UNIVERSITI PUTRA MALAYSIA

ELECTRICAL ENERGY EFFICIENCY FOR RETROFFITTING COMMERCIAL BUILDING

LAM SING YEW

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By

LAM SING YEW

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

May 2003

Dedicated to my wife and my little junior daughter

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirement for the degree of Master of Science

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May 2003

Chairman: **Associate Professor Norman Mariun, Ph.D, P.Eng.**

Faculty: **Engineering**

The objective of this study is to reduce energy operating costs by introducing electrical energy conservation programmes such as improving lighting efficiency, reducing internal energy transmission losses along power cables and to replace inefficient equipment with energy efficient products for retrofit commercial buildings. Retrofitting commercial building has been defined as existing commercial building that will be undergoing major upgrading works such as replacing of wear and tear equipment and use products of new technologies or energy conservation techniques which can increase energy efficiency within the commercial building operation in order to remain competitive in operations.

Energy conservation literature was reviewed and energy conservation techniques were implemented in a Malaysia Airlines System (MAS) headquarters building located at Lot 69, Section 57, Jalan Sultan Ismail, Kuala Lumpur.

In this study energy analysis and inefficient usage of energy was determined by tabulating energy consumption and expenditure by referring to previous monthly electricity bills; monitoring of power consumption by computing variables such as power factor value, reactive energy and harmonic contents using (HIOKI) power monitoring meters and degree of luminance by determining luminaires system lux value using (HIOKI) Lux meter. Analysis of the energy data revealed that practical energy conservation programme techniques can be implemented to alleviate inefficient energy usage and reduction in operation cost. The results showed that by retrofitting the existing luminaires system to the recommended parabolic mirror reflector (PMR) luminaire and replacing the conventional bulb 'EXIT' sign luminaires to light emitting diode (LED) technology, inefficient usage electrical energy can be reduced and will lead to cost saving. The power factor correction method derived from analysis of practical energy data indicated that internal energy transmission losses over power cable can be reduced and also improve power system distribution capacity. The wear and tear of the existing electric motor can be replaced with energy efficient electric motor based on the energy consumption data comparison analysis. Improving the power quality problem especially the harmonic contents in the power system can also reduce electrical energy transmission losses by correcting the non-linear current distorted waveform.

The conclusion that can be drawn here is that the electrical energy conservation programme techniques are indeed able to reduce the electrical energy consumption as shown by cost saving calculations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk ijazah Master Sains

KECEKAPAN TENAGA ELEKTRIK BAGI MENAIK TARAF BANGUNAN KOMERSIAL

Oleh

LAM SING YEW

Mei 2003

Pengerusi: **Profesor Madya Norman Mariun, Ph.D, P.Eng.**

Fakulti: **Kejuruteraan**

Objektif tesis ini adalah untuk mengurangkan kos pengendalian tenaga dengan menperkenalkan program pengabadian tenaga elektrik seperti meningkatkan kecekapan cahaya lampu, mengurangkan kehilangan penghantaran tenaga dalaman pada kabel kuasa dan menggantikan perkakas yang tidak cekap dengan produk tenaga cekap bagi menaik taraf bangunan komersial. Peningkatan taraf bangunan komersial bermaksud sebuah bangunan komersial sedia ada yang melalui kerja-kerja menaik taraf utama seperti penggantian alat-alat kelengkapan yang haus dan koyak dan penggunaan produk berteknologi baru atau teknik pengabadian tenaga yang boleh meningkatkan kecekapan penggunaan tenaga elektrik di dalam operasi bangunan komersial supaya boleh terus mantap di dalam pengendalian.

Kajian latar belakang berkenaan pengabadian tenaga telah dijalankan dan teknik-teknik pengabadian tenaga telah dilaksanakan di bangunan ibu pejabat MAS yang terletak di Lot 69, Seskyen 57, Jalan Sultan Ismail, Kuala Lumpur.

