Determination of Critical Price Per Unit Energy on the Basis of Power Interruption Cost of Industrial Consumer

by

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DEDICATION

This thesis is dedicated to my mother, Mrs. Majeda Begum, mother-in-law, Mrs. Salma Beowa, father, Late Muhammad Shomser Ali Khan and father-in-law, Late Shamsul Alam. May Almighty Allah bless them all.

ABSTRACT

There is increasing interest in the new deregulated electric utility environment in assessing the consumer costs, associated with failures in electric power supply and the responsibilities associated with these failures. Continuous electric supply is a measure of production in industry and profit in the business. The uninterrupted electric supply is a desire of consumers.

The electric power interruption may create a significant loss to the consumers of different sectors. In this study, the types of losses in the industrial sector are identified to evaluate the losses due to power interruption into monetary terms. The major loss components are: (i) loss due to damage of different raw materials under process; (ii) loss due to usage of alternative sources; (iii) loss due to reduced production, loss due to additional wages and (iv) loss due to equipments' trouble and damage. In order to evaluate the loss due to power interruption for consumers of industrial sector, an appropriate mathematical model has been developed. A questionnaire has been developed to collect information relating to power interruption. The evaluated loss has been compared with the electricity bills paid by the consumers. The critical price per unit energy in captive power plant generation on the basis of power interruption cost of industrial consumer has been determined. Also, the relative merits and demerits of the proposed model have been compared with existing power interruption model.

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

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Symbols	Descriptions	Page No.
Ni_{rp}	Number of interruption during the rest of the observation period of the used alternative source (Nos.)	8
Tla	Total life span of used alternative source (Yr.)	8
Trla	Reduced life due to repair of used alternative source (Yr.)	8
To	Observation period (days)	8
$C4_{as}$	Cost component for the trouble of the alternative source due to power interruption (Tk.)	8
C_{rcta}	Total costs of repair of the alternative source (Tk.)	8
C_{rca}	Cost per repair for the alternative source (Tk.)	8
Nra	The total number of possible repair during the life time of the alternative source (Nos.)	8
Nraop	Number of repair of the alternative source during observation period (Nos.)	8
Nrar	Number of repair of the alternative source during rest of period (Nos.)	8
C_{rLa}	Loss due to decrease of the life span of the alternative source (Tk.)	8
$\overline{C2}$	Cost due to the use of alternative source per hour of interruption (Tk.)	9
C2o	Cost due to the use of alternative source during the observation period (Tk.)	9
C2i	Cost due to the use of alternative source per interruption (Tk.)	9
C3rp	Loss due to reduced production (Tk.)	9
Li	Loss due to reduced production per hour of interruption (Tk.)	9
C3aw	Additional wage costs (Tk.)	9
Wi	Wage of ith worker per hour (Tk.)	9

LIST OF SYMBOLS (continued)

Symbols	Descriptions	Page No.
Tot	Total over time (Hr.)	10
Neo	Number of employees' done over time duty for manually operated machines or number of machine unit for automated machines (Nos.)	9
C3	Loss due to reduced production and additional wage costs (Tk.)	9
$\overline{C3}$	Loss due to reduced production and additional wage cost per hour of interruption (Tk.)	10
C3o	Loss due to reduced production and additional wage cost during the observation period (Tk.)	10
C3i	Loss due to reduced production and additional wage cost per interruption (Tk.)	10
C4	Equipments' trouble and damage costs (Tk.)	10
$C4_r$	Cost component due to the trouble of the reparable item (Tk.)	11
G(d)r	Damage function of the reparable item	11
$C4_{ir}$	Cost component due to the damage of the irreparable item (Tk.)	11
G(d)ir	Damage function of the irreparable item	11
Ntd	Number of equipments which faced trouble or damaged (Nos.)	11
C_{rct}	Total costs of repair of the reparable item (Tk.)	11
C_{rc}	Cost per repair of the reparable item (Tk.)	11
Nr	The total number of possible repair during the life time of the reparable item (Nos.)	11
Nrop	Number of repair of the reparable item during observation period (Nos.)	11

LIST OF SYMBOLS (continued)

Symbols	Descriptions	Page No.
Nrrp	Number of repair of the reparable item during rest of observation period (Nos.)	11
Niri	The estimated number of interruption during the life time of the reparable item (Nos.)	11
Ni_n	Number of interruption during the rest of the observation period of the reparable item (Nos.)	12
Trl	Reduced life of the reparable item due to repair (Yr.)	12
C_{rL}	Loss due to decrease of the life span of the reparable item (Tk.)	12
Tri	The life span of the reparable item (Yr.)	12
Pri	The price of reparable item (Tk.)	12
Sri	Salvage value of reparable item (Tk.)	12
$\overline{C4}$	Equipments' damage costs per hour of interruption (Tk.)	12
C4o	Equipments' damage costs during the observation period (Tk.)	12
C4i	Equipments' trouble and damage costs per interruption (Tk.)	12
C	Total costs of interruption during the whole period (Tk.)	13
Co	Total costs of interruption of power during the observation period (Tk.)	13
$\overline{C}$	Total costs per hour of interruption of power (Tk.)	13
Ci	Total costs of power per interruption (Tk.)	13
Cu	Price per unit electric energy (Tk.)	13
Ens	Total energy not served from national grid source (kWh)	13
Pt	Connected load (kW)	13
Ai	Industry area (sft)	15
Ne	Employees' nos.	15
Uavg	Average consumed energy per month (kWh)	15

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LIST OF ABBREVIATIONS

Abbreviations	Elaboration	Page No.
Tk.	Taka	3
kW	KiloWatt	3
sft	Square foot	3
Nos.	Numbers	6
Hr.	Hour	6
Ltr.	Liter	7
int.	Interruption	7
approx	Approximately	7
Yr.	Year	8
kWh	KiloWatt-hour	13
No.	Number	15
Avg.	Average	15
ID.	Identification	15
SL.	Serial	20
SIC	Standard Industrial Classification	29
UPS	Uninterruptible Power Supply	43
IPS	Instant Power System	43
Max	Maximum	56
USD	United States Dollar	83
CAD	Canadian Dollar	83
BDT	Bangladeshi Taka	83
Rs.	Indian Rupees	83
DPDC	Dhaka Power Distribution Company Ltd.	83
DESCO	Dhaka Electric Supply Company Ltd.	83
vol	Volume	87
pp	page to page	87
IEEE	Institute of Electrical and Electronic Engineers	87
kVA	KiloVolt Ampere	94
CFL	Compact Fluorescent Lamp	98

LIST OF ABBREVIATIONS (continued)

Abbreviations	Elaboration	Page No.
H.P.	Horse power	98
BPC	Bangladesh Petroleum Corporation	108
LPG	Liquefied Petroleum Gas	108
kV	Kilo Volt	109

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Electricity is a basic need for the strong economical foundation of a modern civilization. The main function of a modern utility is to provide an adequate supply of electricity to its consumers at an optimal price with a reasonable level of continuity and quality. In direct worth approach, outage costs are divided into two categories; value of lost production and outage related costs (wage costs to make up production, damage costs to materials etc.). Moreover outage related savings have been decreased the outage costs [20]. The review of recent works, objectives add organization of the thesis have been discussed in this chapter.

1.2 REVIEW OF RECENT WORKS

The effect of power interruption is enormous and measured by either the cost of outages or the afford ness to pay for reliability. In the past, researchers studied applications of interruption costs in generation only and composite system reliability planning with key focus on the power system reliability planning practices in North America [1]. It is seen that for the industrial sector, the possible effects include: production loss (during interruption and restart time), overtime cost and other unspecified costs. A Canadian customer survey was carried out to assess only power system reliability worth [2]. Electric service reliability cost / worth has been assessed in a developing country [3], [26] only. Nonresidential consumers carry out paid staff unable to work, loss of sales or production (during failure and restart times), damage to equipment or finished product, cost of running standby generation, loss of goodwill can still be evaluated, to some extent, in terms of lost business. In another study researcher used questionnaires in a form that allowed respondents to fill out each interruption duration presented, the costs corresponding to the cost elements relevant to a customer category. Only factors (and without some other unspecified factors) affecting customer outage costs due to electric service interruptions are determined [4]. The power supply situation in March 2009 and its impacts on the ready made garment sector in Bangladesh are discussed in [5].

Electric power interruption cost and its correlation with system reliability [6], [9], [11], [12], [13], [27], [28], [30] not considering affecting all factors and for that time only.

1.3 OBJECTIVES

(i) To develop an appropriate mathematical model to evaluate the loss of interruption of power for consumers of industrial sector and cost per unit energy in captive power plant generation and

(ii) To compare the relative merits and demerits of the proposed model with existing power interruption models.

1.4 ORGANIZATION OF THE THESIS

This thesis has been structured into six chapters.

Chapter 1 introduces the research area and presents the critical review, objectives and scope of the research work with thesis organization described in this thesis.

To accommodate all possible losses for four cost components of an industrial consumer due to power interruption, an appropriate mathematical model has been developed for raw materials under process damage costs, alternative source usage costs, loss due to reduced production and additional wage costs, equipments' trouble and damage costs, total cost of power interruption and price per unit energy. An overview of the interruption cost methodologies has been presented in Chapter 2.

General information collection of industrial consumers, power interruption information collection, alternative sources information collection, consumers' classification and various difficulties / problems related information / data have been presented. Different types of data and information from the consumers of electricity are required to evaluate various results using the developed mathematical model. Questionnaires which have been shown in Appendix 1 have been developed to collect the necessary information. The customer survey conducted in this research work has been described in Chapter 3.

The losses of different respondents have been calculated by considering the sampling period, by the issues described in tabular form and classifications presented by the histograms, summary of the alternative sources used listed in tabular form have been evaluated and the evaluated interruption costs have been presented in tabular forms. The total interruption costs per hour and per interruption have been calculated and listed them in tabular form. The cost per unit electric energy in captive power plant generation has been evaluated. Critical price per unit energy have been determined. The survey calculation has been presented. Sample of facing various difficulties / problems in performing activities for industrial consumers due to power outage has been shown by graphical representation. Also graphical representation of various types of alternative sources used by consumers, monthly electric bill (Tk.) paid by consumers, connected load (kW) by consumers, industry area (sft) by consumers have been shown in Chapter 4.

The maximum cost of electricity per hour for uninterrupted power supply, the hourly average electricity bill paid has been calculated from the monthly average electricity bill, the ratio between the evaluated total cost per hour of interruption and the expected maximum cost of electricity per hour for uninterrupted power supply, the ratio between the total cost per hour of interruption and the hourly average electricity bill paid by an industrial respondent have been calculated. The losses of different respondents have been compared with the electricity bill paid by the consumers. The evaluated interruption costs have been compared with the expected maximum electricity bill for uninterrupted power supply and with the actual electricity bill paid per hour. Also the losses of consumers due to different factors have been compared. Determined class, interruption costs per hour and average electricity bill per hour for individual consumer have been shown. Interruption average costs per hour, average electricity bill per hour and average determined price per unit energy on the basis of consumers' classes have been shown. Graphical representation of average interruption costs per hour (Tk.) paid by consumers, relation and comparison between interruption costs per hour (Tk.) and average electricity bill (Tk.) per hour paid by consumers in accordance with consumers' classification have been shown. Value from listed in tabular form for industrial sector of the average cost per hour of interruption of consumer and the cost per unit energy in captive power plant generation have been plotted graphically to establish correlation between those and select critical price per unit energy in captive power plant generation. The survey findings and results have been analyzed, discussed and the impacts of various parameters on the calculated indices have also been presented for comparison and analysis in Chapter 5.

Chapter 6 presents decision by using remarks, suggestions and the recommendations of this research work.

CHAPTER TWO

METHODOLOGY

2.1 INTRODUCTION

The consumer interruption cost, when an electric supply failure occurs, depends on many factors; such as (i) the consumer types interrupted, (ii) the actual load demand at time of the outage, (iii) the duration of the outage, (iv) the time of the day and the day which outage occurs etc [22]. This chapter deals with the methodology of evaluating the losses of the industrial consumer due to power interruption. It has been presented a method to evaluate production, alternative source usage, extra wage and equipment damage costs respectively, which is incurred from power interruption. It has been presented methodology to evaluate interruption costs.

2.2 METHODOLOGY

The materials under process get perished or damaged due to interruption of power. During the interruption of power supplied by the utility, either the production of an industry continues with its own alternative source or it is stopped if the arrangement for alternative source does not exist. Production reduces due to interruption of power and 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 usual components of loss in an industry due to power interruption are: [17], [25].

i) Raw materials under process damage costs;

ii) Alternative source usage costs;

iii) Loss due to reduced production and additional wage costs and

iv) Equipments' trouble and damage costs.

2.2.1 Mathematical Model

To accommodate all possible losses for four cost components of an industrial consumer due to power interruption, an appropriate mathematical model has been developed below.

2.2.1.1 Raw Materials under Process Damage Costs

Raw materials under process damage costs (Tk.) may be expressed as [6]

$$C1 = \{P_{mu} \times G(d)_{mu}\} \quad \text{Tk.} \tag{2.1}$$

where, P_{mu} = Price of raw materials under process, Tk.

$G(d)_{mu}$ = Damage function of raw materials under process;

where, if any damages then it will be 1 otherwise 0.

So, raw materials under process damage costs per hour of interruption (Tk.) will be

$$\overline{C}1 = \left(\frac{C1}{Twi}\right) \quad \text{Tk.}$$

$$= \left(\frac{\text{C1o}}{\text{Ti}}\right) \quad \text{Tk.} \tag{2.2}$$

where, Twi = Whole power interruption period, Hr.

Ti = Power interruption period during the observation period, Hr. Raw materials under process damage costs during the observation period (Tk.) will be

$$C1o = \left(\overline{C}1 \times Ti\right) \quad \text{Tk.} \tag{2.3}$$

And raw materials under process damage costs per interruption (Tk.) will be

$$C1i = \left(\frac{C1o}{Ni}\right) \quad \text{Tk.} \tag{2.4}$$

where, Ni = Number of total interruption during the observation period, Nos.

2.2.1.2 Alternative Source Usage Costs

Alternative source usage costs (Tk.) may be expressed as [6]

$$C2 = \left[\sum_{i=0}^{Nas} \left[\begin{array}{l} (Pas - Sas) + \\ \left\{ Cf \times (Nia \times Tia) \times \left(\frac{Tas}{Ti} \right) \right\} + \\ \{ C4_{as} \times G(d)as \} \end{array} \right] \right] \quad Tk. \quad (2.5)$$

The Numbers of used alternative source, capacity and fuel costs of alternative sources' are to be collected from the consumers.

where, Nas = Number of used alternative sources, Nos.

Pas = Price of an alternative source, Tk.

Sas = Salvage value of respective alternative source, Tk.

Tas = Alternative source usage period, Hr.

Fuel cost per unit time (Tk.) can be written as

$$Cf = \left[\begin{array}{l} \{ Diesel(Ltr./Hr.) \} \times \\ \{ Price(Tk./Ltr.) \} \times \left(\frac{Tas}{Ti} \right) \end{array} \right] \quad Tk. \quad (2.6)$$

Average period of an interruption will be

$$Tia = \left(\frac{Ti}{Ni} \right) \quad (Hr. / int.) \quad (2.7)$$

G (d)as = Damage function of the alternative source as a repairable item;

where, if any damages then it will be 1 otherwise 0.

The estimated number of interruption during the life of the used alternative source (Nos.) may be written as

$$Nia = \{ (Ni + Nirp) \times G\,(p) \} \quad Nos.$$

$$= \left[\left\{ Ni + \left(\frac{(Trla \times 365) - To}{To} \right) \times Ni \right\} \times G(p) \right] \quad Nos. \quad (2.8)$$

where, G (p) = probability function of happening occurrence.

As happening of occurrence may be or may not so some % of uncertainty has been considered (assuming 40% approx.)

Number of interruption during the rest of the observation period of the used alternative source (Nos.) will be

$$Ni_{rp} = \left[\left\{ \frac{(Trla \times 365) - To}{To} \right\} \times Ni \right] \quad \text{Nos.} \quad (2.9)$$

when, Tla = Total life span of used alternative source, Yr.

Then reduced life due to repair of used alternative source (Yr.) will be

$$= \text{Trla} \quad \text{Yr.}$$

$$= (\text{Trla} \times 365) \quad \text{days.}$$

To = Observation period, days.

Cost component for the trouble of the alternative source due to power interruption (Tk.) may be written as

$$\text{C4as} = (\text{Crcta} + \text{CrLa}) \quad \text{Tk.} \quad (2.10)$$

Total costs of repair of the alternative source (Tk.) will be

$$\text{Crcta} = (\text{Nra} \times \text{Crca}) \quad \text{Tk.} \quad (2.11)$$

where, C_{rca} = Cost per repair for the alternative source, Tk.

The total number of possible repair during the life time of the alternative source (Nos.) may be written as

$$Nra = (Nraop + Nrar) \quad \text{Nos.}$$

$$= \left[Nraop + \left\{ \left(\frac{Nraop}{Ni} \right) \times (Nia - Ni) \right\} \right] \quad \text{Nos.}$$

$$= \left\{ \left(\frac{Nraop}{Ni} \right) \times Nia \right\} \quad \text{Nos.} \quad (2.12)$$

where, Nraop = Number of repair of the alternative source during observation period, Nos.

Nrar = Number of repair of the alternative source during rest of observation period, Nos.

Loss due to decrease of the life span of the alternative source (Tk.) may be written as

$$C_{rLa} = \left[\left\{ \frac{(Tla - Trla)}{Tla} \right\} \times (P_{as} - Sas) \right] \quad \text{Tk.} \quad (2.13)$$

By putting the required values in equation (2.5) it can be obtained values of C2 for the whole period.

So, cost due to the use of alternative source per hour of interruption (Tk.) will be

$$\overline{C2} = \left\{ \frac{C2}{(Nia \times Tia)} \right\} \quad \text{Tk.}$$

$$= \left(\frac{\text{C2o}}{\text{Ti}} \right) \quad \text{Tk.} \qquad (2.14)$$

Cost due to the use of alternative source during the observation period (Tk.) will be

$$C2o = \left(\overline{C2} \times Tas \right) \quad \text{Tk.} \qquad (2.15)$$

And cost due to the use of alternative source per interruption (Tk.) will be

$$\text{C2i} = \left(\frac{\text{C2o}}{\text{Ni}} \right) \quad \text{Tk.} \qquad (2.16)$$

2.2.1.3 Loss due to Reduced Production and Additional Wage Costs

If production is kept off during power interruption then loss due to reduced production (Tk.) may be expressed as [6]

$$C3_{rp} = \left[\sum_{i=0}^{Neo} \{ Li \times (Ti - Tas) \} \right] \quad \text{Tk.} \qquad (2.17)$$

where, Li = Loss due to reduced production per hour of interruption, Tk.

Since, 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.

Additional wage costs (Tk.) may be expressed as

$$C3aw = \left\{ \sum_{i=0}^{Neo} (W_i \times Tot) \right\} \quad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ W_i \times (Ti - Tas) \} \right] \quad \text{Tk.} \qquad (2.18)$$

where, Wi = Wage of ith worker per hour, Tk.

Total over time (Hr.) will be

$$\text{Tot} = (\text{Ti - Tas}) \qquad \text{Hr.} \qquad (2.19)$$

where, Neo = Number of employees' done over time duty for manually operated machines or number of machine unit for automated machines, Nos.

So, loss due to reduced production and additional wage costs (Tk.) will be

$$\text{C3} = (\text{C3rp} + \text{C3aw}) \qquad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ Li \times (Ti - Tas) \} + \sum_{i=0}^{Neo} (Wi \times Tot) \right] \qquad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ (Li + Wi) \times (Ti - Tas) \} \right] \qquad \text{Tk.} \qquad (2.20)$$

So, loss due to reduced production and additional wage cost per hour of interruption (Tk.) will be

$$\overline{C3} = \left(\frac{C3}{Twi} \right) \qquad \text{Tk.}$$

$$= \left(\frac{\text{C3o}}{\text{Ti}} \right) \qquad \text{Tk.} \qquad (2.21)$$

Loss due to reduced production and additional wage cost during the observation period (Tk.) will be

$$C3o = \left(\overline{C3} \times Ti \right) \qquad \text{Tk.} \qquad (2.22)$$

Loss due to reduced production and additional wage cost per interruption (Tk.) will be

$$\text{C3i} = \left(\frac{\text{C3o}}{\text{Ni}} \right) \qquad \text{Tk.} \qquad (2.23)$$

2.2.1.4 Equipments' Trouble and Damage Costs

Equipments' trouble and damage costs (Tk.) may be expressed as [6]

$$C4 = \left[\sum_{k=0}^{Ntd} \left[\left\{ \text{C4}_{\text{r}} \times \text{G(d)r} \right\} + \left\{ \text{C4}_{\text{ir}} \times \text{G(d)ir} \right\} \right]_k \right] \qquad \text{Tk.} \qquad (2.24)$$

Cost component due to the trouble of the repairable item (Tk.) will be

$$C4r = (Crct + CrL) \quad \text{Tk.} \quad (2.25)$$

where, G (d) r = Damage function of the repairable item;

If any damages then it will be 1 otherwise 0.

$C4_{ir}$ = Cost component due to the damage of the irreparable item, Tk.

G(d)ir = Damage function of the irreparable item;

If any damages then it will be 1 otherwise 0.

Ntd = Number of equipments which faced trouble or damaged, Nos.

Total costs of repair (Tk.) will be

$$Crct = (Nr \times Crc) \quad \text{Tk.} \quad (2.26)$$

where, C_{rc} = Costs per repair, Tk.

Here, total number of possible repair during the life time of the repairable item (Nos.) will be

$$Nr = (Nrop + Nrrp) \quad \text{Nos.}$$

$$= \left[Nrop + \left\{ \frac{Nrop}{Ni} \times (Niri - Ni) \right\} \right] \quad \text{Nos.}$$

$$= \left\{ \left(\frac{Nrop}{Ni} \right) \times Niri \right\} \quad \text{Nos.} \quad (2.27)$$

where, Nrop = Number of repair during observation period of the reparable item, Nos.

Nrrp = Number of repair of the reparable item during rest period, Nos.

$$= \left\{ \left(\frac{Nrop}{Ni} \right) \times (Niri - Ni) \right\} \quad \text{Nos.} \quad (2.28)$$

The estimated number of interruption during the life time of the reparable item (Nos.) will be

$$Niri = \{(Ni + Nin) \times G\,(p)\} \quad \text{Nos.}$$

$$= \left[\left\{ Ni + \left(\frac{(Trl \times 365) - To}{To} \right) \times Ni \right\} \times G(p) \right] \quad \text{Nos.} \quad (2.29)$$

Number of interruption during the rest of the observation period of the reparable item (Nos.) will be

$$Ni_n = \left[\left\{ \frac{(Trl \times 365) - To}{To} \right\} \times Ni \right] \quad \text{Nos.} \qquad (2.30)$$

where, reduced life of the reparable item due to repair, Yr.

= Trl Yr.

$= (Trl \times 365)$ days.

By putting these values in question (2.26) it can be obtained the value of C_{rct}.

Loss due to decrease of the life span of the reparable item (Tk.) will be

$$C_{rL} = \left[\left\{ \left(\frac{Tri - Trl}{Tri} \right) \times P_{ri} \right\} - Sri \right] \quad \text{Tk.} \qquad (2.31)$$

where, Tri = The life span of the reparable item, Yr.

Trl = Reduced life of the reparable item due to repair, Yr.

