Faculty of Engineering

APPLICATION OF A DEMAND CONTROL VENTILATION AT CITDS BUILDING FOR ENERGY SAVING AND INDOOR AIR QUALITY CONTROL

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Bachelor of Engineering with Honours

(Chemical Engineering)

2022

UNIVERSITI MALAYSIA SARAWAK

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(Final Year Project Supervisor)	

APPLICATION OF A DEMAND CONTROL VENTILATION AT CITDS BUILDING FOR ENERGY SAVING AND INDOOR AIR QUALITY CONTROL

ENYLINE ANAK BUJANG

A dissertation submitted in partial fulfilment

of the requirement for the degree of

Bachelor of Engineering with (Hons)

Chemical Engineering

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2022

Dedicated to my parents, the late Mr Ahin Niee and Mdm Nyunyah Ngabek for the unconditional love, constant support and encouragement from the very first day.

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ABSTRACT

Excessive usage of heating, ventilation and air-conditioning (HVAC) systems in buildings without proper mitigation contributes to incredibly high energy consumption in buildings, while emitting outrageous amounts of greenhouse gas (GHG) to the atmosphere. Besides, the GHG emissions subsequently promote adverse health effects on human being. On the other hand, the building occupants would be badly affected due to poor indoor air quality (IAQ), and the excessive usage of HVAC system since it is not designed to fulfil the requirements of thermal comfort of building occupants. An office building, for example, consumes high energy due to the HVAC system, which offers the opportunity to be studied. Therefore, an office located at the Centre for Information Technology (IT) Development and Services, CITDS, UNIMAS was chosen as the case study. Demand control ventilation (DCV) system has been proposed to be applied to the existing HVAC system by utilising Carrier's HAP simulation software. Carrier HAP is well known for its great advantages, especially in designing ventilation and DCV system into the existing HVAC system either for industrial or commercial buildings. The simulation was conducted with in depth analysis in compliance with the objectives. Result shows that the application of the DCV system feasibly reduced precisely 42.81% of the overall energy consumption and GHG emissions to the atmosphere whilst complying with the recommended limit set by ANSI/ASHRAE Standard 62 for indoor air quality control. In this regard, the DCV system application is efficiently designed for the CITDS building HVAC system. Correspondingly, it is discovered that optimum thermal comfort is obtained while simultaneously satisfying the recommended range and limit recommended by MS:1525.

Keywords: *Demand control ventilation (DCV), indoor air quality (IAQ), thermal comfort, Carrier's HAP, CITDS UNIMAS.*

ABSTRAK

Penggunaan sistem HVAC yang berlebihan di dalam sesebuah bangunan tanpa pelan mitigasi yang bersesuaian telah menyumbang kepada penggunaan tenaga yang sangat tinggi dalam sesebuah bangunan tersebut, pada masa yang sama turut mengeluarkan sejumlah gas rumah hijau (GHG) yang besar ke udara. Selain itu, pelepasan GHG kemudiannya menggalakkan kesan kesihatan yang buruk terhadap manusia. Sebaliknya, penghuni bangunan akan terjejas teruk kerana kualiti udara dalaman (IAQ) yang rendah serta penggunaan sistem HVAC yang berlebihan kerana ia tidak dirancang untuk memenuhi keperluan keselesaan haba penghuni bangunan. Bangunan pejabat contohnya, menggunakan tenaga yang tinggi kerana sistem HVAC, telah menawarkan peluang untuk dikaji. Oleh itu, sebuah pejabat yang terletak di Pusat Pembangunan dan Perkhidmatan Teknologi Maklumat, CITDS, UNIMAS telah dipilih sebagai skop kajian. Sistem pengudaraan kawalan permintaan (DCV) telah dicadangkan untuk digunakan pada sistem HVAC yang sedia ada dengan menggunakan perisian simulasi Carrier's HAP. Carrier HAP terkenal dengan kelebihannya yang mampu mereka bentuk pengudaraan dan sistem DCV ke dalam sistem HVAC sedia ada, sama ada untuk bangunan perindustrian ataupun komersial. Simulasi ini dijalankan dengan analisis yang mendalam demi mematuhi objektif kajian. Keputusan menunjukkan bahawa penggunaan sistem DCV telah berjaya menurunkan sebanyak 42.81% kesuluruhan penggunaan tenaga elektrik serta pelepasan GHG ke atmosfera sambil mematuhi had yang ditetapkan oleh ANSI/ASHRAE Standard 62 untuk kawalan kualiti udara dalaman. Dalam hal ini, aplikasi sistem DCV direka dengan cekap untuk sistem HVAC bangunan CITDS. Sehubungan dengan itu, didapati bahawa keselesaan haba optimum diperolehi dan pada masa yang sama berjaya memenuhi julat dan had yang disyorkan oleh MS:1525.

