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ASSESSING THE OVERALL PERFORMANCE OF BRAZILIAN ELECTRIC DISTRIBUTION COMPANIES

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The Brazilian Electricity Regulatory Agency (ANEEL) was created in 1996, under the mission of providing favorable conditions for the electric power market to develop with a balance among agents and in benefit of society. Since then, ANEEL has published several resolutions to regulate the power distribution segment.

Nevertheless, the act of deploying resolutions is not the only way to regulate. The periodic publication of information about companies' performance is, sometimes, even more efficient to improve service performance than producing new rules. In this way, ANEEL monitors and publishes some indicators that give a measure of companies' performance. Besides, ANEEL conducts an annual survey of companies' consumers and produces an indicator of satisfaction. This indicator, called IASC, is a single score of companies' performance in the consumer point of view. This score can be ranked to show the best (and worst) companies which receive an award in a public ceremony sponsored by ANEEL.

However, there is still a need of providing a simpler and more efficient mechanism to show to the consumers how their distribution company is performing. Despite IASC being a comprehensive survey, its sole use as an overall performance assessment mechanism is contestable. Other technical indicators are available, and may be used to compose a more comprehensive and meaningful score. Continuity of supply indicators, for instance, are likely to be used in such a score, since their degradation is usually followed by an increase in consumers' complaints and is widely publicized by the press.

This paper explores the possibility of developing an overall performance index to assess the performance of power distribution companies. In this paper, performance is seen as a broader concept than the traditional quality of supply, embracing the requirements of consumers and Brazilian legislation in relation to the service provided by power distribution companies.

The main goal of this study is to provide useful information and to start a discussion about the possibilities of developing an overall index. Thus, further work would certainly be necessary to complete the development of such index. A secondary goal is to present the Brazilian regulation related to the performance of companies in terms of service.

The overall index concept proposed in this paper would be an additional regulatory tool with the following positive points:

- it would provide a simpler and more attractive information to consumers about companies’ performance;
- the publication of the index in form of ranking is an incentive for companies to improve their performance; and
- it could be used in tariff definition, giving direct incentives (rewards or penalties) to companies according to their performance.

The first chapter presents a brief introduction to the basic concepts related to Brazilian power distribution regulation and market. Chapter II explores the main aspects associated to companies’ performance in the Brazilian electric sector. Chapter III presents two overall performance assessment experiences in other industries, and also the ANEEL IASC. Chapter IV discusses the possibilities of creating an overall performance index to assess Brazilian power distribution companies. Conclusions are then presented closing the study.

CONTENTS

I. INTRODUCTION

This chapter presents an overview of electricity sector in Brazil, focusing on aspects concerned to the performance of Brazilian power distribution companies. It starts showing the legal background since the reform of the Brazilian electric sector – the worldwide movement known as deregulation. Then concepts of incentive regulation are presented, linking the current economic model applied in Brazilian power distribution tariff definition (price cap) to the need of regulating the adequacy of service. This chapter ends with the presentation of basic information about the Brazilian power distribution market, allowing the reader to understand how concessions are organized and their differences within the country.

I.1. Legal Background

In the 1990s, Brazil, as many other countries, started a process of liberalization of its economy, fostering market-oriented reforms in order to promote competition and to attract investments to infrastructure sectors – this movement is known as deregulation. The reform of the Brazilian electric sector began in 1993 with the enactment of Law 8,631 [1] which extinguished the equalization of the tariffs that were in effect and created supply contracts between generators and distributors. This was enhanced by the enactment of Law 9,074, from 1995, that created the Independent Producer of Electric Power and the concept of Free Consumer.

In 1996 the Restructuring Project for the Brazilian Electric Sector (Project RE-SEB) was implemented, coordinated by the Ministry of Mines and Energy. The paramount conclusions for the project were the need to split electric power companies into the generation, transmission, commercialization and distribution segments (de-verticalization) to incentivize competition in the segments of generation and commercialization, keeping the segments of distribution and transmission of electric power under regulation, considered to be natural monopolies under control of the government.

The power distribution in Brazil is considered a public service. The overall principles were given by the fundamental law of state, the Constitution of 1988, followed by specific laws. Therefore, power distribution companies are allowed to operate only under a defined concession

[1] All Brazilian legislation can be found at http://www4.planalto.gov.br/legislacao/legislacao-1/leis-ordinarias#content

(or a permission, in some specific cases), defined in a contract signed between companies and the Brazilian Government.

Among the several constitutional principles that public service operators need to follow, one of the most important is the need to offer an appropriate service. This principle was further detailed in Law 8,987, from February 13, 1995. Known as the “Law of Concessions”, this law was developed in the scenario of deregulation that was adopted in many countries, and established that an appropriate service is the one that satisfies the following conditions:

i. regularity;

ii. continuity;

iii. efficiency;

iv. safety;

v. modernity;

vi. universality;

vii. courtesy;

viii. affordability.

Chapter III of Law 8,987 states users’ rights and obligations. Some points worth noting are, in addition to the right of the appropriate service, the right to receive information to the defense of individual and collective interests; the duty to inform the public power and utility the irregularities that have knowledge regarding the service provided; the duty to notify competent authorities the illegal acts committed by utilities in providing the service; and the need to contribute to the permanence of the good condition of public property, by which their services are provided.

The Brazilian Electricity Regulatory Agency (ANEEL) was created in 1996, by the Law 9,427 of December 26. Following, the Decree 2,335 of October 6, 1997, established ANEEL directives, its powers and responsibilities and its governing and administrative structure. ANEEL then had its Bylaw approved by Ordinance MME 349, on November 28th, 1997.

According to Law 9,427, ANEEL has the aim of regulating and inspecting the production, transmission, distribution and commercializing of electricity, complying federal policies and directives. This aim is stated in ANEEL’s mission of providing favorable conditions for the electric power market to develop with a balance among agents and in benefit of society.

Like other Brazilian regulatory agencies, background laws supporting the role of ANEEL ensured two essential conditions for its proper operation: autonomy and independence. These two features give ANEEL the condition to rely its decisions in technical issues. But they do not guarantee, though, that ANEEL is free of pressures from all parts interested in the electricity sector.

ANEEL is often dealing with legitimate interest from consumers, companies (investors) and the government. These interests are almost always conflicting and even opposed. Therefore, ANEEL needs to provide the equilibrium among parts, deciding technically and with isonomy. Figure 1 illustrates ANEEL's role in electricity sector.

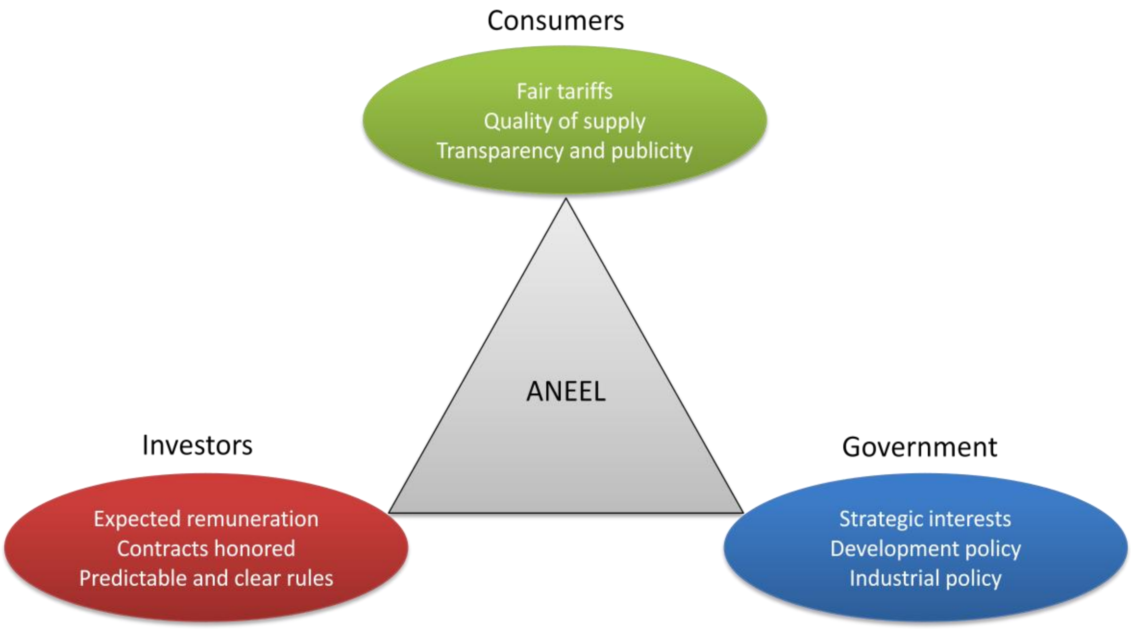


Figure 1. ANEEL's role in providing equilibrium in electric sector.

I.2. Incentive Regulation and the Adequacy of the Service

Power distribution industry is characterized by economy of scale and it is considered a natural monopoly, that is, the production cost is minimized if one firm supplies the entire output (Browning and Zupan, 2009). Monopoly companies are powerful in the sense they can control its price and output, and their power is even bigger in power distribution due to its nature of basic service – characterizing low price elasticity of demand. Therefore, government intervention is required to avoid the harmful consequences of monopoly industry.

One possibility of regulating monopoly in power distribution industry is by defining a tariff that covers company's costs in operating the service. This is known as "cost of service" regulation (Joskow, 2008). The argument for adopting this mechanism would be that the company would not get unreasonable profits at the expense of the consumer – actually, the profits would be entirely defined by the regulator (assuming the regulator has complete information). However, in practice this scenario is not favorable to consumers, since the company will not have incentive to increase efficiency.

In order to stimulate efficiency in regulated sectors, many countries have adopted strategies of incentive regulation. Brazilian economic regulation of power distribution sector makes use of an incentive regulation mechanism worldwide used in the electricity sector: the “price cap”.

In this mechanism, the regulator sets an initial price that will last for a period – the period is stipulated in each contract and are three, four or five years (the majority of companies are four years). Actually in power distribution sector it is common to have not one single price, but a structure of prices for different types of consumers, voltage of connection and the hour of consumption. It is adjusted from one year to the next for changes in inflation and a target productivity change factor “x.” Therefore, companies are encouraged to reduce their costs in the period between reviews to increase their profit (Joskow, 2008).

It is important to notice that any incentive regulation mechanism that provides incentives only for cost reduction also potentially jeopardize the quality of supply (or, in a general view, the performance in providing the service) when quality of supply and costs are positively correlated with one another (Joskow, 2008). Indeed, Ter-Martirosyan and Kwoka (2010) showed by an econometrical analysis that electricity companies in US seemed to jeopardize quality in the period of 1993 to 1999 when there was not a regulation ensuring minimum quality standards. Thus, price caps are often only one component of a larger portfolio of regulatory tools that includes quality of supply standards and incentives to improve service performance.

In general, there are four instruments usually applied by regulators to try to secure or improve the quality of supply in power distribution (Fumagalli, Lo Schiavo and Delestre, 2007). The first and simpler is the publication of data about companies’ performance. Although not efficient enough to be employed alone, it is desirable in any environment of good practice in regulation, as a concept of publicity. It can improve companies’ performance by incentivizing them to prevent the harm impacts of being known as worse than others or, on the other hand, to compete to be better than others.

The second instrument is classified as minimum quality standards. It is probably the most applied instrument, in the sense that it defines the basic performance on with companies need to operate. There can be individual or overall standards (applied to a set or to all consumers). In other words, minimum standards give the “quality cap”, and companies usually need to compensate consumers (or to pay a fine in case of overall standards) when failing to comply with defined limits.

The third instrument is the introduction of a reward and penalty scheme. This is an instrument that operates in two senses: given a certain quality standard, rewards companies that exceed the standard and punishes those who violate. Standards in this case tend to be generic, measuring, for instance, the average performance of companies, or benchmarks.

The last instrument is the promotion of premium quality contracts. This modality is the least common of the instruments presented, and it is suitable for consumers with special needs of quality. In this case, the contract provides a price for differentiated service, the required quality standards and the punishment that should be applied to the company in case of noncompliance of the standards.

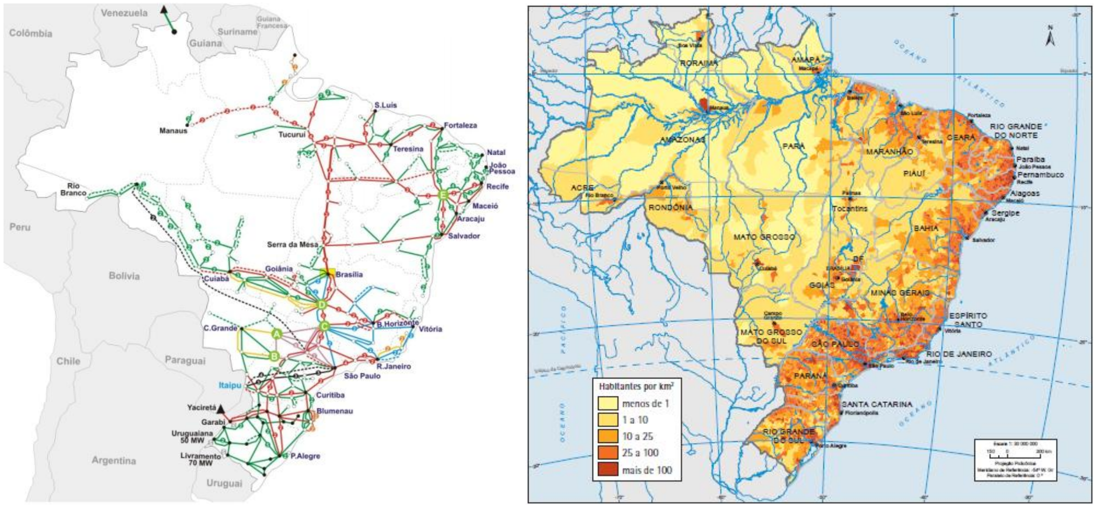
It is worth noting that the instruments shown may be applied separately or jointly, and in all dimensions of quality. However, in practice some instruments are more associated with some dimensions of quality of supply than others (Fumagalli, Lo Schiavo and Delestre, 2007).

