QUALITY OF SERVICE TARGETS BASED ON BALANCE REGARDING SOCIAL DEMANDS AND UTILITY ACTIONS

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ABSTRACT

This paper deals with the definition of collective quality of service, aiming at proposing a method to establish quality indices based on a balance between social demands and the utility possible actions. A specific R&D project was developed with the Brazilian DISCO Association (ABRADEE) in order to elaborate a new methodology to incorporate customer participation in such a process. The results shown in the paper serve as a parameter to the regulators evaluate quality of service standards in accordance to customer willingness to pay and utility related costs.

INTRODUCTION

Nowadays in Brazil targets for SAIDI and SAIFI, in given groups of customers, are determined by benchmarking methods where incentives in electricity tariffs are provided to utilities that improve such indices along time. This model however does not take into account customer surveys regarding interruption costs, for instance, which may lead centrally-determined quality targets to deviate from the most desirable outcome from a social and economic point of view.

This paper deals with the definition of collective quality of service, aiming at proposing a method to establish quality indices based on a balance between social demands and the utility possible actions.

Quality targets are determined by taking into account the economic aspects for customers and utilities. The minimum cost associated to the costs of improving quality of service (utility cost) and of non-supplied energy (customer costs) provides the best economic solution for the definition of such quality of service targets.
The utility costs are related to actions that improve the quality of service, especially those related to interruption failure rates and duration. Such actions are proposed by the utility, with special focus to the ones that affect positively the causes of interruptions. Such causes are well established by the Brazilian quality of service regulations and most of the utilities classify their occurrences in their data bases.

As for the customer costs, a meta-analysis was especially developed considering data from various international surveys. Customers are classified into residential, commercial and industrial types. The value of non-supplied energy adjusted by GDP per consumer is used to quantify interruption costs.
The results shown in the paper serve as a parameter to the regulators evaluate quality of service standards in accordance to customer willingness to pay and utility related costs.

OPTIMAL QUALITY LEVEL

For utilities, the financial cost of upgrading power quality *increases* as the required quality levels become more stringent. On the other hand, the amount of customers that are willing to pay for a better power quality is larger when the power quality is not high. As the quality increases, more and more consumers become satisfied with the current quality level and are no longer willing to pay for a marginal improvement in quality.[1-5]

The “company’s cost” curve in Figure 1 illustrates how quality improvements become progressively more difficult from the utility’s standpoint, whereas the “consumer’s WTP” curve illustrates how consumers’ willingness to pay typically plateaus for high quality levels.
Based on these two curves from Figure 1, the Optimal Quality Level (OQL) is defined as the condition in which the supply-side marginal cost of increasing power quality (based on the “company’s cost” curve) is equal to the demand-side marginal benefit of increasing power quality (based on the “consumer’s WTP” curve), Graphically, this condition implies that the tangent lines of the two curves must be parallel when the quality level is equal to the OQL.

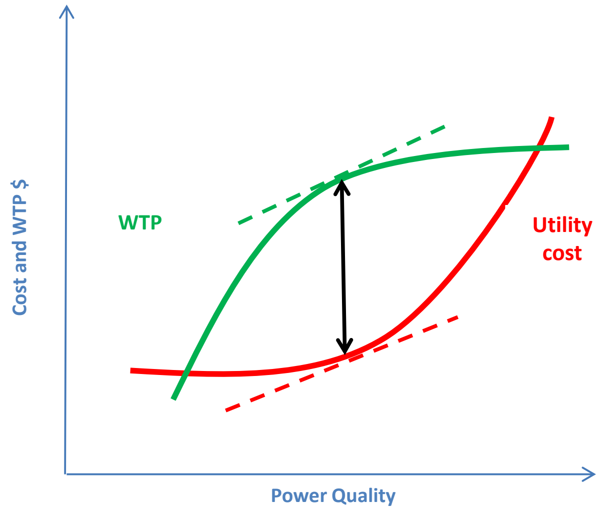

Figure 1. Optimal quality level

The consumers' willingness to pay curve is, in general, difficult to obtain; which implies that in practice it is often approximated from costs effectively incurred – for example, when the low power quality results in electrical equipment being damaged. This concept is illustrated in Figure 2, in which the OQL corresponds to the minimum of the "total costs" function. In turn, the "total costs" function is the sum of the company's cost function, representing financial costs incurred by the utility in order to maintain a given quality level; and the consumer's cost function, representing costs incurred by consumers. In this context, regulation seeks to ensure that the utility operates near the OQL and for this the regulator must estimate both cost curves.

