OPTIMIZATION DESIGN OF THE LIGHTING AND VARIABLE REFRIGERANT FLOW SYSTEM FOR THE IMPROVEMENT OF ENERGY EFFICIENCY IN EXISTING BUILDING

ARSHNAH IRNI YUSNITA BINTI HJ. ARSHAD

A project report submitted in partial fulfilment
of the requirements for the award of the degree of
Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2014

Dedication to my beloved husband, Ab. Khalif bin Othman, whose support me, physically, mentally and emotionally, throughout my Master's study.

For my siblings and friends, appreciate your encouragement and help.
To all my lecturers, you are my inspiration for today and future time, Insya-Allah.

Thank you everyone and only Allah can bestow just reward to all of you.

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to Allah S.W.T, the Almighty and the Greatest Creator for His never-ending blessings and help. Without His permit, I would not be able to reach up to this level.

In preparing this project report, I was in contact with several people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. I am indebted to my respected supervisor Dr. Md Pauzi Abdullah. Without his encouragement, enthusiasm and support, this work could not have been completed. In particular, I would like to convey my deep sense of appreciation to Nasmie Engineers Sdn. Bhd. as Mechanical and Electrical consultancy firm of this dedicated project research has been done for their guidance, helps, and advices throughout the progress of the project and also Head Quarter of Kelantan State Fire Department in the district of Kota Bharu, Kelantan Malaysia (JBPM) as the owner of the building for their valuable information and support throughout the progress of the project.

Last but not least, my sincere appreciation also extends to all my family, colleagues, administrative staffs at Faculty of Electrical Engineering, UTM and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. May Allah s.w.t will bless all of you.

ABSTRACT

Energy efficiency is the most important for reducing the operating costs and manages the electricity efficiently and indirectly will contributes the green building indices. This mean that's the significant cost savings is achieved with energy efficiency improvements, and due to continually improving equipment, lighting and air conditioning system usually provides the highest return on investment of major upgrade. Therefore, the methodology proposed are to analyses the potential of energy saving, life cycle cost and payback period of the retrofitted lighting system and mechanical ventilation system. The research done explores the effectiveness of the proposed idea through case study conducted for an existing commercial building located in Kota Bharu Kelantan. This building belongs to the federal government and functions as a Fire and Rescue Department district headquarters for the state of Kelantan. Currently, the building is using T8 Magnetic ballast type for the lighting system and normal exhaust fan for fresh air system of air conditioning and mechanical ventilation system due to budgetary cost constraint during design and construction stage. The new alternative proposed method was done by replacing the building lighting system to T8 electronic, T5 and LED lamp and pre cooled of VRF System as fresh air supply to the air conditioned area. The software environment has been implemented by using Relux Suite and Diakin HKGSG as simulator in order to perform the design calculation for illumination level and cooling load. The final finding based on the output simulation results show that by implementing both the LED lighting and pre-cooled system can give the highest amount of energy saving and reasonable payback period even with the high cost of installation for the initial stage.

