# Assessment of Interruption Costs by Industrial Customer Type

**Sang-Bong Choi***

**Abstract** - As the power industry moves towards open competition, a need has arisen for appropriate methodology to evaluate power system reliability by using customer interruption costs. This paper presents an assessment of the interruption costs by industrial customer type in Korea using customer survey methodology. When various research results are examined, the customer damage survey methodology becomes much more generalized. Especially, in the case of industrial customers, it is known that evaluation by the customer damage survey is more useful. Accordingly, this paper selected the customer damage survey method to evaluate the interruption costs by industrial customer type in Korea considering interruption and customer characteristics.

**Keywords**: Analysis of customer type, Customer characteristics, Customer damage survey methodology, Industrial customer interruption cost

## 1. Introduction

Power companies at home and abroad have made efforts to provide power service that is highly reliable. However, the electric equipment used by industrial customers these days reacts sensitively to outages of even very short duration, not to mention the duration of 5 minutes, the existing reliability standard, resulting in loss.

For example, a considerable amount of manufacturing equipment used by industrial customers reacts very sensitively to any change in power service. Not only sustained outage but also momentary outage causes problems to high tech electronic equipment like the computer used by most industrial customers. As the load sensitive to momentary outage is expected to rise in the future, power companies need to determine the effect of outages on industrial customers by outage duration including momentary outage.

When competition is introduced to the power industry, power companies have to consider the market value of their power service, while customers have to consider supply reliability and its cost for the power they purchase since the maintenance of supply reliability costs both the power companies and the customers.

In the competitive power market, calculation of interruption cost is very significant as interruption, i.e. supply reliability will be an important factor for decision making for both the supplier and the user. Accordingly, development of a model to assess interruption costs for industrial customers is economical and important since it is one of the basic data to ensure fair power transactions in the future.

Several studies on the outage costs from the power companies' perspective have been carried out in Korea but almost no study has been done on the economic cost of power interruption to customers. In recent years, momentary power outages have tended to cause more damages to industrial customers than the ones lasting more than 5 minutes, the statistical standard for interruption.

Therefore, it is necessary to develop an outage cost model by industrial customer type according to power quality including momentary outage to improve the power supply environment, which will ultimately improve the international competitiveness of Korean enterprises.

While for the estimation of power supply reliability cost, the macroscopic approach or microscopic approach can be taken. The macroscopic approach is an inclusive approach related to the national economy, such as the GNP estimation method, the GDP estimation method, estimation by industry, and the marginal customer damage function estimation method. For the microscopic approach, customers are classified into groups and interruption cost is estimated by customer type or size using a survey or other methods. It includes the customer damage survey method, estimation of willingness to pay and the preventive expenditure survey.

However, as the impact of interruption is different to each customer type, a different estimation method of outage cost is used for each customer type. Therefore, studies on outage cost model by customer type according to power quality are needed.

Especially, the estimation of interruption cost for industrial customers is necessary to ensure economic and adequate power supply and fairness in the future power market. Accordingly, studies to estimate the costs of all

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possible damages from power interruption to each industrial customer type need to be carried out.

For the objective estimation of outage cost for each individual industrial customer or each industrial customer type, a large scale survey using a microscopic approach for each customer type is necessary. Such microscopic methods include several outage cost estimation methods including the customer damage survey that examines the actual loss occurred in production and service activities, survey of people's willingness to pay for planned power facilities or people's willingness to accept outages, and estimation of preventive expenditure to prepare for interruption. And it is time to estimate the customer damage cost for each customer type by using these diverse methods of outage cost estimation.

The examination of various research results indicates that the evaluation of interruption costs by customer damage survey is a much simpler method. In the case of industrial customers, it is known that the evaluation of customer damage methodology is more useful. Therefore, this paper presents an examination of the direct and short/long term interruption costs borne by industrial customer types through a customer damage survey. The questionnaire included interruption characteristics, such as interruption duration, day, time, and month of interruption, whether an advance warning was given or not, as well as customer characteristics, such as business size and type.

