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Time-Division Multiplex of Discrete Air-conditioning Units

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Abstract

In Hong Kong, air-conditioning (a/c) is a major energy end-user in building services. Nowadays, operation modes of various a/c are uncoordinated. Hence, the diversity of this major energy usage is coarse and uncontrolled. The project shall utilize Time-Division-Multiplex (TDM) concept to regulate this. Through research effort, a better diversity of energy utilization in premises will be achieved. The peak demand of current, the sum of steady load currents and the cable heat loss will then be reduced. The cable capacity will be better utilized, and the potential of reserve in buildings will then be significantly enhanced. Beyond this study, the TDM concept can be extended to other appliances, for example, kitchen appliances and storage-type water heater. It is also envisaged that the project becomes an integral part to smart metering communication management. This shall call for a new culture to regulate the load demand pattern with a better diversity in premises.

Keywords: load diversity, Time-Division-Multiplex, electrical appliances, smart metering

1 INTRODUCTION

Air-conditioning is crucial for Hong Kong people. No matter in what season, air-conditioner is also being used in many places and building, for example, restaurants, shopping malls, offices. This is mainly because people do not like to work or live in sweltering heat. Due to the high current demand of air-conditioner, investigation into its operation mode was carried out. Through the investigation, data obtained was used for analysis. With the concept of Time-Division-Multiplex (TDM), improved schedule of operation of air-conditioner was developed. It could help to get better diversity of energy utilization.

The main goal of the project is to utilize Time-Division-Multiplex concept to regulate the operation modes and current diversity of air-conditioners. According to these data, this paper presents the methods for operating the air-conditioners in a more coordinated way. It aims at the following objectives:

(a) Develop TDM algorithm for operating general air-conditioners
(b) Utilize cable capacity in a time-sharing manner
(c) Get a better diversity of energy utilization

The study shall extend to operate other appliances, for example, kitchen appliances in similar way.

2 SET UP FOR SIMULATIONS

A demountable and convertible premise was set up in the laboratory for the simulation. Figure 1 is the floor plan of the laboratory. The apparatuses there were used to measure the temperature of the laboratory, the humidity inside the laboratory, the power and current of the air-conditioners. Manikins acted as constant power heat load or virtual human beings with constant temperature. Figure 2 shows the picture of manikins.

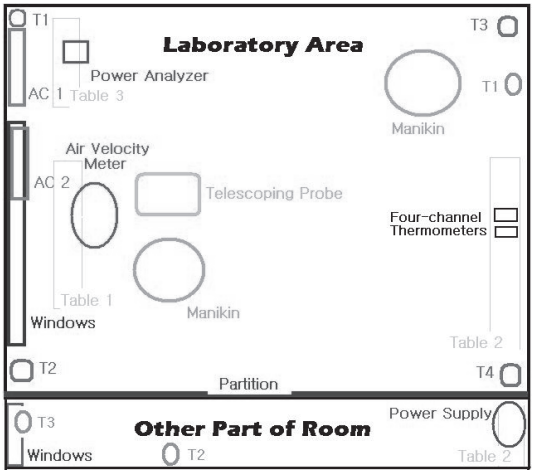

Figure1. Floor plan of laboratory

Simulations were taken place every day for six days. The data obtained included the temperature and humidity inside the laboratory, the outdoor temperature, the current and power consumption of the air-conditioner. These data were used for determining whether the temperature distribution was even inside the room, what factors affected the temperature inside the room and the operation pattern of the air-conditioners.

3 SIMULATION RESULTS

Comparison between the current, duration, power, temperature at different locations was done. According to the data measured by the power analyzer, when current was larger than zero and equaled to zero, the air-conditioner could be interpreted as in “on mode” and “stand-by mode” respectively. The duration of its mode was calculated. It was important because it represented how long and how much the air-conditioner drew current from the cable. It was used to determine how long a time slot is.

In the simulations, the manikins (shown as Figure 2) acted as virtual human beings with constant temperature or constant heat load with constant power. With reference to the data, the temperature near them was higher than when they acted as constant power heat load. Temperature there was always the highest among the middle and four corners of the laboratory area. Meanwhile, the temperature distribution of the room was much more even than that in other simulations in which the manikins were constant power heat load.