ABSTRAK

Kecekapan tenaga adalah penting kerana ia dapat mengurangkan kos operasi dan menguruskan bekalan elektrik dengan cekap, dan secara tidak langsung ia akan menyumbang kepada indeks bangunan hijau. Ini bermakna penjimatan kos dapat dicapai dengan peningkatan kecekapan tenaga, dan dijangka penggunaan peralatan sistem lampu dan sistem penghawa dingin akan memberikan pulangan pelaburan tertinggi sekiranya kerja – kerja naiktaraf dilakukan. Justeru itu, metodologi yang dicadangkan adalah menganalisa potensi penjimatan tenaga, kos kitaran hayat dan tempoh bayar balik modal bagi kerja – kerja penggantian sistem pencahayaan dan sistem pengudaraan mekanik untuk Sistem Penyaman Udara. Penyelidikan terhadap keberkesanan idea tersebut telah dijalankan melalui kajian kes bagi bangunan komersial sedia ada yang terletak di Kota Bharu Kelantan. Bangunan ini dimiliki oleh kerajaan pusat dan berfungsi sebagai Ibu Pejabat Daerah Jabatan Bomba dan Penyelamat Negeri Kelantan. Buat masa ini, bangunan tersebut menggunakan lampu T8 jenis balast Magnetik sebagai sistem pencahayaan dan juga sistem kipas ekzos biasa sebagai sistem pembekal udara segar bagi sistem penyaman udara disebabkan oleh kekangan kos semasa peringkat rekabentuk dan pembinaan. Kaedah alternatif baru telah disarankan dengan menggantikan sistem pencahayaan kepada lampu jenis T8-elektronik, T5 and LED, dan juga Sistem pra-penyejukkan udara segar untuk membekalkan udara di kawasan berhawa dingin. Dua perisian komputer telah digunakan iaitu Relux Suite and Diakin HKGSG sebagai pensimulasi untuk pengiraan rekabentuk sinar pencahayaan dan beban penyejukkan. Penemuan akhir berdasarkan keputusan simulasi menunjukkan bahawa dengan mengaplikasi kedua – dua cadangan alternatif iaitu Sistem Lampu LED dan Sistem Pra-penyejukkan dapat memberikan jumlah penjimatan tenaga yang tertinggi dan tempoh bayar balik yang munasabah meskipun dengan kos pemasangan yang tinggi pada peringkat permulaan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The commercial and residential building sectors consume nearly 40% of total primary energy. Besides accumulated energy use, buildings, especially commercial type, tend to have high demand in electricity simultaneously, which causes significant peak demand exertion on the grid. Both electricity suppliers and customers are concerned with the peak demand due to financial and capacity challenges. For one thing, numerous new power plants are built every year merely to feed the rapidly increasing peak electrical demand, which reduces efficiency at off-peak hours and leads to higher energy costs.

Besides that, the environmental impacts due to emission of polluted gases especially CO_2, CO and others become a big issue in the worldwide. All of these types of gases will pollute the environment and depleting the ozone layer due to product generated by the inefficient electrical appliances such as conventional lighting, using non-rated star product, human activity such as smoke vehicle engine and manufacturing process and many more. In addition, power generation with traditional method by using coals, natural gases and fossil fuel as burning process is not exempted from the problems of gas emissions into the atmosphere which is also contributing the environmental pollution.

Therefore, the increasingly of energy usage around the world can give the drawback to the human life and the environment. The policy to use energy efficient product should be introduced and proposed for the existing building. The advantages of energy efficient products can assist our government and also worldwide;

1. To reduce the electrical consumption.

2. Less global warming due to reduction of power density.

3. Less greenhouse effect by implementing efficient lighting technology such as LED instead of conventional type.

4. To reduce capital cost in order to develop new power plant.

Based on the dedicated case study of existing commercial office building of Bomba Head Quarters, Kota Bharu Kelantan show that the Air Conditioning and Mechanical Ventilation System is the most highest of energy usage for this developement with 37% from the total energy consumption, followed by the lighting system, small power, others block, lift and pumping system with the percentage of 37%, 25%, 23%, 11% and 1% respectively. Therefore, this thesis project will presents the potential of energy saving, life cycle cost analysis and payback period of the retrofitting lighting system and fresh air of Variable Refrigerant Flow System in the existing commercial government office building in order to reduce the energy usage later on.

1.2 Problem Background

The energy efficiency means the efficient utilization of energy during the operational lifespan of building where the comfort of its occupants is not compromised and sacrificed. The design, construction, operation and maintenance of new and existing buildings shall be complying with the minimum recommended requirements of MS 1525:2007; Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision) [1] and ASHRAE 90.1(Rev2010) [2] or other related standard.

The energy efficiency can be achieved by applying both passive and active design strategies involves all multiple disciplines to integrated the realistic design in order to achieve high performance and multiple benefits at a lower cost than the total for all the components combined.

