INTERRUPTION COSTS IN LARGE CUSTOMERS: SURVEY AND APPLICATIONS

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ABSTRACT

The phenomena related to Power Quality, as the voltage dips, imbalances, harmonic distortion and interruptions can cause damage to equipment used in industries and commercial sector. As soon as an outage occurs caused by one of these phenomena, there may be costs of various kinds, like production lost and others. Although there are mechanisms of cost internalization, such as penalties, the real cost evaluation of interruption for large consumers depends necessarily on structured survey and statistical evaluation. This paper presents the results of a survey of this kind, applied on large industrial and commercial consumers served by AES Eletropaulo. To validate the results, the obtained interruption costs were compared with the actual costs of one industrial consumer.

QUALITY COSTS

Usually energy supply quality problems are divided into two types, reliability and power quality. The reliability of the supply is related to long duration outages frequency and duration. In Brazil interruptions beyond three minutes are considered long duration outages. The power quality is dependent on the wave shapes and are disturbed by short duration voltage variations (SDVV), voltage levels, network harmonics, among others aspects. In Brazil the resulting penalties from reliability problems applied to energy distribution utilities are normalized by the regulatory agency ANEEL through the quality indexes SAIDI and SAIFI. For high demand customers derived impacts caused by power quality problems goes beyond reliability matters. Quantifying these impacts economically and searching for the causes are matters that are always being developed.
In the present article the costs caused by power quality problems are named quality costs.
The pioneer power quality researches considered the costs based on the consumed energy or based on the not supplied energy in the interruption period. As a consequence of the inertia of processes and the easiness for perceiving, long duration outages were used as an approximation for developing optimizing methods for power quality as a function of the related costs.

In Brazil the costs of energy not supplied (CENS) were broadly used as a comparison measure among markets, network investments, developing, etc. As new technologies appeared for industrial use such as automation, information, more accurate process and also new equipments capable of measuring electrical quantities with high sampling rate, the power quality problems turned to be more complexes.
SDVV, harmonics, frequency variation and flickers phenomena turned to cause larger economical impacts, but also could be better measured. In this context the use of a unique value of quality cost, grouped or not, turned to be inaccurate for defining better practices for distribution network investments.
For measuring the value of energy quality, three methodology groups could be adopted. The first uses economical, sector data or external comparisons for the company costs to estimate the energy value. As an example for this technique we could mention the use of the GDP variation as a function of the energy consumed in a period. The second methodology uses internal company data for raising costs and calculates the energy value based on financial losses, damages, profits, etc. The last methodology for calculating the energy value is based on questions done for the customer through a questionnaire. Besides a practical difficulty for defining precisely the energy value for this methodology, there are many examples of the use of the method of willing to pay (WTP) or receive for energy quality variations. The methodology used in the present research resides on the second and third types, using customer surveys for defining which are their losses caused by many problem types of power quality and also which is the willingness to pay for improvements on the energy supply.
The method for calculating the energy value as a function of internal costs presents an advantage for obtaining the value of social losses caused by the impact of the power quality. From a different point of view, the willingness to pay allows quantifies the economic value of energy within an appropriate quality and not only the quality costs. In order to turn the customers willing to pay they must feel the service quality improvement as a right to be acquired.
If the customers believe quality is already an acquired right, the method results badly, reflecting the fact that the customers do not have a willingness to pay for an already

owned right.
This article presents results of quality costs for large and medium customers in the metropolitan area of São Paulo, Brazil, served by AES Eletropaulo, an energy distribution utility who serves more than 5,8 million customers in the greatest city of the country. For this, a qualitative and quantitative surveys allowed to calculate the average cost of quality for companies supplied by the utility, obtained by the internal cost method. The resulted willingness to pay allowed to conclude that most of the companies believes their right for better energy quality compared to the value they already pay for the service, even the WTP was not zero.
For consolidating the results some companies were observed through qualitative and quantitative survey, quality measurements and data analysis. The cost of quality was calculated through the survey and measurement results and compared with companies declared costs. All the results were accomplished by experts avoiding data bias. Finally, it is shown a case study for one of the large companies that reported a lot of energy quality problems in the years of 2008 and 2009.