I.3. Overview of Brazilian Power Distribution Market

Brazil is a country with 8,514,877 km^2 of area and about 190 million habitants (IBGE, 2012). It is composed by the Federal District and 26 states that present huge differences in density, development, weather conditions, and geographical issues.

Of all segments of infrastructure, electricity service is the most universal in Brazil. In 2008, about 95% of the population had access to the power grid, which correspond to about 62 million consumer units. Of these, the vast majority (about 85%) is residential. The incidence and dimensions of niches without electricity distribution are directly related to its location – and the physical or economic difficulties for extending the power grid. After all, each of five geographic regions in which Brazil is divided – North, Northeast, Midwest, South and Southeast – has characteristics that are quite peculiar and different from the others. These peculiarities determine the contours that the generation, transmission and distribution acquired over time and also determine the greater or lesser ease of access of the local population to the power grid.

Figure 2 illustrates the Brazilian power grid horizon in 2012 (existing and planned transmission lines) and the density of population in 2007.



a b

Figure 2. Brazilian power grid horizon 2012 (ONS, 2012) (a) and Brazilian population density in 2007 (IBGE, 2012) (b).

The Brazilian power grid (known as National Interconnected System – SIN) is the system of production and transmission of electric energy in Brazil. It is a large hydrothermal system, with strong predominance of hydroelectric and with multiple owners. The SIN is comprised of companies from the South, Southeast, Midwest, Northeast and part of the North. Only 3.4% of the capacity of the country's electricity is out of the SIN, in small isolated systems located mainly in the Amazon region (ONS, 2012).

In Brazil, power distribution companies manage and operate electrical networks less than 230 kV (there are few exceptions above this voltage). They need to provide free access to any consumer or generator and also need to supply energy to the majority of the consumers – these consumers are called captive consumers.

There are two energy trading environments. The Regulated Contracting Environment, where distribution companies need to purchase energy from generators through public auctions under cap prices set by government, and a Free Contracting Environment, where free consumers (non captive) and generators can freely negotiate their own bilateral contracts (CCEE, 2012)[2].

The power distribution in Brazil is operated by 63 companies holding public service concessions. There are also 52 permissions (some of them have not signed a contract yet) to

[2] Except when explicit distinguished, in this paper "consumers" will refer to any customer connected to a power distribution company, regardless if it is a captive or a free consumer.

operate usually small areas[3]. Figure 3 shows the map of the power distribution concessions in Brazil.

Figure 3. Map of power distribution concessions in Brazil.

Analyzing the arrangement of concessions shown in Figure 3 and comparing their locations to aspects shown in Figure 2, it is possible to infer that there are great differences in the reality of each distributor. Assuming that the quality depends on costs (investments and operation and maintenance), it can be stated that the quality will be better in places with higher load density (highly correlated with the habitants density shown in Figure 2 (b), which is larger in the central-south of Brazil and in the coastal region. As the quality is also associated with network reliability, it is clear, from Figure 2 (a), that the eastern region of Brazil has more network resources (SIN).

[3] From now on, all mentions about "distribution companies" will be driven only to those companies that hold a public concession.

II. PERFORMANCE ASSESSMENT OF BRAZILIAN POWER DISTRIBUTION COMPANIES

There are several dimensions that can be considered to assess a distribution company performance. In this paper the focus is on performance in respect to service, and other aspects are not going to be considered (financial performance, for instance).

As previously commented in the Executive Summary, performance in power distribution systems is traditionally assessed in terms of quality of supply, which rely on commercial quality, continuity of supply and voltage quality. However, regulatory approaches usually pursue a wider view of performance, trying to comply with consumers' requirements. In this sense, this chapter will also discuss other dimensions, classified here in the wide concept of the adequacy of the service.

It is noteworthy that this chapter relies on a scenario of Brazilian regulation, and it is not aimed to provide deep concepts about topics.

II.1. The Regulation of the Quality of Supply in Brazil

Supported by Brazilian Constitution and specific laws, ANEEL has enacted resolutions to address the quality of electricity supply. The terms and definitions used in this subject are not common, and may vary among countries. This paper adopts the following concepts depicted in Figure 4.

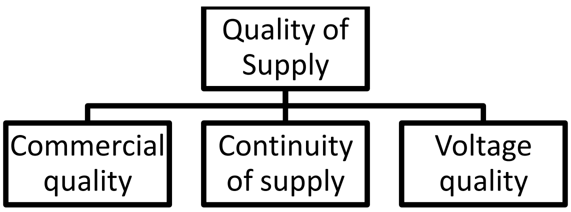


Figure 4. Dimensions of quality of electricity supply.

The commercial quality is related to the transactions between consumers and companies. It covers all possible relations between them, including those happened in the pre-contract period. For instance, some possible transactions are connection request, billing and answer to complaints.

The continuity of supply refers to interruptions of the service. It is the most studied and reported in Brazil and in most countries, as it is usually the parameter that most affects consumers.

Voltage quality is related to imperfections on the product “electricity”, that is, when the electric signal delivered to the consumer is outside the specified parameters. Even though it is intrinsically a technical issue, this aspect of quality is an increasing concern, since consumers’ equipment are becoming more sensible to it. Moreover, new consumers’ equipments are increasingly becoming the source of “pollutions” to the network.

The following subsections present an overview of the Brazilian regulatory aspects of the quality of supply.

II.1.1. Commercial Quality

ANEEL Resolution n° 414/2010[4] establishes all directives related to the general conditions of supply, which need to be followed by distribution companies and also by consumers. Therefore it comprises all directives related to commercial quality.

Resolution n° 414/2010 is a compilation of several other former ANEEL resolutions, especially Resolution n° 456/2000. It contains 17 chapters which give the following directives:

- terminology and general aspects related to consumers units like classification according to activity, nominal voltage connection, electrical boundaries that define the responsibility of each part, the sharing of electrical installations and street lighting services;
- the request of supply and its requirements for consumers electrical assets, the deadline to start the service and the conditions to temporary supply;
- tariff arrangements assigned to class of consumers;
- the standard contract to low voltage (LV) consumers (nominal voltage less than 2.3 kV) and the minimum requirements to other contracts;
- metering issues, including exceptions where meters are not mandatory, conditions to the use of aggregated metering systems and the rules about metering readings;

[4] All ANEEL resolutions are available at http://www.aneel.gov.br/biblioteca/pesquisadigit.cfm.

- billing issues as the maximum and minimum extension of the billing period, the charging of the exceeding demand and the reactive energy, minimum amount of payment, revenues from other services, suitable discounts defined by law, procedure in case of errors in measuring and billing, payment options, information on the invoice and defaulting;
- actions of companies in case of irregular procedures made by consumers;
- companies' responsibilities, like keeping registers of consumers data, commercial quality standards and procedures when handling with complaints;
- consumers responsibilities in causing power disturbances and when there is an increase of load;
- discontinuation of the supply when there is inadequacy in consumer behavior, failure to pay or emergency;
- obligations regarding the public attendance, local structure, telephone assistance and ombudsman requirements; and
- reimbursement to the consumer when there is an electrical damage in LV consumer's electrical equipment.

Specifically on the commercial quality, the Resolution n° 414/2010 states several standards, presented in Table I.

Table I. Commercial standards defined in ANEEL Resolution n° 414/2010 (group A refers to consumers connected in voltage equal or above 2.3 kV or by underground circuit, and group B refers to other consumers connected in voltage bellow 2.3 kV).

Maximum period for inspection of a consumer unit, located in an urban area, after a connection request.	3 working days
Maximum period for inspection of a consumer unit, located in a rural area, after a connection request.	5 working days
Maximum period for connection of a group B consumer, located in an urban area, from the date of approval of installations.	2 working days
Maximum period for connection of a group B consumer, located in a rural area, from the date of approval of installations.	5 working days
Maximum period for connection of a group A consumer from the date of approval of installations.	7 working days
Maximum period to prepare studies, projects and budgets and to inform the consumer when there is a need for improvement in network to allow the connection.	30 days
Maximum period to begin the improvements when the conditions set out in legislation and regulations are fulfilled by the consumer.	45 days
Maximum period to inform consumer the result of the analysis of her/his project, when the improvement of network is due to consumer and it is directly made by her/him	30 days

(counted after its presentation).	
Maximum period to review the project when there is failure or lack of information from the distribution company in the previous analysis.	10 days
Maximum period for attending requests for the inspection of meters and other measurement equipment.	30 days
Maximum period for reconnection when found improper suspension of supply (with company expenses).	4 hours
Maximum period for attending requests of reconnection to a consumer unit located in an urban area, when ceased the reason for suspension.	24 hours
Maximum period for attending requests of reconnection to a consumer unit located in a rural area, when ceased the reason for suspension.	48 hours
Maximum period for attending urgent requests of reconnection in an urban area, when ceased the reason for suspension.	4 hours
Maximum period for attending urgent requests of reconnection in a rural area, when ceased the reason for suspension.	8 hours
Maximum period to send a written notice to the consumer with a list of all companies' local offices (upon request).	30 days
Maximum period for inspection of a consumer's equipment when there is a complaint about electrical damage (only consumers with nominal voltage below 2.3 kV).	10 days
Maximum period for inspection of a consumer's equipment used to store perishable foods or medicines when there is a complaint about electrical damage.	1 working day
Maximum period to send a written notice to the consumer with the result of the request for reimbursement from electrical damage, counted from the date of the inspection or, in the absence of that, from the date of the request for reimbursement.	15 days
Maximum period to compensate from electrical damage the consumer through payment in cash, or the repair or replacement of damaged equipment, after informing the consumer the result of the request for reimbursement from electrical damage.	20 days

Commercial service standards must be assessed on a monthly basis. Failure to comply with the standards presented in Table I requires the company to automatically compensate consumers. They also need to compensate consumers when there is improper suspension of supply.

Specifically about consumers' complaints, the Resolution n° 414/2010 states that any contact made by the consumer should be classified according to 16 different patterns. The company must compute the following information on a monthly basis, by class of complaint:

- number of complaints received;
- number of founded complaints;
- the number of unfounded complaints, and
- average time for resolving founded complaints.

The company must compute complaints made by all provided means, such as call centers, local service offices, internet and correspondence. Resolution n° 414/2010 also established two indicators to assess performance of companies related to consumers' complaints. They are:

$$DER = \frac{\sum_i \mathrm{FC_i} \times \mathrm{ATR_i}}{\sum_i \mathrm{FC_i}} \qquad\qquad FER = \frac{\sum_i \mathrm{FC_i}}{\mathrm{N_t}} \times 1000 \tag{1}$$

where FC_i is the number of founded complaints to the pattern i; ATR_i is the average time of conclusion of founded complaints; N_T is the total number of consumers.

Standards to DER and FER and its penalties were not yet stated in Resolution n° 414/2010, and will be soon handled in a further ANEEL resolution.

The Resolution n° 414/2010 determines that utilities must submit monthly to ANEEL the indicators DER and FER, a summary of their commercial processes and the compensations paid. Companies must follow the Brazilian standard ABNT NBR ISO 10,002 – Customer Satisfaction: Guidelines for Complaints Handling in Organizations, and certify the process of handling consumer complaints in accordance with ISO 9000.

II.1.2. Continuity of Supply

The continuity of supply is strictly related to the reliability of the system. Investments and operational resources are both required to provide reliability. Some engineering models try to emulate the reliability of a system to a given amount of investment and maintenance resources, but these tools are more useful as simulation tools and they cannot provide a deterministic answer to all situations. In fact, there are many different strategies that a company can adopt to reach a desired level of reliability.

The continuity of supply is regulated by ANEEL in Module 8 of the Procedures for Distribution of Electricity in National Electric System – PRODIST, established by Resolution n° 395/2009. This document presents all technical procedures that companies need to follow in this subject, as the characterization of interruptions, how to compute indicators and the required data to be stored by companies or periodically sent to ANEEL. Thus, all information from this subsection can be found in Section 8.2 of Module 8.

The ideal for consumers is to have the system always available. However, to ensure continuity at these levels is neither technically nor economically feasible. Then, the best is to seek for an efficient solution that minimizes the total cost – computed by summing costs of consumers caused by interruptions of supply and the costs to provide the given reliability.