Pri = The price of reparable item, Tk.

Sri = Salvage value of reparable item, Tk.

By putting the required values in equation (2.25) then in equation (2.24) it can be obtained the value of C4.

So, equipments' trouble and damage costs per hour of interruption (Tk.) will be

$$\overline{C4} = \left\{ \frac{C4}{(Niri \times Tia)} \right\} \quad \text{Tk.}$$

$$= \left(\frac{\text{C4o}}{\text{Ti}} \right) \quad \text{Tk.} \qquad (2.32)$$

Equipments' trouble and damage costs during the observation period (Tk.) will be

$$C4o = \left(\overline{C4} \times Ti \right) \quad \text{Tk.} \qquad (2.33)$$

And equipments' trouble and damage costs per interruption (Tk.) will be

$$\text{C4i} = \left(\frac{\text{C4o}}{\text{Ni}} \right) \quad \text{Tk.} \qquad (2.34)$$

2.2.1.5 Total Costs of Power Interruption

Therefore, the sum of all four cost components gives the total cost of interruption during the whole period (Tk.) will be

$$\mathrm{C} = (\mathrm{C1} + \mathrm{C2} + \mathrm{C3} + \mathrm{C4}) \quad \text{Tk.} \tag{2.35}$$

Total costs of interruption of power during the observation period (Tk.) will be

$$\mathrm{Co} = (\mathrm{C1o} + \mathrm{C2o} + \mathrm{C3o} + \mathrm{C4o}) \quad \text{Tk.} \tag{2.36}$$

And the total costs per hour of interruption of power (Tk.) will be

$$\overline{C} = \left(\overline{C1} + \overline{C2} + \overline{C3} + \overline{C4}\right) \quad \text{Tk.}$$

$$= \left(\frac{\mathrm{Co}}{\mathrm{Ti}}\right) \quad \text{Tk.}$$

$$= \left(\frac{\mathrm{C}}{\mathrm{Twi}}\right) \quad \text{Tk.} \tag{2.37}$$

Total costs of power per interruption (Tk.) will be

$$\mathrm{Ci} = (\mathrm{C1i} + \mathrm{C2i} + \mathrm{C3i} + \mathrm{C4i}) \quad \text{Tk.}$$

$$= \left(\frac{\mathrm{Co}}{\mathrm{Ni}}\right) \quad \text{Tk.}$$

$$= \left(\frac{C}{Niri}\right) \quad \text{Tk.} \tag{2.38}$$

2.2.2 Price Per Unit Electric Energy

Therefore, price per unit energy (Tk.) will be

$$\mathrm{Cu} = \left(\frac{\mathrm{Co}}{\mathrm{Ens}}\right) \quad \text{Tk.} \tag{2.39}$$

where, total energy not served from national grid source (kWh) will be

$$\mathrm{Ens} = (\mathrm{Pt} \times \mathrm{Ti}) \quad \text{kWh.} \tag{2.40}$$

where, Pt = Connected load, kW.

CHAPTER THREE

INFORMATION AND STATISTICS

3.1 INTRODUCTION

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. The method utilized, in quantifying the benefit of power delivery service reliability, is to the consumer monetary losses associated with power supply interruptions by collecting data with customer survey [23]. In this chapter, a questionnaire has been developed to collect the necessary information. The survey procedure included selection of sample by area, site visit and survey implementation, collection of power use data analysis [18]. The consumers are classified into categories appropriate with their functions and their sensitivity to interruptions [15], [14].

3. 2 DATA COLLECTION PROCESS

The questionnaire contains industry name, industry address with contact no., electricity bill for last three months (Tk.), connected load (kW) of industry, energy consumption (kWh), industry physical area (sft), no. of employees (Nos.), alternative sources used during power outage, electrical equipments, power outage data, consumers' list and authorized signature with seal. The data have been collected according to the questionnaires shown in Appendix 1.

3.3 GENERAL INFORMATION COLLECTION

The following information of industrial consumers has been tabulated in Table 3.1. The questionnaire format has been shown in Table A1.1 of the Appendix 1:

Consumer ID. no., connected load, industry area, employees' nos., consumed energy, for the three months of the year 2003 (kWh), average consumed energy per month (kWh) and bill of electricity paid for the three months of the year 2003 (Tk.)[6].

Table 3.1: General information of industrial consumers

Consumer ID. No.	Connected load	Industry area	Employees' Nos.	Average consumed energy per month	Bill of electricity paid for the three months of the year 2003 (Tk.)		
	kW	sft	Nos.	kWh	April	May	June
#	Pt	Ai	Ne	Uavg	B1	B2	B3
1	600.000	30000	28	52000	222000	225000	230000
2	4.379	1200	10	800	3280	3280	3300
3	150.000	32000	50	22000	100000	110000	115000
4	8.785	700	14	1400	5690	5700	5700
5	7.825	1500	12	1260	5130	5150	5200
6	320.000	50000	80	68000	271436	290000	300000
7	14.000	1800	16	2464	9972	9990	10000
8	3.298	1000	7	598	2470	2500	2500
9	360.000	38000	45	50000	200000	210000	210000
10	15.220	750	3	2570	10395	10400	10400
11	40.860	12800	22	7040	28371	28380	28400
12	7.322	4000	28	1000	4082	4090	40100
13	351.320	48000	30	50000	200000	205000	210000
14	6.926	475	6	996	4065	4090	4100

Table 3.1: General information of industrial consumers (continued)

Consumer ID. No.	Connected load	Industry area	Employees' Nos.	Average consumed energy per month	Bill of electricity paid for the three months of the year 2003 (Tk.)		
	kW	sft	Nos.	kWh	April	May	June
#	Pt	Ai	Ne	Uavg	B1	B2	B3
15	22.436	4800	35	3229	13045	13066	13100
16	7.111	600	8	1020	4162	4175	4186
17	2.420	500	6	384	1460	1480	1500
18	12.595	1200	9	1817	7367	7379	7390
19	13.084	1750	12	1960	7942	7950	7955
20	13.509	600	9	1948	7897	7900	7900
21	39.308	7800	165	13500	56000	56000	56000
22	40.830	7200	150	14000	58065	58100	58100
23	5.052	1750	9	730	2998	3000	3020
24	7.694	1200	10	1113	4538	4545	4550
25	21.040	1200	12	3030	12248	12260	12270
26	16.346	2925	18	2352	9522	9540	9550
27	12.944	2600	12	1872	7590	7600	7600
28	7.028	600	7	1010	4125	4130	4140
29	10.844	500	2	1561	6340	6350	6350
30	62.100	20000	25	8942	36964	36980	36980
31	87.892	2730	23	11520	47846	47870	47875
32	91.746	12000	45	18200	73400	73500	73500
33	45.514	3250	15	9516	39996	40000	40000
34	9.990	2875	6	1444	5870	5885	5890
35	27.722	3100	12	3996	16133	16150	16150
36	48.514	30200	26	8000	32235	32300	32300
37	45.794	30000	24	6661	26850	26870	26880

Table 3.1: General information of industrial consumers (continued)

Consumer ID. No.	Connected load	Industry area	Employees' Nos.	Average consumed energy per month	Bill of electricity paid for the three months of the year 2003 (Tk.)		
	kW	sft	Nos.	kWh	April	May	June
#	Pt	Ai	Ne	Uavg	B1	B2	B3
38	32.568	23500	18	4700	18964	18970	18975
39	6.860	660	10	990	4044	4050	4050
40	22.394	1250	10	3241	13097	13100	13100
41	24.786	6200	13	3587	14488	15000	15000
42	36.974	6600	7	5392	21747	21760	21775
43	5.476	640	7	792	3250	3270	3280
44	15.000	3200	11	3000	12128	12150	12175
45	72.276	58500	18	14400	58137	58150	58150
46	41.650	62400	16	8000	32235	32240	32300
47	21.614	98032	32	5700	22985	22990	23000
48	218.700	75000	180	8000	41000	41024	41050
49	7.646	3000	8	1101	4490	4495	4500
50	14.500	750	14	1996	8089	8090	8090
51	13.680	600	12	1969	7981	7982	7990
52	26.575	2000	12	3826	16930	16950	16950
53	6.180	500	8	889	3638	3650	3650

3.4 POWER INTERRUPTION INFORMATION COLLECTION

Power interruption related information [6] collected like consumer ID. no., observation period (days), power interruption period (Hr.) and umber of total interruption (Nos.) have been shown in Table 3.2. The questionnaire format has been shown in Table A1.2 of the Appendix 1.

Table 3.2: Power interruption information

Consumer ID. No.	Observation period	Power interruption period	Number of total interruption during observation period	Consumer ID. No.	Observation period	Power interruption period	Number of total interruption during observation period
	days	Hr.	Nos.		days	Hr.	Nos.
#	To	Ti	Ni	#	To	Ti	Ni
1	62	59.18	104	24	62	52.90	108
2	62	71.27	111	25	62	52.93	108
3	63	59.63	105	26	62	52.97	108
4	60	71.43	95	27	61	51.25	106
5	59	70.30	94	28	60	49.80	101
6	64	59.87	106	29	60	51.00	104
7	62	71.32	111	30	62	52.33	149
8	61	70.17	110	31	56	50.27	130
9	63	59.72	105	32	62	53.00	145
10	62	71.25	111	33	62	52.83	107
11	60	69.13	107	34	62	52.87	107
12	58	67.18	131	35	59	51.03	103
13	63	59.53	105	36	58	50.77	102
14	57	65.43	103	37	60	51.50	116
15	56	64.52	126	38	62	52.87	145
16	58	49.33	100	39	61	52.07	107
17	61	52.08	96	40	62	53.07	108
18	60	50.75	105	41	62	81.75	136
19	62	52.83	108	42	62	82.00	136
20	62	52.73	108	43	63	82.20	137
21	62	52.83	139	44	63	82.32	138
22	60	50.20	137	45	64	83.93	141
23	61	51.92	106	46	52	65.62	101

Table 3.2: Power interruption information (continued)

Consumer ID. No.	Observation period	Power interruption period	Number of total interruption during observation period
	days	Hr.	Nos.
#	To	Ti	Ni
47	30	24.53	48
48	62	97.80	119
49	60	88.10	150
50	62	91.07	153

Consumer ID. No.	Observation period	Power interruption period	Number of total interruption during observation period
	days	Hr.	Nos.
#	To	Ti	Ni
51	61	90.05	152
52	62	72.63	125
53	60	88.00	150

3.4.1 Power Outage Required Data

Power outage related required information [6] has been shown in Table 3.3. where symbols To, C4o and Co have been shown in Table 3.3 and the questionnaire format has been shown in Table A1.3 of the Appendix 1.

Table 3.3: Power outage related required information

SL. No.	Consumer ID. No.	Observation period	Raw materials under process damage	Damaged equipments	Damaged equipments' costs	Power interruption total loss (approx)
		days			Tk.	Tk.
#	#	To			C4o	Co
1	06	64	Nothing	Nothing	0	0

3.4.2 Reparable Equipments' Faced Trouble due to power Interruptions

Reparable equipments' faced trouble [6] due to power interruptions related required information has been shown in Table 3.4; where symbols Ntd, Tri, Trl, C_{rc}, Pri and Sri have been shown in Table 3.4 and the questionnaire format has been shown in Table A1.4 of the Appendix 1.

Table 3.4: Reparable equipments' faced trouble related required information

SL. No.	Consumer ID. No.	Reparable equipments	No. of equipments faced trouble	Life span of repairable item	Number of repair during observation	Reduced life of repairable item	Costs per repair	Price of reparable equipments	Salvage value of reparable equipments
			Nos.	Yr.	Nos.	Yr.	Tk.	Tk.	Tk.
#	#		Ntd	Tri	Nrop	Trl	C_{rc}	Pri	Sri
1	06	Motor	1	15	1	13	450	4000	400

3.5 ALTERNATIVE SOURCES INFORMATION COLLECTION

Various alternative sources used during power outage like consumer ID. no.; generator, Tas1 (Hr.); candle, Tas2 (Hr.); charger light and Tas3 (Hr.) have been shown in Table 3.5 by taking required information from Table 3.2. Where the questionnaire format has been shown in Table A1.5 of the Appendix 1.

Table 3.5: Various alternative sources used during power outage

Consumer ID. no.	Generator usage	Candle usage	Charger light usage	Consumer ID. no.	Generator usage	Candle usage	Charger light usage
	Hr.	Hr.	Hr.		Hr.	Hr.	Hr.
#	Tas1	Tas2	Tas3	#	Tas1	Tas2	Tas3
1		41.83		23			51.5
2			40.45	24			21.27
3			59.83	25		21.23	
4			40.47	26			52.43
5		40.05		27			21.13
6	60.17			28	20.5		
7	70.17			29		21.33	
8	39.75			30		21.42	
9	36.93			31			
10	40.78			32	52.33		
11		60		33	21.33		
12		37.02		34		21.03	
13		36.72		35		21.6	
14			35.35	36		22.83	
15			34.52	37		22.33	
16			18.83	38		23.6	
17			21.13	39			23.53
18			19.83	40		23.65	
19			21.23	41		42.25	
20		21.33		42			42.17
21			52.02	43			42.33
22	50.05			44		78.15	

Table 3.5: Various alternative sources used during power outage (continued)

Consumer ID. no.	Generator usage	Candle usage	Charger light usage
	Hr.	Hr.	Hr.
#	Tas1	Tas2	Tas3
45			79.73
46			61.28
47	23.7		
48	92.9		
49			35.8
50			37.13
51	59.83		
52		40.45	
53		41.28	
Total	568.44	638.10	811.96
Total	12	19	21

3.5.1 Alternative Sources Used During Power Outage

Various required information regarding alternative source [6] used during power outage have been shown in Table 3.6; where symbols Nas, Pas and Sas have been shown in Table 3.6 and the questionnaire format has been shown in Table A1.6 of the Appendix 1.

Table 3.6: Information of alternative source used during power outage

Consumer ID. No.	SL. No.	Name of alternative sources	Nos. of used sources	Fuel	Fuel consumption per hour	Cost of fuel consumption per hour	Rating of sources	Price of alternative source	Salvage value of alternative source
			Nos.		Ltr.	Tk.	kVA	Tk.	Tk.
#	#		Nas					Pas	Sas
06	01	Generator	1	Diesel	25	1750.00	500	2525000	25000
45	02	Generator	1	Diesel	12	840.00	100	920000	10000

3.5.2 Alternative Sources Faced Trouble due to power Interruptions

Alternative source faced trouble due to power interruptions [6] related required information has been shown in Table 3.7; where symbols Tla, Trla and C_{rca} have been shown in Table 3.7 and the questionnaire format has been shown in Table A1.7 of the Appendix 1.

Table 3.7: Alternative source faced trouble related required information

SL. No.	Consumer ID. No.	Alternative source faced trouble	Total life span of used alternative source	Number of repair during observation	Reduced life due to repair of used alternative source	Cost per repair for alternative source
			Yr.	Nos.	Yr.	Tk.
#	#		Tla	Nraop	Trla	C_{rca}
1	06	Generator	15	1	13	450

3.6 FACED VARIOUS DIFFICULTIES / PROBLEMS

To obtain information for use in seeking the cooperation of consumer groups to reduce the adverse effects of operating problems which might occur in the future is the one of the purpose and scope of the surveys [15]. Data of facing various difficulties / problems in performing activities for industrial consumers due to power outage [6] has been shown in Table 3.8; where symbols Pd, Sd, Ad, Od, Dm, Ds and To have been shown in Table 3.8 and the questionnaire format has been shown in Table A1.8 of the Appendix 1.

Table 3.8: Various difficulties / problems faced

Consumer ID. No.	Production and processing	Security (encountered days)	Accounting (encountered days)	Others (encountered days)	Moderate (observed days)	Severe (observed days)	Observation period
	days	Days	days	days	days	days	days
#	Pd	Sd	Ad	Od	Dm	Ds	To
1	30	14	4		61	1	62
2	22			12	59	1	60
3	20			11	59	1	60
4	23			12	61	1	62
5	26	15		3	60	1	61
6	24	20			61	1	62
7	48	24	15		60	1	61
8	53	25	16		59	1	60
9	48	35			60	1	61
10	38	30	12		61	1	62
11	22			15	59	1	60
12	33	26	10		61	1	62
13							60

Table 3.8: Various difficulties / problems faced (continued)

Consumer ID. No.	Production and processing	Security (encountered days)	Accounting (encountered days)	Others (encountered days)	Moderate (observed days)	Severe (observed days)	Observation period
	days	Days	days	days	days	days	days
#	Pd	Sd	Ad	Od	Dm	Ds	To
14	22				61	1	62
15	22				61	1	62
16	23			14	61	1	62
17			15	28	58	2	60
18	22	17			59	2	61
19	32	20			57	2	59
20	58	30	16		58	2	60
21	60	38		20	59	2	61
22	60	18		40	60	2	62
23	19	30	15	16	60	2	62
24	22			14	59	2	61
25				24	56	2	58
26				40	55	2	57
27	24				56	2	58
28	44			11	57	2	59
29	47	9	10		54	2	56
30	49	10	14		54	2	56
31	47	9	11		55	2	57
32	35	12	10	3	55	2	57
33	31	8	14		54	2	56
34	63	18	15	8	49	2	51
35	63	15	14	9	50	2	52
36	64	27	19	15	47	1	48
37	60	31	15	14	49	1	50

Table 3.8: Various difficulties / problems faced (continued)

Consumer ID. No.	Production and processing	Security (encountered days)	Accounting (encountered days)	Others (encountered days)	Moderate (observed days)	Severe (observed days)	Observation period
	days	Days	days	days	days	days	days
#	Pd	Sd	Ad	Od	Dm	Ds	To
38	60	30	17	23	47	1	48
39	56	29	15	32	49	1	50
40				22	51	1	52
41	48	16	9	5	49	2	51
42	42	21	7	6	46	2	48
43	42	22	5	8	48	2	50
44	41	19	11		48	1	49
45	54	16	20	12	48	1	49
46	49	25	19	18	49	1	50
47	50	27	18	20	48	1	49
48	64	36	28	62	61	1	62
49	52	25	13	3	62	1	63
50	37	10	12	2	63	2	64
51	31	9	11	4	61	1	62
52	35	7	9	5	61	2	63
53	36	8	10	6	71	2	72

3.7 COST COMPONENTS DUE TO POWER INTERRUPTION

Information of different cost components for industrial consumers due to power outage [6] have been shown in Table 3.9; where symbols C1o, C2o, C3o and C4o have been shown in Table 3.9 and the questionnaire format has been shown in Table A1.9 of the Appendix 1.

Table 3.9: Different cost components of power interruption

Consumer ID. No.	Raw materials under process damage costs	Alternative source usage costs	Loss due to reduced production and additional wage costs	Equipments' trouble and damage costs
	Tk.	Tk.	Tk.	Tk.
#	C1o	C2o	C3o	C4o
1	20000.0	215.00	15000.00	
2		246.00	9000.00	32.74
3		40643.5		
4		62.51	12000.00	
5	12000.0	59.39	11700.00	39.35
6		67254.1		43.71
7	3000.00	13909.8	1000.00	42.68
8		60.79	8500.00	
9	10000.0	69.06	15000.00	
10		210.00	10000.00	
11	25000.0	101.27	7500.00	
12		56.12	23200.00	
13	20000.0	200.00	10000.00	
14		185.00	15000.00	
15		52.90	22050.00	
16		190.00	5400.00	31.91
17	5000.00	210.00	1000.00	
18		120.00	5650.00	
19		220.00	8000.00	58.48
20		330.00	4500.00	
21		11355.4		
22		9867.16		

Table 3.9: Different cost components of power interruption (continued)

Consumer ID. No.	Raw materials under process damage costs	Alternative source usage costs	Loss due to reduced production and additional wage costs	Equipments' trouble and damage costs
	Tk.	Tk.	Tk.	Tk.
#	C1o	C2o	C3o	C4o
23	3000.00		5000.00	
24		220.00	6500.00	
25		210.00	7500.00	
26		5146.21		
27		43.31	8000.00	
28		41.53	6000.00	
29		105.00	2000.00	
30	11000.0	44.47	10000.00	292.51
31	6000.00	36.87	8000.00	232.26
32		24812.2		27.57
33		42.86	6700.00	83.35
34		105.00	5000.00	
35		42.76	7600.00	36.89
36		45.28	10200.00	57.72
37	13000.0	43.41	10000.00	
38	8000.00	47.93	6800.00	
39		46.25	5130.00	38.57
40		35.29	6265.00	46.30
41		470.00	15500.00	55.41
42	2000.00	141.00	8000.00	38.70
43		380.00	15000.00	
44		3090.23	10000.00	
45		30808.8	17080.00	

Table 3.9: Different cost components of power interruption (continued)

Consumer ID. No.	Raw materials under process damage costs	Alternative source usage costs	Loss due to reduced production and additional wage costs	Equipments' trouble and damage costs
	Tk.	Tk.	Tk.	Tk.
#	C1o	C2o	C3o	C4o
46		10749.1		
47		1118.98	2590.00	18.38
48		47080.3	21300.00	
49		570.00	24000.00	
50		88.21	29760.00	
51		91.32	26000.00	
52		80.01	17280.00	30.54
53		570.00	24000.00	

3.8 CONSUMER CHARACTERISTICS

The examples of the consumer characteristics are the type of consumer, the interrupted activities, the size of operation, the energy dependency according to time of day, season and year etc. The sizes of interruption costs or economic losses are mainly dependent on the kinds of manufacturing activities. So, the questionnaires may be distinguished from the Standard Industrial Classification (SIC) when they are designed. Here, 22-category system [10], [29] of SIC has been used as shown in Table 3.10.

Table 3.10: Usable industrial types of survey response sample by SIC.

SL. / SIC No.	Types of consumer / Name of SIC
1	Food, beverage
2	Textile, clothes

Table 3.10: Usable industrial types of survey response sample by SIC (continued)

SL. / SIC No.	Types of consumer / Name of SIC
3	Lumber, wood
4	Pulp, paper
5	Publication, printing
6	Petroleum, natural gas, fuel, chemistry
7	Ceramic industry
8	Basic metal
9	Fabricated metal
10	Other machinery
11	Office apparatus
12	Electricity apparatus
13	Sound, image

SL. / SIC No.	Types of consumer / Name of SIC
14	Medical, optical
15	Motorcar
16	Other transport
17	Furniture, others
18	Recycling
19	Plastic products
20	Non-metal minerals
21	Quarry, sand, cement, bricks
22	Other manufacturing

CHAPTER FOUR

CALCULATION

4.1 INTRODUCTION

Mathematical calculations have been evaluated with the proposed mathematical model in this chapter. In the competitive power market, calculation of interruption costs is very significant as interruption i.e. supply reliability will be an important factor for decision making for both the supplier and the user. Accordingly, development of a model to assess interruption costs for customer is economical and important as it is one of basic data to ensure fair power transactions in the future. The studies to estimate the costs of all possible damages from power interruption to each industrial customer type need to be carried out [19].

4.2 COST DETERMINATION SAMPLE

One sample calculation for one consumer (consumer ID. No. 06) to evaluate the losses of power interruption has been shown in Appendix 5.

4.3 COSTS CALCULATION

The evaluation of costs of interruption is performed for each industrial consumer in Tk. for the sampling period. A sample calculation has been also shown in Appendix 5. Also the costs are evaluated for per interruption (Tk.) and per hour of interruption (Tk.) for each consumer.