Dalam kajian ini analisis tenaga dan ketidakcekapan penggunaan tenaga telah ditentukan dengan menjadualkan penggunaan dan perbelanjaan tenaga dengan merujuk kepada penyata perbelanjaan elektrik bulanan yang lepas; pemantauan penggunaan kuasa dengan mengira nilai yang berubah seperti nilai faktor kuasa, tenaga reaktif dan kandungan harmonik dengan menggunakan (HIOKI) meter pemantauan kuasa dan kadar lar dengan menentukan nilai lux sistem pencahayaan dengan menggunakan (HIOKI) Lux meter. Analisis data tenaga mendedahkan bahawa amalan teknik-teknik program pengabadian tenaga boleh dilaksanakan untuk meringankan ketidakcekapan penggunaan tenaga dan pengurangan dalam kos operasi. Keputusan menunjukkan bahawa pengubahsuaian sistem lampu sedia ada kepada lampu parabola cermin pemantul dan menggantikan lampu mentol tanda 'KELUAR' lazim kepada teknologi diod pemancar cahaya, ketidakcekapan penggunaan tenaga elektrik boleh dikurangkan dan membawa kepada penjimatan kos. Kaedah pembetulan faktor kuasa diperolehi daripada analisis data amalan tenaga yang menandakan bahawa kehilangan penghantaran tenaga dalaman ke atas kabel kuasa boleh dikurangkan dan juga memperbaiki muatan pengagihan sistem kuasa. Motor elektrik sedia ada yang haus dan koyak boleh digantikan dengan motor elektrik tenaga cekap berdasarkan kepada analisis perbandingan data penggunaan tenaga. Memperbaiki masalah kualiti kuasa terutama kandungan harmonik di dalam sisteAm kuasa boleh juga mengurangkan kehilangan penghantaran tenaga elektrik dengan memperbetulkan gelombang terherot arus tak lelurus.

Kesimpulan yang boleh dibuat di sini adalah teknik-teknik program pengabadian tenaga elektrik semenangnya boleh mengurangkan penggunaan tenaga elektrik seperti yang ditunjukkan dalam pengiraan penjimatan kos.

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Nevertheless, my many thanks to the UPM support staff for providing the engineering facilities to enable me to finish my research work.

I certify that an Examination Committee met on 28th May 2003 to conduct the final examination of Lam Sing Yew on his Master of Science thesis entitled "Electrical Energy Efficiency for Retrofitting Commercial Building" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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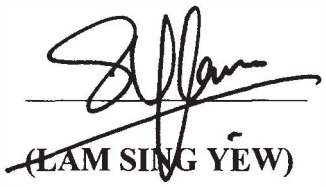
DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



(LAM SING YEW)

Date: 18 July 2003

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AHU	Air handling unit
ASD	Adjustable speed drives
CU	Coefficient of utilisation
CCT	Co-ordinated colour temperature
CRI	Colour rendering index
DPF	Displacement power factor
EC	Energy Commission
ECO's	Energy conservation opportunities
Fc	Foot candles
IEC	International Electrical Codes
IM	Induction Machine
IEEE	Institution Electrical Electronic Engineers
kWh	Kilowatt hour
LDD	Luminaire dirt depreciation
LED	Light Emitting Diodes
LLD	Lamp lumen depreciation
MD	Maximum demand
MAS	Malaysia Airlines System
MPMP	Motor Performance Management Process
O&M	Operation and maintenance
PIR	Passive infrared
PCC	Point of common coupling
PMR	Parabolic mirror reflector

SPP	Simple payback period
TNB	Tenaga Nasional Berhad
US	Ultrasonic
VSD	Variable speed drives

CHAPTER 1

INTRODUCTION

1.1 Introduction

The commercial building sector, defined commercially, consists of establishments and operating locations that provide services. Commercial buildings exist to house commercial establishments and provide a comfortable environment for employees and on-site customers or clients. Defined in such way, the commercial sector is extremely varied. It includes service businesses, such as retail and wholesales stores, hotels and motels, and hospitals, as well as a wide range of facilities that would not be considered "commercial" in a traditional sense, such as public schools, institutions, and religious and fraternal organisations. Each commercial building has a unique application and the building load does exist where the amount of energy is required in order to maintain the desired indoor space conditions and to operate building equipment. Many energy sources, such as heat, cooling, electrical, and mechanical energy are needed for each building operation. As for energy conservation programme, energy can be conserved in many ways either through the energy-building envelope, efficient electrical energy usage or minimising latent heat energy generation such as passive solar heat and internal heat. For successful energy conservation programme, it shall consist of the energy efficiency concept implementation, energy planning in design stage, engaging energy management in operation and utilising of energy efficiency products.

In general, electrical energy is consumed in the commercial buildings to maintain the physical environment and to power any equipment needed to accomplish commercial

activities. Electrical energy is supplied to commercial building through power plants via the power transmission system. For commercial buildings, there are many appliances that require electrical energy to operate such as lighting systems, electric motor pumps, cooling system, heating element, office equipment and etc. The electrical energy usage can be conserved in most of the commercial equipment if the potential energy wastage is identified and eliminated. Thus, an energy efficient usage in the commercial building is highly desirable by facilities management either in the present or new commercial building. This is in order to reduce the energy wastage and to achieve lower operation running cost. The energy conservation programme for commercial building has been widely practised as some of energy conservation manual references handbook has been published dated back from 1976 [1, 2] to support the energy conversation programme.

