

A comparison of the electrical energy consumption of commercial refrigerated cabinets using temperature control by a microcontroller and thermostat

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ABSTRACT: The objective of this research was to compare the electrical energy consumption of commercial refrigerated cabinets using temperature control by utilising a microcontroller and thermostat. Four experiments were conducted. Firstly, commercial refrigerated cabinets were tested when the temperature was controlled by the microcontroller and thermostat in usual conditions without products in the cabinet and with the cabinet's door closed. Secondly, commercial refrigerated cabinets were tested when the temperatures were controlled by the microcontroller and thermostat in usual conditions without the products inside but with the door open. Thirdly, commercial refrigerated cabinets were tested when the temperature was controlled by the microcontroller and thermostat in usual conditions with the products inside but the door closed. Fourthly, commercial refrigerated cabinets were tested when the temperature was controlled by the microcontroller and thermostat in usual conditions with products inside and the door opened. In the experiments, the temperatures were adjusted to 4° C and 12° C. It was found that all four cases resulted in reduced electrical energy usage and costs, with the fourth case being the most beneficial.

INTRODUCTION

According to a survey of electrical energy consumption in the Thai household, business and industrial sectors, it was found that for first nine months in 2005, energy consumption was at 90,854 gigawatt/hour, 6.2% higher than for the previous year. The industrial sector was the highest user, being responsible for 44% of all consumption while the increase in nationwide consumption stood at 6.8% [1-3]. If the types of electrical apparatus are considered, it could be classified into two types, specifically:

- Apparatus that consumes energy at smooth levels when plugged in, eg tubes and fans;
- Apparatus that always turn on, eg air-conditioners, refrigerators and freezers.

According to the Metropolitan Electricity Authority, refrigerators are the second most energy-consuming apparatus, next to air-conditioners [4].

Refrigerators and commercial refrigerated cabinets are freezers commonly used in almost every house because a refrigerator is suitable for food storage in a small house while a commercial refrigerated cabinet is used in restaurants to store meat and drinks [5]. However, commercial refrigerated cabinets utilise vapour-compression systems that use R12 or R134a chemicals as a medium for the freezing circuit [6]. This operation depends on temperature changes inside the cabinet. When the temperature gets high, the chemicals in the metal tube expand to press the electrical circuit switch to operate the compressor. When the temperature gets low, the chemicals in the metal tube shrink to cut off the compressor's electrical circuit. Due to advances in digital systems, a microcontroller, which is an electrical device that has undergone continuous development so that its IC can process and calculate outside signals and control other devices according to set conditions.

As such, the current design and development of a microcontroller circuit could help facilitate the manufacturing of numerous products. Some makes have IC running full features and a microcontroller can be used as a processor for an electrical apparatus [7]. Hence, if a microcontroller is used to control temperature accurately and set it to operate as desired. This is one way to save on the consumption of electrical energy.

OBJECTIVES

The objective of this research was to compare the electrical energy consumption of commercial refrigerated cabinets using temperature control by way of a microcontroller and a thermostat.

HYPOTHESES

The four hypotheses, including the null hypothesis, presented in this study are listed in Table 1.

EXPECTED OUTCOMES OF THIS STUDY

The expected outcomes of this study are as follows:

- Governmental organisations, institutes, department stores, restaurants and mini-marts could apply the research results in order to conserve the energy consumption of commercial refrigerated cabinets accurately as desired by the user;
- Industrial manufacturers could use the research results to make a prototype of a modern commercial refrigerated cabinet that will effectively reduce energy consumption and at an accurate level;
- Electrical technicians could apply the research results to control other electrical devices as desired effectively and accurately.

Table 1: The four hypotheses of the study.

Ho	There is no difference in the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions
H1	There are differences in the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions without products in the cabinet and when the cabinet's door is closed
H2	There are differences in the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions without products in the cabinet and when the cabinet's door is open
H3	There are differences in the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions with products in the cabinet and when the cabinet's door is closed
H4	There are differences in the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions with products in the cabinet and when the cabinet's door is open

RESEARCH METHODOLOGY

Variables

The independent variables consisted of the following:

- Commercial refrigerated cabinets whose thermostat controls the internal temperature;
- Commercial refrigerated cabinets whose microcontroller controls the internal temperature;
- The temperature in the cabinets was fixed at 4 and 12 ±1° C to switch the circuit on and off circuit when the temperature inside the room was 30 ±1° C.

The manipulative variables were composed of the following:

- Commercial refrigerated cabinets (4 types):
 - Without products and a closed door;
 - Without products and an open door;
 - With products and a closed door;
 - With products and an open door.
- The experiment period was 10 hours long.

The dependent variable was the electrical energy consumption of the commercial refrigerated cabinet using temperature control by way of a microcontroller and thermostat. Figure 1 shows the set-up of the room used in the experiment with the placement of the commercial refrigerated cabinet.

