Electric Power Interruption Cost
and
Its Correlation with the System Reliability

by

Akhil Chandra Das

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The thesis titled **"Electric Power Interruption Cost and Its Correlation with the System Reliability"** submitted by Akhil Chandra Das, Roll No. 100006103P, Session: October 2000, Department of Electrical and Electronic Engineering, BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING on July 10, 2004.

Board of Examiners

1. ______ 10/7/2004 — Chairman (Supervisor)
(Dr. Md. Quamrul Ahsan)
Professor
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Bangladesh University of Engineering and Technology

2. ______ 10/7/2004 — Member (Ex-officio)
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Bangladesh University of Engineering and Technology

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Department of Electrical and Electronic Engineering
Bangladesh University of Engineering and Technology

4. ______ 10/7/04 — Member
(Dr. Aminul Hoque)
Professor
Department of Electrical and Electronic Engineering
Bangladesh University of Engineering and Technology

5. ______ 10/7/04 — Member (External)
(Engr. Md. Ataul Masud)
Superintending Engineer
Dhaka Electric Supply Authority
Dhaka

DECLARATION

This is to certify that this research work has been performed by me and it has not been submitted elsewhere for the award of any degree or diploma excepting for publication.

Countersigned

Signature of the Student

10/7/2004

10.07.2004

(Prof. Dr. Md. Quamrul Ahsan)

Supervisor

(Akhil Chandra Das)

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The Author

DEDICATION

Dedicated to my late parents

ABSTRACT

Electricity is essentially required for the existence of the modern society. Continuous electric supply is a measure of production in industry, profit in the business and day-to-day comfort in the household works. The uninterrupted electric supply is a desire of a consumer.

The electric power interruption may create a significant loss to the consumers of different sectors. In this study, the types of losses in the residential, industrial and commercial sectors are identified to evaluate the losses due to power interruption into monetary terms. The major loss components are damage of electrical appliances, cost of alternative sources used, damage of perishable goods/damage of raw materials under process and loss due to inconveniences/additional wages. In order to evaluate the loss due to power interruption, a mathematical model is developed. A questionnaire is developed to collect information relating to power interruption. The evaluated loss is compared with the electricity bills paid by the consumers. Also, correlation between the cost of interruption of power for consumers of different sectors and the reliability indices of power supply is established.

The outcome of this research will be a guideline to the power system planners to justify a plan of increased reliability level. The research will also create awareness among the consumers by observing the losses into monetary terms, incurred to them due to power interruption.

CONTENTS

LIST OF SYMBOLS

Symbol	Description	Page
C_{FAL}	Cost of fuel for a unit duration of use	11
NI_{AL}	Number of interruption during the lifetime of an alternative source	11
T_1	Average duration of interruption	11
w	Rating of an alternative source (charger)	11
t	Time to charge the charger	11
r	Per unit (kWh) cost of electricity	11
t_1	Used time during power interruption period	11
H_{AL}	Total duration of alternative used	11
H_I	Total duration of interruptions	11
$\hat{J}_2$	Cost due to the use of alternative source per hour of interruption for residential sector	12
J_3	Cost of the loss of perishable goods	12
C_{PG}	Cost of perishable goods	12
I(D)	Characteristic function	12
D	Duration of interruption	12
$\bar{D}$	Duration required for an item to be perished	12
$\hat{J}_3$	Cost of the loss of perishable goods per hour of interruption for residential sector	12
J_{IN_1}	Cost of the loss due to inconvenience in study or computer work or accounting	13
C_{TR}	Additional charge for transport	13
C_M	Cost of medication	13
M	Number of members of a residence suffered from the inconvenience	13
J_{IN_2}	Cost relating to inconvenience in sewing	13
CT	Charge of the tailor	13
K	Number of members suffered from the inconvenience in sewing	13
J_{IN3}	Equivalent cost of inconvenience in dinning or cooking	13
C_F	Cost of the cooking material run to waste	13
C_{OF}	Cost of outside food	13
ID	The interruption duration creating wastage of food	14
J_{IN4}	Loss in the family function	14
C_D	Cost of decoration	14
C_F	Cost of food	14

Symbol	Description	Page
C_A	Charge of outside artist	14
J_4	Total inconvenience cost	14
$\hat{J}_4$	Total inconvenience cost per hour of interruption for residential sector	14
W_i	Wage of i_{th} worker per unit time	14
L	Duration of running an industry to compensate power interruption	14
J_4'	Cost due to additional wages per hour of interruption for industrial sector	15
J_{N_1}	Cost relating to the loss due to reduced sales	15
L'	Loss of profit per customer who did not come into the shop during the interruption period	15
C	Probable number of customer not appeared in the shop during the interruption period	15
m	Number of shops of a commercial consumer suffered from the difficulties due to reduced sales	15
J_{N_2}	Cost relating to increased overhead expenditure	15
S	Salary per sales man for overtime works	15
T_O	Overtime	15
n	Number of sales men working in the shop	15
J_4''	Cost due to reduced sale and additional wages per hour of interruption for commercial sector	16
H_S	Total duration of operation of appliances in hour	16
H_O	Daily operating hour of appliances of a consumer	16
P_I	Probability of interruption	16
R	Reliability of power system	16
Ar	Class of the residential respondent whose floor area is below 1000 sq. ft.	49
Br	Class of the residential respondent whose floor area is between 1000 – 1500 sq. ft.	49
Cr	Class of the residential respondent whose floor area is above 1500 sq. ft.	49
Dr	Class of the residential respondent whose connected load is less than 3 kW	49
Er	Class of the residential respondent whose connected load is between 3 – 5 kW	49

Symbol	Description	Page
Fr	Class of the residential respondent whose connected load is above 5 kW	49
Gr	Class of the residential respondent whose monthly electricity bill is less than Taka 500.00	49
Hr	Class of the residential respondent whose monthly electricity bill is between Taka 500.00 – 1000.00	49
Ir	Class of the residential resident whose monthly electricity bill is more than Taka 1000.00	49
J	Total cost of interruption of power	52
j	Total cost per interruption for residential respondent	52
Ai	Class of the industrial respondent whose floor area is below 2000 sq. ft.	55
Bi	Class of the industrial respondent whose floor area is between 2000 – 5000 sq. ft.	55
Ci	Class of the industrial respondent whose floor area is above 5000 sq. ft.	55
Di	Class of the residential respondent whose connected load is less than 20 kW	55
Ei	Class of the industrial respondent whose connected load is between 20 – 50 kW	55
Fi	Class of the industrial respondent whose connected load is above 50 kW	55
Gi	Class of the industrial respondent whose monthly electricity bill is less than Taka 20000.00	55
Hi	Class of the industrial respondent whose monthly electricity bill is between Taka 20000.00 – 60000.00	55
Ii	Class of the industrial resident whose monthly electricity bill is more than Taka 60000.00	55
j'	Total cost per interruption for industrial respondent	59
Ac	Class of the commercial respondent whose floor area is below 500 sq. ft.	61
Bc	Class of the commercial respondent whose floor area is between 500 – 1000 sq. ft.	61
Cc	Class of the commercial respondent whose floor area is above 1000 sq. ft.	61
Dc	Class of the commercial respondent whose connected load is less than 3 kW	61
Ec	Class of the commercial respondent whose connected load is between 3 – 8 kW	61

Symbol	Description	Page
Fc	Class of the commercial respondent whose connected load is above 8 kW	61
Gc	Class of the commercial respondent whose monthly electricity bill is less than Taka 1000.00	61
Hc	Class of the commercial respondent whose monthly electricity bill is between Taka 1000.00 – 5000.00	61
Ic	Class of the commercial resident whose monthly electricity bill is more than Taka 5000.00	61
x	Average interruption cost per hour	82
y	Hourly average electricity bill paid	82
$	Dollar	100
a	Inconvenience in study for residential sector	101
b	Inconvenience in dinning for residential sector	101
c	Inconvenience in cooking for residential sector	101
d	Inconvenience in sewing for residential sector	101
e	Inconvenience in computer works for residential sector	101
f	Inconvenience in enjoying TV, video games etc. for residential sector	101
g	Inconvenience in accounting for residential sector	101
h	Inconvenience in other problem for residential sector	101
a''	Inconvenience in sales and display for commercial sector	102
b''	Inconvenience in transaction for commercial sector	102
c''	Inconvenience in accounting for commercial sector	102
d''	Inconvenience in security for commercial sector	102
e''	Inconvenience in other problem for commercial sector	102

LIST OF ABBREVIATION

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electricity is a basic need for the strong economical foundation of modern civilization. Today's modern life cannot be run without the electricity even for a moment. Living standard of a country depends on how much electrical energy is used by the people. Therefore, it is very important to ensure the quality of electric supply to the consumers.

The main function of a modern electric power supply system is to provide an adequate supply of electrical energy to its consumers at an optimal price with a reasonable level of continuity and quality. Quality, in this case, refers to a constant magnitude of voltage and frequency. Electrical Energy Management System ensures supply of energy to every consumer at all times at rated voltage, rated frequency and specified wave form. The continuity in power supply is a desire of a consumer. Although, in practice it is not possible to get uninterrupted electric supply all the times, but the frequency and duration of power interruption should be limited to an acceptable level. With the increasing dependence of industry, agriculture and day-to-day household comfort upon the continuity of electric supply, the reliability of power system has assumed great importance.

To improve the reliability level, the utility requires more investment. On the otber hand, if reliability of supply is low, the loss of the consumers due to power interruption increases. It is a decision variable to optimize the cost of interruption with the system reliability.

1.2 Critical Review

A list of publications relating to the theory and survey concerned with determining the impacts and estimating the costs to consumer of electrical service interruptions is presented in [1, 2].

E. V. Maduike, T. C. Nwodo and E. E. Ilochi [3] presented the estimation of consumer's loss due to power interruption. They evaluated losses by surveying respondents and the losses are expressed in terms of percentage of their monthly salary. They assumed tbe losses by approximations depending on the information given by the respondents. Again, they showed the standardized cost impact graphically to present the nature of the cost of interruption according to the social/income levels.

Arun P. Sanghvi, Neal J. Balu and Mark G. Lauby [4] presented some selected results from a completed research project for the electric power research institute. They intended to develop and test methodologies for gathering data on how utility customers value service reliability, as measured by either the cost of outage or the willingness to pay for reliability. The authors reported some interruption costs by using survey method. The paper highlighted the results of the survey, including the survey design. It also discussed potential applications of interruption costs in generation and composite reliability planning.

G. Tollefson, R. Billinton, G. Wacker, E. Chan and J. Aweya [5] approached a common survey method to determine interruption costs of the customers of residential, commercial and industrial sectors. The customer survey approach is utilized as the basic methodology of this study. The paper presented the overall results of these surveys with emphasis on the cost results.

R. Billinton, E. Chan and G. Wacker [6] introduced an approach of consumer cost calculation recognizing that the interruption cost data is dispersed in nature. They assumed that the sampling procedure of survey of the consumer provides truly random interruption cost data and that consumer cost variations can be described by continuous probability distributions.

K. K. Kariuki and R. N. Allan [7] presented the study on the characteristics of the residential consumers. They experienced the interruptions as well as variations of undesirability of effects with frequency of interruption, season, time of day and weekend. They discussed issues like qualitative information associated with residential consumers. But, they did not provide any statistical analysis of data. The authors only assessed the faithfulness of data by comparing the correlation of some variables.

K.K. Kariuki and R. N. Allan [8] identified the factors that affect consumer's perceived costs caused by interruption of supply. They collected opinions of consumers on various issues, such as price and quality. The paper observes that the consumers are only concerned about their inability to use their equipments and the costs of likely damages from interruption of supply. According to the remarks of the authors, the actual method of valuation of consumer is more appropriate than evaluate the benefits of consumers of reliability investment by putting a worth value on the "energy not supplied".

Sandra Burns and George Gross [9] presented the value of service reliability by incorporating customer choices and service costs. This approach permits utilities to plan for level of reliability commensurate with the customer's willingness to pay. It is also incorporated the consideration of emergency actions invoked by operators whenever reserve of the generation fall below specified target levels. The methodology described in this paper is based on the use of an average customer outage cost which is related to the reserve margin of the generation.

J. Gates, R. Billinton and G. Wacker [10] investigated the costs of electric service interruptions in the government, institution and office (GIO) building sector. They have collected data by mail survey and the results indicate that the costs of power interruption in the GIO sector compare most closely to those found in the industrial sector. They developed a questionnaire for the GIO sector. The form of the GIO questionnaire is based on a direct cost estimation method designed to obtain the required interruption cost information directly from customers. There is no common denominator in the methods by which the various customers evaluate the cost of an interruption. The estimates of costs are based on past history or a current situation. There is no factual and statistically valid history of the actual cost of interruptions that have been experienced.

R. Billinton, J. Oteng-Adjei [11] presented the cost/benefit approach to establish optimum adequacy level for generation system planning. The paper utilizes the economic criterion for system optimization which extends the traditional approach by treating the reliability level as a variable to be optimized. The authors introduced the basic concept of reliability – cost/worth evaluation and showed the variation of cost that consumers face directly with the planning reserve margin of generation. The consumer survey method has been effectively used to assess consumer costs associated with service interruptions in this paper.

Q. Ahsan, A. Bhuiyan, N. H. Khan and H. Kabir [12 – 13] presented the techniques to quantify the losses of power interruption in residential sector with narrow band of data. The papers propose a methodology of evaluating the loss of interruption of power for residential sector only. They developed a questionnaire and mathematical model for quantification of loss of interruption of power. There is no information in the methodology by which one can determine the reliability of power supply.

Recently, Q. Ahsan, M. Alam, R. Karim and H. Rahman [14] investigated the reliability worth of interruption of power in small industries. This paper presents a methodology to quantify the losses of small industries due to electric power interruption. It incorporates all possible tangible losses. But the sampling domain was very narrow and the response of data collection was also poor. The paper did not give the clear idea about the decreasing tendency of interruption cost with the increasing of reliability of power supply.

In [1 - 14] no attempt has been made to establish a correlation between the cost of interruption of power and the system reliability. Moreover, a generalized mathematical model accommodating all types of consumers is not reported yet.

1.3 Thesis Organization

This thesis is to evaluate the power interruption cost and to correlate it with the system reliability. Different information and necessary data are arranged chapter wise.

The introductory chapter 1 contains introduction, critical review and thesis organization. Introduction of this chapter presents the importance of electrical energy. The power interruption cost and its correlation with the system reliability is introduced. Review of some previous study related to this thesis is presented in the critical review section. Thesis organization discusses the structure of this research work.

Chapter 2 discusses the methodology relating to the research work and the development of mathematical model for the residential, industrial and commercial sectors. All possible losses due to interruption of power for the three sectors are discussed in this chapter. The reliability concept is also described with the appropriate expressions.

In chapter 3, a questionnaire for each sector is developed. The method of distribution of the questionnaire among the respondents is discussed. The procedure of collection of the questionnaires, sampling period, data presentation etc. is discussed sequentially. Basic data relating to residential, industrial and commercial respondents are arranged in tabular forms in this chapter.

Chapter 4 deals with the necessary calculation and evaluation of power interruption cost using the developed mathematical model and data of chapter 3. For the evaluation of loss of interruption of power, all respondents are classified according to some criteria. The alternative sources used by the different respondents are also described in this chapter. It establishes the correlation between the electric power interruption cost and the reliability of power supply, too.

Chapter 5 presents analysis of results. The classes of the respondents, statistics of alternative sources used and the evaluated losses are made to discuss in this chapter. The evaluated losses for the three sectors are summarized separately and presented by the histograms. The losses are compared with the electricity bill, connected load and the area of the premises. It discusses the correlation between the interruption cost and the reliability of supply. It also describes the observation and discussion on the subject matter.

Chapter 6 emphasizes on the conclusion of the research work. It includes introduction, concluding remarks, suggestion to the utility and recommendation for future study.

CHAPTER TWO

METHODOLOGY

2.1 Introduction

This chapter deals with the methodology of evaluating the losses of the consumers of different sectors due to power interruption. These sectors are residential, industrial and commercial. All possible losses due to power interruption for each sector are also discussed in this chapter. In order to evaluate the loss of power interruption into monetary term, a mathematical model is developed for each sector. Although, the inconveniences are mainly intangible in nature and difficult to quantify, an attempt is made to formulate them. The reliability of the power supply system is also described in this chapter with the appropriate expression.

2.2 Methodology

The methodology to quantify the loss of a consumer, into monetary term, due to electric power interruption is based on the identification of the types of losses a consumer may face. Consumers of different sectors face different types of losses.

A residential consumer usually faces the following four types of losses due to the interruption of power:

a) damage of electrical appliances,

b) cost of alternative electrical source to meet the emergencies,

c) damage of perishable goods and

d) loss due to inconvenience.

An industrial consumer does not face the same types of losses as faced by the residential and commercial consumers. During the interruption of power supplied by the utility, either the production of an industry continues with its own alternative source of electricity supply or it is stopped if the arrangement for alternative supply does not exit. In most of the cases, an industry compensates its production by operating it during the period other than the scheduled hours. For this, the industry has to pay the additional wages to the workers. Frequent power interruption damages or shortens the life of electrical appliances.

The materials under process get perished or damaged due to interruption of power. The usual components of loss in an industry due to power interruptions are:

i) cost of damage of electrical appliances,

ii) expenditure due to alternative electrical source to meet the emergencies,

iii) cost of damage of raw materials under process and

iv) additional wage.

A commercial consumer usually faces the following four types of losses due to the interruption of power:

1) damage of electrical appliances,

2) cost of alternative electrical source to meet the emergencies,

3) damage of perishable goods and

4) loss due to reduce sale and additional wage.

In what follows, a mathematical model incorporating the four types of losses for the consumers of the three sectors is developed. Now, the mathematical model for the residential, industrial and commercial sectors covering the four cost components is described res.

2.2.1 Mathematical Model for Residential Consumer

To accommodate all possible losses for four cost components of a residential consumer due to power interruption, an appropriate mathematical model is developed below.

2.2.1.1 Cost Due to the Damage of Appliances

The frequent power interruption causes serious damage to some of the electrical/ electronic appliances. This may also shorten the life of the appliance. Some of the damages are repairable and some are not. Therefore, the cost of the damage of the appliances, J_1, may be expressed as

$$J_1 = \sum_{i=1}^{N} [J_{11} I(da) + J_{12} \perp (da)]_i \qquad (2.1)$$

Where, J_1 = cost component due to the damage of appliances,

J_{11} = cost component due to the damage of the repairable items,

J_{12} = cost component due to the damage of the irreparable items and

N = total number of the damaged appliances.

I(da) and ⊥(da) are characteristic functions and these are defined as,

$$I(da)=\begin{cases}1 & \text{if da is a repairable appliance}\\ 0 & \text{otherwise}\end{cases} \tag{2.2}$$

$$\perp(da)=\begin{cases}1 & \text{if da is an irreparable appliance}\\ 0 & \text{otherwise}\end{cases} \tag{2.3}$$

To evaluate J_{11}, it is required to estimate the number of interruptions during the rest of the life of the appliance. The estimated number of interruptions during the life of the appliance, NI may be expressed as

$$NI = (NI_S + NI_{ns})\hat{\tau}_R k \tag{2.4}$$

Where, k is a function of the uncertainty in interruption due to seasonal variation and the change of the quality of the supply of electricity.

In equation (2.4), NI_S is the number of interruptions during the sampling period and NI_{ns} is the number of interruptions during the rest of the period of a time interval. The time interval may be a year or season or any convenient period, $\hat{\tau}_R$ is the reduced life of the repairable appliance. This decrease in the length of the life of an appliance is because of the interruption of electric power. This decrease depends on the frequency of interruption. NI_{ns} may be evaluated as

$$NI_{ns} = (T - T_S)\frac{NI_S}{T_S} \tag{2.5}$$

In equation (2.5), T and T_S represent the time interval and the duration of sampling period, respectively.

Two components of cost constitute J_{11}; one due to the repair of the appliance and the other one arises due to the decrease of the life span of an appliance. If C is the average cost per repair of an appliance, the cost of repair C_R may be expressed as

$$C_R = NRC \tag{2.6}$$

NR is the total number of possible repair during the lifetime of an appliance. The value of NR may be estimated by considering the number of repair required for NI_s.

The loss due to the decrease of the life span of the repairable appliance, C_{RL}, may be expressed as

$$C_{RL} = \frac{P_R}{\tau_R}(\tau_R - \hat{\tau}_R) - S_R \tag{2.7}$$

In equation (2.7), P_R is the capacity cost, τ_R is the life span and S_R is the salvage value of an appliance.

Therefore J_{11} can be expressed as

$$J_{11} = C_R + C_{RL} \tag{2.8}$$

The cost of the irreparable appliance, J_{12} involves the loss due to the reduced life of the appliance only and this may be expresses by an equation similar to equation (2.7) as

$$J_{12} = \frac{P_{IR}}{\tau_{IR}}(\tau_{IR} - \hat{\tau}_{IR}) - S_{IR} \tag{2.9}$$

In equation (2.9), the subscript, IR, corresponds to the irreparable appliance.

So, the cost of the damage of the appliance per hour of interruption, $\hat{J}_1 = \frac{J_1}{NIT_1}$ (2.10)

Where, T_1 is the average duration of interruption.

2.2.1.2 Cost Due to the Use of Alternative Sources

The alternative sources, the consumer may use during the power interruption, are of different types including charger light, IPS, UPS, generator, candle, kerosene lamp etc. The use of an alternative source during power interruption involves capacity cost and fuel cost. Some of the alternative sources have only capacity cost. For example, the cost of a candle is its capacity cost only. The cost due to the use of alternative sources may be expressed as

$$J_2 = (P_{AL} - S_{AL}) + C_{FAL}NI_{AL}T_1 \tag{2.11}$$

Where, $C_{FAL} = \frac{wtrH_{AL}}{1000t_1H_I}$ (2.12)

In equation (2.11), the subscript AL corresponds to alternative source. P_{AL} is the capacity cost and S_{AL} is the salvage value of the alternative source. NI_{AL} is the number of interruption during the life time of the alternative source. C_{FAL} is the cost of the fuel for unit duration of use. This may be the fuel cost of the generator or the charging cost of IPS, UPS, and charger. T_1 is the mean duration of interruption. This may be evaluated by calculating the mean of the probability density function of interruption duration developed through sampling.

In equation (2.12), w is the rating in watt of the alternative source (charger light), t is the time to charge the charger, r is the per unit (kWh) cost of electricity, t_1 is the used time during power interruption period, H_{AL} and H_I are the total durations of alternative used and interruptions, respectively.

Note that the value of NI_{AL} depends on the life span of an alternative source and it may be expressed as

$NI_{AL} = (NI_s + NI_{ns})\, k$ (2.13)

Where, $NI_{ns} = T - T_S$ (2.14)

In equation (2.13), k is a function of uncertainty and in equation (2.14); T and T_S are total life span of the alternative source and number of observation days, respectively.

So, the cost due to the use of alternative sources per hour of interruption,

$\hat{J}_2 = J_2 \div (NI_{AL} T_I)$ (2.15).

The equation (2.15) is applicable for charger light, IPS, UPS, generator, kerosene lamp, lantern etc.

Again, for candle, the cost due to the use pf alternative source per hour of interruption,

$\hat{J}_2 = J_2 \div H_I$ (2.16)

Where, H_I = Duration of interruption in hour.

2.2.1.3 Cost of Perishable Goods

The damage of perishable goods is a function of the duration of power interruption. Some items get perished in a refrigerator or oven for a short duration of power interruption but some item may stay longer without being perished.

The cost of the loss of perishable goods is

$J_3 = C_{PG}\, I(D)$ (2.17)

In equation (2.17), and in what follows, D represents the duration of interruption. C_{PG} represents the cost of perishable goods. I(D) is a characteristic function given as

$$I(D) = \begin{cases} 1 & \text{if } D \geq \overline{D} \\ 0 & \text{otherwise} \end{cases} \quad (2.18)$$

$\overline{D}$ is the duration required for an item to be perished.

So, the cost of the loss of perishable goods per hour of interruption, $\hat{J}_3 = J_3 \div H_I$ (2.19)

Where, H_I = Duration of interruption in hour.

2.2.1.4 Cost of Inconvenience

The inconvenience to a residential consumer may arise from the disturbance in study, dining, computer works, cooking, sewing, accounting, amusements etc. In a residence, all members may not feel inconvenience for the same kind of disturbance. The magnitude and the cause creating inconvenience depend on the psychological and physical condition, the age, profession and the gender of a resident.

The disturbance in the work during night due to interruption of power may force an incumbent to work late in the night. The incumbent may fail to catch the regular transport to reach his work next day. The repetition of this phenomenon may create sickness. Therefore, the loss due to the inconvenience from the disturbance in study, computer works and or accounting may be expressed as

$$J_{IN_1} = \sum_{i=1}^{M} (C_{TR} + C_M)_i \qquad (2.20)$$

Where,

J_{IN_1} = cost relating to the loss due to inconvenience in study or in computer works or in accounting,

C_{TR} = additional charge for transport,

C_M = cost of medication and

M = number of members of a residence suffered from the inconvenience due to disturbance in stud or computer works or accounting.

Due to power interruption, the sewing may be disturbed. This disturbance may require getting the job done by a professional tailor. The loss due to this inconvenience is

$$J_{IN_2} = \sum_{i=1}^{K} CT_i \qquad (2.21)$$

Where, J_{IN_2} = cost relating to inconvenience in sewing,

CT = the charge of the tailor and

K = number of members of a residence suffered from this inconvenience.

A longer duration of the interruption of power during cooking or dinning may cause wastage of food and the family members may have to get food from outside. This inconvenience may be assessed by estimating the price of outside food and the wastage of cooking material. This may be expressed as

$$J_{IN_3} = (CF + C_{OF}) \perp (D) \qquad (2.22)$$

Where,

J_{IN_3} = equivalent cost of inconvenience in dinning or cooking,

C_F = cost of the cooking material run to waste and

C_{OF} = cost of outside food.

In equation (2.22), $\perp(D)$ is a characteristic function. It is expressed as

$$\perp(D) = \begin{cases} 1 \text{ if } D \geq \overline{ID} \\ 0 \text{ otherwie} \end{cases} \quad (2.23)$$

Where, $\overline{ID}$ is the interruption duration creating wastage of food.

Since inconvenience for the disturbance in amusement is intangible, it is not considered here for quantification. However, the disturbance in family function may be assessed as

$$J_{IN_4} = C_D + C_F + C_A \quad (2.24)$$

Where,

J_{IN_4} = loss in the family function,

C_D = cost of decoration,

C_F = cost of food and

C_A = charge of outside artist.

Therefore, the total inconvenience cost J_4 may be written as

$$J_4 = \sum_i (J_{IN})_i \quad (2.25)$$

So, the cost of inconvenience per hour of interruption, $\hat{J}_4 = J_4 \div H_I$ (2.26)

Where,

H_I = Duration of interruption in hour.

The sum of all four cost components J_1, J_2, J_3, J_4 gives the total cost of interruption during the sampling period.

2.2.2 Mathematical Model for Industrial Consumer

In this case, the first three components of loss are same as those of residential consumers. That is, the loss components; (i) the cost due to the damage of appliances (ii) the use of alternative sources and (iii) the cost due to the damage of raw materials under process may be evaluated using the model developed for residential consumers for these three components.

2.2.2.1 Cost of Additional Wages

Since, an industry compensates its production in most of the cases by operating it during the period other than the scheduled time; it has to pay the extra money to the workers. The cost due to additional wages may be expressed as,

$$J_4 = \sum_i W_i L \quad (2.\ 27)$$

Where,

W_i = The wage of i_{th} worker per unit time

L = Duration of running an industry to compensate power interruption.

So, the cost due to additional wages per hour of interruption, $J_4{'} = J_4 \div H_I$ (2.28)

The sum of all four cost components gives the total cost of interruption during the sampling period.

2.2.3 Mathematical Model for Commercial Consumer

For this type of consumers also, the model for first three components are same. However, the case of inconvenience is different in this case. Instead of inconvenience, a commercial consumer usually faces the loss due to reduced sale and additional wages.

2.2.3.1 Loss due to Reduced Sale and Additional wages

Due to power interruption during the common business time, the less number of customers may appear in the shop. Therefore, the loss due to reduced sale may be expressed as

$$J_{N_1} = \sum_{i=1}^{m}(L'C)_i \qquad (2.29)$$

Where,

J_{N_1} = cost relating to the loss due to reduced sale,

L' = loss of profit per customer who did not come into the shop during the power interruption period,

C = probable number of customers not appeared in the shop during the interruption period.

m = number of shops of a commercial consumer suffered from the loss due to less sales.

To minimize the loss of profit due to power interruption, some of the shopkeepers keep open their shops for more than schedule time and even during holiday. They have to pay extra salaries to the sales men for overtime works. The loss due to these additional wages may be expressed as

$$J_{N_2} = \sum_{i=1}^{n}(ST_o)_i \qquad (2.30)$$

Where,

J_{N_2} = cost relating to additional wages,

S = salary per sales man for overtime works,

T_O = overtime,

n = number of sales men working in the shop.

Therefore, the total loss due to reduced sale and additional wages, J_4, may be written as

$$J_4 = \sum_i (J_N)_i \qquad (2.31)$$

So, the cost due to reduced sale and additional wages per hour of interruption,

$$J_4'' = J_4 \div H_I \qquad (2.32)$$

The sum of all four cost components gives the total cost of interruption during the sampling period.

2.3 Reliability

If number of observation in days is T_S and daily operating duration of appliances of a consumer in hours is H_O, the total duration of operation of appliances i.e. total use of electricity in hours during the sampling period may be expressed as

$$H_S = T_S H_O \qquad (2.33)$$

Relative frequency of interruption of power during the sampling period is the probability of interruption of power. That is, the probability of interruption can be expressed as

$$P_I = \frac{NI_S}{H_S} \qquad (2.34)$$

Where,

NI_S = number of interruption encountered during the sampling period,

H_S = total duration of observation in hour.

Generally, the numerical value of probability of interruption of power is less than unity and it is the important indication for the reliability indices of a power system. If there is no interruption in a power system during a certain period, it may be treated as the supply is 100% secured. The level of continuity of power supply after deduction of probability of interruption from the system is the reliability indices. Therefore, the reliability of power system may be expressed as

$$R = (1 - P_I) \qquad (2.35)$$

i.e. $\% R = (1 - P_I) \times 100$ (2.36)

CHAPTER THREE

BASIC DATA

3.1 Introduction

It has been discussed in chapter 2 that the losses of interruption of power for consumers of residential, industrial and commercial sectors are different types and also an appropriate mathematical model has been developed for each sector. To evaluate the loss of interruption of power using the developed mathematical model, different types of data and information from the consumers of electricity are required. In this chapter, a questionnaire for each sector is developed separately to collect the necessary information. The developed questionnaires are distributed among the different categories of residential, industrial and commercial consumers of different areas of Dhaka City randomly. The procedure of collection of the questionnaires, data presentation etc. are also discussed.

3.2 Development of Questionnaire

Nature of appliances used, connected load, load pattern, type of alternative source used, physical area of premises, number of users of electricity, duration of use of electricity, loss of interruption of power etc. vary consumer to consumer and also from one class of consumer to other. Therefore, for each class, separate questionnaire is developed. The first page of the questionnaires contains general information like name of the consumer, address of the premises where electricity is used, telephone number, connected load, average energy consumption per month, average electricity bill paid per month, connected appliances and alternative source used during power interruption etc. The second and third pages of the questionnaires contain the information about date and duration of interruption, name of the alternative source used during the interruption period, duration of alternative used, type of perishable goods, cost of perishable goods, damage of equipment, type of inconvenience, severity of inconvenience, cost of damaged equipment, approximate loss due to interruption of power in tabular forms and signature of the consumer etc.

There are some differences in the questionnaires of different classes of consumers. In the first page of the questionnaires for all type of consumers, all other items except electrical appliance/equipment used are more or less same. There is a list of the appliances/equipments generally used in the household purpose like fan, tube light, bulb, water pump, television, refrigerator etc. In case of industrial consumers, the questionnaire contains the list of the industrial equipments like motor, compressor etc. with lighting appliances and for commercial questionnaire, it contains the list of fan, tube light, mercury lamp, air conditioner, television, refrigerator etc. In the second and third pages of the questionnaires, the columns one to four of the tables contain date and duration of interruption, name of the alternative sources used, the duration of interruption and these are same for all types of consumers. Rests of the columns of this table of residential questionnaire contain type and cost of perishable goods, nature and severity of inconvenience. But, there is no column for inconvenience in the tables of second and third pages for industrial questionnaire. Rests of the columns of the table contain name and cost of damaged equipment, approximate loss due to power interruption. On the other hand, the last four columns in the table of second and third pages for commercial questionnaire contain name and cost of damaged equipment, cost of perishable goods and approximate loss due to power interruption.

The samples of questionnaires for the residential, industrial and commercial consumer are presented in Appendices A, B and C, respectively.

3.3 Distribution of Questionnaire

Steps are taken to distribute the questionnaires among the consumers of the three sectors of Dhaka City starting from the last week of February and it ends second week of March, 2003. The questionnaires are supplied to the consumers of areas Mirpur, Kallyanpur, Savar, Tongi, Mohammadpur, Dhanmondi, Kalabagan, Mirpur road, Green road, Kathalbagan, Hatirpul, New elephant road, New circular road, Gandaria, Satish sarker road, Dina nath sen road, Mirhazirbag, West jurain, Kazlarpar, Dania, Karimullarbag, Matuail and Konapara of Dhaka City and its adjacent area by visiting their premises. The numbers of questionnaires distributed to the consumers of the three sectors are not same and these are 400, 234, and 304 for residential, industrial and commercial consumers, respectively. Demonstration for filling up the questionnaire is also given to the consumers.

