Model Development of Daily and Hourly Energy Load for Department Stores

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ABSTRACT: Case study was performed to analyze energy load for department stores and develop energy load model to be applied to a cogeneration system. Energy loads of 14 departments were analyzed based on energy load sheets written by operators and energy load of one department store was measured through modem communication for a year. Energy load of department stores showed various trends depending on when they were opened or closed, or by hour, day and month. In this paper, the measurement was compared with the data in energy load sheets and resolved, and energy load model for a department store was built. It is important to use an accurate energy load model for an accurate feasibility study applying a cogeneration system to buildings.

1. Introduction

It is necessary to provide stable electricity in order to expand industrial infrastructure but adding facilities requires lots of money and there are problems such as a difficulty in locating new power plant, loss in power transmission and electricity supply and overload due to increase in cooling load in summer season.

As a measure to overcome above shortcomings, one may install distributed cogeneration system (COGEN below) of which thermal efficiency and electricity efficiency are 50~60% and 25~35%, respectively, where electricity is needed. So an energy use efficiency rises to 80 % by producing heat as well as electricity. And the COGEN has an advantage in grid electricity peak saving. Therefore, it is necessary to activate the popularization of COGEN in Korea where has little natural resource.

The COGEN is economical when energy cost for applying COGEN system is cheaper than existing power system. In addition, reliable COGEN is not yet made in Korea so that COGEN systems are imported and then an energy cost of COGEN gets higher. Therefore, it is more difficult to secure economy of COGEN system.

In other countries, many analyses and researches on technical and economical points are being done, and various programs[1)] are being made to optimize operation of COGEN from viewpoints of end-users, power companies and government.

However, we are now introducing foreign programs and using them without any modification though Korean climate is considerably different from other countries'.

In order to introduce COGEN system, first of all, its economical efficiency should be taken into account, and selecting proper equipment for loads is significantly important. The goal of

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1) COGEN3, DEUS, COGENMASTER etc.

this study is recognizing the importance of load model for selecting proper equipments and building DB for the load models needing considerably long time measurement because the load model can be used as input to COGEN program. The study intends to establish a basic load model of department stores through long time measurements.

2. Research items and methods

2.1 Monthly and daily energy consumptions

In the study, energy consumption status is examined to build a load model that can more exactly predict energy consumption rate which affects the economy of COGEN system significantly.

At first, concerning the energy consumption status, 21 department stores were chosen among many department stores managing both electricity and heat in Seoul, Daejon, Daegu, Pusan and Kwangju. We visited them for examination in person. The results examined from 14 among 21 of which purpose could be regarded as a department store are shown here. Regarding average result of 14 department stores, an averaged height of the stores is of 10 floor above ground and 5 floor underground. Averaged total area, heating area and cooling area are 65,795 m^2, 40,456 m^2 and 40,047 m^2, respectively. Receiving voltage is 22.9 kV and a capacity of

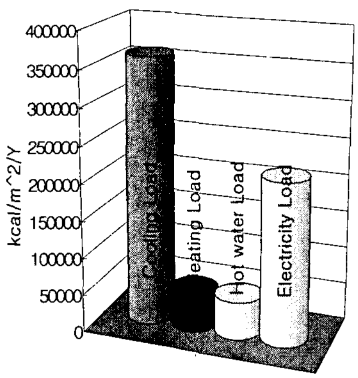


Fig. 1 Yearly energy load for department stores.

an emergency generator is about 1,250 kW, and it is found that cooling load and electrical load are higher than heating load. The load of department stores is concentrated during their work time, i.e., 10 : 30 am to 8 : 00 pm on an average.

If we refer to worksheets of engine rooms of department stores, averaged heating and cooling periods are as follows. Usually, cooling is carried out from 8 am to 7 pm between late March to early December. And heating is carried out from 7 : 30 am to 8 pm between mid December. to early April. Fig. 1 shows yearly energy load per unit area of department stores. From Fig. 1, it is found that as lighting load (electrical load) is high and accordingly cooling load increases with heat due to lighting. In general, cooling load is high and cooling time is long while heating load is relatively low and the term is short.

