Annex C

Cost of Electrical Interruptions in Commercial Buildings

By
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COST OF ELECTRICAL INTERRUPTIONS IN COMMERCIAL BUILDINGS

by

Power Systems Reliability Subcommittee Report
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Abstract

An IEEE sponsored reliability survey to determine the cost of electrical interruptions in commercial buildings was completed in 1974. The survey form was a simplified version of forms used in 1972 reliability study of industrial plants. The survey included building types and locations, and length and cost of electrical service interruptions. The survey results reflect data from 48 companies covering 55 buildings in the United States. This information is useful in the design of electrical systems for commercial buildings.

Introduction

Knowledge of the cost of power outages, both for normal and critical services, is useful in the design of commercial building power systems, allowing cost-effective judgements to be made with respect to the installation of a second utility company service, an emergency generator, or possibly an uninterruptible power supply.

During 1974, the Reliability Subcommittee of the Industrial and Commercial Power Systems Committee completed a survey of the cost of electrical interruptions in commercial buildings in the United States. Included in this paper are the following results:

1 Cost of power outages to commercial buildings ($ per KWH of undelivered energy).

2 Cost of power outages to commercial buildings ($ per square foot/hr and $ per employee/hr).

3 Critical service loss duration time (length of time before an interruption causes a significant loss).

5 Miscellaneous items relative to provision of auxiliary generators, types of electrical service, and other physical data.

Survey Form

The survey form is shown in Appendix A (two pages). A simple multiple choice or single line fill-in form was utilized in an attempt to reduce the time of the responders, but still provide pertinent data for a meaningful analysis.

Response to Survey

A total of 48 companies reporting on 55 buildings responded to the survey with complete data. Incomplete data, omitting the critical outage cost information was received on 121 additional buildings. Unfortunately, this data was of no value in the present survey. Valid data was submitted almost equally for buildings located in the eastern, central, and western regions of the U.S.A.; with 43 percent of the buildings in downtown areas, 17 percent in urban areas, and 40 percent in suburban areas. Forty-six percent of the buildings were used 5 days per week; 39 percent, 6 days per week; and 15 percent, 7 days per week.

Survey Data Preparation

All of the returned survey forms were reviewed. Useable data was punched onto computer cards for use in data processing.

Survey Results -- Cost of Power Outages

Each respondent was asked to report on the cost of power outages as follows:

1 Dollars per failure -- 15-minute duration, one-hour duration, and greater than one-hour duration; total value of lost operation including wages, damages for delays, loss of computer time, and loss of retail sales minus cost of goods not sold was to be included.

2 Critical service loss duration time -- length of time before an interruption causes a significant loss.

3 Building maximum power demand, and usage, as well as area and number of employees.

The data made it possible to calculate the cost of power outages in terms of dollars per kilowatt-hours of undelivered energy at building peak load.

The average cost of power outages from the survey for the buildings surveyed is given in Table 1.

TABLE 1

AVERAGE COST OF POWER OUTAGES
FOR BUILDINGS IN THE UNITED STATES

All commercial buildings	$7.21/KWH not delivered
Office buildings only	$8.86/KWH not delivered

The average maximum demand was 3,095 KW for all commercial buildings reporting outage costs. The maximum demand for the office buildings was only 3,035 KW.

Additional details of the cost of power outages are given in Tables 2, 3, and 4. The tables present additional data including:

1 Outage costs for "office buildings" as a function of duration of outage for three time periods.

2 Effect of computers on outage costs.

3 Relationship of outage costs to: KWH not delivered, to cost per 1,000 square feet per hour of building affected, and to cost per employee per hour affected.

1/ Other members of Sub-Committee: A.D. Patton Chairman; C.R. Heising, Vice Chairman; C.E. Becker; M.F. Chamov; W.H. Dickinson; M.D. Harris; R.T. Kulvicki; D.W. McWilliams; R.W. Parisian; Stanley Wells

TABLE 2

OUTAGE COSTS FOR "OFFICE BUILDINGS"
AS A FUNCTION OF DURATION
(WITH AND WITHOUT COMPUTERS)

	Sample Size	Maximum	Minimum	Average
15-Minute Duration				
Cost/peak KW hr. not delivered	25	$ 22.22	$ 1.50	$ 7.54
Cost/1,000 sq. ft. of bldg./hr.	26	247.6	10.5	63.8
Cost/employee/hr.	26	52.0	3.0	16.0
1-Hour Duration				
Cost/peak KW hr. not delivered	29	$ 24.93	$ 0.64	$ 6.74
Cost/1,000 sq. ft. of bldg./hr.	32	125.00	5.24	53.12
Cost/employee/hr.	32	34.30	1.25	12.22
Duration 1 Hour				
Cost/peak KW hr. not delivered	13	$100.00	$ 0.16	$ 16.16
Cost/1,000 sq. ft. of bldg./hr.	14	320.00	1.05	68.06
Cost/employee/hr.	14	75.80	0.48	16.41