3.4 Data Collection Procedure during the Sampling Period

This is the most troublesome job. Many problems have been faced during the distribution of questionnaires. Because, the consumers are not so much conscious about the loss and impact of interruption of power. They thought the different negative situations of electricity for themselves. They asked why they will have to give the information expected in the questionnaires and what the effects of it are etc. Efforts are made to convince them by describing the advantage of this study. But, all consumers did not start to fill up the questionnaires at the same time. Some consumers started to fill up the questionnaires on the 1st March and some consumers started on the last week of March, 2003. All consumers are monitored time-to-time and they are pursued to fill up the questionnaires as properly as possible. It is seen that the all consumers of the three sectors are not able to give the all expected information. Some consumers have given full information and some consumers have given 50 percent information. However, they observe the power interruption period and record the duration and number of interruption occurred regularly. They also watch the situation, if any appliance is damaged due to interruption of power. Some consumers complete their works at the end of the month of May and some consumers complete at the last week of June, 2003. The numbers of collected questionnaires are not same as distributed as many of them do not respond.

The numbers of collected questionnaires from the consumers of the three sectors are as follows:

a) Collected questionnaires for residential consumers are 110 numbers out of 400.
b) Collected questionnaires for industrial consumers are 54 numbers out of 234.
c) Collected questionnaires for commercial consumers are 67 numbers out of 304.

That is, 27.50, 23.08 and 22.04% of residential, industrial and commercial consumers, respectively, responded.

3.5 Collected Information

Collected information and data for each sector are presented sequentially. At first, general information, data for interruption, alternative sources used and data for inconveniences to residential consumers are presented in tabular forms. Then, the same type of information and data for industrial as well as commercial consumers are also presented in tabular forms. Note that the sample of collected questionnaires filled up with the necessary information and data by the respondents of the three sectors are presented in Appendices G, H and I, respectively.

3.5.1 Information of residential consumers

The list of residential consumers who have responded by filling up the questionnaires is given in Appendix D. The address and identification number of each respondent are also given in this appendix.

General information, data for interruption, alternative sources used by residential respondents and data for the inconvenience are presented in Table 3.1, 3.2, 3.3 and 3.4, respectively.

Table 3.1: General Information of Residential Respondents

Respondent	Area of house	Number of family member	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID. No.	Sq. ft.		kW	kWh	March	April	May	Taka
1	1000	6	3.431	180	535	400	465	466.67
2	1000	4	2.495	160	407	425	450	427.33
3	750	5	3.074	198	503	510	518	510.33
4	800	7	2.585	170	390	415	475	426.67
5	750	4	2.916	165	419	431	431	427.00
6	1200	6	3.095	230	579	600	606	595.00
7	750	4	2.530	220	547	543	560	550.00
8	750	5	1.500	170	526	431	434	463.67
9	750	6	2.740	230	572	576	584	577.33
10	1450	5	2.855	300	690	721	750	720.33
11	1100	5	2.915	250	605	610	619	611.33
12	800	4	1.560	180	451	453	453	452.33
13	1000	6	2.125	306	786	810	825	807.00
14	800	4	1.435	206	518	506	548	524.00
15	800	5	1.460	210	528	547	560	545.00
16	800	5	1.535	221	555	562	588	568.33
17	800	7	2.185	314	814	840	860	838.00
18	800	6	1.435	206	519	519	560	532.67
19	800	5	1.435	206	514	521	543	526.00
20	800	4	1.435	206	514	522	542	526.00
21	800	4	2.185	314	820	850	870	846.67
22	1200	7	2.050	288	712	719	724	718.33
23	750	6	1.535	221	550	557	570	559.00
24	750	5	1.535	221	550	558	570	559.33
25	1500	9	4.300	619	2134	2140	2150	2141.33
26	1500	8	4.300	619	2134	2140	2150	2141.33
27	750	4	1.300	187	468	472	475	471.67
28	750	5	1.300	187	468	472	474	471.33
29	750	4	1.300	187	468	471	474	471.00
30	1600	7	2.200	316	850	900	900	883.33
31	800	5	1.610	230	572	576	569	572.33
32	800	4	1.300	187	468	470	475	471.00
33	800	6	1.535	221	550	552	560	554.00
34	800	6	1.535	191	477	480	494	483.67
35	1600	6	7.125	1026	4273	4280	4290	4281.00
36	800	5	1.460	210	523	530	530	527.67
37	800	6	1.360	195	487	487	494	489.33
38	1000	5	3.020	434	1270	1280	1290	1280.00
39	750	6	1.575	226	562	555	579	565.33
40	800	6	1.435	206	514	521	543	526.00

(To continue)

(Continued)

Respondent	Area of house	Number of family member	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID. No.	Sq. ft.		kW	kWh	March	April	May	Taka
41	850	7	1.585	226	562	567	584	571.00
42	850	4	1.435	206	514	526	550	530.00
43	700	5	1.270	175	443	448	445	445.33
44	700	4	1.270	175	455	463	480	466.00
45	1400	8	4.220	607	2052	2075	2075	2067.33
46	1400	7	4.220	607	2052	2075	2080	2069.00
47	1150	6	2.692	367	1015	1025	1050	1030.00
48	1400	8	4.225	607	2050	2070	2100	2073.33
49	800	5	1.340	207	510	520	518	516.00
50	2000	8	7.339	1047	4696	4700	4700	4698.67
51	1000	4	1.400	207	500	515	520	511.67
52	1000	5	1.400	207	500	515	520	511.67
53	1000	4	1.400	207	500	520	525	515.00
54	1000	6	1.400	207	510	525	530	521.67
55	1000	4	1.400	207	510	525	530	521.67
56	1000	4	1.400	207	510	525	530	521.67
57	1000	6	1.400	207	500	515	530	515.00
58	800	4	1.360	200	490	500	510	500.00
59	800	6	4.360	639	2211	2250	2250	2237.00
60	800	4	1.270	182	400	455	470	441.67
61	1200	7	5.310	764	2917	2930	2950	2932.33
62	1000	5	3.550	475	1425	1450	1460	1445.00
63	1200	5	5.270	755	2860	2875	2900	2878.33
64	1200	6	5.520	756	4543	4537	4555	4545.00
65	1000	6	4.245	630	2180	2200	2200	2193.33
66	1200	8	5.430	782	3030	3050	3075	3051.67
67	1600	7	5.570	802	3158	3170	3200	3176.00
68	800	5	1.970	283	700	705	717	707.33
69	1200	6	5.250	756	2865	2875	2890	2876.67
70	800	4	2.160	311	805	825	850	826.67
71	1600	6	5.370	773	2950	2970	2980	2966.67
72	2500	12	9.900	1425	7076	7090	7100	7088.67
73	1850	7	5.220	751	2846	2870	2890	2868.67
74	1850	6	4.790	689	2459	2480	2490	2476.33
75	1400	5	2.171	270	660	675	700	678.33
76	800	5	1.650	237	588	591	600	593.00
77	1200	6	3.425	562	1830	1860	1860	1850.00
78	2000	8	5.800	835	3189	3200	3200	3196.33
79	1000	5	1.550	223	555	580	600	578.33
80	1000	5	1.425	205	510	525	540	525.00

(To continue)

(Continued)

Respondent	Area of house	Number of family member	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID. No.	Sq. ft.		kW	kWh	March	April	May	Taka
81	1000	6	1.425	205	510	525	540	525.00
82	1000	5	1.425	205	510	530	550	530.00
83	1000	7	2.171	312	1144	1150	1180	1158.00
84	1000	4	1.425	210	520	550	590	553.33
85	1000	5	1.125	162	400	410	445	418.33
86	800	5	2.186	314	814	850	875	846.33
87	800	5	1.185	170	426	440	460	442.00
88	800	6	1.258	185	460	465	480	468.33
89	1000	6	2.611	375	1046	1080	1100	1075.33
90	1200	7	1.825	262	649	656	656	653.67
91	1100	6	1.725	248	615	640	650	635.00
92	1500	30	3.095	445	1310	1335	1350	1331.67
93	750	5	1.025	147	353	370	370	364.33
94	700	5	1.000	100	230	240	250	240.00
95	850	6	1.730	249	580	618	625	607.67
96	1000	7	2.250	324	860	875	880	871.67
97	1000	6	2.580	327	865	880	900	881.67
98	800	6	2.010	289	680	714	720	704.67
99	700	5	1.460	210	500	523	530	517.67
100	800	5	1.690	243	580	603	615	599.33
101	800	4	1.230	177	410	440	450	433.33
102	1000	6	1.110	159	400	445	460	435.00
103	800	4	1.065	124	300	350	380	343.33
104	1200	5	1.780	265	650	675	680	668.33
105	1650	9	2.310	333	900	950	980	943.33
106	700	4	1.471	212	525	560	570	551.67
107	1200	10	1.750	252	600	625	650	625.00
108	1200	9	1.850	266	650	675	690	671.67
109	1000	7	1.220	175	440	460	475	458.33
110	1400	6	2.206	290	700	715	750	721.67

First column of Table 3.1 indicates the identification numbers of residential respondents. Second column of the table indicates the floor areas of houses of the respondents in sq ft. Number of familiy members, connected load of the house and the monthly average energy consumption are given in third, fourth and fifth columns, respectively. Next three columns of this table contain electricity bills paid by the respondents for the month of March, April and May. The last column of the table presents the monthly average electricity bills paid by the respondents.

Table 3.2: Power Interruptions in case of Residential Respondent

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption during the sampling period (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	$T_I = H_I \div NI_S$	H_{AL}
1	76	74	131	98.03	0.75	63.95
2	76	74	131	98.02	0.75	63.57
3	76	74	131	97.85	0.75	66.70
4	76	74	131	97.87	0.75	65.68
5	78	74	131	100.60	0.77	46.25
6	76	74	131	97.60	0.75	67.93
7	92	73	88	57.18	0.65	37.52
8	91	72	87	56.98	0.65	37.07
9	90	71	85	56.68	0.67	36.78
10	61	50	83	52.22	0.63	42.35
11	92	74	104	83.58	0.80	78.97
12	72	38	52	38.58	0.74	29.85
13	73	71	142	80.50	0.57	66.25
14	75	72	142	82.25	0.58	66.88
15	73	71	142	81.90	0.58	56.22
16	73	71	142	81.93	0.58	53.98
17	101	71	140	79.35	0.57	55.85
18	101	71	143	82.40	0.58	54.08
19	101	69	142	76.93	0.54	42.55
20	101	69	141	76.83	0.54	42.75
21	101	70	141	79.50	0.56	50.77
22	101	71	142	80.52	0.57	50.55
23	101	71	142	80.52	0.57	49.60
24	101	68	137	79.30	0.58	49.30
25	101	71	142	80.52	0.57	48.78
26	101	70	141	80.35	0.57	49.75
27	97	70	141	80.42	0.57	50.13
28	97	70	141	80.47	0.57	49.87
29	97	70	141	80.53	0.57	49.60
30	101	71	141	79.50	0.56	48.72
31	101	70	140	79.33	0.57	48.93
32	101	70	140	79.37	0.57	49.07
33	101	69	138	78.50	0.57	48.58
34	101	68	138	78.37	0.57	48.47
35	101	70	140	79.00	0.56	49.33
36	101	68	135	78.25	0.58	48.10
37	101	69	140	79.67	0.57	50.20
38	101	71	141	76.87	0.55	48.25
39	101	67	136	76.75	0.56	47.67
40	97	65	135	76.53	0.57	46.73

(To continue)

(Continued)

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption during the sampling period (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	$T_I = H_I \div NI_S$	H_{AL}
41	97	66	137	76.97	0.56	47.13
42	97	65	136	76.40	0.56	46.77
43	73	49	74	60.72	0.82	33.98
44	73	49	74	61.38	0.83	33.82
45	73	49	74	61.70	0.83	41.10
46	73	49	74	61.00	0.82	37.63
47	73	51	78	61.58	0.79	34.08
48	73	50	76	61.77	0.81	39.73
49	73	50	76	61.23	0.81	35.67
50	73	52	79	61.80	0.78	40.58
51	73	51	77	61.80	0.80	37.42
52	73	51	76	60.67	0.80	34.77
53	73	50	76	60.63	0.80	35.42
54	73	51	77	60.80	0.79	35.67
55	73	52	78	61.80	0.79	36.83
56	73	52	78	61.77	0.79	37.42
57	73	52	78	61.83	0.79	36.58
58	73	49	74	60.68	0.82	33.92
59	73	50	75	60.75	0.81	34.50
60	73	49	74	60.67	0.82	34.03
61	72	57	142	63.67	0.45	35.18
62	72	56	141	63.53	0.45	35.07
63	72	57	142	63.67	0.45	35.17
64	72	57	141	63.40	0.45	35.10
65	72	56	140	63.23	0.45	34.73
66	72	55	140	62.83	0.45	34.42
67	72	57	142	63.67	0.45	35.13
68	72	56	141	63.45	0.45	34.93
69	72	58	143	64.17	0.45	35.68
70	72	58	143	64.25	0.45	34.75
71	72	57	142	63.80	0.45	35.43
72	72	57	142	63.73	0.45	35.25
73	72	56	140	63.53	0.45	35.03
74	72	59	144	64.83	0.45	35.53
75	90	73	120	54.73	0.46	38.92
76	72	58	143	64.33	0.45	35.47
77	72	58	143	64.27	0.45	35.40
78	72	58	143	64.07	0.45	35.30
79	72	59	144	64.37	0.45	35.57
80	90	69	168	96.67	0.58	37.17

(To continue)

(Continued)

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption during the sampling period (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	$T_I = H_I \div NI_S$	H_{AL}
81	90	68	167	96.17	0.58	37.13
82	90	69	168	96.50	0.57	37.33
83	90	69	168	96.55	0.57	37.40
84	90	67	166	96.07	0.58	36.33
85	90	68	167	96.17	0.58	36.50
86	90	69	168	96.53	0.57	36.43
87	90	68	167	96.48	0.58	36.83
88	90	67	166	96.03	0.58	36.27
89	90	69	168	96.55	0.57	37.00
90	90	68	167	96.43	0.58	36.97
91	90	70	169	97.63	0.58	38.00
92	90	70	169	97.58	0.58	38.17
93	103	70	120	59.22	0.49	23.13
94	103	70	120	59.87	0.50	24.83
95	103	70	120	59.42	0.50	25.33
96	103	68	117	58.40	0.50	23.17
97	103	69	120	59.58	0.50	24.17
98	103	68	117	58.37	0.50	23.23
99	103	67	115	57.03	0.50	22.83
100	103	69	119	59.00	0.50	23.37
101	103	70	120	59.57	0.50	23.17
102	82	68	151	89.92	0.60	45.50
103	82	68	151	89.83	0.59	45.33
104	82	69	152	90.08	0.59	45.42
105	82	66	149	85.00	0.57	44.25
106	82	67	150	87.22	0.58	45.33
107	82	68	151	89.87	0.60	45.53
108	82	66	149	86.42	0.58	44.83
109	82	65	148	86.17	0.58	44.17
110	91	74	121	55.30	0.46	39.42

Different types of power interruption data are presented in Table 3.2. First column of the table indicates the identification number of respondent and second column presents the total sampling period in days. Third and fourth columns are selected for the total number of observations in days and the number of interruptions. Fifth and sixth columns of this table present the total and average duration of interruption in hours, respectively. Last column indicates total duration of alternative sources used by the respondents during power interruption period in hours. It is seen from the table that the highest and lowest sampling periods are 103 and 61 days, respectively. Also, the highest and lowest numbers of observations are 74 and 38 days, respectively. Maximum number of interruptions encountered by a residential respondent is 168 and that of minimum is 52. It is also seen form this table that the maximum and minimum average duration of interruptions are 0.83 and 0.45 hours, respectively. Overall average duration of interruption is 0.58 hours.

Table 3.3: Different Alternatives used by Residential Respondents during Power Interruption

Respondent ID No.	Charger light (minute)	Generator (minute)	Candle (minute)	Kerosene lamp (minute)
I			3837	
2			3814	
3	4002			
4	3941			
5	2775			
6			4076	
7			2251	
8	2224			
9	2207			
10	2541			
11				4738
12			1791	
13			3975	
14	4013			
15	3373			
16	3239			
17	3351			
18	3245			
19			2553	
20			2565	
21	3046			
22	3033			
23	2976			
24	2958			
25	2927			
26	2985			
27			3008	
28			2992	
29			2976	
30	2923			
31			2976	
32			2944	
33			2915	
34			2908	
35	2960			
36			2886	
37			3012	
38			2895	
39			2860	
40			2804	

(To continue)

(Continued)

Respondent no.	Charger light (minute)	Generator (minute)	Candle (minute)	Kerosene lamp (minute)
41			2828	
42			2806	
43			2039	
44			2029	
45	2466			
46	2258			
47	2045			
48	2384			
49			2140	
50	2435			
51	2245			
52			2086	
53			2125	
54			2140	
55			2210	
56	2245			
57			2195	
58			2035	
59	2070			
60			2042	
61	2111			
62	2104			
63	2110			
64	2106			
65	2084			
66	2065			
67	2108			
68			2096	
69	2141			
70			2085	
71			2126	
72	2115			
73		3343		
74	2132			
75	2335			
76			2128	
77	2124			
78		3367		
79			2134	
80			2230	

(To continue)

(Continued)

Respondent No.	Charger Light (minute)	Generator (minute)	Candle (minute)	Kerosene Lamp (minute)
81			2228	
82			2240	
83	2244			
84			2180	
85			2190	
86			2186	
87			2210	
88			2176	
89			2220	
90			2218	
91			2280	
92			2290	
93			1388	
94			1490	
95	1520			
96	1390			
97	1450			
98			1394	
99			1370	
100			1402	
101			1390	
102			2730	
103			2720	
104			2725	
105	2655			
106			2720	
107	2732			
108			2690	
109	2665			
110	2365			
Total	60704	6765	85911	4738

Table 3.3 describes the different types of alternative sources used by residential respondents during the power interruption period. It is seen from the table that the respondents have used candles as an alternative source more compared to the other sources. Only one respondent has used kerosene lamp. But, no body has used IPS, UPS and lantern

Table 3.4: Inconveniences to Residential Respondents

Respondent	Type of inconvenience (No. of days encountered)								Severity of inconvenience (No. of days observed)	
ID No.	Study	Dinning	Cooking	Sewing	Computer works	Enjoying TV, video games, music	Accounting	Other problems	Severe	Moderate
1	25		60			69	3		2	72
2	58	2	33	2		23			2	72
3	67		36	2		15			2	72
4	64		39	3		9			2	72
5	51		11	2		13		1	2	72
6	34				41	6			2	72
7	48		5	2		5			1	72
8	44			2		4			1	71
9				2	28				1	70
10	17		9		11	8			3	47
11	71	4	48	2	13				2	72
12	30			2		15		14	3	35
13	42	4	26			24			2	62
14	49	4	27			18			1	61
15	48	2	21			14			3	63
16		5	36			28			3	64
17	47	3	20			16			1	43
18	49	4	21	4		14			3	64
19	22		9	2		18			2	67
20	23		7			11			1	68
21	21					24			1	67
22	25		21			26			1	70
23	19		6	2		7			1	70
24	29		11	2		5			2	66
25	30		15			3			1	70
26	31		16						2	68
27	33		21	2		5			1	69
28	34		22	2						
29				3		9			1	69
30			21		25	9			1	70
31			23	2	21					
32			22	3						
32	21		24			10				
34	26		21			13			1	67
35	28		23			7			1	69
36	27		23	2					1	68
37	32		22	2		5				
38	34		21	2						
39			21		22					
40	24		19	2						

(To continue)

(Continued)

Respondent	Type of inconvenience (No. of days encountered)								Severity of inconvenience (No. of days observed)	
ID No.	Study	Dinning	Cooking	Sewing	Computer works	Enjoying TV, video games, music	Accounting	Other problems	Severe	Moderate
42			21	2					1	64
43	23		21	2		4			2	47
44	22		21	3					2	47
45	18		13			5			2	47
46	21		18	2		6			2	47
47	22		17					1	2	49
48	23		18	2		11				
49	24		19	2		7				
50	19		18		19				2	50
51	25		18							
52	22		17	2					2	49
53	22		18						2	48
54	25		17						2	49
55	26		18	3		5			2	50
56	25		17			9			2	50
57	23		16			10			2	50
58	21		17	2		11			2	47
59	26		18					1	2	48
60	24	1	17	2		6			2	47
61	22	2	18			4			1	56
62		2	17	3				1	1	55
63	23	2	17			12			1	56
64	22	2	18			13			1	56
65	20	3	18			11		1	1	55
66	19	2	17	2		11		1	1	54
67	21	3	18	2		14			1	56
68	22	3	17						1	55
69	20	3	16			9			1	57
70		2	19			15			1	57
71	24	2	17	2		12			1	56
72	21		18	2		13			1	56
73	21		18			13		1	1	55
74	25		17						1	58
75		2	24	3		14	2		2	71
76	24					8			1	57
77	23					10			1	57
78	20					15		1	1	57
79	21	3	23					1	1	58
80	23		21			10			3	66

(To continue)

(Continued)

Respondent	Type of inconvenience (No. of days encountered)								Severity of inconvenience (No. of days observed)	
ID No.	Study	Dinning	Cooking	Sewing	Computer works	Enjoying TV, video games, music	Accounting	Other problems	Severe	Moderate
82	22		17						2	67
83	25			3		15		1	3	67
84	21	2	19			15			2	65
85	22		17	3					2	66
86	21	2	19	3				1	2	67
87		2	19	3		13			2	66
88	21	3	16	2		14			3	33
89	22		19	2		8			2	67
90	22		18			10			2	66
91	24		19			12			3	67
92						15			3	68
93	14		16	3		7			1	69
94	15		13	3		6			1	69
95	15		13	4		12			1	69
96	13		11	2		11			1	68
97	16		13			16			1	68
98	14		13	3		15			1	67
99	13					13			1	66
100	15		14	2					1	68
101	13					9			1	69
102	17		17	3		7			2	66
103	15		11	2		10			2	66
104	13		11	2		12			2	67
105	12					12			2	65
106			12	2		13			2	65
107	14		11	3		6			2	66
108	14		11			11			2	64
109	13		12	2		14			2	63
110	22		16			8	2			
Total	2433	69	1769	132	180	1036	7	25	158	5885

Table 3.4 describes the different types of inconveniences faced by residential respondents during the sampling period. Different types of inconveniences like study, dinning, cooking, sewing, computer works, enjoying TV, accounting and other problems are presented column wise in this table. Other problems in sixth column indicate the inconveniences for shortage of water supply, wash of hands, face and cloths, feeling of warm etc. due to interruption of power. Severity of inconvenience is listed as severe and moderate in the last two columns. Note that some respondents did not give the complete information about the inconveniences.

3.5.2 Information of Industrial Consumers

List of the industrial consumers who have responded to fill up the questionnaire with necessary data and information is presented in Appendix E. General information, data for interruption of power and alternative sources used by industrial respondents are listed in Table 3.5, 3.6 and 3.7, respectively.

Table 3.5: General Information of Industrial Respondents

Respondent	Area of industry	Number of employees	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID No.	Sq. ft.		kW	kWh	March	April	May	Taka
1	500	8	6.180	889	3638	3650	3650	3646.00
2	2000	12	26.575	3826	16930	16950	16950	16943.33
3	600	12	13.680	1969	7981	7982	7990	7984.33
4	750	14	14.500	1996	8089	8090	8090	8089.67
5	3000	8	7.646	1101	4490	4495	4500	4495.00
6	75000	180	218.700	8000	41000	41024	41050	41024.67
7	98032	32	21.614	5700	22985	22990	23000	22991.67
8	62400	16	41.650	8000	32235	32240	32300	32258.33
9	58500	18	72.276	14400	58137	58150	58150	58145.67
10	3200	11	15.000	3000	12128	12150	12175	12151.00
11	640	7	5.476	792	3250	3270	3280	3266.67
12	6600	7	36.974	5392	21747	21760	21775	21760.67
13	6200	13	24.786	3587	14488	15000	15000	14829.33
14	1250	10	22.394	3241	13097	13100	13100	13099.00
15	660	10	6.860	990	4044	4050	4050	4048.00
16	23500	18	32.568	4700	18964	18970	18975	18969.67
17	30000	24	45.794	6661	26850	26870	26880	26866.67
18	30200	26	48.514	8000	32235	32300	32300	32278.33
19	3000	14	27.722	3996	16133	16150	16170	16151.00
20	2875	6	9.990	1444	5870	5885	5890	5881.67
21	3250	15	45.514	9516	39996	40000	40000	39998.67
22	12000	45	91.746	18200	73400	73500	73500	73466.67
23	2730	23	87.892	11520	47846	47870	47875	47863.67
24	20000	25	62.100	8942	36964	36980	36980	36974.67
25	500	2	10.844	1561	6340	6350	6350	6346.67
26	600	7	7.028	1010	4125	4130	4140	4131.67
27	2600	12	12.944	1872	7590	7600	7600	7596.67
28	2925	18	16.346	2352	9522	9540	955	6672.33
29	1200	12	21.040	3030	12248	12260	12270	12259.33
30	1200	10	7.694	1113	4538	4545	4550	4544.33
31	1750	9	5.052	730	2998	3000	3020	3006.00
32	7200	150	40.830	14000	58065	58100	58100	58088.33
33	7800	165	39.308	13500	56000	56000	56000	56000.00
34	600	9	13.509	1948	7897	7900	7900	7899.00
35	1750	12	13.084	1960	7942	7950	7955	7949.00
36	1200	9	12.595	1817	7367	7379	7390	7378.67
37	500	6	2.420	384	1460	1480	1500	1480.00
38	600	8	7.111	1020	4162	4175	4186	4174.33

(To continue)

(Continued)

Respondent	Area of industry	Number of employees	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID No.	Sq. ft.		kW	kWh	March	April	May	Taka
39	4800	35	22.436	3229	13045	13066	13100	13070.33
40	475	6	6.926	996	4065	4090	4100	4085.00
41	48000	30	351.320	50000	200000	205000	210000	205000.00
42	4000	28	7.322	1000	4082	4090	40100	16090.67
43	12800	22	40.860	7040	28371	28380	28400	28383.67
44	750	3	15.220	2570	10395	10400	10400	10398.33
45	38000	45	360.000	50000	200000	210000	210000	206666.67
46	1000	7	3.298	598	2470	2500	2500	2490.00
47	1800	16	14.000	2464	9972	9990	10000	9987.33
48	50000	80	320.000	68000	271436	290000	300000	287145.33
49	1500	12	7.825	1260	5130	5150	5200	5160.00
50	700	14	8.785	1400	5690	5700	5700	5696.67
51	32000	50	150.000	22000	100000	110000	115000	108333.33
52	1200	10	4.379	800	3280	3280	3300	3286.67
53	30000	28	600.000	52000	222000	225000	230000	225666.67
54	14000	20	19.454	7600	30626	30650	30700	30658.67

Table 3.5 presents the general information of industrial consumers. First column of the table indicates the identification numbers of consumers as respondents and second column indicates the physical areas of industries of the respondents in sq ft. Number of employees, connected load of the industry and the monthly average energy consumption are shown in third, fourth and fifth columns of this table, respectively. Next three columns contain electricity bills paid by the respondents for the month of March, April and May. The last column shows the monthly average electricity bills paid by the respondents. It is seen that the highest physical area of an industry is 98032 sq. ft. among all industries of the respondents and the maximum number of employees are 180. It is also observed that the highest connected load and the monthly average energy consumption are 600 kw and 68000 kwh repectively. The highest average electricity bill paid by an industrial respondent is Taka 287145.33 per month. Note that the paisa elements from the monthly electrcity bills have been eleminated.

Table 3.6: Power Interruptions in case of Industrial Respondents

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	T_I	H_{AL}
1	75	60	150	88.00	0.59	35.55
2	87	62	125	72.63	0.58	56.72
3	75	61	152	90.05	0.59	36.13
4	75	62	153	91.07	0.60	37.13
5	75	60	150	88.10	0.59	35.80
6	88	62	119	97.80	0.82	92.90
7	58	30	48	24.53	0.51	23.70
8	58	52	101	65.62	0.65	61.28
9	77	64	141	83.93	0.60	79.73
10	77	63	138	82.32	0.60	78.15
11	77	63	137	82.20	0.60	42.33
12	77	62	136	82.00	0.60	42.17
13	77	62	136	81.75	0.60	42.25
14	93	62	108	53.07	0.49	23.65
15	93	61	107	52.07	0.49	23.53
16	93	62	145	52.87	0.36	23.60
17	93	60	116	51.50	0.44	22.33
18	93	58	102	50.77	0.50	22.83
19	93	59	103	51.03	0.50	21.60
20	93	62	107	52.87	0.49	21.03
21	93	62	107	52.83	0.49	21.33
22	93	62	145	53.00	0.37	52.33
23	89	56	130	50.27	0.39	19.73
24	92	62	149	52.33	0.35	21.42
25	90	60	104	51.00	0.49	21.33
26	90	60	101	49.80	0.49	20.50
27	91	61	106	51.25	0.48	21.13
28	93	62	108	52.97	0.49	52.43
29	93	62	108	52.93	0.49	21.23
30	93	62	108	52.90	0.49	21.27
31	93	61	106	51.92	0.49	52.50
32	93	60	137	50.20	0.37	50.75
33	93	62	139	52.83	0.38	53.02
34	93	62	108	52.73	0.49	21.33
35	93	62	108	52.83	0.49	21.23
36	90	60	105	50.75	0.48	19.83
37	91	61	96	52.08	0.54	21.13
38	90	58	100	49.33	0.49	18.83

(To continue)

(Continued)

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	T_I	H_{AL}
39	90	56	126	64.52	0.51	34.52
40	90	57	103	65.43	0.64	35.35
41	91	63	105	59.53	0.57	36.72
42	87	58	131	67.18	0.51	37.02
43	88	60	107	69.13	0.65	60.00
44	90	62	111	71.25	0.64	40.78
45	91	63	105	59.72	0.57	36.93
46	90	61	110	70.17	0.64	39.75
47	91	62	111	71.32	0.64	70.17
48	91	64	106	59.87	0.56	60.17
49	87	59	94	70.30	0.75	40.05
50	88	60	95	71.43	0.75	40.47
51	91	63	105	59.63	0.57	59.83
52	91	62	111	71.27	0.64	40.45
53	91	62	104	59.18	0.57	41.83
54	87	58	105	67.30	0.64	37.23

Different types of power interruption data are presented in Table 3.6. First column of this table indicates the identification numbers of industrial respondents and second column is for the sampling period in day. Third and fourth columns are for the number of observatioı in days and the number of interruptions, respectively. Fifth and sixth columns of this table present the total and average duartions of interruptions in hour, respectively. Last column indicates the total duration of alternative sources used by the respondents during the poweı interruption period. It is seen from the table that the highest and lowest sampling periods are 93 and 58 days respectively. The higest and lowest number of observations are 64 and 30 days respectively. The maximum number of interruptions encountered by an industrial respondent is 153 and that of minimum is 48. It is also seen that the maximum and the minimum average duration of interruptions are 0.82 and 0.53 hours, respectively. Overall average duration of interruption is 0.55 hours.

Table 3.7: Different Alternatives used by Industrial Repondents during Power Interruption

Respondent ID No.	Charger light (minute)	Generator (minute)	Candle (minute)
1			2133
2	3403		
3	2168		
4	2228		
5			2148
6		5574	
7		1422	
8		3677	
9		4784	
10		4689	
11			2540
12			2530
13			2535
14	1419		
15	1412		
16	1416		
17	1340		
18	1370		
19	1296		
20			1262
21	1280		
22		3140	
23	1184		
24	1285		
25			1280
26	1230		
27	1268		
28		3146	
29			1274
30			1276
31			
32		3045	
33		3181	
34			1280
35			1274
36			1190
37			1268
38			1130

(To continue)

(Continued)

Respondent ID No.	Charger light (minute)	Generator (minute)	Candle (minute)
39	2071		
40			2121
41			2203
42	2221		
43	2327		
44			2447
45	2216		
46	2385		
47	.	3597	
48		3610	
49	2403		
50	2428		
51		3590	
52			2427
53			2477
54			2234
Total	16051	10834	13909

Table 3.7 describes the different types of alternative sources used by industrial respondents during the power interruption period. It is seen from the table that industrial respondents have used charger lights as alternative sources for lighting purpose in large numbers compared to other sources stated in second column. It is also seen that though the duration of use of candles is greater than those of others, but the number of respondents, who have used candles, is less compared to the users of charger lights listed in sixth column. Comparatively few respondents have used generators as alternative sources during the power interruption period. Note that no body has used IPS, UPS, lantern and kerosene lamp.

3.5.3 Information of Commercial Consumers

List of the commercial respondents is presented in Appendix F. For the evaluation of the loss of interruption of power; general information, power interruption data, alternative sources used by commercial respondents and difficulties are presented in Table 3.8, 3.9, 3.10 and 3.11, respectively.