Interruptions of supply are usually assessed by two indicators that measure the duration and the frequency of interruptions. In Brazil, they are called DEC and FEC, according to the following equation.

$$DEC = \frac{\sum_i \mathrm{N_i} \times \mathrm{t_i}}{N_T} \qquad FEC = \frac{\sum_i \mathrm{N_i}}{N_T} \tag{2}$$

where N_i is the number of consumers interrupted by each incident; t_i is the restoration time for each incident; N_T is the total number of consumers of the set of consumers or any portion of the system. DEC and FEC are equivalent to the worldwide known indicators SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index).

DEC and FEC represent an average of all consumers. Each consumer has its own continuity measured by three indicators: DIC, FIC and DMIC. They are defined as:

$$DIC = \sum_i \mathrm{t_i} \qquad FIC = n \qquad \boldsymbol{DMIC = t_i^{max}} \tag{3}$$

where n is the number of interruptions to the given consumer; and t_i^{max} is the duration of the longest interruption to a given consumer. DEC (or FEC) can be computed alternatively by the average of DIC (or FIC) taken from a set of consumers.

It is worth noting that all continuity indicators presented before measure only long interruptions, defined as interruptions that last at least 3 minutes. And there are also some long interruptions that are not accounted to these indicators, like those that are associated to exceptional events (fortuitous reasons or force majeure, for instance).

The DEC and FEC indicators were officially established in 1978, and are computed by sets of consumer units. These sets of consumer units are any arrangement of consumers in a given company with continuous area. In the end of 2009, ANEEL has stated more restricted rules to the definition of set of consumers. They are:

1. Each set of consumers is priority defined by the electrical configuration of networks, that is, the area that includes all medium voltage (MV) networks downstream any high voltage (HV) substation.
2. Very small set of consumers are not allowed (less than 1,000 consumers), and companies need to aggregate them to another neighbor set.
3. Relatively small set of consumers should be avoided (from 1,000 to 10,000 consumers), and companies can aggregate them to another neighbor set.
4. Companies cannot aggregate sets with more than 10,000 consumers.

5. Exceptional cases, like regions with very low density or with different electrical configuration, are analyzed by ANEEL.

The rules presented before generated a wide review in almost all set of consumers of Brazil, which was done during 2010. Now under this definition there are 2,959 sets of consumers in Brazil.

The sets of consumers are the minimum unit to assess collective continuity of supply. The DEC and FEC indicators are computed to each set and sent to ANEEL every month. In addition to these indicators, ANEEL requires some quarterly information from each set. The sets' attributes are:

- area in square kilometers (km^2);
- extension of the MV network, segregated into urban and rural, in kilometers (km);
- energy consumed in the last 12 months, segregated by residential, industrial, commercial, rural and other classes, in megawatt hours (MWh);
- number of consumer units served, segregated by residential, industrial, commercial, rural and other classes;
- installed power in kilovolt-ampere (kVA);
- constructive pattern of the network (overhead or underground);
- location (isolated or connected to the SIN).

Starting from a premise that similar set of consumers should present equivalent performance, ANEEL defines standards to indicators DEC and FEC of each set based on a benchmarking technique. Attributes are used in a statistical method to define similar sets to each consumers' set, and performance in terms of DEC and FEC of a reference set is taken as the goal to the rest – presently the benchmark is taken as the 20^{th} percentile.

Standards defined to DEC and FEC are used to compare and assess companies' performance, and are the reference to the definition of standards to indicators DIC, FIC and DMIC. These standards are defined in three different time frames: months, quarters and years – this division is due to the seasonal characteristic of interruptions – and companies need to compensate consumers if there is a violation in any of these indicators.

Recently, ANEEL has defined a rule to compose a ranking of companies in relation to DEC and FEC indicators. The ranking is an attempt to give incentives to companies by publishing their performance. The rule is a simple composition of DEC and FEC indicators performed in a ratio of its standards, with equal weights to each one.

The ranking will be first published in April 2012. As already discussed in Section I.2, the publication of this ranking is solely a kind of incentive regulation. But in addition to its publication, ANEEL will start to use it as an incentive mechanism in tariff definition next year.

II.1.3. Voltage Quality

Voltage quality is the most complex aspect in the quality of supply, and most of its disturbances are not even perceived by ordinary consumers. The Section 8.1 of Module 8 regulates voltage quality in power distribution systems. The following disturbances are listed:

- voltage in steady state;
- power factor;
- harmonics;
- voltage unbalance;
- voltage fluctuation (flicker);
- rapid voltage variations (voltage dips and swells); and
- voltage frequency deviation.

The most common voltage quality problems in Brazil are voltage variations in steady state, or slow voltage variations in root mean square value – (RMS), and low power factor in some loads. The other disturbances listed before were characterized in Section 8.1 of Module 8, but their regulation is not finished. ANEEL is planning a national coordinated measurement to diagnose the condition of voltage supplied in Brazil, and, in parallel, a discussion about indicators, measurement protocols, responsibilities definition, and standards and penalties has already started.

Reactive energy (related to lower power factor) is treated as a commercial procedure – there is a limit of consumption to loads, and an extra fee is charged when loads exceed this limit. These procedures are established in Resolution n° 414/2010. Therefore, this section will discuss only the voltage variations in steady state.

The steady state voltage variation is assessed in terms of RMS value of the voltage. It is a continuous phenomenon, and measurements to assess it in a given point of the distribution network are taken during one week. Average values are stored every 10 minutes of this period, leading to 1008 average measurements. If interruptions of supply or rapid voltage variations occur during a measurement, this average value needs to be replaced by other taken in a consecutive 10 minutes measurement.

Each average measurement is classified into three ranges in relation to the nominal voltage: adequate, poor and critical. Then, two indicators are computed to each one weekly measurement:

$$DRP = \frac{\text{nlp}}{1008} \times 100[\%] \qquad\qquad DRC = \frac{\text{nlc}}{1008} \times 100[\%] \tag{4}$$

where DRP is the Relative Duration of Poor Voltage Transgression; *nlp* is the number of average measurements classified as poor; DRC is the Relative Duration of Critical Voltage Transgression; and *nlc* is the number of average measurements classified as critical.

Measurements can be taken in answer to a consumer's complaint or in an annual sampled measurement defined by ANEEL. In both cases, if DRP is above 3% or DRC is above 0.5%, companies have a procedure to settle voltage supplied, and need to compensate consumers after a given time until the problem is solved.

The annual measurements defined by ANEEL are sampled randomly among all LV and MV consumers. The sample size depends on the company's total number of consumers. DRP and DRC indicators generated by each measurement need to be sent quarterly to ANEEL. They are used to generate three collective indicators to assess companies' performance. They are:

$$DRP_E = \sum \frac{\text{DRP}_i}{N_L} [\%] \qquad\qquad DRC_E = \sum \frac{\text{DRC}_i}{N_L} [\%] \qquad\qquad ICC = \frac{N_C}{N_L} \times 100[\%] \tag{5}$$

where DRP_E and DRC_E are the collective DRP and DRC indicators, computed to each company as the simple average of indicators DRP_i and DRC_i, measured from consumer *i*; N_L is the number of consumers from the sample; N_C is the number of consumers with DRC non null, that is, consumers that have at least one averaged measurement classified as critical.

II.2. Other Aspects Related to the Adequacy of the Service in Brazil

The concept of quality of supply presented in the previous section is very comprehensive, and is, in general, uniform among researchers and regulators in the area of power quality. However, there are other important issues in the context of the adequacy of service. Aspects such as safety in the operation are increasingly important to society, and could be considered in an analysis of performance of companies. In Brazil, some of these aspects are explicitly described in the Law 8,987, already mentioned in the first chapter.

Here are some considerations that will be presented about five important aspects for companies that operate public services: safety in operation, socio-environment, energy losses, universality and resilience.

II.2.1. Safety in Operation

The distribution of electricity is a service that involves various risks. In Brazil, electricity distribution is mostly performed at voltages from 110 to 230,000 volts. All this voltage range involves risk to the population and to the employees of companies.

The majority of the equipment (lines, transformers, poles, towers, etc) is located on the streets, coexisting with buildings and traffic, and is subject to several dangerous situations. The possible hazards of the power distribution include burns and explosions resulting from unexpected equipment failure. Other possible accidents can occur when proper safety procedures are not followed. Since companies are incentivized to reduce costs, safety and labor regulation need to provide the rules to try to prevent accidents and its severities.

In Brazil, safety and health of workers are regulated by the Ministry of Labor. Companies follow directives from a wide legislation, which include the Consolidation of Labor Laws (CLT) and the Regulating Standards (NRs) from the ministry. The action of ANEEL in this subject is mainly to monitor some statistics from accidents reported by companies, defined in Module 6 of PRODIST:

- Frequency rate of labor accidents, defined as the number of accidents per million man-hours of exposure to risk, in a given period;
- Rate of graveness, defined as the time computed per million man-hours of exposure to risk in a given period;
- Number of deaths of its own employees due to labor accidents;
- Number of deaths of outsourced employees due to labor accidents;
- Number of accidents affecting the general public occurred in electrical installations of company;
- Number of citizen deaths due to accidents occurred in electrical installations of company.

The hours of exposure should be taken from payroll records, considering only the hours worked, including overtime.

II.2.2. Socio-Environment

Issues related to social and environmental responsibility are increasingly important in nationally discussed topics. This concern rises from the perception of population that individual actions have consequences (favorable or harmful) in the living conditions of the whole society, and it is related to the concepts of citizenship and sustainable development.

Nowadays this perception is shared by many investors, which are seeking to invest in companies that show transparently their consequences of its operations to society. One example is the Dow Jones Sustainability Indexes (DJSI), launched in 1999 (Dow Jones Sustainability Indexes, 2012). This attitude makes economic sense, and can be seen as an attempt to capture externalities[5] in firms' production. For this reason, several companies have been investing resources spontaneously in the social development of their employees and the communities in which they operate, a process of awareness of this new social order.

In the context of public services, power distribution companies fit into the social and environmental context using the resources needed to carry out their economic activities (natural materials, manpower, infrastructure and the basic services of third parties) and, in performing their services, promote social, economic, environmental, cultural and technological changes. The awareness of the consequences of those actions and activities in this context is its social and environmental responsibility (ANEEL, 2006).

Given that power distribution is a regulated public service, the analysis of this responsibility should be further expanded through the understanding that such services must primarily serve the public interest, since any concession or permission presupposes the rendering of an appropriate service that satisfies the conditions of regularity, continuity, efficiency, safety, modernity, universality, courtesy and affordability.

In accordance to consumers' desires and the Law 8,987, since 2002 ANEEL demands from electricity companies the Annual Report of Socio-Environmental Responsibility (ARSER), following the guidelines provided in the Accounting Manual for Public Service Electric Power (MCSPEE), established by ANEEL Resolution n° 444/2001.

The ARSER is structured into five dimensions, which include descriptions of activities and quantitative and qualitative performance indicators. They are described hereinafter.

- General Dimension: in this dimension are presented general company information, such as the nature of ownership, the form of management, company history, mission, principles and values that guide decisions, relationships with stakeholders and channels of communication, risk controls and indicators and operational productivity.
- Corporate Governance Dimension: corporate governance is related to the company's adherence to ethical principles, transparency, accountability and values that govern it.

[5] Externalities are the harmful or beneficial side effects of market activities that are not fully borne or realized by market participants (Browning and Zupan, 2009).

- Financial-Economic Dimension: this dimension seeks to provide transparency to the economic impacts of the company, not always included in conventional financial reports. Some information required are wealth generated and distributed to workers, government, lenders and shareholders; the provision of services, income, employment generation and income; and contribution to regional development and reducing social inequality, enabling access to the communities served electricity services.
- Social and Sector Dimension: this item aims to describe the social performance of the company, with its policies and its actions related to some public affected by the activities of the company in internal and external environments: employees, suppliers, consumers, community, government and society in general.
- Environmental Dimension: in this item companies need to report their projects, programs, actions and indicators to enable stakeholders to know and monitor the activities of the company towards an improvement in environment, as well as those voluntary actions, not associated with compensatory measures, aimed at environmental protection areas. Information can be grouped into i) impacts, life cycle and environmental preservation; ii) environmental education; iii) energy efficiency; iv) R&D in environmental issues; v) culture, sport and tourism; and vi) health.

II.2.3. Energy Losses

The process of generating, transmitting and distributing energy generates losses. These losses occur naturally from the dissipation of power in electricity components such as lines, transformers and measurement systems, and are known as technical losses. There are also losses that are caused by external actions to the power system, like errors in measuring and billing, theft and fraud. These losses are known as non-technical losses (or commercial losses). The sum of technical and non-technical losses gives the total losses, which can be defined as the energy injected in the power system that is not sold.

Total losses in the Brazilian power distribution systems during the second review of prices were about 14% of the injected energy, 7% for technical and 7% for non-technical losses. While technical losses lie in an accepted level, non-technical losses are considered very high, especially because their high variance among companies. For instance, while there are companies that do not have non-technical losses, there are others with more than 30% of the injected energy.

There are historical and cultural factors that can be associated with high non-technical losses. However, inefficiency of companies in combating theft and fraud is clear. Therefore, ANEEL defines acceptable levels of losses, establishing goals to incentivize companies with higher level of losses to improve their efficiency. This procedure is carried out in tariff definition of each company.