TABLE 3

OUTAGE COSTS FOR "OFFICE BUILDINGS"
AS A FUNCTION OF DURATION
(WITHOUT COMPUTERS)

	Sample Size	Maximum	Minimum	Average
15-Minute Duration				
Cost/peak KW hr. not delivered	11	$ 10.70	$ 1.50	$ 5.84
Cost/1,000 sq. ft. of bldg./hr.	11	107.4	10.54	49.54
Cost/employee/hr.	11	28.56	3.00	12.56
1-Hour Duration				
Cost/peak KW hr. not delivered	13	$ 13.33	$ 0.91	$ 5.30
Cost/1,000 sq. ft. of bldg./hr.	15	120.0	5.24	49.42
Cost/employee/hr.	15	28.57	1.25	10.64
Duration 1 Hour				
Cost/peak KW hr.	3	$100.00	$ 1.97	$ 36.66
Cost/1,000 sq. ft. of bldg./hr.	3	320.00	48.00	156.00
Cost/employee/hr.	3	50.00	4.00	27.52

TABLE 4

OUTAGE COSTS FOR "OFFICE BUILDINGS"
AS A FUNCTION OF DURATION
(WITH COMPUTERS)

	Sample Size	Maximum	Minimum	Average
15-Minute Duration				
Cost/peak KW hr. not not delivered	14	$ 22.22	$ 1.88	$ 8.89
Cost/1,000 sq. ft. of bldg./hr.	15	250.00	16.57	78.21
Cost/employee/hr.	15	52.00	4.00	18.53
1-Hour Duration				
Cost/peak KW hr. not delivered	16	$ 24.93	$ 1.88	$ 8.30
Cost/1,000 sq. ft. of bldg./hr	17	125.00	15.88	54.52
Cost/employee/hr.	17	34.30	4.00	13.62
Duration 1 Hour				
Cost/peak KW hr. not delivered	10	$ 67.66	$ 0.16	$ 9.81
Cost/1,000 sq. ft. of bldg./hr.	11	226.19	1.05	44.08
Cost/employee/hr.	11	75.82	0.48	12.70

TABLE 5

CRITICAL SERVICE LOSS DURATION TIME
FOR "ALL BUILDINGS"

	Service Loss Duration Time								
	1 Cycle	2 Cycles	8 Cycles	1 Sec.	3 Sec.	5 Min.	30 Min.	1 Hour	12 Hours
Percent of buildings with critical service loss duration less than or equal to the time indicated.	3%	6%	9%	15%	18%	36%	64%	79%	100%

TABLE 6

CRITICAL SERVICE LOSS DURATION TIME
FOR "OFFICE BUILDINGS"

	Service Loss Duration Time								
	1 Cycle	2 Cycles	8 Cycles	1 Sec.	3 Sec.	5 Min.	30 Min.	1 Hour	12 Hours
Percent of buildings with critical service loss duration less than or equal to the time indicated.	5%	10%	15%	25%	30%	50%	70%	75%	100%

TABLE 7

RELATIONSHIP OF AUXILIARY GENERATORS
AND SINGLE FEEDER SERVICE TO "ALL BUILDINGS"

	Number of Responses	Buildings with Auxiliary Generation	No Auxiliary Generation and Only Single Feeder
Buildings with computers	23	15	1
Buildings without computers	32	13	7
TOTAL	55	28	8

Survey Results -- Critical Service Loss Duration Time

The amount of time an electrical service can be interrupted before it causes significant losses is a question which our profession has not been able to suitably define. The results of the survey indicate that individual requirements for electrical energy are such that it is probably not possible to establish a general critical service loss duration time. The survey results are shown in Tables 5 and 6.