THE POWER QUALITY SURVEY

The survey with large customers of the utility was grouped on three main phases: focus groups, chosen customers and field survey for data consolidation.

Focus group– qualitative survey

Two focus group were elected. One of them was composed by companies supplied on high voltage (HV: 88kV – 138kV) and the other supplied by the medium voltage distribution network (MV: 13.8 kV – 34.5 kV).
Five HV companies were chosen for this phase among the most representatives of the city such as the railway company, the water utility company, a chemistry industry and a glass industry. The MV customer focus group was composed by 7 companies from industrial, financial and service sectors. Questions were made about the final electrical usages, the perception of energy quality and distribution utility service, the main impacts caused by supply quality problems and the related losses, divided on 8 main groups.
Through a scale from 0 to 10, HV customers gave a 8.2 note for the quality of the supplied energy and the MV customers 5.4. The difference of supply quality perception among HV and MV customers is notable and their causes can be found on the distribution network type that serves these customers and also on the customer attendance by the utility.
The MV networks in the utility area have different standards: conventional, compact, underground. The diversity of network types and regions supplied impact directly on the quality of energy. Different from MV, the HV customers have exclusive attendance from the distribution utility. The MV customers on emergency contingencies are attended very similar to low voltage (LV) customers.

Field interviews – quantitative survey

After the focus group, a questionnaire format construction was made possible. An extended questionnaire was initially tested on 10 customers and consolidated for the application on more than 90 HV and MV customers chosen on 10 different economical activities with the purpose of mapping the quality cost for large customers and also to raise the main improving service opportunities. The industrial and commercial segments chosen were: public services, mass circulation services, food and beverage, packaging and graphics, vehicles and machinery, plastics and rubber, chemical and pharmaceutical, textiles, mechanical and metallurgical, steel, and paper and glass.
The questionnaire was applied by experts on energy quality surveys and was answered by the energy sector company manager. Among the main results we can highlight:
- the customers consider that a long duration outage is better than many short duration. 87% of the respondents consider that 1 three minute duration outage is better than 3 one minute duration outages.
- Regarding the seasonal aspects, the customers consider the quality of supply on winter somewhat better than on summer
- the predominant electrical usage on large customers is for driving force on production lines, followed by air conditioning/ ventilation and lightning.
- generally, the lost production cost represents the major loss among the studied sectors, followed by the costs of restart production, material costs and the loss of data/ communication.
- concerning the prior outage notification for lowering damages, most customers need to be warning with a minimum period of 10 h prior to the outage. It´s particularly important for those ones that don´t have backup generators.
- concerning the electric energy quality monitoring , 65% of the companies interviewed have an equipment for measuring of any type, 21% hire occasionally services for measuring and 82% do not make any kind of continuous quality measurement.

Interruption costs

Two quality costs valuation methods were used: the asking of costs caused by energy problems and the willingness to pay for the improvements of quality (WTP). The costs caused by quality problems were separated into 10 different cost types, based on the outage duration and frequency, and was answered by customers in accordance to expertise and through the data acquisition to the last months or years. The electrical energy demand profile and the mensal energy consumed were gathered, too. The data were ratified with the distribution utility for liability purposes.

The cost types considered were:
- backup generators cost
- protection costs
- substitution and repair costs
- deteriorated or damaged raw material or primary products stocked
- damaged products on construction
- damaged final products
- lost production
- losses related to production restart
- overtimes
- loss of data/information
- other factor costs and extra costs

The composition of all these partial costs normalized by the kWh interrupted results in an average energy not supplied cost for the large and medium companies supplied by the distribution utility of 10.38 USD/kWh interrupted.

Another aspect of the survey was the observation of the degree of customer´s perception regarding the quality improvements of supplied energy. 82% of the customers judged that if the utility developed a project to improve the quality of supply many benefits would be gained. Despite this amount of customers, 68% are not willing to pay anything for these benefits on energy quality, resulting in a very low WTP. The reason for this low value is that 67.2% of the customers say that the billing cost is already very high and 83.6% answered that the improvement of supply quality is a distribution utility responsibility.