1. <u>Passive Design Strategy</u>

   Passive design strategies includes adopting design measures such as building orientation and shape, site planning, selection of building envelope wall and roof materials with low thermal mass conductivity, building shading design, window type and design, type of glazing, daylight harvesting strategy, using natural ventilation and good landscaping design [1].

   The building envelope can affect the lighting, heating, and cooling needs of the building. These interactions are important to consider when retrofitting or weatherizing buildings to reduce their energy use in the most cost effective manner.

   Architects and engineers have developed innovative new ways to improve overall building design in order to maximize light and heat efficiency. Local climate is an important determinant for identifying the design features that will result in the greatest reductions of energy needs.

2. Active Design Strategy

Active design strategies refers to selecting energy efficiency equipment, utilities system, control system and strategy that result in direct reduction in the building energy running costs. This includes using high efficiency Mechanical & Electrical equipment/ components such as [1];

i. Designing and retrofit on high efficient lighting system; such as T5, LED lamp

ii. Minimizing losses in electrical power and distribution system;

a. High efficiency motors, pumps and fan; such as Variable Speed Drivers (VSDs) with motor driving pumps and fans with variable load with compliance to motor class efficiency of EFF1 and EFF2.

b. All transformers in the building's electrical system shall have efficiencies not lower than 98% for sizes below 1000 KVA and not less than 99% for size equal to or greater than 1000 KVA at full load conditions.

iii. Designing an efficient Air Conditioning and Mechanical Ventilation System (ACMV); such as using Variable Refrigerant Flow System (VRF), multiple compressor chiller system and others.

iv. Designing a good Energy Management Control System (EMS); is a subset of the Building Automation System (BAS) function to control of equipment, monitoring of equipment and integration of equipment subsystems.

This research will include only the active design strategy for designing and retrofit on high efficient lighting system (item i) and designing pre-cooled system for alternative efficient fresh air system (item iv) for variable refrigerant flow of air conditioning and mechanical ventilation system in order to reduce the usage of electrical energy and indirectly will achieved the green building index.

1.3 Problem Statement

Based on research and study for this existing development for the Head Quarter of Kelantan State Fire Department building in the district of Kota Bharu, the electrical energy used is equal to 182.89 KW with gross total area is equal to 4684.94M^2. Therefore the peak design rate is equal to 39Watt/ M^2. The consequence is the cost of electricity bill is high with amounting of Ringgit Malaysia; RM 16,000.00 average a month. Based on the analysis, the main factors to contribute these problems are as follows.

1. The existing internal lighting systems use inefficient lighting type which is standard T8 fluorescent lamp and PLC lamp with magnetic ballast due to budgetary cost constraint for the previous design and construction stage.

2. The existing fresh air system of VRF system used a normal fresh air system for a ventilation purposes. Therefore, the outdoor units will increases the operation during peak hour due to variation of outdoor temperature between 12 p.m. to 5 p.m. when the solar irradiance is high at that particular time.

1.4 Objectives

This research aims are;

1. To study and develop a suitable design method/ strategy over the existing system to reduce the energy consumption and electricity bills. Additionally, the alternative design strategy will contribute to the achievement of minimum requirement of building efficiency in compliance to MS1525:2007 Standard Revision 1 and ANSI/ ASHRAE Standard 90.1 (Rev2010).

2. To analyses the initial cost, operating cost and payback period of the proposed retrofit lighting and pre cooled fresh air system of VRF system.

1.5 Project Scope

The scopes of this project work will be emphasized as below:

1. To study the existing internal lighting system and VRF system and determine the energy used at existing building based on the as-built drawing and schematic diagram.