Table 3.8: General Information of Commercial Respondents

Respondent	Area of shop	Nnmber of employees	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID No.	Sq. ft.		kW	kWh	March	April	May	Taka
1	250	3	1.160	170	915	941	950	935.33
2	500	4	1.040	155	835	850	875	853.33
3	450	6	1.610	270	1444	1450	1450	1448.00
4	150	2	1.700	250	1338	1350	1360	1349.33
5	600	7	7.280	1280	6789	6815	6850	6818.00
6	250	5	1.375	198	1063	1073	1080	1072.00
7	300	6	3.550	324	1730	1761	1800	1763.67
8	600	12	5.330	480	2555	2580	2580	2571.67
9	300	4	4.440	639	3492	3497	3500	3496.33
10	150	3	1.440	207	1143	1160	1200	1167.67
11	450	5	4.100	600	3190	3200	3200	3196.67
12	240	4	2.060	296	1581	1600	1600	1593.67
13	375	3	4.200	610	3243	3250	3250	3247.67
14	2000	10	18.500	2140	11340	11360	11400	11366.67
15	500	4	1.080	155	835	850	875	853.33
16	600	5	4.080	587	3121	3140	3150	3137.00
17	1200	6	5.400	675	3587	3600	3600	3595.67
18	1500	12	6.400	800	4249	4260	4275	4261.33
19	600	4	4.800	590	3137	3140	3150	3142.33
20	1800	18	12.000	1872	9922	9940	9950	9937.33
21	850	6	7.540	1085	5757	5760	5775	5764.00
22	1200	6	10.540	1517	8043	8050	8050	8047.67
23	450	5	1.830	263	1407	1420	1450	1425.67
24	450	6	3.530	508	2703	2730	2750	2727.67
25	450	5	5.050	727	3862	3875	3875	3870.67
26	375	5	1.290	185	994	1000	1000	998.00
27	2250	16	17.330	2498	13234	13250	13250	13244.67
28	1600	14	14.660	2111	10654	10675	10675	10668.00
29	1500	12	13.100	1886	9996	10000	10000	9998.67
30	120	2	1.960	282	1507	1530	1540	1525.67
31	400	5	3.100	388	2068	2080	2100	2082.67
32	300	4	1.305	187	1005	1025	1050	1026.67
33	200	3	1.370	197	1058	1075	1075	1069.33
34	180	2	1.080	155	835	850	850	845.00
35	150	3	1.005	120	650	660	670	660.00
36	300	5	2.471	355	1890	1900	1900	1896.67
37	1000	15	5.175	375	2000	2025	2025	2016.67
38	600	5	2.191	316	1672	1700	1700	1690.67
39	360	3	1.040	150	810	830	850	830.00
40	500	3	1.390	200	1073	1080	1090	1081.00

(To continue)

(Continued)

Respondent	Area of shop	Nnmber of employees	Connected load	Average energy consumption per month	Electricity bill paid for the three months of the year 2003 (Taka)			Average electricity bill paid per month
ID No.	Sq. ft.		kW	kWh	March	April	May	Taka
41	300	2	1.030	150	809	815	820	814.67
42	600	8	3.182	460	2450	2470	2480	2466.67
43	400	4	1.280	185	994	1000	1000	998.00
44	450	7	7.888	1647	8730	8750	8775	8751.67
45	375	5	1.816	262	1400	1420	1430	1416.67
46	720	5	2.630	378	2015	2030	2050	2031.67
47	400	4	2.080	300	1600	1620	1630	1616.67
48	375	3	1.000	144	777	790	795	787.33
49	600	6	1.473	210	1126	1140	1150	1138.67
50	500	5	1.200	172	925	950	960	945.00
51	450	5	1.345	193	1036	1050	1075	1053.67
52	600	6	4.050	583	3100	3120	3130	3116.67
53	150	2	2.340	337	1800	1825	1830	1818.33
54	450	6	2.010	328	1750	1775	1775	1766.67
55	800	6	2.576	410	2180	2200	2200	2193.33
56	300	3	1.167	167	898	920	930	916.00
57	300	4	1.726	250	1323	1340	1350	1337.67
58	750	5	10.080	1450	7688	7700	7700	7696.00
59	200	2	1.040	112	608	610	615	611.00
60	675	6	1.620	233	1248	1260	1275	1261.00
61	600	5	2.170	312	1660	1675	1675	1670.00
62	600	6	2.080	300	1600	1610	1620	1610.00
63	620	8	1.773	254	1360	1375	1375	1370.00
64	750	7	1.700	244	1300	1320	1330	1316.67
65	750	9	11.400	1641	8700	8700	8700	8700.00
66	450	4	3.322	479	2550	2570	2570	2563.33
67	1000	8	1.420	204	1090	1100	1100	1096.67

Table 3.8 presents the general information of commercial consumers. First column indicates the identification numbers of commercial consumers. Second column of this table indicates the floor areas of shops of the respondents in sq ft. Number of employees, connected load of the shop and the monthly average energy consumption are shown in third, fourth and fifth columns respectively. Next three columns contain electricity bills paid by the respondents for the month of March, April and May. The last column of the table presents the monthly average electricity bills paid by the respondents. It is seen from the table that the highest amounts of all elements of this table belong to the consumer number 27. His connected load and the monthly average energy consumption are 17.33 kW and 2498 kWh respectively. He paid maximum bill which is in Taka 13244.67 per month on average. It is also seen that the minimum connected load and the monthly average electricity bill paid by a respondent are 1.0 kW and Taka 611.00 respectively.Note that the paisa elements from the monthly electricity bills have been eleminated.

Table 3.9: Power Interruptions in case of Commercial Respondents

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption during the sampling period (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	T_I	H_{AL}
1	103	72	143	81.08	0.57	66.83
2	89	63	131	75.83	0.58	64.25
3	88	62	130	74.58	0.57	63.58
4	90	64	132	76.20	0.58	65.02
5	73	63	127	74.93	0.59	49.83
6	73	62	126	74.73	0.59	49.50
7	73	49	74	61.40	0.83	40.67
8	73	50	75	61.57	0.82	40.83
9	73	49	74	61.33	0.83	40.47
10	73	49	73	61.07	0.84	39.33
11	73	50	75	61.57	0.82	40.33
12	73	48	72	61.20	0.85	39.83
13	73	51	77	61.63	0.80	40.17
14	73	52	78	61.87	0.79	40.83
15	73	50	75	61.50	0.82	40.70
16	73	48	73	61.03	0.84	39.60
17	73	50	75	61.53	0.82	40.50
18	73	48	72	60.47	0.84	39.77
19	73	52	76	61.73	0.81	40.87
20	73	51	75	61.63	0.82	40.77
21	72	56	141	63.83	0.45	37.40
22	72	57	142	64.50	0.45	36.08
23	72	57	142	64.57	0.45	33.50
24	72	56	141	63.67	0.45	33.40
25	72	56	141	63.70	0.45	34.08
26	72	59	144	64.97	0.45	35.75
27	72	58	142	64.47	0.45	34.73
28	72	57	142	63.73	0.45	35.43
29	72	58	143	63.93	0.45	35.57
30	74	61	153	89.83	0.59	37.22
31	74	62	155	91.05	0.59	37.35
32	74	62	154	90.93	0.59	37.25
33	74	61	153	89.73	0.59	37.33
34	74	60	150	87.85	0.59	36.47
35	74	59	149	87.62	0.59	36.60
36	74	61	153	89.80	0.59	37.27
37	74	60	152	89.60	0.59	37.23
38	94	62	108	53.07	0.49	21.88
39	94	62	108	53.07	0.49	21.80
40	94	62	143	53.07	0.37	22.17

(To continue)

(Continued)

Respondent	Sampling period	No. of observation (days)	No. of interruption encountered	Total duration of power interruption during the sampling period (hours)	Average duration of an interruption (hours)	Duration of alternative use (hours)
ID No.	No. of days	T_S	NI_S	H_I	T_I	H_{AL}
41	94	60	139	51.90	0.37	21.70
42	94	62	108	53.10	0.49	22.33
43	94	60	106	52.67	0.50	21.60
44	94	62	142	53.00	0.37	22.33
45	94	61	141	52.60	0.37	21.73
46	94	60	138	52.43	0.38	22.00
47	94	61	140	52.87	0.38	21.43
48	94	62	108	53.03	0.49	21.77
49	94	61	107	52.83	0.49	21.63
50	94	62	108	53.03	0.49	21.83
51	94	60	105	51.77	0.49	21.00
52	94	60	106	53.10	0.50	21.33
53	94	62	108	52.67	0.49	21.70
54	94	60	106	52.70	0.50	21.33
55	94	62	108	52.90	0.49	21.73
56	94	61	107	52.73	0.49	21.43
57	94	62	108	53.00	0.49	21.97
58	94	61	110	52.57	0.48	21.33
59	94	62	108	53.03	0.49	21.77
60	94	61	106	52.00	0.49	46.92
61	94	60	104	51.33	0.49	21.68
62	94	62	112	52.93	0.47	22.07
63	94	58	102	50.20	0.49	20.30
64	94	62	107	52.73	0.49	21.17
65	94	61	105	51.83	0.49	21.68
66	94	60	103	51.00	0.50	20.77
67	94	62	108	53.00	0.49	22.00

Different types of power interruption data are listed in Table 3.9. First column of this table indicates the identification numbers of commercial respondents and that of second column is for the total sampling period in days. Third and fourth columns are for the total number of observation in days and the numbers of interruptions. Fifth and sixth columns present the total and average durations of interruptions in hours, respectively. The last column indicates the total duration of alternative sources used by the respondents during the power interruption period in hours. It is seen from the above table that the highest and lowest sampling periods are 103 and 72 days, respectively. The highest and lowest numbers of observations are 72 and 48 days, respectively. It is also seen that the maximum numbers of interruptions encountered by a commercial respondent is 153 numbers and that of the minimum is 72 numbers. Again, it is observed that the maximum and minimum average durations of interruptions are 0.85 and 0.37 hours, respectively. Overall average duration of interruption is 0.54 hours.

Table 3.10: Different Alternatives used by Commercial Respondents during Power Interruption

Respondent ID No.	Charger light (minute)	Generator (minute)	Candle (minute)
1	4010		
2			3855
3			3815
4			3901
5	2990		
6			2970
7	2440		
8			2450
9	2428		
10			2360
11	2420		
12			2390
13	2410		
14	2450		
15			2442
16	2376		
17	2430		
18	2386		
19	2452		
20	2446		
21	2244		
22	2165		
23			2010
24			2004
25		2045	
26			2145
27			2084
28		2126	
29		2134	
30			2233
31			2241
32			2235
33			2240
34			2188
35			2196
36	2236		
37			2234
38			1313
39			1308
40			1330

(To continue)

(Continued)

Respondent ID No.	Charger light (minute)	Generator (minute)	Candle (minute)
41			1302
42	1340		
43			1296
44			1340
45			1304
46	1320		
47			1286
48			1306
49			1298
50			1310
51			1260
52			1280
53			1302
54			1280
55			1304
56			1286
57			1318
58			1280
59			1306
60		2815	
61	1301		
62			1324
63			1218
64	1270		
65			1301
66			1246
67	1320		
Total	44434	9163	79091

Table 3.10 describes the different types of alternative sources used by commercial respondents during the power interruption period. It is observed from the table that the respondents have used candles as an alternative source more compared to other sources. But, no body has used IPS, UPS, lantern and kerosene lamp.

Table 3.11: Difficulties of Commercial Respondents

Respondent	Difficulties (No. of days encountered)					Severity of difficulties (No. of days observed)	
ID No.	Sales and Display	Transaction	Accounting	Security	Other problems	Severe	Moderate
1	23	13	10	8	6	2	71
2	19	16	9	7	5	2	61
3	18	13	11	9	4	1	61
4	22	15	12	10	2	2	63
5	32	20	13	25	3	1	62
6	38	26	28	36	62	1	61
7	29	21	18	27	20	1	48
8	29	20	19	25	18	1	49
9	30	24	20	16	12	1	48
10	28	13	11	19		1	48
11	36	6	5	22	8	2	48
12	34	8	7	21	6	2	46
13	37	11	9	16	5	2	49
14					22	1	51
15	38	18	15	29	32	1	49
16	40	20	17	30	23	1	47
17	39	21	15	31	14	1	49
18	40	24	19	27	15	1	47
19	42	21	14	15	9	2	50
20	41	22	15	18	8	2	49
21	22	9	14	8		2	54
22	23	12	10	12	3	2	55
23	32	15	11	9		2	55
24	33	16	14	10		2	54
25	32	15	10	9		2	54
26	32	12			11	2	57
27	24					2	56
28					40	2	55
29					24	2	56
30	16	6			14	2	59
31		19	15	30	16	2	60
32	40	20		18	40	2	60
32	39	21		38	20	2	59
34	38	20	16	30		2	58
35	32			20		2	57
36	22			17		2	59
37			15		28	2	58
38	23				14	1	61
39	22					1	61
40	22					1	61

(To continue)

(Continued)

Respondent	Difficulties (No. of days encountered)					Severity of difficulties (No. of days observed)	
ID No.	Sales and Display	Transaction	Accounting	Security	Other problems	Severe	Moderate
42	21	12	10	26		1	61
43	22				15	1	59
44	23	15	12	30		1	61
45	30	18		35		1	60
46	33	20	16	25		1	59
47	28	20	15	24		1	60
48	24			20		1	61
49	26			15	3	1	60
50	23				12	1	61
51	20				11	1	59
52	22				12	1	59
53	25	5	4	14		1	61
54	28					1	59
55	35	28	28	30	13	1	61
56	22					1	60
57	24				24	1	61
58	30	22	20	15	30	1	60
59				15		1	61
60			22		13	1	60
61					11	1	59
62	20					1	61
63	15					1	57
64		22			12	1	61
65	30	15	12	5	25	1	60
66	22	10	8	20		1	59
67				24	18	1	61
Total	1590	684	519	935	683		

Table 3.11 describes the different types of difficulties faced by commercial respondents during the sampling period. Other problems in sixth column indicates the difficulties for feelings of warm. enjoying television etc. Severity of difficulties is presented as severe and moderate in the last two columns.

CHAPTER FOUR

NUMERICAL EVALUATION OF THE LOSS OF CONSUMERS DUE TO POWER INTERRUPTION

4.1 Introduction

In this chapter, computational procedures of the proposed mathematical model are exemplified. For evaluation of loss of interruption of power, all respondents are classified according to the physical area of the premises, connected electrical load of the premises, monthly average electricity bill paid etc. These classifications with the corresponding percentage of respondents are shown by histograms also. The losses of different respondents of all sectors are calculated by considering the sampling period. Theses are compared with the electricity bill paid by the consumers. The reliability of power supply of every respondent of the three sectors is also calculated in this chapter.

4.2 Determination of Loss of Interruption for Residential Respondents

To evaluate the loss of interruption of power, all of 110 numbers residential respondents are classified according to the criterion described in tabular form and their classifications are presented by the histograms. Summary of the alternative sources used, according to the information supplied by the respondents, is also listed in tabular form. The evaluated interruption costs are presented in tabular forms.

4.2.1 Classification of Residential Respondents

All residential respondents are classified according to the area of house of the respondent, connected electrical load of the house and the monthly average electricity bill paid. Table 4.1 presents the classification of the respondents. Figure 4.1 depicts the classification of residential respondents on the basis of the floor area of house of the respondent. Figures 4.2 and 4.3 are the graphical representations of the classifications according to connected load of the house and the monthly average electricity bill paid, respectively. The particulars of all residential respondents and their corresponding classes are given in Appendix D.

Table 4.1: Classification of Residential Respondents

Basis of clasification	Class	Criterion	No. of respondent
Floor area of house (Sq. ft.)	Ar	Below 1000	51
	Br	1000 - 1500	49
	Cr	Above 1500	10
Connected electric load (kW)	Dr	Less than 3	83
	Er	3 - 5	15
	Fr	Above 5	12
Payment of monthly electricity bill (Taka)	Gr	Less than 500	24
	Hr	500 - 1000	59
	Ir	More than 1000	27

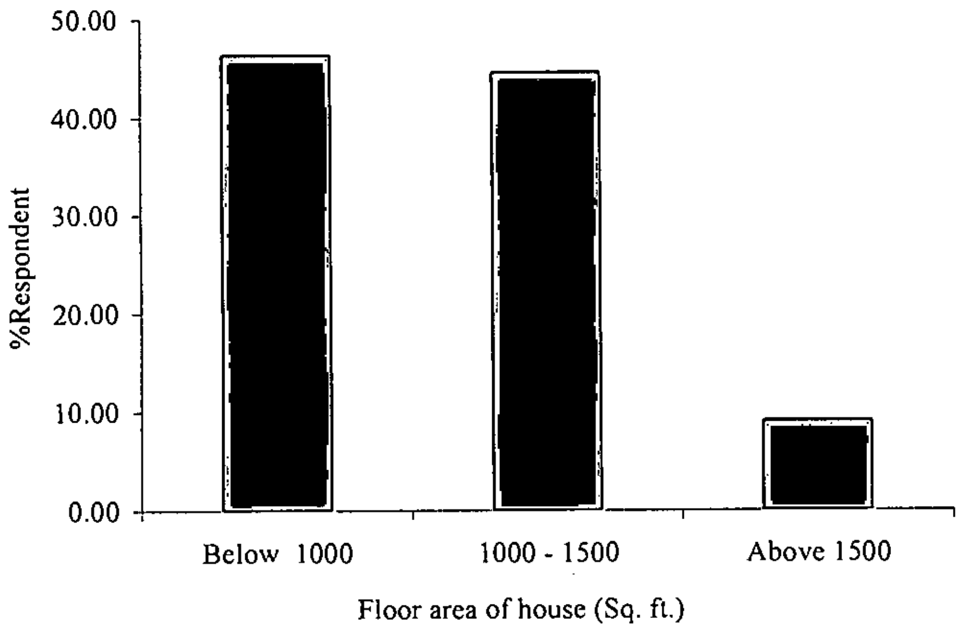

Figure 4.1: The classification of residential respondents on the basis of the floor area of house

Figure 4.1 shows that 46.36% residential respondents have floor area below 1000 sq ft and 9.09% respondents have the floor area above 1500 sq ft. Rest 44.55% respondents have the areas between 1000 - 1500 sq ft.

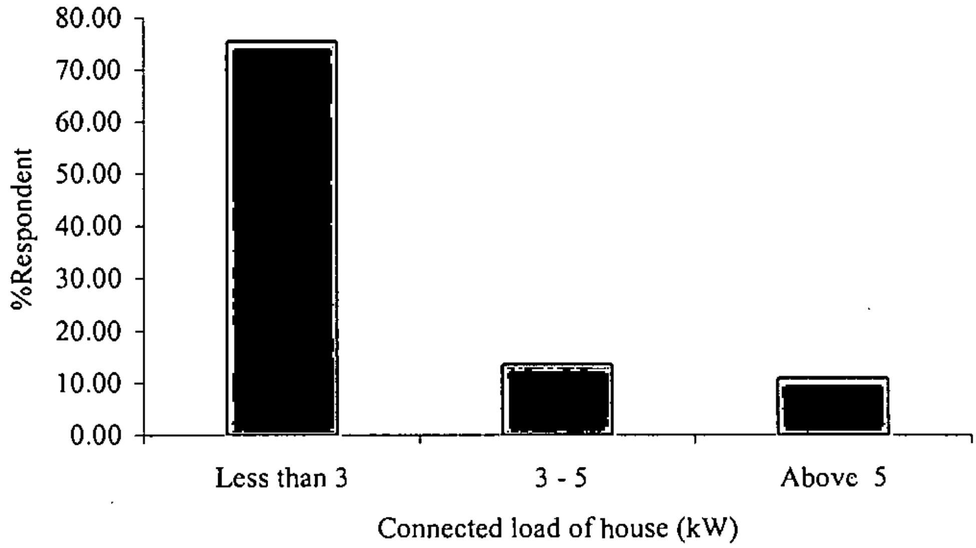

Figure 4.2: The classification of residential respondents on the basis of connected electric load of house

Figure 4.2 presnets the classification of residential respondents on the basis of connected electric load of the houses. It is seen from the figure that the connected loads of 75.45% respondents are less than 3 kW and that of 10.91% respondents are above 5 kW. Rest 13.64% respondents have connected loads between 3 - 5 kW.

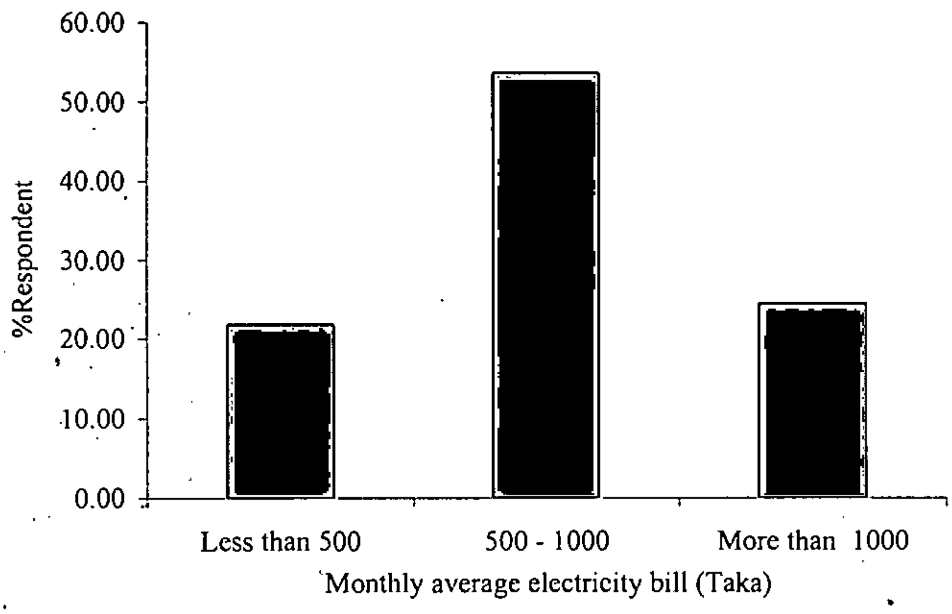

Figure 4.3: The classification of residential respodents on the basis of payment of monthly electricity bill

It is seen from Figure 4.3 that 21.82% respondents have the monthly average electricity bills less than Taka 500.00 and 53.64% respondents have between Taka 500.00 - 1000.00. Rest 24.55% respondents have the monthly average bills more than Taka 1000.00.

4.2.2 Summary of the Alternatives used by Residential Respondents

All residential respondents did not use same type of alternative sources and the duration of use of alternative sources are different. The statistics of alternative sources used is shown in Table 4.2.

Table 4.2: Statistics of Alternative Sources used by Residential Respondents

Name of the alternative source	Number of user	Duration of alternative used (hours)
Charger Light	47	1990.38
Generator	2	111.83
Candle	60	2432.48
Kerosene Lamp	1	78.97

Figure 4.4 presents the statistics of the alternative sources used by residential respondents during the power interruption period.

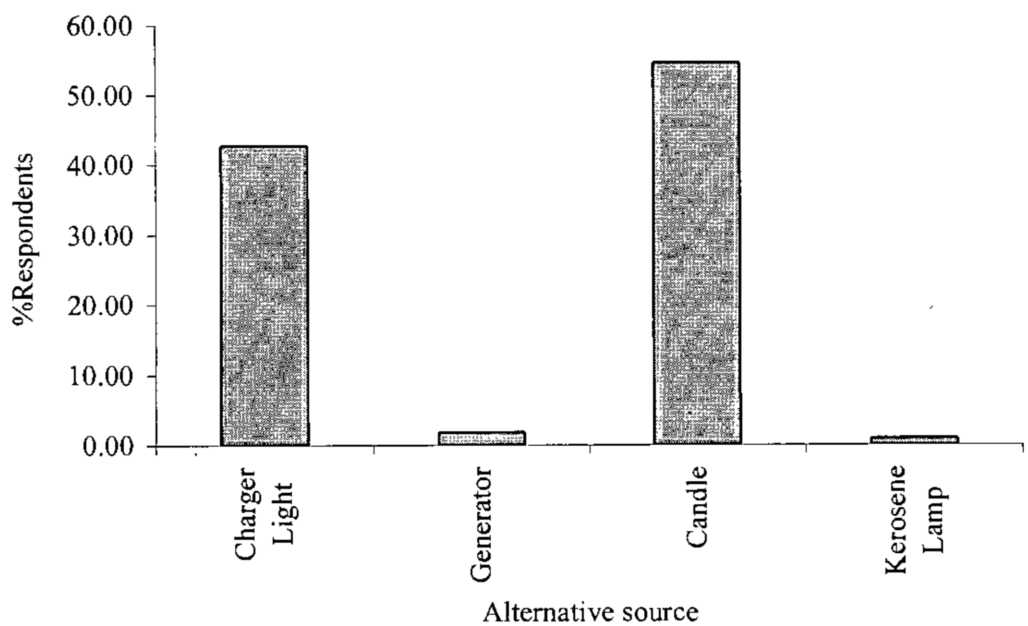

Figure 4.4: The alternative sources used by residential respondents

It is seen from Figure 4.4 that 54.55% residential respondents have used candles as an alternative source and the total duration of use of this source is 2432.48 hours which is maximum among all the alternative sources. It is also seen that 42.73% respondents have used chargers for 1990.38 hours and 1.82% respondents have used generator for 111.83 hours. Only one respondent has used kerosene lamp as an alternative source for 78.97 hours. But, no body has used IPS, UPS and lantern.

4.2.3 Calculation of Loss of Residential Respondent

A sample calculation for the residential respondent number 22 is shown in Appendix J. The losses due to power interruption for all residential respondents are evaluated accordingly and presented in Table 4.3.

Table 4.3: Evaluated Interruption Costs in case of Residential Respondents

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of perishable goods (Taka)	Cost of inconvenience (Taka)	Total cost of interruption during the sampling period (Taka)	Total cost per hour of interruption (Taka)	Total cost per interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	$\hat{J}$	$j = \hat{J} \times T_I$
1	0	625.00	356.00	3000.00	3981.00	40.61	30.39
2	0	400.00	180.00	2690.00	3270.00	33.36	24.96
3	0	100.63	360.00	2493.00	2953.63	30.67	22.90
4	0	96.05	290.00	2434.00	2820.05	29.30	21.89
5	0	62.73	460.00	3056.00	3578.73	36.31	27.88
6	0	390.00	540.00	2955.00	3885.00	39.81	29.65
7	0	230.00	0	950.00	1180.00	20.64	13.41
8	0	58.72	0	880.00	938.72	17.03	11.15
9	0	54.31	0	1150.00	1204.31	21.76	14.51
10	0	62.57	160.00	1537.00	1759.57	33.98	21.37
11	0	224.94	150.00	1931.00	2305.94	27.75	22.30
12	0	114.00	204.00	596.00	914.00	23.69	17.58
13	0	204.00	490.00	2858.00	3552.00	44.12	25.01
14	0	76.90	430.00	2146.00	2652.90	32.47	18.68
15	0	64.42	306.00	1902.00	2272.42	28.11	16.21
16	0	65.70	335.00	1610.00	2010.70	24.96	14.40
17	0	68.86	745.00	2015.00	2828.86	36.02	20.41
18	0	64.44	420.00	1250.00	1734.44	21.46	12.36
19	115.52	258.00	270.00	2370.00	3013.52	39.17	21.22
20	0	258.00	580.00	2218.00	3056.00	39.77	21.67
21	0	74.60	460.00	2085.00	2619.60	33.48	18.88
22	94.21	66.22	400.00	2625.00	3185.43	40.05	22.83
23	0	66.70	560.00	2165.00	2791.70	35.19	19.95
24	0	62.36	500.00	2361.00	2923.36	37.34	21.61
25	73.79	64.49	730.00	2140.00	3008.28	37.88	21.48
26	0	72.20	750.00	2325.00	3147.20	39.72	22.64
27	0	220.00	160.00	1930.00	2310.00	28.73	16.38
28	0	440.00	0	2350.00	2790.00	34.98	19.97
29	0	264.00	0	1755.00	2019.00	25.07	14.32
30	78.92	67.09	556.00	2495.00	3197.01	40.75	22.97
31	0	420.00	450.00	1906.00	2776.00	34.99	19.83
32	0	410.00	480.00	1810.00	2700.00	34.02	19.29
33	0	400.00	430.00	2390.00	3220.00	41.02	23.33
34	0	234.00	0	2798.20	3032.20	38.69	21.97
35	0	68.20	390.00	2542.00	3000.20	38.50	21.72
36	0	222.00	500.00	2343.00	3065.00	39.17	22.70
37	0	234.00	550.00	2503.00	3287.00	41.26	23.48
38	0	410.00	300.00	2336.00	3046.00	39.63	21.60
39	0	228.00	320.00	2355.60	2903.60	37.83	21.35
40	0	360.00	250.00	2270.20	2880.20	37.63	21.33

(To continue)

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Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of perishable goods (Taka)	Cost of inconvenience (Taka)	Total cost of interruption during the sampling period (Taka)	Total cost per hour of interruption (Taka)	Total cost per interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	$\hat{J}$	$j = \hat{J} \times T_1$
41	0	370.00	250.00	2491.80	3111.80	40.43	22.71
42	0	210.00	280.00	2390.00	2880.00	37.70	21.18
43	133.53	114.00	150.00	1423.60	1821.13	29.99	24.61
44	0	190.00	145.00	1620.40	1955.40	32.86	27.25
45	74.18	60.09	240.00	1422.00	1796.27	29.60	24.68
46	0	48.48	140.00	1592.20	1780.68	29.68	24.47
47	0	200.00	0	1783.00	1983.00	32.20	25.42
48	0	53.42	150.00	1948.00	2151.42	35.31	28.70
49	0	117.00	0	1600.20	1717.20	28.04	22.59
50	0	58.95	230.00	1702.40	1991.35	32.72	25.60
51	0	42.79	100.00	1625.00	1767.79	29.06	23.32
52	0	123.00	150.00	1603.00	1876.00	30.92	24.68
53	0	200.00	230.00	928.00	1358.00	22.40	17.87
54	0	246.00	240.00	1550.00	2036.00	41.71	32.93
55	0	190.00	150.00	539.80	879.80	14.24	11.28
56	0	51.05	150.00	940.00	1141.05	19.01	15.06
57	0	420.00	170.00	1035.40	1625.40	26.29	20.84
58	0	190.00	240.00	2299.00	2729.00	44.97	36.88
59	0	46.25	270.00	1840.00	2156.25	36.07	29.22
60	0	228.00	0	899.00	1127.00	18.58	15.23
61	111.53	50.80	460.00	2960.60	3582.94	56.92	25.52
62	0	52.71	0	1955.00	2007.71	32.90	14.83
63	0	55.04	580.00	2482.00	3117.04	49.66	22.27
64	0	56.05	325.00	2583.00	2964.05	47.46	21.34
65	0	60.29	300.00	2446.00	2806.29	45.16	20.40
66	0	59.59	375.00	2746.20	3180.79	51.41	23.07
67	93.56	39.16	280.00	3550.80	3963.53	63.20	28.34
68	0	350.00	370.00	1207.00	1927.00	30.37	13.67
69	73.80	62.32	600.00	3041.00	3777.13	59.64	26.76
70	0	185.00	370.00	1950.00	2505.00	38.99	17.52
71	0	51.10	265.00	1871.00	2187.10	34.92	15.69
72	71.88	110.36	480.00	4071.60	4733.85	**75.68**	33.96
73	0	1435.53	0	2295.00	3730.53	61.89	28.08
74	0	60.39	280.00	2590.00	2930.39	45.97	20.69
75	124.61	90.45	200.00	585.00	1000.06	18.94	8.64
76	0	216.00	0	2466.00	2682.00	41.69	18.76
77	0	51.48	0	3290.40	3341.88	52.65	23.66
78	0	2479.89	380.00	450.00	3309.89	57.15	25.60
79	0	420.00	0	1060.80	1480.80	23.01	10.28
80	113.64	430.00	700.00	3678.60	4922.24	50.92	29.30

(To continue)

(Continued)

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of perishable goods (Taka)	Cost of inconvenience (Taka)	Total cost of interruption during the sampling period (Taka)	Total cost per hour of interruption (Taka)	Total cost per interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	$\hat{J}$	$j = \hat{J} \times T_1$
81	0	420.00	580.00	2606.00	3606.00	37.50	21.59
82	0	440.00	860.00	1145.40	2445.40	25.34	14.56
83	0	50.70	1140.00	2565.00	3755.70	39.73	22.83
84	0	205.00	860.00	1104.00	2169.00	22.58	13.07
85	103.77	252.00	765.00	2973.00	4093.77	42.57	24.51
86	0	258.00	0	2992.20	3250.20	33.67	19.35
87	0	252.00	200.00	2330.00	2782.00	28.83	16.66
88	0	410.00	225.00	2285.80	2920.80	30.41	17.59
89	0	430.00	800.00	2770.00	4000.00	41.43	23.81
90	99.81	420.00	980.00	4300.00	5799.81	60.14	34.73
91	0	440.00	820.00	2970.00	4230.00	39.78	22.98
92	0	660.00	0.00	0	660.00	**6.76**	3.91
93	140.02	156.00	240.00	1739.00	2275.02	38.42	18.96
94	0	260.00	0.00	672.50	932.50	15.58	7.77
95	0	44.73	0.00	1695.00	1739.73	30.29	15.00
96	129.93	42.50	250.00	1867.80	2290.23	40.32	20.13
97	82.23	43.35	280.00	1686.00	2091.58	36.17	17.96
98	0	144.00	0	1634.00	1778.00	29.99	14.96
99	105.47	138.00	200.00	1378.00	1821.47	31.94	15.84
100	76.69	150.00	0	2210.00	2436.69	41.30	20.48
101	0	125.00	0	418.00	543.00	9.12	4.53
102	77.21	300.00	0	3087.11	3464.32	38.53	22.94
103	0	250.00	560.00	2717.00	3527.00	39.26	23.36
104	0	61.81	800.00	2403.00	3264.81	36.92	21.88
105	0	432.00	0	1937.00	2369.00	27.87	15.90
106	104.58	245.00	720.00	2450.00	3519.58	40.35	23.46
107	129.92	56.07	1300.00	3584.00	5069.99	57.02	33.94
108	65.42	282.00	1060.00	2700.00	4107.42	47.53	27.57
109	0	59.28	480.00	2123.00	2662.28	31.55	18.37
110	0	99.47	250.00	1432.00	1781.47	32.94	15.05

Table 4.3 presents the evaluated different costs componemnts and the total costs of interruption for residential respondents. The sum of the four cost components is calculated during sampling period for every respondent and presented in sixth column. Also, the total interruption cost per hour and per interruption are calculated and listed them in the last two columns. It is seen from the table that the cost of inconvenience is the highest and the cost due to damage of appliance is the lowest. The highest total cost per hour of interruption is Taka 75.68 and that of the lowest is Taka 6.76. Also, the average cost per hour of interruption, per interruption and per kWh energy consumption are Taka 35.83, 20.93 and 14.50, respectively.

