CHAPTER 1

INTRODUCTION

1.1 Background

According to the hot and humid conditions in Malaysia, energy required by an air conditioning system for space cooling in the commercial sector accounted up to 40% of the total energy demand [1]. Since the system consumes a lot of energy, it also contributes in releasing quite a lot of carbon dioxide (CO_2) emission. With decreasing trend of heating and increasing trend of cooling in the future [2], energy saving become one of recent research topics and the direction of air conditioning in the future. New air-conditioning techniques which will increase indoor air quality and reduce the energy consumed need to be improved and proposed as soon as possible [3]. Related to this matter, the government of Malaysia has also been implementing energy efficient program which was expected to achieve energy cost saving as much as RM76 million and lower CO_2 emission [4, 5], that is in line with European Union's most economical policy of achieving CO_2 reduction [6]. Nowadays, energy efficient system become an essential ingredients for the successful of future development and operation of net zero (NZEB) and positive energy buildings (PEB) [7].

Heating, ventilating, and air conditioning (HVAC) system using variable air volume (VAV) is widely used in many commercial buildings because of its ability to self-balance the air system according to space cooling load fluctuation. Current development of the system focused on how to get optimal control of indoor thermal environment, how to reduce energy consumption and how to get better indoor air quality [2].

In order to get optimal indoor thermal environment, researchers developed a control system using genetic algorithm, neural network, fuzzy logic or combination of it. The control system would modulate some parameters to its optimum set point according to space cooling load which fluctuates due to dynamic changing of outdoor conditions and occupancy pattern. As a result, the system minimizes cooling/heating load, while maintaining indoor thermal comfort within thermal comfort range [8,9,10]. A tool to optimize multi objectives in building design has also been developed in [11]. The tool integrated genetic algorithm and artificial neural network to get advantage of passive design and to find optimum range of parameters set points in an HVAC system. The simulation results showed that the tool was robust to find the optimum values under various conditions. However, these optimization control could not overcome negative effect from any mistake occurred at the design stage and the limitation of the mechanical HVAC system.

Efforts to reduce internal/external cooling load have also been addressed by researchers. The work focused on reducing major heat gains in an air-conditioning space. In hot and humid areas, the major heat gain was from building envelope as a result from temperature difference between indoor and outdoor environment and intensity of solar radiation [12, 13]. Previous research [14] showed that building insulation could reduce the chiller power consumption up to 30% and total mass flow rate for the air handling unit (AHU) up to 33.8%. The insulation reduced major heat gain from building envelope because of higher thermal resistance which reduced heat transfer from outdoor to indoor environment through the insulated walls and vice versa. The insulation also reduced initial cost of VAV air conditioning system by 22% and operation cost by 25%. Polyurethane insulation on lightweight roofing structures with white-painted color could also add 20% space cooling load reduction [15].

Thermal mass and night-time ventilation were other strategies to reduce major heat gain from building envelope and solar radiation. Appropriate selection of external material with time constant of 400 hours would give as much as more than 60% cooling load reduction. The material selected would store heat from outdoor condition and solar radiation during the day and release the stored heat at night using night-time ventilation. It should be noted that material with time constant more than 1000 h would slightly increase the cooling load due to fact that night-time ventilation was not enough to remove all the heat stored in the material selected and thus, the heat would add to the cooling load in the following day [16]. Even though this strategy could greatly reduce the cooling load, it required huge investment on the material used for the external wall and made it not convenient in future re-layout.

Adaptive comfort studies found that adaptive comfort temperature (ACT) directly relates to outdoor conditions [17]. When the occupants are allowed to do behavioral adaptation to their environment, ACT were found to be higher than recommended value for both air-conditioned (AC) and naturally ventilated (NV) buildings [18-20]. Another research [21] found that an adaptive increment of 1.9^{o}C in neutral temperature could be achieved by allowing adaptation process from the occupant. This increment offers potential energy savings for any indoor cooling or heating system. Recent work on application of ACT showed that the use of the temperature results in energy saving as compared to fixed-set point, without increasing discomfort to the occupants [18-20, 22]. However, the applications of ACT for both AC and NV buildings as indoor temperature set points during occupied and unoccupied periods in an academic building are not investigated on the previous work.

Nowadays, more buildings are built with large glazing areas. Even though glazed area would reduce electricity bill from artificial lighting, it brings a lot of direct solar radiation that in turn burden the HVAC system. Therefore, appropriate arrangement and portion of glazed window area to get energy saving while maintaining connection between occupant and outdoor environment becomes important. A result from simulation work that has been done by Stegou-Sagia et al. [23] to address this issue showed that glazing material and construction selection on early design stage directly affects the energy consumption.