## 2. Evaluation of Interruption Cost by Industrial Customer Type

### 2.1 Survey of the interruption cost by industrial customer type

Estimation of outage costs for industrial customers is one of the essential data for the establishment of stable power supply and the planning of an optimal system. To estimate the outage cost by industrial customer type, the questionnaire for this study included the following; status of power consumption, inconveniences and damages due to interruption, outage cost by interruption duration, existence or non-existence of emergency power supply devices, estimation of outage cost according to the existence or non-existence of emergency power supply devices, estimation of outage cost according to the existence or non-existence of advance warning, and estimation of outage cost by month, day, and time. Based on the questionnaire used by the University of Saskatchewan in Canada, a questionnaire has been developed to fit the Korean situation. The Korean Electrotechnology Research Institute in cooperation with Gallup Korea first conducted an interview survey using the questionnaire, then obtained data, and analyzed them.

The experiences and opinions of survey participants will be reflected in the planning of an optimal system that minimizes economic loss from interruption and maximizes profits by accurately assessing the outage costs due to interruption. Also, the data obtained will be used as a basic data for the calculation of electric charges when interruption is considered as an element for power transactions in the free power market in the future.

As the industrial customers themselves can best assess the damages suffered due to interruption, it was decided to collect data from industrial customers directly. Mail surveys done in the past elicited low response rates and the accuracy of responses was questionable. For this survey, interviews were conducted and the accuracy of responses was improved by explaining the questionnaire. Industrial customers have been classified into 11 categories based on the Korean Standard Industry Classification. To ensure fair and accurate assessment of outage cost by industry type, the industrial customers were allocated in consideration of their location and industry type. For the survey of outage costs for industrial customers, several methods including, damage assessment by customers, willingness to pay, and the assessment of the cost of preparative actions, have been used world-wide. However, damage assessment by customers has been used most widely and this method has been selected for this paper. This clause introduces the survey developed for the damage assessment by customers and the direct and short/long term effects of the interruption obtained through the survey. The survey content included interruption characteristics, such as interruption duration, time, day, and month of interruption, existence of advance warning, and customer characteristics, such as business size and type, etc.

#### *2.1.1 The purpose of the survey of outage costs for industrial customers*

The purpose of this survey is to provide a base for the establishment of an economic and adequate power supply and optimal system planning by finding out information on industrial customers' power consumption and interruption effects. Fig. 1 below illustrates survey subjects, main content, and activities.

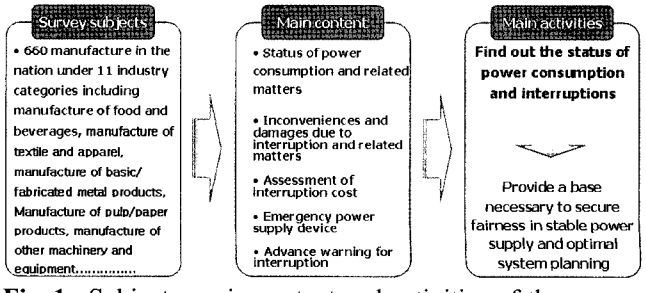



**Fig. 1.** Subjects, main content and activities of the survey of outage cost for industrial customers

### 2.1.2 Design of a survey questionnaire for industrial customers

Based on the questionnaire used by the University of Saskatchewan in Canada, a questionnaire has been developed to fit the Korean situation. Through many steps, a survey method and questions have been decided. Sample subjects were repeatedly tested and experts were consulted for the development of the questionnaire to include various questions and factors. The final questionnaire was used for 660 industrial customers allocated in consideration of their location. In the following, the process of sampling design, fieldwork, data processing and analysis of the survey of outage costs for industrial customers carried out by the Korea Electrotechnology Institute in cooperation with Gallup Korea are introduced.

### 2.1.3 Characteristics and locations of the industrial customer survey respondents

The industrial customer survey was carried out using 660 industrial customers who were selected in consideration of industry category and location. Fig. 2 below presents industrial customers' monthly power consumption/electric charges/ respondent characteristics by industry type.

| Division | No of sample | % |
|---|---|---|
| Total | 660 | 100.0 |
| **Power consumption** | | |
| 10MWH below | 257 | 38.9 |
| 10~100MWH below | 183 | 27.7 |
| 100~1000MWHbelow | 105 | 15.9 |
| 1~10GWHbelow | 46 | 7.0 |
| 10GWH above | 27 | 4.1 |
| No response | 42 | 6.4 |
| **Average power rate** | | |
| 490Thousand won below | 90 | 13.6 |
| 500~1,990 Thousand won | 139 | 21.1 |
| 5,000~9,990 Thousand won | 141 | 21.4 |
| 10,000~99,990 Thousand won | 81 | 12.3 |
| 100,000 Thousand won above | 135 | 20.5 |
| No response | 69 | 10.5 |
| | 5 | 0.8 |
| **Customer type** | | |
| Food and beverages | 49 | 7.4 |
| Textile and apparel | 55 | 8.3 |
| Pulp and paper products | 38 | 5.8 |
| Chemical and chemical products | 127 | 19.2 |
| Basic / fabricated metal | 52 | 7.9 |
| Other machinery and equipment | 49 | 7.4 |
| Electric and electronic equipment | 82 | 12.4 |
| Electric machinery | 53 | 8.0 |
| Audio visual equipment | 48 | 7.3 |
| Motor vehicles | 51 | 7.7 |
| Other transport equipment | 56 | 8.5 |