4.3 Determination of Loss of Interruption for Industrial Respondent

In this section, all industrial respondents are classified. The classifications are presented by the histograms. The statistics of alternative sources used according to the information supplied by the respondents is presented in tabular form and the percentage of users is shown in figure. A sample calculation is also shown in this section. The evaluation of loss of interruption is performed for each industrial respondent in taka for the sampling period. Also, the losses are evaluated for per hour of interruption and per interruption for every respondent.

4.3.1 Classification of Industrial Respondents

All industrial respondents are classified according to the physical area of the industry owned by the respondent, connected electrical load of the industry and the monthly average electricity bill paid etc. This classification is shown in Table 4.4.

Table 4.4: Classification of Industrial Respondents

Basis of classification	Class	Criterion	No. of respondent
Physical area of industry (Sq. ft.)	Ai	Below 4000	32
	Bi	4000 – 30000	13
	Ci	Above 30000	9
Connected electric load (kW)	Di	Less than 20	28
	Ei	20 – 50	16
	Fi	Above 50	10
Payment of monthly electric bill (Taka)	Gi	Less than 20000	34
	Hi	20000 – 60000	14
	Ii	More than 60000	6

Figure 4.5 depicts the classification of industrial respondents on the basis of the physical area of the industry. Figures 4.6 and 4.7 are the graphical representations of the classifications on the basis of the connected load of the industry and the monthly average electricity bill paid, respectively. All industrial respondents with their classes are presented in Appendix E.

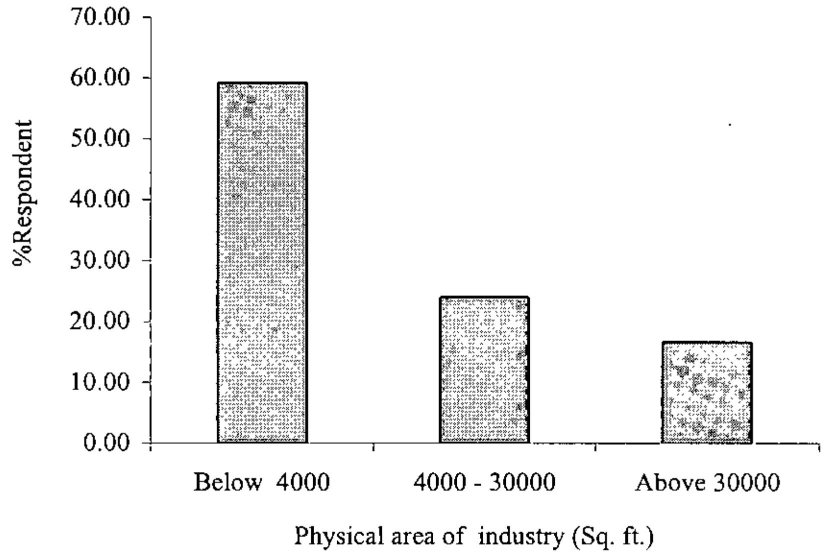


Figure 4.5: The classification of industrial respondents on the basis of the physical area of industry

It is seen from Figure 4.5 that 59.26% industrial respondents have the physical areas of industries below 4000 sq ft and 16.67% respondents have above 30000 sq ft. Rest 24.07% respondent have the physical areas of the industries between 4000 - 30000 sq ft.

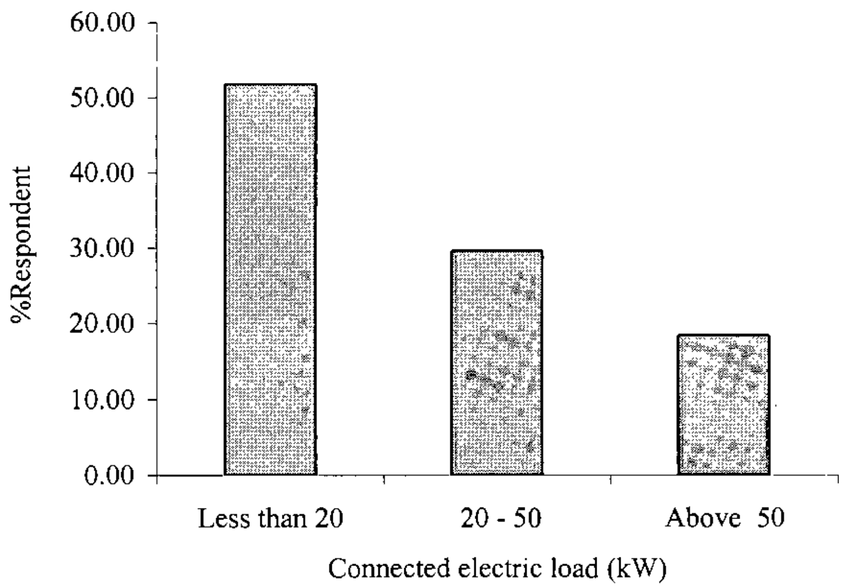


Figure 4.6: The classification of industrial respondents on the basis of connected electric load of industry

Figure 4.6 presents the classification of industrial respondents on the basis of connected electric load. It is seen from the figure that 51.85% respondents have loads less than 20 kW and that of 18.52% respondents have loads above 50 kW. Rest 29.63% respondents have the connected loads between 20 - 50 kW.

Figure 4.7 presents the classification of industrial respondents on the basis of the monthly average electricity bill paid.

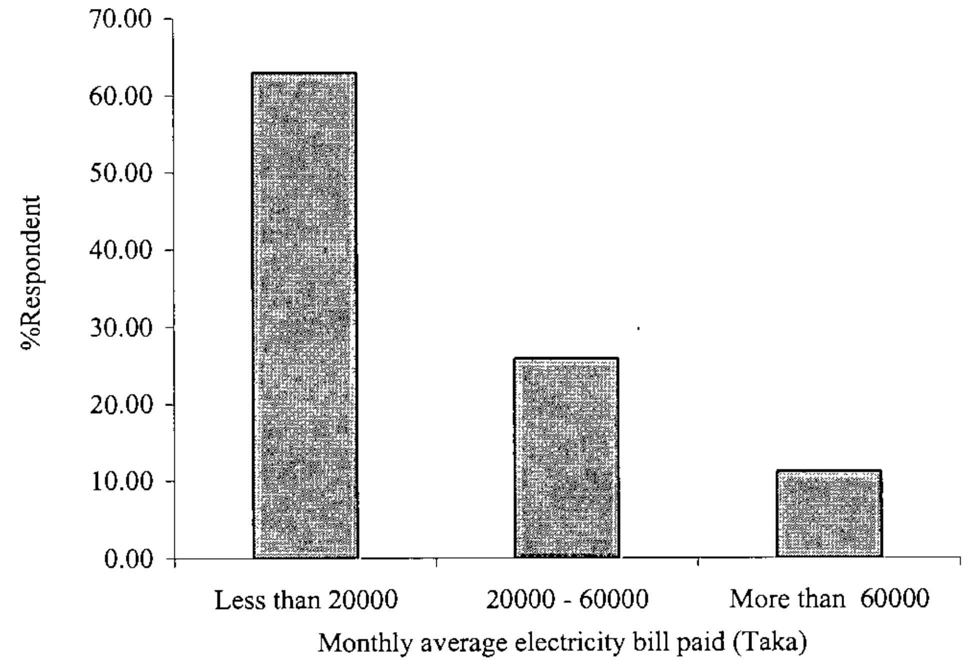


Figure 4.7: The classification of industrial respondents on the basis of payment of monthly electricity bill

It is seen from Figure 4.7 that 62.96% industrial respondents have the monthly average electricity bills less than Taka 20000.00 and 25.93% respondents pay between Taka 20000.00 - 60000.00. Rest 11.11% respondents have the monthly average electricity bills more than Taka 60000.00.

4.3.2: Summary of the Alternatives used by Industrial Respondents

Industrial respondents used the alternative sources during power interruption period. But, all respondents did not use the same type of alternative sources and the durations of use of alternative sources are different. The statistics of alternative sources used is shown in Table 4.5.

Table 4.5: Statistics of Alternative Sources used by Industrial Respondents

Name of the alternative source	Number of user	Duration of alternative used (hours)
Charger light	21	639.17
Generator	12	724.25
Candle	20	617.15

Note that one industrial respondent did not use alternative source during sampling period at all.

Figure 4.8 depicts the alternative sources used by industrial respondents.

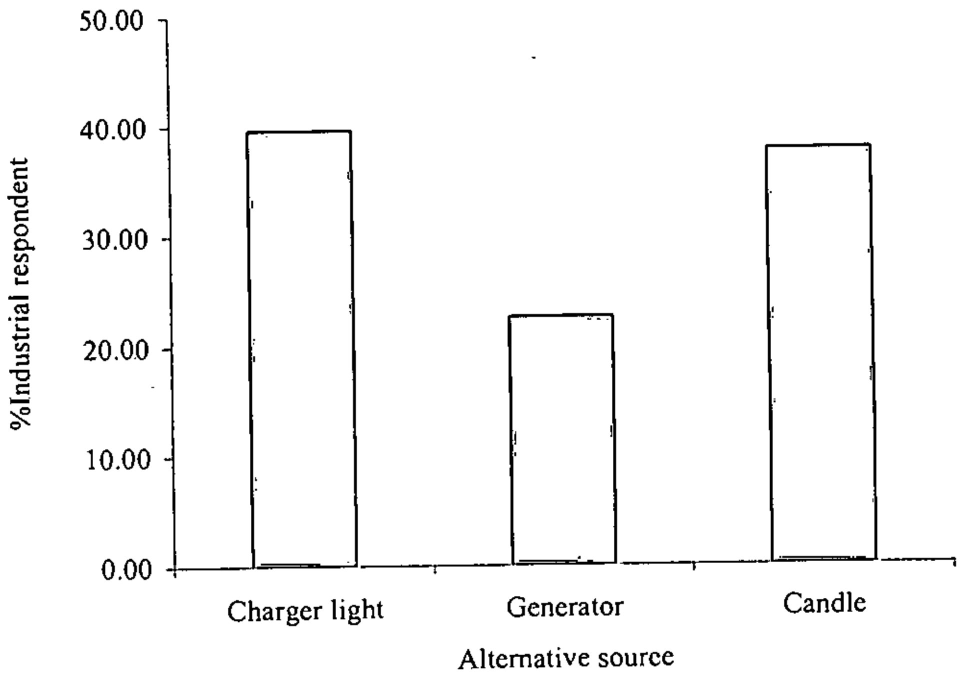


Figure 4.8: Alternative sources used by industrial respondents

It is seen from the figure that 39.62% respondent have used charger lights as alternative sources and 22.64% respondents have used generator as alternative sources. Rest 37.74% respondents have used candles during power interruption period as alternative sources. But, no body has used IPS, UPS, lantern and Kerosene lamp.

4.3.3 Calculation of Loss of Industrial Respondent

A sample calculation for the industrial respondent number 48 is shown in Appendix K. The losses due to power interruption for all industrial respondents are evaluated accordingly and presented in Table 4.6.

Table 4.6: Evaluated Interruption Costs in case of Industrial Respondents

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of damage of raw materials under process (Taka)	Cost due to additional wages (Taka)	Total Cost of interruption during the sampling period (Taka)	Total cost per hour of interruption (Taka)	Total cost per hour of interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	J'	$j' = J' \times T_1$
1	0	570.00	0	24000.00	24570.00	279.20	163.81
2	30.54	80.01	0	17280.00	17390.55	239.74	139.31
3	0	91.32	0	26000.00	26091.32	291.26	172.54
4	0	88.21	0	29760.00	29848.21	329.17	195.92
5	0	570.00	0	24000.00	24570.00	278.89	163.79
6	0	47080.25	0	21300.00	68380.25	724.58	595.46
7	18.38	1118.98	0	2590.00	3727.37	153.53	78.47
8	0	10749.13	0	0	10749.13	175.40	113.96
9	0	30808.84	0	17080.00	47888.84	589.89	351.16
10	0	3090.23	0	10000.00	13090.23	161.02	96.05
11	0	380.00	0	15000.00	15380.00	187.10	112.26
12	38.70	141.00	20000.00	8000.00	28179.70	344.10	207.46
13	55.41	470.00	0	15500.00	16025.41	196.03	117.83
14	46.30	35.29	0	6265.00	6346.59	120.90	59.41
15	38.57	46.25	0	5130.00	5214.82	101.23	49.26
16	0	47.93	8000.00	6800.00	14847.93	281.98	138.03
17	0	43.41	13000.00	10000.00	23043.41	448.55	217.90
18	57.72	45.28	0	10200.00	10303.00	204.04	101.55
19	36.89	42.76	0	7600.00	7679.65	151.62	75.13
20	0	105.00	0	5000.00	5105.00	96.56	47.71
21	83.35	42.86	0	6700.00	6826.21	130.40	64.39
22	27.57	24812.15	0	0	24839.71	474.64	232.90
23	232.26	36.87	6000.00	8000.00	14269.12	285.00	140.45
24	292.51	44.47	11000.00	10000.00	21336.98	408.94	198.17
25	0	105.00	0	2000.00	2105.00	**41.27**	20.24
26	0	41.53	0	6000.00	6041.53	122.51	60.41
27	0	43.31	0	8000.00	8043.31	158.15	76.46
28	0	5146.21	0	0	5146.21	98.15	48.13
29	0	210.00	0	7500.00	7710.00	145.65	71.39
30	0	220.00	0	6500.00	6720.00	127.03	62.22
31	0	0.00	3000.00	5000.00	8000.00	154.09	75.47
32	0	9867.16	0	0	9867.16	194.43	93.85
33	0	11355.37	0	0	11355.37	214.19	104.78
34	0	330.00	0	4500.00	4830.00	91.59	44.72
35	58.48	220.00	0	8000.00	8278.48	156.69	76.65
36	0	120.00	0	5650.00	5770.00	113.69	54.95
37	0	210.00	5000.00	1000.00	3610.00	119.23	58.59
38	31.91	190.00	0	5400.00	5621.91	113.96	56.22

(To continue)

(Continued)

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of damage of raw materials under process (Taka)	Cost due to additional wages (Taka)	Total Cost of interruption during the sampling period (Taka)	Total cost per hour of interruption (Taka)	Total cost per hour of interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	J'	$j' = J' \times T_1$
39	0	52.90	0	22050.00	22102.90	343.30	219.30
40	0	185.00	0	15000.00	15185.00	232.11	147.46
41	0	200.00	20000.00	10000.00	30200.00	507.28	287.63
42	0	56.12	0.00	23200.00	23256.12	346.84	221.91
43	0	101.27	25000.00	7500.00	32601.27	471.79	304.83
44	0	210.00	0	10000.00	10210.00	143.30	91.98
45	0	69.06	10000.00	15000.00	25069.06	420.51	239.15
46	0	60.79	0	8500.00	8560.79	122.67	78.25
47	42.68	13909.79	3000.00	1000.00	17952.47	254.93	163.79
48	43.71	67254.07	0	0	67297.78	**1118.65**	626.44
49	39.35	59.39	12000.00	11700.00	18598.73	339.17	220.77
50	0	62.51	0	12000.00	16062.51	169.53	111.11
51	0	40643.46	0	0	40643.46	679.28	385.76
52	32.74	246.00	0	9000.00	9278.74	130.20	83.59
53	0	215.00	20000.00	15000.00	35215.00	595.02	338.62
54	32.94	380.00	0	12000.00	12412.94	184.44	118.23

Table 4.7 presents the evaluated different cost components and the total cost of interruption for industrial respondents. The evaluated four cost components are presented individually to realize the impact of every cost component. The sum of the four cost components is presented in sixth column of this table. The total cost per hour of interruption and per interruption are shown in the last two columns. It is seen from the table that the cost of additional wages is the highest. It is also seen that the cost due to damage of appliance is the lowest. The table shows that the highest total cost per hour of interruption is Taka 1118.65 and the lowest is Taka 41.27. The average cost per hour of interruption, per interruption and per kWh are Taka 269.60, 155.15 and 4.65.

4.4 Determination of Loss of Interruption for Commercial Respondent

In this section, all commercial respondents are classified. The classifications are presented by the histograms. The statistics of alternative sources used according to the information supplied by the respondents is listed in tabular form and the percentage of users is shown in figure. The evaluation of loss of interruption is performed for each commercial respondent in Taka for the sampling period. Also, the losses are evaluated for per hour of interruption and per interruption for every respondent.

4.4.1 Classification of Commercial Respondents

The classifications according to the floor area of the shop owned by the respondent, connected electrical load of the shop and the average monthly electricity bill paid are shown in Table 4.7.

Table 4.7: Classification of Commercial Respondents

Basis of classification	Class	Criterion	No. of respondent
Floor area of shop (Sq. ft.)	Ac	Below 500	35
	Bc	500 – 1000	24
	Cc	Above 1000	8
Connected electric load (kW)	Dc	Less than 3	40
	Ec	3 – 8	19
	Fc	Above 8	8
Payment of monthly electricity bill (Taka)	Gc	Less than 1000	13
	Hc	1000 – 5000	43
	Ic	More than 5000	11

Figure 4.9 depicts the classification of commercial respondents on the basis of the floor area of shop. Figures 4.10 and 4.11 are the graphical representations of the classifications on the basis of the connected load and the monthly average electricity bills paid by the respondents, respectively. The detailed of commercial respondents are given in Appendix F.

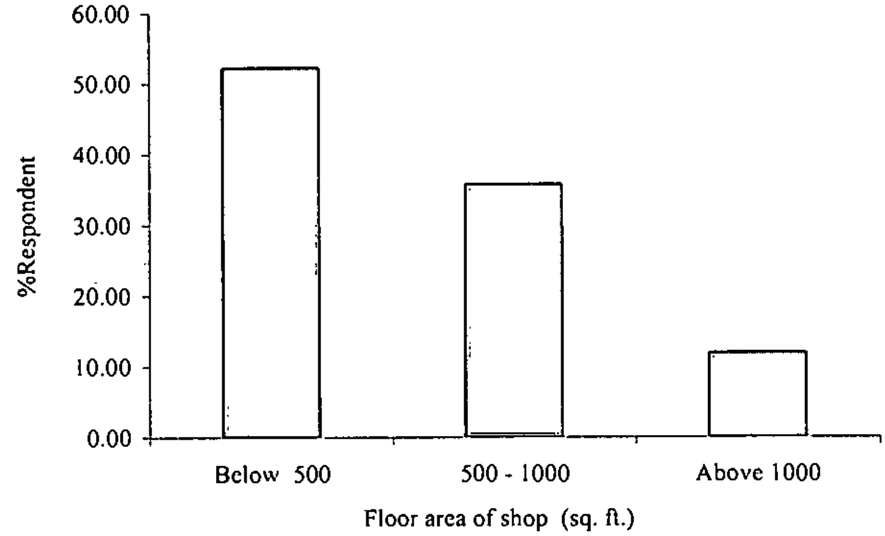


Figure 4.9: The classification of commercial respondent on the basis of the floor area of shop

It is seen from Figure 4.9 that 52.24% commercial respondents have shops of floor areas below 500 sq ft and 35.82% respondents have shops of floor areas between 500 - 1000 sq ft. Rest 11.94% respondents have shops of floor areas above 1000 sq ft.

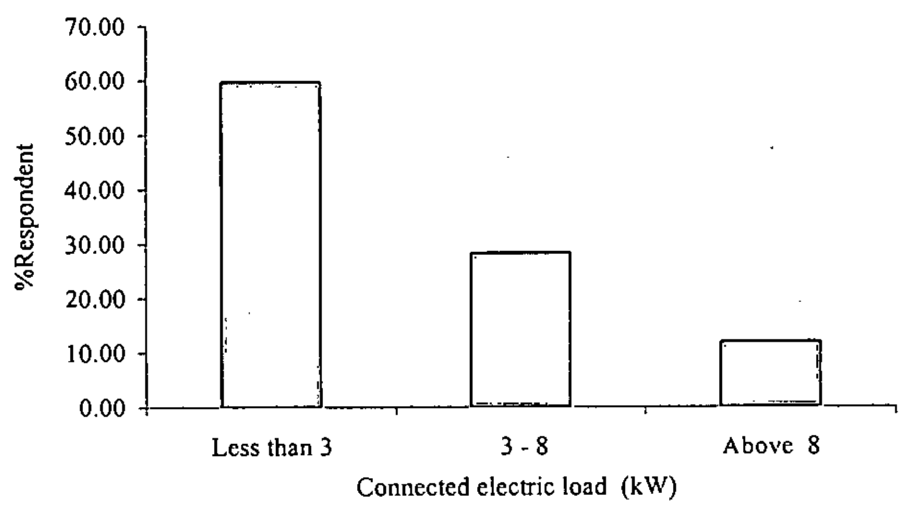


Figure 4.10: The classification of commercial respondents on the basis of connected electric load of shop

Figure 4.10 presents the classification of commercial respondents on the basis of connected load of shop. It is seen from the figure that the connected load of 59.70% respondents is less than 3 kW and that of 11.94% respondents is above 8 kW. Rest 28.36% respondents have connected loads between 3 - 8 kW.

Figure 4.11 presents the classification of commercial respondents on the basis of payment of monthly average electricity bill.

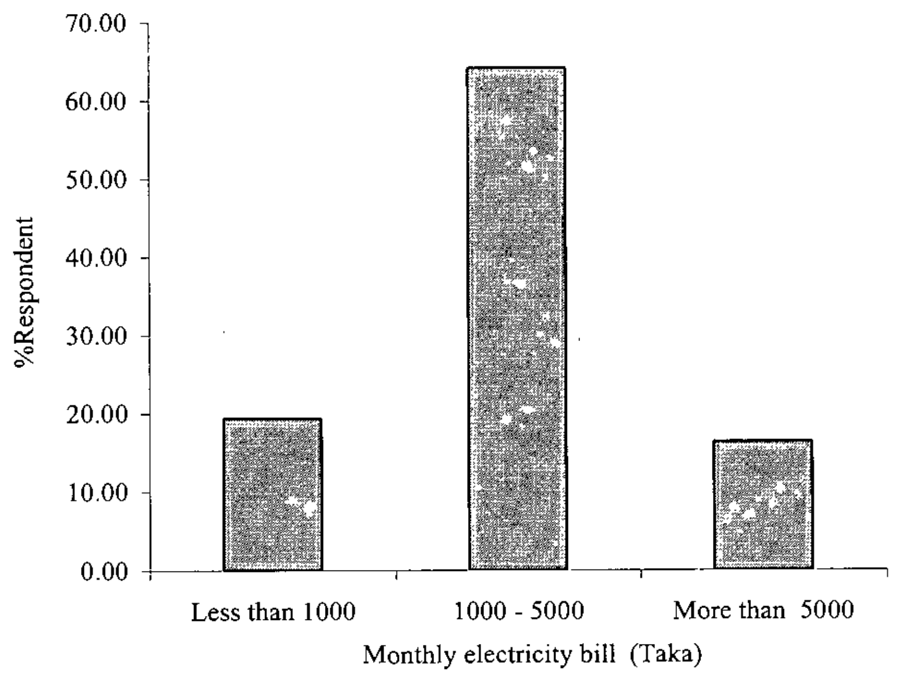


Figure 4.11: The classification of commercial respodents on the basis of payment of monthly electricity bill

It is seen from Figure 4.11 that 19.40% commercial respondents have the monthly average electricity bills less than Taka 1000.00 and 64.18% respondents have between Taka 1000.00 - 5000.00. Rest 16.42% respondents have the monthly average electricity bills more than Taka 5000.00.

4.4.2 Summary of the Alternatives used by Commercial Respondents

All commercial respondents used the alternative sources during power interruption period. But, the type and duration of alternative sources used by them are not same. The durations of alternatives used are also different. The use of alternative sources is shown in Table 4.8.

Table 4.8: Statistics of Alternative Sources used by Commercial Respondents

Name of the alternative source used	Number of user	Duration of alternative used (hours)
Charger light	20	740.57
Generator	4	152.00
Candle	43	1318.18

It is observed from Table 4.8 that 64.18% respondents have used candles which is the maximum usage of alternative source among the other sources.

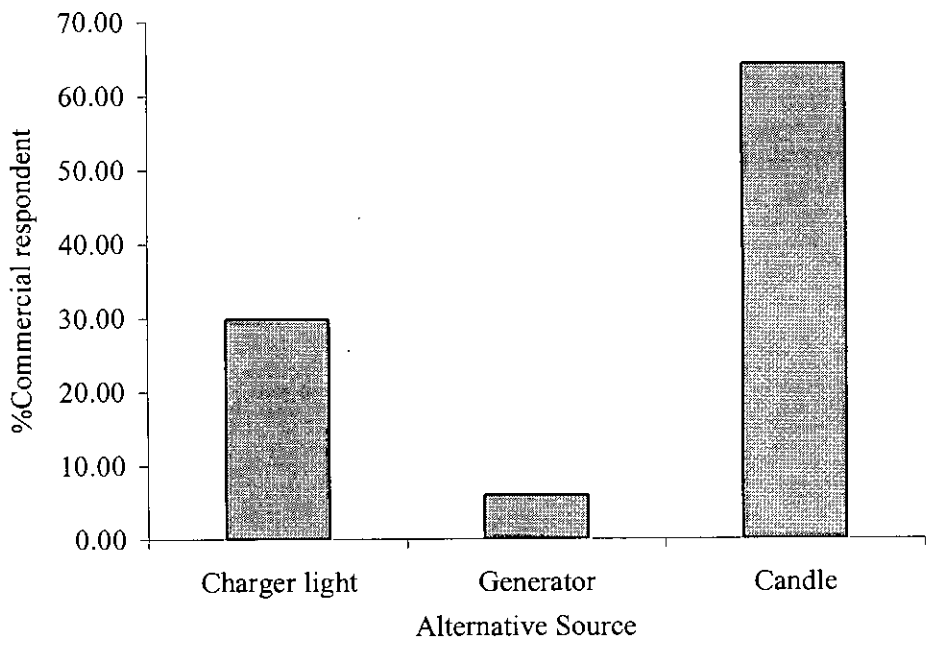


Figure 4.12: The alternative sources used by commercial respondents

Figure 4.12 presents the staitstics of the alternative sources used by commercial respondents. It is seen from the figure that 64.18% respondents have used candles, 29.85% respondents have used charger lights and 5.97% respondents have used generators. But, no body has used IPS, UPS, lantern and kerosene lamp during the sampling period.

4.4.3 Calculation of Loss of Commercial Respondent

A sample calculation for the commercial respondent number 36 is shown in Appendix L. The losses due to power interruption for all commercial respondents are evaluated accordingly and presented in Table 4.9.

Table 4.9: Evaluated Interruption Cost in case of Commercial Respondents

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of perishable goods (Taka)	Cost due to reduced sale and additional wages (Taka)	Total cost of interruption during the sampling Period (Taka)	Total Cost per hour of inteeruption (Taka)	Total cost per interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	J″	$j'' = J'' \times T_1$
1	89.03	97.24	500.00	3000.00	3686.27	45.72	25.92
2	0	420.00	0	3000.00	3420.00	45.10	26.11
3	0	410.00	0	7000.00	7410.00	99.35	57.00
4	0	129.00	0	7000.00	7129.00	93.56	54.01
5	0	77.88	0	10000.00	10077.88	135.01	79.66
6	57.74	378.00	450.00	5000.00	5885.74	78.76	46.71
7	0	59.18	0	2500.00	2559.18	42.17	34.99
8	0	360.00	300.00	3000.00	3660.00	59.45	48.80
9	0	61.15	0	2858.33	2919.48	48.11	39.88
10	0	190.00	0	2000.00	2190.00	35.86	30.00
11	0	59.77	0	3200.00	3259.77	53.46	43.88
12	0	111.00	0	1920.00	2031.00	33.19	28.21
13	0	61.53	0	3468.00	3529.53	57.80	46.26
14	84.43	64.03	0	1500.00	1648.45	27.18	21.56
15	0	360.00	0	2500.00	2860.00	46.50	38.13
16	0	56.05	0	3200.00	3256.05	53.85	45.02
17	0	58.07	0	3200.00	3258.07	53.44	43.84
18	0	55.84	0	3840.00	3895.84	64.91	54.51
19	0	60.05	0	2600.00	2660.05	43.59	35.41
20	85.79	62.26	0	4488.00	4636.06	75.74	62.24
21	0	113.60	0	10000.00	10113.60	159.70	72.29
22	93.15	58.37	0	13680.00	13831.52	215.15	97.72
23	0	400.00	0	7000.00	7400.00	114.61	52.11
24	0	390.00	0	8000.00	8390.00	131.78	59.50
25	71.99	1053.29	1000.00	2500.00	4625.28	86.98	39.30
26	49.97	252.00	0	6400.00	6701.97	103.16	46.55
27	0	960.00	750.00	18000.00	19710.00	**305.74**	138.81
28	223.10	1098.67	0	5000.00	6321.77	112.96	50.70
29	135.90	1072.82	0	3000.00	4208.71	79.21	35.42
30	0	200.00	0	6000.00	6200.00	69.02	40.52
31	0	410.00	500.00	10333.33	11243.33	123.49	72.54
32	45.07	246.00	750.00	6000.00	7041.07	77.43	45.72
33	0	240.00	800.00	8000.00	9040.00	100.74	59.09
34	0	234.00	0	6000.00	6234.00	70.96	41.56
35	0	234.00	700.00	5900.00	6834.00	78.00	45.86
36	45.80	44.71	800.00	7116.67	8007.18	89.87	52.51
37	0	975.00	0	10000.00	10975.00	122.49	72.21
38	52.52	220.00	360.00	2066.67	2699.19	50.86	24.99
39	0	220.00	400.00	2200.00	2820.00	53.14	26.11
40	96.10	42.72	800.00	4133.33	5072.16	96.62	47.48

(To continue)

(Continued)

Respondent	Cost due to damage of appliance (Taka)	Cost due to use of alternative source (Taka)	Cost of perishable goods (Taka)	Cost due to reduced sale and additional wages (Taka)	Total cost of interruption during the sampling Period (Taka)	Total Cost per hour of inteeruption (Taka)	Total cost per interruption (Taka)
ID No.	J_1	J_2	J_3	J_4	J	J″	$j'' = J'' \times T_1$
41	0	100.00	700.00	3000.00	3800.00	73.22	35.85
42	48.42	43.17	250.00	3100.00	3441.59	65.93	32.42
43	43.61	200.00	0	1400.00	1643.61	31.21	15.51
44	35.76	105.00	0	9000.00	9140.76	172.47	84.63
45	50.22	105.00	0	5200.00	5355.22	101.81	50.05
46	47.94	42.48	0	5400.00	5490.42	105.83	52.36
47	0	105.00	0	3000.00	3105.00	58.73	29.02
48	0	100.00	0	4133.33	4233.33	79.82	39.19
49	0	210.00	0	5000.00	5210.00	98.61	48.69
50	51.04	264.00	0	4000.00	4315.04	81.36	39.95
51	78.22	300.00	670.00	3000.00	4048.22	78.20	38.55
52	42.54	120.00	640.00	4000.00	4802.54	90.44	45.30
53	0	110.00	0	3100.00	3210.00	60.95	29.73
54	0	200.00	480.00	2900.00	3580.00	67.93	33.78
55	50.66	264.00	500.00	4133.33	4948.00	93.53	45.81
56	0	210.00	0	3200.00	3410.00	64.67	31.87
57	27.88	220.00	0	3720.00	3967.88	74.87	36.74
58	0	315.00	570.00	5083.33	5968.33	113.54	56.30
59	0	110.00	0	1200.00	1310.00	24.70	12.13
60	0	1050.26	0	1000.00	2050.26	41.62	20.42
61	0	41.96	540.00	3200.00	3781.96	74.79	36.92
62	0	220.00	430.00	3306.67	3956.67	74.75	36.63
63	0	190.00	0	3866.67	4056.67	80.81	39.77
64	79.72	42.60	320.00	2893.33	3335.65	64.46	31.77
65	0	105.00	0	3660.00	3765.00	72.64	35.86
66	0	200.00	280.00	3000.00	3480.00	68.24	33.78
67	48.06	44.16	580.00	0	672.22	**13.86**	6.80

Table 4.9 presents the evaluated four cost components and the total cost of interruption for commercial respondents. The evaluated four cost components are presented individually to realize the impact of every cost component. The sum of the four cost components is presented in sixth column of this table. Also, the total cost of interruption per hour and per interruption are calculated and listed in the last two columns. It is observed from the table that the cost due to reduced sale and additional wages is the highest among all cost components. The highest total cost of interruption per hour is Taka 305.74 and that of the lowest is Taka 13.86. Also, the overall average cost per hour of interruption, per interruption and per kWh are Taka 81.55, 44.53 and 20.70, respectively.

4.5 Evaluation of Reliability of Power Supply

The reliability of power supply to residential, industrial and commercial consumers is determined. The daily average use of electricity in residential, industrial and commercial sectors is considered to be 6, 8 and 10 hours respectively.

The sampling period (T_S) in days is multiplied by the daily average use of electricity (H_O) in hour to find the total use (H_S). The number of interruption encountered (NI_S) is divided by this total use (H_S) to determine the probability of interruption (P_I). The value of the probability of interruption is less than unity. Therefore, to find the reliability of supply (R) in percentage, the probability of interruption is deducted from unity and multiplied by 100. Table 4.10, 4.11 and 4.12 present the reliability values of power supply to respondents of the three sectors.