Davis and Nutter [24] found that the occupancy pattern differ from that in many offices and residential buildings. Since cooling load in these buildings is mostly driven by the occupancy pattern, the difference would result in different cooling load characteristics. In office or residential building, the room is usually occupied during cooling period even though the number of occupants may be changing over the period [12,25]. In a university, there are occupied and unoccupied hours during cooling period [26]. Due to this, during cooling period, the cooling load type is likely to be continuous load for office or residential buildings and intermittent load for a university. The types of rooms are also found to be more divergent in a university than that in an office or a residential building [27].

A current problem in centralized HVAC system in hot and humid area like Malaysia is to maintain indoor humidity within desired comfort range. In most of the cases, the HVAC system would be controlled by space sensible load through space temperature sensors. With this practice, it was found that there was a condition where space humidity level exceeds the set points even though the HVAC system was designed by considering both space latent and sensible load [28]. An alternative to maintain space temperature and humidity was by individually handle latent and sensible cooling load. The humid air was dehumidified using desiccant materials or dedicated outside air system before it enters to the space to remove the sensible heat [29]. However, complexity of the system becomes barriers for wider application.

For large or complex buildings, it would be unrealistic to expect that energy-efficient designs or any improved design could be done without the support of a computer-aided detailed building simulation program. Manual calculations using pre-selected design conditions had frequently led to oversize plant and poor energy system performance especially at part load conditions. Nowadays, Building simulation programs allowed engineers and designers to test their new/modified system to see the performance and characteristic before proceeding to construction and installation. Parametric analysis on the simulated results was important further works to extend the proposed design/system concept using new findings and innovation. It should be highlighted that analyzing annual building energy demand profile and the part load performance of major energy-consuming equipments should be done prior to realize energy-effcient building design [30].

1.2 Problem Statements

In hot and humid area, the energy consumption for cooling system is increasing year by year and thus, requires strategies or technique to reduce it without sacrificing people’s comfort. Typical centralized HVAC systems in most academic buildings use temperature control to maintain indoor thermal comfort which means that the system merely control the space sensible load. With this practice, the indoor relative humidity cannot be well maintained at the set point. Moreover, pre-determined supply air conditions are not always suitable for efficient cooling/heating, especially at part load conditions in an academic building. It results in inefficient cooling/heating process and poor performance at part load conditions. It should be highlighted that part load conditions in an academic building is significantly different from the design value of the centralized HVAC system due to the occupancy pattern. Therefore, a cooling/heating control technique is required to efficiently and effectively handle cooling/heating load in the academic building in order to maintain indoor thermal comfort with minimum energy consumption.

1.3 Objectives

The main objective of this research was to reduce energy consumption from VAV-HVAC system in an academic building (Academic block 16 of Universiti Teknologi PETRONAS) by developing an effective, efficient and economical adaptive cooling technique coupled with dual fan dual duct system.

1.4 Scope of Work

This research is a simulation based work which would be done on an academic block in Universiti Teknologi PETRONAS and limited to academic bloc 16. Local weather conditions, VAV system and control, indoor cooling load, outdoor cooling load, building construction, and building orientation were considered. The work analyzes the cooling load of the centralized VAV-HVAC system according to the building's indoor and outdoor environment. The building model and its HVAC system were first built using a building simulation program (BPS), TRNSYS and validated by comparing the simulation results with experimental results. Strategies to reduce the cooling load were focused on the secondary system of the VAV-HVAC system and it is developed by using adaptive comfort temperature and dual fan dual duct system. The validated model was then used to analyze the performance of the HVAC system using current strategies and proposed technique. At the end of the work, an economic analysis was performed to find out the economic visibility of the proposed techniques.

1.5 Thesis Arrangement

This thesis consists of five chapters: introduction, literature review, methodology, results and discussions, and conclusions. Summary of each chapters were described as below:

Chapter 1 describes background, problem statements, and objectives of the work including recent researches in HVAC system. Current problems and recent strategies in HVAC system were also outlined.

Chapter 2 describes fundamentals of HVAC system and recent research about techniques or strategies to effectively reduce cooling load in HVAC system. Current researches on adaptive comfort temperature and Malaysian standard are also presented in this chapter.

Chapter 3 describes methodology to achieved objective as stated in chapter 1. Building modeling, VAV-HVAC system simulation, experimental measurements, and development of adaptive cooling technique were briefly described in this chapter. In addition, theoretical backgrounds of space cooling load calculations were also explained.

Chapter 4 presents and discusses the validation process and dynamic simulation results using current and adaptive cooling technique with dual supply ducting. The effect of occupancy patterns and various RSHF value on the HVAC system performance were also discussed. At the end of this chapter, energy and cost saving of adaptive cooling technique were analyzed.

Chapter 5 presents the concluding results of the works and the direction for further studies. Related publications regarding to the work are also listed.