CONTROL OF AIR-CONDITIONING SYSTEM FOR LOAD MANAGEMENT

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DEDICATION

This thesis is dedicated to:

My father, Haji Ahmad Bin Sahuri, who taught me that the best kind of knowledge to have is that which is learned for its own sake.

My mother, Hajjah Hasnah Bte Shud, who taught me that even the largest task can be accomplished if it is done one step at a time.

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My family, for their patience, support, love and prayers

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ABSTRACT

The cooling system is one of the major and critical energy consuming loads in any premise. Efficient energy management of this critical load is important to achieve economic operation. Controlling the air conditioning (AC) system allows to reduce the peak consumption, indirectly the electricity bills. Due to privacy concerns, users' participation and limitation of AC's program interfaces is major obstacles in load management. In order to maintain the indoor comfort level and working efficiency, the users' temperature set point is controlled by an adaptive control algorithm. Changing the AC's temperature set-point into multiple time slot show the significant potential in electricity savings. Simulation model using PID controller based on load profile of ACs' installed at Jabatan Penyiaran Negeri Johor will be conducted to determine the effectiveness of proposed control strategy. Then, field measurement is done based on group of AC's unit and individual by setting its temperature set-point and operation time without any changes in comfort level. Both simulation and field measurement results show significantly peak load reduction of 56% which lead to lowering the overall electricity bill of premises.

ABSTRAK

Sistem penyejukan adalah salah satu beban utama dan kritikal dalam mana-mana premis. Pengurusan tenaga yang cekap untuk beban kritikal ini penting untuk mencapai operasi ekonomi. Mengawal sistem penyaman udara (AC) membolehkan mengurangkan penggunaan puncak, secara tidak langsung bil elektrik. Disebabkan kebimbangan privasi, penyertaan pengguna dan had antara muka program AC adalah halangan utama dalam pengurusan beban. Bagi mengekalkan tahap keselesaan dalam bilik dan kecekapan kerja, tetapan suhu oleh pengguna boleh dikawal oleh satu algoritma kawalan penyesuaian. Mengubah tetapan suhu dan menghidupkan / matikan AC ke dalam slot kawalan masa dapat menunjukkan potensi yang ketara dalam penjimatan elektrik. Model simulasi menggunakan pengawal PID berdasarkan profil beban AC yang dipasang di Jabatan Penyiaran Negeri Johor akan dijalankan untuk menentukan keberkesanan strategi kawalan yang dicadangkan. Kemudian, pengukuran lapangan dilakukan berdasarkan kumpulan unit dan individu AC dengan menetapkan suhu tetapan dan masa pengoperasian tanpa sebarang perubahan dalam tahap keselesaan. Kedua-dua hasilan pengukuran lapangan dan simulasi menunjukkan pengurangan beban puncak yang ketara sebanyak 56% yang membawa penurunan kepada keseluruhan bil elektrik sesebuah premis.

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LIST OF ABBREVIATIONS

AC	-	Air-Conditioning
DB	-	Distribution Board
DSM	-	Demand Side Management
HP		Horsepower of AC Conditioning
PID	-	Proportional, Integral and Derivative
RTM	-	Radio Televisyen Malaysia

LIST OF SYMBOLS

θ_{user}	-	Initial AC set-point temperature by user
$\theta_{setpoint}$	-	In-control set-point temperature
θ_{new}	-	New set-point temperature
θ_{max}	-	Maximum set-point temperature

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CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

Demand Side Management (DSM) is the modification of consumer's demand of electricity through various methods such as financial incentives and consumer education. The goal of DSM is to encourage the consumers to use less energy during peak hours or to move the time of energy use to the off-peak hours or night time. Many ways to achieve the load shape objective to reduce the total power consumption by consumers as shown in Figure 1.1. The most popular approach in reducing the demands are peak clipping (peak shaving) application for premises which have shorter working hours. Whereas, conservation and load shifting approach is applicable to premises operated 24 hours daily. Many researchers have proposed peak shaving application in their load management strategies [1]–[3], [7] while [4] proposed the load shifting purposes.