Figure 2. Manikins

4 RESULT ANALYSES

Using the data obtained and utilizing the TDM concept, several time-sharing operation schedule of air-conditioners were developed. Only one air-conditioner, which draws high power and high current, operates in one time-slot. Thus, no superposition of load currents occur and the peak demand of current will be lowered as shown in Figure 3.

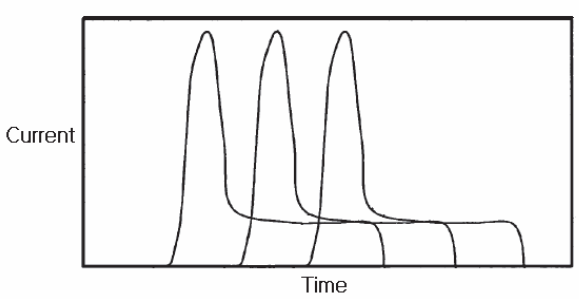

Figure 3. Current versus Time

To design an operation schedule for an air-conditioner, first thing to do is the calculations of cooling load. Using the results, number of air-conditioners and amount of BTUs per hour needed can be known.

Different number of air-conditioners have different operation schedule. There are usually other home appliances, such as washing machine and water heater, affect the operation schedule. Figure 4 – Figure 8 show different operation schedules of the air-conditioner and other home appliances.