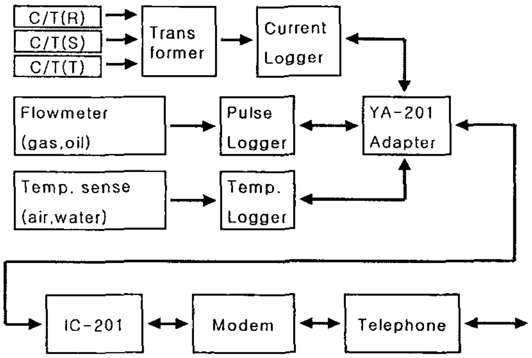
2.2 Measurement of hourly energy use pattern

Used energy was measured by the courtesy of department stores in order to ask the intention of precise measurement for drawing an hourly load model. Realtime measurement of hourly energy consumption is time-consuming and costly process. However, since economy of COGEN system and estimation of capacity are dependent on the accuracy of energy load model, the cost related to the measurement is acceptable, though it is high.

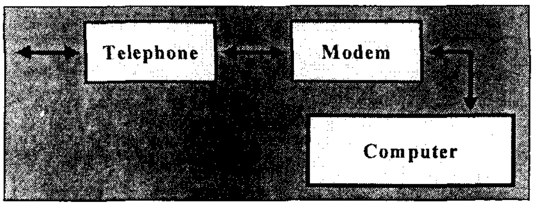
As samples of all department stores could not be taken because of limitation on time, manpower and cost, one among many department stores was chosen for the measurement of hourly energy use pattern. The department store chosen as an object of the study is located in Gwanju, and has a total area of 57,534 m^2 and a cooling/heating area of 34,320 m^2. It has 9 floors above the ground and 3 floors under ground which are used for parking lots.

2.2.1 Setup and plan of measurement

Because manual measurement of hourly en-



(a) The schematic diagram of measurement system at the site



(b) The schematic diagram of measurement at lab

Fig. 2 The method to install measurements.

ergy consumption requires significant labor and effort, remote data measurement system was built so that setting and measurement of a data logger can be carried out on-line through a modem and telephone line between a computer in a lab and a data logger as shown in Fig. 2.

2.2.2 Sampling of data

As shown in Fig. 2, data are measured every 8 second and the data are accumulated for 4 minutes and averaged, so that 15 data are sampled every hour.

3. Energy load model of a department store

3.1 Monthly energy load model

Energy load data of dept. stores were investigated by referring worksheets of engine rooms and 4 department stores of which cooling was electrical-driven (including ice thermal storage system are analyzed.

From Table 1, 80.2% of total energy consumed in a department. store is electricity and the rest is fuel such as oil or gas. Fig. 3 displays Table 1 graphically and Fig. 3 (b) shows 4 energy loads based on energy load model suggested in Reference 1.

From Fig. 3 (a), it is shown that electricity consumption is the most in July due to increase in cooling demand and least in February. However, fuel consumption is the most in January i.e. heating season and least in August when only hot water is needed. And electricity and hot water load are shown to be approximately uniform all the year round.

3.2 Daily energy load model

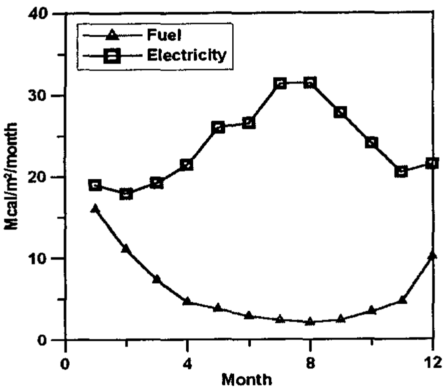
Energy uses of a department. store such as electricity, cooling load, heating load and hot water load are analyzed based on energy load model analysis method suggested in [1] and then daily load change is drawn. Electricity, cooling load, heating load and hot water load of 14 department stores were analyzed and shown in Fig. 4 (a), (b), (c) and (d).

Regarding electricity model in Fig. 4 (a), there

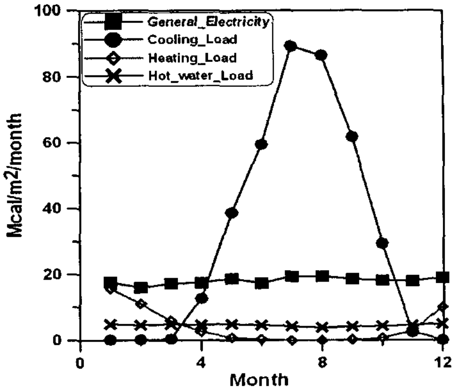
Table 1 Monthly energy load (Mcal/m^2/month, Mcal/m^2/year)

Energy \ Month	1	2	3	4	5	6	7	8	9	10	11	12	Year total
Electricity	19.0	17.9	19.2	21.4	26.0	26.6	31.4	31.5	27.8	24.1	20.5	21.5	287.0
Fuel	16.0	11.1	7.3	4.6	3.8	2.9	2.4	2.1	2.4	3.4	4.7	10.2	70.9
Total	35.1	29.1	26.6	26.1	29.7	29.4	33.8	33.7	30.1	27.4	25.3	31.7	357.9

