

INDIVIDUAL INTERRUPTION COSTS OF INDUSTRIAL CUSTOMERS AS BASIS FOR A CLASSIFICATION.

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ABSTRACT

This paper describes the possibilities to classify electric distribution customers into different categories depending on their individual sensitivity towards supply interruptions. The sensitivity is regarded from an economical view, i.e. the relation between the duration of an interruption and the costs experienced by the customer. For a distribution-system operator (DSO) making decisions on network reinforcements and restoration planning, having information on the individual customer's sensitivity towards interruption is very valuable.

INTRODUCTION

Most of studies and surveys on costs due to power interruptions look at average costs over a number of customers within the same group, e.g. residential or industrial customers. The spread between individual customers in these surveys is very large so that the average value can certainly not be used as a typical value. Unfortunately there is only very limited published information available on the spread among individual customers. This paper will consider individual customers and the possibility of gaining knowledge about the cost/duration relationship for individual customers in an efficient way.

Different customers have different sensitivity towards interruptions, where the preferred indicator of sensitivity is the customer cost. The sensitivity is strongly connected to type of activity performed. Again referring to earlier surveys, a linear cost increase with an initial step is often applied. However, for some customers the step-like increase is not initial but delayed in time up to several hours. Some customers may have several steps and the slope of the linear increase may change at certain points in time due to the characteristics of the activities. A characteristic that cannot be shown in a single cost/duration plot is how the sensitivity changes between parts of a day/week or year. Some customers may show very low sensitivity towards interruptions during weekends or at night. Other customers may be extremely sensitive during a few hours of the week.

The approach of customer classification is to identify some basic categories or classes based on customer surveys. The different customers are then categorized and the actual cost as a function of interruption duration can be estimated using a small number of parameters, i.e. slopes, step sizes and delays.

THE PERFORMED STUDY

The performed study has focused on identifying distribution customers' sensitivity towards power interruptions. A number of interviews have been performed with customers, mainly industrial, to investigate how the customers will be affected by a power interruption and what economical consequences it will result in. Analysis of the result from the interviews shows two main categories of customers with characteristic sensitivity towards interruptions, although the cost/duration relationship is unique for each customer.

The interviewing process

38 customers of Vattenfall Eldistribution, 35 in Sweden, 3 in Poland were selected to participate in the study. Focus was on industrial customers, to emphasize similarities and differences in the sensitivity towards interruptions within the population. All customers were contacted by the responsible account manager to be informed about the interview. Four customers (13 %) choose not to participate in the study.

The customers were next contacted to book time for a face-to-face or telephone interview. Some customers were to be interviewed by e-mail correspondence, hence no booking was required. Nine customers (24 %) could not be reached.

Using a prepared questionnaire the customers were interviewed, face-to-face, by telephone or by e-mail. The questionnaire consisted of eight topics which were discussed during the interview. As a conclusion of each interview a graph was prepared together with the customer to show the cost/duration relationship (see e.g. Figure 6).

Some customers were unable or reluctant to hand over information of economical nature. For these customers a cost/duration relationship was prepared with an ungraded axis for cost. The character of the sensitivity could still be

presented.

Interview results were obtained from 24 (63 %) of the initial 38 customers. Of these 24 customers, five (20 %) gave none or very limited information on actual cost of the interruption.

Results from the interviews

The main focus of the study has been to identify customers' cost/duration relationship during an outage. Next to this, interview methods, possibility of gaining correct information, customers' knowledge of the topic and used questionnaire have also been studied.

The interviewed customers were mainly industrial companies with production. Although the customers were active within the same area the cost/duration relationship were unique for each customer with substantial variations. In Figure 1 and Figure 2 each customer's absolute cost is plotted as a function on duration; in Figure 2 excluding the two highest values at each time instant to increase the resolution where most customers cost is located. In Table 1 statistics for the absolute cost due to an interruption are presented as a function of duration. The variation in cost between customers is considerable for any duration.

Table 1. Cost due to an interruption of different duration.