Every price review, ANEEL performs a simplified calculation of energy losses for each company. The terminology, methodology and procedures used in this calculation are stated in Module 7 of PRODIST. Using energy and physical information (general attributes of each individual MV and LV network, like total length and average resistance), ANEEL can compute energy losses in each aggregate segment of power distribution networks. Figure 5 depicts an example of a simplified aggregated diagram from a Brazilian company. Note that only aggregate transformation and lines are represented, as well as energy input, output and flows on each aggregate segment.

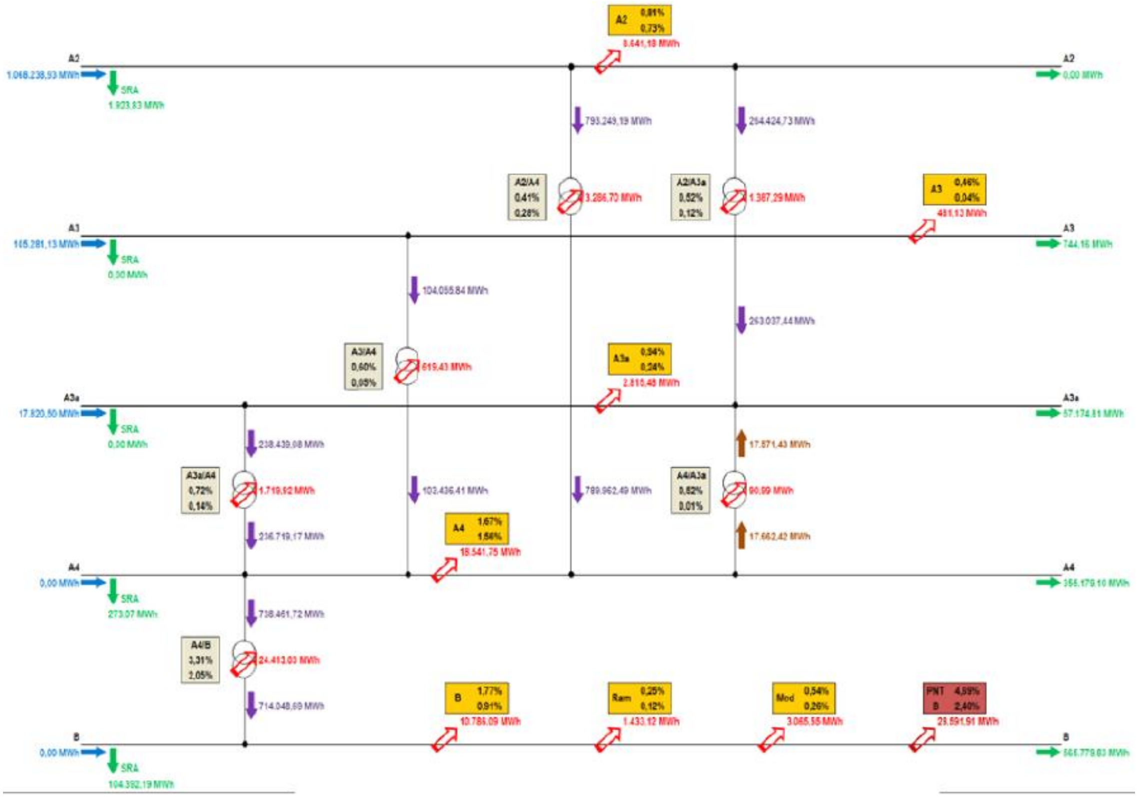


Figure 5. Illustration of a simplified aggregated diagram of a Brazilian company.

The simplified procedure to compute energy losses allows ANEEL to analyze technical losses per aggregate segment (transformations and lines), helping ANEEL to define the acceptable technical losses levels to each company. In the process of calculation, ANEEL uses some parameters settled as a good practice in engineering, what usually leads the acceptable technical losses to smaller values than companies claim they are.

The difference between total losses and acceptable technical losses gives a picture of the current status of companies' non-technical losses in the year of their price review. Then, by the use of benchmarking techniques, ANEEL defines acceptable levels of non-technical losses, proposing a reduction or maintenance of losses in the years until the next price review.

In reality, companies have an acknowledgment of their total losses. Companies above this level are strongly incentivized to reduce losses, technical or non-technical, since no tariff is provided to pay for this energy. This procedure is regulated in Submodule 2.6 of Procedures for Tariff Review – PRORET.

II.2.4. Universality

The International Energy Agency considers that, in 2009, 1.317 billion people worldwide do not have access to electricity (IEA, 2012). Given this reality, several actions should be taken in order to reduce the consequences of this omission. This is because it is widely accepted that the availability of electricity acts as an effective agent of development. In this sense, the challenge is even greater for less developed countries.

In Brazil, surveys have found that areas with lower Human Development Index (HDI) were in regions with lower rates of attendance of electricity. The reduction of these inequalities would be accelerated with the use of electricity as a vector of development (MME and IICA 2011).

Inspired in this scenario and based on the universality principle determined by Law 8,987, the Law 10,438/2002, followed by ANEEL Resolution n° 223/2003, established the foundations for universal access to electricity. In order to accelerate the universal access to electricity in Brazil, the Federal Government created the Light for All Program (*Luz para Todos* – LpT) through the issuance of Decree n° 4,873/200, establishing sector resources for funding.

The LpT is considered the most ambitious power inclusion program implemented in the world. In December 2011, the program had connected 2.9 million families, benefiting 14.5 million habitants (MME, 2011). During the execution of the program, new families without electricity in the home were located and, due to the emergence of a large number of demands and the highest costs associated to these new locations, the program has been extended to be completed in 2014.

ANEEL has an important role in implementing the universalisation of electricity. The agency assigns goals to companies connect unassisted families, establishes indicators to assess the development of the program and settles penalties in case of noncompliance. All these issues are regulated in Resolution n° 223/2003.

Goals were established accordingly to an index of attendance, estimated from data provided by the Brazilian Institute of Geography and Statistics (IBGE). Goals are defined in two ways: to the entire concession and to each Brazilian city. Table II and Table III show these goals.

Table II. Goal to companies' index of attendance.

Company's Index of Attendance (Ia)	Last year to promote the universal service
Ia > 99.50%	2006
98.00% < Ia ≤ 99.50%	2008
96.00% < Ia ≤ 98.00%	2010
80.00% < Ia ≤ 96.00%	2013
Ia ≤ 80.00%	2015

Table III. Goal to cities' index of attendance.

City Index of Attendance (Ia)	Last year to promote the universal service
Ia > 96.00%	2004
90.00% < Ia ≤ 96.00%	2006
83.00% < Ia ≤ 90.00%	2008
75.00% < Ia ≤ 83.00%	2010
65.00% < Ia ≤ 75.00%	2012
53.00% < Ia ≤ 65.00%	2014
Ia ≤ 53.00%	2015

Based on general goals provided in Table II and Table III, each company submitted to ANEEL analysis and approval the Plan for Universal Electric Energy, containing information about planned MV and LV network expansion, average costs of connection, estimated quality of supply and the form of publication of all information to eligible consumers.

ANEEL has set up three indicators to assess the evolution of universalisation. They account to the total (global), urban and rural universalisation level, accordingly to the following equations:

$$NGU = \frac{TUC}{TD} \times 100[\%] \qquad NUU = \frac{TUC_u}{TD_u} \times 100[\%] \qquad NRU = \frac{TUC_r}{TD_r} \times 100[\%] \quad (6)$$

where *TUC* is the number of residential consumers; *TD* is the number of residences in Brazil, accordingly to IBGE; subscripts *u* and *r* refers, respectively, to urban and rural located consumers or residences.

There is a penalty associated in fails of compliance of universalisation goals, which lead companies to tariff reductions. Notwithstanding the penalty, companies must also submit to ANEEL their justifications for the breach of the goal, and submit a proposal containing a schedule for regularization of connections. In some conditions, companies can also receive a fine.

II.2.5. Resilience

Resilience can be defined as the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress, or an ability to recover from or adjust easily to misfortune or change (Merriam-Webster, 2012). Despite its use being originated in physics, nowadays it is a more comprehensive concept, adopted in other areas of study as in computer networking, ecology, and organizational studies.

The National Infrastructure Advisory Council of United States (NIAC) defined Infrastructure Resilience as the ability to reduce the magnitude and/or duration of disruptive events. Thus, the effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event (NIAC, 2009). The definition was used to develop a common construct to describe and organize resilience practices in the electricity sector, consisting of four outcome-focused abilities: robustness – the ability to absorb shocks and continue operating; resourcefulness – the ability to skillfully manage a crisis as it unfolds; rapid recovery – the ability to get services back as quickly as possible; and adaptability – the ability to incorporate lessons learned from past events to improve resilience.

In 2009, NIAC conducted a report on Critical Infrastructure Resilience, which provided a common definition of resilience but recognized that each sector applies resilience strategies and practices differently. Therefore, NIAC decided to conduct a study to describe and clarify sector-specific resilience strategies and practices, and how they can serve as the basis for setting sector-specific resilience goals. The document Critical Infrastructure Resilience – Final Report and Recommendations (NIAC, 2009) contains the first case studies of the electricity and nuclear sectors and proposes a framework for setting resilience goals within all critical infrastructure sectors.

Although the report recognizes the resilience of distribution assets is important, it points out that electric grid performance is driven by the ability of the bulk electric power system to deliver reliable power to distribution systems throughout the United States and Canada. Therefore, the electricity sector case study centered on the generation and transmission capabilities of the electricity sector, with the primary concern of the reliability of the bulk power system. In short, reliability is the ability to meet the electricity needs of end-use consumers, even when events reduce the amount of available electricity (NIAC, 2009).

Indeed, reliability of electrical systems has been historically focused on generation and transmission systems, since failures in these systems affect much of the loads and population. The power distribution, seen as the "retail" in the delivery of energy, only affects consumers sparsely. However, the increasing costs associated with power outages, plus the fact that most of these interruptions occur in distribution systems, do not allow the distribution systems to be neglected. For instance, from the second half of 2007 to the end of 2009, only about 7% of the Brazilian DEC was due to the suppliers (Rôla et al., 2011).

There are several actions that affect power distribution resilience. For instance, the company can incorporate more realistic consumers' costs of interruptions in planning. This can provide more reliable systems with redundancy and automation on network. Other possible ways are to improve labor force investing more in training and equipments or defining goals and incentives. Investment is one of the most significant possible actions to improve system reliability. Companies can purchase mobile transformers and substations, control systems, weather forecast systems, communication systems or more advanced simulation tools. Management of vegetation by regular trimming can also greatly improve system resilience, since this is a source of many interruptions.

The discussion about the acceptable level of regulation in resilience is polemic – actually, many would question if it is desirable at all. Regulation of power distribution is mainly based on incentives, and companies responses are measured by performance indicators. So, there are at least three reasons for regulators to not try to regulate the aspects mentioned before:

- it can be considered an intrusion on the right of the company to manage its business, and as the co-manager, the regulator could be blamed if the company performance is bad;
- these aspects are already measured indirectly in other performance indicators; and
- these information is hard to standardize and to control, due to its high level of information asymmetry.

Perhaps the only, but strong, reason that may support a certain level of direct regulation of resilience in power distribution is the inertial characteristics of the most management actions in power distribution networks. As other infrastructure sectors, power distribution requires complex management, with many different options of investments and other expenditures that can lead to a given level of reliability – all of them associated with huge amount of money. Many of these options may take some time to be noticed in indicators, when the problem can be realized by the regulator. And that could be too late. Some actions that can take a long time to be reflected in indicators are the mismanagement of labor force and assets age.

The management of assets may be the easiest characteristic to be assessed by ANEEL. Information about the age of assets is already considered in the review process, so it is standardized and available. And it is undoubtedly related to the system reliability, since equipments generally present a behavior depicted in Figure 6.

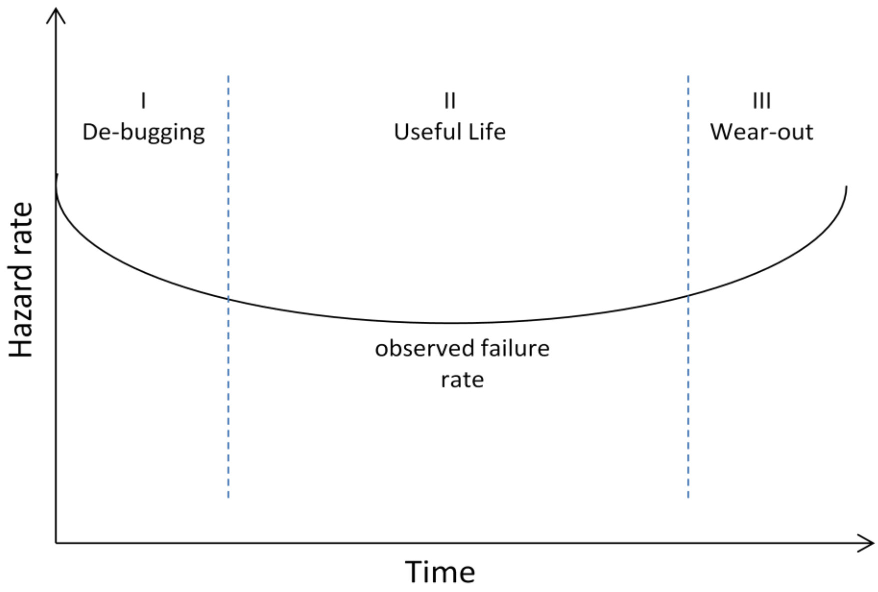


Figure 6. The bath-tub curve.

