 1000 RT, 1500 RT with and without base load, on different tariff rates are calculated. It shows that integration of smallest percentage of TES is most feasible in terms of payback period and electricity consumption. However, the amount of savings is small. As the ice making process operates at lower temperature, there is also penalty on energy consumption. On tariff imposed, the acceptable range for base load and percentage of ice supply that is feasible are identified while most of the rates in no base condition qualify to entitlement of payback period under five years. The parameters whereby TES integrated DCS are not advisable are also acknowledged.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PEMBANGUNAN ATURCARA SIMULASI BAGI SISTEM PENYEJUKAN DAERAH DAN PENYIMPANAN TENAGA HABA SEPADU

Oleh

AMIR IHSAN BIN ABD. SALAM

November 2002

Pengerusi: **Profesor Madya Megat Hamdan Megat Ahmad, Ph.D.**

Fakulti: **Kejuruteraan**

Kesedaran terhadap alam sekitar dan manfaat yang diperolehi pengguna telah menerajui peningkatan dalam penggunaan Penyimpanan Tenaga Haba di Malaysia. Kebanyakan aplikasi tersebut melibatkan pusat penjanaan air dingin bersaiz sederhana hingga besar bagi menyejukkan beberapa buah bangunan dalam satu kawasan yang luas atau disepadukan ke dalam Sistem Penyejukan Daerah. Bagi kaedah ais berkapsul, perbezaan di antara jumlah ais yang dibekalkan bagi mengatasi kekurangan air dingin yang dijana semasa waktu puncak memainkan peranan penting dalam menentukan hasil penjimatan bil elektrik dan seterusnya tempoh pulangan balik. Berdasarkan perlaksanaan sebenar di Cyberjaya, Selangor, satu kaedah aturcara mudah bagi mengkaji kesan Penyimpanan Tenaga Haba dan Sistem Penyejukan

Daerah Sepadu terhadap penjimatan bil elektrik, tempoh pulangan balik, guna tenaga dan penggunaan elektrik dibandingkan dengan Sistem Konvensional, telah dihasilkan. Pengiraan dilakukan dengan cara mempelbagaikan peratusan bekalan ais, penggunaan ke atas kapasiti penyejukan yang berbeza iaitu 500 RT, 1000 RT, 1500 RT, sama ada dengan aplikasi beban asas atau pun tidak, di samping pelbagai kadar tarif yang dikenakan. Hasil kajian menunjukkan bahawa penggunaan Penyimpanan Tenaga Haba dalam peratusan yang terkecil adalah paling memberangsangkan dari segi tempoh pulangan balik dan penggunaan elektrik. Walaubagaimanapun, jumlah penjimatan adalah kecil. Keburukan sistem ini juga didapati dari segi guna tenaga, disebabkan proses membuat ais berlaku pada suhu yang rendah. Berhubung dengan kadar tarif pula, julat yang dapat diterima bagi aplikasi dengan beban asas dan peratusan bekalan ais telah dikenalpasti di mana sebahagian besar kadar tariff dengan aplikasi tiada beban asas berjaya mendapat tempoh pulangan balik kurang dari lima tahun. Parameter di mana Sistem Penyejukan Daerah dan Penyimpanan Tenaga Haba adalah tidak menguntungkan, juga dapat dipastikan.

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To those who have made contributions, I pray that Allah's blessing is rendered to you and your family.

Thank you.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AHU	Air Handling Unit
CEPSI	Conference of Electricity and Power Supply Industry
CHW	Chilled Water
DCS	District Cooling System
DSM	Demand Side Management
EG	Ethylene Glycol
FFDS	Four Fuel Diversification Strategy
HDPE	High Density Poly Ethylene
IkW/rt	Input Kilowatt per Refrigerant Ton
IPP	Independent Power Producer
KLCC	Kuala Lumpur City Centre
KLIA	Kuala Lumpur International Airport
KWh	Kilowatt Hour (10^3)
KWr	Kilowatt refrigerant
Ib/hr	Pound per Hour
L/s	Liter per second
MEC	Malaysian Energy Center
MmBtu	Million British Thermal Unit
MP	Malaysian Plan
MW	Megawatts
MWh	Mega Watt Hour (10^6)
PETRONAS	Petroliam Nasional Berhad
PG	Propylene Glycol
RM	Ringgit Malaysia
RT	Refrigerant Ton
RTh	Refrigerant Ton Hour
SIRIM	Standard Industries Research Institute, Malaysia
TNB	Tenaga Nasional Berhad
TES	Thermal Energy Storage
TWh	Tetra Watt Hour (10^{12})
USD	U S Dollar
Usgpm	U S gallon per minute

CHAPTER 1

INTRODUCTION

1.1 Background

Demand for energy has become critical now than ever before. Most of the developing countries recorded energy growth each year of more than 10 %. At average, Asian countries require 30,000 MW of new generation of energy every year while total of the world demand increase as high as 90,000 MW annually (Jusoh, 1996). In Malaysia alone, the demand for electricity soars at the rate of 11% a year (Shamsuddin, 1996). With current capacity of about 13,000 MW and expected 19,000 MW of capacity required in year 2005 (Pua, et al., 1996), Tenaga Nasional Berhad (TNB), the national electricity provider, is rigorously taking steps in sustaining the economic growth with sufficient energy supply.