**Fig. 2.** Industrial customer's monthly power consumption /electric charges/respondent characteristics by industry type

## 2.2 Evaluation and analysis of the interruption cost by industrial customer type

For the assessment and analysis of outage costs for industrial customers, the industrial customers were classified into 11 categories based on the examination of outage costs for industrial customers included in this year's technology development plan as follows; manufacture of food and beverages, manufacture of textiles and apparel, manufacture of pulp and paper products, manufacture of chemicals and chemical products, manufacture of basic/fabricated metal products, manufacture of other machinery and equipment, manufacture of electric and electronic equipment, manufacture of electric machinery, manufacture of audio and visual equipment, manufacture of motor vehicles, and manufacture of other transport equipment.

### 2.2.1 Analysis of the survey respondents by industry type

Table 1 shows the customer types for the survey of outage costs for industrial customers.

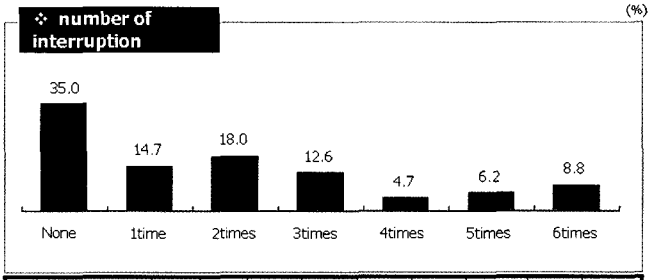
**Table 1.** Analysis of the respondents by industrial customer type

| No | Customer type | Details |
|---|---|---|
| 1 | Food and beverages | Manufacture of food and beverages, processing of meat, fruit, vegetables and grains, manufacture of tobacco products, manufacture of starch and feed products, and processing of fat and oil |
| 2 | Textile and apparel | Manufacture of fabric and textile products, sewn articles and apparel, leather goods, yarns, and luggage and footwear, and dyeing |
| 3 | Pulp and paper products | Manufacture of pulp and paper products, corrugated cardboard, paper containers, and cardboard |
| 4 | Chemicals and chemical products | Manufacture of coke and related products, rubber and plastic, compounds and chemical products, and medical products |
| 5 | Basic/fabricated metal | Manufacture of basic metal products, basic steel products, basic non-metallic mineral products, fabricated metal products, metal products for structural purposes, and other fabricated metal products, die-casting and metal processing |
| 6 | Other machinery and equipment | Manufacture of other machinery and equipment, weaponry, shells and bullets, home machinery, and machine tools for processing |
| 7 | Electric and electronic equipment | Manufacture of semi conductors, electric and electronic related components, home appliances, insulations and cables, storage batteries, and bulbs and lighting devices |
| 8 | Electric machinery | Manufacture of motors, generators, storage batteries, power supply devices, and other electric machinery |
| 9 | Audio visual equipment | Manufacture of audio, visual, and communication equipment, and broadcasting equipment |
| 10 | Motor vehicles | Manufacture of automobiles and trailers and engine, body, and automobile parts |
| 11 | Other transport equipment | Manufacture of freight transportation and other transportation equipment |

