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Investigation and Analysis of Interruption Characteristics for Industrial Customers

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Abstract

Electric power is an important element in any modern economy. The availability of a reliable power supply at a reasonable cost is important for the economic growth and development of a country. Electric power utilities throughout the world therefore strive to meet customer demands economically with high quality and reliability. As the power industry moves towards open competition, therefore, there has been a call for a methodology by which to evaluate power system reliability through the use of customer interruption characteristics. This paper presents the results of an investigation and analysis of interruption characteristics of an industrial customer in Korea. This study used a direct visit survey to determine the investigation and analysis of electric service quality and the characteristics of industrial customers in Korea. A customer survey conducted throughout Korea via personal interviews of 660 sample customers is presented here. Variation according to characteristics of interruption such as duration, time of day, frequency and day of interruption was also investigated

Key Words : Power System Reliability, Customer Survey Methodology, Personal Interview, Customer Characteristics.

1. Introduction

Along with the deregulation of electrical utilities, customers' willingness to pay for a higher level of reliability has increased due to their own particular electricity demands and the competitive mechanism of liberalization[1-3].

In light of these situations, ensuring reliability has been and will continue to be a priority for the restructuring of the electricity industry.

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Reliable electric power delivered on demand is a corner stone of electricity's ubiquitous adoption and use. A central feature in electricity's value to consumers, whether they are individual households or large industrial complexes, is the infrequent occurrence of outages or other power disturbances that interrupt the use of appliances, motors, electronics, or any other of the myriad end uses for which electricity is the primary energy source.

Accordingly, power utilities at home and abroad have made efforts to provide highly reliable power service. However, the electric equipment used by industrial customers these days is extremely sensitive to outages of even a very short duration, not to mention a duration of 5 minutes, the existing reliability standard, which results in loss.

For example, much of the manufacturing equipment used by industrial customers is very sensitive to any change in power service. Along with sustained outages, momentary outages also cause problems to high-tech electronic equipment such as the computers used by most industrial customers. As the load sensitive to momentary outages is expected to rise in the future, power companies must determine the effect of outages on industrial customers by outage duration, including momentary outage.

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

Therefore, this paper presents an investigation and analysis of interruption characteristics by industrial customer type through a customer survey methodology.

2. Main Discourse

2.1 Survey of interruption characteristics by industrial customer type

The purpose of this survey is to provide a base for the establishment of an economical and adequate power supply as well as optimal system planning by discovering information on industrial customers' power consumption and the effects of interruption.

2.1.1 Design of a survey questionnaire for industrial customers

Based on the questionnaire used by the University of Saskatchewan in Canada, a questionnaire was developed to fit the Korean market. Through many steps, a survey method and the appropriate questions were decided upon. 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 with 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.

2.1.2 Characteristics 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. Table 1 shows the customer types for the survey of interruption characteristics by industrial customers.

2.2 Analysis of interruption characteristics by industrial customer type

For the investigation and analysis of characteristics of industrial customers, these industrial customers were classified into 11 categories based on the examination of outage costs for each customer included in this year's technology development plan as follows: the manufacture of food and beverages, the manufacture of textiles and apparel, the manufacture of pulp and paper products, the manufacture of chemicals and chemical products, the manufacture of basic/fabricated metal products, the manufacture of other machinery and equipment, the manufacture of electric and

electronic equipment, the manufacture of equipment, the manufacture of electric machinery, the manufacture of audio and visual equipment, the manufacture of motor vehicles, and the manufacture of other transportation equipment.

2.2.1 Analysis of the existence of economic loss due to interruption

When the economic loss due to interruptions incurred by the survey respondents was analyzed, the higher the monthly power consumption, the greater the loss. When this was analyzed by industry type, 100[%] of the respondents in the motor vehicle category answered that interruption caused economic loss. Fig. 1 below shows the existence of economic loss due to interruption by monthly power consumption and by industry type.

Table 1. Characteristics 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, 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, trailers and engines, auto bodies, and automobile parts
11	Other transportation equipment	Manufacture of freight transportation and other transportation equipment

❖ Existence of economic loss by monthly power consumption

Division	Total	Existence	Nothing
10MWH below	257	219	38
10~100MWH below	183	166	17
100~1000MWH below	105	98	7
1~10GWH below	46	46	0
10GWH above	27	27	0
No response	42	33	9

❖ Existence of economic loss by industrial customer type

Customer type	Total	Existence	Nothing
Food and beverage	49	39	10
Textile and apparel	55	47	8
Pulp and paper products	38	25	13
Chemicals and chemical products	127	115	12
Basic/fabricated metal	52	50	2
Other machinery and equipment	49	41	8
Electric and electronic equipment	82	80	2
Electric machinery	53	44	9
Audio visual equipment	48	42	6
Motor vehicles	51	51	0
Other transport equipment	56	55	1

