ESTIMATION OF CUSTOMERS DAMAGE FUNCTION BY QUESTIONNAIRE METHOD

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ABSTRACT

Financial compensation of customer interruption costs and its determination is the important issue in the new deregulated and restructured power system environment. Usually utility pay interruption costs of customers. The standard way to describe interruption costs is customer damage function (CDF) that determines relationship between interruption duration and its customer economic losses. This paper present a practical method to estimate CDF for domestic customers. Proposed method has been applied to estimation of CDF in a distribution network.

INTRODUCTION

Electric service interruption is unpleasant event and has various social, economic and psychological effects on the society. Customers and retailers contract for supply of electric service. In the contracts usually financial compensation of interruption is considered. Also utilities or wire companies are responsible for interruption to retailers and/or customers. From economic view, main challenge in this matter is determination of interruption cost. From reliability viewpoint customer interruption cost is important for utility because utilities with customer interruption and supply costs of electric service optimizes their costs and select best plan for expansion. Figure 1 show that if the utility invests correspond to "R*" the total cost of service reliability is in optimal point of investment in reliability.

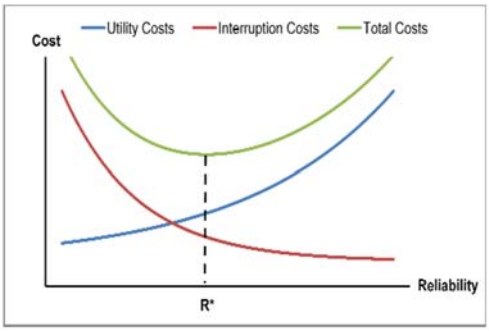

Figure 1. Valuing Reliability Benefits and Costs

Customers' economic losses as a result of reliability and power-quality problems can be summarized by what is called CDF. CDF explains relationship between interruption duration and its Customer economic losses and has key role in interruption cost determination. This idea was first suggested in 1994 by Goel and Billinton. They described the customer damage function as a simple linear equation relating average interruption cost to the duration of an interruption. They used data collected from customers to describe this function. In 1995, Keane and Sullivan suggested a more general form of the CDF – that could be used to predict interruption cost values from a number of variables that have been shown in interruption cost surveys to influence customer interruption costs. CDF is function of interruption attributes, customer characteristics, environmental attributes that Interruption attributes are factors such as interruption duration, season, time of day, and day of the week during which the interruption occurs. Customer characteristics include factors such as: customer type, customer size, business hours, household family structure, presence of interruption-sensitive equipment, and presence of back-up equipment. Environmental attributes include: temperature, humidity, storm frequency, and other external/climate conditions [1].

CDF determination is important issue in interruption cost evaluation. Many researches determined CDF from some methods for example in Ref. [2] discrete CDF for some sector of customer in Canada has been reported. CDF also is used in system studies as input [3,4].

The interruption cost determination has many difficulties in economic theories and techniques of calculation. It possible that the interruption cost is reported with various result dependent to many factors. Reference [5] includes a bibliography of many researches on the subject of interruption cost evaluation. Based on literature review, methods of determined interruption cost can be classified as follows:

macroeconomic indicators based methods

Interruption cost can be determined by dividing gross national product (GNP) by total power consumption [6]. This method is simple and inexpensive, but has very Unrealistic.

Case study based methods

In this method interruption cost estimate after a major event [7]. Result of this method is more accurate but major Interruption rarely occurs and method is expensive.

Market based method

Interruption costs are determined using data gathering on purchases of backup generation and subscriptions to interruptible rate options. Like the macroeconomic method, these data are relatively inexpensive to acquire [7].

Customer survey based method

In this method customer survey is used. Usually in this method interruption cost are calculated by questionnaire method. In this method willingness to pay (WTP) and Willingness to accept (WTA) are important that defined bellow [8]:

WTP: An approach to determine how many the consumers are willing to pay to avoid an outage.

WTP: An approach to determine how many the consumers would be willing to accept in compensation for an outage that has occurred.