Report by Chua (2000) which, illustrate the electricity demand curve in Peninsular Malaysia as reflected in Figure 1.1, shows that the curve for electricity demand is somewhat similar to that of air conditioning load. Since conventional air conditioning system and apparatus contribute 60 % to 75 % of total electricity peak demand, as shown in Figures 1.2, 1.3 and 1.4, energy management is said best be achieved through proper arrangement of air conditioning utilization.

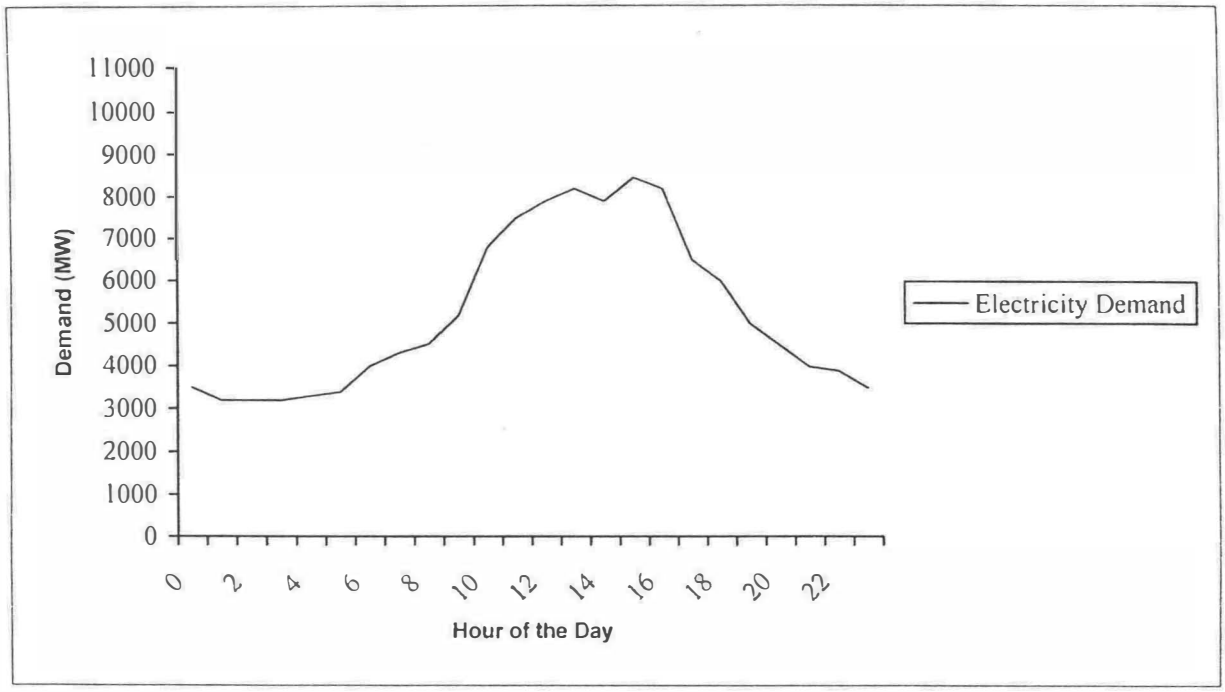

Figure 1.1: TNB's System Demand Curve for Peninsular Malaysia (Chua, 2000)

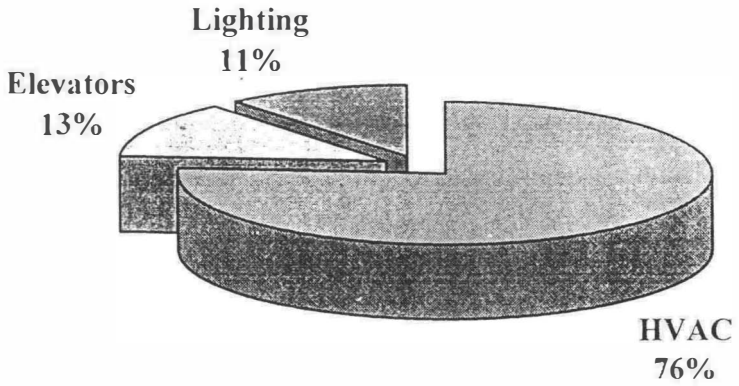

Figure 1.2: Energy Consumption in Typical Office Buildings (Thomas, 1997)