Kata kunci: *pengudaraan kawalan permintaan (DCV), kualiti udara dalaman (IAQ), keselesaan haba, Carrier's HAP, CITDS UNIMAS.*

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ABBREVIATIONS

AHU	-	Air Handling Units
ANSI	-	American National Standards Institute
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAV	-	Constant Air Volume
CITDS	-	Centre for IT Development and Services
COPD	-	Chronic Obstructive Pulmonary Disease
COVID-19	-	Coronavirus Disease 2019
DCV	-	Demand Control Ventilation
EN	-	European Standards
ETS	-	Environmental Tobacco Smoke
GHG	-	Greenhouse Gases
GWP	-	Global Warming Potential
HAP	-	Hourly Analysis Program
HVAC	-	Heating, ventilation and air conditioning
IAQ	-	Indoor Air Quality
IEQ	-	Indoor Environmental Quality
ISO	-	International Organization for Standards
IT	-	Information Technology
LEED	-	Leadership in Energy and Environmental Design
ML	-	Machine Learning model
MLP	-	Multilayer Perceptron
MS	-	Malaysian Standards
OA	-	Outdoor Air
PC	-	Personal Computers
PM	-	Particulate Matter
R&D	-	Research and Development
RH	-	Relative Humidity
SBS	-	Sick Building Syndrome
SEB	-	Sarawak Energy Berhad
UNIMAS	-	Universiti Malaysia Sarawak

US	-	United States
VAV	-	Variable Air Volume
VOCs	-	Volatile Organic Compounds
VRF	-	Variable Refrigerant Flow

NOMENCLATURES

%	-	percentage
°C	-	Degree celcius
cfm	-	Cubic feet per minute (airflow)
mg/m^3	-	Milligram per cubic metre
Bq/m^3	-	Becquerel per cubic metre
L/s	-	Litre per second (airflow)
W	-	Watts
kWh	-	Kilo Watt hour
RM	-	Ringgit Malaysia
ppm	-	Parts per million
kg/m^2	-	Kilogram per squared metre
m	-	Metre
m^2	-	Squared metre
TWh	-	Terawatt hours
As	-	Arsenic
Cd	-	Cadmium
CH_4	-	Methane
CO_2	-	Carbon Dioxide
CFC	-	Chlorofluorocarbon gases
Cr	-	Chromium
Cu	-	Copper
Fe	-	Iron
HFCs	-	Hydrofluorocarbon gases
Hg	-	Mercury
Mn	-	Manganese
N_2O	-	Nitrous Oxide
NF_3	-	Nitrogen trifluoride
Ni	-	Nickel
NO_2	-	Nitrogen Dioxide
O_3	-	Ozone
Pb	-	Lead

PFCs	-	Perfluorocarbon gases
Rn	-	Radon
SF_6	-	Sulphur hexafluoride
SO_2	-	Sulphur dioxide
Zn	-	Zinc

CHAPTER 1

INTRODUCTION

1.1 Research Background

Rapid urbanization following the significant growth and development in the third world countries and developed countries all around the world has increased environmental concerns such as global warming, climate change, ozone layer depletion, and air pollution. It is common knowledge that air pollution is harmful to human health. This is mainly due to various pollutants being discharged into the ambient air, leading to both outdoor and indoor pollution. One of the fundamental necessities for human health and fitness is respiring clean air. Although distinctive cleaner technologies have been established in industries, energy production and transport, air pollution issue continues to become a major health risk. The air pollution issues exhibit a pessimistic impact on human health for over 40 years which concerns the World Health Organization (World Health Organization, 2000).