Fig. 1. Existence of economic loss due to interruption by monthly power consumption and by industry type

2.2.2 Analysis of economic loss due to interruption according to the time of occurrence

Survey respondents who experienced economic loss due to interruption were asked about the time of loss occurrence. 51.3[%] said that economic loss occurred within 1 minute after the interruption occurred, which means more than half of the respondents suffered economic loss within 1 minute of an interruption. On average, economic loss occurred after 13.1 minutes. In addition, the survey respondents who had not experienced economic loss from interruption were asked to estimate the time when loss would occur. 73.2[%]

said within 30 minutes with 39.9 minutes as the average. Fig. 2 below shows the time of loss occurrence and the estimated time of loss occurrence according to the experience or non-experience of loss from interruption.

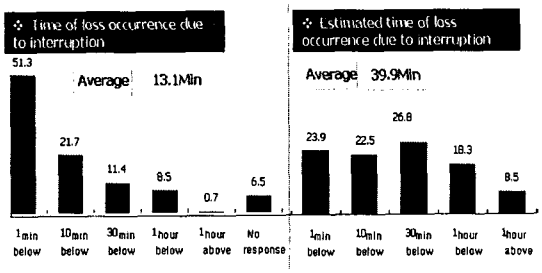


Fig. 2. Time of loss occurrence and the estimated time of loss occurrence according to the experience or non-experience of loss from interruption

2.2.3 Analysis of automatic restoration possibility according to interruption duration

Survey respondents were asked about the possibility of automatic restoration according to interruption duration. For an interruption of less than 30 minutes, the rate of automatic restoration dropped to under 20[%]. The percentage of no automatic restoration increased to over 50[%] from interruptions of less than 1 hour. Except for an interruption of less than 3 seconds, the percentage of almost full automatic restoration remained at about 20[%] even though the interruption duration increased. The analysis of the rates of automatic restoration after a temporary interruption of less than 3 seconds showed that the rate decreased as the amount of monthly power consumption increased. This means power interruption causes greater damage to larger-sized customers even though it is a temporary interruption of very short duration because automatic restoration is not possible. Fig. 3 shows the possibility of automatic restoration after a temporary interruption of less than 3 seconds, which is the most sensitive period during an interruption, by monthly power consumption and by monthly electric charge.

Division	No of Customer	Percentage of restoration due to number of customer(%)			
		No necessary	No automatic restoration	Partial restoration	Almost restoration
T o t a l	660	33.2	26.4	15.5	25.0
Power Consumption					
10MWH below	257	39.3	21.0	10.1	29.6
10~100MWH below	183	28.4	30.6	12.6	28.4
100~1000MWHbelow	105	34.3	20.0	26.7	19.0
1~10GWHbelow	46	10.9	43.5	28.3	17.4
10GWH above	27	3.7	55.6	29.6	11.1
No response	42	57.1	19.0	9.5	14.3
Average power rate					
490thousand won below	90	58.9	13.3	5.6	22.2
200~499 Thousand	139	35.3	29.5	9.4	25.9
500~1,990 Thousand	141	29.1	28.4	9.9	32.6
5,000~9,990 Thousand	81	29.6	22.2	17.3	30.9
10,000~99,990 Thousand	135	34.8	20.0	26.7	18.5
100,000 Thousand won	69	7.2	50.7	27.5	14.5
No response	5	-	20.0	20.0	60.0

Fig. 3. Analysis of automatic restoration possibility according to interruption duration

2.2.4 Analysis of the existence or non-existence of advance warning for interruptions and its effects on reduction of loss

Survey subjects were asked whether they had received advance warning about an interruption. The effects of interruption cost reduction by the timing of an advance warning were surveyed and analyzed by comparing the costs of a 1-hour interruption with advance warning and that without advance warning. Only 5.3[%] answered that they received advance warning for an interruption. It seems, therefore, that advance warning for industrial customers is highly inadequate. The effect of interruption cost reduction according to the timing of an advance warning was examined by asking the respondents who received advance warnings to compare a 1-hour interruption without advance warning and that with advance warning of different timing. The results showed that the earlier the advance warning given, the higher the reduction of interruption costs. Fig. 4 below shows the analysis of industrial customers' experiences or

non-experiences of advance warning. It also shows the amount that interruption costs were reduced with a 1-hour interruption without advance warning and that with advance warning according to the timing of the warning.