APPLICATION IN AN INDUSTRIAL CUSTOMER

In order to take the research further, an application project was made for a large customer in the steel sector. This customer has had frequent complains on the quality of the energy supplied, which caused losses in its productive process. The same questionnaire used in the quantitative survey was used to calculate the customer's perceived interruption cost, and energy quality meters were installed in two intersections of the customer's facility: the power grid connection point and an intersection pointed by the customer as feeding a particularly sensitive process.

BLACK BOX G4000 and G4500 meters from ELSPEC® were used for continuously monitoring the power supply for 40 days. In order to make a complete analysis of those measurements compared to supply quality phenomena that affect production, it is necessary to observe the company's perception of the events as well as the actual measurements. Therefore, the customer was asked to note down all perceived events in energy supply that had an effect on the production line.

Table 1 presents three events that had place in the period studied, which the company pointed to have caused interruptions in the industrial process.

Table 1 Perception of Energy Quality Events by the Surveyed Company

Event	Total Duration (hh:mm)	Type of Event
1	00:15	undervoltage
2	05:10	Outage
3	00:05	Outage

Analyzing the measured quantities, three outages were registered (Table 2). Among these events, two were caused by circuit breakers in the supply circuit, while the last one was a programmed maintenance interruption, about which the customer had been warned in advance.

Table 2 Voltage Interruption Events Registered in Sensible Process's Supply

Event	Duration (hh:mm:ss.sss)	minimum V_{RMS} (V)	Magnitude (pu)
1	00:00:01.014	0.024	0.000055
2	05:21:22	0.000	0.000
3	00:00:01.058	0.065	0.00015

Besides interruptions, 51 short duration voltage variation (SDVV - sags) events of various magnitudes and duration were observed in this period, not causing interruption of the productive process. These events are mostly caused by circuit breakers in feeders connected to the same bar as the company's supply feeder.

Crossing the data obtained from the customer and the measured variables, it is noticeable that micro-interruptions such as events 1 and 3 from Table 2, which took barely more than a second, lead to a 7-hour delay to restart the process. This value was estimated from the measured electric current before and after energy supply was re-established.

Evaluation of the company's interruption costs followed two parallel approaches. A generic questionnaire was used to collect data on possible causes for losses, to be aggregated into the companies' Total Interruption Cost. In the questionnaire, an 8-hour period was pointed as average to resume the process after an outage, and the costs due to the restarts were also estimated. This duration is consistent with the data from measured electrical currents. In parallel, the company was asked to provide a report on losses due to supply problems observed in the measurement period. Damages caused by these events were calculated at R$ 58,976.28[1] (USD 34,796.01).

In comparison, average monthly losses obtained from the questionnaire were R$ 79,876.52 (USD 47,127.15) considering all variables. Taking into consideration only lost production costs, including overtime, restarting production and lost of raw material goods, this total is R$ 56.432,62 (USD 33,295.25) per month. These totals are

[1] R$ 1,00 is about USD 0,59

fairly close to the monthly average pointed out in the questionnaire.
It is recommended that the surveyed company studies its own sensitive processes, either with its own personnel or with an energy quality consultant. Such a study would quantify possible investments to reduce sensitivity to short duration outages or tension variations detected in the measurement period, allowing the company to define a strategy comparing investment costs and benefits from reduced production losses.

CONCLUSIONS

This work has shown partial results of a survey made in 2009 with large customers of AES Eletropaulo on the interruption costs of energy supply due to energy quality phenomena. A loss quantification method was applied to customers from 10 different segments, based on questionnaires.
In order to illustrate possible applications of this method, energy quality data was collected in a major steel company supplied by the utility.
The methodology for quantifying individual costs of interruption will be automated in a web portal, where a questionnaire will be available for major customers of AES Eletropaulo with interruption problems. As a result, the distribution company will have an updated database of costs of interruptions, which will provide additional improvement in the process of assessing the need for investments in the quality of the service.

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