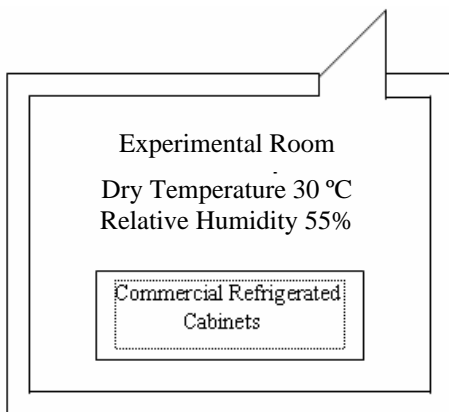
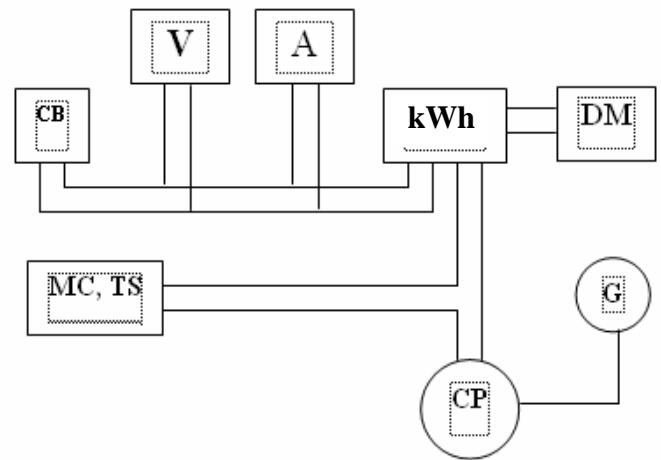


Figure 1: Set-up of the room used in the experiment with the placement of the commercial refrigerated cabinet.

The components of an electrical circuit board in commercial refrigerated cabinets are illustrated in Figure 2.



- | | |
|---------------------------|--------------------|
| CB = Circuit breaker | V = Volt meter |
| kWh = kilowatt/hour meter | A = Amp meter |
| MC = Microcontroller | DM = Digital meter |
| TS = Thermostat | G = Gauge manifold |

Figure 2: The board components of an electrical circuit in commercial refrigerated cabinets.

RESULTS OF THE STUDY

Experiment I

The use of a microcontroller to control the temperature in a commercial refrigerated cabinet could reduce electrical energy consumption to 17.48% compared to a thermostat, or 147.83 baht per month and 1,798.54 baht per year. In this experiment, there were no products and the door was closed so it was better to stop or cut off the electrical circuit in order to save on electrical energy consumption. Experiment I's results are shown in Figure 3.

Experiment II

The use of a microcontroller to control the temperature in a commercial refrigerated cabinet could reduce the electrical energy consumption to 11.81% compared to a thermostat, or 105.98 baht per month and 1,289.36 baht per year. This experiment had no products in the cabinet and the door was open, so it was not practical. It was better to stop or cut off the

electrical circuit so as to save on the consumption of electrical energy. Experiment II's results are shown in Figure 4.

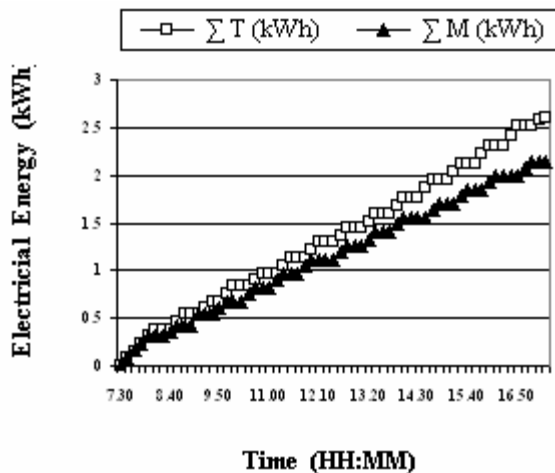


Figure 3: A comparison of the electrical energy consumption of a commercial refrigerated cabinets when the temperature is controlled by a microcontroller and thermostat in usual conditions without products in the cabinet and the door closed.

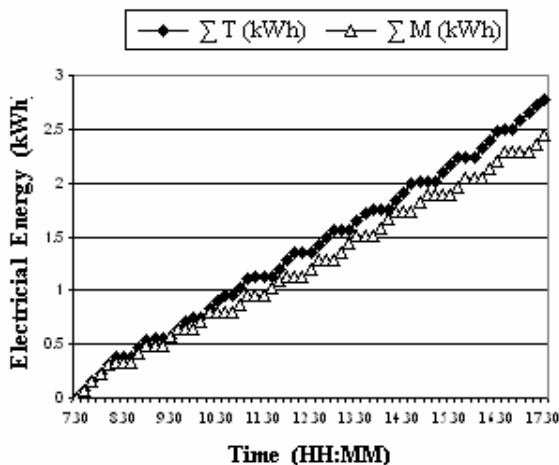


Figure 4: A comparison of the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions without the products in the cabinet and the door open.