1 kWh = 860 kcal, LNG 1 Nm^3 = 9,500 kcal

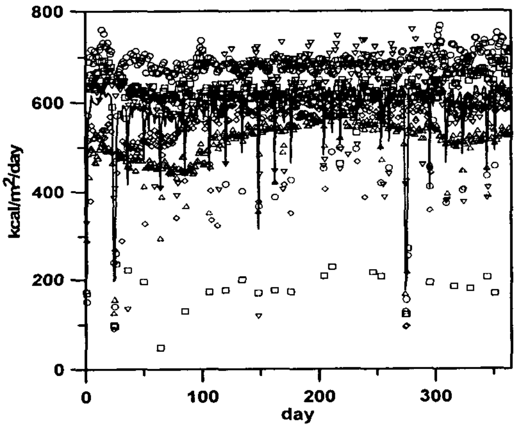


(a) Fuel and electricity consumption

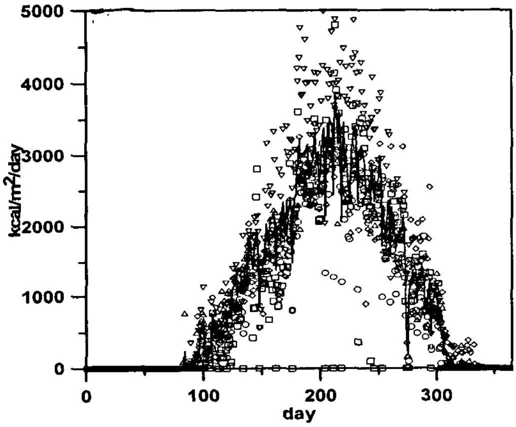


(b) Load variation

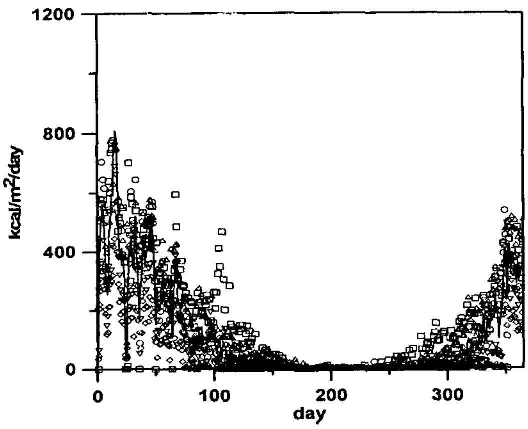
Fig. 3 Monthly energy consumption.



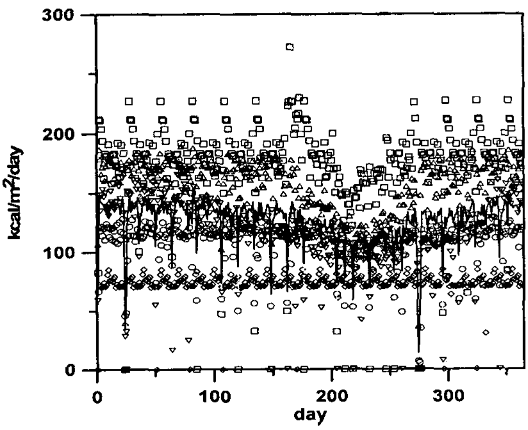
(a) Electricity load



(b) Cooling load



(c) Heating load



(d) Hot water load

(○ : Seoul △ : Daejun ◇ : Daegu □ : Busan ▽ : Gwangju —— : AVG)

Fig. 4 Daily model of energy load.

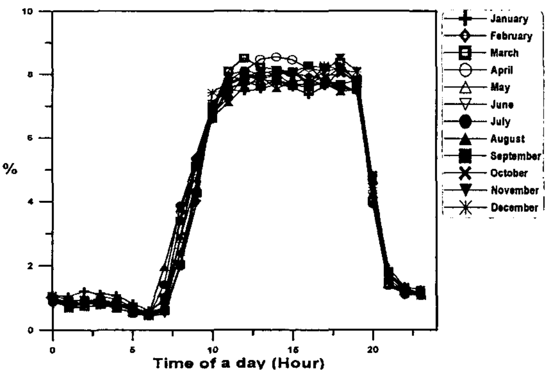
is no distinct maximum value and it is almost uniform all the year round. It seems to be closely related to electricity consumed by lighting for illuminating shops, that is, one of characteristics of department. stores. Difference in load among department stores is about 100 kcal/day/m^2. Cooling load of Fig. 4 (b) is practically little and begins to rise early spring and reaches its top summer. In case of department stores, it is a feature that cooling time is long and cooling load is high because of increase in indoor temperature due to lighting in shops. Amounts of cooling load of department stores vary with their location, utilities and sizes, and a difference among cooling loads is 500 kcal/day/m^2, which is relatively high.

