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Power Quality: A Comparative Study of the Quality of Electric Power and Real Trends

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Abstract:

Electric power for the present world is a necessity. All known materials, somehow, use as a power source. With this, the generation, transmission and use demands quality of this energy, because depending on the quality of the energy its use will produce efficiency and advantages for all segments. Science has evolved and together requires more energy quality, technological materials are passive incorporating new commands and requires high standards of energy and services. In view of such arguments and supported by the factors that imply the quality standards in energy used by society, this paper brings to the discussion the quality of energy (QE) and seeks to question the factors exposed in the specialized literature of the area and to address the trends *of improvements, new implementations of quality and globalization of services. The approach is bibliographical and intends to discuss trends and implications in energy quality.*

Keywords: Quality, Disorders, Stress, Consumption.

INTRODUCTION:

Modern society lives a reality of high energy consumption and, the sources of obtaining these energies increasingly scarce, require studies that enhance their offer and that, in some way, are not so aggressive to the environment and that may also have their minimized added value. Among its numerous definitions, Energy Quality - QE is the frequency and severity of deviations in amplitude and aspect of the wave, voltage and current. This pillar is based on a major factor for the competitiveness of the most varied industrial and service sectors. Maintaining the voltage level within the acceptable operating limits, whether at the transmission level as well as in the distribution, requires control and monitoring measures for all instances linked to the energy sector, whether in Organs inspection agencies or in the energy concessionaires, private or public.

The evaluation of the operating mechanism of a system that works beyond its normal conditions, triggers two basic electrical quantities capable of being used. The quantities themselves are voltage factors and the frequency at which the system operates.

Thus, in an interconnected system, its frequency oscillates in the range of 60 ± 0.5Hz. Regarding the voltage, the most relevant aspects are the three mentioned below: first the waveform, which must be the closest to a sine wave; according to the symmetry of phases present in the electrical system and third, the importance of voltages within potentially acceptable limits. In this field of studies, the existence of some phenomena, whether random or intrinsic, that occur in the electrical system, leading to changes, precarious the supply pattern and implying the quality of the electricity supplied, is noted.

For such phenomena it is possible to discriminate some relevant aspects: such as submersion and / or elevation of voltages, between pauses, harmonic distortions, voltage fluctuations, oscillatory or impulsive ephemeris, signal noises, over and under voltages. In power systems, instability can be caused by numerous factors, but those that often have a relevant effect and imply the normal operation of an electrical system and are commonly, in practice, those that can be triggered by atmospheric phenomena, for example, magnetization of transformers, due to sustained high-impedance single-phase faults, by operations of large motors, by capacitive effect sensors, even by switching on transmission lines.

There are several current tools that can assist in this process, such as the Fourier Transform with Window (TFJ), the Wavelet Transform (TW) and Artificial Neural Networks (ANNs) are widely used tools for the analysis of disturbances in Electrical Systems of Power (SEP) linked to Power Quality. There is a growing evolution of tools capable of enhancing studies and generating efficiency in the implemented processes.

The study presented here refers to a comparative analysis of energy quality standards, trends in approaches that justify the improvement of systems for generation, transmission and use of electricity.

The quality of the energy supplied to the electrical system can be a differentiating factor to produce goods and services that will serve society, here we seek to discuss the factors that enhance quality, raising innovations and new market trends. Within the institutions that deal with this aspect of action aimed at the quality of the energy served to society, it is often too veiled to be efficient for sustainable consumption. The discussion about these factors may suggest the amplification of the "quality" factor, passing not only an aesthetic mechanism that accredits an institution, giving it standards and subsidies, but that this quality can really be implemented, for the social good, and that can generate new forms of subsidies, widening their uses and minimizing situations of deviations and neglect that make the service more expensive.