Figure 6 describes a particular form of the hazard function which comprises three parts. The first represents a decreasing failure rate, known as infant mortality or de-bugging phase. The second part represents a constant failure rate, known as useful life period or normal operating phase. The third part represents an increasing failure rate, known as wear-out or fatigue phase (Billinton and Allan, 1992).

Companies need not to replace assets when they are exactly at the end of designed life. Some companies have been successful in increasing asset lives through a better control of equipment and its risk of failure. However, these actions can delay the substitution of equipment for only a restricted time. Companies which strategy is to not invest may postpone equipment replacement more than the recommended, and, if it is a policy broadly used in electrical assets, failures may increase exponentially (as showed in Figure 6), especially in adverse weather conditions. When it happens, companies may not be financially capable to restore an satisfactory level of performance, ANEEL penalties are no longer effective, and consumers face a long period of low quality.

ANEEL currently does not regulate any of the resilience aspects mentioned in this subsection. However, there is a discussion about the appropriateness of starting to monitor companies' practices by requiring some periodic information. ANEEL, just like other government regulators (House of Commons, 2004)[6], has being increasingly asked to improve its monitoring practices to anticipate some problems that may arise.

[6] The report prepared by the UK House of Commons states: "We agree that neither the relevant government department nor the regulator should seek to micro-manage the private companies engaged in an industry. However, the energy industry is not quite like any other sector: all other industries, the public sector and every person depend on its efficient operation. While not wanting Government or regulator to manage the industry, we thought it right to question whether either has enough resources to enable it to make an independent assessment of the performance of the network companies and to determine what more, if anything, needs to be done to ensure a reliable electricity supply."

III. REGULATORY APPROACHES TO ASSESS COMPANIES' OVERALL PERFORMANCE

This chapter presents some regulatory approaches that intent to describe, in a single number, the overall performance of companies. Performance is a general concept. While the traditional approach tends to rely more on technical indicators, contemporaneous approaches tend to translate also the consumers' need. This can be realized in many infrastructure sectors, where surveys on consumers' satisfaction are widely applied.

The chapter starts by showing a proposal that is currently being discussed in land transportation sector in Brazil. The second section describes two experiences in the regulation of water and sewerage in England and Wales. The chapter ends with the description of the ANEEL experience with the overall assessment of consumers' satisfaction.

Rather than describing a large number of methodologies, this chapter aims to show few of them, presenting more accurately the dimensions of performance considered by regulators, as well as the weighting mechanism to combine them.

III.1. Regulation of the Land Transportation in Brazil – ANTT

Set up in 2001, the Brazilian Agency for Land Transportation (ANTT) is linked to the Ministry of Transport, and has financial and administrative independence. The agency is responsible for the concession of railways and roads, for the use of infrastructure, and also for granting permission for regular passenger transport by rail and road. In addition, the ANTT is the organization that authorizes passenger transport by tourism companies on a charter basis, international cargo transport and the use of terminals and multimodal transport (integrated transport that makes use of several different means of transport).

In 2008, ANTT has launched the Project of the National Interstate and International Road Transport of Passengers – *ProPass Brasil* (ANTT, 2012), aiming at restructuring the services of interstate and international road transportation of passengers. After a public consultation in 2009, ANTT conducted countrywide research to collect information to develop plans of granting and basic projects of lines' batches to be auctioned. ANTT is currently discussing the documents related to the Public Tender and the Permission Contract to interstate road lines in the Public Hearing n° 121/2011 (ANTT, 2012).

The Annex V of the proposed contract defines the Performance Assessment System, which can be seen as a set of indexes that measures companies' performance (ANTT, 2012). All indexes can be combined to compute the overall index of performance: the Transport Quality Index (*Índice de Qualidade do Transporte* – IQT).

Standards to each index will be established after a period of collecting information. Then, accordingly to companies' performance, a mechanism of rewards and penalties will be applied. Penalties are defined as a result of the trespassing severity from the standard, varying from fines to the extinction of the contract. Excellence on Performance certificates will be issued to companies with good performance. The possible additional incentives are:

- preference in selection of companies to operate authorized services in special cases or in emergences;
- creation of a quota to explore the batch that company currently operates; and
- discount of 10% in the annual tax paid to ANTT.

III.1.1. The IQT methodology

The Transport Quality Index (IQT) is computed by composing several other indexes, accordingly to five main characteristics. Figure 7 shows a hierarchical disposal of all indicators that compose IQT (ANTT, 2012).

IQT is computed in a simple weighted sum of the five main indicators, as described in Equation (7):

$$IQT = 0.16 \times ICG + 0.31 \times IOP + 0.30 \times IS + 0.11 \times NIL + 0.12 \times IEG \tag{7}$$

where ICG is the General Comfort Index; IOP is the Operational Efficiency Index; IS is the Safety Index; NIL is the score of the Legality Index; and IEG is the Service Management Efficiency Index.

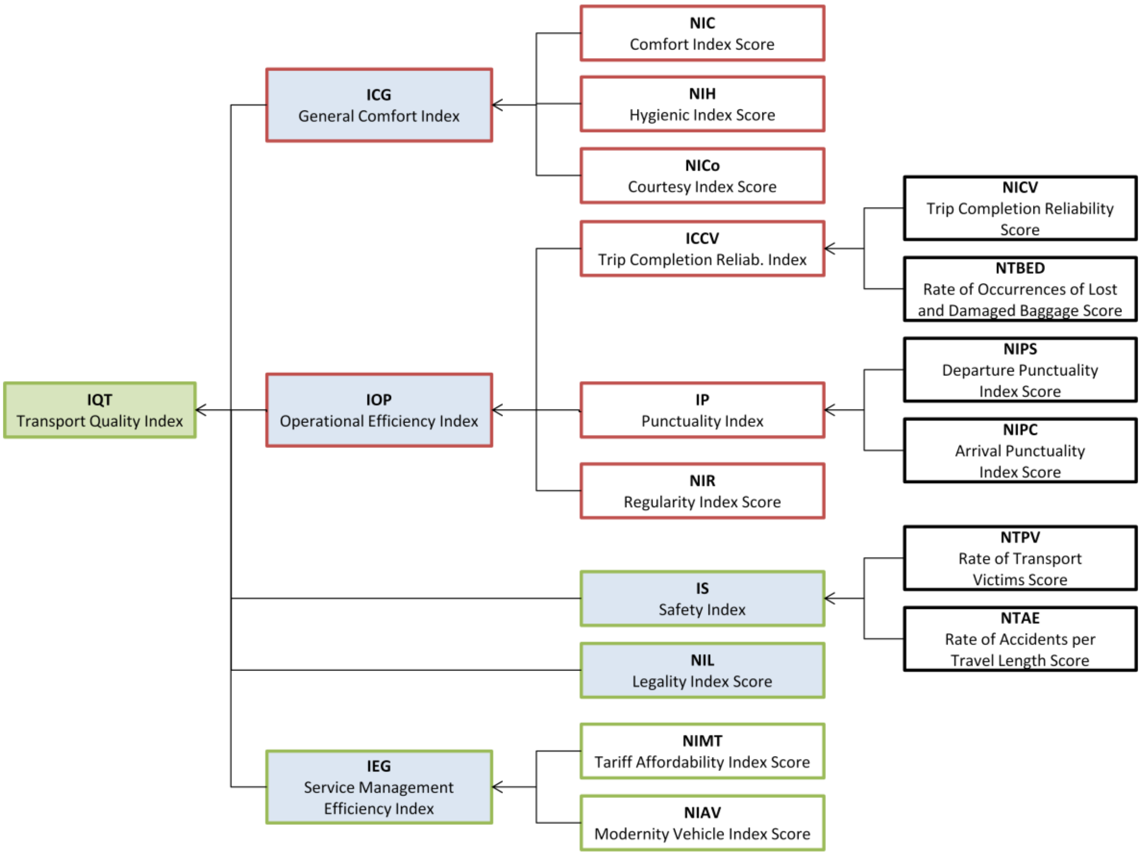


Figure 7. IQT composition – adapted from (ANTT, 2012).

The General Comfort Index (ICG) assesses aspects related to the welfare of consumers while procuring and using companies' services. It is composed by three specific indexes, according to Equation (8):

$$ICG = 0.32 \times NIC + 0.46 \times NIH + 0.21 \times NICo \tag{8}$$

where NIC is the score of the Comfort Index; NIH is the score of the Hygienic Index; and NICo is the score of the Courtesy Index. These three scores are obtained from evaluations of users surveyed regarding these aspects.

The Operational Efficiency Index (IOP) assesses operational aspects of the companies' operation while transporting passengers. It is composed by three specific indexes, according to Equation (9):

$$IOP = 0.48 \times ICCV + 0.28 \times IP + 0.24 \times NIR \tag{9}$$

where ICCV is the Trip Completion Reliability Index; IP is the Punctuality Index; and NIR is the score of the Regularity Index.

The ICCV is calculated using the indicator of completion of trips (the ratio of the number of trips completed without transshipment and the number of trips offered in the same type of service) and the rate of occurrences of lost and damaged baggage (ratio between the total occurrences of lost and damaged baggage and total passengers). It is computed by:

$$ICCV = 0.1 \times (0.54 \times ICV) + 0.46 \times NTB_{ED} \tag{10}$$

where ICV is the Trip Completion Reliability; and NTB_{ED} is the score given to the Rate of Occurrences of Lost and Damaged Baggage. The ICV represents the relationship between the number of trips completed without transshipment and the number of trips offered by the same company, and it is obtained from the NICV – a score for the ICV. The NTB_{ED} represents the ratio for each 10,000 passengers between the total occurrences of lost and damaged luggage and total passengers carried.

The Punctuality Index (PI) is calculated by considering the degree of scheduled and verified compliance of departures and arrivals of interstate travel.

$$IP = 0.52 \times IPS + 0.48 \times IPC \tag{11}$$

where IPS is the Departure Punctuality Index; and IPC is the Arrival Punctuality Index. The IPS represents the degree of compliance of scheduled and verified times for the departures of interstate trips. It is obtained from the NIPS (a score for the IPS), and delays or advances of less than 15 minutes are tolerable. The IPC represents the degree of compliance of scheduled and verified times for the arrival of a trip (delays or advances of less than 10% of the scheduled time are tolerable). Like IPS, there is a score to the index IPC – the NIPC.

The Regularity Index (IR) is calculated by considering the relationship between the number of scheduled trips that happened and the total of scheduled trips.

The Safety Index (SI) is calculated by considering the relationship between the total number of people victimized during transport and total passengers carried and the relationship between the number of accidents per mile traveled. It is given by:

$$IS = 0.52 \times NTPV + 0.48 \times NTAE \tag{12}$$

where NTPV is the score given to the Rate of Transport Victims; NTAE is the score given to the Rate of Accidents per Travel Length. The Rate of Transport Victims (TPV) represents the relationship for each 10,000 passengers of the total people affected during transport and total passengers carried. The Rate of Accidents per Travel Length (TAE) represents the relationship between the number of accidents per distance traveled – it is computed for each million kilometers traveled.

The Legality Index (IL) represents the compliance of the services provided with current legislation, contract and pertinent technical standards. It addresses the relationship between the weighted average number of fines (with final decisions) and the distance traveled by the company. It also includes the aspect of service appropriateness regarding the universal access.

The Service Management Efficiency Index (IEG) assesses the management policies of companies. It is composed by two specific indexes, accordingly to Equation (13):

$$IEG = 0.67 \times NIMT + 0.33 \times NIAV \tag{13}$$

where NIMT is the score given to the Tariff Affordability Index; and NIAV is the score of Modern Vehicle Index. The IMT is calculated based on the relationship between the current tariff and the reference tariff (provided in the bidding documents). The IAV is calculated by considering the relationship between the sum of the age of vehicles of the company and the number of vehicles in its fleet. Poor and unacceptable ratings are not assigned to both indexes, since ANTT already establishes and controls the maximum rate and the average maximum age for the fleet (five years). Thus, the operator who set prices within the stipulated maximum value or offer services with a fleet within the allowed parameters is not necessarily running an inappropriate service. However, operators who make more discounts in the price or use newer vehicles will better assess this indicator. Therefore, the IMT and the IAV are only capable of incentive and no penalty.

After their computation, all indexes are scaled in a range from 0 to 10. The final qualitative classification of each index is shown in Table IV.

Table IV. Qualitative classification of indexes **(ANTT 2012)**.

Score Interval	**Classification**
8 |—| 10	Excellent
6 |— 8	Good
4 |— 6	Regular
2 |— 4	Poor*
0 |— 2	Unacceptable*

* IMT and IAV do not fulfill these categories.

III.2. Regulation of the water and sewerage sectors in England and Wales – Ofwat

Ofwat (The Water Services Regulation Authority) is the economic regulator of the water and sewerage sectors in England and Wales. Ofwat launched the Overall Performance Assessment (OPA) score in 1999, and was last published and used in the report of performance of the water companies in England and Wales in 2009-10 (OFWAT, 2010).