Table 4.10: Reliability of Supply to Residential Respondent during the Sampling Period

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption/hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
1	74	444	131	0.30	70.50
2	74	444	131	0.30	70.50
3	74	444	131	0.30	70.50
4	74	444	131	0.30	70.50
5	74	444	131	0.30	70.50
6	74	444	131	0.30	70.50
7	73	438	88	0.20	79.91
8	72	432	87	0.20	79.86
9	71	426	85	0.20	**80.05**
10	50	300	83	0.28	72.33
11	74	444	104	0.23	76.58
12	38	228	52	0.23	77.19
13	71	426	142	0.33	66.67
14	72	432	142	0.33	67.13
15	71	426	142	0.33	66.67
16	71	426	142	0.33	66.67
17	71	426	140	0.33	67.14
18	71	426	143	0.34	66.43
19	69	414	142	0.34	65.70
20	69	414	141	0.34	65.94
21	70	420	141	0.34	66.43
22	71	426	142	0.33	66.67
23	71	426	142	0.33	66.67
24	68	408	137	0.34	66.42
25	71	426	142	0.33	66.67
26	70	420	141	0.34	66.43
27	70	420	141	0.34	66.43
28	70	420	141	0.34	66.43
29	70	420	141	0.34	66.43
30	71	426	141	0.33	66.90
31	70	420	140	0.33	66.67
32	70	420	140	0.33	66.67
33	69	414	138	0.33	66.67
34	68	408	138	0.34	66.18
35	70	420	140	0.33	66.67
36	68	408	135	0.33	66.91
37	69	414	140	0.34	66.18
38	71	426	141	0.33	66.90
39	67	402	136	0.34	66.17
40	65	390	135	0.35	65.38

(To continue)

(Continued)

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption/hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
41	66	396	137	0.35	65.40
42	65	390	136	0.35	65.13
43	49	294	74	0.25	74.83
44	49	294	74	0.25	74.83
45	49	294	74	0.25	74.83
46	49	294	74	0.25	74.83
47	51	306	78	0.25	74.51
48	50	300	76	0.25	74.67
49	50	300	76	0.25	74.67
50	52	312	79	0.25	74.68
51	51	306	77	0.25	74.84
52	51	306	76	0.25	75.16
53	50	300	76	0.25	74.67
54	51	306	77	0.25	74.84
55	52	312	78	0.25	75.00
56	52	312	78	0.25	75.00
57	52	312	78	0.25	75.00
58	49	294	74	0.25	74.83
59	50	300	75	0.25	75.00
60	49	294	74	0.25	74.83
61	57	342	142	0.42	58.48
62	56	336	141	0.42	**58.04**
63	57	342	142	0.42	58.48
64	57	342	141	0.41	58.77
65	56	336	140	0.42	58.33
66	55	330	140	0.42	57.58
67	57	342	142	0.42	58.48
68	56	336	141	0.42	58.04
69	58	348	143	0.41	58.91
70	58	348	143	0.41	58.91
71	57	342	142	0.42	58.48
72	57	342	142	0.42	58.48
73	56	336	140	0.42	58.33
74	59	354	144	0.41	59.32
75	73	438	120	0.27	72.60
76	58	348	143	0.41	58.91
77	58	348	143	0.41	58.91
78	58	348	143	0.41	58.91
79	59	354	144	0.41	59.32
80	69	414	168	0.41	59.42

(To continue)

(Continued)

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption/hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
81	68	408	167	0.41	59.07
82	69	414	168	0.41	59.42
83	69	414	168	0.41	59.42
84	67	402	166	0.41	58.71
85	68	408	167	0.41	59.07
86	69	414	168	0.41	59.42
87	68	408	167	0.41	59.07
88	67	402	166	0.41	58.71
89	69	414	168	0.41	59.42
90	68	408	167	0.41	59.07
91	70	420	169	0.40	59.76
92	70	420	169	0.40	59.76
93	70	420	120	0.29	71.43
94	70	420	120	0.29	71.43
95	70	420	120	0.29	71.43
96	68	408	117	0.29	71.32
97	69	414	120	0.29	71.01
98	68	408	117	0.29	71.32
99	67	402	115	0.29	71.39
100	69	414	119	0.29	71.26
101	70	420	120	0.29	71.43
102	68	408	151	0.37	62.99
103	68	408	151	0.37	62.99
104	69	414	152	0.37	63.29
105	66	396	149	0.38	62.37
106	67	402	150	0.37	62.69
107	68	408	151	0.37	62.99
108	66	396	149	0.38	62.37
109	65	390	148	0.38	62.05
110	74	444	121	0.27	72.75

Table 4.10 presents the reliability of supply to residential respondents during the sampling period. It is seen from the table that the reliability depends on the probability of interruption. If the probability of interruption increases, the reliability of supply decreases and vice versa. It is also seen that the highest and lowest reliabity levels of supply to residential respondents are 80.05 and 58.04%, respectively. The overall average reliability level is 66.75%.

Table 4.11: Reliability of Supply to Industrial Respondent during the Sampling Period

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption/hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
1	60	480	150	0.31	68.75
2	62	496	125	0.25	74.80
3	61	488	152	0.31	68.85
4	62	496	153	0.31	69.15
5	60	480	150	0.31	**68.75**
6	62	496	119	0.24	76.01
7	30	240	48	0.20	80.00
8	52	416	101	0.24	75.72
9	64	512	141	0.28	72.46
10	63	504	138	0.27	72.62
11	63	504	137	0.27	72.82
12	62	496	136	0.27	72.58
13	62	496	136	0.27	72.58
14	62	496	108	0.22	78.23
15	61	488	107	0.22	78.07
16	62	496	145	0.29	70.77
17	60	480	116	0.24	75.83
18	58	464	102	0.22	78.02
19	59	472	103	0.22	78.18
20	62	496	107	0.22	78.43
21	62	496	107	0.22	78.43
22	62	496	145	0.29	70.77
23	56	448	130	0.29	70.98
24	62	496	149	0.30	69.96
25	60	480	104	0.22	78.33
26	60	480	101	0.21	78.96
27	61	488	106	0.22	78.28
28	62	496	108	0.22	78.23
29	62	496	108	0.22	78.23
30	62	496	108	0.22	78.23
31	61	488	106	0.22	78.28
32	60	480	137	0.29	71.46
33	62	496	139	0.28	71.98
34	62	496	108	0.22	78.23
35	62	496	108	0.22	78.23
36	60	480	105	0.22	78.13
37	61	488	96	0.20	**80.33**
38	58	464	100	0.22	78.45

(To continue)

(Continued)

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption/hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
39	56	448	126	0.28	71.88
40	57	456	103	0.23	77.41
41	63	504	105	0.21	79.17
42	58	464	131	0.28	71.77
43	60	480	107	0.22	77.71
44	62	496	111	0.22	77.62
45	63	504	105	0.21	79.17
46	61	488	110	0.23	77.46
47	62	496	111	0.22	77.62
48	64	512	106	0.21	79.30
49	59	472	94	0.20	80.08
50	60	480	95	0.20	80.21
51	63	504	105	0.21	79.17
52	62	496	111	0.22	77.62
53	62	496	104	0.21	79.03
54	58	464	105	0.23	77.37

Table 4.11 presents the reliability of supply to industrial respondents during the sampling period. It is observed from the table that the reliability of supply depends on the probability of interruption. If the probaility of interruption increases, the system relibility decreases and and vice versa. The highest and lowest system relaibility values are 80.33, and 68.75%, respectively. The overall average reliability value of supply is 75.94%.

Table 4.12: Reliability of Supply to Commercial Respondent during the Sampling Period

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption /hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
1	72	720	143	0.20	80.14
2	63	630	131	0.21	79.21
3	62	620	130	0.21	79.03
4	64	640	132	0.21	79.38
5	63	630	127	0.20	79.84
6	62	620	126	0.20	79.68
7	49	490	74	0.15	84.90
8	50	500	75	0.15	85.00
9	49	490	74	0.15	84.90
10	49	490	73	0.15	85.10
11	50	500	75	0.15	85.00
12	48	480	72	0.15	85.00
13	51	510	77	0.15	84.90
14	52	520	78	0.15	85.00
15	50	500	75	0.15	85.00
16	48	480	73	0.15	84.79
17	50	500	75	0.15	85.00
18	48	480	72	0.15	85.00
19	52	520	76	0.15	85.38
20	51	510	75	0.15	**85.29**
21	56	560	141	0.25	74.82
22	57	570	142	0.25	75.09
23	57	570	142	0.25	75.09
24	56	560	141	0.25	74.82
25	56	560	141	0.25	74.82
26	59	590	144	0.24	75.59
27	58	580	142	0.24	75.52
28	57	570	142	0.25	75.09
29	58	580	143	0.25	75.34
30	61	610	153	0.25	74.92
31	62	620	155	0.25	75.00
32	62	620	154	0.25	75.16
33	61	610	153	0.25	74.92
34	60	600	150	0.25	75.00
35	59	590	149	0.25	74.75
36	61	610	153	0.25	74.92
37	60	600	152	0.25	**74.67**
38	62	620	108	0.17	82.58
39	62	620	108	0.17	82.58
40	62	620	143	0.23	76.94

(To continue)

(Continued)

Respondent	No. of observation (days)	Total use of electricity (hours)	No. of interruption encountered	Probability of interruption (interruption /hour)	% Reliability
ID No.	T_S	$H_S = T_S \times H_O$	NI_S	$P_I = NI_S \div H_S$	$R = (1 - P_I)100$
41	60	600	139	0.23	76.83
42	62	620	108	0.17	82.58
43	60	600	106	0.18	82.33
44	62	620	142	0.23	77.10
45	61	610	141	0.23	76.89
46	60	600	138	0.23	77.00
47	61	610	140	0.23	77.05
48	62	620	108	0.17	82.58
49	61	610	107	0.18	82.46
50	62	620	108	0.17	82.58
51	60	600	105	0.18	82.50
52	60	600	106	0.18	82.33
53	62	620	108	0.17	82.58
54	60	600	106	0.18	82.33
55	62	620	108	0.17	82.58
56	61	610	107	0.18	82.46
57	62	620	108	0.17	82.58
58	61	610	110	0.18	81.97
59	62	620	108	0.17	82.58
60	61	610	106	0.17	82.62
61	60	600	104	0.17	82.67
62	62	620	112	0.18	81.94
63	58	580	102	0.18	82.41
64	62	620	107	0.17	82.74
65	61	610	105	0.17	82.79
66	60	600	103	0.17	82.83
67	62	620	108	0.17	82.58

Table 4.12 presents the reliability of supply to commercial respondents during the sampling period. It is observed from the table that the system reliability depends on the probability of interruption. If the probability of interruption increases, the reliability of supply decreases and vice versa.The highest and lowest reliability levels are 85.29 and 74.67%, respectively. Also, the overall average reliability value of supply to commercial respondents is 80.37%.

CHAPTER FIVE

ANALYSIS OF EVALUATED LOSS

5.1 Introduction

This chapter presents discussions on the evaluated losses due to power interruptions of different categories of consumers. The losses due to interruptions of power for residential, industrial and commercial respondents are not same. The evaluated losses for all respondents in chapter 4 are analyzed here separately. The evaluated interruption costs are compared with the expected maximum electricity bill for uninterrupted power supply and with the actual electricity bill paid per hour. Also, the losses of different types of consumers, classified according to the area of the premises, connected load of the premises and the hourly average electricity bill, are compared. A correlation between the evaluated interruption cost and the system reliability is established. The evaluated interruption costs are also compared with the results recently published in the journal. Observation and discussion on the analysis of data are also made to draw the real picture of the losses of interruptions.

5.2 Analysis of Loss of Interruption of Power

The evaluated losses for different categories of all respondents are analyzed sector wise. The total cost per hour of interruption for every respondent of the three sectors is arranged in tabular form. Then, the interruption costs are compared with the costs of electricity.

5.2.1 Analysis of Interruption Cost for Residential Sector

The total cost of interruption for every residential respondent is compared with expected bill of uninterrupted electric supply and also with the hourly average electricity bill paid. The costs of interruption of different classes of respondents are compared in this section. The variation of cost of interruption with the system reliability is also presented in this section.

5.2.1.1 Comparison of Interruption Cost with the Cost of Electricity in Residential Sector

The evaluated total costs of interruption for residential respondents are presented in Table 5.1. The maximum cost of electricity per hour if the power supply is not interrupted is calculated by using the average rate of electricity from the utility and the connected load of the house. The hourly average electricity bill paid by each respondent is calculated from the monthly average electricity bill paid and these are also listed in Table 5.1. The total cost of interruption for every respondent is compared with the maximum cost of electricity for uninterrupted power supply and with the average electricity bill paid.

Table 5.1: Comparison of the Ratios of Losses of Residential Respondents

Respondent	Expected maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total cost per hour of interruption	Ratio of cost of interruption and expected maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
1	8.03	0.65	40.61	5.06	62.66
2	5.84	0.59	33.36	5.71	56.21
3	7.19	0.71	30.67	4.26	43.26
4	6.05	0.59	29.30	4.84	49.44
5	6.82	0.59	36.31	5.32	61.21
6	7.24	0.83	39.81	5.50	48.17
7	5.92	0.76	20.64	3.49	27.01
8	3.51	0.64	17.03	4.85	26.44
9	6.41	0.80	21.76	3.39	27.14
10	6.68	1.00	33.98	5.09	33.96
11	6.82	0.85	27.75	4.07	32.68
12	3.65	0.63	23.69	6.49	37.71
13	5.89	1.12	44.12	7.50	39.37
14	3.36	0.73	32.47	9.67	44.61
15	3.42	0.76	28.11	8.23	37.13
16	3.59	0.79	24.96	6.95	31.61
17	6.05	1.16	36.02	5.95	30.94
18	3.36	0.74	21.46	6.39	29.01
19	3.36	0.73	39.17	11.67	53.61
20	3.36	0.73	39.77	11.84	54.44
21	6.05	1.18	33.48	5.53	28.47
22	4.80	1.00	40.06	8.35	40.16
23	3.59	0.78	35.19	9.80	45.32
24	3.59	0.78	37.34	10.40	48.07
25	100.19	2.97	37.88	0.38	12.74
26	14.19	2.97	39.72	2.80	13.36
27	3.04	0.66	28.73	9.44	43.85
28	3.04	0.65	34.98	11.50	53.44
29	3.04	0.65	25.07	8.24	38.32
30	6.09	1.23	40.75	6.69	33.21
31	3.77	0.79	34.99	9.29	44.02
32	3.04	0.65	34.02	11.18	52.00
33	3.59	0.77	41.02	11.42	53.31
34	3.59	0.67	38.69	10.77	57.60
35	29.93	5.95	38.50	1.29	6.47
36	3.42	0.73	39.17	11.47	53.44
37	3.18	0.68	41.26	12.96	60.71
38	8.37	1.78	39.63	4.74	22.29
39	3.69	0.79	37.83	10.27	48.18
40	3.36	0.73	37.63	11.21	51.51

(To continue)

(Continued)

Respondent	Expected maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total cost per hour of interruption	Ratio of cost of interruption and expected maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
41	3.71	0.79	40.43	10.90	50.98
42	3.36	0.74	37.70	11.23	51.21
43	2.97	0.62	29.99	10.09	48.49
44	2.97	0.65	32.86	11.06	50.77
45	13.93	2.87	29.60	2.13	10.31
46	13.93	2.87	29.68	2.13	10.33
47	7.46	1.43	32.20	4.32	22.51
48	13.94	2.88	35.31	2.53	12.26
49	3.14	0.72	28.04	8.94	39.13
50	30.82	6.53	32.72	1.06	5.01
51	3.28	0.71	29.06	8.87	40.89
52	3.28	0.71	30.92	9.44	43.52
53	3.28	0.72	22.40	6.84	31.31
54	3.28	0.72	41.71	12.73	57.57
55	3.28	0.72	14.24	4.35	19.65
56	3.28	0.72	19.01	5.80	26.24
57	3.28	0.72	26.29	8.02	36.75
58	3.18	0.69	44.97	14.13	64.76
59	14.39	3.11	36.07	2.51	11.61
60	2.97	0.61	18.58	6.25	30.28
61	22.30	4.07	56.92	2.55	13.98
62	11.72	2.01	32.90	2.81	16.40
63	22.13	4.00	49.66	2.24	12.42
64	23.18	6.31	47.46	2.05	7.52
65	14.01	3.05	45.16	3.22	14.83
66	22.81	4.24	51.41	2.25	12.13
67	23.39	4.41	63.20	2.70	14.33
68	4.61	0.98	30.37	6.59	30.91
69	22.05	4.00	59.64	2.70	14.93
70	5.98	1.15	38.99	6.52	33.96
71	22.55	4.12	34.92	1.55	8.48
72	41.58	9.85	75.68	1.82	7.69
73	21.92	3.98	61.89	2.82	15.53
74	15.81	3.44	45.97	2.91	13.36
75	5.08	0.94	18.94	3.73	20.11
76	3.86	0.82	41.69	10.80	50.62
77	11.30	2.57	52.65	4.66	20.49
78	22.16	4.44	57.15	2.58	12.87
79	3.63	0.80	23.01	6.34	28.64
80	3.33	0.73	50.92	15.27	69.83

(To continue)

(Continued)

Respondent	Expected maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total cost per hour of interruption	Ratio of cost of interruption and expected maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
81	3.33	0.73	37.50	11.25	51.42
82	3.33	0.74	25.34	7.60	34.43
83	6.01	1.61	39.73	6.61	24.70
84	3.33	0.77	22.58	6.77	29.38
85	2.63	0.58	42.57	16.17	73.27
86	6.06	1.18	33.67	5.56	28.64
87	2.77	0.61	28.83	10.40	46.97
88	2.94	0.65	30.41	10.33	46.76
89	7.23	1.49	41.43	5.73	27.74
90	4.27	0.91	60.14	14.08	66.24
91	4.04	0.88	39.78	9.85	45.11
92	8.57	1.85	6.76	0.79	3.66
93	2.40	0.51	38.42	16.02	75.93
94	1.48	0.33	15.58	10.52	46.73
95	4.05	0.84	30.29	7.48	35.89
96	6.23	1.21	40.32	6.47	33.31
97	7.15	1.22	36.17	5.06	29.54
98	4.70	0.98	29.99	6.38	30.64
99	4.04	0.72	31.94	7.90	44.42
100	4.68	0.83	41.30	8.82	49.62
101	2.88	0.60	9.12	3.17	15.14
102	2.60	0.60	38.53	14.83	63.77
103	2.02	0.48	39.26	19.40	82.33
104	4.93	0.93	36.92	7.49	39.77
105	6.40	1.31	27.87	4.36	21.27
106	3.44	0.77	40.35	11.72	52.67
107	4.10	0.87	57.02	13.93	65.69
108	4.33	0.93	47.53	10.98	50.95
109	2.85	0.64	31.55	11.05	49.56
110	5.16	1.00	32.94	6.38	32.86

Second column of Table 5.1 gives the maximum cost of electricity per hour for uninterrupted power supply. The hourly average electricity bill paid is calculated from the monthly average electricity bill and listed in third column. The ratio between the evaluated total cost per hour of interruption (J) and the expected maximum cost of electricity per hour for uninterrupted power supply (E_1) is calculated and listed in fifth column. Also, the ratio between the total cost of interruption (J) and the hourly average electricity bill paid by a residential respondent (E_2) is calculated and presented in the last column. It is observed from the above table that the ratio between the evaluated total cost per hour of interruption (J) and the average electricity bill paid by a residential respondent (E_2) is greater than the ratio between the evaluated total cost per hour of interruption (J) and the maximum hourly cost of uninterrupted power supply (E_1) i. e. $J/E_2 > J/E_1$.

5.2.1.2 Interruption Costs of different Classes of Residential Respondents

The evaluated interruption costs per hour for all residential respondents are summarized according to their classes to compare. Figure 5.1 shows this comparison.

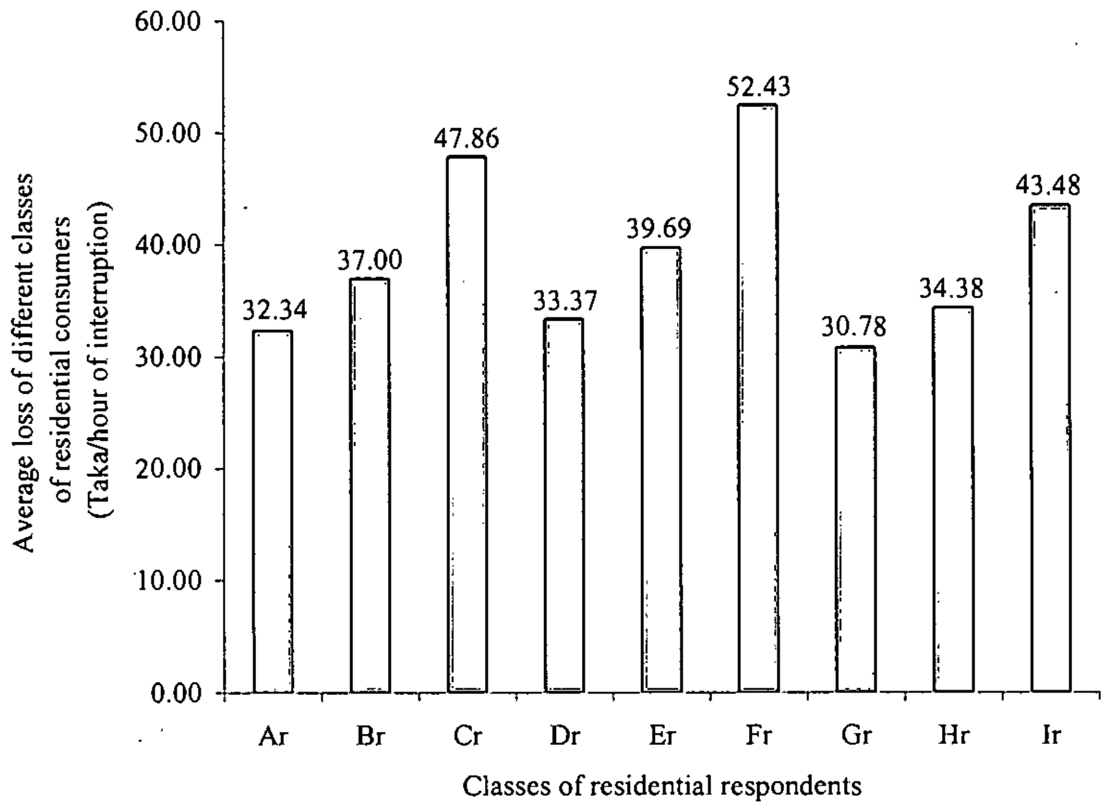


Figure 5.1: Comparison of the average cost per hour of interruption with the classes of residential respondents

It is observed from Figure 5.1 that the costs of interruption are the highest for the classes Cr, Fr and Ir. In other words, the costs of interruption are the highest for the respondents who have the houses with large areas, the highest amount of connected loads and the highest electricity bills. The cost of interruption is increased with the increase of the floor area of house, connected load and the monthly average electricity bill.

5.2.1.3 Comparison of Interruption Cost with the Electricity Bill of Residential Respondent

The average interruption costs per hour and the hourly average electricity bills paid by residential respondents are calculated accroding to the classes. These are compared in Figure 5.2.

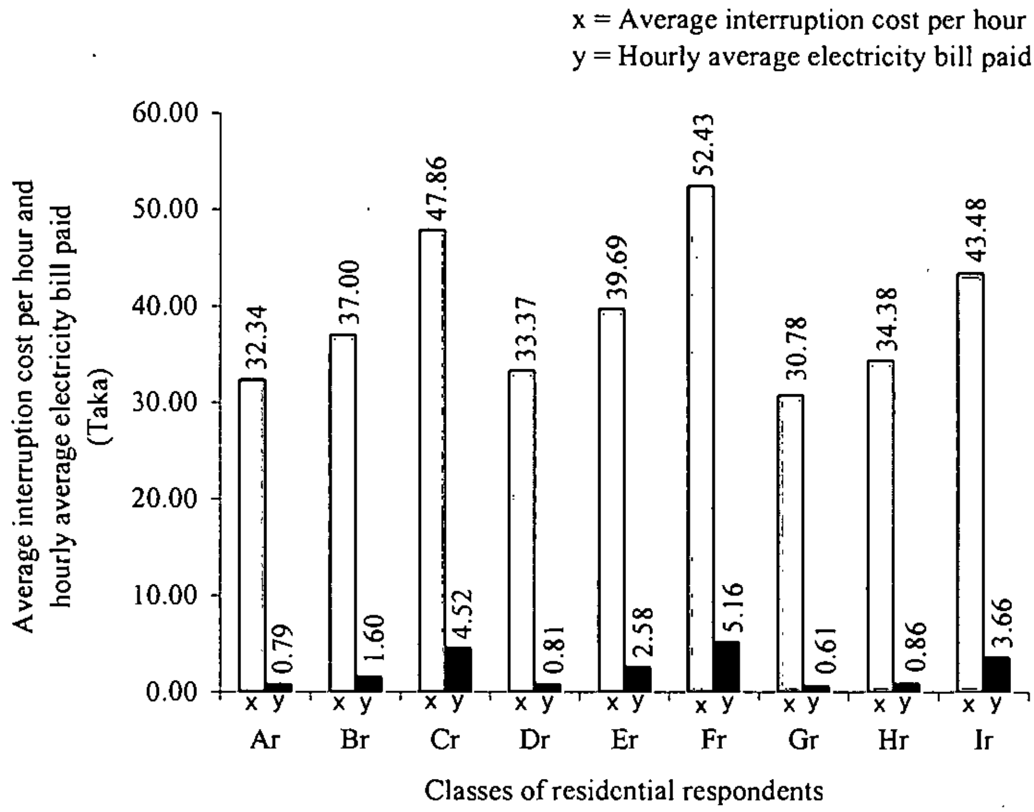


Figure 5.2: Average interruption cost per hour and the hourly average electricity bill paid according to the classes of residential respondents

It is observed from Figure 5.2 that the average cost of interruption and the hourly average electricity bill are the highest for the respondents of class Cr, who have the houses with the largest floor areas. Similarly, the costs are the highest for the respondents of class Fr, who have connected loads more. It is also seen that these costs are the highest for the respondents of class Ir, who have the highest payment of electricity bills.

It is clearly observed from the figure that the cost of interruption are higher than the electricity bill for all classes of residential respondents.

5.2.1.4 Correlation between the Interruption Cost and the Reliability of Power Supply to Residential Respondent

Table 5.2 presents the average cost of interruption of a group of residential respondents. This group is identified by the power supply reliability range. The average cost of interruption of each group is calculated by adding the cost of interruption of all respondents of that group.

Table 5.2: Interruption Cost and Reliability of Supply to Residential Respondents

% Power supply reliability range	Number of respondents	Average cost per hour of interruption
(R)	(Nos.)	(Taka)
57.0 – 59.99	31	42.85
60.0 – 62.99	7	40.30
63.0 – 65.99	6	38.60
66.0 – 68.99	25	35.42
69.0 – 71.99	15	32.21
72.0 – 74.99	16	30.18
75.0 – 77.99	7	25.42
78.0 – 80.99	3	19.81

It is observed from the above table that the highest average cost of interruption is Taka 42.85 of a group whose reliability of supply is the lowest. It is also observed that the lowest average cost of interruption is Taka 19.81of that group whose reliability of supply is the highest.

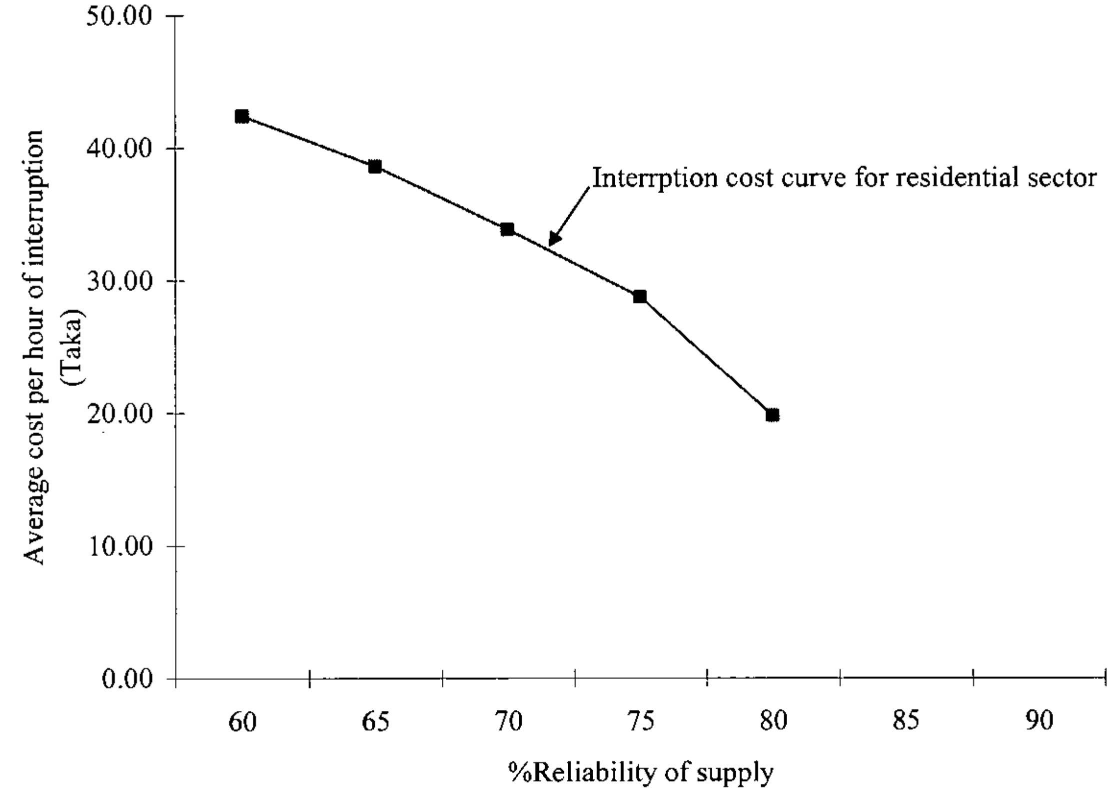


Figure 5.3: Correlation between the average cost per hour of interruption and the average reliability of supply to residential respondent

Figure 5.3 presents the correlation between the average cost per hour of interruption and the reliability of power supply of residential respondents. It is clearly observed from the figure that the cost of interruption decreases with the increases of reliability of power supply.

5.2.2 Analysis of Interruption Cost for Industrial Sector

The total cost of interruption for every industrial respondent is compared with the expected bill of uninterrupted electric supply and also with the hourly average electricity bill paid. The costs of interruption of different classes of respondents are compared in this section. The variation of interruption with the system reliability is also presented in this section.

5.2.2.1 Comparison of Interruption Cost with the Cost of Electricity in Industrial Sector

The comparison of cost of interruption of power with the cost of electricity in industrial sector is presented in Table 5.3. The maximum cost of electricity per hour if the power supply is not interrupted is calculated for every respondent by using the connected load of the industry and the corresponding average rate of electricity charged by the utility. The rate of electricity is Taka 3.83 per unit of energy consumption and it is treated as flat rate for industrial consumers. Here, this tariff is considered as because the industries under considerations are operated normally in the off-peak period. The calculated maximum cost of electricity per hour (E_1) for uninterrupted supply is given in second column of Table 5.3. The average electricity bill paid per hour (E_2) is calculated for every respondent from the monthly average electricity bill and given in third column. The evaluated total cost per hour of interruption (J) for every industrial respondent is listed in fourth column of this table.

Table 5.3 also shows the ratio between the total cost per hour of interruption (J) and the maximum cost of electricity per hour if the power supply is not interrupted (E_1). This ratio $\frac{J}{E_1}$ is presented in fifth column. The ratio between the total cost per hour of interruption (J) and the hourly average electricity bill paid (E_2) is presented in the last column.

Table 5.3: Comparison of the Ratios of Losses of Industrial Respondents

Respondent	Expexted maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total interruption cost per hour	Ratio of cost of interruption and expected maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
1	23.67	5.06	279.20	11.80	55.14
2	101.78	23.53	239.74	2.36	10.19
3	52.39	11.09	291.26	5.56	26.26
4	55.54	11.24	329.17	5.93	29.30
5	29.28	6.24	278.89	9.52	44.67
6	791.69	56.98	724.58	0.92	12.72
7	82.78	31.93	153.53	1.85	4.81
8	159.52	44.80	175.40	1.10	3.91
9	261.64	80.76	589.89	2.25	7.30
10	57.45	16.88	161.02	2.80	9.54
11	20.97	4.54	187.10	8.92	41.24
12	141.61	30.22	344.10	2.43	11.39
13	94.93	20.60	196.03	2.06	9.52
14	85.77	18.19	120.90	1.41	6.65
15	26.27	5.62	101.23	3.85	18.01
16	124.74	26.35	281.98	2.26	10.70
17	175.39	37.31	448.55	2.56	12.02
18	185.81	44.83	204.04	1.10	4.55
19	106.18	22.43	151.62	1.43	6.76
20	38.26	8.17	96.56	2.52	11.82
21	174.32	55.55	130.40	0.75	2.35
22	332.12	102.04	474.64	1.43	4.65
23	318.17	66.48	285.00	0.90	4.29
24	224.80	51.35	408.94	1.82	7.96
25	41.53	8.81	41.27	0.99	4.68
26	26.92	5.74	122.51	4.55	21.35
27	49.58	10.55	158.15	3.19	14.99
28	62.61	9.27	98.15	1.57	10.59
29	80.58	17.03	145.65	1.81	8.55
30	29.47	6.31	127.03	4.31	20.13
31	19.35	4.18	154.09	7.96	36.91
32	156.38	80.68	194.43	1.24	2.41
33	150.55	77.78	214.19	1.42	2.75
34	51.74	10.97	91.59	1.77	8.35
35	50.11	11.04	156.69	3.13	14.19
36	48.24	10.25	113.69	2.36	11.09
37	9.27	2.06	119.23	12.86	58.00
38	27.24	5.80	113.96	4.18	19.66

(To continue)

(Continued)

Respondent	Expexted maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total interruption cost per hour	Ratio of cost of interruption and expected maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
39	85.93	18.15	343.30	4.00	18.91
40	26.53	5.67	232.11	8.75	40.94
41	1271.78	284.72	507.28	0.40	1.78
42	28.04	22.35	346.84	12.37	15.52
43	156.49	39.42	471.79	3.01	11.97
44	58.29	14.44	143.30	2.46	9.92
45	1303.20	287.04	420.51	0.32	1.47
46	12.63	3.46	122.67	9.71	35.45
47	53.62	13.87	254.93	4.75	18.38
48	1158.40	398.81	1113.43	0.96	2.79
49	29.97	7.17	339.17	11.32	47.30
50	33.65	7.91	169.53	5.04	21.43
51	543.00	150.46	679.28	1.25	4.51
52	16.77	4.56	130.20	7.76	28.55
53	2172.00	313.43	595.02	0.27	1.90
54	74.51	42.58	184.44	2.48	4.33

It is observed from Table 5.3 that the ratio between the total cost per hour of interruption (J) and the hourly average electricity bill paid by a respondent (E_2) is greater than the ratio between the total interruption cost per hour (J) and the maximum cost of electricity per hour for uninterrupted power supply (E_1).