4.3.1 Evaluation of Electric Bills of Industrial Consumers

The average bill of electricity paid per month in Tk. has been calculated as

$$\text{Bavg} = \left(\frac{\text{B1} + \text{B2} + \text{B3}}{3}\right) \quad \text{Tk.} \tag{4.1}$$

where B1, B2 and B3 have been shown in Table 4.1.

Bill of electricity paid for the three months of the year 2003 in Table 3.1 was shown by taking flat rate of electricity tariff = 3.83 Tk.

But at present flat rate of electricity tariff = 6.02 Tk. which has been shown in Table A4.1 i.e. % increase of electricity tariff = 57.18 %.

So, value of B1, B2 and B3 for each consumer will be increased by 57.18 %.

Then calculated values from data of Table 3.1 and using equation (4.1) have been shown in Table 4.1.

Table 4.1: Evaluated electric bills of industrial consumers

Consumer ID. No.	Bill of electricity paid for the three months of the year 2003 (Tk.)			Average bill of electricity paid per month
	April	May	June	Tk.
#	B1	B2	B3	Bavg
1	348940	353655	361514	354703.22
2	5156	5156	5187	5165.99
3	157180	172898	180757	170278.50
4	8944	8959	8959	8954.03
5	8063	8095	8173	8110.50
6	426644	455822	471540	451335.48
7	15674	15702	15718	15698.11
8	3882	3930	3930	3913.79
9	314360	330078	330078	324838.99
10	16339	16347	16347	16344.12
11	44594	44608	44639	44613.49
12	6416	6429	63029	25291.34

Table 4.1: Evaluated electric bills of industrial consumers (continued)

Consumer ID. No.	Bill of electricity paid for the three months of the year 2003 (Tk.)			Average bill of electricity paid per month
	April	May	June	Tk.
#	B1	B2	B3	Bavg
13	314360	322219	330078	322219.32
14	6389	6429	6444	6420.81
15	20504	20537	20591	20543.97
16	6542	6562	6580	6561.22
17	2295	2326	2358	2326.27
18	11579	11598	11616	11597.80
19	12483	12496	12504	12494.25
20	12413	12417	12417	12415.66
21	88021	88021	88021	88020.89
22	91267	91322	91322	91303.33
23	4712	4715	4747	4724.84
24	7133	7144	7152	7142.79
25	19251	19270	19286	19269.24
26	14967	14995	15011	14990.80
27	11930	11946	11946	11940.45
28	6484	6492	6507	6494.16
29	9965	9981	9981	9975.70
30	58100	58125	58125	58116.84
31	75204	75242	75250	75232.19
32	115370	115527	115527	115475.02
33	62866	62872	62872	62869.97
34	9226	9250	9258	9244.81
35	25358	25385	25385	25375.69
36	50667	50769	50769	50735.13
37	42203	42234	42250	42229.07

Table 4.1: Evaluated electric bills of industrial consumers (continued)

Consumer ID. No.	Bill of electricity paid for the three months of the year 2003 (Tk.)			Average bill of electricity paid per month
	April	May	June	Tk.
#	B1	B2	B3	Bavg
38	29808	29817	29825	29816.55
39	6356	6366	6366	6362.65
40	20586	20591	20591	20589.03
41	22772	23577	23577	23308.77
42	21747	34202	34226	30058.46
43	3250	5140	5156	4515.10
44	19063	19097	19137	19098.96
45	91380	91400	91400	91393.45
46	50667	50675	50769	50703.70
47	36128	36136	36151	36138.34
48	64444	64482	64522	64482.64
49	7057	7065	7073	7065.25
50	12714	12716	12716	12715.35
51	12545	12546	12559	12549.79
52	26611	26642	26642	26631.56
53	5718	5737	5737	5730.79

4.3.2 Evaluation Of Power Interruption Parameters

In the Table 4.2 total over time, Hr. has been calculated as

$$\text{Tot} = (\text{Ti} - \text{Tas}) \quad \text{Hr.} \tag{4.2}$$

where Ti and Tas have been shown in Table 3.2 and Table 4.3 respectively.

And average period of an interruption (Hr.) may be calculated as

$$\text{Tia} = \left(\frac{\text{Ti}}{\text{Ni}}\right) \quad \text{Hr.} \tag{4.3}$$

where Ti and Ni have been shown in Table 3.2. Then calculated values from data of Table 3.2 and using the equations (4.2) and (4.3) have been shown in Table 4.2.

Table 4.2: Calculated required results of power interruption parameters

Consumer ID. No.	Total over time	Average period of an interruption	Consumer ID. No.	Total over time	Average period of an interruption
	Hr.	Hr.		Hr.	Hr.
#	Tot	Tia	#	Tot	Tia
1	17.35	0.57	21	0.81	0.38
2	30.82	0.64	22	0.15	0.37
3	-0.20	0.57	23	0.42	0.49
4	30.96	0.75	24	31.63	0.49
5	30.25	0.75	25	31.70	0.49
6	-0.30	0.56	26	0.54	0.49
7	1.15	0.64	27	30.12	0.48
8	30.42	0.64	28	29.30	0.49
9	22.79	0.57	29	29.67	0.49
10	30.47	0.64	30	30.91	0.35
11	9.13	0.65	31	30.54	0.39
12	30.16	0.51	32	0.67	0.37
13	22.81	0.57	33	31.50	0.49
14	30.08	0.64	34	31.84	0.49
15	30.00	0.51	35	29.43	0.50
16	30.50	0.49	36	27.94	0.50
17	30.95	0.54	37	29.17	0.44
18	30.92	0.48	38	29.27	0.36
19	31.60	0.49	39	28.54	0.49
20	31.40	0.49	40	29.42	0.49

Table 4.2: Calculated required results of power interruption parameters (continued)

Consumer ID. No.	Total over time	Average period of an interruption
	Hr.	Hr.
#	Tot	Tia
41	39.50	0.60
42	39.83	0.60
43	39.87	0.60
44	4.17	0.60
45	4.20	0.60
46	4.34	0.65
47	0.83	0.51

Consumer ID. No.	Total over time	Average period of an interruption
	Hr.	Hr.
#	Tot	Tia
48	4.90	0.82
49	52.30	0.59
50	53.94	0.60
51	53.92	0.59
52	15.91	0.58
53	52.45	0.59

4.3.3 Evaluation Of Alternative Sources Parameters

In the Table 4.3 total alternative source usage period (Hr.) has been calculated as

$$Tas = (Tas1 + Tas2 + Tas3) \quad \text{Hr.} \qquad (4.4)$$

where, Tas1, Tas2 and Tas3 have been shown in Table 4.3.

Then calculated values from data of Table 3.5 and using equation (4.4) have been shown in Table 4.3.

It is observed from Table 3.5 that consumers used total 1896.67 hours various alternative sources during power outage.

Table 4.3: Calculated results of alternative sources usage for each consumer during power outage

Consumer ID. No.	Total alternative source usage period
	Hr.
#	Tas
1	41.83
2	40.45
3	59.83
4	40.47
5	40.05
6	60.17
7	70.17
8	39.75
9	36.93
10	40.78
11	60
12	37.02
13	36.72
14	35.35
15	34.52
16	18.83
17	21.13
18	19.83
19	21.23
20	21.33
21	52.02
22	50.05
23	51.5
24	21.27
25	21.23
26	52.43
27	21.13
28	20.5
29	21.33
30	21.42
31	
32	52.33
33	21.33
34	21.03
35	21.6
36	22.83
37	22.33
38	23.6
39	23.53
40	23.65
41	42.25
42	42.17
43	42.33
44	78.15
45	79.73
46	61.28
47	23.7
48	92.9
49	35.8
50	37.13
51	36.13
52	56.72
53	35.55
Total	1896.67

4.3.3.1 Calculation of Consumers and Usage of Various Alternative Sources

Total number of consumers and various alternative sources usage period during power outage have been calculated from data of Table 3.5 and Table 4.3. One consumer among a total of 53 used no alternative source in power outage during observation period. Then calculated values have been shown in Table 4.4.

Table 4.4: Calculated results of alternative sources used during power outage (continued)

SL. No.	Generator usage	Candle usage	Charger light usage	Total
	Hr.	Hr.	Hr.	
#	Tas1	Tas2	Tas3	
1	568.44	638.10	811.96	1896.67
Total Number of consumers used various alternative sources during power outage				
2	12	19	21	52

4.3.4 Calculation Of Facing Various Difficulties / Problems

In the Table 3.8 Observation period (days) will be

$$To = Dm + Ds \quad \text{days.} \tag{4.5}$$

where, Dm = Faced problem moderate in performing activities (days)

and Ds = Faced problem severe in performing activities (days).

To has been calculated using equation (4.5) and Dm, Ds shown in Table 3.8 and evaluated results of To have been shown in Table 3.8.

Total values and also in percentage of various difficulties / problems faced in performing activities for industrial consumers due to power outage have been calculated using data from Table 3.8 and then calculated results have been shown in Table 4.5; where symbols Pd, Sd, Ad and Od have been shown in Table 4.5.

Table 4.5: Evaluated various difficulties / problems faced statistics

Issues	Production and processing	Security (encountered days)	Accounting (encountered days)	Others (encountered days)
	days	days	days	days
#	Pd	Sd	Ad	Od
Total	1951	781	429	537
In %	52.76	21.12	11.60	14.52

4.3.4.1 Various Difficulties / Problems Graphical Representation

Data of facing various difficulties / problems in performing activities for industrial consumers due to power outage have been obtained from Table 4.5 and has been shown by graphical representation in Figure 4.1. The different types of difficulties faced by consumers have been shown in Figure 4.1. It is observed from the Figure 4.1 that consumers suffered more (i.e. 1951 days or 52.76%) in production and processing (in sense of monetary term) compared to others difficulties.

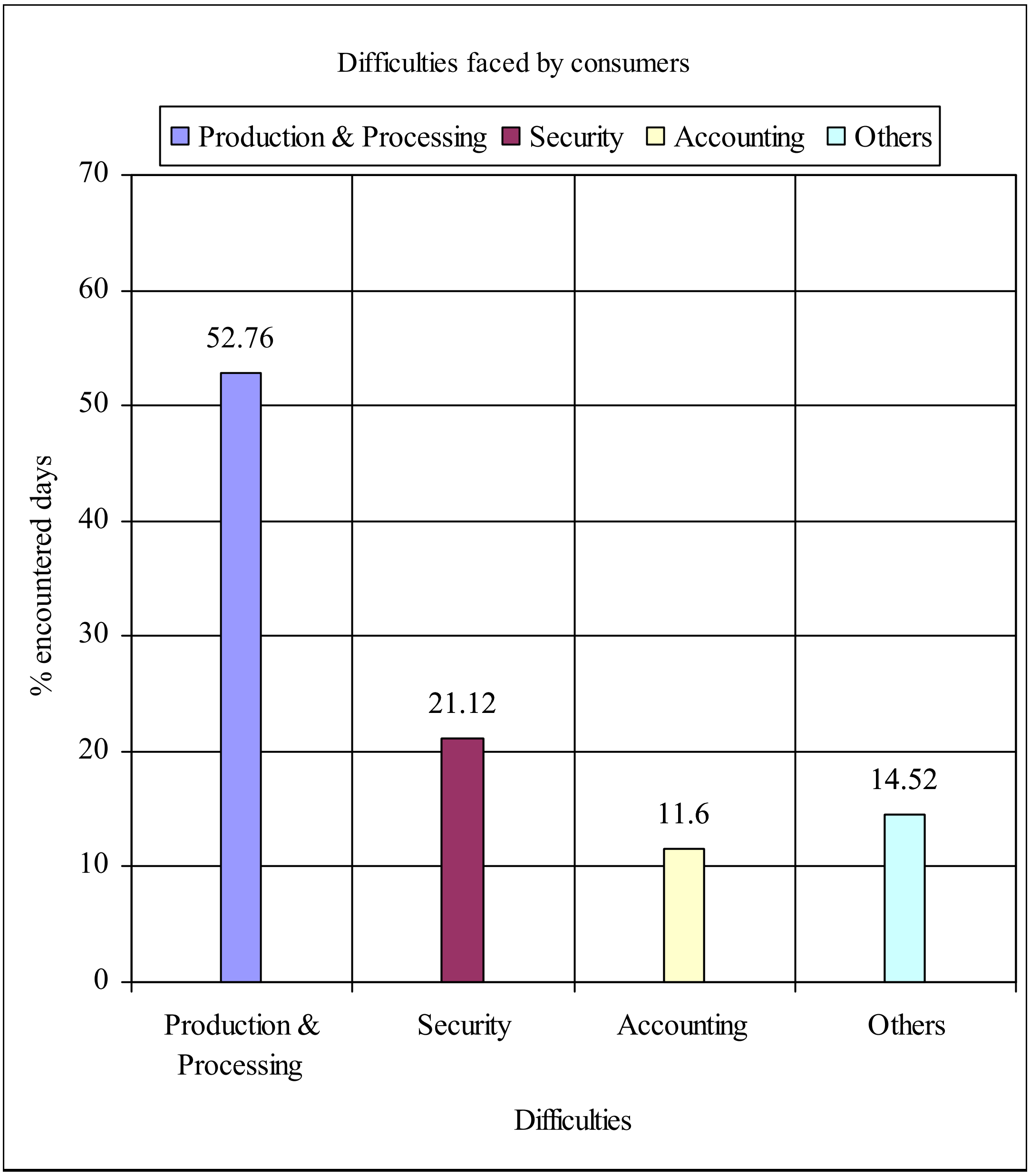

Figure 4.1: Difficulties faced by consumers

4.3.5 Determination Of Consumers' Class

Classification has been done according to alternative sources used (Generator, Candle, Charger light), employees' nos. (<20, =20-39, >39), monthly electric bill (Tk.) (< 10000, =10000-40000, >40000), connected load (kW) (< 21, =21-49, > 49) and industry area (sft) (< 3500, =3500-20000, > 20000). All consumers have been classified into fifteen classes and designated as F, G, H, I, J, K, L, M, N, P, Q, R, X, Y and Z respectively. where meaning of all symbols have been shown in Table 4.6 and in list of symbols at contents. Calculations have been performed using required data from Table 3.1 and Table 3.5. Then the obtained results of calculation have been shown in Table 4.6.

Table 4.6: Evaluated class of consumers'

Consumer's ID. No.	Consumer classes basis on				
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)
1	G	J	N	R	Z
2	H	I	L	P	X
3	H	K	N	R	Z
4	H	I	L	P	X
5	G	I	L	P	X
6	F	K	N	R	Z
7	F	I	M	P	X
8	F	I	L	P	X
9	F	K	N	R	Z
10	F	I	M	P	X
11	G	J	N	Q	Y
12	G	J	M	P	Y
13	G	J	N	R	Z
14	H	I	L	P	X
15	H	J	M	Q	Y
16	H	I	L	P	X
17	H	I	L	P	X
18	H	I	M	P	X
19	H	I	M	P	X
20	G	I	M	P	X
21	H	K	N	Q	Y

Consumer's ID. No.	Consumer classes basis on				
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)
22	F	K	N	Q	Y
23	H	I	L	P	X
24	H	I	L	P	X
25	G	I	M	Q	X
26	H	I	M	P	X
27	H	I	M	P	X
28	F	I	L	P	X
29	G	I	L	P	X
30	G	J	N	R	Y
31	H	J	N	R	X
32	F	K	N	R	Y
33	F	I	N	Q	X
34	G	I	L	P	X
35	G	I	M	Q	X
36	G	J	N	Q	Z
37	G	J	N	Q	Z
38	G	I	M	Q	Z
39	H	I	L	P	X
40	G	I	M	Q	X
41	G	I	M	Q	Y
42	H	I	M	Q	Y

Table 4.6: Evaluated class of consumers' (continued)

Consumer's ID. No.	Consumer classes basis on				
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)
43	H	I	L	P	X
44	G	I	M	P	X
45	H	I	N	R	Z
46	H	I	N	Q	Z
47	F	J	M	Q	Z
48	F	K	N	R	Z

Consumer's ID. No.	Consumer classes basis on				
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)
49	H	I	L	P	X
50	H	I	M	P	X
51	F	I	M	P	X
52	G	I	M	Q	X
53	G	I	L	P	X

4.3.5.1 Number Of Consumers' In Obtained Class

The number of consumers in each class has been calculated in percentage. Criteria and data range of classification for each class have been shown in Table 4.7. Calculations have been performed using required data from Table 4.6. Finally the obtained results of calculation have been shown in Table 4.7.

Table 4.7: Obtained number of consumers' with obtained class

SL. No.	Issue of classification	Unit	Criteria	Consumers' Nos.	Class	Consumers' Nos. in %
1	Alternative sources used	-	Generator	12	F	23.08
			Candle	19	G	36.54
			Charger light	21	H	40.38
2	Employees' Nos.	Nos.	<20	36	I	67.92
			=20-39	10	J	18.87
			>39	7	K	13.21

Table 4.7: Obtained number of consumers' with obtained class

(continued)

SL. No.	Issue of classification	Unit	Criteria	Consumers' Nos.	Class	Consumers' Nos. in %
3	Monthly electric bill	Tk.	< 10000	16	L	30.19
			=10000-40000	20	M	37.74
			>40000	17	N	32.08
4	Connected load	kW	< 21	27	P	50.94
			=21-49	16	Q	30.19
			> 49	10	R	18.87
5	Industry area	sft	< 3500	32	X	60.38
			=3500-20000	9	Y	16.98
			> 20000	12	Z	22.64

4.3.5.1.1 Alternative Sources Used Graphical Representation

Graphical representation of various types of alternative sources used by consumers has been shown in Figure 4.2 by calculation using data shown in Table 9.7. It is observed from Table 9.7 that nobody uses other alternative sources (like IPS, UPS etc.) except generator, candle and charger light during power outage. It is seen from Table 4.4 that total 12 nos. i.e., the minimum number of consumers used total 568.44 hours generators as alternative source during power outage. It is observed from Figure 4.2 that consumers used generator less i.e. 23.08% compared to other classes shown in Table 9.7.

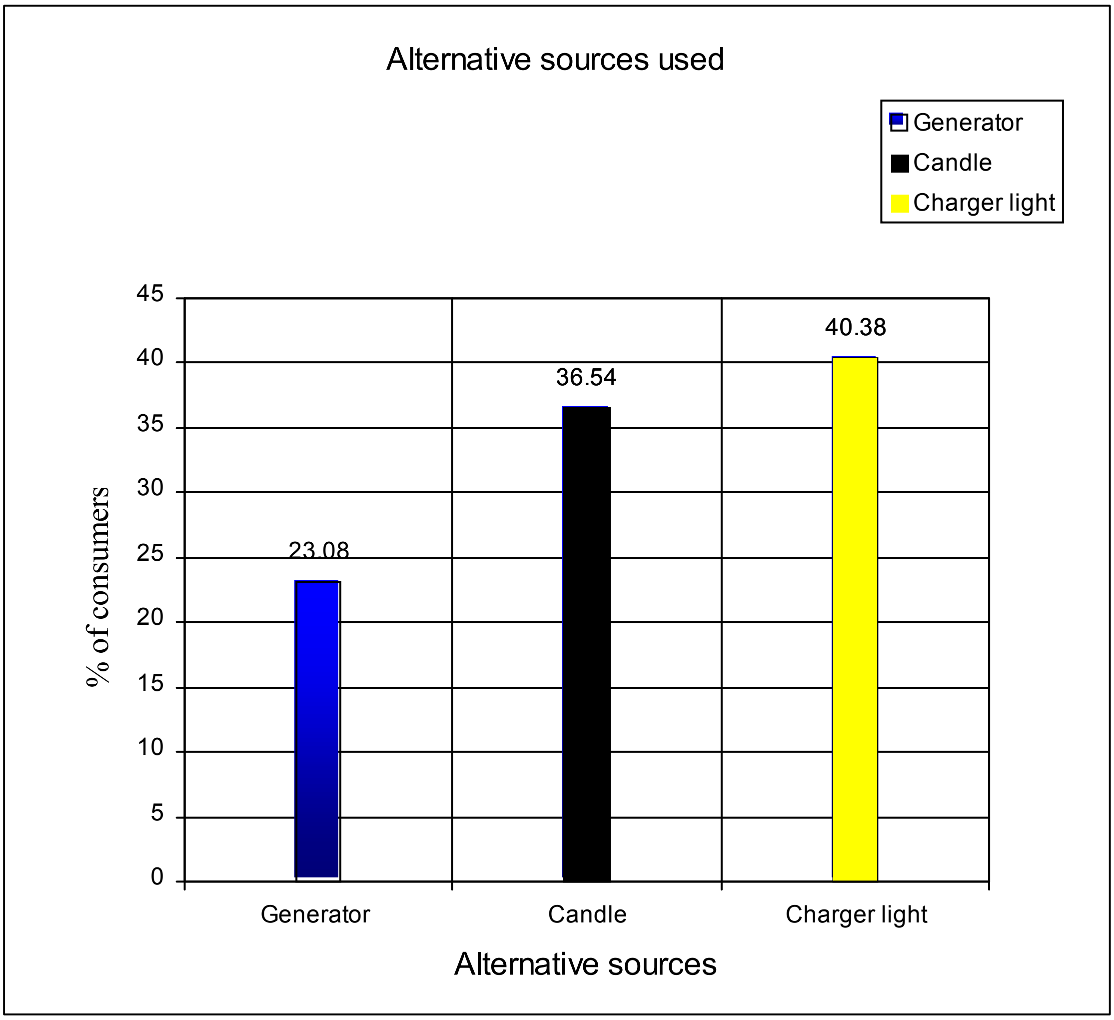

Figure 4.2: Alternative sources used

4.3.5.1.2 Employees' Nos. Graphical Representation

Graphical representation of employees' nos. has been shown in Figure 4.3 by calculation using data shown in Table 9.7. It is observed from Figure 4.3 that 67.92% consumers have number of employees less than 20. Consumers have number of employees greater than 39 is lowest compared to other classes shown in Figure 4.3.