Figure 4 (c) shows that heating load is concentrated on winter and spring, and relatively low since room temperature of department stores is kept to some degree constant by lighting heat contrary to other buildings.

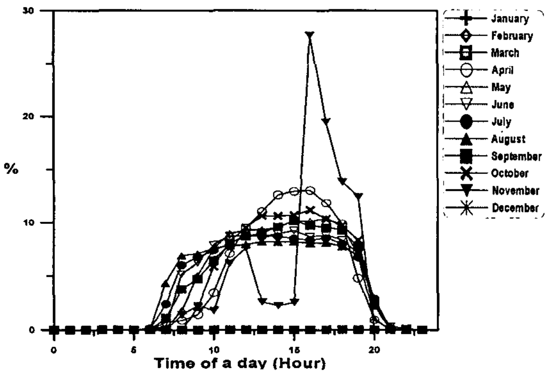
From Fig. 4 (d), hot water load is demanded for supplying hot water to bathrooms and cafeteria in department stores, and has no local maximum and is kept constant all the year round. Difference in hot water load among department stores is 50 kcal/day/m^2, that is relatively low, regardless of region, size and utilities of department stores.

3.3 Hourly energy load model

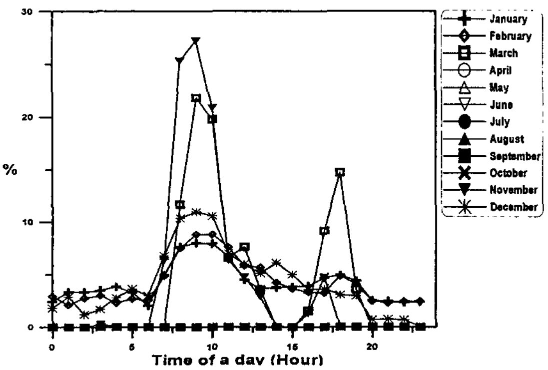
Yearly energy load model by energy load which is essential to a simulation for economy analysis of COGEN system can be established by incorporating daily and hourly energy load



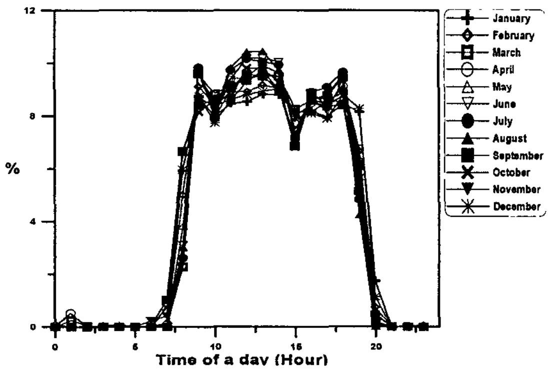
(a) Electricity load



(b) Cooling load



(c) Heating load



(d) Hot water load

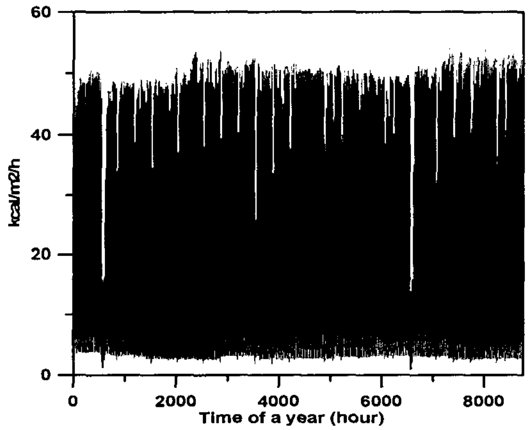
Fig. 5 The each energy load over total energy (%) per hour for a day of each month.

models. The model of energy load per hour for a day of each month is measured at a department store.