Tsui (2020) explains that although air quality has improved significantly for the past 50 years, it persists as one of the environmental concerns in massive population cities. Air pollution is contributed by various reasons ranging from human activities such as industrial activities and motor vehicles to natural occurrences like bush fires. By all means, this environmental issue affects health in a broad range when being exposed to it. Regardless of the fact that outdoor pollution remains distressed, Harrison (1997) has acknowledged in his study that there has been an increasing recognition that indoor air pollution may bring greater if not similar implications towards human health. Substantially, indoor air pollution can present as much or greater risk as outdoor pollution. Many contributing factors that lead to indoor air pollution and one of them is the outdoor air that enters a building. Indoor activities such as cooking and cleaning contributes just as much pollutants to Indoor Air Quality (IAQ).

In recent years, following the inevitable outbreak of the COVID-19 pandemic, people have spent most of their time indoors. In fact, about 60% to 90% of their time is spent in various indoor environments or institutional buildings, according to a study by Al-Jeelani (2017), even way before the pandemic hits the entire world. It has been proven that poor indoor air quality may lead to various health problems occurring either in the short period of time or long period of time. Health problems, along with allergic reactions, respiratory problems, eye irritation, sinusitis, bronchitis and pneumonia are frequently associated with poor indoor air quality (IAQ, 2010). Therefore, it is critical to ensure that the IAQ is as clean as possible since it is an essential factor in occupant comfort and health, considering that most of time is spent indoors (Elbayoumi et al, 2018). On that account, it is fittingly appropriate to the main focus of research to control the indoor air quality by implementing a proper ventilation system such as demand control ventilation (DCV) that also helps in energy improvement as well as greenhouse gases (GHG) emissions reduction.

Bednarova (2016) stated that although the idea regarding ventilation and air quality were connected back in ancient time which further associates ventilation and health from as early as possible, there was no particular point in time as to when ventilation system was invented or utilized solely for ventilation purposes. Back in 1660, the word ‘ventilation’ originates from the Latin word, ‘ventilatio’ which means wind, which allegedly implied as a process to replace poor air in a confined space with fresh and clean air. According to Bednarova, David Boswell Reid was one of the most important and outstanding figures throughout the historical development of the ventilation system during the 1800s. He particularly specialized in the fire-driven technology up to near perfection and contributorily brought ventilation in entering the era of machines with steam-driven fans and systems similar to the current technologies. Bednarova (2016) also mentioned that Reid has come to a realization concerning the importance of the reciprocation amongst ventilation, indoor environment, and the building designs back in the days.

Ventilation allows outdoor air to enter and disseminates the air accordingly inside the building. Atkinson et al. (2009) explained that the main aim of ventilation within buildings is to supply healthy air for respiration by diluting the pollutants generated indoors and removing the pollutants outside. The ventilation rate, airflow direction and air dispersion are three essential factors of building ventilation. Poor indoor air quality results from good for nothing the inadequacy of proper ventilation rates. According to a study by Apte (2006), poor indoor air quality is closely related to insufficient ventilation rates, leading to various health problems that are generally recognized as sick building syndrome (SBS) aside from causing discomfort and well-being. Numerous researches have proven that lower rates of sick leaves are result from higher ventilation rates in commercial buildings, according to Apte (2006). Hence, proper ventilation is essential in order to remove any airborne pollutants generated by various activities from both indoor and outdoor sources.

As important as ventilation system for buildings, too much or too little of anything is good for nothing. For instance, over ventilated buildings may bring little to no leverage to the occupants aside from energy wastage, whereas under-ventilated buildings may adversely affect the occupant (Apte, 2006). Among all the available technical approaches in today's market, DCV is the most suitable strategy for matching building ventilation rates to their occupancy. The reason for this is that DCV allows the system to control the airflow of outdoor air intake into the buildings accordingly based on the number of occupants demand, and at the same time, reduce fan energy consumption. DCV is designed on the basis of minimum per-occupant outdoor air intake rates simultaneously with the varying occupancy rates whilst supplying sufficient ventilation of occupied spaces as well as minimising the energy usage in thermal conditioning. In short, the primary goal of this research is to thoroughly study the application of DCV by studying the data and its efficacy through a simulation program called Carrier's Hourly Analysis Program (HAP) software.

