POWER QUALITY IN THE ARGENTINE COMPETITIVE MARKET. FIVE YEARS OF CONTROL EXPERIENCE

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In this document we show the main advances in Quality Service control, provided by the Distribution companies which supply power for the city of Buenos Aires and its surroundings, involving approximately 5 million customers. We have particularly addressed aspects related to the Technical Product (i.e. voltage level and .distortions) and to the Technical Service (i.e. frequency and duration of interruptions). Controls started in September 1993, one year after the first privatizations were made, by means of performance global indicators of companies, to change, since 1996, into idividual indicators for each customer. We could mention that, as a consequence of controls and penalties imposed, the companies have improved the service quality level, thus evidencing their response to the clear economic signals they received. They have had to make investments, not only in those facilities directly affected to the service supply, but also in the management tools which allowed them to acknowledge the situation and take the necessary correction measures

TECHNICAL PRODUCT. VOLTAGE LEVEL

Since 1992, with the privatization of the three distribution companies which supplied energy for the Great Buenos Aires to more than five million customers, the Ente Nacional Regulador de la Electricidad (ENRE) (Regulatory Agency) has controled the Technical Product supplied by the companies, the latter were in charge of developing the metering campaign. Metering consist in a 7-day register of efficient voltage values separated in 15-minute periods. Until 1996 only voltage level was controled, and more than 22.000 measurements were performed on customers and connection terminals at the Medium / Low Voltage Subestation. Deviations from admissible levels were punished, according to their size, by the Regulation Authority, with economic penalties that returned to affected customers in the form of a discount from the amount billed for a total of M.US$.1.7. This acted as an economic signal, for the companies to solve existing problems. In September 1996, a new control stage started, aimed at establising the quality of the service supplied to each customer, which was also extended to distortions. From then on 670 measurements per month were made only of customers. First years' results registered within the new control scheme evidenced an improvement in Service Quality, though not the complete solution of the problem. From the analysis performed, we concluded that economic signals sent to the companies by the fines imposed had been adequate to solve the most severe problems, but that they are insufficient for the overall solution of the problem; and a study is being conducted for a probable modification of present regulations. This experience has been used for the development of quality requirement rules for other Argentine companies later privatized, as well as for quality considerations made by other countries like Venezuela, Guatemala and Costa Rica. Taking advantage of the great number of measurements performed, a statistical control method was designed which separates quality supplied in various areas. It considers the 15-minute registers performed along a year as a whole, by taking 6-month periods, with the new semester replacing the previous one, and separating them according to frequency of occurrence as a percentage of their deviation with respect to the voltage nominal value. In this way, each area reveals an occurrence frequency curve that indicates the quality supplied at the area; in relation to which a penalty mechanism has been developed to ensure that the companies receive the correct signals to allow for the solution of the previously mentioned problems. The formulas utilized are the following:

$$FEB_B = \frac{Nrg_B}{Nrg_{TOT}} \qquad FEBP_B = \frac{NrgP_B^{(p)}}{NrgP_{TOT}}$$

$$FEEC_B = \frac{\sum_{med=1}^{TotMed} Eng_B^{(med)}}{Eng_T}$$

$$\text{FINE} = \text{ETF} \cdot \left[\sum_{B=BP} \text{FEEC}_B \cdot C_B \cdot \text{FEBP}_B \right]$$

Where :

B: Voltage Band

FEB_B : Equivalent Frequency associated to Band "B".
$FEBP_B$: Equivalent Frequency for penlized Band "B".
$FEEC_B$: Equivalent Frequency for Consumed Energy separated by Band "B"
Nrg_B : Number of Valid Registers associated to Band "B".
Nrg_{TOT} , **$NrgP_T$** : Total Number of Total and Penalized Registers.
$NrgP_B^{(p)}$: Number of Penalized Registers associated with Band "B".
$Eng_B^{(med)}$: Power Registered while metering associated with Band "B".
TotMed :Number of Measurements made during the period monitored.
ETF:Total Power Billed by the Distribution companies during the period monitored.
C_B : Penalization Ratio, related to Medium Voltage levels.