MATERIALS AND METHODS

This work consists of a form of bibliographic research, as it intends to raise the available knowledge about the electricity quality system, analyze and compare the data to discuss the aspects, problems, advantages, trends, and raise new forms of approaches to conduct a look broader view on the quality and sustainability of services. According to Chiara (2008), bibliographic research leads to the survey of available knowledge about theories, in order to analyze, produce or explain an object being investigated, aiming to analyze the main theories of a theme, and can be carried out for different purposes.

The work was carried out as a research with the intuition of knowing existing factors in the literature on the theme of energy quality, observing the existence of information that helps in the formulation of the study's target problem. In this way, a proposal was formulated on the quality of energy, on the factors that imply the process from generation to final consumption. The central point of the work is to raise subsidies that can generate new conditions for analysis and to stimulate trends to better take advantage of existing tools, suggest new insertions and discuss in the social environment, a new way of looking at the condition of energy quality.

As Koche (2006) defines bibliographic research; It develops trying to explain a problem, using the knowledge available from the theories published in books or similar works. In this approach, the researcher will raise the knowledge available in the area, identifying the theories produced, analyzing them, and evaluating their contribution to help understand or explain the problem that is the subject of the investigation.

In this way, the structure of the work presented here tends to raise data on studies related to energy quality, relating the tools used to analyze problem factors and to seek a broader conception on the capacity for improvements and new approaches.

RESULTS AND DISCUSSION

The expression “energy quality” addresses a series of phenomena, encompassing areas of interest in electrical energy systems culminating in problems related to communication in data transmission networks. However, they must be denoted and recognized in all sectors involved with the consumption, transmission and generation of electricity (PAULILO, 2010). Its interpretation, related to the phenomena, more widely the distortions of voltages and currents, located either at the point of common coupling, as well as, inside the installations of the energy consumers themselves. The direct association with the correction of the power factor, rationalization of energy and increased productivity. The occurrence of problems determines the need for a mutual search for solutions, between both parties, to carry out practical and economic measures.

The quality of electric energy (QEE) has become a trend in the electric sector in recent years, lato-sensu has been used to express the most varied characteristics of the electric energy delivered by the concessionaires to consumers (CSPE, 1997 and RIBEIRO, 1996). A comprehensive definition defines QEE as a measure of how well electricity can be used by consumers (NOS, 2000 and Power quality, 2004).

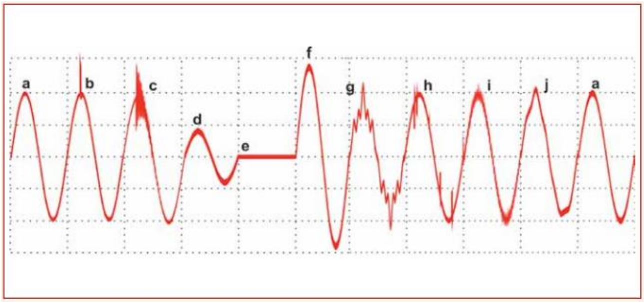
According to Pomilio (2017) this measure includes characteristics of continuity of supply and compliance with certain parameters considered desirable for safe operation, both supply system and of electrical loads. Among the parameters to consider are:

- Distortions;
- Voltage fluctuations;
- Short-term voltage variations;
- Imbalance of three-phase systems;
- Fast transients.

The deviations from the ideal concept of the "electric energy" product presented are treated, at an international level, under the title of Power Quality and Voltage Quality, the latter being treated as such within the scope of Cigré. In Brazil, although without a fully consolidated terminology, the subject has been treated under the name of Electric Power Quality (QEE). (PAULILO, 2010).

Figure 1 below shows the disturbances involving the quality of energy in the electrical systems, in which the items - sinusoidal voltage; b - impulsive transitory; c - oscillatory transient; d - sinking of tension; e - interruption; f - voltage jump; g - harmonic; h - voltage cut; i - noises; j – inter-harmonics.

Figure 1 - Main disturbances in the quality of electricity



Source: Paulilo, 2010.