Duration time [h]	Cost [kSEK]			
	Min.	Median	Mean	Max.
Initial	0	30	593	5000
2	20	150	1061	7000
4	40	250	1363	9000
8	80	450	1975	13000

Interviewed customers varied in size which could cause the variations in absolute cost. Therefore normalization of cost was performed using annual electric energy consumption and electric power usage. In Figure 3 and Figure 4 the normalized cost for each customer is plotted, in Table 2 and Table 3 statistics are shown. Normalization by power usage was also performed for those customers where the actual power usage was known. The variations in normalized cost are considerable for all interruption durations. Comparing the figures and tables shows that normalization does not reduce the spread in values among different customers.

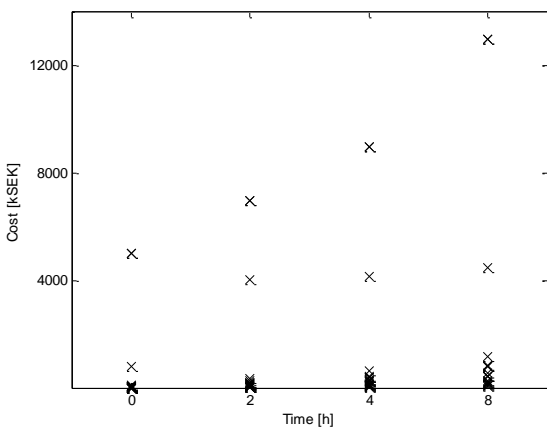


Figure 1 Absolute cost for all customers as a function of duration.

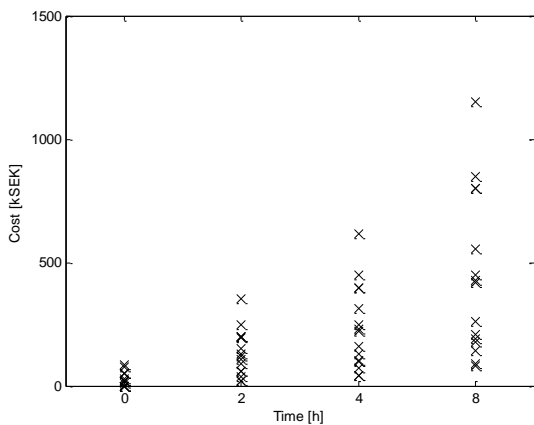


Figure 2. Absolute cost, excluding extreme values.

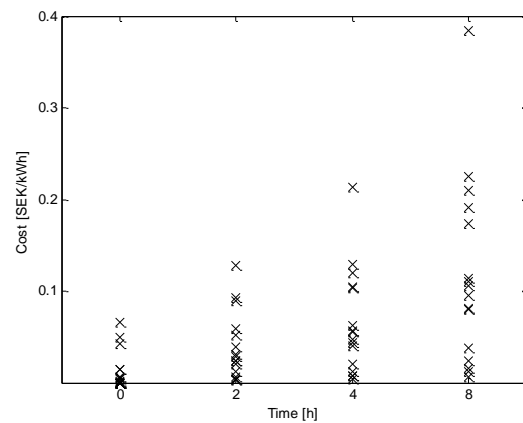


Figure 3. Cost (SEK/kWh) for customers normalized by annual electric energy consumption, excluding extreme values.

TABLE III

Table 2. Cost due to an interruption of different duration, normalized by annual electric energy consumption.

Duration time [h]	Cost [SEK/kWh]			
	Min.	Median	Mean	Max.
Initial	0	0.004	0.036	0.4
2	0.003	0.028	0.144	2.025
4	0.004	0.056	0.170	2.075
8	0.007	0.106	0.227	2.250

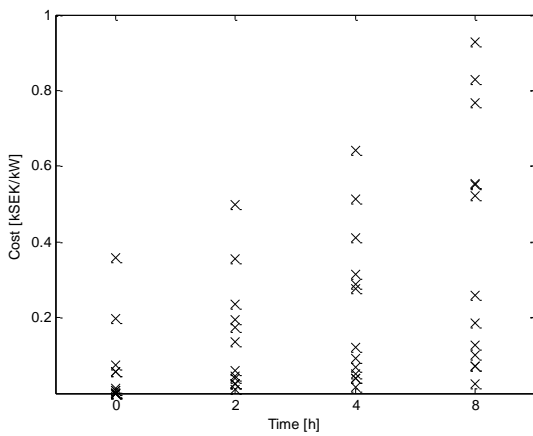


Figure 4. Cost (kSEK/kW) for all customers normalized by electric power usage.