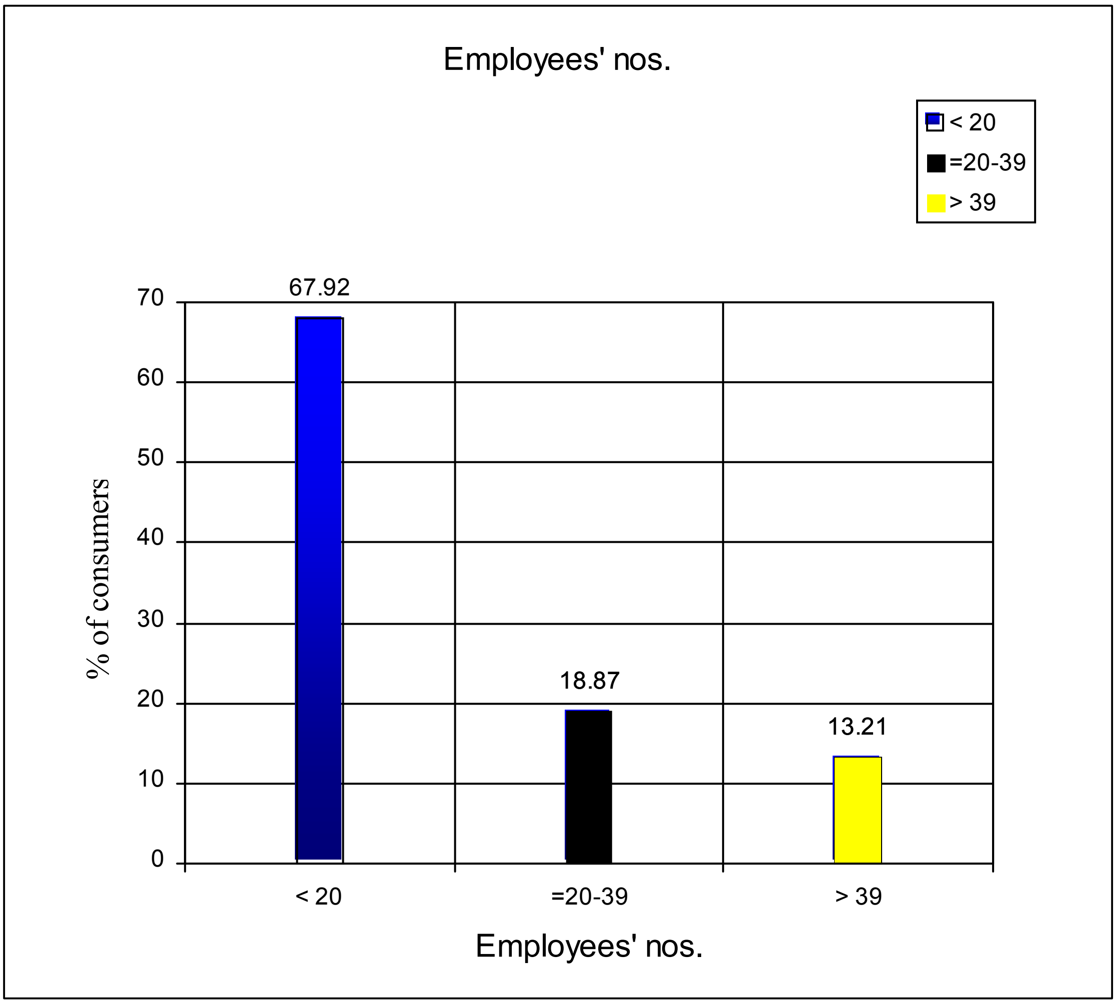

Figure 4.3: Employees' Nos.

4.3.5.1.3 Monthly Electric Bill Graphical Representation

Graphical representation of monthly electric bill (Tk.) paid by consumers has been shown in Figure 4.4 by calculating from data shown in Table 4.7. It is observed from Figure 4.4 that the number of consumers is the highest i.e. 37.74% in case of monthly electric bills paid by consumers in between 10000 Tk. to 40000 Tk. compared to other classes of consumers.

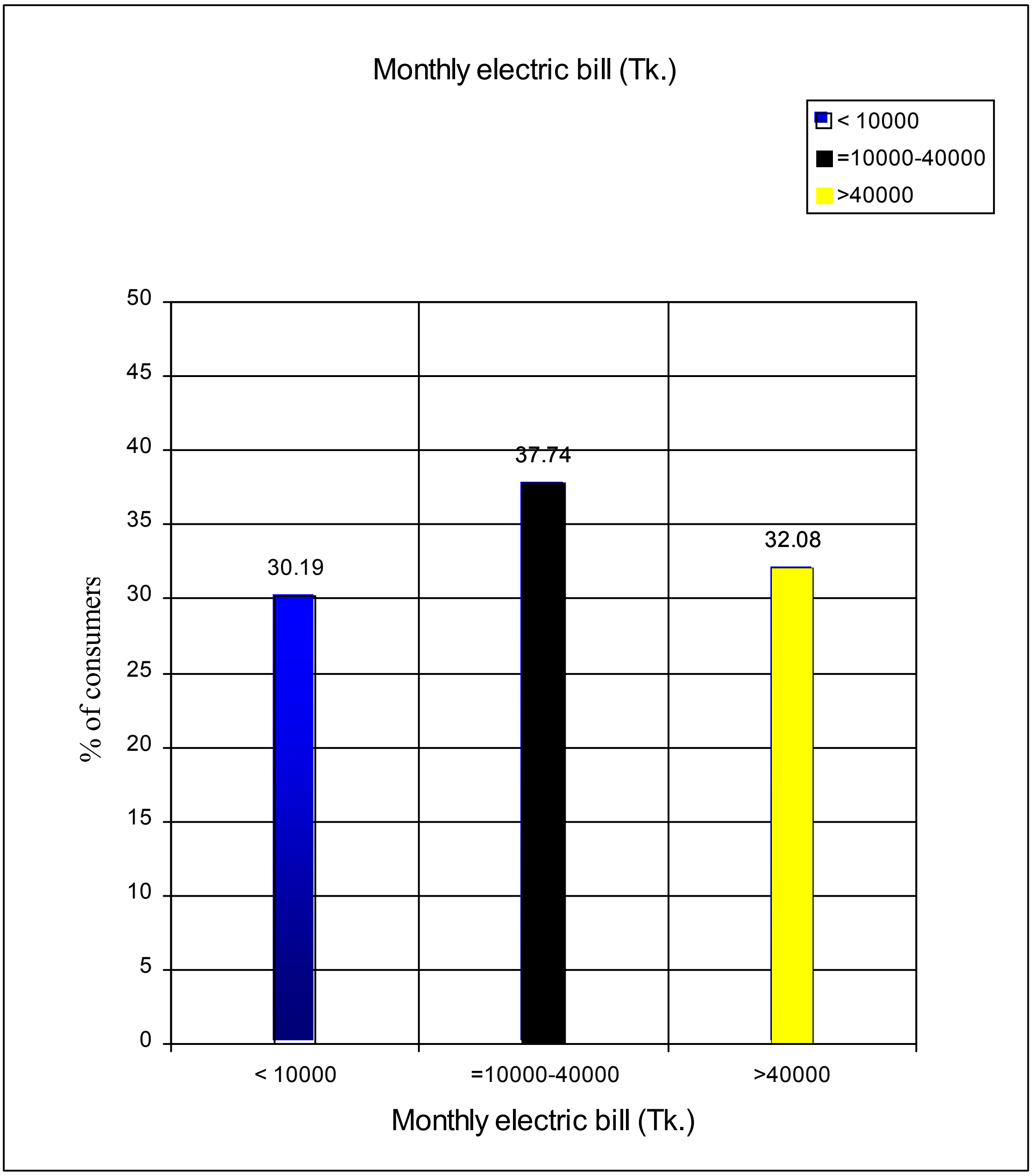

Figure 4.4: Monthly electric bill (Tk.)

4.3.5.1.4 Connected Load Graphical Representation

Graphical representation of connected load (kW) by consumers has been shown in Figure 4.5 by calculating from data shown in Table 4.7. It is observed from Figure 4.5 that the number of consumers is the lowest i.e. 18.87% in case of having connected load less than 49 kW compared to other classes of consumers.

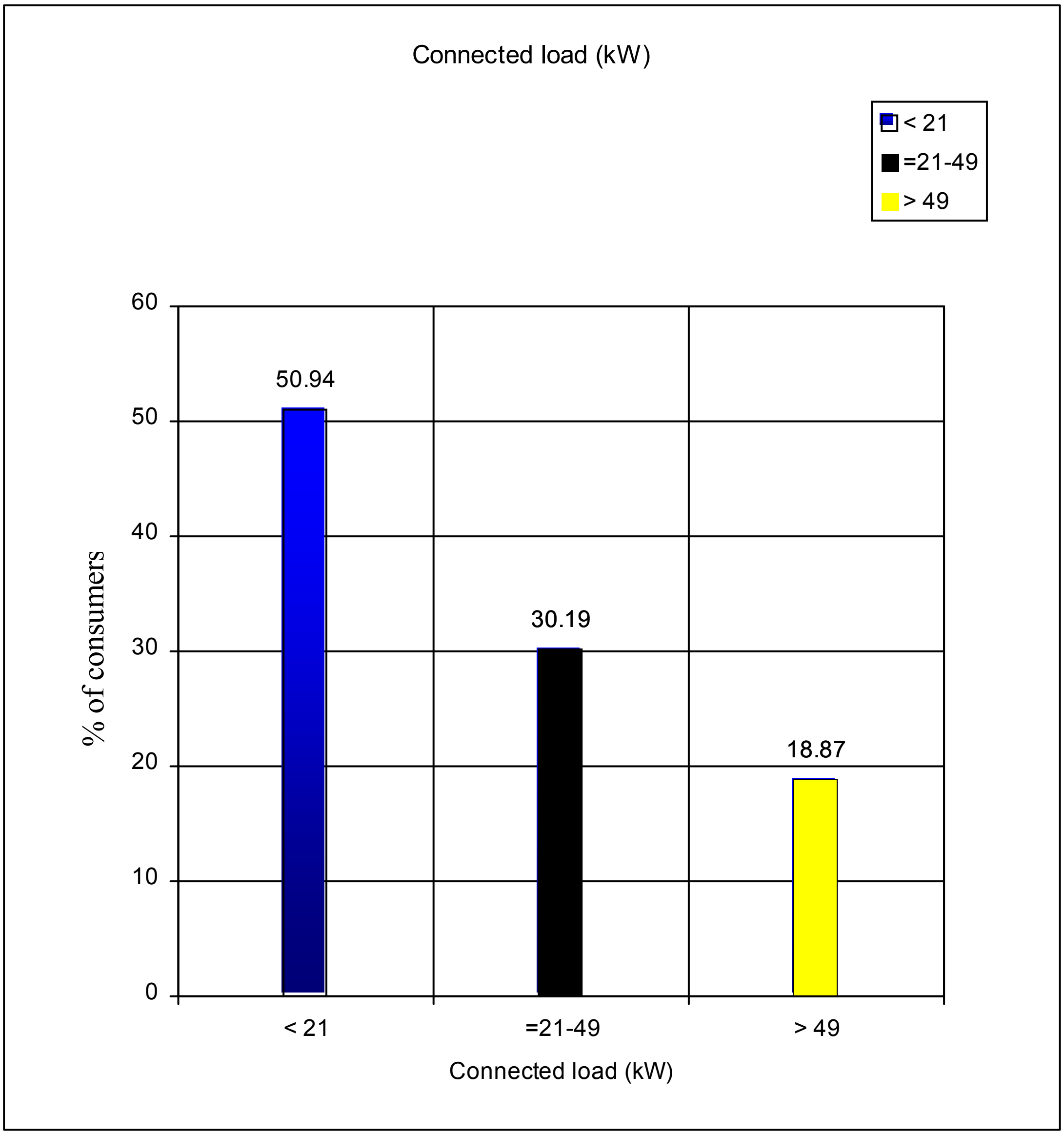

Figure 4.5: Connected load (kW)

4.3.5.1.5 Industry Area Graphical Representation

Graphical representation of industry area (sft) by consumers has been shown in Figure 4.6 by calculating from data shown in Table 4.7. It is observed from Figure 4.6 that the number of consumers is the lowest i.e. 16.98% in case of having industry area in between 3500 sft to 20000 sft compared to other classes of consumers.

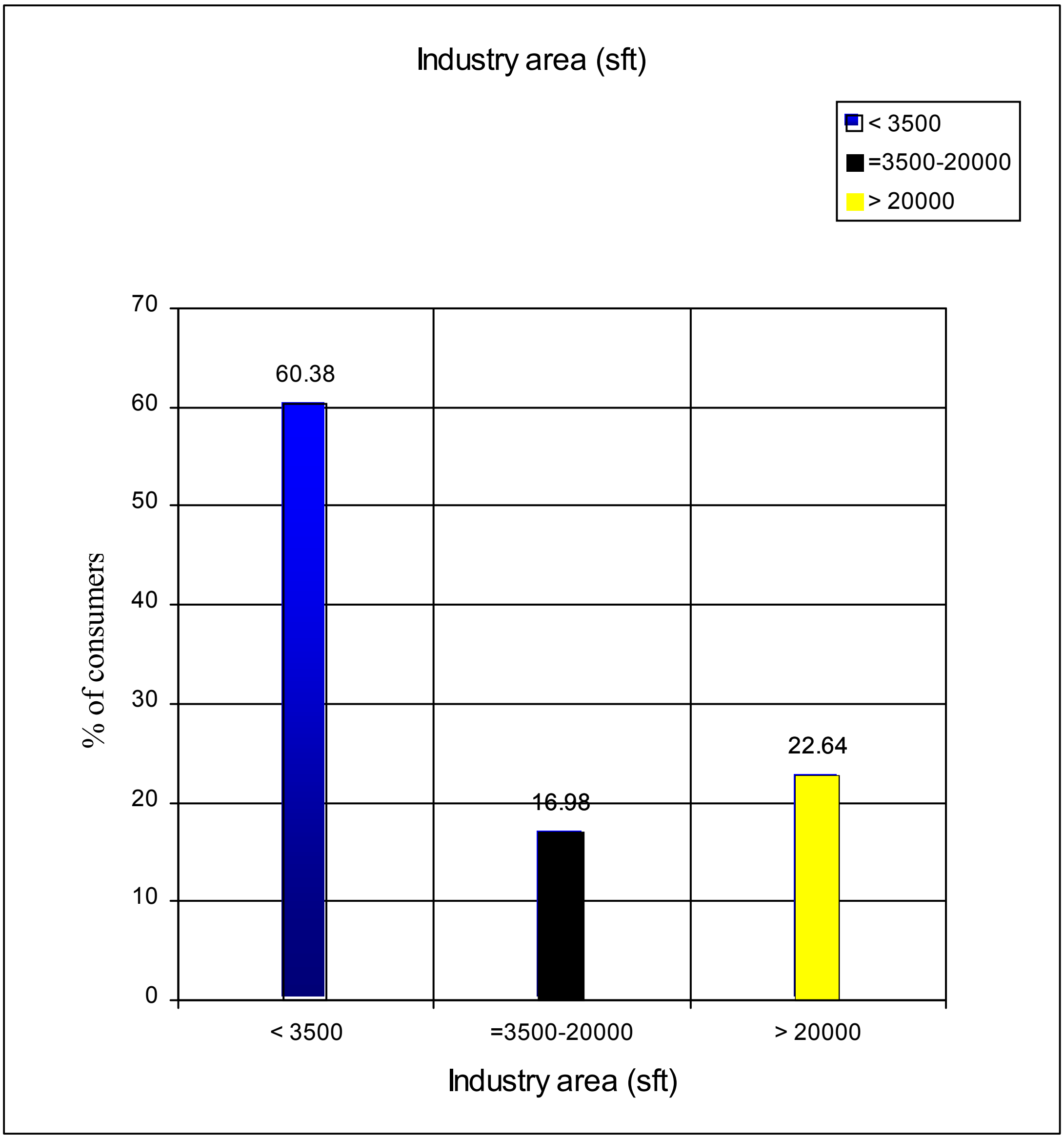

Figure 4.6: Industry area (sft)

4.3.6 Evaluation Of Costs Of Power Interruption

The evaluation of costs of interruption is performed for each industrial consumer in Tk. for the sampling period. A sample calculation has been also shown in Appendix 5. The total costs of interruption for industrial consumers have been calculated. Also the costs are evaluated for per interruption (Tk.) and per hour of interruption (Tk.) for each consumer. The values of C1o and C4o have been taken from data of Table 3.9. The values of Ti and Ni have been taken from data of Table 3.2.

Cost due to the use of alternative source during the observation period (Tk.) C2o = 67254.07 Tk. which has been shown in Table 3.9 for consumer ID. no. 06. The value of C2o = 155107.53 Tk. This has been shown in Appendix 5.

So, % increase of C2o will be

$$= \left[\frac{\{(155352.29 - 67254.07) \times 100\}}{67254.07} \right] \% = 130.63 \%.$$

So, the values of C2o have been evaluated with an increase of 130.63% and similarly the values of C3o have been evaluated with an increase of 138.16% which calculation has been shown in Appendix 5.

In the Table 4.8 total interruption costs during observation period in Tk. will be

$$Co = (C1o + C2o + C3o + C4o) \quad \text{Tk.} \tag{4.5}$$

The values of C1o, C4o have been taken from Table 3.9 and those of C2o, C3o have been calculated and have been shown in Table 4.8. Then values of Co have been calculated using data of Table 3.9, Table 4.8 by putting in equation (4.5) and obtained results have been shown in Table 4.8.

Costs per hour of interruption in Tk. will be

$$\overline{C} = \left(\frac{Co}{Ti} \right) \quad \text{Tk.} \tag{4.6}$$

where Ti has been shown in Table 3.2. The values of $\overline{C}$ have been calculated using data of Table 3.9, Table 4.8 by putting in equation (4.6) and obtained results have been shown in Table 4.8.

And costs per interruption in Tk. will be

$$Ci = \left(\frac{Co}{Ni}\right) \quad \text{Tk.} \qquad (4.7)$$

where Ni has been shown in Table 3.2. The values of Ci have been calculated using data of Table 3.9, Table 4.8 by putting in equation (4.7) and obtained results have been shown in Table 4.8.

Average costs per interruption (Tk.) and average costs per hour of interruption (Tk.) have been evaluated.

Finally all the evaluated costs of power interruption have been shown in Table 4.8.

Table 4.8: Evaluated costs of power interruption

Consumer ID. No.	Alternative source usage costs	Loss due to reduced production and additional wage costs	Total interruption costs	Costs per interruption	Costs per hour of interruption
	Tk.	Tk.	Tk.	Tk.	Tk.
#	C2o	C3o	Co	Ci	$\overline{C}$
1	215.0	35724	55939.00	537.88	945.23
2	246.0	21434	21713.14	195.61	304.66
3	40643.5	0	40643.46	387.08	681.59
4	62.5	28579	28641.71	301.49	400.98
5	59.4	27865	39963.46	425.14	568.47
6	155108	0	155151.24	1463.7	2591.47
7	32080.0	2382	37504.32	337.88	525.86
8	140.2	20244	20383.80	185.31	290.49
9	159.3	35724	45883.27	436.98	768.31
10	484.3	23816	24300.32	218.92	341.06
11	101.3	17862	42963.27	401.53	621.49

Table 4.8: Evaluated costs of power interruption (continued)

Consumer ID. No.	Alternative source usage costs	Loss due to reduced production and additional wage costs	Total interruption costs	Costs per interruption	Costs per hour of interruption
	Tk.	Tk.	Tk.	Tk.	Tk.
#	C2o	C3o	Co	Ci	$\overline{C}$
12	56.1	55253	55309.24	422.21	823.30
13	200.0	23816	44016.00	419.20	739.39
14	185.0	35724	35909.00	348.63	548.82
15	52.9	52514	52567.18	417.20	814.74
16	190.0	12861	13082.55	130.83	265.20
17	210.0	2382	7591.60	79.08	145.77
18	120.0	13456	13576.04	129.30	267.51
19	220.0	19053	19331.28	178.99	365.91
20	330.0	10717	11047.20	102.29	209.51
21	11355.4	0	11355.37	81.69	214.94
22	22756.6	0	22756.55	166.11	453.32
23	0.0	11908	14908.00	140.64	287.13
24	220.0	15480	15700.40	145.37	296.79
25	210.0	17862	18072.00	167.33	341.43
26	5146.2	0	5146.21	47.65	97.15
27	43.3	19053	19096.11	180.15	372.61
28	95.8	14290	14385.38	142.43	288.86
29	105.0	4763	4868.20	46.81	95.45
30	44.5	23816	35152.98	235.93	671.76
31	36.9	19053	25321.93	194.78	503.72
32	57224.1	0	57251.64	394.84	1080.22
33	98.8	15957	16138.92	150.83	305.49

Table 4.8: Evaluated costs of power interruption (continued)

Consumer ID. No.	Alternative source usage costs	Loss due to reduced production and additional wage costs	Total interruption costs	Costs per interruption	Costs per hour of interruption
	Tk.	Tk.	Tk.	Tk.	Tk.
#	C2o	C3o	Co	Ci	$\overline{C}$
34	105.0	11908	12013.00	112.27	227.22
35	42.8	18100	18179.81	176.50	356.26
36	45.3	24292	24395.32	239.17	480.51
37	43.4	23816	36859.41	317.75	715.72
38	47.9	16195	24242.81	167.19	458.54
39	46.3	12218	12302.43	114.98	236.27
40	35.3	14921	15002.31	138.91	282.69
41	470.0	36915	37440.21	275.30	457.98
42	141.0	19053	21232.50	156.12	258.93
43	380.0	35724	36104.00	263.53	439.22
44	3090.2	23816	26906.23	194.97	326.85
45	30808.8	40678	71486.57	507.00	851.74
46	10749.1	0	10749.13	106.43	163.81
47	2580.7	6168	8767.42	182.65	357.42
48	108581	50728	159308.89	1338.7	1628.93
49	570.0	57158	57728.40	384.86	655.26
50	88.2	70876	70964.63	463.82	779.23
51	210.6	61922	62132.21	408.76	689.97
52	80.0	41154	41264.60	330.12	568.15
53	570.0	57158	57728.40	384.86	656.00
Average costs per interruption (Tk.)				292.03	
Average costs per hour of interruption (Tk.)					524.89

4.3.7 Determination Of Critical Price Per Unit Electric Energy

Determined price of per unit energy for each industrial consumer has been shown in Table 4.9.

In the Table 4.9, total energy not served from grid source (kWh) can be calculated as $\text{Ens} = (\text{Pt} \times \text{Ti})$ kWh. (4.8)

where Pt and Ti have been shown in Table 3.1 and Table 3.2 respectively for data of all consumers. The values of Ens have been calculated using data of Table 3.1, Table 3.2 by putting in equation (4.8) and obtained results have been shown in Table 4.9.

Price per unit energy (Tk.) may be calculated as

$$\text{Cu} = \left(\frac{\text{Co}}{\text{Ens}}\right) \quad \text{Tk.} \tag{4.9}$$

where Co for data of all corresponding consumers have been shown in Table 4.8. The values of Cu have been calculated using data of Table 4.8, Table 4.9 by putting in equation (4.9) and obtained results have been shown in Table 4.9.

Finally the critical price per unit electric energy has been estimated and shown in table 4.9.

Table 4.9: Determined price per unit electric energy

Consumer SL. No.	Total energy not served from grid source	Determined price per unit energy	Critical price per unit energy
	kWh	Tk.	Tk.
#	Ens	Cu	Ccr
1	35508.00	1.58	
2	312.09	69.57	
3	8944.50	4.54	
4	627.51	45.64	

Consumer SL. No.	Total energy not served from grid source	Determined price per unit energy	Critical price per unit energy
	kWh	Tk.	Tk.
#	Ens	Cu	Ccr
5	550.10	72.65	
6	19158.40	8.10	
7	998.48	37.56	
8	231.42	88.08	

Table 4.9: Determined price per unit electric energy (continued)

Consumer SL. No.	Total energy not served from grid source	Determined price per unit energy	Critical price per unit energy
	kWh	Tk.	Tk.
#	Ens	Cu	Ccr
9	21499.20	2.13	
10	1084.43	22.41	
11	2824.65	15.21	
12	491.89	112.44	
13	20914.08	2.10	
14	453.17	79.24	
15	1447.57	36.31	
16	350.79	37.29	
17	126.03	60.23	
18	639.20	21.24	
19	691.23	27.97	
20	712.33	15.51	30.46
21	2076.64	5.47	
22	2049.67	11.10	
23	262.30	56.84	
24	407.01	38.57	
25	1113.65	16.23	
26	865.85	5.94	
27	663.38	28.79	
28	349.99	41.10	
29	553.04	8.80	
30	3249.69	10.82	
31	4418.33	5.73	
32	4862.54	11.77	
33	2404.50	6.71	
34	528.17	22.74	
35	1414.65	12.85	
36	2463.06	9.90	
37	2358.39	15.63	
38	1721.87	14.08	
39	357.20	34.44	
40	1188.45	12.62	
41	2026.26	18.48	
42	3031.87	7.00	
43	450.13	80.21	
44	1234.80	21.79	
45	6066.12	11.78	
46	2733.07	3.93	
47	530.19	16.54	
48	21388.86	7.45	
49	673.61	85.70	
50	1320.52	53.74	
51	1231.88	50.44	
52	1930.14	21.38	
53	543.84	106.15	

4.3.8 Results

Critical price per unit electric energy on the basis of power interruption cost of industrial consumer has been determined in Tk. 30.46 as shown in Table 4.9.