1.2 Research Problems

Indoor air pollution that has been elaborately explained previously, may promote the dispersion of biological risk factors and cause thermohydrometric alterations within the confined space in buildings as mentioned by Balocco and Leoncini (2020). Therefore, it has become a top priority to prevent health risks issues caused by indoor environment pollution that it is necessary to advocate for the engagement of various efficient subjects and extensive approach in assessing indoor pollution, sustainability as well as the quality of indoor environments, especially for those that spends most time indoors such as office buildings (Balocco & Leoncini, 2020). Furthermore, multiple studies in Malaysia in regard to the IAQ, thermal comfort and SBS documented that this has been a common issue for buildings in Malaysia. However, there is no establishment on the obligatory regulations on IAQ for office buildings until this very day. Conversely, regulations and standards were set throughout the last 10 years only for industrial building (Elbayoumi et al., 2018).

The rising population and development across the globe evidently led to an increase in energy demands, with construction sector as the major contributor to energy consumption. Thus, growing demand for housings as well as commercial buildings that is followed by an increase in energy demands exist as repercussions (Hassan et al., 2014). The energy consumption by buildings in Malaysia accounts for a rough total of 48% of the electricity being generated in the country, as mentioned by Hassan et al. (2014), thus rising an issue of apprehension over greenhouse gas emissions and carbon dioxide. According to ASI Controls (2014), the main contributors to high consumption of energy are lighting in addition to heating, ventilation, and air conditioning (HVAC) as such that 35% average of total building energy is consumed by HVAC system whereas about 11% of energy are utilized by lighting. Since these factors are all very crucial in ensuring a productive building environment to the occupants, it is essential to comprehend building efficiency designs as well as the methods that could be implemented in order to reduce energy consumption within the building (Quadrennial Technology Review, 2015). Nevertheless, the amount of energy consumed within a building varies depending on various factors such as mechanical equipment and lighting.

In a study by Domínguez et al. (2012), high air renewal rates with distinct filtration stages and constant flow are required to meet the current standards for indoor air quality in buildings. In conjunction, Ismail et al. (2010) has made significant discovery showing that 77% of the indoor air quality problems arises from insufficient ventilation supply into the facility in opposition to the number of air changes rate per occupant range 20 cfm per person. Moreover, thermal discomfort and moisture issues are risks that may occur indoor due to high humidity and high temperatures experienced within the building (Ismail et al., 2010). On the other hand, as claimed by Balocci and Leoncini (2020), current research discovered that existing office buildings consumes much higher energy compared to the recently constructed buildings. This may be due to the fact that the former buildings were not designed by considering the correct and appropriate ventilation system. Moreover, there are still limited literature that focuses on the application of DCV in an office building in terms of energy efficiency and reduction of GHG emissions. Additionally, insufficient studies are available to examine the DCV in building HVAC system to improve IAQ and at the same time reduce energy consumption. Hence, a substantial principle of demand control is used to conserve energy and improve indoor air quality control in this particular research. The application of DCV requires further investigation in order to design a suitable DCV in an office building.

1.3 Research Questions

In light of the problem statements mentioned above, the research structure concentrates on the application of the DCV system implemented in an office building for the purpose of energy saving and air quality control, whereupon has bring forth the following research questions.

i) How does the application of DCV help to improve energy efficiency and reduce GHG emissions?
ii) How does DCV impact the ventilation rate of the HVAC system?
iii) How does DCV impact the thermal comfort of occupants?

1.4 Aim and Objectives

On the basis of the research questions aforementioned, the main aim of this study is to study the application of demand control in an office building for energy saving and indoor air quality control by using a software called the Hourly Analysis Program (HAP) by Carrier. Thus, several objectives are identified and stated in the following in order to achieve the aim of this study.

i) To investigate the application of demand control ventilation for IAQ control, energy efficiency improvement, and GHG emissions reduction.
ii) To design demand control ventilation application for building HVAC system.
iii) To analyse the thermal comfort impact from the utilization of demand control ventilation.

1.5 Scope of Study

The scope of the research is to design and simulate the demand control ventilation by using a software called the Carrier HAP, created by Carrier Global Corporation. The