TABLE 8

TYPE OF ELECTRICAL SERVICE
TO "ALL BUILDINGS"

	Number of Responses	Type of Service			
		Single Feeder	Network	Multiple Feeder	Other
Buildings with computers	23	1	8	12	2
Buildings without computers	32	12	10	7	3
TOTAL	55	13	18	19	5

TABLE 9

PHYSICAL DATA -- "ALL BUILDINGS"

Item	Sample Size	Maximum	Minimum	Average
Area, sq. ft. x 10^3	54	2,085	3	400
Number of floors	55	52	1	12
Number of employees	51	7,000	12	1,384
Annual usage - Megawatt hours	52	101,349	210	11,973
Peak Kilowatt demand	52	17,250	95	3,095

TABLE 10

PHYSICAL DATA -- "OFFICE BUILDINGS"

Item	Sample Size	Maximum	Minimum	Average
Area, sq. ft. x 10^3	35	1,600	38	371
Number of floors	35	44	2	13
Number of employees	35	7,000	150	1,651
Annual usage - Megawatt hours	32	51,046	840	9,444
Peak Kilowatt demand	32	17,000	270	3,035

TABLE 11

AVERAGE OF PHYSICAL DATA
FOR "ALL BUILDINGS"
AND FOR "OFFICE BUILDINGS"

Item	All Buildings	Office Buildings
Megawatt hours/1,000 sq. ft. of buildings area/year	35.5	33.5
Megawatt hours/employee/year	20.2	7.5
Peak Kilowatt demand/1,000 sq. ft. of building area	11.3	11.5
Peak Kilowatt demand/employee	5.0	2.5
Employees/1,000 sq. ft. of building area	3.9	4.7

Thirty-six percent of "all buildings" reporting could be without electrical energy for 5 minutes before the lack of energy was considered to be critical, while 6 percent could be without energy for only 2 cycles and 3 percent for only one cycle before significant losses were incurred.

Fifty percent of the "office buildings" reporting could be without electrical energy for 5 minutes before the lack of energy was considered to be critical, while 10 percent could be without energy for only 2 cycles, and 5 percent for only one cycle before significant losses were incurred.

Precautionary measures taken to minimize critical outages in buildings where computers are installed are indicated in Table 7, where 65 percent (15 of 23) of the buildings reporting have auxiliary generating units. Only 4 percent (1 of 23) of the buildings reporting have no auxiliary generation and are served by a single feeder from the utility company. A like comparison is shown for buildings not having computers; in these instances, 41 percent of the buildings have auxiliary generation and 22 percent are served by single feeders from the utility company.

Table 8 shows the type of electrical service to all buildings reporting. Eighty-seven percent of the buildings with computers have network or multiple feeder service, while 53 percent of the buildings without computers have network or multiple feeder service.

Survey Results -- Demand and Usage Data

Each respondent was asked to report gross floor area, number of floors, number of employees, and electrical energy usage and demand. While not directly related t the subject of this paper, the data is of interest, an will perhaps allow the reader to make a better judgement of the validity of the data presented previously. The details are given in Tables 9, 10, and 11.

It is believed that the employee data for the "All Buildings" category may not be valid, since it appears that not all employees were reported for some multi-function buildings, the office/retail category in particular.

Conclusions and Discussion of Results

1 Cost of Power Outages (Tables 1, 2, 3, and 4)

a There is a wide spread in the cost of power outages (KWH not delivered) in commercial buildings. Even within like types of buildings, with or without computers, there is a great difference in the costs assigned.

b The cost per KWH not delivered increases greatly when the outage duration time exceeds one hour. An exception to this is buildings with computers.

It is probable that for outages of less than one hour, employees may remain partially productive and the temperature of their environment remains tolerable. For longer outages, employees may have to be furloughed for the remainder of the day.

c The cost of power interruptions for buildings with computers varies from $8.89/KWH average for outages of 15-minutes duration to $9.81/KWH for outages of greater than one hour. It is suspected that the small differential is due to the fact that a short duration as well as a long outage renders the computer inoperable, and the employees are either non-productive during this period or repairing possible damage caused by the outage.

d A comparison of the average costs of outages for commercial buildings with that for industrial plants (Reference 1)[2] is shown in Table 12. The data is interpreted to mean that short-term outages in industrial plants could be more costly than those in commercial buildings, while long-term outages are more costly in commercial buildings.

e Additional information on the cost of power outages in Sweden, Norway, and the United States is contained in Reference 3.

2 Critical Service Loss Duration Time (Tables 5 and 6)

a As would be expected, there is a wide spread in the critical time of a power interruption. This is probably due to the wide variations of type of work being accomplished, the type of equipment involved, and the general work environment. For example, a windowless building in which a sensitive computer operation is performed would be more rapidly affected than a window-wall building performing normal office functions.

b It is suggested that a future survey attempt to define the reasons for the wide variances.

3 Demand and Usage Data (Tables 9, 10, and 11)

a Of the "all building" data reported, the areas averaged 400,000 square feet, 12 floors in height, with an annual usage of almost 12,000 megawatt hours, and a demand of 3,095 KW. Minimum and maximum data were not available.