In Malaysia, many commercial buildings were constructed to support the business activities here and the electrical energy is prominent usage. According to the electricity consumption consensus in year 2000 which is conducted by Malaysia Department of Electricity & Gas [3], the commercial consumer consumed 27.8%, industry consumed 53.5%, domestic consumed 17.5% and public lighting & mining sector consumed 1.2% from the total electricity generation consumption of 55,629 GWh. The consensus statistics has shown that almost one third of the total electricity consumption is being utilised by commercial building. Therefore, Malaysia government has formed the Energy Commission (EC) committee in May 2001 to tackle the electricity generation consumption problem and also to play a vital role in the energy areas for planning, regulation and efficiency under the 8th Malaysian energy plan [4].

Some of the existing commercial consumer buildings are constructed since 1980s' and there might not support any energy conservation programme in their facilities operation. This may lead to inefficient energy utilisation in the commercial building. When a building is modified in a way which involves construction or additional equipment, this is referred as retrofitting works. The retrofit works incorporate energy conservation which could involve matters such as modification like redesigning the lighting system, adding equipment to reduce electrical power demand, or changing present equipment in order to increase the efficiency of the said equipment. The refurbishment work is necessary to be carried out due to the normal building ageing process and its installed equipment, new requirement by building occupants and new technologies which can offer cost benefits for justifying the replacement of those already operative within the building. Nevertheless, retrofitting the existing buildings that is incorporating energy conservation programme in mind is a valuable capital investment to the building management.

As technology progresses with time and also an unavoidable ageing building, the building owner has to allocate some refurbishment capital cost either for upgrading the building image or to replace the wear and tear equipment. By introducing the energy conservation programme into the retrofitting building exercise, it will yield benefit results to the building owner in the long run as substantial saving is obtained through the reduction of energy expenditure bill, although it will incur a higher investment in the initial programme. To ensure that energy conservation programme is implemented successfully, professional trained personnel like certified energy manager is engaged to introduce the energy efficiency concept for the retrofitting commercial building exercise and able to carry out energy auditing. An energy audit

can identify the saving energy areas and hence ways of saving money can be discovered. The certified energy manager need to attend postgraduate energy efficiency short course in order to sharpen their skills or has accomplished a few energy conservation projects. Therefore, the energy manager can advise the building owners of the benefits by taking an energy conservation programme.

1.2 Problem Statement

The current commercial buildings may have inefficient electrical energy usage and poor energy optimisation consumption due to the following reason below.

a. High energy consumption equipment is in place

b. Internal power losses unanticipated such as poor power factor

c. Energy conservation programme has not been engaged

As a result of that, the high electricity bill is anticipated due to unwanted power losses in the building system which can cause high operation cost for the commercial buildings expenditure. Therefore, this thesis is to focus how to improve electrical energy utilisation and reduce unwanted high operation cost for the building load which has been installed in the commercial buildings.

1.3 Research Objective

The objective of this thesis is to reduce energy operation cost in the commercial building. Reduction in the electricity expenditure is equal to reduction of the building operation cost, since it is a major expense for every commercial building. Every

facility management in the commercial building is opting for an efficient electrical energy usage. One of the possible solutions to achieve this objective is to introduce the energy conservation programme to the commercial buildings.

Nevertheless, this thesis also covers the energy retrofit potential area, perform energy auditing for commercial building on the electrical component, propose energy saving recommendation to the commercial plant system and analyse the retrofitting cost involvement. The energy review covers the power factor, power quality issue and operation mode on installed electrical equipment for commercial facilities plants. Energy efficiency study is carried on the existing installed electrical equipment. This is in order to identify the possibility of energy efficiency enhancement like replacing inefficient operation equipment or recommends energy saving solution to the electrical equipment.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Energy engineering is a very wide topic to be covered and it has been divided into many fields for practising engineers who seek to explore and venture into this business. It has provided a very lucrative business to energy consultants in the long run, which is claimed by a renowned energy consultant, Amory Lovins [5].

Operating the plant facilities with energy conversation programme in place is like doing a good deed to the earth because of the pollution emission from electricity generation plant is reduced significantly. In addition to that, successful implementation of energy conservation programme brings advantages in tremendous opportunity of saving large amounts of money each year from energy expenditure costs to the facilities management. Beside that, every facility in operation has a role to play when it comes to energy utilisation within the organisation like installation of electrical equipment, building operation system and occupants behaviour.

In the engineering principal, what does the 'energy efficiency' mean? It is using less energy/electricity to perform the same function. Programmes designed to use electricity more efficiently -- doing the same with less. Many definitions have been defined for energy efficiency or energy conservation. But the energy conservation is a common term in energy fields and it has also been used widely. Many people use these terms interchangeably when efficient energy usage is concerned. There are many ways to improve the present energy system to efficient energy usage. For