Such disturbances can be addressed and corrected using appropriate tools so that the system can be efficient and generate quality service performance. The quality of energy in a given bar of the electrical system is adversely affected by a wide variety of disturbances. The disturbances can be transient, short-term voltage variations, long-term voltage variations, imbalances, waveform distortions: harmonics, voltage cuts, noise and others, voltage fluctuations and frequency variations. The sum of these factors is indicative of system failures and interfering with the quality of the energy generated and supplied.

Table 1 shows the disturbances, causes, effects and possible solutions to problems caused by energy quality. Once such disturbances are enunciated and studied, it is possible to use tools that can correct such disturbances, providing a more qualified and capable system to function with the proper quality. But its implementations are not simple, because as they can be denoted in the graph of figure 1, all disturbances have their specificities and require a more adequate look for their correction, so a specific tool or a set of them must be activated so that the system fits sustainably.

Table 1 - Categories of classification of disorders associated with energy quality. Source: Paulilo, 2010.

Disorders	Causes	Effects	Solutions
Impulsive transients	• Atmosferic discharges. • Load switching and / or protection devices.	• Excitation of resonant circuits. • Reduction of the useful life of motors, generators, transformers, etc .; • Processing errors and signal losses.	• Filters; • Surge suppressors; • Isolating transformers;
Oscillatory transients	• Atmosferic discharges; • Switching of capacitors, lines, loads and transformers; • Impulsive transients.	• Malfunction of electronically controlled equipment, power converters, others; • Reduction of the useful life of engines, generators, others.	• Filters; • Surge suppressors; • Isolating transformers;
Under and overvoltages	• Engine starts; • Load variations; • Switching capacitors; • Transformer taps set incorrectly.	• Small reduction in the speed of the induction motors and in the reactive capacitor banks; • Failures in electronic equipment; • Reduction of the useful life of rotating machines, transformers, cables, circuit breakers, TPs and TCs; • Improper operation of protection relays, motors, generators, others.	• Voltage regulators; • Reserve energy sources; • Static keys; • Power generators.
Interruptions	• Short circuit; • Operation of circuit breakers; • Maintenance.	• Failure of electronic and lighting equipment; • Equipment shutdown; • Interruption of the production process (high costs).	• Spare energy sources; • UPS systems; • Power generators
Imbalances	• Arc furnaces; • Single-phase and two-phase loads; • Asymmetries between impedances; • Failure to transpose transmission lines.	• Reduction of the useful life of induction motors and synchronous machines; • Generation, by the rectifiers, of 3rd harmonic and its multiples.	• Symmetric operation; • Compensating devices.
CC level	• Optimal operation of half-wave rectifiers, etc.	• Transformer saturation; • Electrolytic corrosion of grounding electrodes and other connectors.	
Harmonics	• Non-linear loads.	• Overheating of cables, transformers and induction motors; • Damage to capacitors, etc .; • Improper operation of circuit breakers, relays, fuses, etc.	• Filters; • Isolating transformers; • Line reactors.
Interharmonics	• Static power converters; • Cycloconverters; • Induction motors; • Arc equipment, etc.	• Interference in the transmission of Carrier signals; • Visual flicker induction on the equipment display	
Notching	• Electronic power equipment.	• Improper operation of measuring and protection devices.	
Noises	• Switching of electronic power equipment; • Electromagnetic radiation	• Disturbances in electronic equipment (computers and programmable controllers)	• Grounding of facilities; • Filters.
Voltage fluctuations	• Intermittent loads; • Arc furnaces; • Engine starts.	• Flicker; • Oscillation of power and torque in electrical machines; • Drop in performance of electrical equipment; • Interference with protection systems.	• Static reactive compensation systems; • Series capacitors.
Frequency variation	• Loss of generation, loss of transmission lines, others.	• Severe damage to generators and turbine blades, others. may occur.	

