EVALUATION OF COST OF UNSERVED ENERGY IN SRI LANKA

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ABSTRACT

Quantitative reliability evaluation is an important aspect of power system planning and operation. The indices produced in these applications are utilised in a wide range of management decisions throughout a utility. One issue, which is often debated, is the cost associated with a particular level of reliability. In order to make this argument complete, it is necessary to examine the benefit of having a particular level of reliability based on the losses incurred as a result of losing the power supply. Estimates of the impacts of interruptions in service can be obtained by assessing the losses incurred by different customer types and categories. These data can then be used to calculate cost of energy not served in the selected utility service area. This paper presents the results of an investigation of direct, short-term impacts and associated costs incurred by three categories of electrical consumers, industrial, general purpose and household consumers, resulting from interruptions to the power supply.

INTRODUCTION

The primary function of a modern power system is to supply electricity to the customers at a reasonable level of reliability and quality. The specification of what constitutes a reasonable level of reliability is a difficult problem of balancing the need for power supply and the cost involved. The conventional method of calculating an acceptable level of reliability is mainly based on judgement and experience. Significant increase in energy costs, construction costs, and interest rates, recognition of conservation and environmental concerns have emphasised the need for a more rational and consistent approach to determine the acceptable reliability levels.

The term "reliability" applied to complex power systems involves two basic aspects : system adequacy and system security. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer demand whereas security relates to the ability of the system to respond to disturbances arising within the system [2]

System adequacy studies are an integral part of overall reliability assessment. The evaluation of reliability cost through the identification analysis of criteria and methods used to predict and quantify reliability levels has significantly progressed during the past decade. By comparison, the assessment of reliability worth is in its infancy with most approaches used providing only an indirect or a boundary evaluation. This is because the assessment of societal worth of electric service reliability is a very complex task. One method, which has been used to successfully establish reliability worth estimates is to survey electrical consumers,

sector by sector to determine the costs or losses resulting from electric service interruptions [3].

The main objective of this study is to determine the average cost of not serving electrical energy to consumers in different sectors, through a consumer survey.

CONSUMER SURVEY

There have been a number of approaches used in the literature to determine the customer costs of interruptions through direct and indirect means. One of such methods is evaluation through customer surveys and associated analysis of different consumer groups. The study discussed in this paper used a customer survey based on regular postal mail for general purpose consumer sector and industrial sector while domestic sector was addressed through personal interviews.

Sample Selection

The distribution of sectoral consumption of electricity in Sri Lanka is as shown in Figure 1 [5,8].

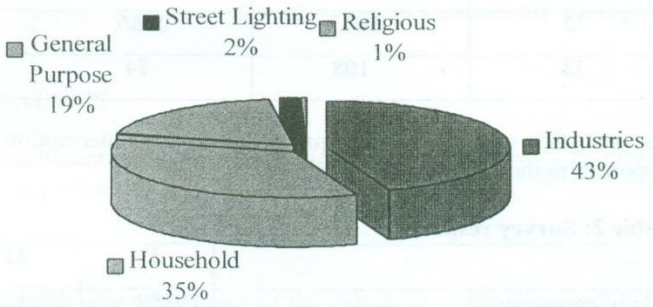

Figure 1: Distribution of Sectoral Electricity Consumption –1997

Source: Ceylon Electricity Board

The selection of the sample was entirely based on the energy consumption levels of each of the above categories of consumers giving due consideration to sub-groups within each of these categories [4]. Also the availability and the level of access to data relating to these consumer groups played an important role in sample selection.

Three categories of industrial consumers and three categories of General-Purpose consumers were separately addressed in the study along with one household consumer category. They are,

I1, G1- Industrial 1/ General Purpose 1 Contract Demand <42kVA supplied at 400/230V
I2, G2- Industrial 2/ General Purpose 2 Contract Demand >42kVA supplied at 400/230V
I3, G3- Industrial 3/ General Purpose 3 supplied at 11/33/132kV

The sample was selected based on the availability of information in the consumer database as given in Table 1[7].

Table 1: Number of consumers and sample sizes

Category	No of Accounts 1997	No of consumers in the computer database	Selected sample size
General Purpose			
G1	202509	101	86
G2	1346	1283	641
G3	26	24	23
Industrial			
I1	19889	423	423
I2	3013	2366	1253
I3	108	74	74

The statistics related to the requests for supply interruption information and responses to them are shown in Table 2.

Table 2: Survey responses

	I1	**I2**	**I3**
No of consumers	19889	3013	108
No of questionnaires Mailed	423	1253	74
No of completed questionnaires Received	10	67	13
	G1	**G2**	**G3**
No of consumers	202509	1346	26
No of questionnaires Mailed	86	641	23
No of completed questionnaires Received	8	58	-

Questionnaire

Three separate questionnaires giving due consideration to specific details of each category, were prepared for industrial, general purpose and domestic consumers to obtain the cost of electricity interruption information.