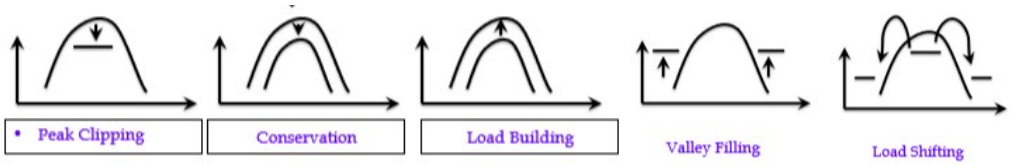

Figure 1.1 Different type of load shape objective

Many premises or buildings especially in big city installed large amount of air conditioning unit either in package unit or individual unit. There are many types of AC unit produced by manufacturers to fit the purposes of functional of premises or building in offering the thermal comfort to whom occupied the offices, spaces and rooms. Spaces like Auditorium require a package water-chiller cooling system to provide desired level of comfort to audiences, where as rooms or offices require one

or more individual air-conditioning (AC) unit either split, cassette or fan-coil type depending on their size, application and functionality.

Due to this, the specification of AC is depended on the area of coverage need to be covered. One of most popular parameters need to be considered is BTU (British Thermal Unit) rating, which indicates the amount of heat it can remove from a room. The air conditioner EER is its British thermal units (BTU) rating over its wattage. For example, if a 10,000-BTU air conditioner consumes 1,200 watts, its rating is 8.3 (10,000 BTU/1,200 watts). The higher the BTU rating is, the more efficient the air conditioning unit is. Besides that, horsepower (HP) also is among the most popular parameter in which measuring the power consumed by AC unit. Converting to wattage unit is a matter of multiplying by a conversion factor where one HP is equal to 745.7 watts, and one kilowatt equals 1.337 HP. The higher the HP rating is the higher the power consumption.

Imagine that, the large number of AC units installed in premises will increase the power consumption as well as the load demand. If the load is not managed properly, the generation needs to be expanded that will increase the cost to utilities, indirectly the energy (electricity) cost will also increase. It will burden the consumers. The loads need to be controlling to overcome the shortage of demand.

The AC unit is a machine operated on the vapor compression cycle. It consists of an evaporator, a condenser, a compressor and an expansion valve. Conventionally, when the indoor temperature is higher than the set point, the compressor turns on; otherwise it turns off. The on/off operation not only consume significant power, but also causes large variations in indoor temperature. Thus, an adaptive control system to AC units need to be developed and designed based on simulation and field measurement.

MathWorks MATLAB is an applicable software in various aspects of engineering such as Electrical engineering and its different sub majors. There are a lot of examples and demos on these majors, although there is a few text or example on MATLAB application in energy management. In this project, I have provided a

simulation model of set-point temperature control algorithm for air-conditioning unit using MATLAB® Simulink software.

1.2 Motivation of Study

The purpose of this study is to investigate the simulation of MATLAB® Simulink in modelling control system for air-conditioning (AC) unit and develop an adaptive control algorithm based on simulation model. Temperature control method was used as the benchmark for the proposed algorithm. A PID controller based on power consumption of AC's installed in Jabatan Penyiaran Negeri Johor as in Table 1.1 has been proposed in this study to reduce the energy consumption of each AC unit.

The effect of changing the AC's temperature set-point into multiple time slots was studied and the effectiveness and shortcomings of control strategy were highlighted. Results were compared between actual load profile and benchmark temperature control method. It was discovered that with different load characteristic, in most cases, temperature control method performs effectively in contribution of peak load reduction of each AC.