According to the work of Mehl, (2001) the availability of electric energy represents an increase in the quality of life of the populations. In the first moment in which an electric energy distribution system is implanted, the local population immediately started to count with countless benefits, both from the point of view of greater domestic comfort and better possibilities of employment and production.

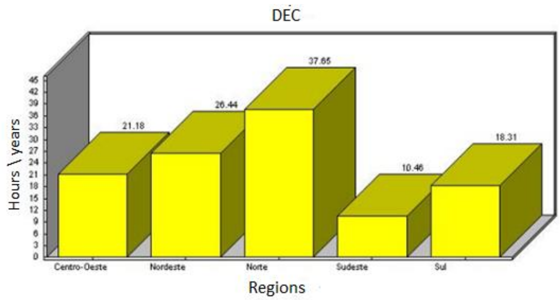
The work deals with the evolution of electric energy services in Brazil, because until the end of the 70's it was very different to what we see today, regarding the consumption of electric energy. Generalizing the consumer profile, three types could be found: Residential, urban and industrial. With the technological advancement, the equipment and a whole technological infrastructure were triggered from the electric energy, this created new demands and culminated in the production of new problems, with the even greater demand for energy subsidies. The convenience with electronic equipment amplifies the demand for solutions that can be efficient and generate quality.

Electric charges with electronic controls have an intrinsic characteristic, which is non-linearity, as it does not constantly require electric current, but only requires power surges at certain times. Depending on the electronic converter used, the input current is triggered at a certain period or angle of the sinusoidal oscillation. With this, the electronic charges end up distorting the waveform (voltage and current) delivered to it and consequently, generating a "pollution" in the electric power network.

In view of such inputs and challenges of the 21st century for the production of quality energy, the disturbances existing in the electricity grid are indicative that need to be reassessed, thus several aspects may allow the evaluation of the quality of the energy supply, problem must be evaluated its causes and effects, among them, the continuity of supply, voltage level, voltage fluctuations, imbalances, harmonic voltage distortions and interference in communications systems are most notable.

Still on Mehl's work, the DIC (Interruption Duration per Consumer Unit) and FIC (Interruption Frequency per Consumer Unit) indicators indicate how long and the number of times, respectively, that a consumer unit was without electricity during a considered period. The DMIC (Maximum Interruption Duration per Consumer Unit) is an indicator that limits the maximum time for each interruption, preventing the concessionaire from leaving the consumer without electricity for a very long period. This indicator starts to be controlled as of 2003. The DEC (Equivalent Interruption Duration per Consumer Unit) can be seen in figure 2, for the Brazilian regions in July 2001.

Figure 2: Average DEC values obtained by ANEEL.



Source: Mehl (2001).

The calculation of the DEC can be done as follows:

$$DEC = \frac{\sum_{i=1}^{n} Ca(i) \times T(i)}{Cs} \qquad 1$$

i = Number of interruptions, from 1 to n
T (i) = Duration of each interruption of the group of consumers considered, in hours.
Ca (i) = Number of consumers in the group considered, reached in interruptions
Cs = Total number of consumers in the group considered.

In this study, looking at the figure, it is evident that the Northern Region at the time was more affected by situations resulting from the poor quality of the energy supplied by the concessionaire that operates in the region. This condition calls for the search for projections of studies that accompany such existing difficulties and the development of more specific mechanisms to remedy such problems that persist in less developed regions in the country.

A study carried out by Tolmasquim (2012) that portrays the perspectives and planning of the energy sector in Brazil presents an overview of the Brazilian energy sector through updated statistics, referring to the evolution of the internal energy supply and its evolution until the year 2020. In particular, the electrical system is addressed, showing the current situation and the evolution of installed capacity.

Regarding the fuel sector, the issues of oil, natural gas and biofuels are addressed.

The present study clarifies that it would not have been possible to maintain the high economic growth in Brazil that occurred in the last eight years without an increasing supply of energy. For this, many and diversified long-term investments were made, such as the construction of hydroelectric, thermoelectric and wind power plants, gas and oil pipelines, energy conservation measures, the increase in electrical transmission systems, among other projects.