The information requested from the consumers included estimates of the costs per kW for different supply interruption periods such as momentary, 1 minute, 30minutes, 1hour, 4hours, 12hours and 24hours.

CALCULATION METHODOLOGY

The values obtained for each type of industrial consumers were weighted based on their relative contribution towards value addition in the national economy, to determine the average cost of electricity supply losses within each industry group. Then these values for each group were further weighted based on their relative energy consumption patterns to obtain the final average value for the industrial sector.

The same approach was employed to determine the average value of cost of electricity supply losses in the general-purpose consumer sector with weighting factors based on relative energy consumption patterns. In the domestic sector equal weighting factors were used for all types of households during the calculations.

RESULTS & ANALYSIS

Data acquired for different categories of consumers were processed to fit into the above calculation requirements.

Industrial Sector

The cost data related to nine sub groups of the industrial sector directly obtained from the survey have been weighted in proportion to the value addition of each of these sub groups in the national economy. Table 3 shows these weighted averages of losses in each industrial sector tariff category (I1, I2 & I3).

Table 3: Interruption costs in the Industrial Sector

	Loss Incurred (Rs/kW)					
Duration	Momentary	30mins	1hour	4hour	8hour	24hour
Industrial 1	4.35	56.75	109.15	431.65	882.99	1790.24
Industrial 2	37.67	57.75	78.69	180.3	332.12	621.75
Industrial3	115.9	127.15	138.41	205.94	295.98	656.15

Later the average value corresponding to I1, I2 and I3 values was calculated by weighting each of them in proportion to the energy consumption within each of

these categories since the final impact of supply loss to the national economy will be in those proportions. Table 4 provides these weighting factors based on 1997 electricity consumption data.

Table 4: Energy consumption in different sub groups in Industrial Sector

	Energy Consumption (GWh)	Weighting Factors
Industrial 1	101.40	0.07
Industrial 2	805.00	0.56
Industrial3	524.00	0.37

The variation of cost of interruptions with duration of the interruption is shown in figure 2.

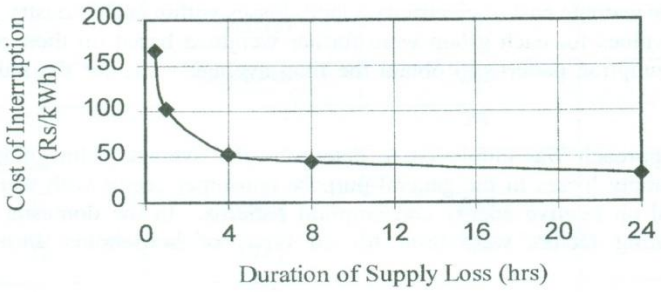

Figure 2: Variation of cost of interruption with its duration - Industrial Sector

General Purpose

The monetary values of losses obtained from the general purpose consumer sector through the survey were averaged giving equal weightage to all forms of General Purpose institutions due to unavailability of data on contributions to the national economy by individual subsectors. These weighted averages are given in Table 5.

Table 5: Interruption costs in the General Purpose Consumer Sector

	Loss Incurred (Rs/kW)						
Duration	momentary	10mins	30mins	1hour	4hour	12hour	24hour
General Purpose 1	8.07	246.85	511.67	1004	2278.8	4835.7	6430.2
General Purpose 2	302.03	310.14	333.91	370.2	569.74	1010.5	1331.1

Similar to the approach used in the industrial sector calculation of the average monetary values related to energy losses was based on weighting factors derived using 1997 consumption pattern. These weighting factors are given in Table 6.

Table 6: Energy consumption in different sub groups in General Purpose consumer Sector

	Energy Consumption (GWh)	Weighting Factors
General Purpose 1	389	0.65
General Purpose 2	214	0.35

The variation of cost of energy losses with duration of interruption is shown in Figure 3 for the General-Purpose category.

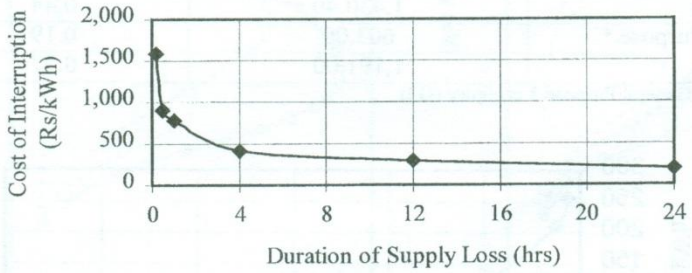

Figure 3: Variation of cost of interruption with its duration - General Purpose Consumer Sector

Domestic Sector

Data obtained for the domestic sector were averaged with all types of households given equal weightage. These final values are shown in Table 7 with the variation presented in Figure 4.