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

The survey findings and results have been analyzed, discussed and the impacts of various parameters on the calculated indices have also been presented in this chapter. The number of customers considered in estimating the costs of power interruptions or power quality events will have a significant impact on the magnitude of the estimate [21].

5.2 COMPARISON OF INTERRUPTION COSTS WITH ELECTRICITY BILL PAID BY THE CONSUMERS

In the Table 5.1, average electricity bill per hour (Tk.) has been calculated as

$$\text{Bavgh} = \left(\frac{\text{Bavg}}{720}\right) \quad \text{Tk.} \qquad (5.1)$$

As 1 Month = 720 Hr.

Maximum electricity bill per hour (Tk.) has been calculated as

$$\text{Bmax} = \left(\text{Pt} \times Tf\right) \quad \text{Tk.} \qquad (5.2)$$

Here, Tf = Flat rate of F tariff

= 6.02 Tk. [8]

where data of Bavg, Pt, $\overline{C}$ shown in Table 4.1, Table 3.1 and Table 4.8 respectively have been used for calculations and by using equations (5.1), (5.2) then results have been shown in Table 5.1.

The comparison of interruption costs with electricity bill paid by the consumers parameters, hourly average electricity bill paid have been evaluated by using data from Table 4.8, Table 5.1 and then have been shown in Table 5.1. It is observed that the ratio of interruption costs and average electricity bill ($\overline{C}$ / Bavgh) is greater than the ratio of interruption costs and maximum electricity bill ($\overline{C}$ / Bmax).

Table 5.1: Cost ratios' comparison

Consumer SL. No.	Average electricity bill per hour	Maximum electricity bill per hour	Ratio of interruption costs and average electricity bill	Ratio of interruption costs and maximum electricity bill
	Tk.	Tk.		
#	Bavgh	Bmax	$\overline{C}$/Bavgh	$\overline{C}$/Bmax
1	492.64	3612.00	1.92	0.26
2	7.17	26.36	42.46	11.56
3	236.50	903.00	2.88	0.75
4	12.44	52.89	32.24	7.58
5	11.26	47.11	50.47	12.07
6	626.85	1926.40	4.13	1.35
7	21.80	84.28	24.12	6.24
8	5.44	19.85	53.44	14.63
9	451.17	2167.20	1.70	0.35
10	22.70	91.62	15.02	3.72
11	61.96	245.98	10.03	2.53
12	35.13	44.08	23.44	18.68
13	447.53	2114.95	1.65	0.35
14	8.92	41.69	61.54	13.16
15	28.53	135.06	28.55	6.03
16	9.11	42.81	29.10	6.20
17	3.23	14.57	45.12	10.01
18	16.11	75.82	16.61	3.53
19	17.35	78.77	21.09	4.65
20	17.24	81.32	12.15	2.58

Table 5.1: Cost ratios' comparison (continued)

Consumer SL. No.	Average electricity bill per hour	Maximum electricity bill per hour	Ratio of interruption costs and average electricity bill	Ratio of interruption costs and maximum electricity bill
	Tk.	Tk.		
#	Bavgh	Bmax	$\overline{C}$/Bavgh	$\overline{C}$/Bmax
21	122.25	236.63	1.76	0.91
22	126.81	245.80	3.57	1.84
23	6.56	30.41	43.76	9.44
24	9.92	46.32	29.92	6.41
25	26.76	126.66	12.76	2.70
26	20.82	98.40	4.67	0.99
27	16.58	77.92	22.47	4.78
28	9.02	42.31	32.03	6.83
29	13.86	65.28	6.89	1.46
30	80.72	373.84	8.32	1.80
31	104.49	529.11	4.82	0.95
32	160.38	552.31	6.74	1.96
33	87.32	273.99	3.50	1.11
34	12.84	60.14	17.70	3.78
35	35.24	166.89	10.11	2.13
36	70.47	292.05	6.82	1.65
37	58.65	275.68	12.20	2.60
38	41.41	196.06	11.07	2.34
39	8.84	41.30	26.74	5.72
40	28.60	134.81	9.89	2.10
41	32.37	149.21	14.15	3.07
42	41.75	222.58	6.20	1.16
43	6.27	32.97	70.04	13.32

Table 5.1: Cost ratios' comparison (continued)

Consumer SL. No.	Average electricity bill per hour	Maximum electricity bill per hour	Ratio of interruption costs and average electricity bill	Ratio of interruption costs and maximum electricity bill
	Tk.	Tk.		
#	Bavgh	Bmax	$\overline{C}$/Bavgh	$\overline{C}$/Bmax
44	26.53	90.30	12.32	3.62
45	126.94	435.10	6.71	1.96
46	70.42	250.73	2.33	0.65
47	50.19	130.12	7.12	2.75
48	89.56	1316.57	18.19	1.24
49	9.81	46.03	66.78	14.24
50	17.66	87.29	44.12	8.93
51	17.43	82.35	39.58	8.38
52	36.99	159.98	15.36	3.55
53	7.96	37.20	82.42	17.63
	77.52	←Hourly average electricity bill paid		

5.3 DETERMINED CLASS, INTERRUPTION COSTS PER HOUR AND AVERAGE ELECTRICITY BILL PER HOUR FOR INDIVIDUAL CONSUMER

Determined class, interruption costs per hour and average electricity bill per hour for individual consumer data shown in Table 4.6, Table 4.8 and Table 5.1 respectively have been shown in Table 5.2.

Table 5.2: Determined class, interruption costs per hour and average electricity bill per hour

Consumer ID. No.	Consumers' classes on basis of					Costs per hour of interruption (Tk.)	Average electricity bill per hour (Tk.)
	Alternative sources used	Employees' No.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)		
#						$\overline{C}$	Bavgh
1	G	J	N	R	Z	945.23	313.43
2	H	I	L	P	X	304.66	4.56
3	H	K	N	R	Z	681.59	150.46
4	H	I	L	P	X	400.98	7.91
5	G	I	L	P	X	568.47	7.17
6	F	K	N	R	Z	2591.5	398.81
7	F	I	M	P	X	525.86	13.87
8	F	I	L	P	X	290.49	3.46
9	F	K	N	R	Z	768.31	287.04
10	F	I	M	P	X	341.06	14.44
11	G	J	N	Q	Y	621.49	39.42
12	G	J	M	P	Y	823.30	22.35
13	G	J	N	R	Z	739.39	284.72
14	H	I	L	P	X	548.82	5.67
15	H	J	M	Q	Y	814.74	18.15
16	H	I	L	P	X	265.20	5.80
17	H	I	L	P	X	145.77	2.06
18	H	I	M	P	X	267.51	10.25
19	H	I	M	P	X	365.91	11.04
20	G	I	M	P	X	209.51	10.97
21	H	K	N	Q	Y	214.94	77.78
22	F	K	N	Q	Y	453.32	80.68
23	H	I	L	P	X	287.13	4.18

Table 5.2: Determined class, interruption costs per hour and average electricity bill per hour (continued)

Consumer ID. No.	Consumers' classes on basis of					Costs per hour of interruption (Tk.)	Average electricity bill per hour (Tk.)
	Alternative sources used	Employees' No.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)		
#		$\overline{C}$	Bavgh			$\overline{C}$	Bavgh
24	H	I	L	P	X	296.79	6.31
25	G	I	M	Q	X	341.43	17.03
26	H	I	M	P	X	97.15	13.25
27	H	I	M	P	X	372.61	10.55
28	F	I	L	P	X	288.86	5.74
29	G	I	L	P	X	95.45	8.81
30	G	J	N	R	Y	671.76	51.35
31	H	J	N	R	X	503.72	66.48
32	F	K	N	R	Y	1080.2	102.04
33	F	I	N	Q	X	305.49	55.55
34	G	I	L	P	X	227.22	8.17
35	G	I	M	Q	X	356.26	22.42
36	G	J	N	Q	Z	480.51	44.83
37	G	J	N	Q	Z	715.72	37.31
38	G	I	M	Q	Z	458.54	26.35
39	H	I	L	P	X	236.27	5.62
40	G	I	M	Q	X	282.69	18.19
41	G	I	M	Q	Y	457.98	20.60
42	H	I	M	Q	Y	258.93	30.22
43	H	I	L	P	X	439.22	4.54
44	G	I	M	P	X	326.85	16.88
45	H	I	N	R	Z	851.74	80.76
46	H	I	N	Q	Z	163.81	44.80

Table 5.2: Determined class, interruption costs per hour and average electricity bill per hour (continued)

Consumer ID. No.	Consumers' classes on basis of					Costs per hour of interruption (Tk.)	Average electricity bill per hour (Tk.)
	Alternative sources used	Employees' No.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)		
#						$\overline{C}$	Bavgh
47	F	J	M	Q	Z	357.42	31.93
48	F	K	N	R	Z	1628.9	56.98
49	H	I	L	P	X	655.26	6.24
50	H	I	M	P	X	779.23	11.24
51	F	I	M	P	X	689.97	11.09
52	G	I	M	Q	X	568.15	23.53
53	G	I	L	P	X	656.00	5.06

5.4.1 Electricity Bill Per Hour, Interruption Costs Per Hour and Price Per Unit Energy on the Basis of Alternative Sources Used

Electricity bill per hour (Bavgh), interruption costs per hour ($\overline{C}$) and price per unit energy (Cu) for each consumer on the basis of used alternative sources only values shown in Table 5.2 and Table 4.9 have been tabulated in Table. Then total value of above mentioned three indices have been calculated on the basis of each class of used alternative sources. Then evaluated parameters have been shown in Table 5.3.

Table 5.3: Costs parameters on the basis of each class of used alternative sources

Consumer ID. No.	Consumers' classes on basis of alternative sources used	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
6	F	626.85	2595.5	8.11	12	1668.67	9804.47	305.68
7	F	21.80	526.56	37.61				
8	F	5.44	290.49	88.08				
9	F	451.17	768.31	2.13				
10	F	22.70	341.07	22.41				
22	F	126.81	454.03	11.12				
28	F	9.02	288.87	41.10				
32	F	160.38	1081.9	11.79				
33	F	87.32	305.49	6.71				
47	F	50.19	357.58	16.54				
48	F	89.56	2104.7	9.62				
51	F	17.43	689.98	50.44				
1	G	492.64	945.23	1.58	19	1538.16	9545.94	510.96
5	G	11.26	568.47	72.65				
11	G	61.96	621.49	15.21				
12	G	35.13	823.30	112.44				
13	G	447.53	739.39	2.10				
20	G	17.24	209.51	15.51				
25	G	26.76	341.43	16.23				
29	G	13.86	95.45	8.80				
30	G	80.72	671.76	10.82				

Table 5.3: Costs parameters on the basis of each class of used alternative sources (continued)

Consumer ID. No.	Consumers' classes on basis of alternative sources used	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
34	G	12.84	227.22	22.74				
35	G	35.24	356.26	12.85				
36	G	70.47	480.51	9.90				
37	G	58.65	715.72	15.63				
38	G	41.41	458.54	14.08				
40	G	28.60	282.69	12.62				
41	G	32.37	457.98	18.48				
44	G	26.53	326.85	21.79				
52	G	36.99	568.15	21.38				
53	G	7.96	656.00	106.15				
2	H	7.17	304.66	69.57	22	901.68	8951.99	800.20
3	H	236.50	681.59	4.54				
4	H	12.44	400.98	45.64				
14	H	8.92	548.82	79.24				
15	H	28.53	814.74	36.31				
16	H	9.11	265.20	37.29				
17	H	3.23	145.77	60.23				
18	H	16.11	267.51	21.24				
19	H	17.35	365.91	27.97				
21	H	122.25	214.94	5.47				
23	H	6.56	287.13	56.84				

Table 5.3: Costs parameters on the basis of each class of used alternative sources (continued)

Consumer ID. No.	Consumers' classes on basis of alternative sources used	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
24	H	9.92	296.79	38.57				
26	H	20.82	97.15	5.94				
27	H	16.58	372.61	28.79				
31	H	104.49	503.72	5.73				
39	H	8.84	236.27	34.44				
42	H	41.75	258.93	7.00				
43	H	6.27	439.22	80.21				
45	H	126.94	851.74	11.78				
46	H	70.42	163.81	3.93				
49	H	9.81	655.26	85.70				
50	H	17.66	779.23	53.74				

5.4.2 Electricity Bill Per Hour, Interruption Costs Per Hour and Price Per Unit Energy on the Basis of Employees' Nos.

Electricity bill per hour (Bavgh), interruption costs per hour ($\overline{C}$) and price per unit energy (Cu) for each consumer on the basis of employees' nos. only values shown in Table 5.2 and Table 4.9 have been tabulated in Table. Then total value of above mentioned three indices have been calculated on the basis of each class of employees' nos. Then evaluated parameters have been shown in Table 5.4.

Table 5.4: Costs parameters on the basis of each class of employees' nos.

Consumer ID. No.	Consumers' classes on basis of employees' Nos.	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	For specified class: Total electricity bill per hour	For specified class: Total interruption costs per hour	For specified class: Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
2	I	7.17	304.66	69.57	36	864.68	13728.01	1337.78
4	I	12.44	400.98	45.64				
5	I	11.26	568.47	72.65				
7	I	21.80	526.56	37.61				
8	I	5.44	290.49	88.08				
10	I	22.70	341.07	22.41				
14	I	8.92	548.82	79.24				
16	I	9.11	265.20	37.29				
17	I	3.23	145.77	60.23				
18	I	16.11	267.51	21.24				
19	I	17.35	365.91	27.97				
20	I	17.24	209.51	15.51				
23	I	6.56	287.13	56.84				
24	I	9.92	296.79	38.57				
25	I	26.76	341.43	16.23				
26	I	20.82	97.15	5.94				
27	I	16.58	372.61	28.79				
28	I	9.02	288.87	41.10				
29	I	13.86	95.45	8.80				
33	I	87.32	305.49	6.71				
34	I	12.84	227.22	22.74				
35	I	35.24	356.26	12.85				

Table 5.4: Costs parameters on the basis of each class of employees' nos. (continued)

Consumer ID. No.	Consumers' classes on basis of employees' Nos.	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
38	I	41.41	458.54	14.08				
39	I	8.84	236.27	34.44				
40	I	28.60	282.69	12.62				
41	I	32.37	457.98	18.48				
42	I	41.75	258.93	7.00				
43	I	6.27	439.22	80.21				
44	I	26.53	326.85	21.79				
45	I	126.94	851.74	11.78				
46	I	70.42	163.81	3.93				
49	I	9.81	655.26	85.70				
50	I	17.66	779.23	53.74				
51	I	17.43	689.98	50.44				
52	I	36.99	568.15	21.38				
53	I	7.96	656.00	106.15				
1	J	492.64	945.23	1.58	10	1430.31	6673.43	226.27
11	J	61.96	621.49	15.21				
12	J	35.13	823.30	112.44				
13	J	447.53	739.39	2.10				
15	J	28.53	814.74	36.31				
30	J	80.72	671.76	10.82				
31	J	104.49	503.72	5.73				
36	J	70.47	480.51	9.90				

Table 5.4: Costs parameters on the basis of each class of employees' nos. (continued)

Consumer ID. No.	Consumers' classes on basis of employees' Nos.	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
37	J	58.65	715.72	15.63				
47	J	50.19	357.58	16.54				
3	K	236.50	681.59	4.54	7	1813.52	7900.96	52.79
6	K	626.85	2595.5	8.11				
9	K	451.17	768.31	2.13				
21	K	122.25	214.94	5.47				
22	K	126.81	454.03	11.12				
32	K	160.38	1081.9	11.79				
48	K	89.56	2104.7	9.62				

5.4.3 Interruption Costs Per Hour, Electricity Bill Per Hour and Price Per Unit Energy on the Basis of Monthly Electric Bill

Electricity bill per hour (Bavgh), interruption costs per hour ($\overline{C}$) and price per unit energy (Cu) for each consumer on the basis of monthly electric bill only values shown in Table 5.2 and Table 4.9 have been tabulated in Table. Then total value of above mentioned three indices have been calculated on the basis of each class of monthly electric bill. Then evaluated parameters have been shown in Table 5.5.

Table 5.5: Costs parameters on the basis of each class of monthly electric bill

Consumer ID. No.	Consumers' classes on basis of monthly electric bill	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
2	L	7.17	304.66	69.57	24	328.28	9015.07	1168.51
4	L	12.44	400.98	45.64				
5	L	11.26	568.47	72.65				
8	L	5.44	526.56	37.61				
14	L	8.92	290.49	88.08				
16	L	9.11	548.82	79.24				
17	L	3.23	265.20	37.29				
23	L	6.56	145.77	60.23				
24	L	9.92	267.51	21.24				
28	L	9.02	365.91	27.97				
29	L	13.86	209.51	15.51				
34	L	12.84	287.13	56.84				
39	L	8.84	296.79	38.57				
43	L	6.27	97.15	5.94				
49	L	9.81	372.61	28.79				
53	L	7.96	288.87	41.10				
7	M	21.80	95.45	8.80				
10	M	22.70	227.22	22.74				
12	M	35.13	236.27	34.44				
15	M	28.53	439.22	80.21				
18	M	16.11	655.26	85.70				

Table 5.5: Costs parameters on the basis of each class of monthly electric bill (continued)

Consumer ID. No.	Consumers' classes on basis of monthly electric bill	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
19	M	17.35	779.23	53.74	18	2682.23	8346.28	374.35
20	M	17.24	689.98	50.44				
25	M	26.76	656.00	106.15				
26	M	20.82	341.07	22.41				
27	M	16.58	621.49	15.21				
35	M	35.24	823.30	112.44				
38	M	41.41	814.74	36.31				
40	M	28.60	341.43	16.23				
41	M	32.37	671.76	10.82				
42	M	41.75	305.49	6.71				
44	M	26.53	356.26	12.85				
47	M	50.19	480.51	9.90				
50	M	17.66	715.72	15.63				
51	M	17.43	458.54	14.08				
52	M	36.99	282.69	12.62				
1	N	492.64	457.98	18.48				
3	N	236.50	258.93	7.00				
6	N	626.85	326.85	21.79				
9	N	451.17	163.81	3.93				
11	N	61.96	357.58	16.54				
13	N	447.53	568.15	21.38				

Table 5.5: Costs parameters on the basis of each class of monthly electric bill (continued)

Consumer ID. No.	Consumers' classes on basis of monthly electric bill	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
21	N	122.25	945.23	1.58	11	1098.00	10941.05	73.99
22	N	126.81	681.59	4.54				
30	N	80.72	2595.5	8.11				
31	N	104.49	768.31	2.13				
32	N	160.38	739.39	2.10				
33	N	87.32	214.94	5.47				
36	N	70.47	454.03	11.12				
37	N	58.65	503.72	5.73				
45	N	126.94	1081.9	11.79				
46	N	70.42	851.74	11.78				
48	N	89.56	2104.7	9.62				

5.4.4 Interruption Costs Per Hour, Electricity Bill Per Hour and Price Per Unit Energy on the Basis of Connected Load

Electricity bill per hour (Bavgh), interruption costs per hour ($\overline{C}$) and price per unit energy (Cu) for each consumer on the basis of connected load only values shown in Table 5.2 and Table 4.9 have been tabulated in Table 5.6. Then total value of above mentioned three indices have been calculated on the basis of each class of connected load. Then evaluated parameters have been shown in Table 5.6.

Table 5.6: Costs parameters on the basis of each class of connected load

Consumer ID. No.	Consumers' classes on basis of connected load	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	For specified class: Total electricity bill per hour	For specified class: Total interruption costs per hour	For specified class: Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
2	P	7.17	304.66	69.57	27	372.01	10506.29	1325.15
4	P	12.44	400.98	45.64				
5	P	11.26	568.47	72.65				
7	P	21.80	526.56	37.61				
8	P	5.44	290.49	88.08				
10	P	22.70	341.07	22.41				
12	P	35.13	823.30	112.44				
14	P	8.92	548.82	79.24				
16	P	9.11	265.20	37.29				
17	P	3.23	145.77	60.23				
18	P	16.11	267.51	21.24				
19	P	17.35	365.91	27.97				
20	P	17.24	209.51	15.51				
23	P	6.56	287.13	56.84				
24	P	9.92	296.79	38.57				
26	P	20.82	97.15	5.94				
27	P	16.58	372.61	28.79				
28	P	9.02	288.87	41.10				
29	P	13.86	95.45	8.80				
34	P	12.84	227.22	22.74				
39	P	8.84	236.27	34.44				
43	P	6.27	439.22	80.21				

Table 5.6: Costs parameters on the basis of each class of connected load (continued)

Consumer ID. No.	Consumers' classes on basis of connected load	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	For specified class: Total electricity bill per hour	For specified class: Total interruption costs per hour	For specified class: Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
44	P	26.53	326.85	21.79				
49	P	9.81	655.26	85.70				
50	P	17.66	779.23	53.74				
51	P	17.43	689.98	50.44				
53	P	7.96	656.00	106.15				
11	Q	61.96	621.49	15.21	16	919.73	6852.28	223.48
15	Q	28.53	814.74	36.31				
21	Q	122.25	214.94	5.47				
22	Q	126.81	454.03	11.12				
25	Q	26.76	341.43	16.23				
33	Q	87.32	305.49	6.71				
35	Q	35.24	356.26	12.85				
36	Q	70.47	480.51	9.90				
37	Q	58.65	715.72	15.63				
38	Q	41.41	458.54	14.08				
40	Q	28.60	282.69	12.62				
41	Q	32.37	457.98	18.48				
42	Q	41.75	258.93	7.00				
46	Q	70.42	163.81	3.93				
47	Q	50.19	357.58	16.54				
52	Q	36.99	568.15	21.38				
1	R	492.64	945.23	1.58				

Table 5.6: Costs parameters on the basis of each class of connected load (continued)

Consumer ID. No.	Consumers' classes on basis of connected load	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
3	R	236.50	681.59	4.54	10	2816.77	10943.84	68.22
6	R	626.85	2595.5	8.11				
9	R	451.17	768.31	2.13				
13	R	447.53	739.39	2.10				
30	R	80.72	671.76	10.82				
31	R	104.49	503.72	5.73				
32	R	160.38	1081.9	11.79				
45	R	126.94	851.74	11.78				
48	R	89.56	2104.7	9.62				

5.4.5 Interruption Costs Per Hour, Electricity Bill Per Hour and Price Per Unit Energy on the Basis of Industry Area

Electricity bill per hour (Bavgh), interruption costs per hour ($\overline{C}$) and price per unit energy (Cu) for each consumer on the basis of industry area only values shown in Table 5.2 and Table 4.9 have been tabulated in Table 5.7. Then total value of above mentioned three indices have been calculated on the basis of each class of industry area. Then evaluated parameters have been shown in Table 5.7.