### 2.2.2 Analysis of the status of interruptions

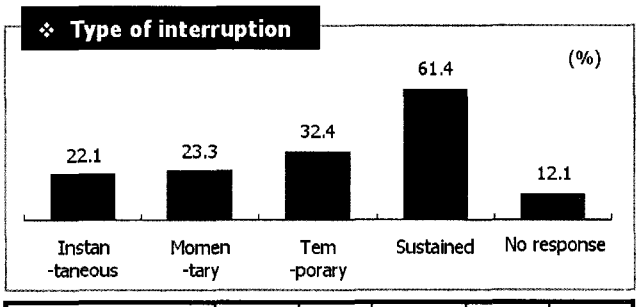
Survey subjects were asked about the number of interruptions, the number of interruptions lasting more than 5 minutes, and the types of interruptions that caused loss during the previous year. The highest percentage, 35.0% answered that they had not experienced interruption during the previous year. On average, 2.19 interruptions occurred annually. As for the interruptions lasting more than 5 minutes, 65.3% answered they had not experienced such an interruption. From this, it can be said that interruptions lasting more than 5 minutes are not frequent. As for the types of interruption, 61.4% were sustained interruptions and 32.4% were temporary interruptions. 48.7% answered that they experienced temporary interruptions of less than 3

seconds. 11.8% experienced more than 4 temporary interruptions during the previous year. Fig. 3 below shows the number of interruptions by industrial customer type during the previous year. And Fig. 4 shows the types of interruptions that caused economic loss by industrial customer type during the previous year.




| Type | None | 1time | 2times | 3times | 4times | 5times | above 6times | No of case | Average (times) |
|---|---|---|---|---|---|---|---|---|---|
| Total | 35.0 | 14.7 | 18.0 | 12.6 | 4.7 | 6.2 | 8.8 | 660 | 2.19 |
| Food and beverage | 24.5 | 16.3 | 22.4 | 6.1 | 2.0 | 6.1 | 22.4 | 49 | 2.90 |
| Textile and apparel | 47.3 | 12.7 | 7.3 | 14.6 | 5.5 | 7.3 | 3.6 | 55 | 1.71 |
| Pulp and paper products | 39.5 | 15.8 | 10.5 | 10.5 | 2.6 | 13.2 | 7.9 | 38 | 2.13 |
| Chemicals and chemical products | 31.5 | 19.7 | 15.0 | 10.2 | 5.5 | 3.1 | 15.0 | 127 | 2.41 |
| Basic/fabricated metal | 38.5 | 11.5 | 19.2 | 17.3 | 3.8 | 3.8 | 5.8 | 52 | 1.73 |
| Other machinery and equipment | 34.7 | 18.4 | 14.3 | 8.2 | 6.1 | 12.2 | 6.1 | 49 | 2.69 |
| Electric and electronic equipment | 45.1 | 9.8 | 14.6 | 14.6 | 3.7 | 3.7 | 8.5 | 82 | 2.12 |
| Electric machinery | 35.8 | 13.2 | 24.5 | 11.3 | 3.8 | 7.5 | 3.8 | 53 | 1.83 |
| Audio visual equipment | 37.5 | 10.4 | 20.8 | 12.5 | 2.1 | 6.3 | 10.4 | 48 | 2.40 |
| Motor vehicles | 27.5 | 11.8 | 27.5 | 13.7 | 9.8 | 5.9 | 3.9 | 51 | 2.08 |
| Other transport equipment | 23.2 | 17.9 | 26.8 | 17.9 | 5.4 | 7.1 | 1.8 | 56 | 1.93 |

**Fig. 3.** Number of interruptions by industrial customer type during the previous year




| Type | Instan -taneous | Momen -tary | Tem -porary | Sustained | No response |
|---|---|---|---|---|---|
| Total | 22.1 | 23.3 | 32.4 | 61.4 | 12.1 |
| Food and beverage | 20.4 | 16.3 | 30.6 | 67.3 | 12.2 |
| Textile and apparel | 14.5 | 12.7 | 25.5 | 63.6 | 20.0 |
| Pulp and paper products | 44.7 | 13.2 | 10.5 | 26.3 | 23.7 |
| Chemicals and chemical products | 22.0 | 32.3 | 35.4 | 52.0 | 12.6 |
| Basic/fabricated metal | 13.5 | 15.4 | 38.5 | 65.4 | 11.5 |
| Other machinery and equipment | 16.3 | 32.7 | 40.8 | 71.4 | 8.2 |
| Electric and electronic equipment | 15.9 | 15.9 | 36.6 | 67.1 | 1.2 |
| Electric machinery | 22.6 | 24.5 | 24.5 | 56.6 | 18.9 |
| Audio visual equipment | 18.8 | 18.8 | 22.9 | 62.5 | 12.5 |
| Motor vehicles | 33.3 | 37.3 | 47.1 | 70.6 | 3.9 |
| Other transport equipment | 30.4 | 26.8 | 32.1 | 73.2 | 16.1 |