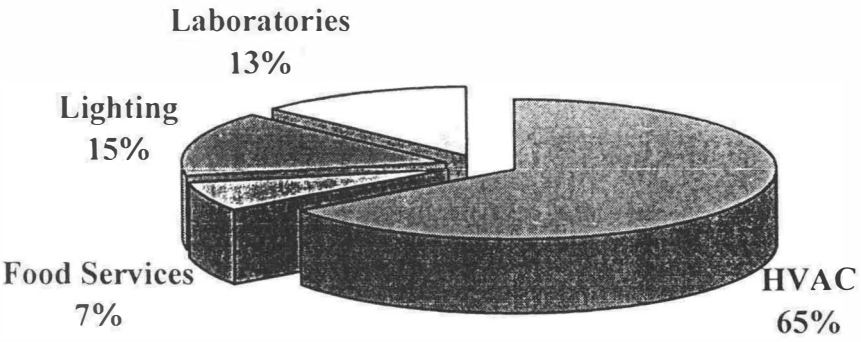

Figure 1.3: Energy Consumption in Educational Buildings (Thomas, 1997)

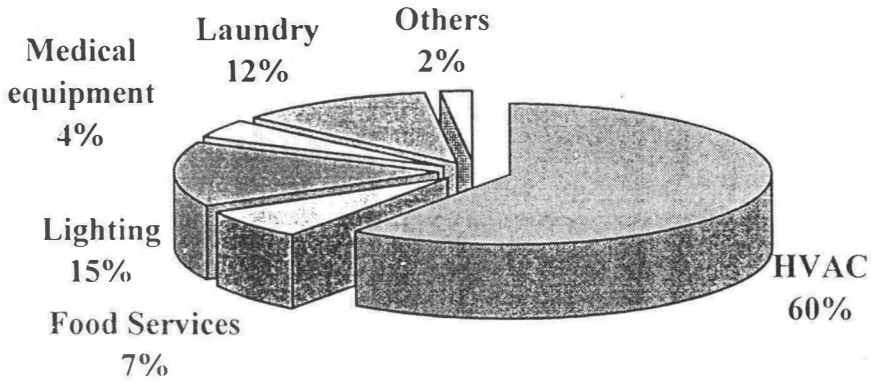

Figure 1.4: Energy Consumption in Hospitals (Thomas, 1997)

*Notes: HVAC – Heating, Ventilation and Air Conditioning

One major strategy to efficiently manage the imbalance energy utilization is to promote better customer participation through a program called Demand Side

Management (DSM)'. The program boasts an approach taken to reorganize the electricity utilization by reducing both peak and base electricity loadings. Thermal Energy Storage (TES) system, being part of DSM program, has been identified as a proven technology in elcctrical load management (Thomas, 1997).

Recent emergence of so-called 'Mega Projects' such as Kuala Lumpur International Airport (KLIA), Kuala Lumpur City Centre (KLCC), KL Sentral, Putrajaya and Cyberjaya have all participated in DSM program through application of TES technology with some implementation of District Cooling System (DCS). Depending on TES size, the contribution of TES application could reduce the electrical peak demand to as much as 20 % to 30 % (Rosli, et al., 1997).

1.2 Energy Overview

Being one of the fast growing developing nation in the region, Malaysia has been noted as one of the 'Asian Tigers' with its economic strength recognized globally. Before the economic turmoil during the period of 1997 to 1999, Malaysia has been experiencing strong economic growth at the average of 9 % for eight consecutive years (Mohamad, 1999), which in turn put the country through an unpredicted crisis of energy supply. The fact is, history of energy crisis in this country has dated back since 1973, when together with the rest of the world, faced with the famous oil crisis caused by the embargo of oil by Middle East Countries. From that date, a number of policies have been established by the Government to sustain the economic growth while maintaining sufficient supply of energy. Report released by Anon., Department of Statistic, Malaysia (1998), highlights that during the period of 1992 to 1998 alone, the production of natural gas has been increased by 115 % and crude oil by 10 %. While on the other hand, electrical power supply expanded up to 84 % (at annual rate of 11 %). The figure is significant as compared to the world growth of 2~3 %. The sales growth from 1978 to 1998 (20 years span) together with sales forecast until 2010 is illustrated in Figure 1.5 while sectional distribution of energy utilization and sectored growth rate is shown in Table 1.1 for the fifth, Sixth, and Seventh Malaysia plans (MP5, MP6 and MP7).