Table 5.7: Costs parameters on the basis of each class of industry area

Consumer ID. No.	Consumers' classes on basis of industry area	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
2	X	7.17	304.66	69.57	32	656.28	12040.72	1288.23
4	X	12.44	400.98	45.64				
5	X	11.26	568.47	72.65				
7	X	21.80	526.56	37.61				
8	X	5.44	290.49	88.08				
10	X	22.70	341.07	22.41				
14	X	8.92	548.82	79.24				
16	X	9.11	265.20	37.29				
17	X	3.23	145.77	60.23				
18	X	16.11	267.51	21.24				
19	X	17.35	365.91	27.97				
20	X	17.24	209.51	15.51				
23	X	6.56	287.13	56.84				
24	X	9.92	296.79	38.57				
25	X	26.76	341.43	16.23				
26	X	20.82	97.15	5.94				
27	X	16.58	372.61	28.79				
28	X	9.02	288.87	41.10				
29	X	13.86	95.45	8.80				
31	X	104.49	503.72	5.73				
33	X	87.32	305.49	6.71				
34	X	12.84	227.22	22.74				

Table 5.7: Costs parameters on the basis of each class of industry area (continued)

Consumer ID. No.	Consumers' classes on basis of industry area	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class			
					Consumers' Nos.	Total electricity bill per hour	Total interruption costs per hour	Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
35	X	35.24	356.26	12.85				
39	X	8.84	236.27	34.44				
40	X	28.60	282.69	12.62				
43	X	6.27	439.22	80.21				
44	X	26.53	326.85	21.79				
49	X	9.81	655.26	85.70				
50	X	17.66	779.23	53.74				
51	X	17.43	689.98	50.44				
52	X	36.99	568.15	21.38				
53	X	7.96	656.00	106.15				
11	Y	61.96	621.49	15.21	9	689.91	5399.08	228.64
12	Y	35.13	823.30	112.44				
15	Y	28.53	814.74	36.31				
21	Y	122.25	214.94	5.47				
22	Y	126.81	454.03	11.12				
30	Y	80.72	671.76	10.82				
32	Y	160.38	1081.9	11.79				
41	Y	32.37	457.98	18.48				
42	Y	41.75	258.93	7.00				
1	Z	492.64	945.23	1.58				
3	Z	236.50	681.59	4.54				
6	Z	626.85	2595.5	8.11				

Table 5.7: Costs parameters on the basis of each class of industry area (continued)

Consumer ID. No.	Consumers' classes on basis of industry area	Electricity bill per hour	Obtained interruption costs per hour	Determined price per unit energy	For specified class: Consumers' Nos.	For specified class: Total electricity bill per hour	For specified class: Total interruption costs per hour	For specified class: Total determined price per unit energy
#		Tk.	Tk.	Tk.	Nos.	Tk.	Tk.	Tk.
9	Z	451.17	768.31	2.13	12	2762.33	10862.60	99.97
13	Z	447.53	739.39	2.10				
36	Z	70.47	480.51	9.90				
37	Z	58.65	715.72	15.63				
38	Z	41.41	458.54	14.08				
45	Z	126.94	851.74	11.78				
46	Z	70.42	163.81	3.93				
47	Z	50.19	357.58	16.54				
48	Z	89.56	2104.7	9.62				

5.4.6 Average Interruption Costs Per Hour, Average Electricity Bill Per Hour And Average Determined Price Per Unit Energy On The Basis Of Consumers' Classes

Average value of Interruption average costs per hour, average electricity bill per hour and average determined price per unit energy for each fifteen classes have been evaluated by dividing total values of each parameter for a specific class by number of consumers containing that class using data shown in Table 5.3, Table 5.4, Table 5.5, Table 5.6 and Table 5.7. Then evaluated values of each three above mentioned indices on basis of all fifteen classes have been shown in Table 5.8.

Table 5.8: Average interruption costs per hour, average electricity bill per hour and average determined price per unit energy on the basis of consumers' classes.

Issue of classification	Criteria	Consumers' classes	For specified class			
			Consumers' Nos.	Average electricity bill per hour	Average interruption costs per hour	Average determined price per unit energy
			Nos.	Tk.	Tk.	Tk.
Alternative sources used	Generator	F	12	139.06	817.04	25.47
	Candle	G	19	80.96	502.42	26.89
	Charger light	H	22	40.99	406.91	36.37
Employees' Nos.	<20	I	36	24.02	381.33	37.16
	=20-39	J	10	143.03	667.34	22.63
	>39	K	7	259.07	1128.7	7.54
Monthly electric bill (Tk.)	< 10000	L	24	13.68	375.63	48.69
	10000-40000	M	18	149.01	463.68	20.80
	>40000	N	11	99.82	994.64	6.73
Connected load (kW)	< 21	P	27	13.78	389.12	49.08
	21-49	Q	16	57.48	428.27	13.97
	> 49	R	10	281.68	1094.4	6.82
Industry area (sft)	< 3500	X	32	20.51	376.27	40.26
	3500-20000	Y	9	76.66	599.90	25.40
	> 20000	Z	12	230.19	905.22	8.33

5.4.6.5 Bill Per Hour In Accordance With Consumers' Classification

Graphical representation of average electricity bill per hour (Tk.) paid by consumers has been shown in Figure 5.1 by calculation using data shown in Table 5.8. Where symbols for consumer classes i.e. F, G, H, I, J, K, L, M, N, P, Q, R, X, Y and Z have been shown in Table 5.8. It is observed from figure 5.1 that the electric bills per hour paid by the consumers are higher for classes K, R and Z compared to other classes of consumers. That is the electric bills per hour paid by the consumers are higher for consumers who used generator and having higher number of employees (nos.), connected load (kW) and industry area (sft).

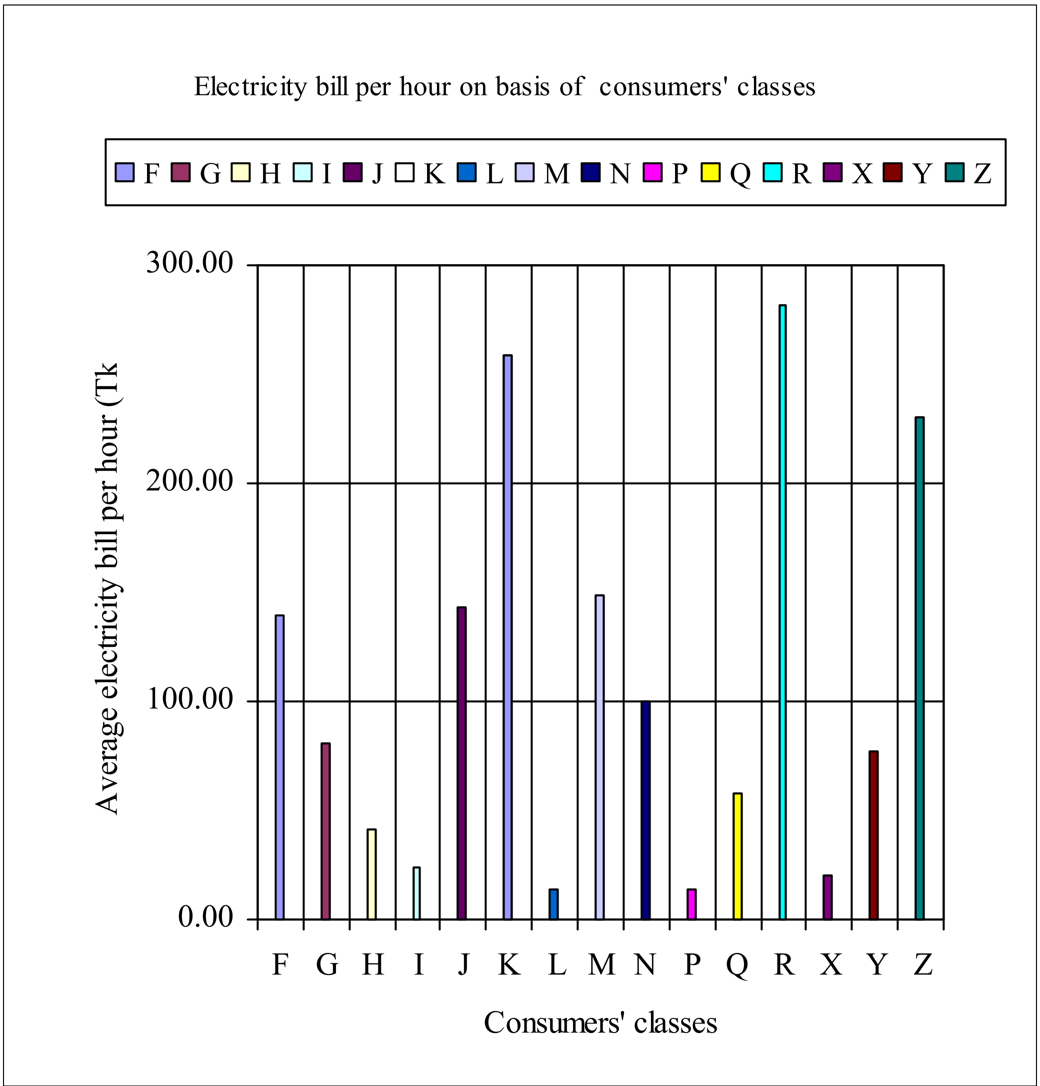

Figure 5.1: Electricity bill per hour on the basis of consumers' classes

5.4.6.6 Interruption Costs Per Hour In Accordance With Consumers' Classification

Graphical representation of average interruption costs per hour (Tk.) paid by consumers has been shown in Figure 5.2 by calculation using data shown in Table 5.8. where symbols for consumer classes i.e. F, G, H, I, J, K, L, M, N, P, Q, R, X, Y and Z have been shown in Table 5.8. It is observed from figure 5.2 that the interruption costs per hour are higher for classes F, K, N, R and Z compared to other classes. That is the interruption costs per hour are higher for consumers who used generator and having higher number of employees (nos.), monthly electric bills (Tk.), connected load (kW) and industry area (sft).

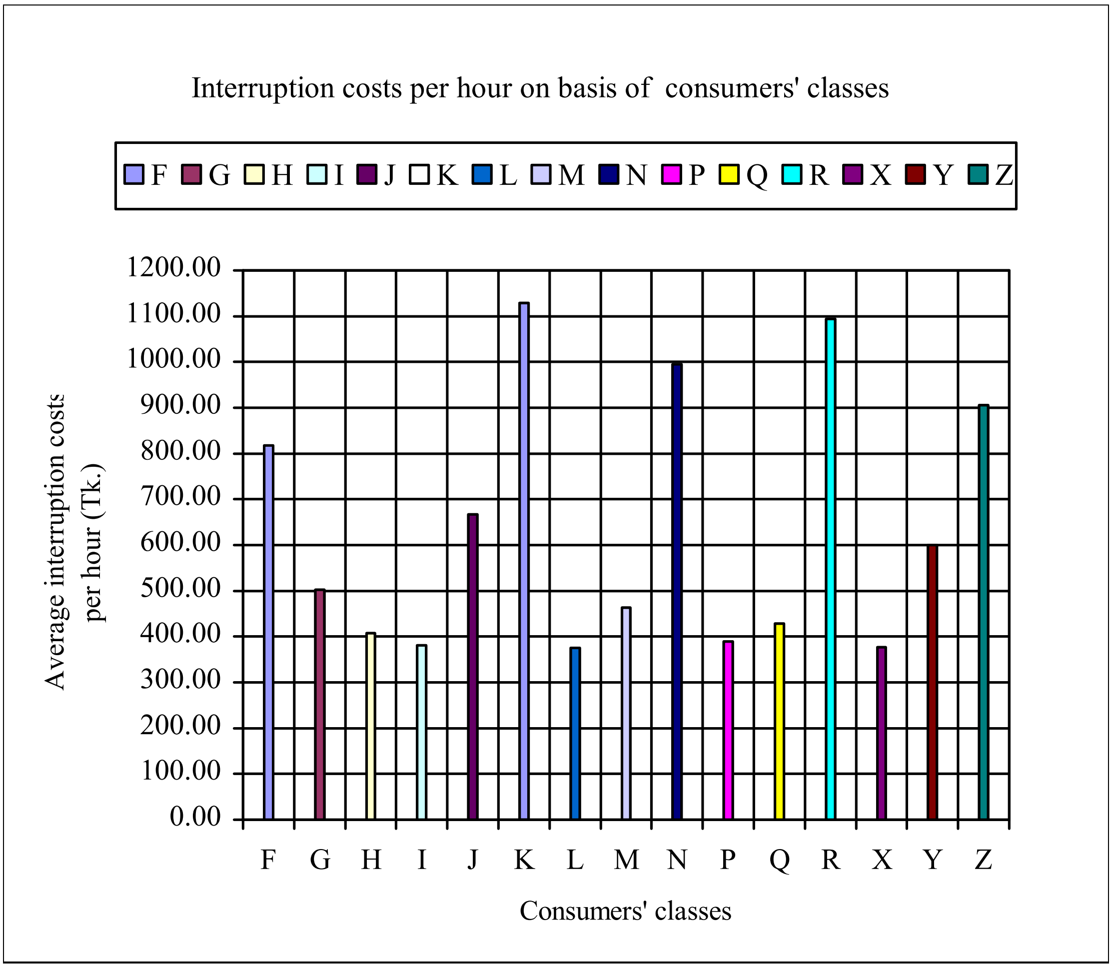

Figure 5.2: Interruption costs per hour on the basis of consumers' classes

5.4.6.7 Comparison Between Interruption Costs Per Hour And Average Electricity Bill Per Hour In Accordance With Consumers' Classification

Relation and comparison between interruption costs per hour (Tk.) and average electricity bill (Tk.) per hour paid by consumers in accordance with consumers' classification has been shown by graphical representation of in Figure 5.3 by calculation using data shown in Table 5.8. It is clearly observed from Figure 5.3 that the interruption costs per hour are higher than the electric bill per hour paid for all classes.

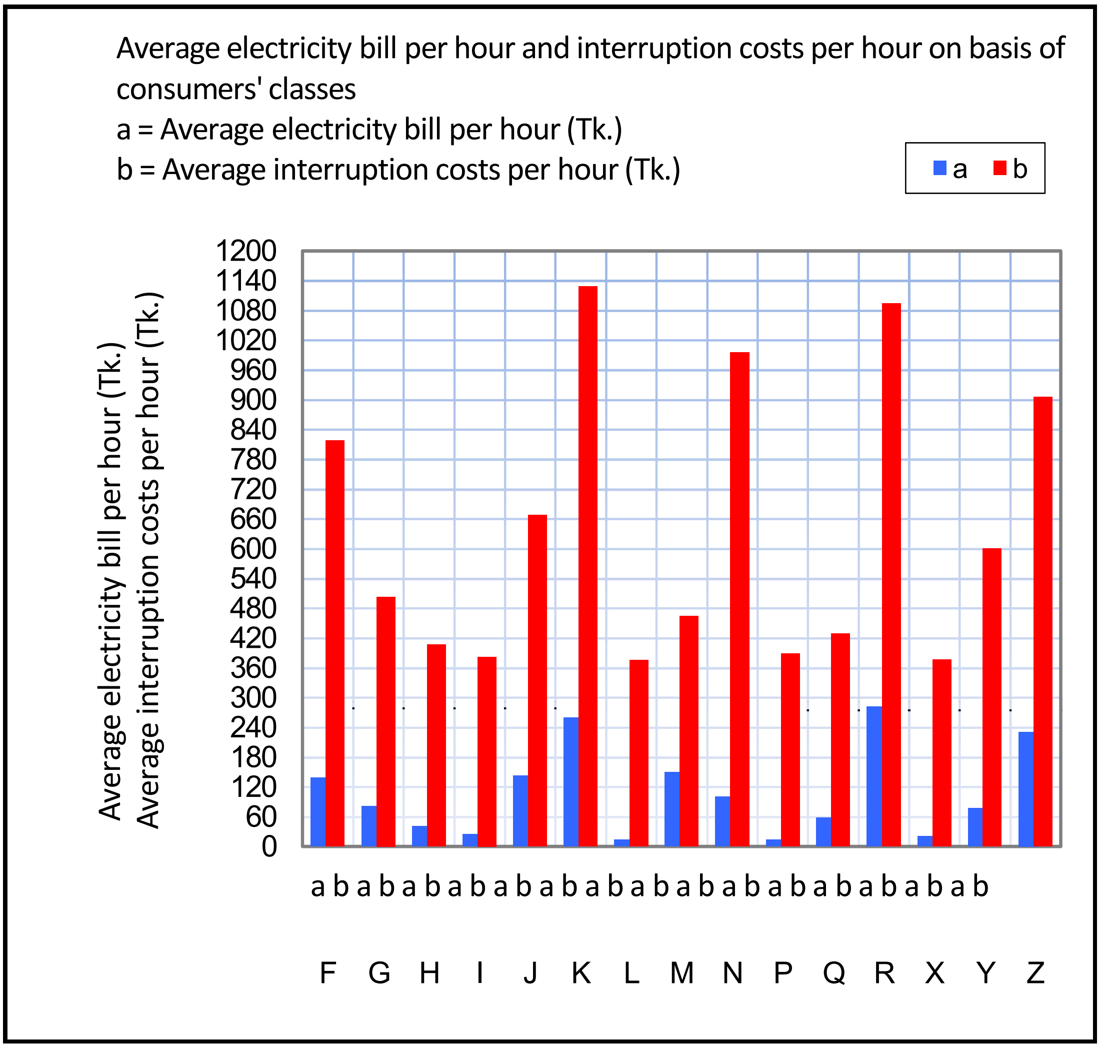

Figure 5.3: Average electricity bill per hour and interruption costs per hour on the basis of consumers' classes

5.4.6.8 Critical Price Per Unit Electric Energy In Accordance With Consumers' Classification

The costs per unit energy in captive power plant generation have been plotted graphically to establish correlation between those and selected critical price per unit energy in captive power plant generation while outage of power from national grid source in Figure 5.4 by calculation using data shown in Table 5.8. It has been obtained the value of critical price per unit energy 30.46 Tk. from figure 5.4.

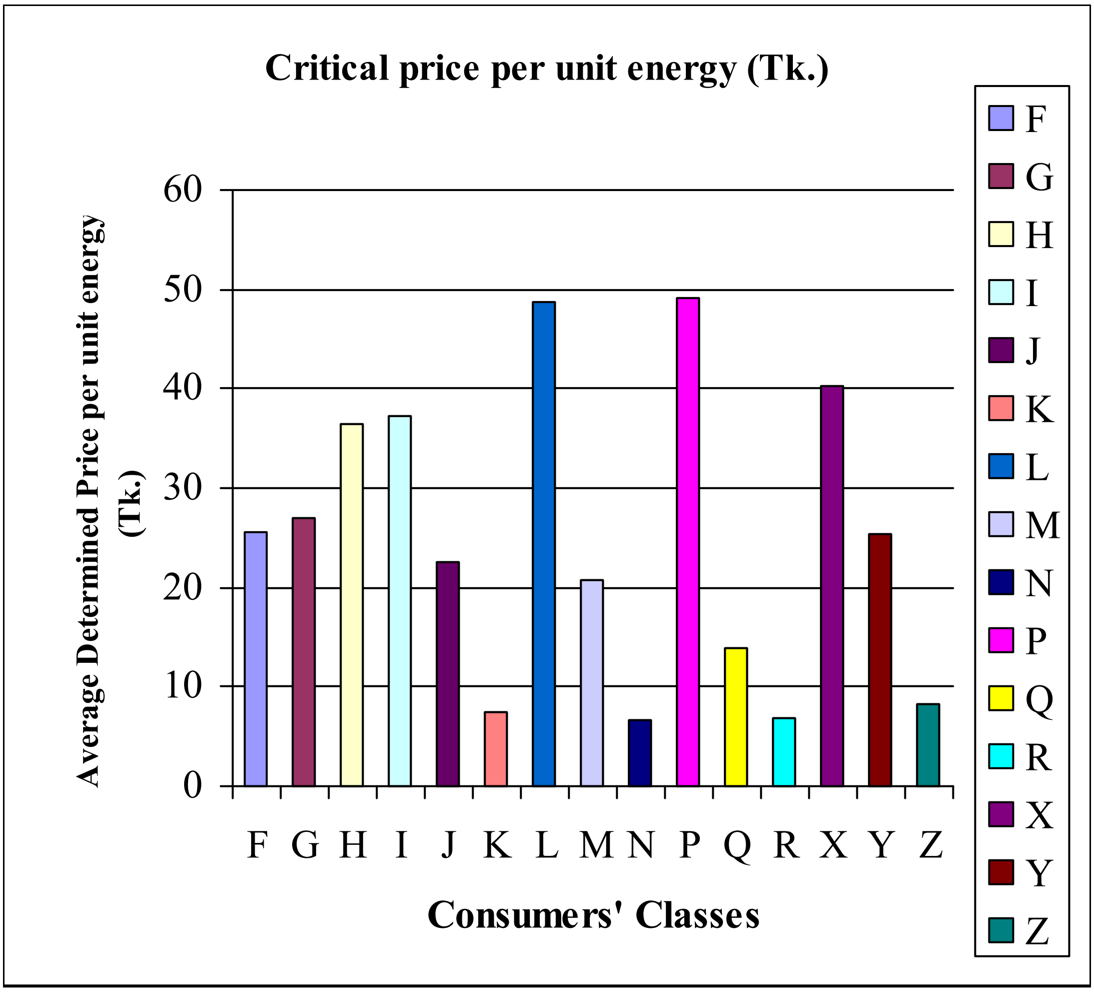

Figure 5.4: Critical price per unit energy in accordance with consumers' classification

5.5 COMPLIANCE WITH THE RECENT OTHER STUDIES PUBLISHED

The research paper [1] presents selected results from a recently completed research work of USA. In this reference, the authors estimated the interruption costs per kWh for 1-hour outage for the consumers of industrial sector of the American and Canadian utilities by surveying the consumers in 1990 which was published in the journal of IEEE transactions on Power System in 1991. The research paper [2] presents selected results of the interruption costs per kWh and costs per interruption from a recently completed Canadian research which was published in the journal of IEEE transactions on Power System in 1991. The research paper [16] presents selected results from consumers of Indian utilities by surveying the consumers which was published in the journal of IEEE transactions on Power System in 2002. The research paper [6] presents selected results from consumers of Bangladeshi utilities by surveying the consumers which was published in the paper of M. Sc. Thesis, Dept. of EEE, BUET, Dhaka, Bangladesh in 2004. It has been taken 2% interest from results of the reference for calculating them as 22 years from 1991 to 2012, 11 years from 2002 to 2012 and 9 years from 2004 to 2012 respectively in [1], [16] and [6]. Here, it has been considered that 1 USD~CAD $ = 82.00 BDT and 1 Rs. = 1.7 BDT. The results have been shown in Table 5.9.

It is observed from the Table 5.9 that cost per kWh of American utility 12 [1] is the highest among all other utilities. On the other hand cost per interruption of Canadian utility [2] is the highest compared to other utilities.

It is also observed from the determinate results shown in Table 5.9 that the results of Indian utility, Punjab [16] shown in sl. no. 5 are close to those of this research works shown in sl. no. 6 for Bangladeshi utilities including DPDC (Dhaka Power Distribution Company Ltd.) and DESCO (Dhaka Electric Supply Company Ltd.) area of Dhaka metropolitan city. These are also close to the results with the research work [24], [6] shown in sl. no. 4. The results of research works for utilities of almost same geographical areas like south Asian region complies closely due to almost similar geographical and socioeconomic factors whereas results vary accordingly for utility areas as much as difference with areas having varying factors.