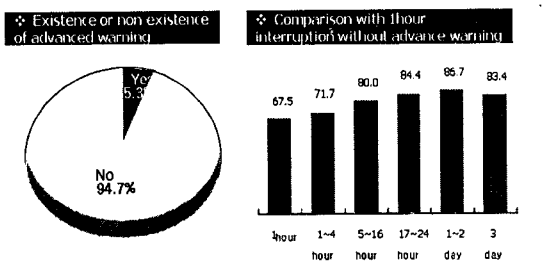


Fig. 4. Analysis of industrial customers' experience or non-experience of advance warning

2.2.5 Analysis of emergency power supply equipment, their types and installation costs

The survey subjects were asked whether they owned any kind of emergency power supply equipment in preparation for an interruption and the cost of the equipment if they owned any. The results were analyzed by industry type. Seven point eight percent(7.8[%]) said they owned emergency power supply equipment. These respondents were further asked about the emergency power supply equipment they owned. Seventeen respondents owned UPS/CVCFs and 15 respondents owned emergency generators. Of the UPS/CVCF owners, most owned 1 unit while 11 respondents owned more than 2 units. Thirty-five point three percent(35.3[%],) the highest percentage, of the cost of UPS/CVCF installation was between 10 million~20 million won. Of the emergency generator owners, 12 of the 15 owned 1 unit. Thirty-three point three percent(33.3[%]), the highest percentage, of the cost of generator installation was between 20 million~100 million won. Fig. 5 shows the existenceor non-existence of emergency power supply equipment and their type. Fig. 6 and Fig. 7 show the costs of UPS/CVCF and emergency generator installation.

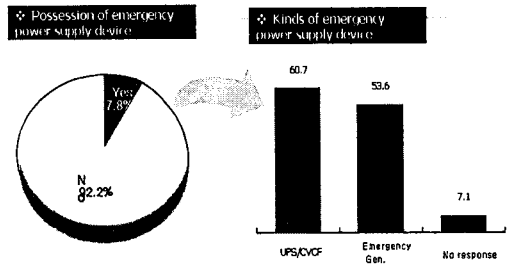


Fig. 5. Existence and type of emergency power supply equipment

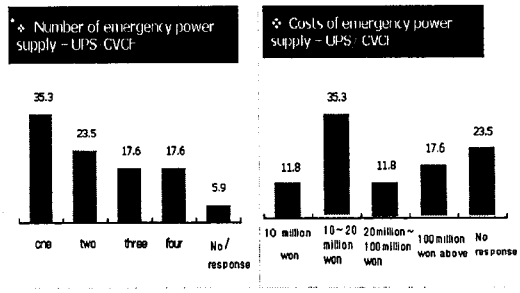


Fig. 6. Installation and costs of UPS/CVCF

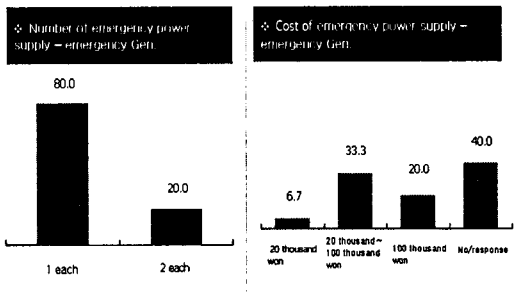
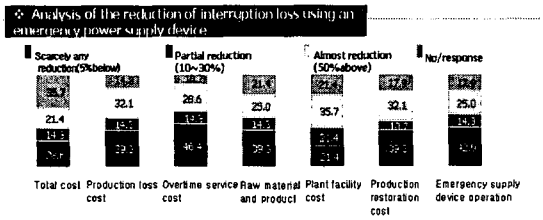


Fig. 7. Installation and costs of emergency generators

2.2.6 Analysis of the reduction of interruption loss through the use of emergency power supply equipment

The survey subjects who owned emergency power supply equipment for the event of a power

interruption were asked about how much interruption costs could be reduced through the use of the emergency power supply equipment. Thirty-five point seven percent(35.7[%]) said they could reduce interruption costs partially but 35.7[%] did not know or did not respond. This result shows that it is difficult to assess interruption costs reduction through an emergency power supply. The respondents who answered they could reduce about 50[%] of interruption costs through an emergency power supply were asked about the area of reduction. The highest percentage, 35.7[%], answered that it was in the plant facility cost area, which was followed by 32.1[%] reporting it to be in the production restart cost area and production loss area. Fig. 8 below shows the total amount of interruption costs reduction by emergency power supply equipment and the area of reduction.



Division	Scarcely any reduction (5%below)	Partial reduction (10~30%)	Almost reduction (50%above)	No/ response
Total Cost	28.6	14.3	21.4	35.7
Production loss cost	39.3	14.3	32.1	14.3
Overtime service cost	46.4	14.3	28.6	10.7
Raw material & product	39.3	14.3	25.0	21.4
Plant facility cost	21.4	21.4	35.7	21.4
Production restoration	39.3	10.7	32.1	17.9
Emergency power supply operation cost	42.9	14.3	25.0	17.9

Fig. 8. Analysis of the interruption costs reduction of interruption loss using an emergency power supply

2.2.7 Analysis of the reason for operating emergency power supply equipment and the effect thereof

Those survey subjects who owned emergency power supply equipment were asked about the reason for operating this equipment and the effects of the operation thereof. The highest percentage, 42.9[%], answered that the reason was "to reduce the loss of "equipment/production", which was followed by 32.1[%] answering "to avoid danger to workers". As for the effect of the operation of an emergency power supply, it had the greatest effect on the reduction of the loss of "equipment/ production." Fig. 9 below shows the reasons for operating emergency power supply equipment and the effect of its operation.