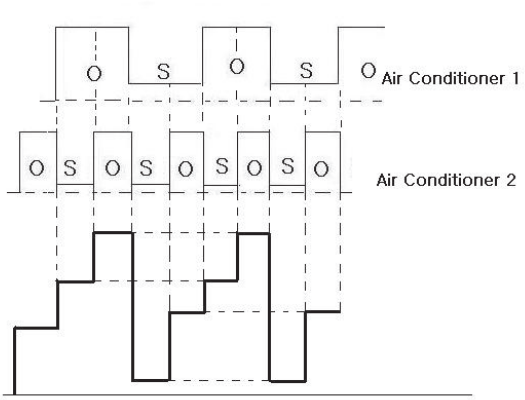

Figure 4. Operation Schedules

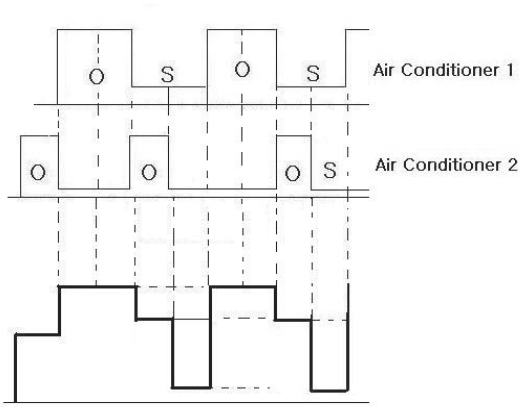

Figure 5. Operation Schedules

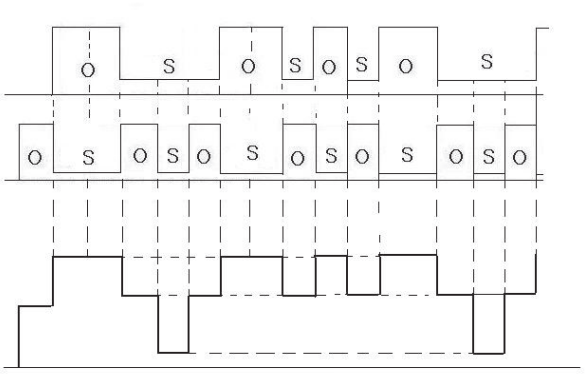

Figure 6. Operation Schedules

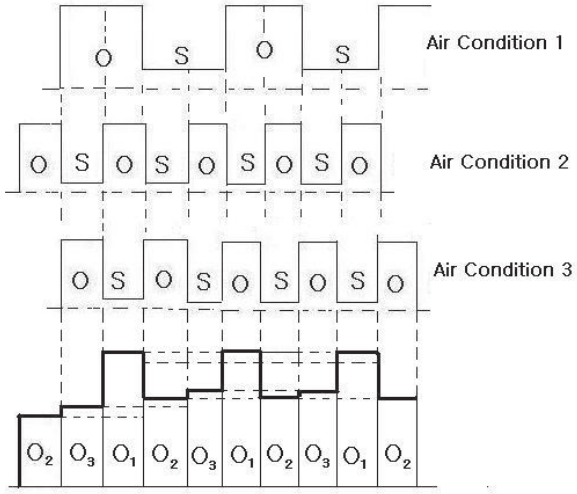

Figure 7. Operation Schedules

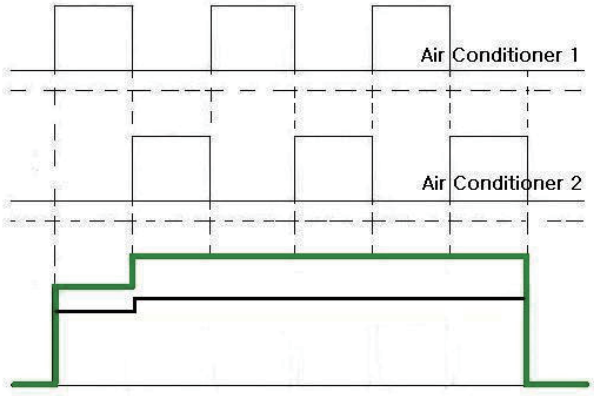

Figure 8. Operation Schedules

5 PRIORITY OF OPERATION

5.1 Start-up

The start-up of the air-conditioners is in the first priority. The set temperature must be first satisfied. Since the start-up of the air-conditioners draws large amount of current, they get started in a queue. This can also avoid the summing up of large amount of power consumed by three air-conditioners.

5.2 Working with other appliances

In a classroom, teachers often use a classroom projector. For the projector to start operation, the air-conditioners need to go into stand-by mode. The start-up time for the projector is only a few seconds. The projector should only go into on mode after one period of the air-conditioners. So the set temperature can be reached and thermal comfort can be acquired before all the air-conditioners go into stand-by mode. Since the starting surge current of the projector is high, the air-conditioners need to stay in stand-by mode. Only one air-conditioner is in on mode in one time slot. This ensures that the no superposition of the peak current of air-conditioners.

5.3 Thermal comfort

Longer time it takes to for an air-conditioner to meet the required set temperature, more uncomfortable may people feel. It is no doubt that thermal comfort depends on many factors, but different operation schedules of the air-conditioner do affect the thermal comfort. So, people should have the right to choose which operation schedule of the air-conditioner to use according to their needs.

6 EXTENSION TO HOMES AND OFFICES

The TDM concept can also be applied to kitchen appliances, such as washing machine. Washing machine washes clothes in four processes, pre-washing, rinsing, draining water, and spinning. Spinning consumes the most power. If other high power consuming appliance, for example, a water heater goes in to on mode when spinning proceeds, the peak demand current will be very high. To avoid this, the water heater should wait until the washing machine finishes the spinning process, or the washing machine can extend the draining process to allow the water heater to go into on mode first. The latter choice requires the collaboration of the smart metering system.

7 COLLABORATION WITH SMART METERING SYSTEM

The Smart Metering System can update the load prediction data, calculate the power consumption, and use those data to manage those appliances [1]. Having these functions, the system knows when the peak load period is every day. It can then control when the electrical appliances should start operation and go into stand-by mode to prevent them from operating at one time slot and leading high power consumption.

With the smart metering system, energy management will be easier. For example, when three air-conditioners in the classroom have already switched on and they undergo the schedule with time-sharing method, the teacher wants to switch on the projector for teaching. The system analyzes the command and makes calculation. The system then asks the teacher if he wants to "wait until the air-conditioners go into stand-by mode", "start the projector now" or "stop the air-conditioner and start the projector". The teacher can choose according to his need.

8 CONCLUSIONS

Time-division-multiplex concept aims to prevent a predictable load from occurring in the peak load period. Its target is that appliances share the time domain so that superposition of steady load currents could be reduced. "Stand-by" mode of the appliances plays an important role. During this mode, other appliances can go into on mode. The timing for the appliances is important.

Using TDM concept, better load management is achieved. The greatest benefit is to reduce the peak demand of current so that frustration to the power network reduces, as well as the copper losses. The time-sharing method for the operation of air-conditioners is a kind of innovation. Nevertheless, it is achievable and practical. With this concept, various ways of operating the air-conditioners were developed. Different ways have their pros and cons. Users can choose one of them according their needs.

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