If, at the end of the monitored period of time, the sum of **FEB_B** for the penalized voltage bands (FRp) is higher than 3%, then the Distributor shall be penalized according to the above described equations.

In order to test whether the method developed was useful to achieve the goals, a test was made with the information available from 12.000 one-week measurements from the three companies controled since 1996.

Results obtained allowed them to confirm that goals had been achieved, as regards the possibility of identifying the areas where there are problems and of sending the correct economic signals in order that they place incentives on the companies so that they design the solutions.

The amounts of the penalties (US$) resulting from this method are summed up in the following Tables:

Area	Semester-1		Semester-2	
	FRp	Penalty (US$)	FRp	Penalty US$)
1	6,7%	268.565	3,1%	59.594
2	1,2%	0	0,6%	0
3	7,1%	559.785	5,6%	168.764

In the graphics enclosed, we show the curves obtained for one of the companies in three typical areas for two different semesters. We were able to verify, for each area, a similar behaviour in the period of time considered.

Figure 1

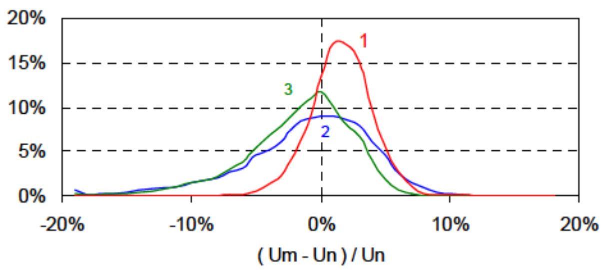
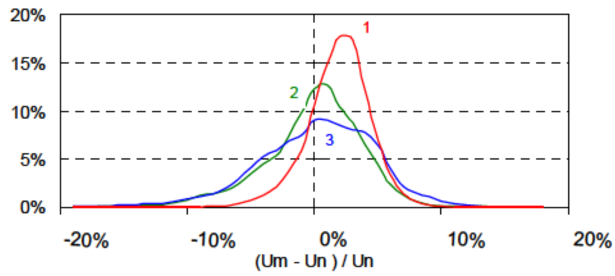