Experiment III

Using a microcontroller so as to control the temperature in a commercial refrigerated cabinet could reduce the electrical energy consumption to 17.29% when compared to one controlled by a thermostat, or 147.42 baht per month and 1,793.61 baht per year. This experiment had products inside the refrigerated cabinet and the door was closed, so it was practical. However it was practical only at night when nobody opened the door. Experiment III's results are shown in Figure 5.

Experiment IV

Using a microcontroller to control the temperature in a commercial refrigerated cabinet could reduce the electrical energy consumption to 11.98% compared to the thermostat model, or 109.89 baht per month and 1,337 baht per year. This experiment had products and the door was open, so it was practical during daytime. Figure 6 shows Experiment IV's results.

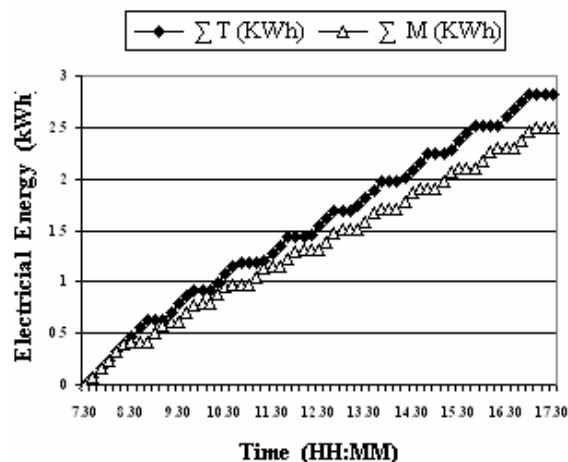


Figure 5: A comparison of the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions with products in the cabinet and the door closed.

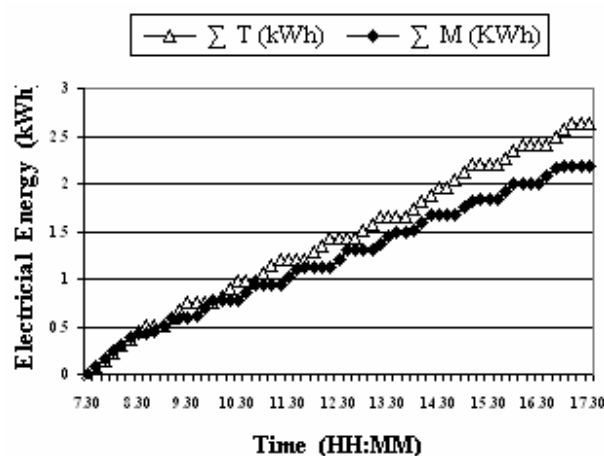


Figure 6: A comparison of the electrical energy consumption of a commercial refrigerated cabinet when the temperature is controlled by a microcontroller and thermostat in usual conditions with products in the cabinet and the door open.

DISCUSSION AND CONCLUSION

A microcontroller uses less energy to control temperature levels in commercial refrigerated cabinets due to its accuracy of transferring the temperature signal and its potential to turn the electrical circuit on and off. As for household devices, energy-consuming appliances should be taxed according to their energy consumption, ie the higher the energy usage, the higher the tax. Moreover, the researchers suggest using microcontrollers in energy-consuming appliances in order to reduce electricity consumption.

It was found that the number of times that a cabinet is opened and closed affects energy consumption since the action affects the temperature inside the cabinet. If there is nothing inside, then the temperature will increase at a faster rate. However, if there are items inside, then the items will initially retain their temperature and make the cabinet somewhat hotter. Therefore, the researchers suggest designing a cabinet with a proper size for storage.

Most stores and mini-marts prefer no-frost commercial refrigerated cabinets, which use thermostats to control the temperature. These should be replaced with microcontrollers to

control the timer switch and turn off the cabinet during peak load times (6-9 a.m. and 6-9 p.m.) so that the electricity amount meets the demands of all consumers.

Newer commercial refrigerated cabinets should be equipped with a microcontroller, especially those that are 22.4 cubic feet size. Using the results of Experiment IV, the researchers suggest that the government reduce the tax on those refrigerated cabinets that utilise less electricity but generate more power.

It was found that plain water plastic bottles use glass, foil and aluminium, along with plastic. Aluminium is the most suitable for beverages, which needs a rapid decrease in temperature, like beer and aerated water. Therefore, the researchers suggest conducting research on packaging that complies with no-frost commercial refrigerated cabinets.

SUGGESTIONS

The following suggestions are made:

- A comparison be made of the electricity consumption between microcontroller-equipped refrigerated cabinets and no-frost ones under normal condition over a whole year;
- An experimental study of microcontrollers should be undertaken to control the temperature in heat devices like iron and electrical pan;
- Research work be conducted on designing doors of an appropriate size to store food and other products inside cabinets;
- Experimental research work be carried out on temperature sensor devices that can be used with microcontrollers and

under a virtual normal state, such as the number of times that a door is opened/closed each day, as well as the behaviour of taking products in and out of the cabinet.

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