PROPOSED METHOD FOR DETERMINATION OF CDF FOR DOMESTIC CUSTOMERS BASED ON QUESTIONNAIRE

CDF can be determined by interruption cost results. Proposed method uses from questionnaire to determination of WTP and WTA for customers, then CDF should be determined. Outage cost (OC) can be calculated from equation 1:

$$OC = \frac{WTP + WTA}{2} \quad \textbf{(1)}$$

In the designed questionnaire WTA and WTP is asked for outage duration: 30min and 2,4,8,16,24 hours and WTP is average of two parts, one is normalized WTP for 30min and 2,4,8,16,24 hours, another is maximum WTP for avoid of one hour interruption in day and night. With two part for WTA, this term can be had more accuracy. All of WTP and WTA normalized per hour. Usually The System Average Interruption Duration Index (SAIDI) that is the average outage duration for each customer served is less than 10 hours and it is suitable to estimate CDF for 10 hours, but CDF is estimated for 16 and 24 hours to eliminate sensitivity of estimated CDF to other duration of interruption. Method described in figure 2. In questionnaire can be ask about other data such as existence of backup generator, reaction to service interruption, equipment that is important to work in interruption time and etc for additional analyses.

This method should be done every 3-5 years and applied for similar customers that classified in some categories. It is possible that estimate CDF in seasons but it is more expensive. With regard to CDF should have reasonable value for any interruption duration, “a” and “b” defined. Considering “a” obtained from macroeconomic indicators based methods. Parameter of “c” and “g” determined by expert in CDF issue and is more than one. These parameters determine OCmax calculated by equation 2:

$$OC\ \max = \frac{g(a+b)}{2} \quad \textbf{(2)}$$

In statistics, reliability refers to the consistency of a measure. The reliability coefficient of Cronbach’s Alpha used to estimate the reliability of the questions [9, 10].

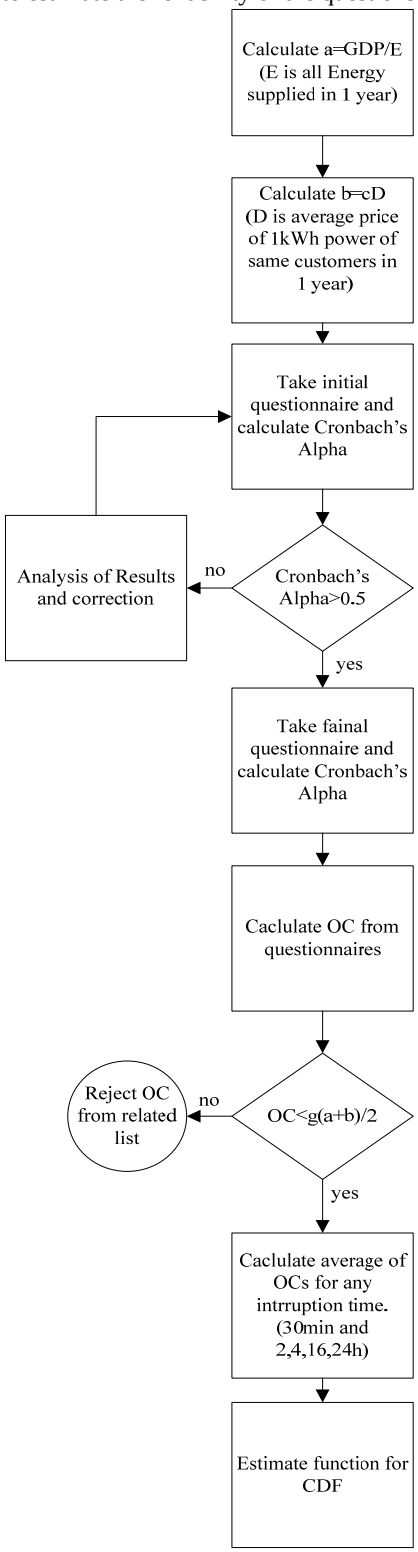

Figure 2. Proposed method for determination CDF

CASE STUDY

In a small area, proposed algorithm has been implemented. Questionnaires distributed between 40 Customers of Imam Khomeini street, Ben County, ChaharMahal Va Bakhtiary, Iran and 35 ones completed and returned. These customers were, single phase, 25 A. in this study Cronbach's Alpha is equal to 0.53 Table 1 shows OC in 30min and 2,4,8,16,24 hours in May 2012 as gathered and processed data.