OPA provided a relative performance among companies, in a quantitative scale based on key areas. It was used to take account of relative performance when setting limits on the prices the companies charge consumers through their water bills. So, according to companies' performance, the price limits could be adjusted in a range from +0.5% for the best performing companies to –1.0% for the worst.

Recently, Ofwat replaced OPA by a new approach called Service Incentive Mechanism (SIM). Whereas both indexes pursue the same aim (assess the overall performance of companies), SIM is based on consumers' experience instead of technical indicators. Both will be presented in next subsections.

III.2.1. The OPA methodology

The OPA score is a numeric indicator computed by a combination of different key areas (OFWAT, 2010):

- Water supply, levels of service: Properties at risk of low pressure; Properties with unplanned interruptions; Water quality failing DWI standards.
- Sewerage service, levels of service: Sewer flooding incidents (capacity); Sewer flooding incidents (other causes); Properties at risk of sewer flooding.
- Security of supply: Population with hosepipe restrictions; Leakage – performance against target; Security of supply index – absolute performance; Security of supply index – performance against target.
- Customer service: Company contact score (response to billing contacts, response to written complaints, billing of metered customers and telephone contact combined); Other customer service.
- Environmental performance: Category 1 and 2 pollution incidents – sewage; Category 3 pollution incidents – sewage; Category 1 and 2 pollution incidents – water; Sewage treatment works in breach of their consent; Sludge disposal – percentage of sewage sludge disposed of unsatisfactorily.

The calculation of the OPA score follows these steps (OFWAT, 2004):

1. Each performance score is changed so that it is in the range of 0 to 1. Then all scores are on the same scale and when the scores are added together one performance measure

does not dominate the score. This is calculated, for each element of performance, using the following equation:

$$\frac{Company\ score - range\ min}{Range\ \max - range\ min} \tag{14}$$

2. The score is increased so that it is between 0 and 45. This is calculated by multiplying the above score, which is now between 0 and 1, by 45. This is to avoid scores being below one decimal place which are more difficult to read.

3. Finally the score is changed so that it is between 5 and 50. The OPA score is calculated by adding 5 to the above scores (currently between 0 and 45). This is to set the minimum score for each assessment to be 5 and the maximum to be 50.

The ranges have been chosen based on historic performance. If a company performs better than the maximum expected they will receive the top score of 50. If they perform below the minimum expected then they will receive the lowest score of 5.

A detailed methodology to all OPA measures can be found in (OFWAT, 2004). The following table shows the weights applied to each element of performance.

Table V. Weighting of performance measures (OFWAT, 2006).

Key area/measure	**Weighting for water and sewerage companies**	**Weighting for all companies**
Water supply, levels of service	**2.50**	**2.50**
Properties at risk of low pressure	0.75	0.75
Properties with unplanned interruptions	0.75	0.75
Water quality failing DWI standards	1.00	1.00
Sewerage service, levels of service	**1.50**	**0.00**
Sewer flooding incidents (capacity)	0.50	-
Sewer flooding incidents (other causes)	0.75	-
Properties at risk of sewer flooding	0.25	-
Security of supply	**1.00**	**1.50**
Population with hosepipe restrictions	0.25	0.375
Leakage – performance against target	0.25	0.375
Security of supply index – absolute performance	0.25	0.375
Security of supply index – performance against target	0.25	0.375

Customer service	**1.50**	**1.50**
Company contact score (response to billing contacts, response to written complaints, billing of metered customers and telephone contact combined)	0.75	0.75
Other customer service	0.75	0.75
Environmental performance	**2.25**	**0.25**
Category 1 and 2 pollution incidents – sewage	0.50	-
Category 3 pollution incidents – sewage	0.25	-
Category 1 and 2 pollution incidents – water	0.25	-
Sewage treatment works in breach of their consent	1.00	-
Sludge disposal – percentage of sewage sludge disposed of unsatisfactorily	0.25	0.25
TOTAL	8.75	5.75

Figure 8 shows the OPA results for the water and sewerage companies for 2009-10, compared with 2008-09. Figure 9 shows the results for all companies[7]. The best performing companies have the highest scores.

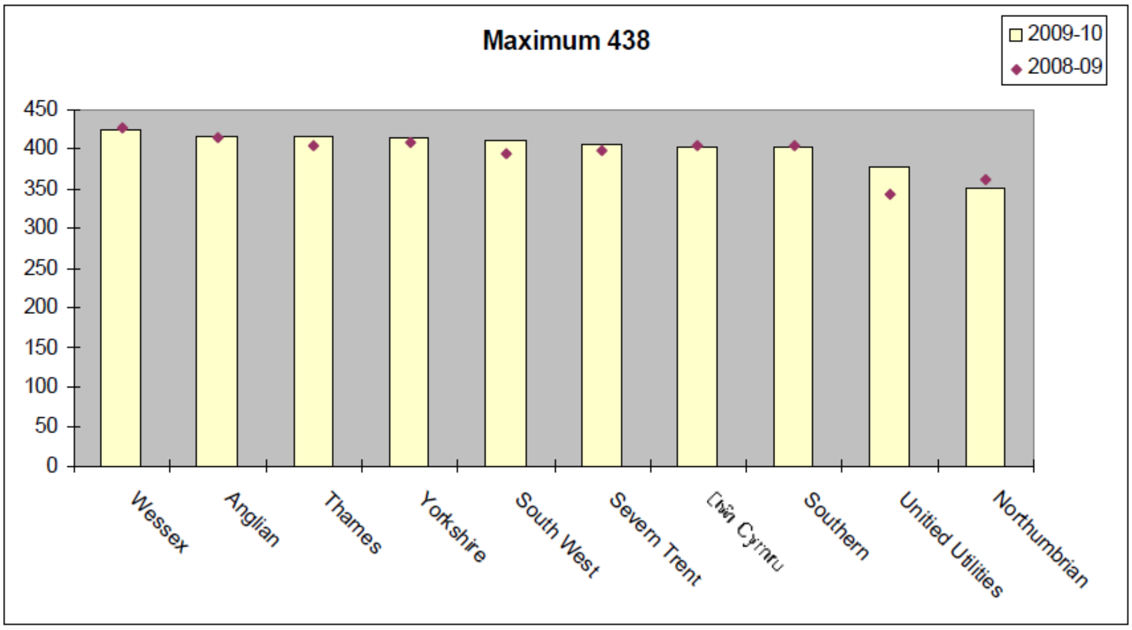


Figure 8. Overall performance assessment – water supply, sewerage service and consumer service for water and sewerage companies 2008-09 and 2009-10 (OFWAT, 2010).

[7] Ofwat regulates water only companies (WoCs) and water and sewerage companies (WaSCs).

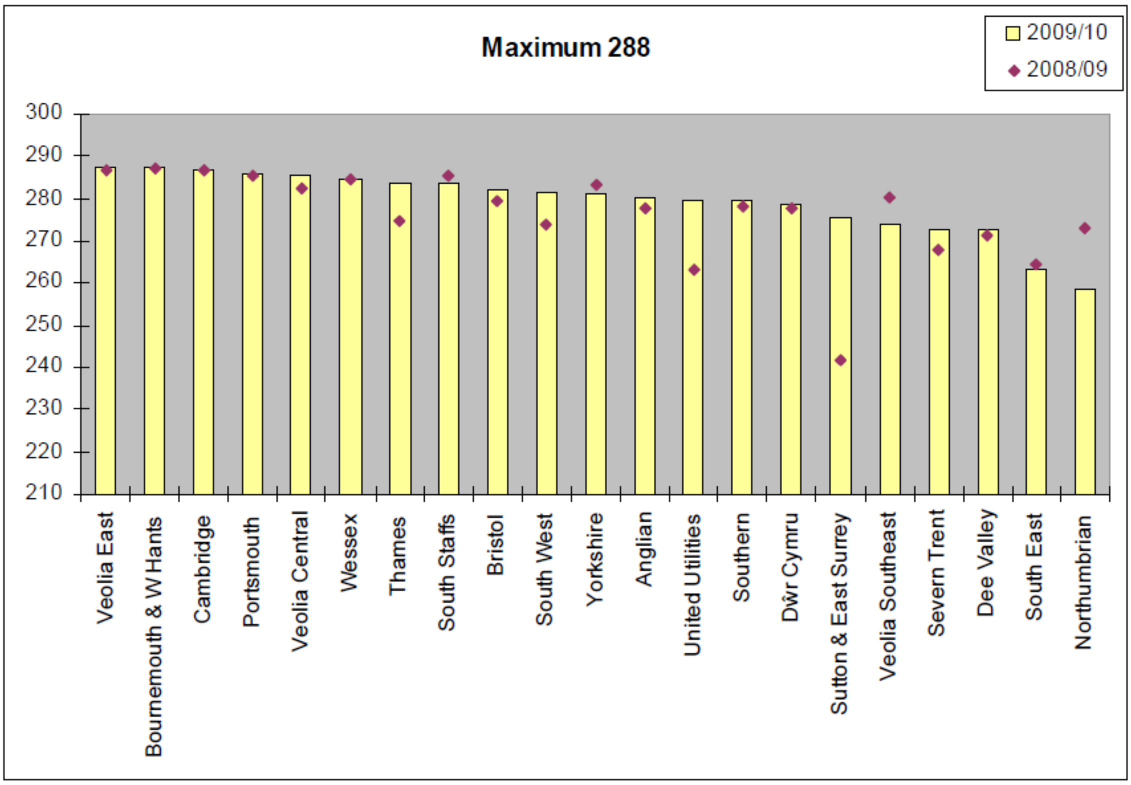


Figure 9. Overall performance assessment – water supply and consumer service for all companies 2008-09 and 2009-10 (OFWAT, 2010).

III.2.2. The SIM methodology

OPA incentivizes the companies to improve performance against specific measures defined by the regulator. Ofwat has realized that while the OPA has achieved a great deal, it has reached its limits. The historical evolution of OPA scores across three price reviews shows that companies' OPA scores were grouped at the top end of the range, what suggests, accordingly to Ofwat, that the OPA will not drive further significant service improvements. Figure 10 presents this view.

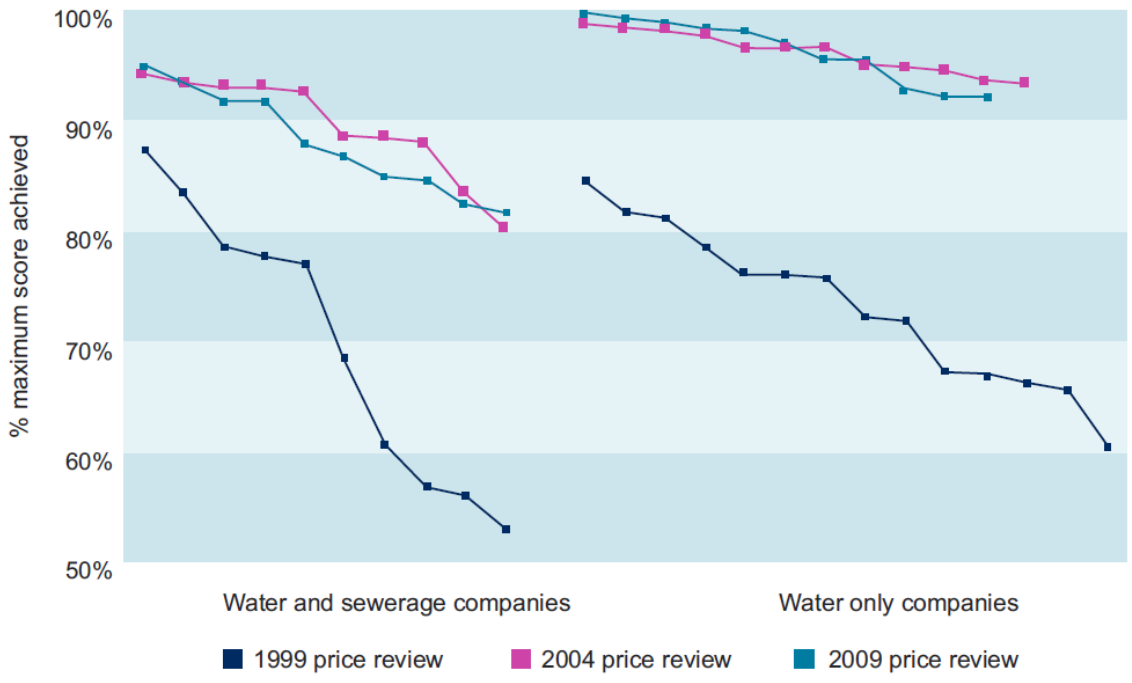


Figure 10. OPA performances at successive price reviews (OFWAT, 2010).

In addition to that scenario of saturation, Ofwat realized that most consumers are satisfied with the basic aspects of the service they receive, but about 6% are not. The companies and the Consumer Council for Water continue to receive a significant number of complaints about service. Therefore, instead of focusing on a rigid set of performance measurements, Ofwat has decided to focuses more on the consumer experience itself. It has them replaced OPA by a new approach called Service Incentive Mechanism (SIM) (OFWAT, 2010).