5.2.2.2 Interruption Costs of different Classes of Industrial Respondents

The interruption costs of different classes of industrial respondents are shown in Figure 5.4.

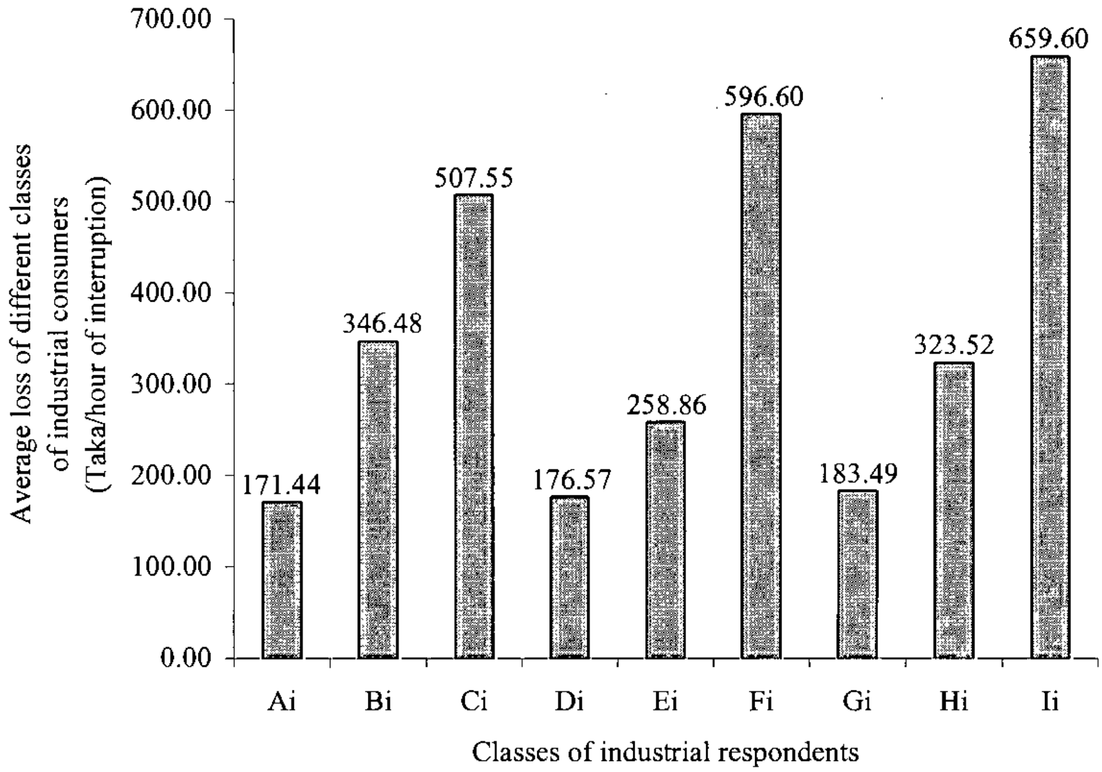


Figure 5.4: Comparison of the average cost per hour of interruption with the classes of industrial respondents

It is observed from the figure that the costs of interruptions of classes Ci, Fi and Ii are the highest. That is, the costs of interruptions are the highest for those respondents who have the industries with large physical areas, higher connected loads and the highest payment of electricity bills.

5.2.2.3 Comparison of Interruption Cost with the Electricity Bill of Industrial Respondent

The average costs per hour of interruption and the hourly average electricity bills paid by industrial respondents are compared in Figure 5.2.

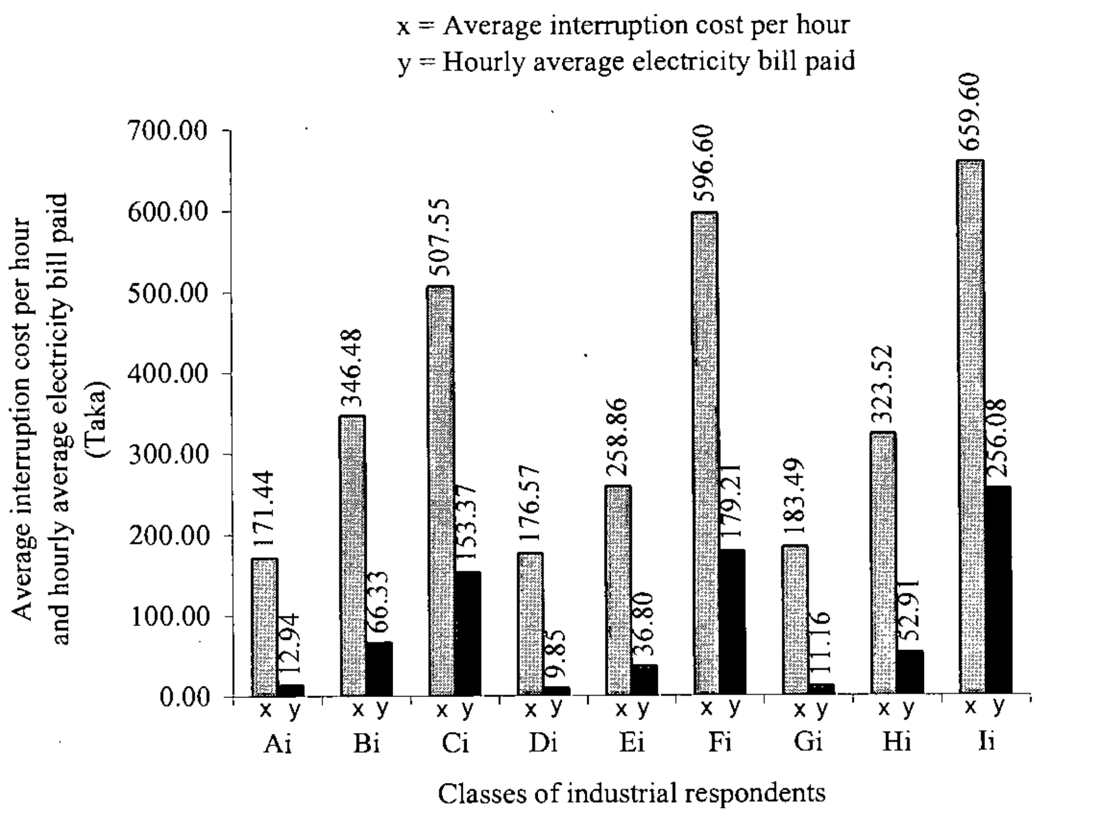


Figure 5.5: Average interruption cost per hour and the hourly average electricity bill paid according to the classes of industrial respondents

It is clearly observed from the figure that the cost of interruption are higher than the electricity bill for all classes of industrial respondents.

5.2.2.4 Correlation between the Interruption Cost and the Reliability of Power Supply to Industrial Respondent

Table 5.4 presents the average cost of interruption of a group of industrial respondents. This group is identified by the power supply reliability range. The average cost of interruption of each group is calculated by adding the cost of interruption of all respondents of that group.

Table 5.4: Interruption Cost and Reliability of Supply to Industrial Respondents

% Power supply reliability range	Number of respondents	Average cost per hour of interruption
(R)	(Nos.)	(Taka)
68.0 – 69.99	5	317.49
70.0 – 71.99	7	305.77
72.0 – 73.99	5	295.63
74.0 – 75.99	3	287.89
76.0 – 77.99	8	283.00
78.0 – 79.99	22	247.41
80.0 – 81.99	4	195.37

It is observed from the above table that the highest average cost of interruption is Taka 317.49 of a group whose reliability of supply is the lowest. It is also observed that the lowest average cost of interruption is Taka 195.37 of that group whose reliability of supply is the highest.

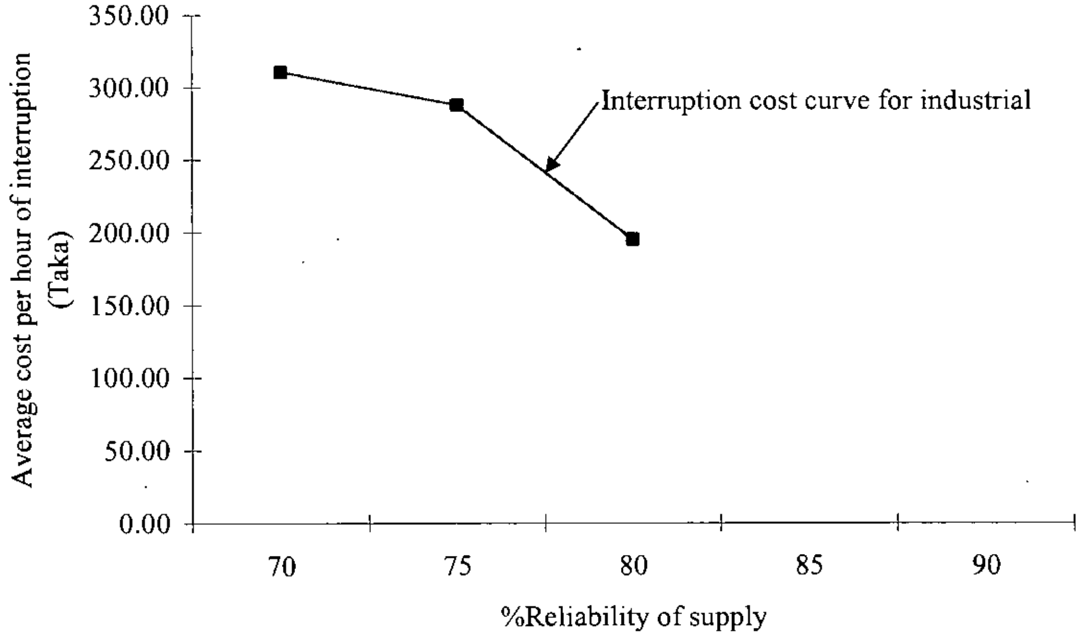


Figure 5.6: Correlation between the average cost per hour of interruption and the average reliability of supply to industrial respondent

Figure 5.6 presents the correlation between the average cost per hour of interruption and the reliability of power supply to industrial respondents. It is clearly observed from the figure that the cost of interruption decreases with the increases of reliability of power supply.

5.2.3 Analysis of Interruption Cost for Commercial Sector

The total cost of interruption for every commercial respondent is compared with the expected bill of uninterrupted electric supply and also with the hourly average electricity bill paid. The costs of interruption of different classes of respondents are compared in this section. The variation of cost of interruption with the system reliability is also presented in this section.

5.2.3.1 Comparison of Interruption Cost with the Cost of Electricity in Commercial Sector

The comparison of cost of interruption of power with the cost of electricity in commercial sector is presented in Table 5.5. The maximum cost of electricity per hour for uninterrupted power supply is calculated for every respondent by using the connected load of the shop and the corresponding average rate of electricity charged by the utility. The rate of electricity is Taka 5.04 per unit of energy consumption and it is treated as flat rate for commercial consumers. The calculated maximum cost of electricity per hour for uninterrupted power supply (E_1) is given in second column of Table 5.5. The average electricity bill paid per hour (E_2) is calculated for every respondent from the monthly average electricity bill and given in third column. The evaluated total cost per hour of interruption (J) for every commercial respondent is presented in fourth column of this table.

Table 5.5 also shows the ratio between the total cost per hour of interruption (J) and the maximum cost of electricity per hour for uninterrupted power supply (E_1). This ratio $\frac{J}{E_1}$ is presented in fifth column. The ratio between the total cost per hour of interruption (J) and the hourly average electricity bill paid (E_2) is presented in the last column.

Table 5.5: Comparison of the Ratios of Losses of Commercial Respondents

Respondent	Expected maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total interruption cost per hour	Ratio of cost of interruption and expexted maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
1	5.85	1.30	45.72	7.82	35.17
2	5.24	1.19	45.10	8.61	37.90
3	8.11	2.01	99.35	12.25	49.43
4	8.57	1.87	93.56	10.92	50.03
5	36.69	9.47	135.01	3.68	14.26
6	6.93	1.49	78.76	11.36	52.86
7	17.89	1.45	42.17	2.36	29.08
8	26.86	3.57	59.45	2.21	16.65
9	22.38	4.86	48.11	2.15	9.90
10	7.56	1.62	35.86	4.74	22.14
11	20.66	4.44	53.46	2.59	12.04
12	10.38	2.21	33.19	3.20	15.02
13	21.17	4.51	57.80	2.73	12.82
14	93.24	15.79	27.18	0.29	1.72
15	5.44	1.19	46.50	8.55	39.08
16	20.56	4.36	53.85	2.62	12.35
17	27.22	4.99	53.44	1.96	10.71
18	32.26	5.92	64.91	2.01	10.96
19	24.19	4.36	43.59	1.80	10.00
20	60.48	13.80	75.74	1.25	5.49
21	38.00	8.01	159.70	4.20	19.94
22	53.12	11.18	215.15	4.05	19.24
23	9.22	1.98	114.61	12.43	57.88
24	17.79	3.79	131.78	7.41	34.77
25	25.45	5.38	86.98	3.42	16.17
26	6.50	1.39	103.16	15.87	74.22
27	87.34	18.40	305.74	3.50	16.62
28	73.89	14.82	112.96	1.53	7.62
29	66.02	13.89	79.21	1.20	5.70
30	9.88	2.12	69.02	6.99	32.56
31	15.62	2.89	123.49	7.91	42.73
32	6.58	1.43	77.43	11.77	54.15
33	6.90	1.49	100.74	14.60	67.61
34	5.44	1.17	70.96	13.04	60.65
35	5.07	0.92	78.00	15.38	84.78
36	12.45	2.63	89.88	7.22	34.18
37	26.08	2.80	122.49	4.70	43.75
38	11.04	2.35	50.86	4.61	21.64
39	5.24	1.15	53.14	10.14	46.21
40	7.01	1.50	96.62	13.78	64.41

(To continue)

(Continued)

Respondent	Expected maximum cost of electricity per hour for uninterrupted power supply	Average electricity bill paid per hour (monthly bill/720)	Evaluated total interruption cost per hour	Ratio of cost of interruption and expexted maximum electricity bill	Ratio of cost of interruption and electricity bill paid
ID No.	E_1 (Tk.)	E_2 (Tk.)	J (Tk.)	J / E_1	J / E_2
41	5.19	1.13	73.22	14.11	64.79
42	16.04	3.43	65.93	4.11	19.22
43	6.45	1.39	31.21	4.84	22.45
44	39.76	12.16	172.47	4.34	14.18
45	9.15	1.97	101.81	11.13	51.68
46	13.26	2.82	105.83	7.98	37.53
47	10.48	2.25	58.73	5.60	26.10
48	5.04	1.09	79.82	15.84	73.23
49	7.42	1.58	98.61	13.29	62.41
50	6.05	1.31	81.36	13.45	62.11
51	6.78	1.46	78.20	11.53	53.56
52	20.41	4.33	90.44	4.43	20.89
53	11.79	2.53	60.95	5.17	24.09
54	10.13	2.45	67.93	6.71	27.73
55	12.98	3.05	93.53	7.21	30.67
56	5.88	1.27	64.67	11.00	50.92
57	8.70	1.86	74.87	8.61	40.25
58	50.80	10.69	113.54	2.24	10.62
59	5.24	0.85	24.70	4.71	29.06
60	8.16	1.75	41.62	5.10	23.78
61	62	2.32	74.79	6.84	32.24
62	10.48	2.24	74.75	7.13	33.37
63	8.94	1.90	80.81	9.04	42.53
64	8.57	1.83	64.46	7.52	35.22
65	57.46	12.08	72.64	1.26	6.01
66	16.74	3.56	68.24	4.08	19.17
67	7.16	1.52	13.86	1.94	9.12

It is observed from Table 5.5 that the ratio between the total cost per hour of interruption (J) and the hourly average electricity bill paid by a respondent (E_2) is greater than the ratio between the total cost per hour of interruption (J) and the maximun cost of electricity per hour for uninterrupted power supply (E_1).

5.2.3.2 Interruption Costs of different Classes of Commercial Respondents

The interruption cost of different classes of commercial respondents are summarized according to their classes to compare. Figure 5.7 presents this comparison.

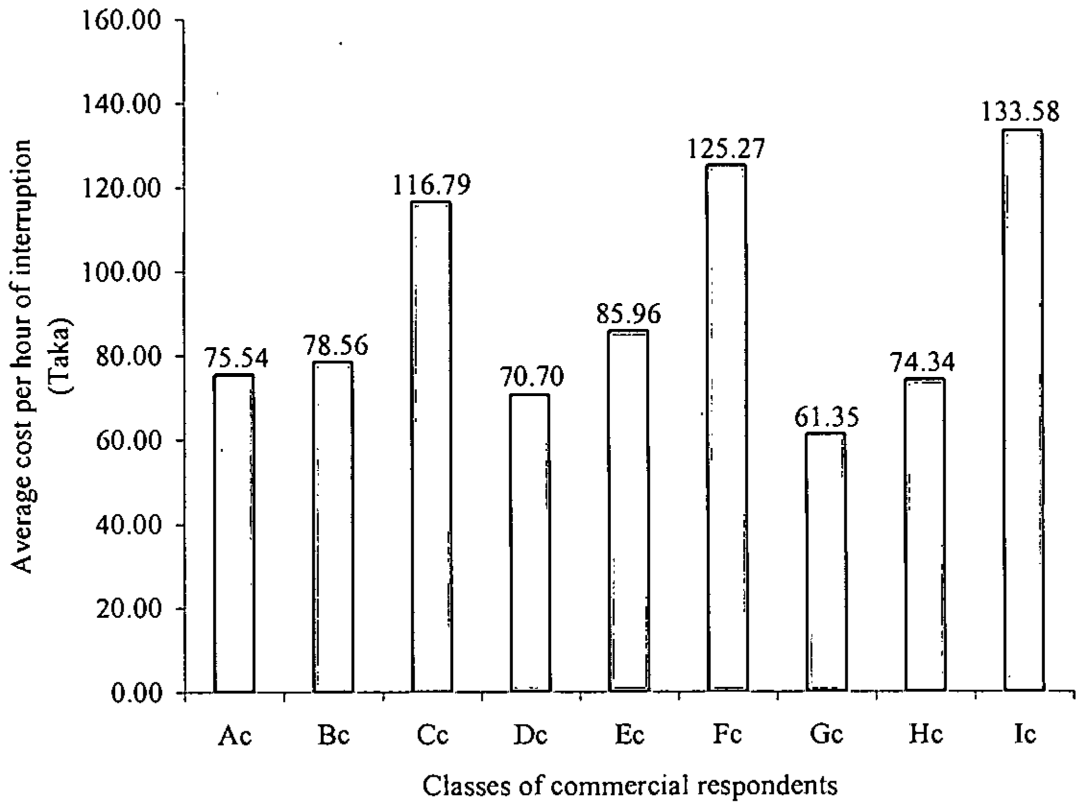


Figure 5.7: Comparison of the average cost per hour of interruption with the classes of commercial respondents

It is observed from Figure 5.7 that the costs of interruptions are the highest for the classes Cc, Fc and Ic. In other words, the interruption costs are the highest for the respondents who have the shops with large areas, the highest amount of connected loads and the highest payment of electricity bills.

5.2.3.3 Comparison of Interruption Cost with the Electricity Bill of Commercial Respondent

The average total costs per hour of interruption and the hourly average electricity bills paid by commercial respondents are compared in Figure 5.8.

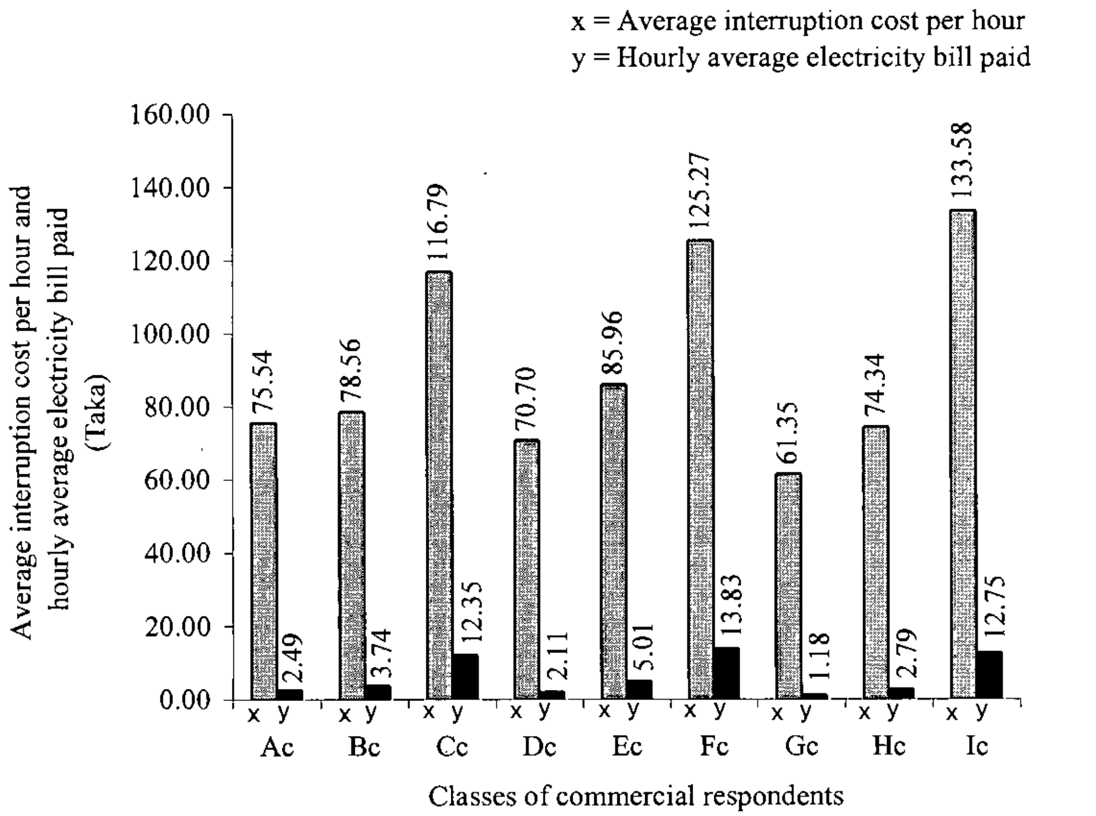


Figure 5.8: Average interruption cost per hour and the hourly average electricity bill paid according to the classes of commercial respondents

It is observed from Figure 5.8 that the average cost of interruption and the hourly average electricity bill are the highest for the respondents of class Cc, who have the shops with the largest floor areas. Similarly, the costs are the highest for the respondents of class Fc, who have more connected loads. It is also observed that the costs are the highest for the respondents of class Ic, who have the highest payment of electricity bills.

It is clearly observed from the figure that the costs of interruption are higher than the electricity bill for all classes of commercial respondents.

5.2.3.4 Correlation between the Interruption Cost and the Reliability of Power Supply to Commercial Respondent

Table 5.6 presents the average cost of interruption of a group of commercial respondents. This group is identified by the power supply reliability range. The average cost of interruption of each group is calculated by adding the cost of interruption of all respondents of that group.

Table 5.6: Interruption Cost and Reliability of Supply to Commercial Respondents

%Power supply reliability range	Number of respondents	Average cost per hour of interruption
(R)	(Nos.)	(Taka)
74.0 – 75.99	17	120.07
76.0 – 77.99	6	101.45
78.0 – 79.99	5	90.36
80.0 – 81.99	3	78.00
82.0 – 83.99	22	65.12
84.0 – 85.99	14	49.66

It is observed from the above table that the highest average cost of interruption is Taka 120.07 of a group whose reliability of supply is the lowest. It is also observed that the lowest average cost of interruption is Taka 49.66 of that group whose reliability of supply is the highest.

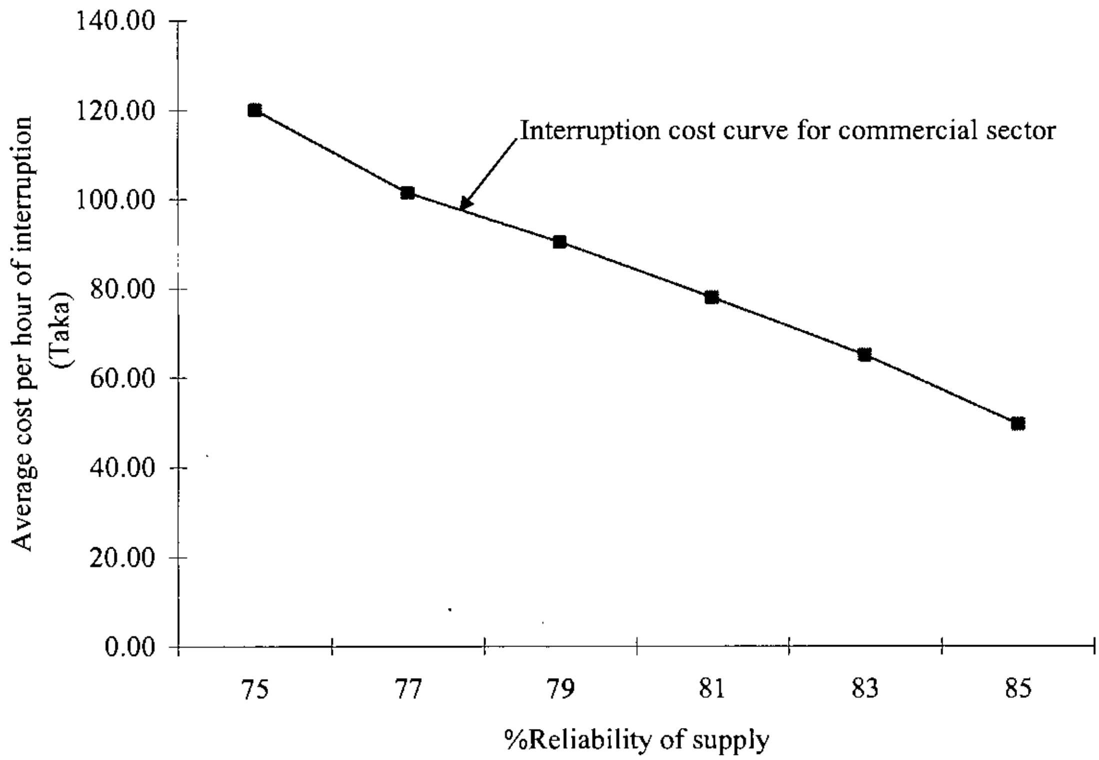
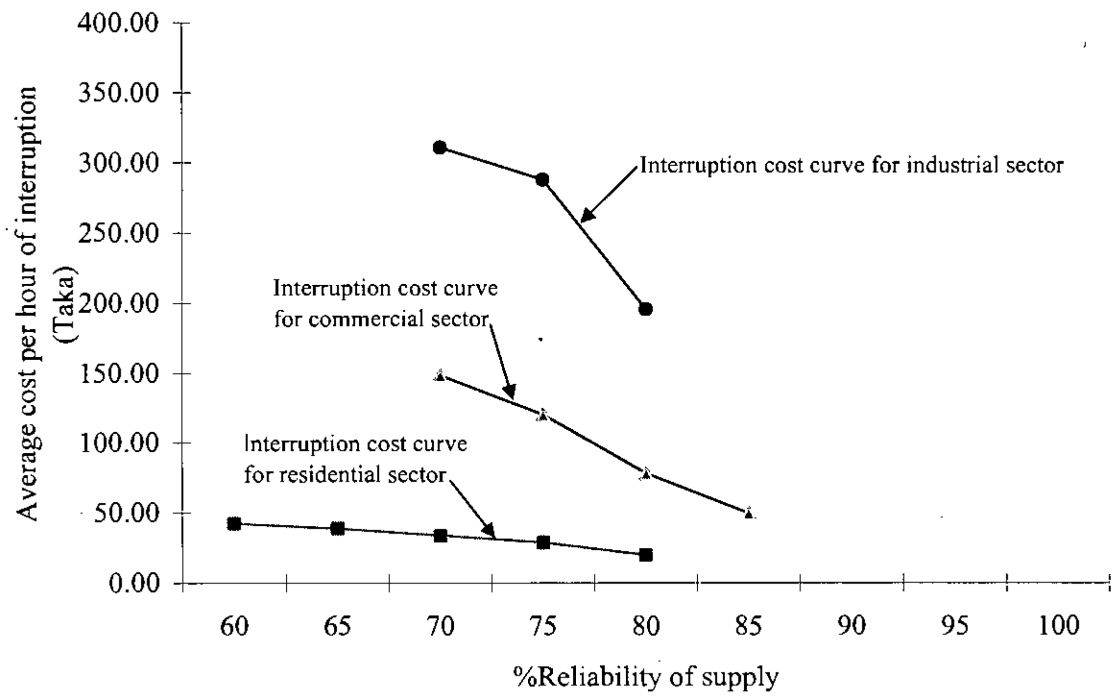


Figure 5.9: Correlation between the average cost per hour of interruption and the average reliability of supply to commercial respondent

Figure 5.9 presents the correlation between the average cost per hour of interruption and the reliability of power supply to commercial respondents. It is clearly observed from the figure that the cost of interruption decreases with the increases of reliability of power supply.

5.3 Comparison of Interruption Costs of different Classes of Consumers with the Variation of Reliability of Power Supply

The variation of interruption cost with the variation of the reliability of power supply is shown in Figure 5.10 for all three types of consumers.



Figuire 5.10: Comparison of interruption costs of different classes of consumers with the variation of reliability of supply

It is clearly observed from the figure that the interruption cost decreases with the increases of the reliability of power supply for any type of consumer. It is also observed that the interruption cost for an industrial consumer is higher than those of the consumers of the other two sectors.

The nature of the interruption cost curve for residential sector is more or less flat. The other two curves are decreasing in nature with the increasing of reliability level of power supply. If the three curves are extrapolated, the interruption costs for residential, industrial and commercial consumers will be zeros at points where approximate reliability levels of power supply are 88, 90 and 92%, repectively. In reality, interruption cost should be zero at point where reliability level of supply is 100%. The difference in the results from the reality arises due to the inaccurate data supplied by the respondents.

5.4 Comparison of Interruption Costs with the Results Recently Published

The evaluated average costs of interruption per hour for residential, industrial and commercial sectors are converted to costs per kWh to compare with the results recently published in the journal [4]. The research paper [4] presents selected results from a recently completed research project for the electric power research institute of USA. In this reference, the authors estimated the interruption costs per kWh for 1-hour outage for the consumers of residential, industrial and commercial sectors of the American and Canadian utilities by surveying the consumers in 1990 which was published in the journal of IEEE transactions on power systems in 1991. The comparison between the evaluated interruption costs and the results of the reference [4] is shown in Table 5.7. The results of the reference are considered with 1.5% interest and presented in the following table by calculating them for 13 years from 1990 to 2003. Again, it is considered that 1 US $ = Taka 58.00.

Table 5.7: Comparison of the Evaluated Interruption Cost with that of North American Utilities

Utility	Sector of consumer					
	Residential		Industrial		Commercial	
	Average outage cost ($/kWh)	Average outage cost (Taka/kWh)	Average outage cost ($/kWh)	Average outage cost (Taka/kWh)	Average outage cost ($/kWh)	Average outage cost (Taka/kWh)
American-1	0.60	34.80	7.20	417.60	8.40	487.20
Canadian-1	0.46	26.68	15.24	883.92	15.78	915.24
DESA, Bangladesh	0.25	14.50	0.08	4.65	0.36	20.70

It is observed form Table 5.7 that the average interruption cost (outage cost) for residential consumers of American utility-1 is the highest compared to other utilities. On the other hand, the average interruption costs per kWh for the consumers of industrial and commercial sectors of Canadian utility-1 are the highest among all utilities.

5.5 Inconveniences to Residential Respondents

The tangible inconveniences to residential respondents have been evaluated into monetary terms. But, it has not been possible to quantify the loss due to intangible inconvenience into monetary term. Because, it is very difficult to assume the amount of loss due to inconvenience which is intangible in nature. For example, some respondents faced water supply problem and could not enjoy television due to power interruption. These inconveniences are intangible in nature and not possible to quantify into monetary terms.

All types of inconveniences to residential respondents presented in Table 3.4 are summarized in Tabl 5.8.