Table 1. OC($/kW) in 30min and 2,4,8,16,24 hours in May 2012

Oc(0.5)	Oc(2)	Oc(4)	Oc(8)	Oc(16)	Oc(24)
0.8	3.63	7.28	11.91	22.69	34.46
1.21	5.62	10.67	19.29	38.63	57.73
0.79	3.29	6.94	12.11	22.67	36.91
0.78	3.74	6.35	12.15	23.08	34.34
1.09	4.64	8.79	16.87	33.38	48.84
0.79	3.59	6.91	12.35	23.21	34.61
1.09	5.22	9.32	16.92	32.82	51.32
0.96	4.04	8.64	14.76	30.44	45.47
1.15	4.89	9.93	17.76	34.09	51.69
0.82	3.74	7.18	12.59	26.04	35.98
0.55	2.54	4.92	8.76	16.72	25.32
0.71	3.62	5.9	10.77	22.02	32.93
0.54	3.13	5.25	8.17	14.38	24.46
0.59	2.52	5.26	9.33	18.68	25
1.04	4.38	8.31	16.1	31.38	46.39
0.81	3.94	7.18	12.51	24.01	36.6
0.53	2.49	4.75	7.91	14.97	23.09
0.9	4.58	7.27	13.61	26.25	42.12
0.68	3.67	6.29	10.1	21.43	29.6
0.95	4.45	7.94	14.35	27.99	42.47
0.62	3.33	5.16	9.81	18.13	27.81
0.5	2.41	4.12	7.8	13.96	22.28
0.88	4.16	7.36	13.64	27.56	40.44
0.91	4.61	7.47	13.52	27.33	42.32
0.98	4.48	8.49	14.89	29.25	44.34
0.87	4.4	7	13.41	24.85	37.97
0.66	3.34	5.52	10.15	19.63	27.81
1.02	4.57	8.46	16.3	32.46	46.09
0.46	2.48	4.57	6.64	14.59	21.1
0.75	3.87	6.4	11.41	21.95	33
0.79	3.36	7.08	12.44	22.89	37.39
0.9	3.98	7.77	13.91	26.61	42.53
0.54	3.13	5.06	8.39	16.08	24.92
0.72	3.26	5.83	10.69	20.04	33.74
0.74	3.63	6.92	11.51	22.2	33.3

From [11] Iran GDP in 2009 equal to 331.01 B$ and from [12] total consumption in of 2009 electric energy is 165.177GWh, then "a" is 2.0039. For "g" equal to 1, 2 and 3 and "b" equal to 1, 10, 50, 100 and 200 OCmax calculated and presented in table 2. ("D" is 0.02$)

Table 2. OCmax($/kW) for "g" equal to 1,2 and 3 and "b" equal to 1, 10, 50 ,100 and 200

OCmax \ g	1	2	3
OCmax(b=200)	3.001955	6.003909	9.005864
OCmax(b=100)	2.001955	4.003909	6.005864
OCmax(b=50)	1.501955	3.003909	4.505864
OCmax(b=10)	1.101955	2.203909	3.305864
OCmax(b=1)	1.011955	2.023909	3.035864

Regarding to Tables 1 and 2 and proposed algorithm, average of OCs is presented in table 3.

