ENHANCING THE COOLING SYSTEM OF A RESIDENTIAL BUILDING USING INTEGRATED BUILDING INFORMATION MODELLING WITH SOLAR ABSORPTION SYSTEM

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To who left me early …. My Father

To whom the Heaven under her feet … My Mother

To the soulmate … My Wife

To whom I live For … Abdulqader and Rooh

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ABSTRACT

Building energy management is concerned with the energy consumption of the building. The used electricity in the residential building has the highest percentage when applying HVAC systems among all other building services installations and other electric appliances. For that, the present work focuses on the cooling load capacity issues and the methods to reduce the amount of electricity used in the building, particularly in air conditioning systems. In order to achieve this target, three main steps were applied; the first step was calculating the cooling load capacity by using the Cooling Load Temperature Difference method (CLTD) method. The second step was to find a sustainable wall material that could reduce the cooling load requirements using Building Information Model (BIM). The sustainable material was a new type of concrete block with a high insulation capability. The final step was to analyse the required energy of the cooling system device by using an applied Engineering Equation Solver (EES) to obtain accurate results. Two types of cooling systems were tested to determine the economic device based on the energy required to operate them under the same conditions. The two cooling systems were the conventional vapour-compression and solar absorption systems. The EES program evaluates the mathematical model and calculations for these systems to investigate the performance coefficient of the selected air-conditioning systems within (May, June, July and August) months in Iraq. This program evaluated the cooling systems by calculating the cost of used power. The results observed that the use of sustainable material reduces the building energy consumption by about 20%, and the solar absorption system is the best device for cooling systems. The solar absorption system provided the best COP in May, which was 0.8048.

ABSTRAK

Pengurusan tenaga bangunan adalah berkaitan pengunaan tenaga di bangunan. Pengunaan elektrik di bangunan kediaman memperolehi peratus yang tertinggi apabila sister HVAC digunakan bersama pemasangan perkhidmatan dan perkakasan elektrik yang lain. Oleh itu, kajian ini tertumpu kepada isu beban pendinginan dan kaedah untuk mengurangkan jumlah pengunaan elektrik dalam bangunan terutamanya pada penyaman udara. Untuk mencapai sasaran ini, tiga langkah utama telah digunakan; langkah pertama ialah mengira kekuatan beban peryejukan dengan kaedah *Cooling Load Temperature Difference (CLTD)*. Langkah kedua melibatkan penentuan bahan dinding mampan yang mampu mengurangkan permintaan beban pendinginan dengan mengunakan *Building Information Model (BIM)*. Bahan mampan adalah bahan baru bongkah konkrit yang berkapasiti tebatan tinggi. Langkah akhir adalah untuk menganalisa permintaan tenaga untuk sistem peranti penyejukan dengan pengunaan *Engineering Equation Solver (EES)* untuk menghasilkan keputusan yang jitu. Dua jenis sistem pendinginan diuji untuk menentukan peranti ekonomi berdasarkan keperluan tenaga operasi di bawah kondisi yang sama. Dua sistem pendinginan tersebut adalan mampatan-wap lazim dan penyerapan tenaga suria. Model matematik dan pengiraan sistem ini dinilai dengan program EES untuk mendapatkan kecekapan penyaman udara diantara bulan yang terpilih (Mei, Jun, Jul dan Ogos) di Iraq. Perisian ini menilai sistem pendinginan dengan mengira kos pengunaan tenaga. Keputusannya pengunaan bahan mampan didapati dapat mengurangkan pengunaan tenaga bangunan sebanyak 20% dan sistem serapan suria adalah terbaik untuk sistem pendinginan. Sistem penyerapan suria memberikan COP yang terbaik pada bulan Mei dengan nilai 0.8048.

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LIST OF SYMBOL AND ABBREVIATIONS

AC	-	Air-conditioning
ACF	-	Annual cash flow
CLF	-	Cooling load factor
CLTD	-	Cooling load temperature change
C.O.P	-	Coefficient of Performance
CO_2	-	Carbon dioxide
DMEU	-	Di methyl ethylene urea
h	-	Enthalpy (kJ/kg)
HCFC	-	hydrochlorofluorocarbon
HFC	-	hydrofluorocarbon
HVAC	-	Heat ventilation air-conditioning
IC	-	Investment cost
kWh	-	kilowatt-hour
Kg	-	kilogram
$LiBr$- H_2O	-	Lithium Bromide- Water
$\dot{m}$	-	mass flow rate (kg/s)
NH_3- H_2O	-	Ammonia- Water
P_e	-	Pressure of evaporator
PBP	-	payback period (year)
PCM	-	Phase-change material
PHX	-	plate heat exchanger
PMV	-	Predicted mean vote
PPD	-	Predicted percentage dissatisfied
PTAC	-	Package terminal air conditioning system
PV	-	Photovoltaic
Q_C	-	rate of heat input to condenser (kW)
Q_E	-	refrigeration effect (kW)