Table 7: Interruption costs in the Domestic Sector

Duration	30mins	1hour	4hour	8hour	24hour
Loss Incurred (Rs/kW)	16.26	50.16	196.23	226.31	341.27

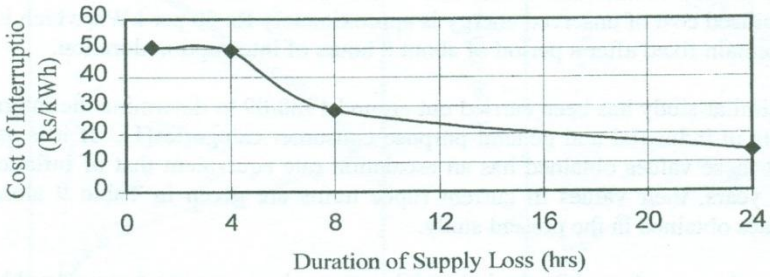

Figure 4: Variation of cost of interruption with its duration - Domestic Sector

General Analysis

Interruption costs in different sectors within the electricity industry can be weighted in proportion to their individual energy consumption levels to determine a single interruption cost for the whole electricity industry. These weighting factors are given in Table 8. The variation of the interruption costs with corresponding duration is given in Figure 5.

Table 8: Energy consumption in different sectors

	Energy Consumption (GWh)	Weighting Factors
Industrial	1,430.40	0.44
General Purpose *	603.00	0.19
Domestic	1,191.00	0.37

* Excludes General Purpose 3 category (G3)

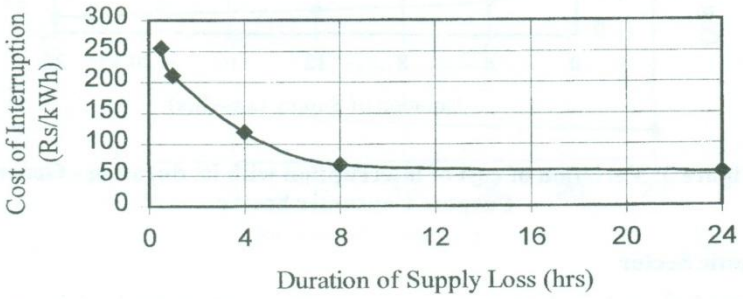

Figure 5: Variation of cost of interruption with its duration

It can be seen from all the graphs of interruption costs versus duration of interruption that the unit cost of supply loss gradually decreases with the duration and then stabilises. The average of the interruptions costs shown in figure 5 can be used as the per unit system unserved energy cost.

The survey results show that this value is Rs 140.72 per kWh whereas the stabilised cost of unserved energy is approximately Rs 50 per kWh which is likely to remain fixed after a period of about 8 hours of interruption duration.

A similar study has been carried out around 1988/89 to determine the interruption costs in industrial and general purpose consumer categories[1]. If it is assumed that these values obtained has an escalation rate equivalent that of inflation over the years, their values in current rupee terms are given in Table 9 along with values obtained in the present study.

It can be seen that while the industrial sector values agree to a considerable level, general-purpose consumer related values are approximately 10 to 25 times higher in the present study than those in the previous study.

Table 9: Comparison of results from previous and present studies

Industrial Sector					
Duration	*30 minutes*	*1 hour*	*4 hours*	*8 hours*	*24 hours*
Previous Study (Rs/kWh)	119.68	104.13	70.20	60.60	41.58
Present Study (Rs/kWh)	166.20	102.73	51.88	44.74	29.88
General Purpose					
Previous Study (Rs/kWh)		29.00	26.23	26.26	17.07
Present Study (Rs/kWh)	897.17	779.06	418.07	(*12hr*) 289.85	192.52

This clearly shows that the general-purpose consumers consisting of large commercial institutions now experience major losses due to power supply interruptions and it has escalated at a faster rate than the general rate of inflation. This may be largely due to rapid expansion of the commercial sector and higher energy intensity of activities carried out within these institutions in comparison to those around 10 years ago.

LIMITATIONS

The major limitation of the survey and the analysis is the absence of a large response to the set questionnaires in different sectors. This was particularly apparent in General Purpose Consumer Sector G3 category where the response was nil. Even in other sub sectors response rate was less than 10% of the total number of questionnaires mailed.

The cost of interruptions is entirely dependent on the estimates given by the individual respondents in the survey. The accuracy of these estimates is likely to vary from one respondent to another, which will have an impact on the final results.

CONCLUSIONS

The interruption cost estimates evaluated from this research project may be used in electrical system planning purposes in Sri Lanka bearing in mind the limitations of the consumer survey carried out. These values can used as a good guideline for generation planning or any related analysis in the absence a recently carried out study addressing the cost of supply interruptions. The dynamic nature of the unserved energy cost obtained in this can be effectively utilised in the calculations rather than using a single value across all interruption periods. Where necessary sectoral studies can be carried out using the unserved energy cost for the sector instead of using the average value for the whole electricity industry.

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