Table 3. OCmax($/kW) for OCmax equal to 2.2, 2.02, 2, 1.5, 1.1, 1.01 and greater than 2.2

Ocma\h	0.5	2	4	8	16	24
>2.2	0.81	3.8	6.92	12.4	24	36.48
2.2	0.78	3.42	6.56	12	23.68	35.76
2.02	0.74	3.3	6.28	11.52	22.4	34.32
2	0.74	3.3	6.28	11.36	22.4	34.32
1.5	0.61	2.5	5.12	9.6	19.52	28.8
1.1	0.52	0	4.12	7.76	15.2	23.76
1.01	0.48	0	0	7.44	14.56	22.08

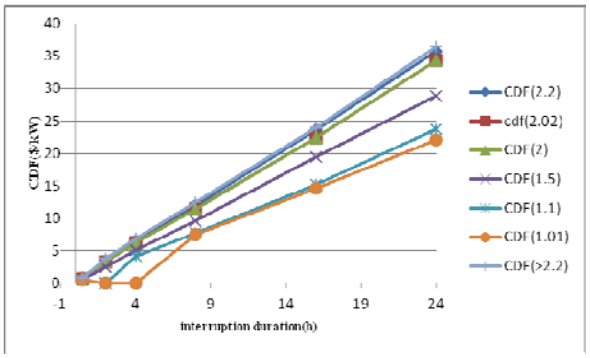

Figure 3. CDF for OCmax equal to 2.2, 2.02, 2, 1.5, 1.1, 1.01 and more than 2.2

From figure3 is seen that for OCmax less than 1.1 zero points appear. Also for OCmax more than 2, diagrams near together. Sensitivity analysis of diagrams and parameters help to select appropriate parameters

For complete proposed algorithm steps with table 3 data CDF curves is estimated in linear, quadric and cubic functions for OCmax=2.2 and based on Sig(significant) index on Analysis of Variance (ANOVA) one function is selected. All the information presented in [13], the major interest of the researcher will most likely be focused on the value located in the "Sig." column. If the number (or numbers) found in this column is (are) less than the critical value (alpha) set by the experimenter, then the effect is said to be significant. Since this value is usually set at .05, any value less than this will result in significant effects, while any value greater than this value will result in nonsignificant effects. Sig of 3 way of curve estimation is presented in table 4.

Table 4. Sig for linear, quadric and cubic function

	item	Sig
Linear	t	.000
	Constance	.141
Quadric	t	.000
	t^2	.865
	Constance	.300
Cubic	t	.000
	t^2	.119
	t^3	.120
	Constance	.731

Figure 4 shows estimated curves of CDF.

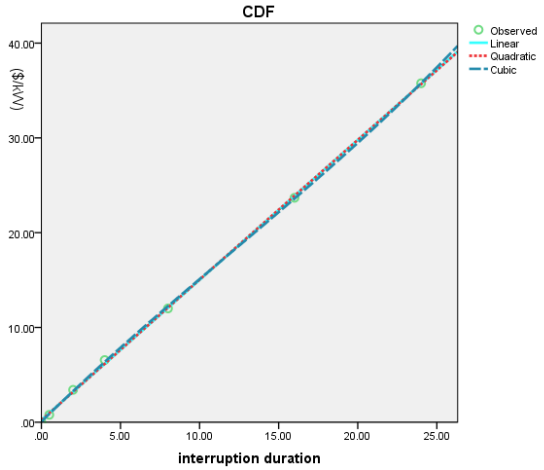

Figure 4. Estimated curves of CDF.

Based on Sig index, cubic function is selected for CDF. It is important that cubic and quadric function after of 24 hours goes to left side and it is possible that estimated CDF after 24 hours be incorrect.

CONCLUSION

In this paper, a new algorithm based on interruption cost determination methods is proposed to estimate domestic CDF. Because of relation between domestic CDF and welfare of costumers that couldn't convert to monetary equivalent, this method uses some benchmarks including "a","b" and "g".

Curve estimation is an important step in this paper that implemented with regard to Sig index. Finally in a case study, domestic CDF has been estimated.

Although domestic CDF estimation is difficult but proposed method with benchmarks and statistics tools make it easier and reasonable.

FUTURE WORK

This project aims to propose practical and reasonable method for domestic CDF estimation and implementation of it in case study. In future work authors will use from more statistics tools specially statistics test and other tools for more accurate domestic CDF estimation. Consequently will be using from feedback control for evaluating results.

Acknowledgments

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