Q_G	-	rate of heat input to generator (kW)
S	-	Specific entropy, J/(kg K)
SCL	-	Solar cooling load
$TETD$	-	Time equivalent temperature difference
T_{abc}	-	Heat of absorber (°C)
T_C	-	Heat of condenser (°C)
T_g	-	Heat of generator (°C)
T_{Win}	-	Internal water temperature (°C)
T_{Wout}	-	Outer water temperature (°C)
W_{Comp}	-	Work of compressor
X	-	Constant of solution

Greek Letters

η	-	Efficiency

Subscripts

e	-	evaporator
g	-	generator
r	-	refrigerant
ss	-	strong refrigerant-absorbent solution
ws	-	weak refrigerant-absorbent solution
$1–5$	-	system state points

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Improving energy efficiency is considered a cost-effective strategy for building economies. The total contribution of building energy consumption has risen and surpassed the other primary sectors, such as transport and industrial sectors. It makes up nearly 40% of emerging countries' energy consumption (Farah 2016). In order to control the energy used in residential buildings, the use of heating, ventilation, and air-conditioning (HVAC) systems are the central components which must be considered in the energy consumption. The researcher focused on this issue due to its importance in energy consumption. Realizing building energy efficiency is essential in calculating the cooling load of a building; this is the primary procedural approach to achieve this target. Cooling load computation is the first step in designing building air conditioning systems (Wang et al., 2018). It measures the required energy that consumes power based on Energy Efficiency Ratio, which represents the appliance's cost.

1.2 Research Background

The vast extent of residential buildings observed a problem of increasing demand for electricity due to the need to create a comfortable environment inside the building. A comfortable life involves various instruments and devices that are used by the people live day. The extent of these instruments and devices increases the electricity demand and causes a non-significance environmental effect such as a high rise in environmental temperature due to the ozone damage from CO_x and NO_x. The growth in the number of buildings that require summer air-conditioning are the augmented thermal load, the increase in living standards and the human needs of the occupants. In addition, the architectural features and trends of buildings include the growth in the percentage of transparent to solid surfaces in the cover of building and extend to ordinary buildings of glass covering.

In particular, in large systems ranging around (50 kW) and beyond, various techniques of heat-driven cooling exist on the market that could be utilized in combination with solar thermal collectors. Currently, 30% of used energy is utilized to cool or heat residential and commercial buildings that have received growing focus today (Chang, Lin, & Chung, 2013). In the 1980s, solar energy regimes for air-conditioning use evolved, especially in the U.S. and Japan. The evolution of the solar air conditioning (SAC) method is preferred due to its economic profit. In previous works (Bellos & Tzivanidis, 2017) concerning heating and cooling consumption analysis, it is proposed to consider an integrated tactic for energy saving assessment. Furthermore, in solar air-conditioning systems, performance is highly related to external circumstances and the dynamics of the cooling load (Bellos et al., 2017).

Many researchers have implemented several methods to decrease the effect of using conventional energy resources. They tried to change the types of used material in building construction and add insulation material to protect the residential occupants, as shown in Figure 1.1 (Ruuska & Häkkinen, 2014). Other researchers developed or suggested new methods to use natural resources to heat or cool the buildings, such as using earth heat (Jain et al., 2013). Nowadays, most international cooperative projects use solar energy as a promising renewable energy resource (Eicker et al., 2012).

Figure 1.1: Thermal insulation system for residential building (Ruuska & Häkkinen, 2014)

1.3 Problem Statement

Buildings in Iraq need to be improved due to the high ambient temperature. Improving energy efficiency will reduce the use of electricity and lowering energy expenses. Also, it provides a more comfortable life and lowers bad environmental effects, including CO_2 emissions. The overall potential benefits of technologies and policies targeted at reducing energy usage in buildings. In addition, Iraq suffers from providing electric power, which is essential for social needs. One of the solutions to this problem was to use renewable energy. Renewable energy sources for heating, cooling, and electricity are being examined, as well as changes to the building envelope, such as materials, natural ventilation, and daylighting, and enhancements to building services, such as heating, mechanical ventilation, and air conditioning. (Berardi & U, 2015; Yu, Evans, & Shi, 2014).

Several types of energy-saving buildings are given, along with progressive retrofitting criteria. Low-energy buildings, for example, with yearly thermal loads that include active solar collectors or solar heating, zero-energy houses, energy selfsufficient households, and Plus-energy houses are all examples. ASHRAE's objective is that smart houses with intelligent energy management systems would develop market-viable NZE buildings (NZEBs) that are technically near to the zero-energy buildings performance target. For comparative value, the collected information by the audit team must specify the building operation characteristics and the technical characteristics of its various cooling parameters with a long-term analysis of the cost. Also, the team must investigate the available equipment that can be used in cooling the building and know the equipment specifications (Young et al., 2020; Menezes et al., 2014).