TABLE 12

COMPARISON OF AVERAGE COSTS OF POWER OUTAGES
IN COMMERCIAL BUILDINGS AND INDUSTRIAL PLANTS

Type	Cost
All commercial buildings	$7.21/KWH not delivered
Office buildings	$8.86/KWH not delivered
Industrial plants — all	$1.89/KW interrupted + $2.68/KWH not delivered

The data for "office buildings" indicate average values within 10 percent of that for "all buildings," except for the number of employees, which is 16 percent greater.

b The average electrical usage for all buildings and for office buildings only is nearly equal when placed on a per unit basis (33.5 KWH/Sq. Ft.) as is the peak demand (11.3 Watts/Sq. Ft. to 11.5 Watts/Sq. Ft.). The relationship of usage and demand to employees does not correlate for all buildings and office buildings only. As mentioned heretofore, the validity of employee data with regard to the Office/Retail category of buildings is questionable. On this basis, no attempt to draw conclusions has been made.

References

1 A.D. Patton, et al, "Report of Reliability Survey of Industrial Plants, Part 4 - Additional Detailed Tabulation of Some Data Previously Reported in the First Three Parts," IEEE I & CPS Conference Record, June 2-6, 1974.

2 W.H. Dickinson, et al, "Report of Reliability Survey of Industrial Plants, Part 2 - Cost of Power Outages, Plant Restart Time, Critical Service Loss Duration Time, and Type of Loads Lost vs. Time of Power Outages," IEEE I & CPS Conference Record, May 14-16, 1973.

3 R.B. Shipley, A.D. Patton, J.S. Denison, "Power Reliability Cost vs. Worth," IEEE Transactions on Power Apparatus and Systems, PAS-91, P. 2204-2212, September/October 1972.

SURVEY FORM ON COST OF ELECTRICAL INTERRUPTIONS IN COMMERCIAL BUILDINGS

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

INDUSTRY AND GENERAL APPLICATIONS GROUP

RELIABILITY SUBCOMMITTEE OF THE INDUSTRIAL & COMMERCIAL POWER SYSTEMS COMMITTEE

Electricity is an integral part of our every day life. If it isn't available -- what is its economic effect? Please help us to find out by filling out this form.

Please address reply to:

A. D. Patton
Texas A & M University
Electric Power Institute
College Station, TX 77843

Date _____

1. COMPANY NAME (Fill in 3-letter abbreviation of name) _____

2. BUILDING NO. (Fill in sequence number 1, 2, 3, etc. for building(s) reported on) _____

3. BUILDING TYPE (Check type which best describes your building):

☐ Office ☐ Office/Retail Sales ☐ Office/Retail Sales/Apartment

☐ Retail Sales ☐ Other (describe) _____

4. BUILDING LOCATION (Check applicable items):

☐ Downtown; ☐ Urban; ☐ Suburban;

☐ USA: Eastern; ☐ USA: Central; ☐ USA: Western

5. BUILDING DATA - GENERAL

Gross Area, square feet _____

Number of Floors _____

Average Usage of Building: Hours/Day _____ Days/Week _____

Estimated Number of Office Employees (if any) _____

Estimated Annual Retail Sales (if any) _____

Is Auxiliary or Emergency Generation Provided: ☐ Yes ☐ No

SURVEY FORM - COMMERCIAL BUILDINGS IN USA Page 2 of 2

6. BUILDING ELECTRICAL USAGE DATA

Electrical Energy Usage for 12-month Period _____ KWH

Electrical Maximum Demand for this Period _____ KW

Type of Service: ☐ Single Feeder; ☐ Network; ☐ Multiple Feeders With Automatic Transfer

☐ Other (Explain) _____

7. COST OF A TOTAL INTERRUPTION OF ELECTRICAL SERVICE TO YOUR BUILDING DURING PEAK PERIOD: (Best Opinion - If no interruptions have occurred, assume hypothetical instances)

a) 15-Minute Duration $ _____

b) 1-Hour Duration $ _____

c) _____ Hours Duration $ _____

Does a, b, or c include losses from an "on-line" electronic computer? ☐ Yes ☐ No

For "Office Buildings" loss should include wages of all employees affected, plus any other direct costs incurred including delays, and damage to equipment. This would include any losses from an "on-line" electronic computer.

For "Retail Sales" cost should include estimated loss of sales minus cost of goods not sold, plus cost of any damage incurred.

8. LENGTH OF INTERRUPTION OF ELECTRICAL SERVICE

If there a definitive length of time before an interruption causes a significant loss? ☐ Yes ☐ No

If "Yes", what is maximum time before significant losses will be incurred? _____ Hours _____ Minutes