**Fig. 4.** Types of interruptions by industrial customer type that caused economic loss during the previous year

### *2.2.3 Analysis of the worst period for interruption*

● *Analysis of the worst period for interruption (by month)*

Survey subjects were asked about the worst month for interruption. Most of the respondents (80%), except those in textiles and the apparel category and pulp and paper products category, answered that there was no worst period for interruption. The highest percentage, 67.7% answered that all the months were the same and 9.2% and 8.2% responded that the worst months were the summer months, July and August, respectively. By industry type, August was considered the worst month for interruption by the respondents in the food and beverage, textiles and apparel, and pulp and paper products categories more often than those in other categories. Fig. 5 below shows the worst month for interruption by industrial customer type.

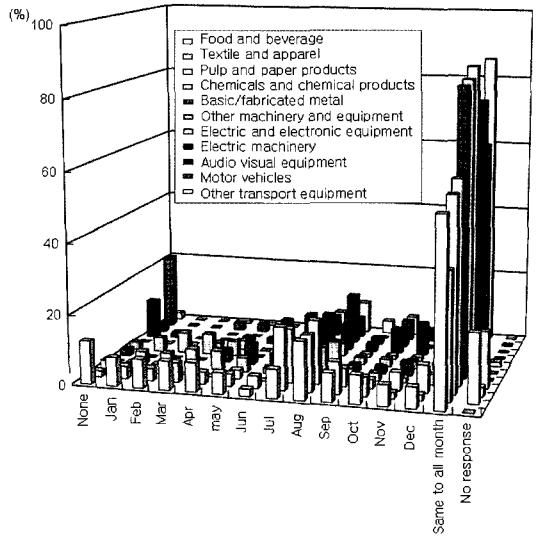



**Fig. 5.** Worst month for interruption by industrial customer type

● *Analysis of the worst period for interruption (by day of the week)*

Survey subjects were asked about the worst day of the week for interruption. The highest percentage, 8.6% answered that Monday was the worst. Except for Monday and Sunday, the remaining 5 days elicited almost the same percentage of response of 5%, which means there is not much difference between days of the week. Especially, differences between days of the week were smaller for the food and beverages, basic/fabricated metal, and other transport equipment categories than other categories. In addition, the highest percentage, 35.8% answered that when an interruption occurred, the loss was about the same for all days of the week. Of the weekdays, Monday was most frequently mentioned as the worst day specifically. Fig. 6 below indicates the worst day of the week for interruption by industrial customer type.

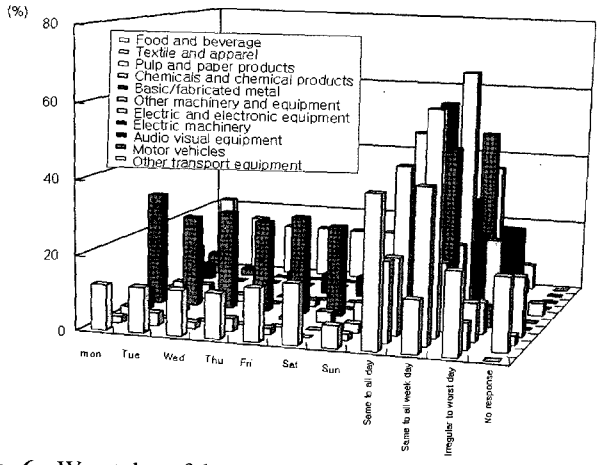



**Fig. 6.** Worst day of the week for interruption by industrial customer type

- *Analysis of the worst period for interruption (by time of day)*

Survey respondents were asked about the worst time for interruption. The highest percentage, 30.6% answered that the loss was the same for night and day. 26.7% responded that all working hours were the same. 13.8% answered that 9-12 AM was the worst. 12.6% answered that 1-4PM was the worst. When the data was analyzed by industry type, respondents in the other machinery and motor vehicle categories were more likely to respond that there was no difference between night and day than others. And the respondents in the pulp and paper products category were more likely to answer that there was no difference during the working hours than others. And 33.9% of the respondents in the other transport equipment category indicated that 9-12AM was the worst. The interruptions occurred in the morning hours caused more damages to the other transport equipment category than other categories. Fig. 7 below shows the worst time for interruption by industrial customer type.