1.4 Research Questions

The research questions that are needed to highlight the problem of this study were as in below:

i. What is the influence of using different materials on the cooling building capacity?
ii. What is the impact of material properties on the environment and the economy?
iii. How to decrease the impact of the cooling load on the economy and the environment?
iv. What is the benefit of using solar absorption cooling systems?

1.5 Objective

The objectives of this study are:

i. To determine the required cooling load based on effective factors of residential building characteristics by using a mathematical model.
ii. To evaluate the solar effect on the cooling load differences based on different materials using BIM software.
iii. To investigate the operation condition of two practical cooling systems (solar absorption system and vapour compression system) used in residential buildings and compare them to choose the best for the building.

1.6 Scope of Research

The scope of the present study is:

i. The cooling load calculation method is the Cooling Load Temperature Difference (CLTD).

ii. The building sample was taken in Iraq, Baghdad, which is in the coordinates: 33°20′N 44°23′E, 33°20′N 44°23′E (33.333°N 44.383°E)

iii. The environmental data for the selected building was gathered from Climate Data for Cities Worldwide, Climate Data.org, and National Centers for Environmental Information, Iraqi electrical official office.

iv. Building information modelling is used to evaluate the solar energy heat gain to the building.

v. Engineering Equation Solver (EES) software is used to calculate the selected cooling system functions.

vi. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standard has been used as a reference book.

1.7 Significance of Research

The rate of energy consumption is increasing daily as Iraq is a developing country. The younger generation lives in a world full of state-of-the-art devices and equipment powered by electrical energy. These conditions have increased the demand for electrical energy. The energy issue has become less prioritized by Iraqis today, mainly due to a lack of awareness. It is necessary to raise their awareness regarding the consequences of extensive electricity usage on the natural environment. In addition, Iraq has experienced up to a 50% decrease in electrical power in the last thirty years due to war. Hence, it is crucial to identify and evaluate the energy consumption of a building.

By identifying the electrical equipment used in residential buildings, the energy consumption and electrical cost can be evaluated. This will help to raise awareness of energy expenditure. Through the proposal of potential energy saving, the number of utility bills every year can be reduced.

1.8 Thesis Organization

This thesis includes five chapters relating to this research, and each chapter summary is as follows:

Chapter one introduces the overview of the current research, which contains the introduction, brief background of the energy consumption, and the potential saving in the residential building located in Kithara city, Baghdad, Iraq. This is succeeded by the problem statement, objectives of the study, and the scope of research that will obtain the importance of the current study.

Chapter two shows the related literature of the previous similar research from key people in the energy field. It presents the relations depicted in the theoretical framework and the hypothesis formulation of the present research.

Chapter three explains the methodology of research and looks to clarify the method used in this work. Also, it illustrates the building identification, location, and user trend in addition to the procedure and collection of data collection to determine the initial data for the current study. Details of the utilized methods are explained in this chapter by the analysis of data.

Chapter four comprises the outcomes and discussion and outlines the performed analysis of data. Also, it illustrates the proposed solutions and recommendations after the results are found to improve this research in future works. Additionally, the chapter focuses on the analysis of data, where the results are listed in a table in the last part of the chapter.

Lastly, chapter five presents the conclusion and recommendation. The research of the results, discussion and clarification of the results of the analysis were briefed. It offers the researchers an understanding of the implications and limitations of this study; furthermore, it provides insights into how the researcher deals with a future study inside the scope of energy consumption and potential saving for intermittent.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The current chapter offers a survey study of journals, articles, theses, books, and other sources concerning the research topic. This is necessary to increase knowledge in a related research topic for the researcher to have a clear objective and expected outcome. The present work discussed the solar energy concept and applications. It provides the research with a clear idea about the solar energy system in the following chapters. Also, it presents the air conditioning systems used in residential buildings with all details, such as the efficiency of the systems and capacity with respect to the energy usage. The final important step of this chapter is the related studies of the building information system (BIM), which is used to calculate the number of used materials and solar effect. This provides the researcher with all the cooling load information needed in the building.

2.2 Air Conditioning System

Air conditioning eliminates heat and moisture within an occupied space to enhance occupant comfort. Air conditioning may be utilized in both local and commercial environments. This procedure is commonly utilized to obtain a further comfortable indoor environment, usually for humans and other animals; however, air conditioning is likewise utilized to cool and rooms dehumidification packed with heat-making electronic instruments, for example, computer servers and energy amplifiers, and to show and store some delicate goods, for example, the air conditioner regularly utilizes

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