The SIM is based on two consumer experience measures (OFWAT, 2010):

- A quantitative measure, based on the number of complaints and phone contacts a company receives. It measures the number of complaints at different stages of the process, and also takes account of whether or not the company resolved the consumer's issue the first time round.

- A qualitative measure, reflecting consumers' satisfaction about the quality of service. It is based on a survey of consumers who have had direct contact with their company – for example, if they have asked for a service or made a complaint.

Figure 11 presents the elements used in the quantitative measure and its corresponding weight (OFWAT,2010):

Element	Weighting
All lines busy/calls abandoned	1
Unwanted telephone contacts	1
Written complaints	5
Escalated written complaints	100
CCWater investigations	1,000

Figure 11. Weighting of individual measures (OFWAT, 2010).

The main point of the qualitative measure is that the survey is made only with consumers that have had contact with the company. That is, it does not capture the views of those consumers who do not contact their supplier. That was the goal of Ofwat. Since general satisfaction surveys tend to show that most consumers are satisfied with the overall service, the survey is designed specifically to give companies an incentive to get things right first time and to deal well with those who need a service or have a complaint. These are the issues that companies need to address in order to deliver further improvements in general satisfaction (OFWAT, 2010).

The qualitative measure score will be calculated from consumers' overall satisfaction with their billing or operational experience. Consumers will be asked to rate in a scale of 1 to 5 (where 1 is very dissatisfied, 5 is very satisfied) their satisfaction with the way their company dealt with their billing or operational issue. Both issues are going to have the same weight, and companies will get an average score, that is, a score per consumer.

Finally, qualitative and quantitative measures are going to be combined with equal weights to produce a final score for each company. The relative score are going to be used to compare companies (OFWAT, 2010).

III.3. Regulation of the Electricity in Brazil – ANEEL

As already commented in the Executive Summary, ANEEL fosters an annual survey with all residential electricity consumers in Brazil, aiming to assess their satisfaction with services offered by distribution companies. The survey has a countrywide coverage with about 20,000 consumers being listened each year. Consumers are chosen randomly, accordingly to a given sample defined to each company (ANEEL, 2010).

The main goals of the survey are:

- assess throughout consumers perception the level of satisfaction due to power distribution companies' service;

- generate comparable indicators by region and company size;
- generate a single indicator of consumer satisfaction indicating the overall perception in the sector; and
- complement information of a domestic nature (e.g. DEC and FEC, records in the Ombudsman, among others);

The processing of surveys' data generates a score to each company. That's the ANEEL Index of Consumer's Satisfaction – IASC. This index is published annually since 2001, and an award is given to the best companies in a public ceremony. Furthermore, ANEEL turns available a seal (logotype) that can be used by the winners. Winners of annual IASC can use a seal as a marketing strategy.

Throughout Resolution ANEEL n° 55/2004, ANEEL established the use of the IASC in the tariff definition. Accordingly to its performance measured by IASC, companies were penalized or awarded in a range of + - 1% or their Factor X (called Factor Xc).

Whereas the incorporation of IASC in companies' prices was a strong advance in allowing consumers to influence directly in price definition, it was rejected by companies and it was not even unanimity among ANEEL's board of directions. Some arguments against Factor Xc were mainly about these topics:

- the so argued subjective aspect of the procedure (especially when compared with technical indicators, like DEC and FEC and call center complaints);
- the possibility of negative answers from consumers because they were aware that it could decrease their tariffs;
- the low variability of IASC scores associated with surveys' accuracy (+-3.5%) could lead to unfair situations.
- according to a company, a research showed that distribution companies, even those private owned, were seen at that time as a part of the Government, and it could lead consumers to assess companies as they were assessing a regional public administration.

In 2007, the beginning of the second period of tariff revisions, ANEEL decided to drop IASC from price definition. In 2010, the beginning of the third period of tariff revisions, ANEEL returned to consider performance of companies in price definition. But the performance is now measured only by continuity of supply indicators (DEC and FEC).

It is important to highlight that even though IASC is not used anymore in price definition, it is still a mechanism used to incentivize or penalize companies indirectly, because of the publicity of its award.

III.3.1. IASC methodology

The model used to assess consumers' satisfaction is composed by five variables: Perceived Quality, Perceived Value, Confidence, Faithfulness and Satisfaction. Figure 12 presents these variables, its specific aspects and their interaction.

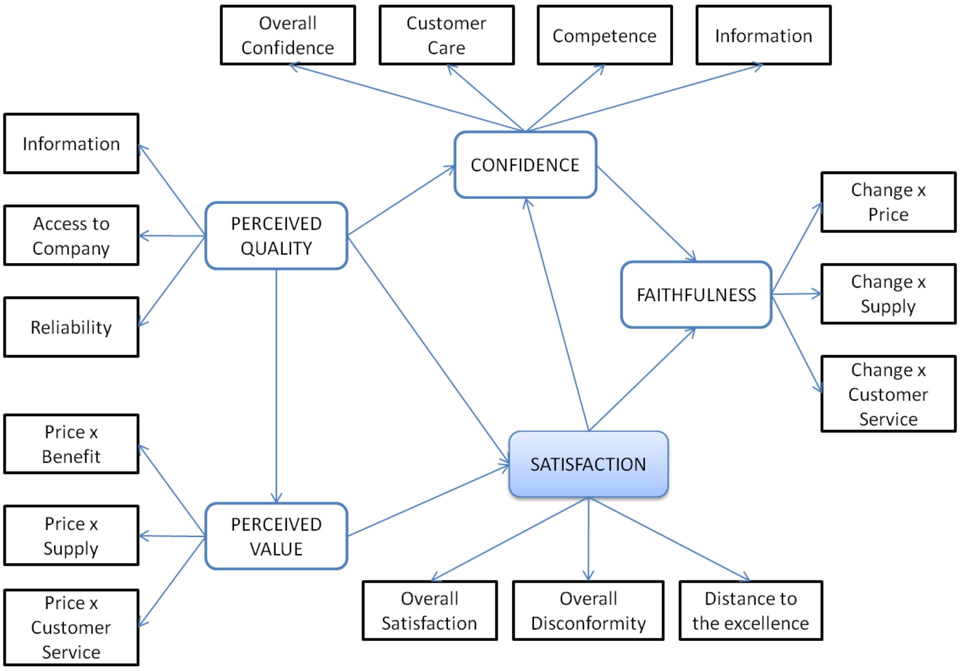


Figure 12. ANEEL IASC model (ANEEL, 2010).

The Perceived Quality was measured by a group of 17 items generated from a qualitative research held in 2000, and consolidated in discussions with representatives of ANEEL, state agencies and distribution companies. These items were grouped into three dimensions, resulting from a factor analysis procedure. They are presented bellow.

- Customer Information: clarification of their rights and duties, information/guidance on risks associated with the use of energy, details of the bills; explanation of the proper use of energy, equitable service to all consumers and security in the amount charged.

- Access to Company: easy to get in touch with the company, rapid response to consumer requests, on-time delivery of services, cordial service and accessibility to positions of receipt of the account.

- Reliability of Services: power supply without interruptions, power supply without voltage variation, early warnings about the interruption of the supply due to a failure to pay, reliability of the available solutions, speed in restoration of power supply when there are interruptions and early warning about supply interruptions due to maintenance.

The Perceived Value is assessed according to the following trade-off aspects:

- the fairness of the price regarding the facilities, comfort, convenience and security that electricity brings to consumers' life;
- the fairness of the price regarding the quality of supply (for instance, interruptions and voltage variations, speed and punctuality of repairs on the network, early warning, etc); and
- the fairness of the price regarding all aspects relating to consumer service, such as courtesy and good will, the ability to solve problems, etc).

The Confidence on the company is assessed by four indicators:

- how reliable the company is (overall confidence);
- if the company is competent in its services;
- the confidence that company is worried about consumers (customer care); and
- the confidence in company's information.

Faithfulness is assessed by three indicators:

- the chance of the consumer to choose other company if (supposing) the its **price** is better;
- the chance of the consumer to choose other company if (supposing) the **quality of supply** (interruptions and voltage variations) is better; and
- the chance of the consumer to choose other company if (supposing) the **customer care** (commercial quality) is better.

Satisfaction was then assessed according to three indicators:

- overall satisfaction;
- how far is the company of the excellence; and

- overall disconformity.

These indicators were selected to measure overall satisfaction in different dimensions, and by the valuation method used, the common variance to these three indicators can be considered as the synthesis of satisfaction.

All indicators presented before were measured in a scale that ranges from zero up to ten. The combination of indicators is given by the Partial Least Squares – PLS method. IASC errors varied by company in a range of 1.57 up to 4.33. The error for the IASC Brazil was 0.36 (ANEEL, 2010).

Figure 13 shows the results of the IASC Brazil from 2001 to 2010. It also shows a comparison among IASC 2010, the American Consumer Satisfaction Index – ACSI 2010 for energy utilities and the Hong Kong Consumer Satisfaction Index – HKCSI 2009 for electric power companies in Hong Kong.

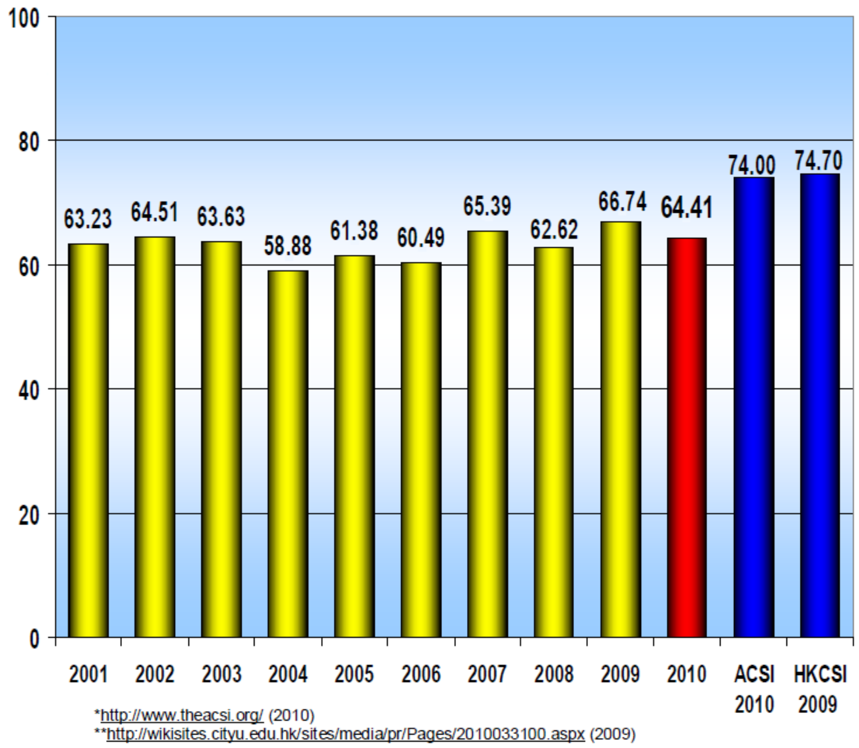


Figure 13. IASC BRAZIL 2001-2010, ACSI 2010 and HKCSI 2009 (ANEEL, 2010).

III.4. Some Considerations about Presented Methods

Experiences presented in previous sections showed different ways to assess overall performance of companies in monopoly regulation. They rely basically in two different paradigms: i) combination of predefined (technical) indicators developed by regulators; ii) consumers’ experience gathered from qualitative surveys and/or measurements of consumers’ contacts with company.

In a simplistic and general view, the presented methods can be divided in three steps:

- the choice of which aspects are going represent companies’ performance;
- the definition of each aspects in terms of indicator(s); and
- the combination (weights) of aspects (and also indicators) to reveal a final overall score.

Actually, the weights associated to each performance aspect are the most important parameter of all approaches. A high weight means that the aspect is predominant among others, and that’s what companies are going to pursue if there is some incentive. On the other hand, an aspect that was not considered can actually be seen as considered with null weight.

It is interesting to note different trends between regulators. Ofwat has first adopted the first paradigm above indicated (i) and has recently moved towards the second paradigm (ii), whereas ANEEL has presented the opposite strategy. Both changes were guided by regulatory scenarios captured by regulators and it is hard to judge which is the most suitable.

IV. A PROPOSAL OF A FRAMEWORK TO ASSESS OVERALL PERFORMANCE OF BRAZILIAN POWER DISTRIBUTION COMPANIES

Overall performance assessment is not widely addressed in regulation. The most common approach is to apply standards to indicators in an attempt to guide companies to match consumers' requirements, measured by periodic consumers' overall satisfaction surveys. The matter is whether it is possible to describe companies' performance by a single number.

There is a myriad of possibilities to address this issue. Possibility here is a broad concept: is not just setting an equation combining many indicators. It is the definition of a reasonable set of dimensions, described by coherent indicators and combined by a precise and meaningful set of weights.

Given the polemic nature of this issue, a question arises: should regulators try to describe companies' performance in such a strong way? This is not an easy question to answer, but, in the current case of ANEEL, the answer seems to be yes. There are some companies that already entitle themselves as the best companies in Brazil, based in one sole aspect (continuity of supply, for instance). Others support their argument based on consumers' satisfaction surveys – ANEEL IASC and other survey developed by the biggest association of the sector. On the other hand, the worst companies in Brazil are unknown, in a silence that hides their inefficiency. ANEEL, as the regulator of the sector, has the duty to make information available and as clear as possible to the society. An overall performance index leads to this goal.