Table 1.1 : Load (AC unit) Information at Jabatan Penyiaran Negeri Johor

Model No.	Quantity	Energy Consumption (W)	Operation hours	Total Consumption (W)
YORK/YWM20G-AMLBF	14	1793	9	225,918.00
YORK/YWM15G-AMLBF	17	1201	9	183,753.00
YORK/YCC25C-AMSLA	7	2060	24	346,080.00
ACSON A5WM25S	4	2140	24	205,440.00
YORK/YCK20AL-AFAB	6	2071	9	111,834.00
ACSON A5CK30F-AMOIA-R	1	2568	9	23,112.00
Grand Total	**49**			**1,096,137.00**

1.3 Problem Statement

Air-conditioning (AC) systems are one of the major consumers of energy and have significant influence on the overall energy usage of homes and buildings. Thus, controlling the energy consumption of ACs can lead to a significant energy savings for an entire electricity system and enormous impact of ACs on the overall energy consumption of buildings. Studying the energy consumption behavior and developing means for effective control without compromising users' comfort have become a central focal point of energy management research. Air conditioning units that can be controlled remotely and the customers can purchase such units that subsidies from the utilities company. The approach where the utilities can turn off the air conditioners through network for about 10 to 15 min each time when it needs to shed the loads. However, it is inconvenient to both the customers and the utilities company. Each customer does not know when the air conditioner is going to be turned off. For the utilities company, controlling hundreds of small air conditioner loads is neither effective nor efficient. Thus, this project is proposed with an approached a simulation model of control strategy to changing the AC's temperature set-point and switching on/off into multiple time slot show the significant potential in electricity savings.

1.4 Project Objectives

The objectives of this project have been identified and it should be achieved to produce a successful simulation system for air-conditioning temperature control system. The objectives of this project are as follows:

(a) To design of temperature control strategy using PID controller on MATLAB® Simulink.

(b) To determine the effectiveness of the proposed control algorithm in peak shaving application

(c) To *validate* the proposed method based on field testing for peak load reduction

1.5 Project Scope

In achieving the objectives of the project, the scope is required to assist and set milestone and direction of the project development. These scopes should be identified and planned appropriately, which are:

(a) Perform load research on total power consumption to shape the real-time load curve on daily energy consumption at Jabatan Penyiaran Negeri Johor (RTM).

(b) Study the load shape of power consumption of AC unit installed in offices and rooms at Studio Block based on user set-point temperature.

(c) Model the algorithm for temperature control using PID controller to meet new set-point temperature.

(d) Use MATLAB® Simulink to simulate load characteristics for AC unit of 1.0HP, 2.0HP and 2.5HP type of related to temperature control system.

(e) Perform field test to verify the load characteristics for individual and group of AC units using proposed control strategy.

(f) Validate the simulation results with field measurement to show the effectiveness of control strategy for verification of peak load reduction.

1.6 Project Report Outline

This project report presented in five chapters which is beginning with Introduction (Chapter 1), Literature Review (Chapter 2), Methodology (Chapter 3), Result and Discussions (Chapter 4) and Conclusion (Chapter 5). Chapter 1 will give an introduction of project contains project's background, motivation of study, problem statement, objectives and scopes.

Chapter 2 focuses on literature review of various control method in demand side management as well as their advantages in reducing power consumption.

Studying in each limitation presented by past researchers, the gap is laid out to propose new control strategy based on selected pilot papers.

The methodology involved in completing this project was designated in Chapter 3. The determination of the proposed control strategy based on load research and the development of control model in MathWorks MATLAB are briefly explained. Then, the develop model are tested for verification on effectiveness of control system.

Chapter 4 provides the discussion on the results obtained from simulation and field measurement. The developed model will run on simulation and validate with field test to access the performance and effectiveness of the proposed control system.

In last chapter, the project outcomes are concluded, and recommendation of future works are stated.

1.7 Chapter Summary

As summary, this chapter briefly discussed about the DSM and its application, and the AC load and its control in which provided the motivation to overcome problem stated to meet the objectives based on scopes presented in next the following chapter.

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