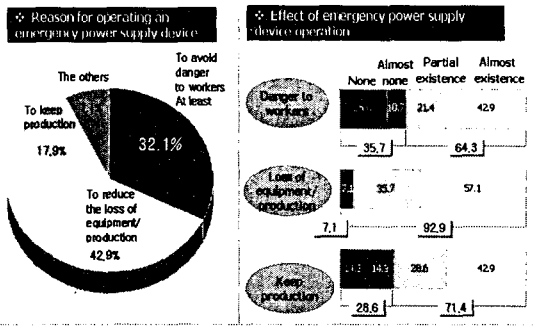


Fig. 9. Analysis of the reason for operating an emergency power supply and the effect of its operation

3. CONCLUSION

Electric power is an important element in any modern economy. The availability of a reliable power supply at a reasonable cost is important for the economic growth and development of a country. Electric power utilities throughout the world therefore strive to economically meet customer demands with a high quality, reliable power supply.

Ensuring reliability has been and will continue to be a priority for electricity industry restructuring. Reliable electric power delivered on demand is a cornerstone of electricity's ubiquitous adoption and use. A central feature in electricity's value to customers, whether they are individual

households or large industrial complexes, is the infrequent occurrence of outages or other power disturbances that interrupt the use of appliances, motors, electronics, or any of the myriad other end uses for which electricity is the primary energy source.

In recent years, the level of power service reliability in advanced countries and Korea has been quite high. Accordingly, in order to raise the reliability level beyond the current level, the investment necessary to expand power facilities must increase drastically. However, the level of advantage that customers receive from improved reliability is not as high as compared to the amount of investment necessary. This is because the increase of investment for facility expansion increases the cost of the power supply, which in turn causes an increase of electric utilities fees for customers.

From this point, it is not advantageous to customers. Therefore, it is important to plan and operate power facilities in consideration of a balance between the advantages customers will gain from improved reliability and the cost increase that customers will bear. In other words, it is necessary to decide the size of power supply facilities that minimizes the total costs customers must pay, which are the sum of the power supply costs and customer interruption costs.

It is necessary to establish a plan in consideration of service reliability. For this, the interruption characteristics must be reviewed from the customer's standpoint. Accordingly, this paper presents the results of an investigation and analysis of interruption characteristics for industrial customers in Korea. The results of this paper can be summarized as follows.

(1) Economic loss due to interruptions suffered by the survey respondents was analyzed, and it was found that the higher the monthly power consumption, the greater the loss. When this was analyzed by industry type, 100[%] of the respondents in the motor vehicle category answered that interruptions caused economic loss.

(2) Concerning respondents who have experienced economic loss due to interruption, 51.3[%] said that economic loss occurred within 1 minute after the interruption occurred, which means more than half of the respondents suffered economic loss within 1 minute of an interruption.

(3) For an interruption of less than 30 minutes, the rate of automatic restoration dropped to under 20[%]. The percentage of no automatic restoration increased to over 50[%] from the interruption of less than 1 hour, as well.

(4) For the effect of the timing of advance warning on interruption costs, the results showed that the earlier the advance warning given, the higher the interruption costs reduction.

(5) Referring to the analysis of emergency power supply equipment, their types and installation costs, 17 respondents owned UPS/CVCFs and 15 respondents owned emergency generators. Of the UPS/CVCF owners, most owned 1 unit while 11 respondents owned more than 2 units. Thirty-five point three percent(35.3[%]), the highest percentage, of the cost of UPS/CVCF installation was between 10 million~20 million won. Of the emergency generator owners, 12 of 15 owned 1 unit. Thirty-three point three percent(33.3[%]), the highest percentage, of the cost of generator installation was between 20 million~100 million won.

(6) Respondents who answered they could reduce about 50[%] of interruption costs through an emergency power supply were asked about the area of reduction. The highest percentage, 35.7[%], answered that it was in the plant facility cost area, which was followed by 32.1[%] reporting that it was in the production restart cost area and production loss area.

(7) Referring to the reason for operating emergency power supply equipment and the effect of its operation, the highest percentage, 42.9[%], answered that the reason was "to reduce the loss of equipment/production", which was followed by 32.1[%] answering "to avoid danger to workers".

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Biography

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