Table 5.9: Comparison of evaluated results with those of South Asian and North American utilities

SL. No.	Results → Utility ↓	USD $ / kWh	Tk. / kWh	USD $ / int. (Ci)	Tk. / int. (Ci)	USD $ / Hr. of int. ($\overline{C}$)	Tk. / Hr. of int. ($\overline{C}$)
1	American-12 [1]	7.20 to 43.20	590.40 to 3542.40	-	-	-	-
2	Canadian-1 [1]	18.29	1499.78	-	-	-	-
3	Canadian [2]	0.0182	1.49	4785.42	392404.44	-	-
4	Dhaka, Bangladesh [24]	0.057	4.65	1.89	155.15	3.29	269.60
5	Punjab, India [16]	1.14	93.50	-	-	-	-
6	Dhaka, Bangladesh [This research]	0.37	30.46	3.56	292.03	6.40	524.89

CHAPTER SIX

CONCLUSION

6.1 INTRODUCTION

The electric service interruption causes losses to the consumers. The amount of loss is higher than the bill that would be paid by the consumers. It presents concluding remarks, suggestions and recommendation for future work. In direct measurement consumers are asked about damages, they have suffered during interruption, their capability to pay for hedging power interruptions and the minimum amount of monetary value to compensate their damages.

6.2 REMARKS

The average cost per hour of interruption is determined to carry out the actual amount of loss of the consumer. It is obtained from the study that the higher the area of the industry, average monthly electricity bill and connected load, the cost of interruption is higher.

The cost of power interruption is many times higher than the electricity bill that a consumer pays. 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 consumer to pay electricity bill at higher tariff. Critical price per unit energy on the basis of power interruption cost of industrial consumer is Ccr = 30.46 Tk.

6.3 SUGGESTIONS

The obtained average power interruption cost per hour for industrial consumer is 524.89 Tk. Also, the average cost per interruption is 292.03 Tk. But, the hourly average electricity bill paid by the consumer is 77.52 Tk. That is, the cost of power interruption is many times higher than the electricity bill that a consumer pays. The utility should consider this with great emphasis in expansion planning and in design phase.

Industrial consumer may use the procedure. They may run the industry with generation with this critical value obtained procedure for more profit from the business without keeping off by getting rid of losses.

6.4 RECOMMENDATION

The study has been conducted within industrial sector of Dhaka city. The study may include areas of outside Dhaka to obtain a generalized picture of the power interruption cost. Correlation between the interruption cost of consumer and the loss in the revenue earned by the utility due to power interruption can be developed.

It is necessary to develope the questionnaires with due careness to get all necessary information and data. Steps may be taken to convince the consumers, so that they can respond without any hesitation to give the proper data and information.

Loss due to decrease of the life span of the generator may be evaluated and added to alternative source usage costs.

IPS, charger light may be taken in case of evaluation for alternative source usage costs.

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APPENDIX 1

SAMPLE QUESTIONNAIRE

A sample questionnaire has been made to collect required information for the study and shown in Appendix 1.

Information To Be Required

A1.1 General Information

Sample questionnaire of required general information has been structured from Table 3.1 and shown in Table A1.1; where symbols Pt, Ai, Ne, Uavg, B1, B2 and B3 have been shown in Table A1.1.

Table A1.1: Sample questionnaire of required general information

Consumer ID. No.	Industry name and address with contact No.	Connected load	Industry area Industry area	Employees' No.	Average consumed energy per month	Bill of electricity paid for the three consecutive months of the observation period		
		kW	sft	Nos.	kWh	Tk.	Tk.	Tk.
#		Pt	Ai	Ne	Uavg	B1	B2	B3
1	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-

A1.2 Power Interruption Information

Sample questionnaire of required information regarding power interruption information has been structured from Table 3.2 and shown in Table A1.2; where symbols To, Ti, Tas, and Ni have been shown in Table A1.2.

Table A1.2: Sample questionnaire regarding power interruption information

Consumer ID. No.	Observation period	Date of data collection	Power interruption period	Alternative source usage period	Number of total interruption during observation period
	days		Hr.	Hr.	Nos.
#	To		Ti	Tas	Ni
1	-	-	-	-	-
-	-	-	-	-	-
53	-	-	-	-	-

A1.3 Power Outage Data Format

Sample questionnaire of required information regarding power outage has been structured from Table 3.3 and shown in Table A1.3; where symbols C4o and Co have been shown in Table A1.3.

Table A1.3: Sample questionnaire regarding power outage

Consumer ID. No.	SL. No.	Date of data collection	Raw materials under process damage	Damaged equipments	Damaged equipments' costs	Power interruption total loss (approx)
					Tk.	Tk.
#	#				C4o	Co
-	1	-	-	-	-	-
	-	-	-	-	-	-
	64	-	-	-	-	-

A1.4 Reparable Equipments' Faced Trouble Information Format

Sample questionnaire of reparable equipments' faced trouble [6] due to power interruptions has been structured from Table 3.4 and shown in Table A1.4; where symbols Ntd, Tri, Trl, $C_{rc,}$ Pri and Sri have been shown in Table A1.4.

Table A1.4: Sample questionnaire regarding reparable equipments' faced trouble

SL. No.	Consumer ID. No.	Reparable equipments	No. of equipments faced trouble or damaged	Life span of repairable item	Reduced life of repairable item	Costs per repair	Price of reparable equipments	Salvage value of reparable equipments
			Nos.	Yr.	Yr.	Tk.	Tk.	Tk.
#	#		Ntd	Tri	Trl	C_{rc}	Pri	Sri
1	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-

A1.5 Various Alternative Sources Used During Power Outage

Sample questionnaire of required information regarding various alternative sources used during power outage has been structured from Table 3.5 and shown in Table A1.5; where symbols Tas1, Tas2 and Tas3 have been shown in Table A1.5.

Table A1.5: Sample questionnaire regarding various alternative sources used during power outage

Consumer ID. No.	Date of data collection	Generator usage	Candle usage	Charger light usage
		Hr.	Hr.	Hr.
#		Tas1	Tas2	Tas3
1		-	-	-
-		-	-	-
53		-	-	-

A1.6 Information of various alternative sources

Sample questionnaire of various required information regarding alternative sources used during power outage has been structured from Table 3.6 and shown in Table A1.6; where symbols Nas, Pas and Sas have been shown in Table A1.6.

Table A1.6: Sample questionnaire regarding information of various alternative sources

Consumer ID. No.	SL. No.	Name of alternative sources	Nos. of used sources	Fuel	Fuel consumption per hour	Cost of fuel consumption per hour	Rating of sources	Price of alternative source	Salvage value of alternative source
			Nos.		Ltr.	Tk.	kVA	Tk.	Tk.
#	#		Nas					Pas	Sas
-	01	Generator	-	-	-	-	-	-	-
	02	IPS	-		-	-	-	-	-

Table A1.6: Sample questionnaire regarding information of various alternative sources (continued)

Consumer ID. No.	SL. No.	Name of alternative sources	Nos. of used sources	Fuel	Fuel consumption per hour	Cost of fuel consumption per hour	Rating of sources	Price of alternative source	Salvage value of alternative source
			Nos.		Ltr.	Tk.	kVA	Tk.	Tk.
#	#		Nas					Pas	Sas
-	03	UPS	-		-	-	-	-	-
	04	Charger light	-		-	-	-	-	-
		Others:							
	05	a)-	-		-	-	-	-	-
	06	b)-	-		-	-	-	-	-
	07	c)-	-		-	-	-	-	-

A1.7 Alternative Sources Faced Trouble Information Format

Sample questionnaire regarding information of alternative source faced trouble due to power interruptions has been structured from Table 3.7 and shown in Table A1.7; where symbols Tla, Trla and C_{rca} have been shown in Table A1.7.

Table A1.7: Sample questionnaire regarding alternative source faced trouble (continued)

SL. No.	Consumer ID. No.	Alternative source faced trouble	Total life span of used alternative source	Reduced life due to repair of used alternative source	Cost per repair for alternative source
			Yr.	Yr.	Tk.
#	#		Tla	Trla	C_{rca}
1	-	-	-	-	-
-	-	-	-	-	-

A1.8 Various difficulties / problems faced

Sample questionnaire regarding information of difficulties / problems faced in performing various activities for industrial consumers due to power outage has been structured from Table 3.8 and shown in Table A1.8; where symbols Ps, Sd, Ad, Od, Dm, Ds and To have been shown in Table A1.8.

Table A1.8: Sample questionnaire regarding various difficulties / problems faced due to power outage

Consumer ID. No.	Production and processing (encountered days)	Security (encountered days)	Accounting (encountered days)	Others (encountered days)	Moderate (observed days)	Severe (observed days)	Observation period
#	days	days	days	days	days	days	days
	Pd	Sd	Ad	Od	Dm	Ds	To
1	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-

A1.9 Different Cost Components Of Power Interruption

Sample questionnaire regarding information of different cost components for industrial consumers due to power outage has been structured from Table 3.9 and shown in Table A1.9; where symbols C1o, C2o, C3o and C4o have been shown in Table A1.9.

Table A1.9: Sample questionnaire regarding different cost components of power interruption

Consumer ID. No.	Raw materials under process damage costs	Alternative source usage costs	Loss due to reduced production and additional wage costs	Equipments' trouble and damage costs
	Tk.	Tk.	Tk.	Tk.
#	C1o	C2o	C3o	C4o
1	-	-	-	-
-	-	-	-	-
53	-	-	-	-

A1.10 Consumers' List

Sample questionnaire of consumers' list with consumers' classes has been structured from Table 4.1 and shown in Table A1.10.

Table A1.10: Sample questionnaire of consumers' list with consumers' classes

Consumer's ID. No.	Consumer classes basis on					Consumer location
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)	
1	-----	-----	-----	-----	-----	-----
-----	-----	-----	-----	-----	-----	-----
53	-----	-----	-----	-----	-----	-----

A1.11 Electrical Equipments

Sample questionnaire of electrical equipments may be structured and shown in Table A1.11.

Table A1.11: Sample questionnaire of electrical equipments

SL. No.	Equipment name	Quantity	Rating
#		Nos.	Watt
1	Incandescent bulb	-	-
2	CFL bulb	-	-
3	Tube light	-	-
4	Mercury lamp	-	-
5	Fan	-	-
6	Air Conditioner	-	-
7	Computer	-	-
8	Stabilizer	-	-

SL. No.	Equipment name	Quantity	Rating
#		Nos.	Watt
9	Motors	-	-
	Other equipments :		
10	a) Motor, 40 H.P	-	-
11	b) Motor,10 H.P	-	-
12	c) Motor, --- H.P	-	-
13	d) ---	-	-

A1.12 Signature: Authorized Signature with Seal:-------------------------

APPENDIX 2

SAMPLE DATA RESPONSE AND CONSUMERS' LIST

The data obtained from one of the industrial consumers (Consumer's ID. No. 45) has been presented as a sample and list of all consumers [6] have been shown in Appendix 2.

A2.1 Information of Industry

Industry name and address with contact No. have been shown in Table A2.1.

Table A2.1: Industry address

SL. No.	Items	Unit	Value
1	Consumer ID. No.		45
2	Industry name		A.D Engineering.
3	Industry address with contact No.		20, Mirhazirbag,Dhaka-1236

A2.2 Electrical Equipments

Data of electrical equipments for consumer ID. no. 45 have been shown in Table A2.2.

Table A2.2: Electrical equipments related data

SL. No.	Equipment name	Quantity	Rating	SL. No.	Equipment name	Quantity	Rating
#		Nos.	Watt	#		Nos.	Watt
1	Incandescent bulb	3	300	4	Mercury lamp		
2	CFL bulb			5	Fan	4	160
3	Tube light	5	200	6	Air		

Table A2.2: Electrical equipments related data (continued)

SL. No.	Equipment name	Quantity	Rating
#		Nos.	Watt
	Conditioner		
7	Computer		
8	Stabilizer		
9	Motors		
	Other equipments		
10	a) Motor, 40 H.P.	2	59680
11	b) Motor,10 H.P.		

SL. No.	Equipment name	Quantity	Rating
#		Nos.	Watt
12	c) Motor, 5 H.P.	3	11190
13	d) Motor, 1.5 H.P.		
14	e) Motor, 1 H.P.	1	746
15	f)--------------		
16	g)-------------		
	Total	374	72276

A2.3 Power Outage Data

Power outage data for consumer ID. no. 45 have been shown in Table A2.3.

Table A2.3: Power outage related data

SL. No.	Date of data collection	Power outage period	Used alternative sources	Alternative sources' usage period	Damaged equipments	Damaged equipments' costs	Power interruption total loss (approx)
		Hr.		Hr.		Tk.	Tk.
#		Ti		Tas		C4o	Co
1	02/04/03	0.32	Generator	0.17			
2	03/04/03	0.17		0.00			400.00
3	04/04/03	0.22		0.00			500.00
4	05/04/03	1.87	"	1.67			400.00
5	06/04/03	2.83	"	2.58			450.00
6	07/04/03	1.17	"	1.10			
7	09/04/03	1.07	"	0.98			400.00
8	10/04/03	1.13	"	1.07			480.00
9	11/04/03	0.42	"	0.37			
10	12/04/03	1.72	"	1.67			520.00
11	13/04/03	9.33	"	9.12			1000.00
12	15/04/03	1.00	"	0.95			
13	16/04/03	0.05	FALSE	0.00			
14	22/04/03	0.37	"	0.32			
15	23/04/03	0.88	"	0.77			
16	24/04/03	1.97	"	1.88			570.00
17	25/04/03	1.12	"	1.03			
18	26/04/03	0.92	"	0.85			
19	27/04/03	1.27	"	1.17			

Table A2.3: Power outage related data (continued)

SL. No.	Date of data collection	Power outage period	Used alternative sources	Alternative sources' usage period	Damaged equipments	Damaged equipments' costs	Power interruption total loss (approx)
		Hr.		Hr.		Tk.	Tk.
#		Ti		Tas		C4o	Co
20	28/04/03	1.48	"	1.37			450.00
21	29/04/03	0.67	"	0.67			
22	30/04/03	2.65	"	2.50			700.00
23	01/05/03	1.90	"	1.88			600.00
24	02/05/03	0.52	"	0.48			
25	03/05/03	1.42	"	1.42			510.00
26	04/05/03	4.20	"	4.17			800.00
27	05/05/03	0.45	"	0.43			
28	06/05/03	0.92	"	0.90			
29	07/05/03	3.42	"	3.33			800.00
30	08/05/03	2.37	"	2.33			750.00
31	09/05/03	0.08	"	0.08			
32	10/05/03	2.72	"	2.67			900.00
33	11/05/03	3.18	"	3.17			800.00
34	12/05/03	1.38	"	1.33			
35	13/05/03	1.00	"	0.97			
36	14/05/03	0.12	FALSE	0.00			
37	15/05/03	2.38	"	2.33			800.00
38	16/05/03	0.38	"	0.37			
39	18/05/03	0.92	"	0.90			
40	19/05/03	1.00	"	0.97			
41	20/05/03	0.53	"	0.50			
42	21/05/03	1.62	"	1.50			600.00

Table A2.3: Power outage related data (continued)

SL. No.	Date of data collection	Power outage period	Used alternative sources	Alternative sources' usage period	Damaged equipments	Damaged equipments' costs	Power interruption total loss (approx)
		Hr.		Hr.		Tk.	Tk.
#		Ti		Tas		C4o	Co
43	22/05/03	1.13	"	1.08			
44	25/05/03	0.33	"	0.33			
45	26/05/03	0.83	"	0.80			
46	27/05/03	1.80	"	1.75			400.00
47	28/05/03	1.75	"	1.67			850.00
48	29/05/03	1.82	"	1.70			700.00
49	30/05/03	0.28	"	0.30			
50	31/05/03	1.00	"	0.97			
51	01/06/03	2.15	"	2.08			750.00
52	02/06/03	0.17	"	0.17			
53	04/06/03	1.00	"	0.98			
54	06/06/03	0.53	"	0.43			
55	07/06/03	0.22	"	0.25			
56	09/06/03	0.83	"	0.80			
57	10/06/03	0.17	FALSE	0.00			1450.00
58	11/06/03	2.58	"	2.50			
59	12/06/03	1.05	"	1.00			
60	14/06/03	0.22	"	0.17			
61	15/06/03	0.45	"	0.37			
62	16/06/03	0.58	"	0.52			
63	17/06/03	0.32	"	0.33			
64	18/06/03	1.62	"	1.58			
	Total	59.72		36.93			16580.00

A2.4 Consumers' List

Consumers have been classified on the basis of alternative sources used, number of employees (Nos.), monthly electric bill (Tk.), connected load (kW) and industry area (sft) shown in Table 4.6 then with location listed and have been shown in Table A2.4.

Table A2.4: Consumers' list with classes

Consumer ID. No.	Consumer classes basis on					Consumer location
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)	
1	G	J	N	R	Z	Konapara, Demra
2	H	I	L	P	X	Palashpur, Dania
3	H	K	N	R	Z	Bhangapress, Kazlarpar, Demra
4	H	I	L	P	X	Dania
5	G	I	L	P	X	South Dania
6	F	K	N	R	Z	Konapara, Matuail, Demra
7	F	I	M	P	X	South Dania
8	F	I	L	P	X	Dania
9	F	K	N	R	Z	Konapara, Matuail, Demra
10	F	I	M	P	X	Dania
11	G	J	N	Q	Y	Dania
12	G	J	M	P	Y	Dania
13	G	J	N	R	Z	Kazlarpar, Demra
14	H	I	L	P	X	Dania
15	H	J	M	Q	Y	Dania
16	H	I	L	P	X	Satish Sarker Road, Gandaria
17	H	I	L	P	X	West Jurain
18	H	I	M	P	X	Satish Sarker Road, Gandaria

Table A2.4: Consumers' list with classes (continued)

Consumer ID. No.	Consumer classes basis on					Consumer location
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)	
19	H	I	M	P	X	DIT Plot, Gandaria
20	G	I	M	P	X	Satish Sarker Road
21	H	K	N	Q	Y	Satish Sarker Road
22	F	K	N	Q	Y	Satish Sarker Road
23	H	I	L	P	X	Karimullarbag
24	H	I	L	P	X	Satish Sarker Road, Gandaria
25	G	I	M	Q	X	DIT Plot, Gandaria
26	H	I	M	P	X	Satish Sarker Road, Gandaria
27	H	I	M	P	X	Satish Sarker Road, Gandaria
28	F	I	L	P	X	Dhalkanagar
29	G	I	L	P	X	Satish Sarker Road
30	G	J	N	R	Y	Dina Nath Sen Road, Gandaria
31	H	J	N	R	X	Dina Nath Sen Road, Gandaria
32	F	K	N	R	Y	Karimullarbag
33	F	I	N	Q	X	Karimullarbag
34	G	I	L	P	X	Gurain Graveyard
35	G	I	M	Q	X	Dina Nath Sen Road, Gandaria
36	G	J	N	Q	Z	Dina Nath Sen Road, Gandaria
37	G	J	N	Q	Z	Dhalkanagar Lane
38	G	I	M	Q	Z	Dhalkanagar Lane
39	H	I	L	P	X	Dhalkanagar Lane
40	G	I	M	Q	X	Satish Sarker Road
41	G	I	M	Q	Y	Mirhazirbag
42	H	I	M	Q	Y	Mirhazirbag
43	H	I	L	P	X	Mirhazirbag

Table A2.4: Consumers' list with classes (continued)

Consumer ID. No.	Consumer classes basis on					Consumer location
	Alternative sources used	Employees' Nos.	Monthly electric bill (Tk.)	Connected load (kW)	Industry area (sft)	
44	G	I	M	P	X	Mirhazirbag
45	H	I	N	R	Z	Mirhazirbag
46	H	I	N	Q	Z	BSCIC Industrial Estate, Tongi
47	F	J	M	Q	Z	BSCIC Industrial Estate, Tongi
48	F	K	N	R	Z	Jhamur, Rajfulbari, Savar
49	H	I	L	P	X	Free School Street, Kathalbagan
50	H	I	M	P	X	Free School Street, Kathalbagan
51	F	I	M	P	X	Free School Street, Kathalbagan
52	G	I	M	Q	X	Mirpur Road
53	G	I	L	P	X	Kathalbagan

APPENDIX 3

A3.1 FUEL INFORMATION

The price of furnace oil is 26 Tk per litre. Bangladesh Petroleum Corporation produces liquefied petroleum gas or LPG and furnace oil. The Bangladesh Energy Regulatory Commission approves the Bangladesh Petroleum Corporation's proposal. The demand for LPG in the country is around 80,000 tones per year. The liquid gas is mostly used by urban consumers in most district towns where there is no piped gas supply, as well as by light engineering workshops. The BPC produces around 2.5-3 lakh tones of furnace oil annually at the Eastern Refinery when it refines crude oil to produce diesel, kerosene and petrol. The four major fuel oils are- diesel, kerosene, octane and petrol [7].

APPENDIX 4

A4.1 ELECTRICITY TARIFF

Electricity tariff rates have been shown in Table A4.1. The following tariffs were effective from March 1, 2012 [8].

Table A4.1: Electricity tariff rates

SL. No.	Class of tariff	Type of consumer	Slot of unit (kWh)	Rate per unit
			Hr.	Tk.
1	C	Low tension and industry	Flat rate	6.02
			Off peak (From 23:00 to 05:00 Hr.)	5.16
			Peak (From 17:00 to 23:00 Hr.)	7.33
2	E	Commercial	Flat rate	7.79
			Off peak (From 23:00 to 05:00 Hr.)	6.25
			Peak (From 17:00 to 23:00 Hr.)	10.26
3	F	Medium voltage General use (11 kV)	Flat rate	5.90
			Off peak (From 23:00 to 05:00 Hr.)	5.16
			Peak (From 17:00 to 23:00 Hr.)	8.08

APPENDIX 5

SAMPLE COST DETERMINATION

A5.1 SAMPLE CALCULATION

One sample calculation for one consumer (ID. no. 06) to evaluate the losses of power interruption has been shown in Appendix 5.

A5.1.1 Raw Materials under Process Damage Costs

It can be obtained using equation (2.1):

Raw materials under process damage costs (Tk.),

$$C1 = \{P_{mu} \times G(d)_{mu}\} \quad \text{Tk.} \qquad \text{(A5.1)}$$

$= (0.00 \times 0)$ Tk. (By putting values in equation A5.1)

= 0.00 Tk.

Here, Pmu = Price of raw materials under process, Tk.

= 0.00 Tk. As nothing damaged under process as shown in Table 3.3.

G(d)mu = Damage function of raw materials under process

= 0. where, if any damages then it will be 1 otherwise 0. (As nothing was damaged under process as shown in Table 3.3.)

Amount of raw materials under process damage = 0. It has been shown in Table 3.3.

It can be obtained using equation (2.2):

So, raw materials under process damage costs per hour of interruption (Tk.),

$$\overline{C1} = \left(\frac{C1}{Twi}\right) \quad \text{Tk.}$$

$$= \left(\frac{\text{C1o}}{\text{Ti}}\right) \quad \text{Tk.} \qquad \text{(A5.2)}$$

$$\overline{C1} = \left(\frac{C1}{Twi}\right) \quad \text{Tk.}$$

$= \left(\frac{0.00}{59.87} \right)$ Tk. = 0.00 Tk. (By putting values in equation A5.2)

Here, Twi = Whole power interruption period, Hr.

= 59.87 Hr.

Ti = Power interruption period during the observation period, Hr.