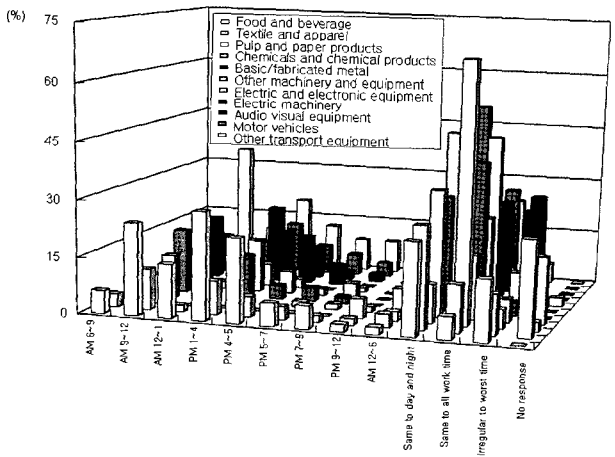



**Fig. 7.** Worst time for interruption by industrial customer type

### *2.2.4 Estimation of outage cost for average power consumption*

As explained above, the interruption cost by interruption duration was estimated by assessing the direct costs such as the loss of production and sales and the cost of overtime working, etc. To estimate the outage cost for average power consumption by industry type and by interruption duration from the interruption costs calculated above, monthly power consumption by industry type is shown in Table 2 first. Using the interruption cost by industry type and power consumption by industry type presented in Table 2, the outage cost for average power consumption according to the interruption duration has been calculated by industry type and shown in Table 3. Outage cost for average power consumption by interruption duration and that by industry type are indicated in Fig. 8 and Fig. 9 with a 2 dimensional graph and a 3 dimensional graph respectively.

**Table 2.** Monthly power consumption by industry type

| Type | Monthly power consumption [kWh/month] |
|---|---|
| Food and beverage | 43,927 |
| Textile and apparel | 1,233,844 |
| Pulp and paper products | 3,093,209 |
| Chemical and chemical products | 5,046,603 |
| Basic/fabricated metal | 69,283 |
| Other machinery and equipment | 107,437 |
| Electric and electronic equipment | 1,087,592 |
| Electric machinery | 158,957 |
| Audio visual equipment | 94,041 |
| Motor vehicles | 184,107 |
| Other transport equipment | 103,562 |

**Table 3.** Outage cost for average power consumption according to the interruption duration by industry type

| Type | Monthly average power use(kWh) | Interruption cost per average kw (unit : won) | | | |
|---|---|---|---|---|---|
| | | 3sec below | 1min below | 5min below | 30min below |
| Food and beverage | 1,233,844 | 8,421 | 8,724 | 9,500 | 13,935 |
| Textile and apparel | 3,093,209 | 1,650 | 1,678 | 1,781 | 2,100 |
| Pulp and paper products | 5,046,603 | 39,806 | 50,284 | 52,042 | 61,505 |
| Chemicals and chemical products | 1,087,592 | 80,335 | 120,718 | 174,493 | 230,076 |
| Basic/fabricated metal | 43,927 | 22,783 | 44,747 | 78,020 | 128,504 |
| Other machinery and equipment | 69,283 | 12,886 | 18,706 | 33,359 | 63,288 |
| Electric and electronic equipment | 107,437 | 11,594 | 15,950 | 26,605 | 59,443 |
| Electric machinery | 158,957 | 7,700 | 13,634 | 21,470 | 45,794 |
| Audio visual equipment | 94,041 | 9,647 | 12,709 | 23,045 | 53,517 |
| Motor vehicles | 184,107 | 23,699 | 36,683 | 49,706 | 83,612 |
| Other transport equipment | 103,562 | 9,316 | 12,862 | 15,782 | 39,420 |

| Type | Monthly average power use(kWh) | Interruption cost per average kw (unit : won) | | | |
|---|---|---|---|---|---|
| | | 1hour below | 4hour below | 8hour below | 8hour above |
| Food and beverage | 1,233,844 | 16,952 | 22,881 | 34,388 | 39,768 |
| Textile and apparel | 3,093,209 | 2,619 | 9,017 | 15,381 | 22,055 |
| Pulp and paper products | 5,046,603 | 70,181 | 84,372 | 98,950 | 115,854 |
| Chemicals and chemical products | 1,087,592 | 229,300 | 299,389 | 405,556 | 430,514 |
| Basic/fabricated metal | 43,927 | 182,430 | 410,426 | 896,906 | 1,103,595 |
| Other machinery and equipment | 69,283 | 111,716 | 210,649 | 420,882 | 554,733 |
| Electric and electronic equipment | 107,437 | 106,757 | 229,865 | 399,013 | 619,161 |
| Electric machinery | 158,957 | 86,786 | 226,114 | 388,452 | 604,103 |
| Audio visual equipment | 94,041 | 92,411 | 215,753 | 337,946 | 448,962 |
| Motor vehicles | 184,107 | 120,061 | 206,528 | 351,617 | 560,296 |
| Other transport equipment | 103,562 | 66,047 | 142,871 | 253,682 | 298,673 |