Table 5.8: Different types to Inconveniences to Residential Respondents

Symbolic representation	Types of inconveniences	Total number of days suffered by all respondents
a	Study	2433
b	Dinning	69
c	Cooking	1769
d	Sewing	132
e	Computer works	180
f	Enjoying TV,	1036
g	Accounting	7
h	Other problems	25

It is seen from the above table that the family members of residential respondents suffered from the study more compared to other inconveniences.The different inconveniences are compared in Figure 5.11.

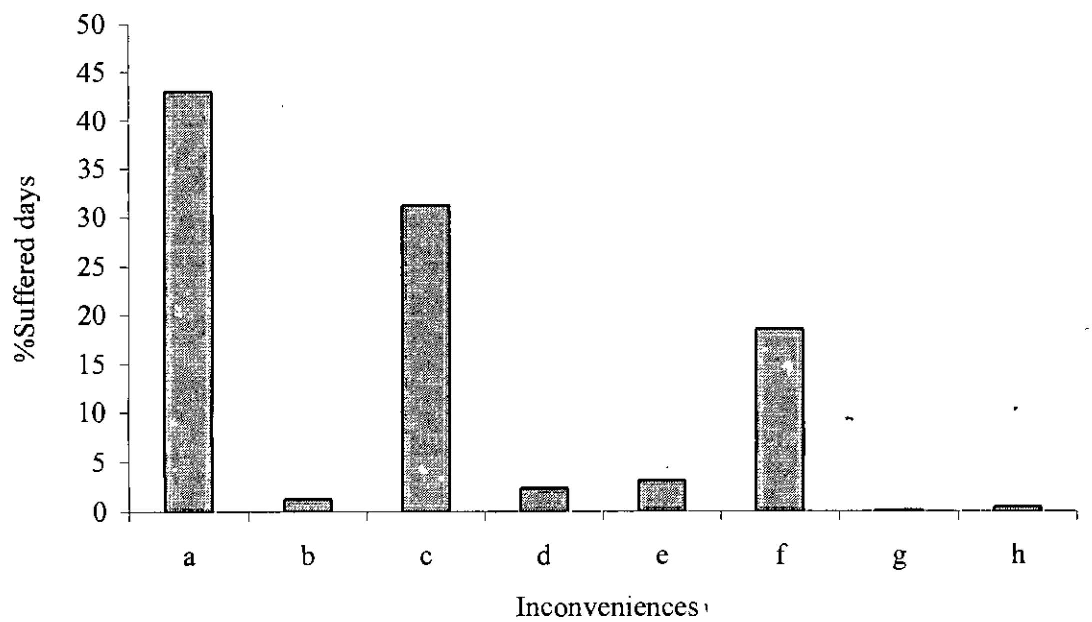


Figure 5.11: Comparative presentation of different types of inconveniences encountered by residential respondents

5.6 Difficulties of Commercial Respondents

It has not been possible to quantify the difficulties faced by commercial respondents into monetary terms due to intangible in nature. All types of difficulties of commercial respondents presented in Table 3.11 are summarized in Table 5.9.

Table 5.9: Different types of Difficulties of Commercial Respondents

Symbolic representation	Types of difficulties	Total number of days suffered by all respondents
a"	Sales and display	1590
b"	Transaction	684
c"	Accounting	519
d"	Security	935
e"	Other problems	683

It is seen from the above table that commercial respondents suffered more from the difficulties of sales and display of goods compared to other difficulties. The different types of difficulties are compared in Figure 5.12.

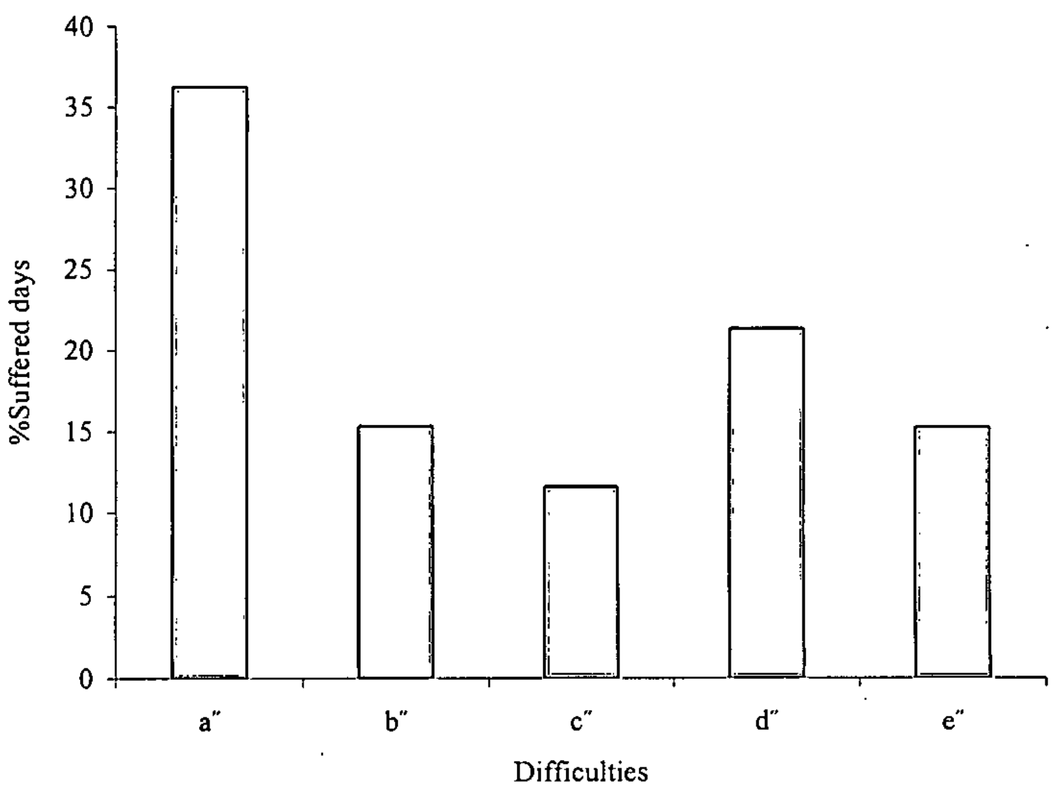


Figure 5.12: Comparative presentation of different types of difficulties encountered by commercial respondents

5.7 Observation and Discussion

The questionnaires are distributed among the consumers of different areas of Dhaka City and its adjacent. The areas are Savar, Tongi, Mirpur, Kallyanpur, Mohammadpur, Dhanmondi, Mirpur road, Green road, Kathalbagan, Elephant road, New circular road, Satish sarkar road, Dino nath sen road, West jurain, DIT plot, Gandaria, Mirhazirbag, Karimullarbag, Kazla, Matuail, Konapara and Demra. The rates of responses are 27.5, 23.08 and 22.04% in case of residential, industrial and commercial consumers, respectively. These rates of responses of consumers of the three sectors are comparatively low and due to lack of their knowledge, they did not give the proper information relating to interruption of power.

It is observed that the power supply was interrupted maximum 7 (seven) times in a day and the classical interruption was the scheduled load shedding. The overall average durations of interruptions for the three sectors are found as 0.58, 0.55 and 0.54 hours, respectively. It is seen that charger light, generator, candle and kerosene lamp are used as alternative sources by 42.73, 1.82, 54.55 and 0.91% residential respondents respectively. In commercial sector; charger light, generator and candle are used by 39.62, 22.64 and 37.74% of the respondents, respectively. It is also observed that charger light, generator and candle are used as alternative sources by 29.85, 5.97 and 64.18% respondents of industrial sector respectively. But IPS, UPS and lantern are not used in anywhere.

It is seen that among different factors 'study' creates major inconveniences to residential respondents and 'accounting' has the lowest impact towards inconveniences. According to the surveyed opinions, most of the inconveniences are moderate in nature.

It is observed that the average cost per hour of interruption and per interruption are Taka 35.83 and 20.93 for the respondents of residential sector. Also, the average interruption cost per kWh is Taka 14.50 in residential sector. The average cost per hour of interruption and per interruption for the respondents of industrial sector are Taka 269.60 and 155.15. The average interruption cost per kWh for industrial sector is found to be Taka 4.65. Similarly, the average cost per hour of interruption and per interruption for the respondents of commercial sector are Taka 81.55 and 44.53. The average cost per kWh for commercial sector is Taka 20.70.

For any respondent of the three sectors, the ratio between the total cost per hour of interruption (J) and the hourly average electricity bill paid by the respondent (E_2) is found as much more greater than the ratio between the total cost per hour of interruption (J) and the maximum hourly cost of electricity for uninterrupted supply (E_1). i.e. $\frac{J}{E_2} > \frac{J}{E_1}$.

The highest and lowest reliability levels of power supply to residential sector are calculated as 80.05 and 58.04%. In industrial sector, these are 80.33 and 68.75%. Also, the highest and lowest reliability values of the commercial sector are 85.29 and 74.67% respectively. It is clearly observed that the overall average reliability levels of power supply to residential, industrial and commercial sectors are 66.75, 75.94 and 80.37%, respectively. It is seen from the comparison of interruption costs of different classes of consumers with the variation of reliability of supply (Figure 5.10) that the cost of interruption for any type of consumer decreases with the increases of reliability of supply and vice versa. Again, it is seen that the interruption cost for an industrial consumer for a certain reliability level of power supply is higher than those of the consumers of the other two sectors.

Also, it is observed from Table 5.7 that the interruption costs for the consumers of residential, industrial and commercial sectors of American and Canadian utilities are higher as compared to the consumers of Bangladeshi utility like Dhaka Electric Supply Authority (DESA).

However, the result indicates that the cost of interruption per hour for any consumer is greater than the cost of electricity per hour. The variation of interruption cost with the variation of the reliability of power supply is found as meaningful.

CHAPTER SIX

CONCLUSION

6.1 Introduction

This chapter is the conclusive part of the thesis. It presents concluding remarks, suggestions to the utility and recommendation for future study.

6.2 Concluding Remarks

The average cost per hour of interruption is evaluated to study the actual amount of loss of the consumer of electricity. Among the residential, industrial and commercial sectors; the loss in the industrial sector is the highest. It is observed from the costs of interruption of the respondents of each sector that the higher the area of the premises, average electricity bill and connected load, the cost of interruption is higher. That is, the consumer with higher reliable supply suffers less in terms of interruption cost.

Most of the observations of the study are expected. However, the loss of power interruption is many times higher than the electricity bill that a consumer pays. It is clearly observed that the interruption cost will be decreased with the improved reliability of power supply. To increase the supply reliability, the utility should have more investment. However, the optimal point of investment and interruption cost should be carefully identified. Once, the data of the ratio of interruption cost and the payment of present electricity bill is available, it will be easier to motivate the consumers to pay electricity bill at higher tariff. This will also be encouraging for the utility to invest more to improve its system reliability.

6.3 Suggestion to the Utility

The evaluated average cost per hour of interruption for the residential, industrial and commercial sectors are Taka 35.83, 269.60 and 81.55 respectively. Also, the average cost per interruption for the three sectors are Taka 20.93, 155.15 and 44.53 respectively. But, the hourly average electricity bill paid by the respondents of the residential, industrial and commercial sectors are Taka 1.49, 49.16 and 4.11 respectively. That is, the loss due to the interruption of power is much more greater than that of the electricity bill paid by a consumer. The utility should consider this with great emphasis in expansion planning and in design phase. The interruption cost can be reduced by improving the reliability level of power supply. Therefore, to improve the reliability level of power supply, the utility should invest adequate money.

6.4 Recommendation for Future Study

The study has been conducted within the residential, industrial and commercial sectors of Dhaka city and its adjacent areas. The study should include agriculture sector and rural areas as well to obtain a generalized picture of the cost of interruption. Correlation between the interruption cost of consumer and the loss in the revenue earned by the utility due to power interruption can be developed.

The questionnaires should be carefully developed to get all necessary information and data. Steps should be taken to convince the consumers of electricity, so that they can respond without any hesitation to give the necessary data and information about power interruption.

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APPENDICES

APPENDIX A

Sample of questionnaire for residential consumer:

RESIDENTIAL INFORMATION

1. Name : ....
2. Address : ....
3. Telephone No. : ....
4. Area of House : .... Sq. ft.
5. No. of Family Member : .... Nos.
6. Connected Load : .... kW
7. Energy Consumption : .... Unit (kWh/Month)
8. Electricity Bill for the last Three Months : .... Tk.
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan		
Radio Set / Cassette Player		
Tube Light		
Incandescent Lamp (Bulb)		
Refrigerator		
Computer		
Microwave Oven		
Motor for Water Pump		
Television		
A / C		
Washing Machine		
Electric Iron		
Electric Cooker / Oven		
VCR / VCP		
VCD		
Sewing Machine		
Voltage Stabilizer		
Water Heater		
Blender Machine		
Others		

10. Alternative Source Used During Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light			
IPS			
UPS			
Generator			
Candle			
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of power failure (mint.)	Name of the Alternative Source used	Duration of Alternative used (mint.)	* Type of Perishable goods (put tic mark)	Cost of Perishable goods (Taka)	** Type of Inconvenience (put tic mark)	*** Severity of Inconvenience (put tic mark)
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
				i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y

* Type of Perishable goods:

i) Fish, ii) Meat, iii) Curry, iv) Milk, v) Curd, vi) Fruit etc.

** Type of Inconvenience:

a) Study, b) Dinning, c) Cooking, d) Sewing, e) Computer Works,

f) Enjoying TV, Video Games, Music, g) Accounting, h) Other Problems etc.

*** Severity of Inconvenience:

x) Sever, y) Moderate.

Signature........................

APPENDIX B

Sample of questionnaire for industrial consumer:

INDUSTRIAL INFORMATION

1. Name of the Industry : ....
2. Address of Industry : ....
3. Telephone No. : ....
4. Physical Area of Industry : .... Sq. ft.
5. No. of Employees : .... Nos.
6. Connected Load : .... kW
7. Energy Consumption : .... Unit (kWh/Month)
8. Electricity Bill for the last Three Months : .... Tk.
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan		
Incandescent Lamp (Bulb)		
Tube Light		
Mercury Lamp		
Computer		
Voltage Stabilizer		
Air Conditioner		
Different Electrical Motors and Other Electrical Equipment :		
a)		
b)		
c)		
d)		
e)		
f)		
g)		
h)		

10. Alternative Source used during Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light			
IPS			
UPS			
Generator			
Candle			
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of Power failure (mint.)	Name of the Alternative Source used	Duration of Alternative used (mint.)	Name of Damaged Equipment due to Power failure	Cost of Damaged Equipment due to Power failure (Taka)	Approximate Loss due to Power Interruption (Taka)

Signature.........................

APPENDIX C

Sample of questionnaire for commercial consumer:

COMMERCIAL INFORMATION

1. Name of Shopkeeper/Shop : ....
2. Address of Shop : ....
3. Telephone No. : ....
4. Area of Shop : .... Sq. ft.
5. No. of Employees : .... Nos.
6. Connected Load : .... kW
7. Energy Consumption : .... Unit (kWh/Month)
8. Electricity Bill for the last Three Months : .... Tk.
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan		
Incandescent Lamp (Bulb)		
Tube Light		
Mercury Lamp		
Computer		
Voltage Stabilizer		
Air Conditioner		
Television		
Refrigerator		

10. Alternative Source used during Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light			
IPS			
UPS			
Generator			
Candle			
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of Power failure (mint.)	Name of the Alternative Source used	Duration of Alternative used (mint.)	Name of Damaged Equipment due to Power failure	Cost of Damaged Equipment due to Power failure (Taka)	Cost of Perishable goods (Taka)	Approximate Loss due to Power Interruption (Taka)	* Difficulties (put tic mark)
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
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								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e
								a, b, c, d, e

* Difficulties:

a) Sales and Display, b) Transaction, c) accounting, d) Security, e) Others.

Signature........................

APPENDIX D

List of Residential Consumers as Respondents

Respondent ID No.	Location of Respondent	Classes of Respondent
1	Kallyanpur	Br, Er, Gr
2	Kallyanpur	Br, Dr, Gr
3	Kallyanpur	Ar, Er, Hr
4	Kallyanpur	Ar, Dr, Gr
5	Kallyanpur	Ar, Dr, Gr
6	Kallyanpur	Br, Er, Hr
7	Mirpur	Ar, Dr, Hr
8	Mirpur	Ar, Dr, Gr
9	Mirpur	Ar, Dr, Hr
10	Mohammadpur	Br, Dr, Hr
11	Mohammadpur	Br, Dr, Hr
12	Dhanmondi	Ar, Dr, Gr
13	Mirpur Road	Br, Dr, Hr
14	Mirpur Road	Ar, Dr, Hr
15	Mirpur Road	Ar, Dr, Hr
16	Mirpur Road	Ar, Dr, Hr
17	Mirpur Road	Ar, Dr, Hr
18	Mirpur Road	Ar, Dr, Hr
19	Mirpur Road	Ar, Dr, Hr
20	Mirpur Road	Ar, Dr, Hr
21	Mirpur Road	Ar, Dr, Hr
22	Mirpur Road	Br, Dr, Hr
23	Mirpur Road	Ar, Dr, Hr
24	Mirpur Road	Ar, Dr, Hr
25	Mirpur Road	Br, Er, Ir
26	Mirpur Road	Br, Er, Ir
27	Mirpur Road	Ar, Dr, Gr
28	Mirpur Road	Ar, Dr, Gr
29	Mirpur Road	Ar, Dr, Gr
30	Mirpur Road	Cr, Dr, Hr
31	Mirpur Road	Ar, Dr, Hr
32	Mirpur Road	Ar, Dr, Gr
33	Mirpur Road	Ar, Dr, Hr
34	Mirpur Road	Ar, Dr, Gr
35	Mirpur Road	Cr, Fr, Ir
36	Mirpur Road	Ar, Dr, Hr
37	Mirpur Road	Ar, Dr, Gr
38	Mirpur Road	Br, Er, Ir
39	Mirpur Road	Ar, Dr, Hr
40	Mirpur Road	Ar, Dr, Hr
41	Mirpur Road	Ar, Dr, Hr
42	Mirpur Road	Ar, Dr, Hr
43	Lake Circus, Kalabagan	Ar, Dr, Gr
44	Lake Circus, Kalabagan	Ar, Dr, Gr
45	Lake Circus, Kalabagan	Br, Er, Ir

Respondent ID No.	Location of Respondent	Classes of Respondent
46	Lake Circus, Kalabagan	Br, Er, Ir
47	Green Road	Br, Dr, Ir
48	North Dhanmondi	Br, Er, Ir
49	North Dhamondi	Ar, Dr, Hr
50	North Dhanmondi	Cr, Fr, Ir
51	North Dhanmondi	Br, Dr, Hr
52	North Dhanmondi	Br, Dr, Hr
53	North Dhanmondi	Br, Dr, Hr
54	North Dhanmondi	Br, Dr, Hr
55	North Dhanmondi	Br, Dr, Hr
56	North Dhanmondi	Br, Dr, Hr
57	North Dhanmondi	Br, Dr, Hr
58	North Dhanmondi	Ar, Dr, Hr
59	Dhanmondi	Ar, Er, Ir
60	Dhanmondi	Ar, Dr, Gr
61	Dhanmondi	Br, Fr, Ir
62	Dhanmondi	Br, Er, Ir
63	Dhanmondi	Br, Fr, Ir
64	Dhanmondi	Br, Fr, Ir
65	Dhanmondi	Br, Er, Ir
66	Dhanmondi	Br, Fr, Ir
67	Dhanmondi	Cr, Fr, Ir
68	Dhanmondi	Ar, Dr, Hr
69	Dhanmondi	Br, Fr, Ir
70	Dhanmondi	Ar, Dr, Hr
71	Dhanmondi	Cr, Fr, Ir
72	Dhanmondi	Cr, Fr, Ir
73	Dhanmondi	Cr, Fr, Ir
74	Dhanmondi	Cr, Er, Ir
75	Southpara, Mohakhali	Br, Dr, Hr
76	Lake Circus, Kalabagan	Ar, Dr, Hr
77	Dhanmondi	Br, Er, Ir
78	Dhanmondi	Cr, Fr, Ir
79	Dhanmondi	Br, Dr, Hr
80	Free School Street, Kathalbagan	Br, Dr, Hr
81	Free School Street, Kathalbagan	Br, Dr, Hr
82	Free School Street, Kathalbagan	Br, Dr, Hr
83	Free School Street, Kathalbagan	Br, Dr, Ir
84	Free School Street, Kathalbagan	Br, Dr, Hr
85	Kathalbagan	Br, Dr, Gr
86	Kathalbagan	Ar, Dr, Hr
87	Free School Street, Kathalbagan	Ar, Dr, Gr
88	Free School Street Kathalbagan	Ar, Dr, Gr
89	Kathalbagan	Br, Dr, Ir
90	Kathalbagan	Br, Dr, Hr
91	Kathalbagan	Br, Dr, Hr
92	Kathalbagan	Br, Er, Ir
93	West Jurain	Ar, Dr, Gr
94	West Jurain	Ar, Dr, Gr

Respondent ID No.	Location of Respondent	Classes of Respondent
95	West Jurain	Ar, Dr, Hr
96	Satish Sarker Road	Br, Dr, Hr
97	DIT Plot, Gandaria	Br, Dr, Hr
98	Dhalkanagar	Ar, Dr, Hr
99	Shahidnagar	Ar, Dr, Hr
100	Shahidnagar	Ar, Dr, Hr
101	DIT Plot, Gandaria	Ar, Dr, Gr
102	Mirhazirbag	Br, Dr, Gr
103	Mirhazirbag	Ar, Dr, Hr
104	Mirhazirbag	Br, Dr, Hr
105	Mirhazirbag	Cr, Dr, Hr
106	Mirhazirbag	Ar, Dr, Hr
107	Mirhazirbag	Br, Dr, Hr
108	Mirhazirbag	Br, Dr, Hr
109	Mirhazirbag	Br, Dr, Gr
110	Southpara, Mohakhali	Br, Dr, Hr

APPENDIX E

List of Industrial Consumers as Respondents

Respondent ID No.	Location of Respondent	Classes of Respondent
1	Kathalbagan	Ai, Di, Gi
2	Mirpur Road	Bi, Ei, Gi
3	Free School Street, Kathalbagan	Ai, Di, Gi
4	Free School Street, Kathalbagan,	Ai, Di, Gi
5	Free School Street, Kathalbagan	Ai, Di, Gi
6	Jhamur, Rajfulbaria, Savar	Ci, Fi, Hi
7	BSCIC Industrial Estate, Tongi	Ci, Ei, Hi
8	BSCIC Industrial Estate, Tongi	Bi, Ei, Hi
9	Mirhazirbag	Ci, Fi, Hi
10	Mirhazirbag	Bi, Di, Gi
11	Mirhazirbag	Ai, Di, Gi
12	Mirhazirbag	Ai, Ei, Hi
13	Mirhazirbag	Ai, Ei, Gi
14	Satish Sarker Road	Ai, Ei, Gi
15	Dhalkanagar Lane	Ai, Di, Gi
16	Dhalkanagar Lane	Bi, Ei, Gi
17	Dhalkanagar Lane	Bi, Ei, Hi
18	Dina Nath Sen Road, Gandaria	Bi, Ei, Hi
19	Dina Nath Sen Road, Gandaria	Bi, Ei, Gi
20	Jurain Graveyard	Ai, Di, Gi
21	Karimullarbag	Bi, Ei, Hi
22	Kkarimullarbag	Ci, Fi, Ii
23	Dina Nath Sen Road, Gandaria	Bi, Fi, Hi
24	Dina Nath Sen Road, Gandaria	Bi, Fi, Hi
25	Satish Sarker Road	Ai, Di, Gi
26	Dhalkanagar	Ai, Di, Gi
27	Satish Sarker Road, Gandaria	Bi, Di, Gi
28	Satish Sarker Road, Gandaria	Bi, Di, Gi
29	DIT Plot, Gandaria	Ai, Ei, Gi
30	Satish Sarker Road, Gandaria	Ai, Di, Gi
31	Karimullarbag	Ai, Di, Gi
32	Satish Sarker Road, Gandaria	Ci, Ei, Hi
33	Satish Sarker Road, Gandaria	Ci, Ei, Hi
34	Satish Sarker Road, Gandaria	Ai, Di, Gi
35	DIT Plot, Gandaria	Ai, Di, Gi
36	Satish Sarker Road, Gandari	Ai, Di, Gi
37	West Jurain	Ai, Di, Gi
38	Satish Sarker Road, Gandaria	Ai, Di, Gi
39	Dania	Ai, Ei, Gi
40	Dania	Ai, Di, Gi
41	Kazlarpar, Demra	Bi, Fi, Ii
42	Dania	Bi, Di, Gi
43	Dania	Bi, Ei, Hi
44	Dania	Ai, Di, Gi

Respondent ID No.	Location of Respondent	Classes of Respondent
45	Konapara, Matuail, Demra	Bi, Fi, Ii
46	Dania,	Ai, Di, Gi
47	South Dania	Ai, Di, Gi
48	Konapara, Matuail, Demra	Bi, Fi, Ii
49	South Dania	Ai, Di, Gi
50	Dania	Ai, Di, Gi
51	Bhangapress, Kazlarpar,Demra	Bi, Fi, Ii
52	Palashpur, Dania	Ai, Di, Gi
53	Konapara, Demra	Bi, Fi, Ii
54	Noorpur, Dania	Ai, Di, Hi

APPENDIX F

List of Commercial Consumers as Respondents

Respondent ID No.	Location of Respondent	Classes of Respondent
1	Elephant Road, Hatirpul Bazaar	Ac, Dc, Cc
2	Elephant Road, Hatirpul Bazar	Bc, Dc, Cc
3	Free School Street, Hatirpul Bazar	Ac, Dc, Hc
4	Free School Street, Hatirpul Bazar	Ac, Dc, Hc
5	Mirpur Road	Bc, Ec, Ic
6	Mirpur Road	Ac, Dc, Hc
7	North dhanmondi	Ac, Ec, Hc
8	North dhanmondi	Bc, Ec, Hc
9	Lake Circus, Kalabagan	Ac, Ec, Hc
10	Lake Circus, Kalabagan	Ac, Dc, Hc
11	Green Road	Ac, Ec, Hc
12	Green Road	Ac, Dc, Hc
13	Lake Circus, Kalabagan	Ac, Ec, Hc
14	North Dhanmondi	Cc, Fc, Ic
15	North Dhanmondi	Bc, Dc, Gc
16	North Dhanmondi	Bc, Ec, Hc
17	North Dhanmondi	Cc, Ec, Hc
18	North Dhanmondi	Cc, Ec, Hc
19	Green Road	Bc, Ec, Hc
20	Green Road	Cc, Fc, Ic
21	Dhanmondi	Bc, Ec, Ic
22	Dhanmondi	Cc, Fc, Ic
23	Lake Circus, Kalabagan	Ac, Dc, Hc
24	Lake Circus, Kalabagan	Ac, Ec, Hc
25	Lake Circus, Kalabagan	Ac, Ec, Hc
26	Lake Circus, Kalabagan	Ac, Dc, Gc
27	Kalabagan, Mirpur Road	Cc, Fc, Ic
28	Dhanmondi	Cc, Fc, Ic
29	Dhamndi	Cc, Fc, Ic
30	Free School Street, Kathalbagan	Ac, Dc, Hc
31	Kathalbagan Bazar	Ac, Ec, Hc
32	Kathalbagan	Ac, Dc, Hc
33	Kathalbagan Bazar	Ac, Dc, Hc
34	Ktahalbagan Bazar	Ac, Dc, Gc
35	Kathalbagan Bazar	Ac, Dc, Gc
36	Free School Street, Kathalbagan	Ac, Dc, Hc
37	Kthalbagan	Bc, Ec, Hc
38	Dino Nath Sen Road	Bc, Dc, Hc
39	Dino Nath Sen Road	Ac, Dc, Gc
40	West Jurain	Bc, Dc, Hc
41	West Jurain	Ac, Dc, Gc
42	Karimullarbag	Bc, Ec, Hc
43	Karimullarbag	Ac, Dc, Gc
44	West Jurain	Ac, Ec, Ic

Respondent ID No.	Location of Respondent	Classes of Respondent
45	West Jurain	Ac, Dc, Hc
46	West Jurain	Bc, Dc, Hc
47	West Jurain	Ac, Dc, Hc
48	Dino Nath Sen Road	Ac, Dc, Gc
49	Dhalkanagar Lane	Bc, Dc, Hc
50	Dhalkanagar	Bc, Dc, Gc
51	Dhalkanagar Lane	Ac, Dc, Hc
52	Dhalkanagar	Bc, Ec, Hc
53	Dhalkanagar	Ac, Dc, Hc
54	DIT Plot, Gandaria	Ac, Dc, Hc
55	Satish Sarker Road	Bc, Dc, Hc
56	Satish Sarker Road	Ac, Dc, Gc
57	Satish Sarker Road	Ac, Dc, Hc
58	DIT Plot, Gandaria	Bc, Fc, Ic
59	Satish Sarker Road	Ac, Dc, Gc
60	Satish Sarker Road	Bc, Dc, Hc
61	Satish Sarker Road	Bc, Dc, Hc
62	DIT Plot, Gandaria	Bc, Dc; Hc
63	Satish Sarker Road	Bc, Dc, Hc
64	Satish Sarker Road	Bc, Dc, Hc
65	West Jurain	Bc, Fc, Ic
66	Jurain	Ac, Ec, Hc
67	Shahidnagar	Bc, Dc, Hc

APPENDIX G

Sample of Response from Residential Consumer:

In this appendix, the data obtained from one of the residential consumers are presented as a sample.

RESIDENTIAL INFORMATION

1. Name : Prosenjit Roy
2. Address : 487 / 1, South Paik Para, Kallyanpur, Dhaka - 1207
3. Telephone No. : 9006866
4. Area of House : 1000 Sq. ft.
5. No. of Family Member : 6 Nos.
6. Connected Load : 1 kW
7. Energy Consumption : 180 Unit (kWh / Month)
8. Electricity Bill for the last three months: Tk.535/-, 400/-, 565/-
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan	5	360
Radio Set / Cassette Player .	1	60
Tube Light	6	240
Incandescent Lamp (Bulb)	8	800
Refrigerator	1	150
Computer		
Microwave Oven		
Motor for Water Pump	1	746
Television	1	75
A / C	1	1000
Washing Machine		
Electric Iron		
Electric Cooker / Oven		
VCR / VCP		
VCD		
Sewing Machine		
Voltage Stabilizer		
Total		**3431**

10. Alternative Source Used During Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light			
IPS			
UPS			
Generator			
Candle	125	TK.5.00 / pc	
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of power failure (mint.)	Name of the Alter-native Source used	Duration of Alternative used (mint.)	* Type of Perishable goods (put tic mark)	Cost of Peri-shable goods (Taka)	** Type of Inconvenience (put tic mark)	*** Severity of Incon-venienc e
20.2.03	35	Candle	35	i, ii, iii, iv, v, vi.		a, b, c, d, √e, √f, g, h.	x, y
21.2.03	38	”	33	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
23.2.03	30			i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
25.2.03	50	”	50	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
27.2.03	45	”	45	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
28.2.03	25	”	25	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
01.3.03	55			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
02.3.03	50	”	50	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
03.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
04.3.03	40			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
05.3.03	50	”	50	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
06.3.03	45	”	45	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
07.3.03	38			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
08.3.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
09.3.03	55	”	55	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
10.3.03	65	”	65	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
11.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
12.3.03	70	”	70	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
13.3.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
14.3.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
15.3.03	68	”	68	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
16.3.03	65		65	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
17.3.03	70	”		i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
18.3.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
19.3.03	65	”	65	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
20.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
21.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
22.3.03	55			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
23.3.03	70	”	70	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
24.3.03	65	”	65	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
25.3.03	68	”	63	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
26.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
27.3.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
28.3.03	65			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
29.3.03	70	”	70	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
30.3.03	67	”	67	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
31.3.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
01.3.03	75	”	75	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
02.3.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
03.3.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
04.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
05.4.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
06.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
07.4.03	65	”	65	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
08.4.03	60			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
09.4.03	55	”	55	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
10.4.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, c, d, e, √f, g, h.	x, y
11.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
12.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, √g, h.	x, y
13.4.03	65			i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
14.4.03	1080	”	108	√i, √ii, iii, iv, v, vi.	300	√a, b, √c, d, e, √f, g, h.	√x, y
15.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
16.4.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y

Date	Duration of power failure (mint.)	Name of the Alter-native Source used	Duration of Alternative used (mint.)	* Type of Perishable goods (put tic mark)	Cost of Peri-shable goods (Taka)	** Type of Inconvenience (put tic mark)	*** Severity of Incon-venienc e
17.4.03	50	”	50	i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
18.4.03	75	”	75	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
19.4.03	60			i, ii, iii, iv, v, vi.		a, b, c, d, e, √f, g, h.	x, y
20.4.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
21.4.03	60	”	60	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
22.4.03	68	”	68	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
23.4.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
24.4.03	60	”	60	I, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
25.4.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
26.4.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
27.4.03	70	”	70	i, ii, iii, iv, v, vi.		√a, b, √c, d, e, √f, g, h.	x, y
28.4.03	60			i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
29.4.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, √g, h.	x, y
30.4.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
01.5.03	480	”	120	i, ii, iii, √iv, v, vi.	56	√a, b, √c, d, e, √f, g, h.	√x, y
02.5.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, √g, h.	x, y
03.5.03	70	”	70	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
04.5.03	65	”	65	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
05.5.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
06.5.03	55			i, ii, iii, iv, v, vi.		a, b, c, d, e, f, g, h.	x, y
07.5.03	60	”	60	i, ii, iii, iv, v, vi.		a, b, √c, d, e, √f, g, h.	x, y
Total	5882		3837	.	356		

Total Sampling Period = 76 days

Total No. of Observation = 74 days

Total No. of Interruption = 131

* Type of Perishable goods-

i) Fish, ii) Meat, iii) Curry, iv) Milk, v) Curd, vi) Fruit etc.