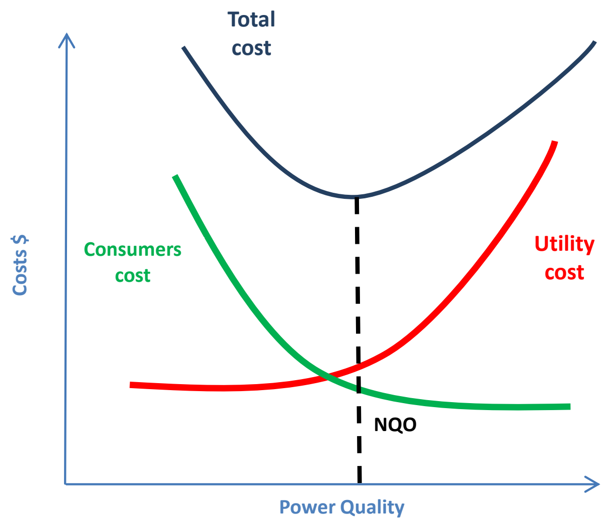

Figure 2. Optimal quality level

Surveys carried out with electricity consumers are the most common instruments used to determine costs incurred by the consumer when different levels of power quality are adopted. On the other hand, engineering studies offer useful benchmarks for estimating the cost of ensuring a certain level of power quality on the utility's side; supported by historical information for the utility itself.

In the presence of an incentives/penalties policy enforced by the regulator, utilities must compensate consumers for any costs incurred, thus internalizing consumers' costs in their own cost function. As a consequence, having a good estimate of the value of quality for consumers is the key element for an efficient incentives/penalties scheme.
Implementing this theoretical framework in practice in a regulatory framework is not a simple task, due to the multidimensional nature of the energy quality variable. Avoiding this complexity, penalties and incentives policies in Brazil and abroad tend to represent only *continuity* of service as a proxy for quality of service in general.
The regulator uses collective continuity indicators (i.e. regional averages) to incentivize utilities to seek a balance between the benefits of continuity to its consumers and the costs of investing in quality improvements. This principle implies that:
• When potential benefits to consumers are greater than the costs of quality improvements, the power quality ought to be upgraded;
• When the cost of improving power quality is greater than the consumer's displeasure from maintaining the current quality level, investments should be postponed.

UTILITIES' COSTS

In order to pinpoint the OQL, it is necessary to identify the minimum costs that ought to be incurred by a distribution company in order to change the system's quality standards. It is assumed is that any actions to shift the quality level will always seek a *positive* improvement in quality (which is consistent with typical practical applications).
Commonly, the utility itself can use its team's engineering expertise to estimate these costs of quality improvements. In order to have an alternative, independent assessment, a parallel methodology has been devised, based on the following information:

- Historical outage records, classified according to the cause for the fault;
- A list of typical modular actions that may improve system quality;
- Modular costs of said actions, both in terms of fixed costs (CAPEX) and variable costs (OPEX)
- Impact of each of those actions on quality;
- Technical information on transformers and substations, indicating whether the possible actions are possible and where