= 59.87 Hr. (As shown in Table 3.2 for consumer ID. no. 06)

It can be obtained using equation (2.3):

Raw materials under process damage costs during the observation period (Tk.), $C1o = \left(\overline{C}1 \times Ti \right)$ Tk. (A5.3)

$= (0.00 \times 59.87)$ Tk. (By putting values in equation A5.3)

= 0.00 Tk.

It can be obtained using equation (2.4):

And raw materials under process damage costs per interruption (Tk.),

$$C1i = \left(\frac{C1o}{Ni} \right) \text{ Tk.} \quad (A5.4)$$

$= \left(\frac{0.00}{106} \right)$ Tk. (By putting values in equation A5.4)

= 0.00 Tk.

where, Ni = Number of total interruption during the observation period, Nos.

= 106 Nos. (As shown in Table 3.2 for consumer ID. no. 06)

A5.1.2 Alternative Source Usage Costs

It can be obtained using equation (2.5):

Alternative source usage costs (Tk.),

$$C2 = \left[\sum_{i=0}^{Nas} \left[\begin{array}{l} (Pas - Sas) + \\ \left\{ Cf \times (Nia \times Tia) \times \left(\frac{Tas}{Ti} \right) \right\} + \\ \{ C4_{as} \times G(d)as \} \end{array} \right]_i \right] \text{ Tk.} \quad (A5.5)$$

The Number of used alternative sources, capacity and fuel costs of alternative sources' are to be collected from the consumer.

Here, Nas = Number of used alternative source, Nos.

= 1 Nos. (shown in Table 3.6)

Pas = Price of an alternative source, Tk.

= 2525000.00 Tk. (shown in Table 3.6)

Sas = Salvage value of respective alternative source, Tk.

= 25000.00 Tk. (shown in Table 3.6)

Tas = Alternative source usage period, Hr.

= 60.17 Hr. (shown in Table 4.3)

It can be obtained using equation (2.6):

Fuel cost per unit time (Tk.),

$$Cf = \left[\begin{array}{l} \{Diesel(Ltr./Hr.)\} \times \\ \{Price(Tk./Ltr.)\} \times \left(\frac{Tas}{Ti} \right) \end{array} \right] \text{ Tk.} \qquad (A5.6)$$

$$= \left\{ (25) \times (70) \times \left(\frac{60.17}{59.87} \right) \right\}$$ Tk. (By putting data shown in Table 3.6 in equation A5.6)

= 1758.77 Tk.

Diesel = 25 (Ltr / Hr.) (shown in Table 3.6)

Price = 70 (Tk. / Ltr.) (shown in Table 3.6)

It can be obtained using equation (2.7):

Average period of an interruption will be

$$\text{Tia} = \left(\frac{\text{Ti}}{\text{Ni}}\right) \quad \text{(Hr. / int.)} \qquad \text{(A5.7)}$$

$$= \left(\frac{59.87}{106}\right)$$ (Hr. / int.) (by putting data shown in Table 3.2 in equation A5.7)

= 0.56 (Hr. / int.)

G(d)as = Damage function of the alternative source as a repairable item

= 1.

If any damages then it will be 1 otherwise 0. (As used alternative source faced trouble and required repair shown in Table 3.7).

It can be obtained using equation (2.8):

The estimated number of interruption during the life of the used alternative source (Nos.),

$$\text{Nia} = \{(\text{Ni} + \text{Nirp}) \times \text{G (p)}\} \quad \text{Nos.}$$

$$= \left[\left\{\text{Ni} + \left(\frac{(\text{Trla} \times 365) - \text{To}}{\text{To}}\right) \times \text{Ni}\right\} \times \text{G(p)}\right] \quad \text{Nos.} \qquad \text{(A5.8)}$$

$$= \left[\left\{106 + \left(\frac{(20 \times 365) - 64}{64}\right) \times 106\right\} \times 0.60\right]$$ Nos. (By putting data in equation A5.8).

= 7254.38 ≈ 7254 Nos.

G (p) = probability function of happening occurrence

= 60 % = 0.60 (assumed). As happening of occurrence may be or may not so some % of uncertainty have been considered (assuming 40% approx.)

It can be obtained using equation (2.9):

Number of interruption during the rest of the observation period of the used alternative source (Nos.),

$$Ni_{rp} = \left[\left\{\frac{(Trla \times 365) - To}{To}\right\} \times Ni\right] \quad \text{Nos.} \qquad \text{(A5.9)}$$

Tla = Total life span of used alternative source, Yr.

= 30 Yr. (shown in Table 3.7)

Reduced life due to repair of used alternative source (Yr.),

Trla = 20 Yr. (shown in Table 3.7)

$= (\mathrm{Trla} \times 365)$ days.

To = Observation period, days

= 64 days. (shown in Table 3.3)

It can be obtained using equation (2.10):

Cost component for the trouble of the alternative source due to power interruption (Tk.),

$$\mathrm{C4as} = (\mathrm{Crcta} + \mathrm{CrLa}) \quad \text{Tk.} \qquad \text{(A5.10)}$$

It can be obtained using equation (2.11):

Total cost of repair of the alternative source (Tk.)

$$\mathrm{Crcta} = (\mathrm{Nra} \times \mathrm{Crca}) \quad \text{Tk.} \qquad \text{(A5.11)}$$

Here, C_{rca} = Cost per repair for the alternative source, Tk.

= 600.00 Tk. (shown in Table 3.7)

It can be obtained using equation (2.12):

The total number of possible repair during the life time of the alternative source (Nos.) will be

$$Nra = (Nraop + Nrar) \quad \text{Nos.}$$

$$= \left[Nraop + \left\{ \left(\frac{Nraop}{Ni} \right) \times (Nia - Ni) \right\} \right] \quad \text{Nos.}$$

$$= \left\{ \left(\frac{Nraop}{Ni} \right) \times Nia \right\} \quad \text{Nos.} \qquad \text{(A5.12)}$$

$$= \left\{ \left(\frac{1}{106} \right) \times 7254 \right\}$$ Nos. (By putting values in equation A5.12)

= 68.434 Nos.

But in practice, it is not acceptable and according to the opinion of the consumer, this may be 4 or 5 numbers during the life time of the alternative source.

So, total number of possible repair during the life time of the alternative source is taken as

Nra = 5 Nos.

Nraop = Number of repair of the alternative source during observation period, Nos.

= 1 Nos. (Data shown in Table 3.7)

Nrar = Number of repair of the alternative source during rest of observation period, Nos.

By putting these values in question (A5.11), Crcta can be obtained as

$$\mathrm{Crcta} = (5 \times 600.00) \quad \text{Tk.}$$

= 3000.00 Tk.

It can be obtained using equation (2.13):

Loss due to decrease of the life span of the alternative source (Tk.),

$$C_{rLa} = \left[\left\{\frac{(Tla - Trla)}{Tla}\right\} \times (P_{as} - Sas)\right] \quad \text{Tk.} \qquad \text{(A5.13)}$$

$$C_{rLa} = \left[\left\{\frac{(30-20)}{30}\right\} \times (2525000.00 - 25000.00)\right] \quad \text{Tk.}$$

(By putting values in equation A5.13)

= 816666.67 Tk.

Cost component for the trouble of the alternative source due to power interruption (Tk.),

$$\mathrm{C4as} = (3000.00 + 816666.67) \quad \text{Tk.}$$

(By putting values in equation A5.10)

= 819666.67 Tk.

By putting the obtained required values in equation (A5.5) it can be obtained value of C2 for the whole period,

$$\mathrm{C2} = \left[\sum_{i=0}^{\mathrm{Nas}} \begin{bmatrix} (\mathrm{Pas} - \mathrm{Sas}) + \\ \left\{\mathrm{Cf} \times (\mathrm{Nia} \times \mathrm{Tia}) \times \left(\frac{\mathrm{Tas}}{\mathrm{Ti}}\right)\right\} + \\ \{\mathrm{C4}_{as} \times \mathrm{G(c)as}\} \end{bmatrix}_i\right] \quad \text{Tk.}$$

$$= \left[\sum_{i=0}^{1} \begin{bmatrix} (2525000 - 25000) + \\ \left\{ 1758.77 \times (7254 \times 0.56) \times \left(\frac{60.17}{59.87} \right) \right\} \\ + (819666.67 \times 1) \end{bmatrix}_1 \right] \quad \text{Tk.}$$

(By putting values in equation A5.5)

$= [10561699.67]_1$ Tk.

= 10561699.67 Tk.

It can be obtained using equation (2.14):

So cost due to the use of alternative source per hour of interruption (Tk.),

$$\overline{C2} = \left\{ \frac{C2}{(Nia \times Tia)} \right\} \quad \text{Tk.}$$

$$= \left(\frac{\mathrm{C2o}}{\mathrm{Ti}} \right) \quad \text{Tk.} \qquad \text{(A5.14)}$$

$$\overline{C2} = \left\{ \frac{10561699.67}{(7254 \times 0.56)} \right\}$$ Tk. (By putting values in equation A5.14)

= 2577.82 Tk.

It can be obtained using equation (2.15):

Cost due to the use of alternative source during the observation period (Tk.),

$$C2o = \left(\overline{C2} \times Tas \right) \quad \text{Tk.} \qquad \text{(A5.15)}$$

$= (2581.89 \times 60.17)$ Tk. (By putting values in equation A5.15)

= 155107.53 Tk.

It can be obtained using equation (2.16):

And cost due to the use of alternative source per interruption (Tk.),

$$\mathrm{C2i} = \left(\frac{\mathrm{C2o}}{\mathrm{Ni}} \right) \quad \text{Tk.} \qquad \text{(A5.16)}$$

$= \left(\frac{155107.53}{106} \right)$ Tk. (By putting values in equation A5.16)

= 1463.28 Tk.

A5.1.3 Loss due to Reduced Production and Additional Wage Costs

It can be obtained using equation (2.17):

If production is kept off during power interruption then loss due to reduced production (Tk.) becomes as

$$C3_{rp} = \left[\sum_{i=0}^{Neo} \{ Li \times (Ti - Tas) \} \right] \quad \text{Tk.} \qquad \text{(A5.17)}$$

= 0.00 Tk. (By putting values in equation A5.17)

where, Li = Loss due to reduced production per hour of interruption, Tk.

Since, 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.

It can be obtained using equation (2.18):

Additional wage costs (Tk.),

$$C3aw = \left\{ \sum_{i=0}^{Neo} (W_i \times Tot) \right\} \quad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ W_i \times (Ti - Tas) \} \right] \quad \text{Tk.} \qquad \text{(A5.18)}$$

= 0.00 Tk. (By putting values in equation A5.18)

where, Wi = Wage of ith worker per hour, Tk.

It can be obtained using equation (2.19):

Total over time (Hr.),

$$\text{Tot} = (\text{Ti - Tas}) \quad \text{Hr.} \qquad \text{(A5.19)}$$

= 0 Hr. (By putting data shown in Table 4.2 in equation A5.19)

Here, Neo = Number of employees' done over time duty for manually operated machines or number of machine unit for automated machines, Nos.

= 0 Nos. (As it needed no extra works because, industry used to run within the schedule time.)

It can be obtained using equation (2.20):

So, Loss due to reduced production and additional wage costs (Tk.),

$$C3 = (C3rp + C3aw) \quad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ Li \times (Ti - Tas) \} + \sum_{i=0}^{Neo} (Wi \times Tot) \right] \quad \text{Tk.}$$

$$= \left[\sum_{i=0}^{Neo} \{ (Li + Wi) \times (Ti - Tas) \} \right] \quad \text{Tk.} \qquad \text{(A5.20)}$$

$$= (0.00 + 0.00) \quad \text{Tk. (By putting values in equation A5.20)}$$

= 0.00 Tk.

It can be obtained using equation (2.21):

So, Loss due to reduced production and additional wage cost per hour of interruption (Tk.),

$$\overline{C3} = \left(\frac{C3}{Twi} \right) \quad \text{Tk.}$$

$$= \left(\frac{C3o}{Ti} \right) \quad \text{Tk.} \qquad \text{(A5.21)}$$

$$\overline{C3} = \left(\frac{C3}{Twi} \right) \quad \text{Tk.}$$

$$= \left(\frac{0.00}{59.87} \right) \quad \text{Tk. (By putting values in equation A5.21)}$$

= 0.00 Tk.

It can be obtained using equation (2.22):

Loss due to reduced production and additional wage cost during the observation period (Tk.),

$$C3o = \left(\overline{C3} \times Ti \right) \quad \text{Tk.} \qquad \text{(A5.22)}$$

$$= (0.00 \times 59.87) \quad \text{Tk. (By putting values in equation A5.22)}$$

= 0.00 Tk.

It can be obtained using equation (2.23):

And loss due to reduced production and additional wage cost per interruption (Tk.),

$$C3i = \left(\frac{C3o}{Ni}\right) \quad \text{Tk.} \qquad (A5.23)$$

$$= \left(\frac{0.00}{106}\right) \quad \text{Tk. (By putting values in equation A5.23)}$$

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

A5.1.4 Equipments' Trouble and Damage Costs

It can be obtained using equation (2.24):

Equipments' trouble and damage costs (Tk.),

$$C4 = \left[\sum_{k=0}^{Ntd}\left[\left\{C4_r \times G(d)r\right\} + \left\{C4_{ir} \times G(d)ir\right\}\right]_k\right] \quad \text{Tk.} \quad (A5.24)$$

It can be obtained using equation (2.25):

Cost component due to the trouble of the repairable item (Tk.),

$$C4r = (Crct + CrL) \quad \text{Tk.} \qquad (A5.25)$$

G(d)r = Damage function of the repairable item

= 1.

where, if any damages then it will be 1 otherwise 0. (data shown in Table 3.4)

$C4_{ir}$ = Cost component due to the damage of the irreparable item, Tk.

= 0.00 Tk. (data shown in Table 3.3)

G(d)ir = Damage function of the irreparable item

= 0.

If any damages then it will be 1 otherwise 0. (data shown in Table 3.3)

It is seen from the questionnaire filled up by this respondent that one single phase motor has been damage due to the frequent power interruption which is a repairable item.

Here, Ntd = Number of equipments which faced trouble and damaged, Nos.

= $(1+0)$ Nos. (data shown in Table 3.4 and Table 3.3 respectively)

= 1 Nos.

It can be obtained using equation (2.26):

Total costs of repair (Tk.),

$$Crct = (Nr \times Crc) \quad \text{Tk.} \tag{A5.26}$$

where, C_{rc} = Costs per repair, Tk.

= 450.00 Tk. (data shown in Table 3.4)

It can be obtained using equation (2.27):

The total number of possible repair during the life time of the repairable item (Nos.), $Nr = (Nrop + Nrrp)$ Nos.

$$= \left[Nrop + \left\{ \frac{Nrop}{Ni} \times (Niri - Ni) \right\} \right] \quad \text{Nos.}$$

$$= \left\{ \left(\frac{Nrop}{Ni} \right) \times Niri \right\} \quad \text{Nos.} \tag{A5.27}$$

Here, Nrop = Number of repair during observation period of the repairable item, Nos.

= 1 Nos. (data shown in Table 3.4)

It can be obtained using equation (2.28):

Nrrp = Number of repair of the reparable item during rest period, Nos.

$$= \left\{ \left(\frac{Nrop}{Ni} \right) \times (Niri - Ni) \right\} \quad \text{Nos.} \tag{A5.28}$$

It can be obtained using equation (2.29):

The estimated number of interruption during the life time of the repairable item (Nos.), $Niri = \{(Ni + Nin) \times G(p)\}$ Nos.

$$= \left[\left\{ Ni + \left(\frac{(Trl \times 365) - To}{To} \right) \times Ni \right\} \times G(p) \right] \quad \text{Nos.} \tag{A5.29}$$

$$= \left[\left\{ 106 + \left(\frac{(13 \times 365) - 64}{64} \right) \times 106 \right\} \times 0.6 \right]$$ Nos. (By putting values in equation A5.29)

= 4758 Nos.

It can be obtained using equation (2.30):

Number of interruption during the rest of the observation period for the repairable item (Nos.),

$$Ni_n = \left[\left\{\frac{(Trl \times 365) - To}{To}\right\} \times Ni\right] \quad \text{Nos.} \qquad (A5.30)$$

Reduced life of the reparable item due to power interruption and repair (Yr.),

= Trl Yr.

$= (Trl \times 365)$ days.

G (p) = probability function of happening occurrence

= 60 % = 0.6 (assumed). As happening of occurrence may be or may not so some % of uncertainty has been considered (assuming 40% approx.)

So, now by putting all values in equation (A5.27), it can be obtained value of Nr

$$Nr = \left\{\left(\frac{Nrop}{Ni}\right) \times Niri\right\} \quad \text{Nos.}$$

$$= \left\{\left(\frac{1}{106}\right) \times 4758\right\} \quad \text{Nos.}$$

= 44.88 Nos.

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 no. of possible repair during the life time of the motor is taken as,

Nr = 4.4884 ≈ 4 Nos.

By putting these values in question (A5.26) it can be obtained the value of Crct as follows

$$\text{Crct} = (\text{Nr} \times \text{Crc}) \quad \text{Tk.}$$

$$= (4 \times 450) \quad \text{Tk.}$$

= 1800.00 Tk.

It can be obtained using equation (2.31):

Loss due to decrease of the life span of the repairable item (Tk.),

$$C_{rL} = \left[\left\{ \left(\frac{Tri - Trl}{Tri} \right) \times P_{ri} \right\} - Sri \right] \quad \text{Tk.} \qquad \text{(A5.31)}$$

$$C_{rL} = \left[\left\{ \left(\frac{15 - 13}{15} \right) \times 4000 \right\} - 400 \right]$$ Tk. (By putting values in equation A5.31)

= 133.33 Tk.

Here, Tri = The life span of the repairable item, Yr.

= 15 Yr. (data shown in Table 3.4)

Trl = Reduced life of repairable item, Yr.

= 13 Yr. (data shown in Table 3.4)

Pri = The price of repairable item, Tk.

= 4000.00 Tk. (data shown in Table 3.4)

Sri = Salvage value of repairable item, Tk.

= 400.00 Tk. (data shown in Table 3.4)

By putting the required values in equation (A5.25) then in equation (A5.24), it can be obtained the value of C4.

$$\text{C4r} = (\text{Crct} + \text{CrL}) \quad \text{Tk.}$$

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

= 1933.33 Tk.

$$C4 = \left[\sum_{k=0}^{Ntd} \left[\left\{ C4_r \times G(d)r \right\} + \left\{ C4_{ir} \times G(d)ir \right\} \right]_k \right] \quad \text{Tk.}$$

$$C4 = \left[\sum_{k=0}^{1} \left[\left\{ 1933.33 \times 1 \right\} + \left\{ 0.00 \times 0 \right\} \right]_1 \right] \quad \text{Tk.}$$

$$= [1933.33]_1 \quad \text{Tk.}$$

= 1933.33 Tk.

It can be obtained using equation (2.32):

So, equipments' trouble and damage costs per hour of interruption (Tk.),

$$\overline{C4} = \left\{ \frac{C4}{(Niri \times Tia)} \right\} \quad \text{Tk.}$$

$$= \left(\frac{\text{C4o}}{\text{Ti}} \right) \quad \text{Tk.} \qquad \text{(A5.32)}$$

$$\overline{C4} = \left\{ \frac{C4}{(Niri \times Tia)} \right\} \quad \text{Tk.}$$

$$= \left\{ \frac{1933}{(4758 \times 0.56)} \right\}$$ Tk. (By putting values in equation A5.32)

$= 0.7195$ Tk. ~ 0.72 Tk.

It can be obtained using equation (2.33):

Equipments' trouble and damage costs during the observation period (Tk.),

$$C4o = \left(\overline{C4} \times Ti \right) \quad \text{Tk.} \qquad \text{(A5.33)}$$

$= (0.72 \times 59.87)$ Tk. (By putting values in equation A5.33)

$= 43.11$ Tk.

It can be obtained using equation (2.34):

And equipments' trouble and damage costs per interruption (Tk.),

$$\text{C4i} = \left(\frac{\text{C4o}}{\text{Ni}} \right) \quad \text{Tk.} \qquad \text{(A5.34)}$$

$$= \left(\frac{43.11}{106} \right)$$ Tk. (By putting values in equation A5.34)

$= 0.41$ Tk.

A5.2.1 Total Cost of Power Interruption

It can be obtained using equation (2.35):

Therefore, the sum of all four cost components gives the total cost of interruption during the whole period (Tk.),

$$\text{C} = (\text{C1} + \text{C2} + \text{C3} + \text{C4}) \quad \text{Tk.} \qquad \text{(A5.35)}$$

$C = (0.00 + 10561699.7 + 0.00 + 1933.33)$ Tk. (By putting values in equation A5.35)

$$C = 10563633.00 \text{ Tk.}$$

It can be obtained using equation (2.36):

Total costs of interruption of power during the observation period (Tk.),

$$\text{Co} = (\text{C1o} + \text{C2o} + \text{C3o} + \text{C4o}) \quad \text{Tk.} \qquad \text{(A5.36)}$$

$$Co = (0.00 + 155107.53 + 0.00 + 43.11) \quad \text{Tk. (By putting values in equation A5.36)}$$

$$\text{Co} = 155150.64 \text{ Tk.}$$

It can be obtained using equation (2.37):

And the total costs per hour of interruption of power (Tk.),

$$\overline{C} = \left(\overline{C1} + \overline{C2} + \overline{C3} + \overline{C4}\right) \quad \text{Tk.}$$

$$= \left(\frac{\text{Co}}{\text{Ti}}\right) \quad \text{Tk.}$$

$$= \left(\frac{\text{C}}{\text{Twi}}\right) \quad \text{Tk.} \qquad \text{(A5.37)}$$

$$\overline{C} = \left(\overline{C1} + \overline{C2} + \overline{C3} + \overline{C4}\right) \quad \text{Tk.}$$

$$= (0.00 + 2577.82 + 0.00 + 0.72) \quad \text{Tk. (By putting values in equation A5.37)}$$

$$= 2578.54 \text{ Tk.}$$

It can be obtained using equation (2.38):

Total costs of power per interruption (Tk.),

$$\text{Ci} = (\text{C1i} + \text{C2i} + \text{C3i} + \text{C4i}) \quad \text{Tk.}$$

$$= \left(\frac{\text{Co}}{\text{Ni}}\right) \quad \text{Tk.;}$$

$$= \left(\frac{C}{Niri}\right) \quad \text{Tk.} \qquad \text{(A5.38)}$$

$$\text{Ci} = (\text{C1i} + \text{C2i} + \text{C3i} + \text{C4i}) \quad \text{Tk.}$$

$$= (0.00 + 1463.28 + 0.00 + 0.41) \quad \text{Tk. (By putting values in equation A5.38)}$$

$$= 1463.69 \text{ Tk.}$$

A5.3.1 Price of Per Unit Energy

It can be obtained using equation (2.39):

Therefore, price per unit energy (Tk.),

$$Cu = \left(\frac{Co}{Ens}\right) \quad \text{Tk.} \qquad \text{(A5.39)}$$

It can be obtained using equation (2.40):

where, total energy not served from national grid source (kWh),

$$Ens = (Pt \times Ti) \quad \text{kWh.} \qquad \text{(A5.40)}$$

Here, Pt = Connected load, kW

= 320.00 kW. (data shown in Table 3.1)

$Ens = (320.00 \times 59.87)$ kWh. (By putting values in equation A5.40)

= 19158.40 kWh.

Therefore, price per unit electric energy (Tk.),

$$Cu = \left(\frac{155150.64}{19158.40}\right) \quad \text{Tk. (By putting values in equation A5.39)}$$

= 8.10 Tk.