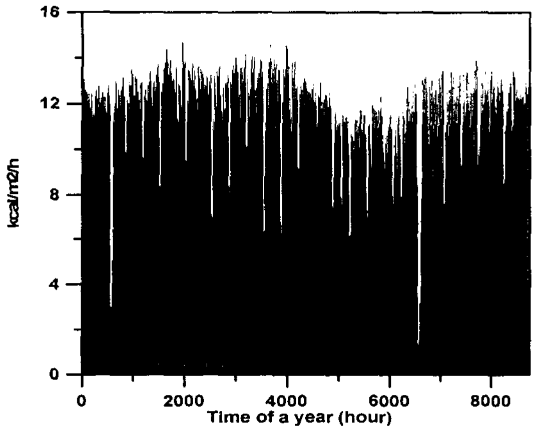
This study built a energy load model by not season but month to get an accurate energy load model.

Figure 5 (a) indicates electricity load changes for a day averaged for days of a month. It is shown that most of electricity load is used by lighting in shops and concentrated on business hours of a department store. The electricity load increases abruptly 2~3 hours before the opening hour of the department store and decreases just after the closing hour. As for electricity load pattern by month, there is not a significant difference among loads since electricity loads by cooling in summer and heating in winter are not included in Fig. 5 (a).

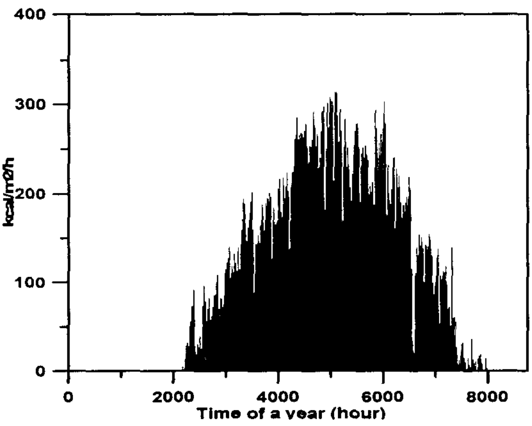
Figure 5 (b) indicates cooling load changes for a day averaged for days of a month. In summer most of cooling load is demanded 7 am to 8 pm, and cooling load is constant without change in July and August when the temperature is the hottest. It is because cooling is continuously supplied due to high temperature. In case of cooling load in spring and fall, cooling load is concentrated on time after noon when is relatively hotter than other time of a day. There is no cooling load in February, January, March and December.



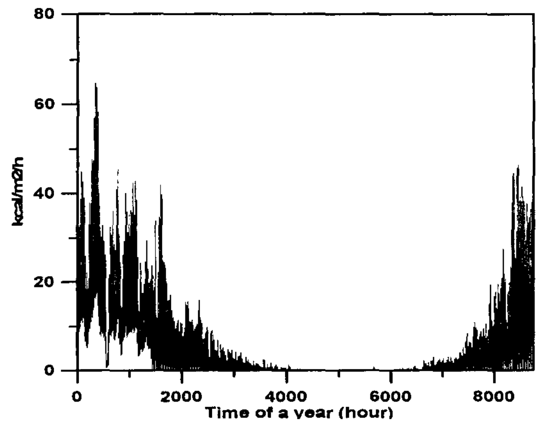
(a) Electricity load



(b) Hot water load



(c) Cooling load



(d) Heating load

Fig. 6 The energy load per hour for a year.

Average heating load changes with time of a day of each month are shown in Fig. 5 (c). It is found that heating load is relatively low since a department store is a closed building somewhat insulated from outdoor and extra heat is produced by lighting. For example, coolers sometimes operated even in early winter due to increase in indoor temperature at "S" department store in Gwangju. Heating load patterns are of continuous operation without large fluctuation in February and January while intermittent operation in spring and fall. And there is no heating load in April to October.

Figure 5 (d) displays average hot water load changes with time of a day of each month and they are almost constant. Hot water loads are almost continuous during business hours. It is because hot water is continuously supplied to bathrooms and cafeteria. In general, department stores provide hot water for the customers' convenience during business hours.

The energy load per hour for a year is shown in Fig. 6 by incorporating daily energy load model in Fig. 4 and hourly energy load model in Fig. 5.

4. Conclusions

In this study, energy load models show the significant difference between business hours and closed hours. And they give information about electricity, cooling, heating and hot water load patterns for a year by a day, for a day by an hour and for a year by an hour. When an operation simulation is applied to COGEN system, the result of the simulation is so sensitive to the energy load model that the simulation can set forth different results according to different energy load models. Therefore, the simulation should employ energy load models which can reflect these differences. That is, 8,760 hour energy load model can estimate the load demanded by a department store most accurately when it is applied to the simulation.

In conclusion, this study suggests methods for establishing the energy load model of department. stores which can be useful to economy analysis of COGEN system and fundamental information about the results of the model. In addition, the energy load model should be systematically analyzed and managed in a form of database after researches on buildings where COGEN system is applicable are done.

Acknowledgements

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