** Type of Inconvenience-

a) Study, b) Dinning, c) Cooking, d) Sewing, e) Computer Works, f) Enjoying TV, Video Games, Music, g) Accounting, h) Other Problems etc.

*** Severity of Inconvenience-

x) Sever, y) Moderate.

Signature: Signed by the respondent.

APPENDIX H

Sample of Response from industrial Consumer:

In this appendix, the data obtained from one of the industrial respondents are presented as a sample.

INDUSTRIAL INFORMATION

1. Name of the Industry : A .D Engineering
2. Address of Industry : 20, Mirhazirbag, Dhaka - 1236
3. Telephone No. : ....
4. Physical Area of Industry : 58500 Sq. ft.
5. No. of Employees : 18 Nos.
6. Connected Load : 40 kW
7. Energy Consumption : 14400 Unit (kWh / Month)
8. Electricity Bill for the last three months : Tk.58137/-, 58150/-, 58150/-
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan	4	160
Incandescent Lamp (Bulb)	3	300
Tube Light	5	200
Mercury Lamp		
Computer		
Voltage Stabilizer		
Air Conditioner		
Different Electrical Motors and Other Electrical Equipment :		
a) Motor, 40 H P	2	59680
b) Motor, 5 H P	3	11190
c) Motor, 1 H P	1	746
d)		
e)		
f)		
g)		
h)		
Total		**72276**

10. Alternative Source used during Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light			
IPS			
UPS			
Generator	1	100 kVA	Diesel 12 ltr
Candle			
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of power failure (mint.)	Name of the Alternative Source used	Duration of Alternative used (mint.)	Name of Damaged Equipment due to Power failure	Cost of Damaged Equipment due to Power failure (Taka)	Approximate Loss due to Power Interruption (Taka)
02.04.03	19	Generator	10			
03.04.03	10					400
04.04.03	13					500
05.04.03	112	"	100			400
06.04.03	170	"	155			450
07.04.03	70	"	66			
09.04.03	64	"	59			400
10.04.03	68	"	64			480
11.04.03	25	"	22			
12.04.03	103	"	100			520
13.04.03	560	"	547			1000
15.04.03	60	"	57			
16.04.03	3					
22.04.03	22	"	19			
23.04.03	53	"	46			
24.04.03	118	"	113			570
25.04.03	67	"	62			
26.04.03	55	"	51			
27.04.03	76	"	70			
28.04.03	89	"	82			450
29.04.03	40	"	40			
30.04.03	159	"	150			700
01.05.03	114	"	113			600
02.05.03	31	"	29			
03.05.03	85	"	85			510
04.05.03	252	"	250			800
05.05.03	27	"	26			
06.05.03	55	"	54			
07.05.03	205	"	200			800
08.05.03	142	"	140			750
09.05.03	5	"	5			
10.05.03	163	"	160			900
11.05.03	191	"	190			800
12.05.03	83	"	80			
13.05.03	60	"	58			
14.05.03	7					
15.05.03	143	"	140			800
16.05.03	23	"	22			
18.05.03	55	"	54			
19.05.03	60	"	58			
20.05.03	32	"	30			
21.05.03	97	"	90			600
22.05.03	68	"	65			
25.05.03	20	"	20			
26.05.03	50	"	48			
27.05.03	108	"	105			400
28.05.03	105	"	100			850
29.05.03	109	"	102			700

Date	Duration of Power failure (mint.)	Name of the Alternative Source used	Duration of Alternative used (mint.)	Name of Damaged Equipment due to Power failure	Cost of Damaged Equipment due to Power failure (Taka)	Approximate Loss due to Power Interruption (Taka)
30.05.03	17	"	18			
31.05.03	60	"	58			
01.06.03	129	"	125			750
02.06.03	10	"	10			
04.06.03	60	"	59			
06.06.03	32	"	26			
07.06.03	13	"	15			
09.06.03	50	"	48			
10.06.03	10					1450
11.06.03	155	"	150			
12.06.03	63	"	60			
14.06.03	13	"	10			
15.06.03	27	"	22			
16.06.03	35	"	31			
17.06.03	19	"	20			
18.06.03	97	"	95			
Total	5036		4784			17080/-

Note:

- Sampling period = 77 days
- Total no. of observation = 64 days
- Total no. of interruption = 141
- Price of generator = Tk.920000/-
- Salvage value of generator = Tk.10000/-

Signature: Authorized signature

APPENDIX I

Sample of Response from Commercial Consumer:

In this appendix, the data obtained from one of the commercial respondents are presented as a sample.

COMMERCIAL INFORMATION

1. Name of Shopkeeper/Shop : Masers Mayami Traders
2. Address of Shop : 44/16, North Dhanmondi, Dhaka - 1205
3. Telephone No. : ....
4. Area of Shop : 300 Sq. ft.
5. No. of Employees : 6 Nos.
6. Connected Load : 2 kW
7. Energy Consumption : 324 Unit (kWh / Month)
8. Electricity Bill for the last three months : Tk.1729.60, 1761.36, 1800.00
9. Electrical Appliance / Equipment used :

Name of Equipment/Appliance	Quantity	Rating (Watt)
Fan	1	70
Incandescent Lamp (Bulb)	2	200
Tube Light	7	280
Mercury Lamp		
Computer		
Voltage Stabilizer		
Air Conditioner, 1.5 ton	1	3000
Television		
Refrigerator		
Total		**3550**

10. Alternative Source used during Power failure :

Type of Sources	No. of Equipment	Rating of Equipment	Cost of fuel consumption/hr.
Charger Light	1	20 Watt	
IPS			
UPS			
Generator			
Candle			
Lantern			
Kerosene Lamp			
Others			

11. Table for Collection of Data in each Power failure :

Date	Duration of Power failure (mint.)	Name of the Alter-native Source used	Duration of Alter-native used (mint.)	. Name of Damaged Equip-ment due to power failure	Cost of Damaged Equip-ment due to Power failure (Taka)	Cost of perishable goods (Taka)	Approxi-mate Loss due to power Interrup-tion (Taka)	* Difficulties
01.4.03	45	Charger	45					√ a, b, c, d, e
02.4.03	58	”	58					√ a, b, c, d, e
03.4.03	66	”	56					√ a, b, c, d, e
05.4.03	65	”	60					√ a, b, c, d, e
07.4.03	74	”	70					√ a, b, c, d, e
08.4.03	65	”	65					√ a, b, c, d, e
10.4.03	65	”	55					√ a, b, c, d, e
11.4.03	48	”	45					√ a, b, c, d, e
13.4.03	66	”	56					√ a, b, c, d, e
14.4.03	190							a, b, c, d, e
16.4.03	82	”	76					√ a, b, c, d, e
17.4.03	75	”	75					√ a, b, c, d, e
18.4.03	35	”	35					a, b, c, d, e
20.4.03	135	”	115					√ a, b, c, d, e
22.4.03	380	”	98					√ a, b, c, d, √ e
23.4.03	241	”	95					√ a, b, c, d, e
24.4.03	14							√ a, b, c, d, e
26.4.03	62	”	62					a, b, c, d, e
27.4.03	60	”	60					√ a, b, c, d, e
28.4.03	70	”	70					√ a, b, c, d, e
29.4.03	105	”	45					√ a, b, c, d, e
02.5.03	58	”	18					a, b, c, d, e
04.5.03	58	”	56					√ a, b, c, d, e
05.5.03	57						Total	a, b, c, d, e
07.5.03	60	”	58				2500/-	a, b, c, d, e
08.5.03	146	”	95					√ a, b, c, d, e
09.5.03	5	”						a, b, c, d, e
10.5.03	64	”	62					√ a, b, c, d, e
11.5.03	60	”	58					a, b, c, d, e
12.5.03	80	”	76					√ a, b, c, d, e
13.5.03	60	”	59					a, b, c, d, e
14.5.03	52	”	50					√ a, b, c, d, e
16.5.03	65	”	63					√ a, b, c, d, e
18.5.03	104	”	85					√ a, b, c, d, e
20.5.03	88	”	74					√ a, b, c, d, e
21.5.03	5							a, b, c, d, e
24.5.03	25							a, b, c, d, e
26.5.03	132	”	66					√ a, b, c, d, e
27.5.03	115	”	52					√ a, b, c, d, e
28.5.03	75	”						a, b, c, d, e
29.5.03	66	”	65					√ a, b, c, d, e
31.5.03	42	”	30					a, b, c, d, e

Date	Duration of Power failure (mint.)	Name of the Altern-ative Source used	Duration of Altern-ative used (mint.)	Name of Damaged Equip-ment due to Power failure	Cost of Damaged Equip-ment due to Power failure (Taka)	Cost of Perishable goods (Taka)	Approxi-mate Loss due to Power Interrup-tion (Taka)	*Difficulties
01.6.03	60	"	58					√ a, b, c, d, e
02.6.03	60	"	57					√ a, b, c, d, e
03.6.03	80	"	78					√ a, b, c, d, e
04.6.03	40	"	39					a, b, c, d, e
10.6.03	11							a, b, c, d, e
11.6.03	10							a, b, c, d, e
12.6.03	5							a, b, c, d, e
Total	3684		2440				2500/-	

*Difficulties:

a) Sales and Display, b) Transaction, c) accounting, d) Security, e) Others.

Note:

i) Sampling period = days

ii) Total no. of observation = 49 days

iii) Total no. of interruption = 74

iv) Summation of loss due to less sales and increased overhead expenditure = Tk.2500/-

Signature: Signed by the shopkeeper

APPENDIX J

Sample Loss Calculation for Residential Respondent:

A sample calculation for a residential respondent to evaluate the losses of interruption of power is shown below.

Respondent ID No. 22:

Sampling period = 101 days,

No. of observation, T_S = 71 days,

No. of interruption, NI_S = 142,

Total duration of interruption, H_I = 4831 mints. = 80.52 hours,

Total duration of alternative used, H_{AL} = 3033 mints. = 50.55 hours.

Now, average duration of interruption, $T_1 = H_I \div NI_S$

$= 80.52 \div 142$

$= 0.57$ hours/interruption.

Cost due to damage of appliance,

$$J_i = \sum_{i=1}^{N} [J_{i1}\, I(da) + J_{i2} \perp (da)]_i \qquad \text{... (i)}$$

It is seen from the questionnaire filled up by this respondent that one refrigerator has been damaged due to the frequent power interruption which is a repairable item. The price of this refrigerator is Tk.30000.00 and the life span of it is 20 years. Also cost per repair of it is Tk.1200.00.

So, number of damage appliance, N = 1,

Characteristic function, I(da) = 1,

Cost component due to the damage of the irreparable item, J_{12} = Tk.0.00

Characteristic function, $\perp(da) = 0$

The estimated number of interruption during the life time of the refrigerator,

$NI = (NI_S + NI_{nS})\hat{\tau}_R\, k$

$= [NI_S + (T - T_S)\frac{NI}{T_S}]\, \hat{\tau}_R\, k$ — Since, time interval, T = 365 days,

$= [142 + (365 - 71)\frac{142}{71}] \times 19 \times 0.6$ — Reduced life due to repair of refrigerator, $\hat{\tau}_R$ = 19 yrs.

$= 8322$ — Function of uncertainty assumed, k = 60 %

Cost of repair of the refrigerator, $C_R = NRC$ .... (ii)

Where, NR = total number of possible repair during the life time of the refrigerator

$$= 1 + \frac{NI - NI_S}{NI_S}$$

$$= \frac{NI}{NI_S}$$

$$= \frac{8322}{142}$$

$$= 58.61$$

but in practice, it is not acceptable and according to the opinion of the respondent, this may be 3 or 4 numbers during the life time of the refrigerator. So, the total number of possible repair during the life time of the refrigerator is taken as 4 and the cost per repair from the filled up questionnaire is taken as C = Tk.1200.00. Putting these values in equation (ii),

$$C_R = 4 \times 1200.00$$

$$= \text{Tk. } 4800.00$$

Loss due to decrease of the life span of the refrigerator,

$$C_{RL} = \frac{P_R}{\tau_R}(\tau_R - \hat{\tau}_R) - S_R$$

$$= \frac{30000.00}{20}(20-19) - 750.00$$

$$= \text{Tk.}750.00$$

Since, life of refrigerator, $\tau_R = 20$ yrs.

Reduced life of refrigerator, $\hat{\tau}_R = 19$ yrs.

Salvage value of refrigerator, S_R = Tk.750.00

$\therefore$ Cost component due to the damage of the repairable item, $J_{11} = C_R + C_{RL}$

$$= \text{Tk.}(4800.00 + 750.00)$$

$$= \text{Tk.}5550.00$$

Putting the required values in equation (i),

$$J_1 = J_{11}I(da) + J_{12}\perp(da)$$

$$= 5550.00 \times 1 + 0.00 \times 0$$

$$= \text{Tk.}55550.00$$

$\therefore$ Cost due to damage of the refrigerator per hour of interruption,

$$\hat{J}_1 = \frac{J_1}{NIT_1} = \frac{5550.00}{8322 \times 0.57} = \textbf{Tk. 1.17}$$

and cost due to damage of the refrigerator during the sampling period,

$$J_1 = \hat{J}_1 \times H_1 = 1.17 \times 80.52 = \textbf{Tk.94.21}$$

Cost due to the use of alternative sources,

$$J_2 = (P_{AL} - S_{AL}) + C_{FAL} NIT_1 \qquad \text{.................................... (iii)}$$

Since, the respondent has used charger as an alternative source, the capacity and fuel costs are to be considered.

Price of the charger light as an alternative source, P_{AL}= Tk.1180.00,

Salvage value of the charger light as an alternative source, S_{AL}= Tk.40.00,

Fuel cost for an unit duration, $C_{FAL} = \frac{w\ tr\ H_{AL}}{1000 t_I H_I} = \frac{20 \times 12 \times 2.26 \times 50.55}{1000 \times 2 \times 80.52} =$ Tk.0.17

The estimated number of interruption during the life of the charger,

$$NI_{AL} = (NI_s + NI_{ns})\ k$$

$$= [NIs + (T - Ts)\frac{NIs}{Ts}]k$$

$$= [142 + (1460 - 71)\ \frac{142}{71}\ ] \times 0.60$$

$$= 1752$$

Here,

NI_{ns} = No. of interruption during the rest of the life of charger

$$= (T - T_S)\frac{NIs}{Ts}$$

T = Total life span of the charger

= 4 years = 1460 days

k = Function of uncertainty assumed = 60%

Putting the required values in equation (iii),

$$J_2 = 1180.00 - 40.00 + 0.17 \times 1752 \times 0.57$$

$$= \text{Tk.}1309.76$$

$\therefore$ Cost due to the use of charger per hour of interruption, $\hat{J}_2 = \frac{J_2}{NI_{AL} T_I}$

$$= \frac{1309.07}{1752 \times 0.57}$$

= Tk.1.31

and cost due to the use of charger during the sampling period, $J_2 = \hat{J}_2 \times H_{AL}$

$$= 1.31 \times 50.55$$

= Tk. 66.22

Cost of perishable goods, $J_3 = C_{PG}\ I(D)$

= Tk.400.00 x 1 , since I(D) = 1 as because $D \geq \bar{D}$.

= Tk.400.00

$\therefore$ Cost of perishable goods per hour of interruption, $\hat{J}_3 = \frac{J_3}{H_I} = \frac{400.00}{80.52} =$ **Tk.4.97**

$\therefore$ Cost of perishable goods during the sampling period, $J_3 = \hat{J}_3 \times H_I = 4.97 \times 80.52 =$ Tk.**400.00**

Cost of inconvenience,

$$J_4 = \sum_{i=1}^{4} J_{IN_i}$$

$$= J_{IN_1} + J_{IN_2} + J_{IN_3} + J_{IN_4} \qquad \text{.............................. (iv)}$$

Now, cost due to disturbance in study, $J_{IN_1} = \sum_{i=1}^{M} (C_{TR} + C_M)_i$ .... (v)

In this case,

No. of student, M = 1,

No. of inconvenience for study = 25days,

Cost of private transport = Tk.10.00 per trip,

Probability of loss of the college bus = 50 %,

Doctor's fee for 1 time = Tk.300.00

Cost of medicine = Tk.50.00

$\therefore$ Additional charges for transport, C_{TR} = Tk.10.00 x 25 x 0.5 x 1 = Tk.125.00,

and cost of medication, C_M = Tk.300.00 + 50.00 = Tk.350.00,

So, putting the values of C_{TR} and C_M in equation (v),

$$J_{IN_1} = C_{TR} + C_M$$

$$= 125.00 + 350.00$$

$$= \text{Tk.}475.00$$

Cost of sewing due to power interruption,

$$J_{IN_2} = \sum_{i=1}^{K} CT_i$$

= Tk.0.00; because no body in the house faced such kind of inconvenience.

The inconvenience period for cooking and dinning is 21 days. Due to this inconvenience cocking foods have damaged amounting to Tk.150.00 and the respondent has purchased some foods from out side amounting to Tk.200.00. So, cost of inconvenience in dining or cooking,

$$J_{IN_3} = (C_F + C_{OF}) \perp(D)$$

$$= \text{Tk.}(150.00 + 200.00) \times 1 \qquad \text{since, } \perp(D) = 1.$$

$$= \text{Tk.}350.00$$

Birthday party of the respondent has been postponed due to interruption of power. Cost of decoration of the rooms are of Tk.400.00 and the cost of the foods collected from the market is Tk.1400.00. But nothing has been paid for artist.

∴ Cost of inconvenience in family function,

$$J_{IN4} = C_D + C_F + C_A$$
$$= Tk.(400.00 + 1400.00 + 0.00)$$
$$= Tk.1800.00$$

putting the values of J_{IN1}, J_{IN2}, J_{IN3} and J_{IN4} in equation (iv),

Cost of inconvenience, $J_4 = \sum_{i=1}^{4} J_{IN\,i}$

$$= J_{IN1} + J_{IN2} + J_{IN3} + J_{IN4}$$
$$= Tk.(475.00 + 0.00 + 350.00 + 1800.00)$$
$$= Tk.2625.00$$

∴ Cost of inconvenience per hour of interruption, $\hat{J}_4 = \frac{J_4}{H_I} = \frac{2625.00}{80.52} =$ **Tk.32.60**

and cost of inconvenience during the sampling period, $J_4 = \hat{J}_4 \times H_I$

$$= 32.60 \times 80.52$$
$$= Tk.\mathbf{2625.00}$$

Therefore,

Total cost of interruption of power during the sampling period,

$$J = J_1 + J_2 + J_3 + J_4$$
$$= Tk.(94.21 + 66.22 + 400.00 + 2625.00)$$
$$= \mathbf{Tk.3185.43}$$

and the total cost per hour of interruption of power, $\hat{J} = \hat{J}_1 + \hat{J}_2 + \hat{J}_3 + \hat{J}_4$

$$= 1.17 + 1.31 + 4.97 + 32.60$$
$$= \mathbf{Tk.40.05}$$

APPENDIX K

Sample Loss Calculation for Industrial Respondents:

A sample calculation for an industrial respondent to evaluate the losses of interruptions of power is shown below.

<u>Respondent No. 48:</u>

Sampling period = 91 days,

No. of observation, T_S = 64 days,

No. of interruption, NI_S = 106,

Total duration of interruption, H_I = 3592 mints. = 59.86 hours,

Total duration of alternative used, H_{AL} = 3610 mints. = 60.16 hours.

Now, hour per interruption, $T_I = H_I \div NI_S = 59.86 \div 106 = 0.56$ hours.

Cost due to damage of appliance,

$$J_i = \sum_{i=1}^{N} [J_{11}\, I(da) + J_{12} \perp (da)]_i \qquad \text{...} (i)$$

It is seen from the questionnaire filled up by this respondent that one single phase motor was damaged due to the frequent power interruption. It is a repairable item. The price of this motor is Tk.4000.00 and the life span of it is 15 years. Also, the cost per repair is Tk.450.00.

So, No. of damage appliance, N = 1,

Characteristic function, I(da) = 1,

Cost component due to the damage of the irreparable item, J_{12} = Tk.0.00

Characteristic function, $\perp$(da) = 0

The estimated number of interruption during the life time of the motor,

$$NI = (NI_S + NI_{nS})\,\hat{\tau}_R\, k$$

$$= [NIs + (T - Ts)\frac{NI}{Ts}]\,\hat{\tau}_R\, k$$

$$= [106 + (365 - 64)\frac{106}{64}] \times 13 \times 0.6$$

$$= 4715 \text{ (Approximate)}$$

Since, time interval, T = 365 days,

Reduced life due to repair of motor, $\hat{\tau}_R$ = 13 yrs.

Function of uncertainty assumed, k = 60 %

Cost of repair of the motor, $C_R = NRC$ ....(ii)

Where,

Total number of possible repair during the life time of the motor, $NR = 1 + \frac{NI - NIs}{NIs}$

$$= \frac{NI}{NIs}$$

$$= \frac{4715}{106}$$

$$= 44.48.$$

But in practice, it is not acceptable and according to the opinion of the respondent, this may be 3 or 4 numbers during the life time of the motor. So, the total number of possible repair during the life time of the motor is taken as 4 and the cost per repair from the filled up questionnaire is taken as C = Tk.450.00. Putting these values in equation (ii),

$$C_R = 4 \times 450.00$$

$$= \text{Tk.}1800.00$$

Loss due to decrease of the life span of the motor,

$$C_{RL} = \frac{P_R}{\tau_R}(\tau_R - \hat{\tau}_R) - S_R$$

$$= \frac{4000.00}{15}(15 - 13) - 400.00$$

$$= \text{Tk.}133.33$$

Since, life of motor, $\tau_R = 15$ yrs.

Reduced life of motor, $\hat{\tau}_R = 13$ yrs.

Salvage value of motor, $S_R = \text{Tk.}400.00$

$\therefore$ Cost component due to the damage of the repairable item, $J_{11} = C_R + C_{RL}$

$$= \text{Tk.}(1800.00 + 133.33)$$

$$= \text{Tk.}1933.33$$

Putting the required values in equation (i),

$$J_1 = J_{11}I(da) + J_{12}\bot(da)$$

$$= 1933.33 \times I + 0.00 \times 0$$

$$= \text{Tk.}1933.33$$

$\therefore$ Cost due to damage of the motor per hour of interruption, $J_1' = \frac{J_1}{NIT_1} = \frac{1933.33}{4715 \times 0.56}$

$$= \textbf{Tk.0.73}$$

and cost due to damage of the motor during the sampling period, $J_1 = J_1' \times H_I$

$$= 0.73 \times 59.87$$

$$= \textbf{Tk.43.71}$$

Cost due to the use of alternative sources,

$$J_2 = (P_{AL} - S_{AL}) + C_{FAL} NIT_I \qquad \text{.............................. (iii)}$$

Since, the respondent usually used a generator of 500 kVA as an alternative source, the capacity and fuel costs are to be considered.

Here,

Price of the generator as an alternative source, P_{AL}= Tk.2525000.00,

Salvage value of the generator as an alternative source, S_{AL}= Tk.25000.00,

Fuel cost per hour, $C_{FAL} = \dfrac{\text{diesel/hr} \times \text{Tk/ltr} \times H_{AL}}{H_I} = \dfrac{25 \times 20 \times 60.16}{59.86} = \text{Tk.}502.51$

The estimated number of interruption during the life of the generator,

$$NI_{AL} = (NI_s + NI_{ns})\,k$$
$$= [NI_S + (T - T_S)\frac{NI_S}{T_S}]k$$
$$= [106 + (7300 - 64)\ \frac{106}{64}\ ] \times 0.60$$
$$= 7254.38$$
$$\approx 7254 \text{ (Approximate)}$$

Here,

NI_{ns} = Number of interruption during the rest of the life of the generator $= (T - T_S)\dfrac{NI_S}{T_S}$

T = Total life span of the generator = 20 years = 7300 days

k = Function of uncertainty assumed = 60%

Putting the calculated values in equation (iii),

$$J_2 = 2525000.00 - 25000.00 + 502.51 \times 7254 \times 0.56$$
$$= \text{Tk.}4541299.35$$

$\therefore$ Cost due to the use of generator per hour of interruption, $J_2' = \dfrac{J_2}{NI_{AL}T_I}$

$$= \frac{4541299.35}{7254 \times 0.56}$$
$$= \textbf{Tk.1117.92}$$

$\therefore$ Cost due to the use of generator during the sampling period, $J_2 = J_2' \times H_{AL}$

$$= 1117.92 \times 60.16$$
$$= \textbf{Tk.67254.07}$$

Cost of damage of raw materials under process,

$$J_3 = C_{PG}\, I(D)$$
$$= \text{Tk.}0.00\,; \quad \text{because, nothing has been damaged.}$$

$\therefore$ Cost of damage of raw materials under process per hour of interruption, $J_3' = \frac{J_3}{H_I} = \frac{0.00}{59.86}$

$= \textbf{Tk.0.00}$

and cost of damage of raw materials under process during the sampling period,

$J_3 = J_3' \times H_I$

$= 0.00 \times 59.86$

$= \text{Tk.}\textbf{0.00}$

Cost of additional wages,

$$J_4 = \sum_{i=1} W_i L$$

= Tk.0.00; no needed extra works because, industry used to run within the schedule time.

$\therefore$ Cost of additional wages per hour of interruption, $J_4' = \frac{J_4}{H_I} = \frac{0.00}{59.86} = \textbf{Tk.0.00}$

and cost of additional wages during the sampling period, $J_4 = J_4' \times H_I = 0.00 \times 59.86 = \text{Tk.}\textbf{0.00}$

Therefore,

Total cost of interruption of power during the sampling period, $J = J_1 + J_2 + J_3 + J_4$

$= 43.71 + 67254.07 + 0 + 0$

$= \textbf{Tk.67297.78}$

and the total cost per hour of interruption of power, $J' = J_1' + J_2' + J_3' + J_4'$

$= 0.73 + 1117.92 + 0 + 0$

$= \textbf{Tk.1118.65}$

APPENDIX L

Sample Loss Calculation for Commercial Respondents:

A sample calculation for a commercial respondent to evaluate the losses of interruption of power is shown below.

<u>Respondent No. 36:</u>

Sampling Period = 74 days,

No. of Observation, T_S = 61 days,

No. of Interruption, NI_S = 153,

Total duration of Interruption, H_I = 5388 mints. = 89.80 hours,

Total duration of alternative used, H_{AL} = 2236 mints. = 37.26 hours.

Now,

Hour per Interruption, $T_I = H_I \div NI_S = 89.80 \div 153 = 0.59$ hours.

Cost due to damage of appliance,

$$J_I = \sum_{i=1}^{N} [J_{I1}\, I(da) + J_{I2} \perp (da)]_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

It is seen from the questionnaire filled up by this respondent that one color television of 14″ has been damaged due to the frequent power interruption which is repairable item. The price of this television is Tk.13000.00 and the life span of it is 20 years. Also cost per repair of it is Tk.700.00.

So, No. of damage appliance (TV), N = 1,

Characteristic function, I(da) = 1,

Cost component due to the damage of the irreparable item, J_{12} = Tk.0.00

Characteristic function, $\perp$(da) = 0

The estimated number of interruption during the life time of the television,

$$NI = (NI_S + NI_{nS})\hat{\tau}_R\, k$$

$$= [NI_S + (T - T_S)\frac{NI_S}{T_S}]\,\hat{\tau}_R\, k$$

$$= [153 + (365 - 61)\frac{153}{61}] \times 19 \times 0.6$$

$$= 10436.60$$

$$\approx 10437 \text{ (approximate)}$$

Since, time interval, T = 365 days,

Reduced life due to repair of TV, $\hat{\tau}_R$ = 19 yrs.

Function of uncertainty assumed, k = 60 %

Cost of repair of the television, $C_R = NRC$ .... (ii)

where, NR = total number of possible repair during the life time of the TV

$$= 1 + \frac{NI - NI_S}{NI_S}$$

$$= \frac{NI}{NI_S}$$

$$= \frac{10437}{153}$$

$$= 68.21.$$

But in practice, it is not acceptable and according to the opinion of the respondent, this may be 3 or 4 numbers during the life time of the television. So, the total number of possible repair during the life time of the television is taken as 4 and the cost per repair from the filled up questionnaire is taken as C = Tk.700.00. Putting these values in equation (ii),

$$C_R = 4 \times 700.00$$

$$= \text{Tk.}2800.00$$

Loss due to decrease of the life span of the TV,

$C_{RL} = \frac{P_R}{\tau_R}(\tau_R - \hat{\tau}_R) - S_R$	Since, life of TV, $\tau_R = 20$ yrs.
$= \frac{13000.00}{20}(20-19)-400.00$	Reduced life of TV, $\hat{\tau}_R = 19$ yrs.
= Tk.350.00	Salvage value of TV, S_R = Tk.300.00

$\therefore$ Cost component due to the damage of the repairable item, $J_{11} = C_R + C_{RL}$

$$= \text{Tk.}(2800.00 + 350.00)$$

$$= \text{Tk.}3150.00$$

Putting the required values in equation (i),

$$J_1 = J_{11}I(da) + J_{12}\perp(da)$$

$$= 3150.00 \times 1 + 0.00 \times 0$$

$$= \text{Tk.}3150.00$$

$\therefore$ Cost due to damage of the television per hour of interruption, $J_1'' = \frac{J_1}{NIT_1} = \frac{3150.00}{10436 \times 0.59}$

= **Tk.0.51**

and cost due to damage of the television during the sampling period, $J_1 = J_1'' \times H_1$

$$= 0.51 \times 89.80$$

= **Tk.45.80**

Cost due to the use of alternative sources, $J_2 = (P_{AL} - S_{AL}) + C_{FAL}NIT_1$ .... (iii)

since, the respondent has used charger as an alternative source, the capacity and fuel costs are to be considered.

Here,

Price of the charger light as an alternative source, P_{AL}= Tk.1100.00,

Salvage value of the charger light as an alternative source, S_{AL}= Tk.30.00,

Charging cost for an unit duration, $C_{FAL} = \frac{w\ tr\ H_{AL}}{1000 t_1 H_l} = \frac{18 \times 12 \times 2.26 \times 37.26}{1000 \times 2 \times 89.80} =$ Tk.0.10

The estimated number of interruption during the life of the charger,

$NI_{AL} = (NI_s + NI_{ns})\ k$

$= [NI_s + (T - T_S)\frac{NI_s}{T_S}]k$

$= [153 + (1095 - 61)\ \frac{153}{61}] \times 0.60$

$= 1647.8852$

≈ 1648 (approximate)

Here,

NI_{ns} = Number of interruption during the rest of the life of the charger $= (T - T_S)\frac{NI_s}{T_S}$

T = Total life span of the charger = 3 years = 1095 days

k = Function of uncertainty assumed= 60%

Putting these values in equation (iii),

$$J_2 = 1100.00 - 30.00 + 0.10 \times 1648 \times 0.59$$
$$= \text{Tk.}1167.23$$

∴ Cost due to the use of charger per hour of interruption, $J_2'' = \frac{J_2}{NI_{AL}T_1} = \frac{1167.23}{1648 \times 0.59}$

$= \textbf{Tk.1.20}$

and cost due to the use of charger during the sampling period, $J_2 = J_2'' \times H_{AL}$

$= 1.20 \times 37.26$

$= \textbf{Tk.44.71}$

Cost of perishable goods,

$J_3 = C_{PG}\ I(D)$

$=$ Tk.800.00 x 1 , since I(D) = 1 as because $D \geq \bar{D}$.

$=$ Tk.800.00

∴ Cost of perishable goods per hour of interruption, $J_3'' = \frac{J_3}{H_I} = \frac{800.00}{89.80} = \textbf{Tk.8.91}$

and cost of perishable goods per hour of interruption, $J_3 = J_3'' \times H_I = 8.91 \times 89.80$ =Tk.**800.00**

Cost due to reduced sale and additional wages,

$$J_4 = \sum_{i=1}^{2} J_{N_i}$$

$$= J_{N1} + J_{N2}$$

$$= \frac{Tk.3500}{30day} \times 61day$$

$$= Tk.7116.67$$

$\therefore$ Cost due to reduced sale and additional wages per hour of interruption, $J_4'' = \frac{J_4}{H_I}$

$$= \frac{7116.67}{89.80}$$

$$= \mathbf{Tk.79.25}$$

and cost due to reduced sale and additional wages during the sampling period,

$$J_4 = J_4'' \times H_I$$

$$= 79.25 \times 89.80$$

$$= Tk.\mathbf{7116.67}$$

Therefore,

Total cost of interruption of power during the sampling period,

$$J = J_1 + J_2 + J_3 + J_4$$

$$= 45.80 + 44.71 + 800.00 + 7116.67$$

$$= \mathbf{Tk.8007.18}$$

and the total cost per hour of interruption of power, $J'' = J_1'' + J_2'' + J_3'' + J_4''$

$$= 0.51 + 1.20 + 8.91 + 79.25$$

$$= \mathbf{Tk.89.87}$$

APPENDIX M

Electricity Tariff

The following tariffs were effective from August 1, 2002 to September 1, 2003.

Serial No.	Class of Tariff	Type of Consumer	Slab of Unit (kWh)	Rate / Unit (Taka)
1	A	Commercial	000 - 100	2.26
			101 - 300	2.42
			301 - 500	3.62
			501 - 700	4.73
			Above 700	5.99
2	C	Low tension and industry	Flat rate	3.83
			Off peak (From 23:00 to 05:00 hr.)	3.05
			Peak (From 17:00 to 23:00 hr.)	5.36
3	E	Commercial	Flat rate	5.04
			Off peak	3.62
			Peak	7.82
4	F	Medium voltage General use (11 KV)	Flat rate	3.62
			Off peak	2.99
			Peak	6.41
5	B	Agriculture	Flat rate	1.84