This way, a relationship can be established between the immediate causes of outage events, their duration, and potential mitigation measures. The information used in this assessment ought to be reliable; preferably auditable by an independent company. Outages are routinely classified according to the regulator's Distribution Procedures (Prodist Module 8, ANEEL); and therefore no changes are needed tothe classification of occurrences.
It is then possible to evaluate the possible actions in

matrix form, associating to each immediate cause of an outage event (lines) and to each mitigation action taken by the utility (columns) the net impact on quality. CAPEX costs of individual actions are periodically researched and audited by the regulator, which allows for easy verification; whereas for OPEX costs it is desirable to incentivize utilities efficiency – for example, introducing a benchmarking scheme involving multiple utilities.
The matrix detailed above is referred to as the Matrix of Causes, Actions, and Impacts, synthetizing a large amount of relevant information. An initial assessment of the impact of each action on each immediate cause can be produced based on the experience of system planners; to be validated later using statistical data throughout the procedure's history.
Finally, it is necessary to correctly identify which actions can be carried out at each transformer and substation. This requires a detailed characterization of each feeder and possible action. Because the regulator requires each utility to maintain an up-to-date georeferenced database with this information, once again this does not pose a major obstacle

CONSUMERS' COSTS

There are several methods that can be used to estimate consumes' costs associated with power quality. In this paper, we focus on costs associated with unplanned power outages that are not related to power rationing.
According to Cruz [6], either direct or indirect approaches can be used to estimate the cost of power quality to the consumer. Indirect methods typically involve measuring costs effectively incurred as a direct consequence of power quality issues; whereas direct methods typically involve directly surveying consumers regarding their willingness to pay for a quality improvement or their willingness to receive for a quality downgrade.
Ideally, individual outage costs should be estimated for each area, in order to better represent the Brazilian social and economic landscape. However, there are no nationwide studies that can be used to determine the cost of energy quality in Brazil – while certain regional studies offer useful local benchmarks, their results cannot reasonably be extrapolated for the entire country.
Due to this limitation, the authors have adopted for this study a meta-analysis approach, using both national and international survey databases in order to estimate the cost of quality of service for the three classes of consumers: residential, commercial, and industrial.
The data used in this study has been produced by ENERQ (*Centro de estudos em regulação e qualidade da energia*) in a 2014 study[7-20]. The cost of quality of service is calculated for a given region based on the economic value of one hour of interrupted power supply, based on the classification of the consumer unit and its typical consumption. This data is used in this paper's case study.
Using the above methodology, it is possible to estimate the cost of non-served energy based on a procedure involving the following steps:

- Separating consumers between residential, commercial, and industrial categories
- Valuing costs of power outages for each consumer category
- Valuing impact according to market share and evolution of the market
- The model assumes that power outage costs vary between a minimum and a maximum according to the equivalent duration of the event. An exponential rate describes the shift from the minimum to the maximum cost.

CASE STUDY

In order to evaluate the applicability of the methodology, an optimal quality level (OQL) was calculated for a particular case study based on the utility's investment VS quality curve and on the consumer's costs incurred VS outage events curve.
The distribution area has more than 1.3 million consumers, and the energy consummation is about 3,174 GWh/year. The SAIDI in 2012 was 10.3 hours/years, excluding exceptional events.

Consumers data.

Customers are classified into residential, commercial and industrial types. The value of non-supplied energy of each consumer type is used to quantify interruption costs. To adjust interruptions cost in meta-analysis is used GDP per consumer.
For the case study, the customers were characterized by the typical values of interruption costs. For example, the cost values for residential clients vary between 2.00 to 5.00 R$/kWh.

Table 1: Interruption costs for residential, commercial and industrial customers, estimated in the study case

	Cmax R$/kWh	Cmin R$/kWh	Tau
Residential	20,62	2	200
Commercial	47,58	4	50
Industrial	18,55	4	10

The calculated values for the case study are presented in table 2. From the results presented in table 2, it is possible to interpolate representative curves of quality costs for the customer. The equations that represent the curve can be described as quadratic polynomials and are presented in (1).

Table 2: Values for the interpolation of results of the collective costs of consumers.

Costumers interruptions costs - 2012

SAIDI	55	45	35	25	15	5
Costs[10^6R$]	30,19	23,21	16,87	11,2	6,15	1,87

$$y = 0{,}0213x^2 + 0{,}4104x - 0{,}605 \qquad (1)$$

Utility cost

The information needed to execute the tests was provided by a distribution company, which participated in the data gathering for the experiment. The following data were used:

- Detailed information on past outage events
- Description of network feeders
- Description of consumer units (consumer class, historical consumption, etc.)
- Possible actions to improve quality of service
- Impacts of said actions on the quality of service
- Costs incurred in order to implement the possible actions

Two actions were evaluated for this sample case study, selected based on their large impact in improving the system's quality: pattern shifting from aerial non isolated network for protected networks (with spacers) and creating auxiliary (or interconnection) branches. Figure 4 illustrates the investment VS quality curve obtained from this model.