As already stated in the beginning, this paper does not aim to propose a complete methodology of the regulation of this issue. Rather, the aim is to start the discussion of the Brazilian power distribution sector. In this sense, this chapter discusses all performance dimensions described in Chapter II and suggests some of them to be used in an overall performance index.

IV.1. The Overall Performance Index Approach

ANEEL, as the Brazilian agency in charge of regulating the electric power sector, needs to follow directives established by our Constitution and laws. Furthermore, its actions need to meet consumers' requirements of quality and fair prices, and, on the other side, need to indicate clearly to companies' managers the directions to reach a good service. Trying to fulfill these requirements, an overall index can be designed to match the following premises:

- comprehensiveness, in the sense that all performance aspects expected from consumers should be addressed;
- coherently tuned (weighted), regarding the importance of aspects; and
- simplicity, allowing its easy understanding and reproducibility.

The framework here proposed is inspired in other references presented before, regarding, mainly, ANEEL experience within last decade. Indicators are chosen from each selected performance aspect and combined throughout weights to compose a single index.

IV.1.1. Characteristics that should be addressed

Traditionally, the electric sector evaluates the quality of service provided by distribution companies through measurements and indicators relying in concepts of quality of supply. The three major concepts, continuity of supply, voltage and commercial quality, are usually seen as covering the needs of the consumer.

Within these three concepts, in Brazil (as in many other countries) the continuity of supply has been receiving wider attention from consumers. Since costumers (households, commerce and industry) are increasingly relying their activities on electrical equipments and machines, it is clear that the cost of interruptions is increasing in our society. Besides, Brazil is experiencing a period of economy expansion, which, in a simpler analysis, turns the cost of interruption even bigger.

DEC and FEC are the two available indicators to measure continuity of supply. They are equivalent to the worldwide indicators SAIDI and SAIFI. The use of DEC and FEC to assess overall aspects of continuity of supply is, therefore, natural.

The commercial quality is another important aspect to measure quality of supply, and should be considered in any overall index. There are several aspects that can be used to measure companies' performance due to commercial quality. However, as presented in Subsection II.1.1, ANEEL has established two main indicators to address this issue – DER and FER. They seem to fit well in the concept of the overall assessment of commercial issues, and this paper proposes their use in an overall performance index.

The last aspect concerned with the quality of supply is the voltage quality. As presented in Subsection II.1.3, there are several parameters measuring different technical aspects of voltage quality. Among all parameters, the steady state voltage variation is the one that most concerns Brazil nowadays, since it reflects systemic problems that may affect several consumers. Besides, DRPeq, DRCeq and ICC are the most well established indicators of voltage quality, and ANEEL has such information, which dates back more than ten years. On the other hand, all other voltage quality indicators measure phenomenon that are not the concern of all consumers, since they do not happen so often, and the regulation of these issues are not finished yet. Therefore, this paper proposes the use of the steady state voltage variation parameter to assess distribution companies' voltage quality performance.

Continuity of supply and commercial quality have one indicator to measure the duration of the violation of the standards, DEC and DER. In steady state voltage variation, there are two indicators related to the collective (average to all consumers) duration of the violation of the standards, DRPeq and DRCeq. They measure the intensity of trespassing, poor for DRPeq and critical for DRCeq. Thus, a situation when DRCeq = 10% and DRPeq = 10% is certainly worse than when DRCeq = 0% and DRPeq = 20%, since in both situations consumers are supplied with voltage outside the satisfactory level 20% of the time, but in the first one they were supplied in a critical level in 10% of the time. But it is hard to define if the first situation is worse than when DRCeq = 5% and DRPeq = 20%.

Therefore, it is clear that there is a need of defining a weight to combine DRPeq and DRCeq, with a higher weight to the DRCeq. This issue is pretty controversial and, for simplicity, this paper proposes the sole use of the ICC as the index to assess overall voltage quality.

Safety in operation was presented in Subsection II.2.1 as one aspect important in Brazilian background of adequacy of the service. Six indicators related to this aspect are periodically sent to ANEEL. As mentioned before, there are no standards or incentives in ANEEL regulation that could guide companies to keep or improve their safety in operation.

This paper proposes to consider only two parameters to compose the overall index: number of deaths due to labor accidents (owned and outsourced employees). They were chosen based on two reasons. The first is because of the confidence of this information. Labor unions are very active in the electric sector, and are constantly monitoring accidents. The same does not happen in the case of accidents and deaths affecting the general public (although they are historically reported to a Brazilian electric institution, they are harder to monitor). The second reason is that they present one of the most desirable characteristic in regulation: they are easily defined. There is no space (or few) for misunderstandings when computing these parameters.

Section II.2 presented five aspects relevant to the Brazilian regulatory framework: safety in operation, socio-environment, energy losses, universality and resilience. As previously mentioned, the only aspect that this paper proposes to be considered in an overall performance index is the safety in operation. The reasons for not adopting the remaining aspects are given below.

The socio-environmental aspect is increasingly important, but in this author's opinion, ANEEL is not ready to reward or penalize companies in this subject. Although there is a standard report described in Subsection II.2.2, the aim of the report is to show information to the society, not to assess companies based on it. So, there is still much more to know and standardize before any attempt of proposing any stronger incentives to this subject.

Energy losses and universality are already regulated, and there are incentives for companies to improve efficiency – otherwise, they will lose money. Hence, the proposal here is to not compute them to an overall performance index.

Resilience is an increasing concern in the Brazilian electricity sector. Some companies are being accused of letting their networks exist in a process of continuous deterioration, due to long low investment periods. Besides, seeking for the reduction of their operational costs, some companies are not operating their networks as best as they can, lowering, for instance, planned maintenance inspections. This behavior can drive networks to a weak reliability and, due to the inertial characteristic of network industry, continuity of supply indicators are now starting to capture this condition.

Given this scenario, some people are now arguing that ANEEL should control more closely the investment of companies. In this way, the age of the electrical assets could possibly be one indicator to be used. This paper does not propose it to be considered in a performance assessment framework, but maybe ANEEL should improve the monitoring of some resilience related parameters.

The discussion presented in this subsection was based on aspects related to performance assessment in each specific dimension. Four performance dimensions are being proposed to be used in an overall performance index: continuity of supply, voltage quality, commercial quality and safety in operation. Indicators selected in each dimension provide a quantitative measurement of companies' performance. But the quality, in a broad view, cannot be simply measured.

According to Falconi (1992), a product or a service with quality is one that fits perfectly, reliably, affordably, safely and on time to consumer needs. The true criterion of good quality is the consumer preference. Continuity of supply, for instance, accounts for interruptions at any time of the day with the same “weight”. But one can suppose that if all interruptions had occurred between 2am and 4am, the majority of consumers would not be affected at all. So there may be different levels of satisfactions even if the indicators measured the same number.

ANEEL Index of Consumer’s Satisfaction – IASC is the actual index that ANEEL uses to assess companies’ overall performance. It is a consolidated methodology, applied for more than 10 years, and fits the requirements to assess consumers’ satisfaction. Therefore, the proposal of this paper is to combine IASC with the other four aspects already detailed to generate a single index. The combination of the aspects will be detailed in the next subsection.

Figure 14 summarizes the framework of the overall performance index proposed in this paper.

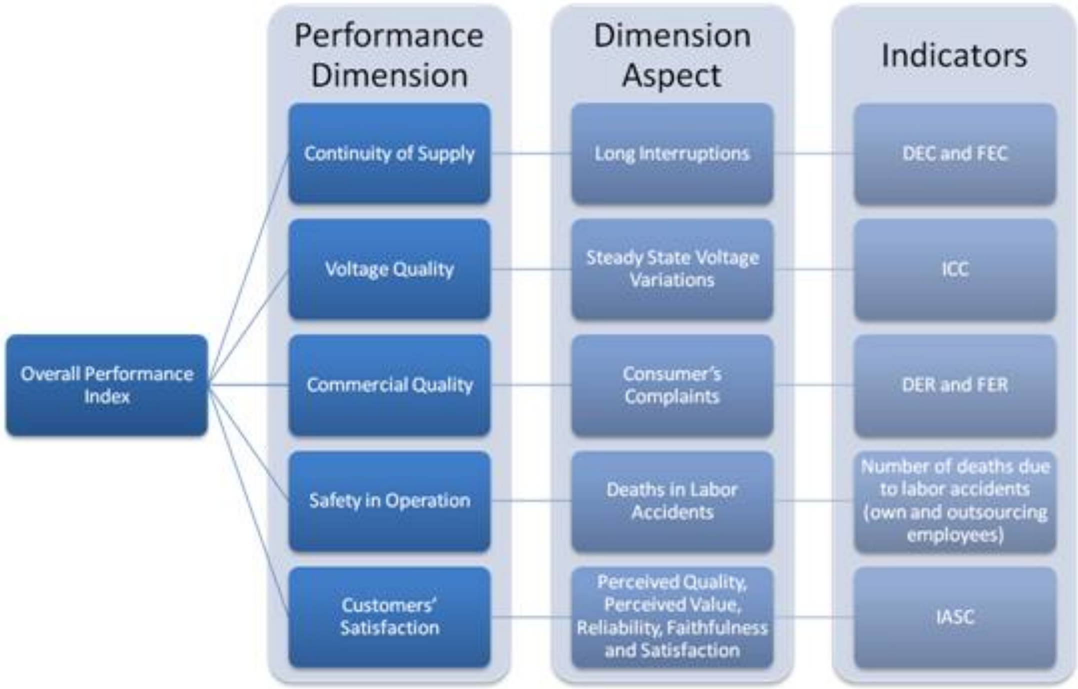


Figure 14. Framework of the overall performance index proposed.

IV.1.2. Combination of indicators and performance aspects weights

Indicators in each aspect need to be combined to generate a comparable score for each performance dimension. An overall performance index can then be generated by weighting the scores.

The combination of indicators in each aspect is not as simple as it seems. In the case of DEC and FEC, for instance, ANEEL defines standards to each set of consumers. Therefore, two sets with DEC of 10 hours per year present the same absolute performance, that is, consumers will realize the same continuity of supply (in average). But the performance relative to the standard is the most suitable measurement to assess companies' performance, since it (should) reflect the expected quality for the average consumer. Conversely, standards were not assigned to other indicators presented in Figure 14, and can be used in their absolute values.

Indicators measure different magnitudes, and need to be rescaled to allow their combination. A simpler way to do this is to transform them in real numbers ranging from 0 to 1. A linear function can be used in this case. Dimension with more than one indicator can be simply averaged to create a unique number.

When a single number is available to each performance dimension, the combination of them to generate the final score is usually made by assigning weights to each dimension. Higher weights should be assigned to the most relevant dimension. One possible set of weights is presented in Equation (**15**).

$$0.35 \times IASC + 0.15 \times COM + 0.35 \times CONT + 0.1 \times VOLT + 0.05 \times SFT \qquad (15)$$

where *COM* is the commercial quality dimension score; *CONT* is the continuity of supply score; *VOLT* is the voltage quality score; and *SFT* is the safety in operation score. All scores are numbers between 0 and 1.

This is a controversial issue, and much more discussion will be necessary to reach a reasonable set of weights. The suggestion presented in Equation (**15**) assigns a strong weight to consumers' satisfaction and continuity of supply. Commercial issues (also captured in IASC) contribute with 15% of the index. Voltage quality and safety in operation contribute with the remainder 15%.

After the proceeding described above, each company will have a final score. They can now be ranked to be finally compared. One additional issue to be considered when comparing companies is the need to split them in different sets, according to their characteristics. ANEEL usually split companies in two sets, based on their size. This can be more efficient in emulating competition to improve performance.

V. CONCLUSION

This paper studied the assessment of the overall performance of Brazilian power distribution companies. The adoption of a single index to assess the whole performance of a company is a strong regulatory tool which needs to be carefully designed to avoid some possible harmful consequences. However, the benefits of regulating this issue show that it can be advantageous.

The concept of performance in this paper is focused on the service provided by companies. Traditional dimensions of quality of supply were considered, as well as more contemporary aspects whose consumers' interests (and stakeholders in general) have grown in recent years.

Regarding the current status of regulation of some performance dimensions showed in Chapter II, and based in the need of simplicity in regulation, the proposal of this paper is to consider in a first step five aspects to compute the overall performance index: continuity of supply, commercial quality, voltage quality, safety in operation and consumers' satisfaction. The set of weights proposed is an attempt to balance consumers' needs, and should certainly be exhaustively discussed if ANEEL decides to regulate this issue. After all, these weights will provide directions that companies need to follow in their strategy.

Besides of the five aspects chosen to compose the overall index, this paper presented other performance dimensions that are also eligible to be used in an overall performance assessment. Some of them need, though, to be better defined (standardized) and monitored before their use in any incentive mechanism.

This paper provided an initial discussion about the subject. This work is expected to be an input to the regulation of power distribution segment in Brazil, as ANEEL has just started to take into account the quality of supply in price reviews. The possibility of a more comprehensive indicator will comply with ANEEL's aim of providing better information to consumers and to incentivize power distribution companies to provide a better service.

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