Table 3. Cost due to an interruption normalized by power usage..

Duration time [h]	Cost [kSEK/kW]			
	Min.	Median	Mean	Max.
Initial	0	0.008	0.060	0.357
2	0.011	0.060	0.140	0.499
4	0.016	0.121	0.221	0.642
8	0.026	0.260	0.384	0.928

Due to the large variations in cost, with a few customers having exceptional cost/duration relationship, this will result in a bad representation of customers cost within a segment if the mean value is used, independent of using absolute or normalized costs. Seen from the presented results the cost/duration relationship varies considerably between the interviewed customers. This is independent of the normalization method used: by energy consumption or by power usage. Statistical evaluation of cost shows that the mean value is not a good representation of customers cost but the individual cost/duration relationship for each customer is needed.

The interviews have been performed using three different methods: face-to-face interview; telephone interview and a questionnaire sent to the customer via e-mail. It is experienced that the different methods each have their advantages and drawbacks making them suitable in different situations.

For larger customers or customers with complex electrical system it is experienced that more than one representative from the customer is needed in order to cover all topics in the questionnaire. It is recommended that such a customer is interviewed face-to-face allowing a number of participants and making a discussion possible. The method is however time consuming allowing approximately only three interviews per day.

Telephone interview has the same benefit as the face-to-face method, allowing a discussion with the customer. It is also

more efficient as the travelling time is excluded. However it does not allow a sufficient discussion between many participants and graphical illustration possibilities are limited. Therefore this method is recommended for customers where one person has good insight in how operation and economics are affected by an interruption.

Sending the questionnaire to the customer via e-mail is the most time-efficient method. Possibilities of having a dialog with the customer are limited however; although follow-up questions are possible, and there is an imminent risk that the impact caused by a power interruption will only be covered partly.

Knowledge about the impact of a power interruption varies substantially between interviewed customers and is often related to the customers' sensitivity towards it. Customers for which an interruption will cause great harm have good knowledge about the impact, whereas other customers had less knowledge about it or had not considered the issue. All customers interviewed face-to-face or via telephone were informed in advance of what information was of interest. It was experienced that such a notification is sufficient as the customer could be prepared by finding the required information in advance, mainly of economical nature.

The questionnaire used during the interviews turned out to cover all questions/topics of interest in a sufficient way. The interviewing process often resulted in a discussion about the topic based on the questions in the questionnaire. The most difficult question to retrieve information on concerned the type of connection towards the local grid, energy consumption and power usage. It is therefore recommended that such questions are not asked to the customers but obtained from the network operator. For some customers the economical estimations required further investigation and could not be answered during the interview itself but were supplemented afterwards.

Customer classification

A majority of the customers included in the study are industrial customers manufacturing products sold to their own customers. Due to this focus on industrial customers it is difficult to draw a conclusion on classification of other types of customers having other main activities.

The results from performed interviews were analyzed to identify different categories of customers, i.e. the cost/duration relationships were compared to see similarities and differences between the customers.

Two main categories could be identified, related to two different types of activities: industrial manufacturing and pharmaceutical manufacturing. Customers within both categories often had processes sensitive to voltage dips, resulting in a more or less considerable initial cost during an interruption. Common for both categories was also the following linear increase in cost as the interruption lasted. However, the pharmaceutical manufacturing customers were

often characterized by one or two additional steps in cost, both occurring within hours from the start of the interruption. Characterizing for the pharmaceutical industry was also that the sensitivity towards interruptions was often limited to shorter periods in time every week (some hours). For the general manufacturing industry the sensitivity was more homogenous during the working hours. Of the interviewed customers, 17 were classified as industrial manufacturing and 3 as pharmaceutical industry.