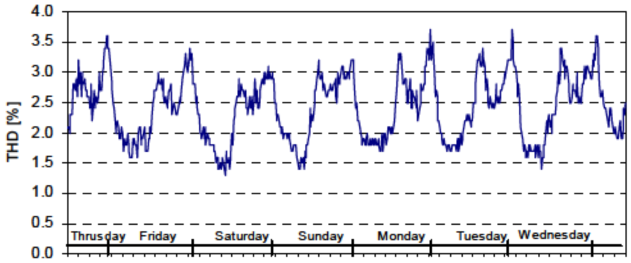
Figure 2



TECHNICAL PRODUCT. DISTORTIONS

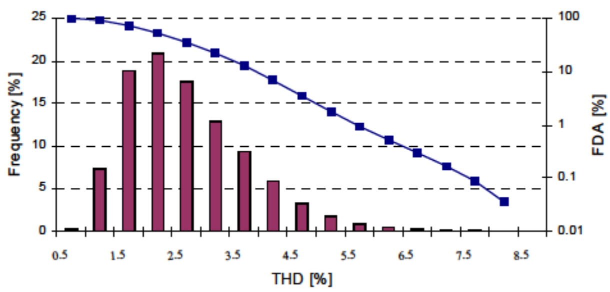
In the case of distortions, controls had been performed since September 1996 on flicker and harmonics by means of 30 measurements per month of harmonics and 15 of Flicker. The points over which to perform the measurements are selected by means of prior monitoring the Tasa de Distorsión Total (TDT%) [Total Distortion Rate] for harmonics and an indicator which reflects the short term severity PST. This control is made together with the voltage level metering campaign of 670 points per month; very unexpensive monitoring modules have been incorporated in the equipment for registering the voltage level. According to the results obtained from the 670 measurements on consumers, the points where distortions had been registered in the transformation stations are selected pursuant to procedures and equipment established in Rule the IEC standars. Duration of metering is of at least a week, in 10-minute intervals. In measuring harmonics the TDT and the harmonics are registered up to order 40, while for flickers the PST must be registered. Besides, and at the same time, the integrated three-phase power supplied every 10 minutes is registered, also, in both cases. Resolution ENRE 465/96 establishes the levels of reference for harmonics as well as for flicker. In case they are too high for a period of time longer than 5 %, the distribution company shall be penalized and shall have to pay to every affected customer. The amount of said penalty relates to the degree in which reference values were exceeded and to the power supplied under these conditions. Penalty ends when the distribution company is able to show, through a new metering, that the problem has been solved. Following is an analysis of the data obtained during the previous metering campaign of one of the companies, having a total of 1470 measurements. Given that the average duration of measurements is somewhat longer than one week and that a register is performed every 15 minutes, the number of registers we have is more than a million, so a statistical analysis is suitable in this case. The commented information allows us to analyze the data in two conceptually different ways. The first is by creating a set with all the registers, without differentiating the various measurements. The second, in turn, is to work with the set of 1470 measurements without combining, in any way, those registeres which belong to different metering. As an introduction, in figure 3 a TDT metering is shown (from now on in percent values) for a particular point of the campaign.

Figure 3



Analysis will be commenced by making an histogram and the accumulated distribution curve of TDT over the totality of 15-minute registers available. These graphics are shown in Figure 4.

Figure 4



The mean value of the million registers is 2,31 and the P_{95} (value not exceeded by 95% of registers) 4,31, which is within the range of half the value of TDT admitted of 8 in BT [Low Voltage].

Less than 0,1% registers exceed the value TDT=8. (This percentage is not completely representative of the number of places in which there would be an infringement of harmonics , since, at times, it is a particular harmonic – not registered in this campaign – the one that exceeds the permitted value, and not TDT). In figures 3 and 4 the graphics shown are similar to the previous ones, though they consider each of the 1470 meterings individually. In Figure 5, each measurement is representedd by the average of all its registers, considering the set of one-week registers as the mean value of each measurement, thus the mean value of the whole of the measurements is 2,31 and as P_{95}, 3,6. No measurement exceeds TDT=8 value.

Figure 5

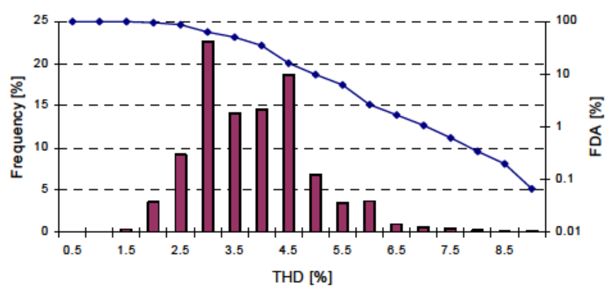
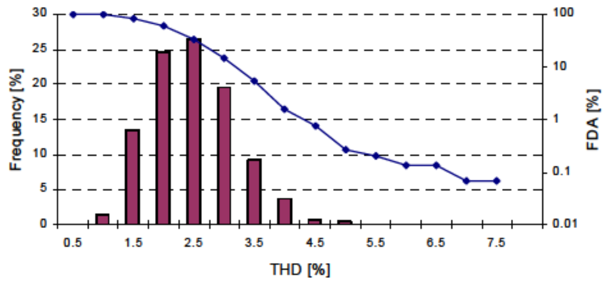


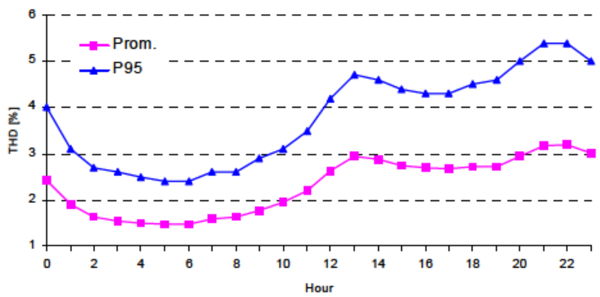
Figure 6



On the contrary, in Figure 6, each metering is represented by the P_{95} of the total of its registers, mean value being 3,67 and as P_{95}, 5,6. Of all the measurements, 0,32% exceeds the TDT=8 value.