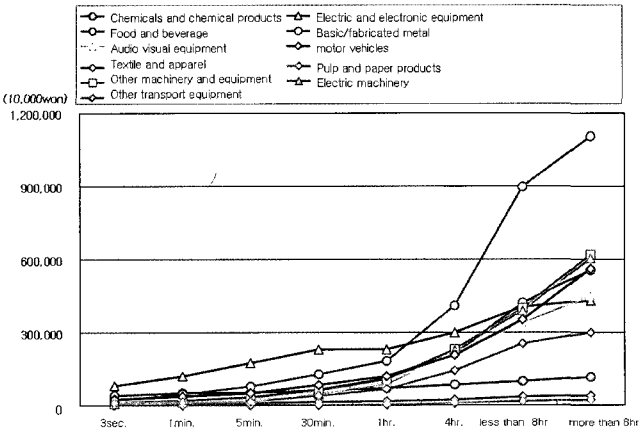



**Fig. 8.** Outage cost for average power consumption by interruption duration and by industry type with a two dimensional graph

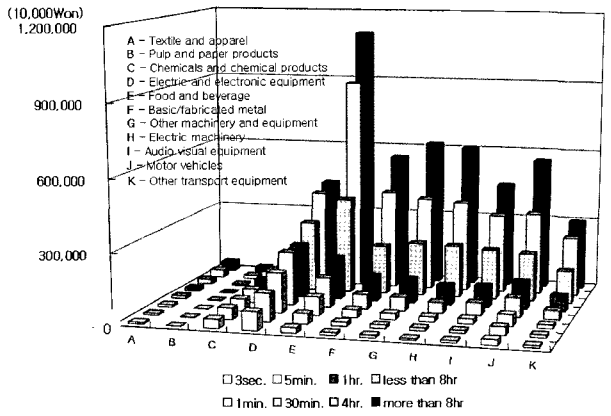



**Fig. 9.** Outage cost for average power consumption by interruption duration and by industry type with a three dimensional graph

## 3. Conclusion

This paper evaluates the interruption costs for industrial customers by customer type in Korea. While assessing customer interruption costs, the importance of the electric facility, characteristics of emergency power supply use and interruption cost changes by period were analyzed statistically.

The proposed major contents to evaluate industrial customer interruption costs are summarized as follows. First, we present a method to evaluate production, sales and extra labor costs respectively, which is incurred from interruption duration. Secondly, we present methodology to evaluate interruption costs per power use according to interruption duration by industrial customer type. To acquire this, we use interruption costs by hour, load factor and power use by month and customer type.

Through survey study, it is concluded that the proposed evaluation methodology can be used to evaluate interruption costs of other customer types with the exception of residential customers. The results of this paper can be summarized as follows.

- The interruption costs per average kW for chemical and chemical products among the industrial type category is higher than the other industrial type category during the short term interruption duration.
- The interruption costs per average kW for basic/fabricated metal among the industrial type category is higher than the other industrial type category during the long term interruption duration.
- For the worst period for interruption by month, it is analyzed that there is no worst period for interruption, thus the highest percentage, which is 67.7% was the same for all months and 9.2% and 8.2%, were the percentages for the worst summer months being July and August respectively.
- By industrial type, August is analyzed to be the worst month for interruption in the food and beverage, textiles and apparel, and pulp and paper products categories.
- For the worst period for interruption by day of the week, it is analyzed that the highest percentage of 8.6% showed Monday to be the worst.
- By industrial type, differences between days of the week were smaller for the food and beverages, basic/ fabricated metal and other transport equipment categories than other categories.
- For the worst period for interruption by time of day, it is analyzed that the highest percentage of 30.6% showed that the loss was the same for day and night.
- By industrial type, the interruptions that occurred in the morning hours caused more damage to the other transport equipment category than to other categories.

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