2. To study the energy efficiency lighting technology alternative and make a comparison in term of performance indices, lighting properties and cost based on these criteria.

a. The lux illumination level according to the MS 1525:2007/ Part 6.2.2/ Table 13 for each type of existing and alternative lamp.

b. The technical analysis comparing in term of energy consumption, power density, luminaire efficacy and lifetime for each type of existing; T8 Magnetic and alternative lamp; T8 Electronic, T5 and LED.

c. The economic evaluation comparing in term of cost saving, initial cost, operation cost and payback period for each type of alternative lamp versus existing type.

3. To study the energy efficiency of fresh air processor technology alternative (pre-cooled system) instead of normal fresh air system as per existing and make a comparison in term of energy performance and cost based on these criteria.

a. The air change design requirement shall be complying with the ANSI/ ASHRAE Standard 62-1999 of comfort criteria with respect to human bio-effluents.

b. The technical analysis comparing in term of heat load capacity and energy consumption for one day usage for both type of ventilation system.

c. The economic evaluation comparing in term of cost saving, initial cost, operation cost and payback period for both type of ventilation system (Total heat exchanger versus ventilation fan).

4. To simulate the existing and proposed new alternative system by using software implementation as well as manual calculation.

a. The Relux simulation software will be used to simulate the illumination level and energy consumption and to mix-match the suitable power system to be retrofitted.

b. The Diakin simulation software will be used to simulate the heat load capacity as well as for pre-cooled system sizing purposes.

5. To integrate the technical and economical evaluation for both integrated system based on seven (7) alternative proposals versus the existing system.

6. To propose the most significant of techno-economical system from the seven alternative proposal.

1.6 Significant of Project

Increase in energy consumption has negative impact on the environment, therefore the policy to use energy efficiently should be proposed. Based on the research shows that the inefficient product will produce the losses and dissipated the power losses in the form of heat to the environment. It will result higher energy consumption and also contribute to the global warming.

Due to this issue, the development of energy efficient system product is rapidly growth in the current market. By performing energy efficient product such as lighting and mechanical equipment will result in reducing the power density (Watt/ m2), power losses (Watt) and electricity bill. This project introduced the technical method or strategy to optimize the active design in the existing building and select the appropriate replacement product for retrofitting purposes with consideration of visual and thermal comfort.

1.7 Organization of Report

In general, this report mainly consists of five main chapters; introduction, literature review, methodology, simulation result analysis and also conclusion and future works.

In chapter 1, this thesis will discuss the research project in collectively. This chapter explained the crucial aspect of the research work such as a problem background, problem statements, objectives, scope of project scope and significant of project as well the thesis outline will also be discussed finally.

Chapter 2 completely dedicated to literature review about the implementation of energy efficiency system for the existing commercial office building. This chapter will be solely theoretically in detail discussing on the energy efficient internal lighting system and fresh air intake processing unit of variable refrigerant flow system versus as per ordinary installed.

The energy efficient lighting system will discuss deeply inclusive of type of ballast/ driver such as; magnetic, electromagnetic, electronic and LED driver, variety of lamp tubes such as; standard T8, T8-E, HPT8, T5 and LED and the comparison in term of lighting performance such as wattage (W), lumens (lm), efficacy (lm/W), colour temperature (°K), colour rendering index (CRI), harmonic pollution and also the toxicity of the product material.

Meanwhile, the basic principle of air conditioning and mechanical ventilation system will be discussed on the cooling strategy over the heat load generated by the internal and external parameter. The heat load capacity is related to the air conditioned environment such a lighting system and function of the room itself.

In this section the cost related to the system such as operating cost, life cycle cost and payback period will be discussed.

Chapter 3 will be explaining on the methodology of project implementation such as introduction, preliminary research and study, preliminary implementation, data gathering and information analysis, and simulation execution for lighting and heat load by using the Relux and Diakin simulation software.

Chapter 4 presented the in depth discussion of the obtained simulation results. The result will be analysed in terms of technical compliance and economic feasibility inclusive of start-up cost and payback period analysis. Conclusion and suggestion in improvising this research work shall be detailed out in Chapter 5.

Chapter 5 presented the main conclusion of the research project works and also gathers the future works.

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