With these data it can be suggested that the implementation of new forms of energy production and transmission, generated improvements with regard to the framework related to the quality of the energy supplied, which shows an advance and reflects a better quality in the service offered. This reflects the matter conveyed by uncritical on 03/16/2018, Eletrobras Amazonas Distribution is the electricity distributor of the northern region that best stood out in the ranking of the National Electric Energy Agency (Aneel).

The list pointed to the situation of energy distributors across the country, in relation to the quality of the service provided for the year 2017. In 2016, the Distributor was in 9th place. Eletrobrás group, the Company was also the one that obtained the best position in the ranking that is carried out every year by the regulatory body. According to the regulatory agency, the quality of electricity distribution services improved in 2017, Aneel evaluated the DEC (Equivalent Duration of Interruption per Consumer Unit) indicators - Time that, on average, in the observation period, each consumer unit no electricity), and FEC (Equivalent Interruption Frequency per Consumer Unit - Number of interruptions, on average, during the observation period).

The assessment covered all concessionaires in the country from January to December 2017, divided into two groups: 33 large concessionaires, with a number of consumer units, greater than 400 thousand; and 25 smaller concessionaires, with the number of consumer units, less than or equal to 400 thousand.

Distribuidor a attributed the good result to a set of investments that were applied in 2017, such as the delivery of a new fleet of vehicles and motorboats to 43 locations in the interior of the State, with 85 vehicles and 42 motorboats that were used in emergency, commercial services and improvement in the electricity network, reinforcing service in isolated and difficult-to-access communities, allowing greater speed and quality in the handling of incidents. In the same year, 62 new generator sets were also delivered to 52 locations in the interior of the State, with an investment of R $ 31 million, totaling 20,600 kilowatts of power generation for the interior.

This whole situation described above shows that there has been a great advance in the process of improving the structure of the energy sector in the northern region, and that it contrasts with the graph in figure 1, which showed a very large gap when compared to other concessionaires in the country. The northern region is very extensive and the reach of means of insertion to amplify the energy sector comes up against the geographical difficulty in rural and difficult to access regions. As the transmission network "runs" within the forest, many of the problems are caused by the seasonality of rivers, storms that cut down trees and damage the network and limitations on maintenance and assistance capacity.

The quality for central regions such as the city of Manaus is more real, as mechanisms that aim to combat risk factors are improved to activate all possible mechanisms to maintain service quality. For rural regions, thermoelectric plants are still solutions and, therefore, it is a flawed service, subject to interruptions and inconsistent for the quality factor that accumulates numerous problems for maintenance and subsidies. Most of them generate more expenses than advantages, that is why the big centers keep the costs for the existence of precarious sectors that work to the limit.

CONCLUSIONS

The quality of electrical energy is a trend in the electrical system, because its administration in a correct way and consistently implemented potentiates the actions taken in face of the challenges in generating, transmitting and using electricity, it is through this aspect that it is possible to diagnose disorders that affect the proper functioning of the system, generating losses and creating problematic demands. It is worth mentioning that even the Brazilian electrical system has advanced and become more efficient, in the face of the crises it has been experiencing, reconfiguring its goals and adapting the generation to meet needs and act effectively. This poorly structured planning and without much descriptive character in the literature, makes the system vulnerable to the insertion of energy policies inefficient,

The suggestion is to favor the implementation of studies to socialize the difficulties and by the sum of knowledge and new perspectives, subsidies capable of corroborating with the improvement of services can be provided, reducing the existing environmental and economic impacts resulting from poor organization and inappropriate use of tools. It is understood that when carrying out such research, few studies were found that validate conditions to obtain consistent and more up-to-date data to suggest conditions of advantages so that students, technicians and professionals of the environment can take advantage of the data to discuss the guiding aspects of QEE.

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