In Figure 5 a typical cost/duration relationship for an industrial customer is shown. Figure 6 shows a typical cost/duration relationship from a pharmaceutical customer.

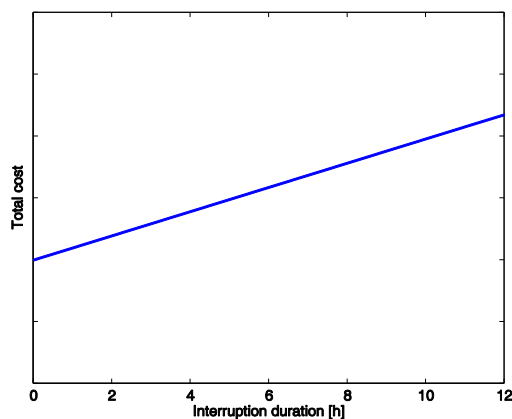


Figure 5. Typical cost/duration curve for industrial customers.

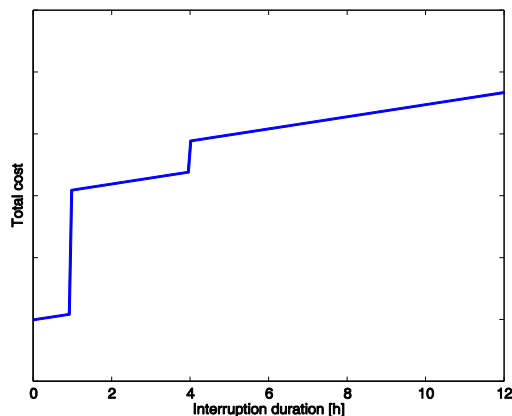


Figure 6. Typical cost/duration curve for pharmaceutical customers.

Comparison with Other Surveys

As was mentioned in the introduction, many earlier surveys after interruption costs have been performed in many countries. The survey performed for this study differed in a number of ways from other surveys.

The interviewing approach allows for face-to-face contact and more detailed explanation of the questions. The aim of the survey was not only to obtain hard data on customer

interruption costs but also to get a better understanding of the sensitivity of the customer's installation and process to supply interruptions of different durations. This open approach to the questions resulted among others in valuable information on the sensitivity of the customer to voltage dips.

Where it concerns the presentation of the results, the emphasis of this study has not so much been on the average results over all customers but on the specific cost-duration curves for individual customers. It is our experience that the variation between industrial customers is so large that average values have no meaning in the design and operation of a specific network.

During many other surveys the customers are asked for the costs due to interruptions of pre-defined duration (like 3 hours, 8 hours, and 24 hours). We did not use this approach, but instead asked the customers to identify the total curve of costs versus duration with special emphasis on the durations for which the interruption costs show a large increase. This resulted among others in the realization that the interruption costs for pharmaceutical customers showed a rather different pattern than for other industrial customers.

CONCLUSIONS

The cost/duration relationship for an interruption varies substantially between different customers even within the same type of activity. Normalization by energy consumption or by power usage does not reduce the spread between customers. Therefore, investigation of the individual customer is required to identify the customer's unique cost. Even if the actual costs are unique for each customer the cost/duration relationship may be similar for a large number of customers, depending on the type of activities. Thus, it is possible to classify the customers into different categories, where within each category each customer's cost may be estimated using a small number of parameters, i.e. slope, steps and delays.

Three methods of interviewing have been used in the study, each having its pros and cons. A larger and more complex operational and economical situation at the company requires a more extensive discussion in order to obtain a reliable result.

The participating customers were mainly industrial companies, which limits the conclusion drawn to this type of customers. Two categories of customers could be identified; manufacturing industrial companies and pharmaceutical manufacturing companies, each category showing its characterizing cost/duration relationship.

The used questionnaire has worked sufficient and covers topics required to obtain wanted information. Customers' knowledge about the topic varied but required information was possible to obtain, sometimes requiring that supplementary information be sent afterwards.