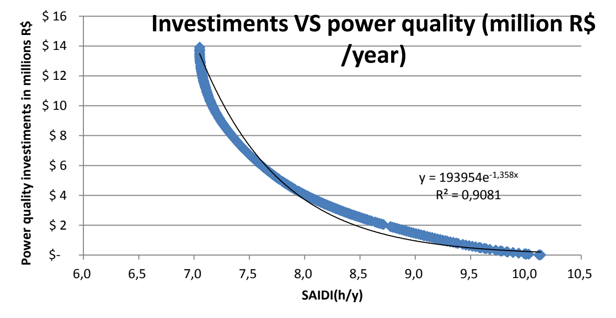

Figure 4: Investment VS power quality for the case study, in 10^6R$/year (annualized) and SAIDI in hour/year

The costs incurred by representative consumers as a consequence of outage events were calculated based on the formulation presented in Table 4, The resulting curve is represented in Figure 5.

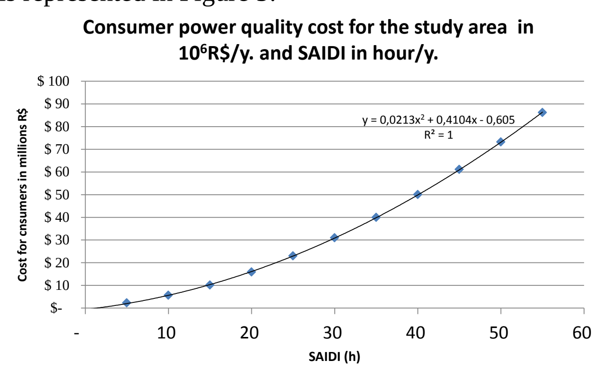

Figure 5: Consumer power quality for the study area in 10^6R$/year and SAIDI in hour/year

Based on these two curves, the optimal quality level (OQL) is mathematically obtained by finding the outage level in which the two derivatives are equal, as discussed in the first Section of this paper.

Results

For the case study evaluated, the OQL was equal to 9.35h. This result implies that, in this particular case, social welfare is maximized if the level of quality of service provided by the utility corresponds to an outage rate of 9.35 hours per year, in terms of collective equivalent duration.

At the moment when the case study was carried out, the utility had been experiencing a collective outage rate equivalent to 10.3h. This implies that a small investment in improving quality of service could be justified – however, introducing a major program to drastically reduce the outage levels could be undesirable in terms of global social benefits, as the costs outweigh the gains.

CLOSING REMARKS

The present methodology is an alternative way to determine desired levels for the quality of electricity service, as opposed to the current methodology that chiefly relies on benchmarking. The proposed alternative explicitly describes an economic relationship between the demand for power quality on the consumers' side and the ability to supply power quality on the utilities' side. This way, the consumer's opinion is taken into account when electing the desired level of quality based on total social benefits – which represents an important strength of the methodology.

Estimates of the adequate value of quality and the definition of standards and targets can be improved using methods based on data obtained from the utility and consumers. Although benchmarking approaches impose less of a burden on the regulator by not requiring a detailed assessment of the relevant curves, using only utilities' performance as a reference will not accurately represent the consumer's perceived value.

Another interesting element of the approach proposed in this paper is that the immediate causes of each outage event (or, more generally, any loss of quality) must be closely monitored. The resulting database would be instrumental in guiding distribution companies to establish quality improvement policies; and in the future it could be used to design alternative solutions.

Finally, it is important to remark that studies to estimate the costs incurred from lower power quality on the consumers' side are not properly regulated or systematic. It would be desirable to invest further in this type of study in order to obtain more robust estimates for the value of quality.

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