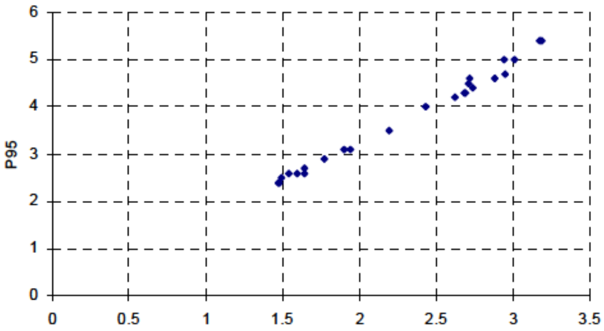
For the second type of the analysis, the information was processed in way so as to obtain a TDT profile along the day. In order to do this, we took the whole registers and grouped them by hour, thus getting 24 subgroups of approximately one million/24 registers. The result of the foregoing is shown in Figure 7, where we can see two curves, one of them considers the average value of the registers of each subgroup that represent a certain hour, and the other takes the P_{95} value.

Figure 7



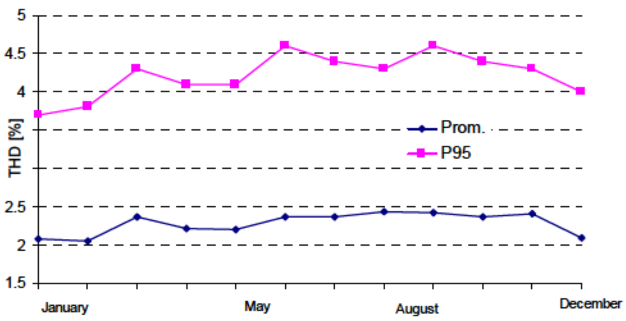
When observing these graphics, it is apparent that there is an important variation in the TDT along the day, and that it would be in direct relation with the systems load. This means that TDT's lowest values appear at dawn and the highest are divided into two peaks, the lowest at noon and the highest in the evening. From Figure 7 on we can see a considerable correlation between the graphics which show the average and the P_{95} value of TDT. In Figure 8 the ***x*** axis represents the average and ***y*** axis the P_{95} for each hour, from which we can extract a *correlation factor* of approximately 1,67. In conclusion, we could say that this factor would allow us to make a simplification of metering procedures and information processing, since if we know the average TDT we could estimate P_{95} value.

Figure 8



Another analysis made consisted in observing TDT's profile along the year, for which we grouped all the registers by month. Results obtained are shown in Figure 9, for which, again, we used the criteria of the mean value and P_{95} within each month. As can be seen, there is not a deterministic variation along the year, though we can have slightly higher values during the coldest months. For the flicker register, we had 1025 measurements, and the result is a series of values which can be considered, in certain area of the metering range, proportional to PST.

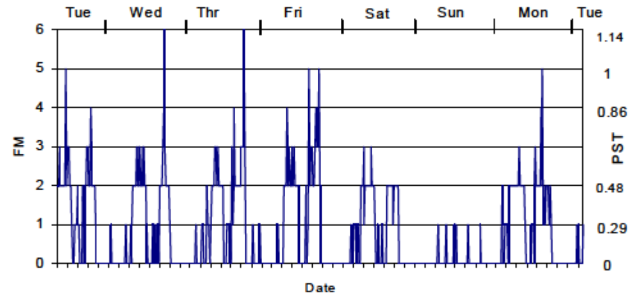
Figure 9



These are whole numbers and, in most practical cases, are between 0 and 6, this is the reason why the equipment has poor resolution; however, it is adequate for the purpose of the control proposed. In order to correlate the values measured by these low-performance equipment with PST values, we made a test by provoking a 8.8 Hz sinusoidal flicker, and the values thus generated were compared to the Metered Flicker (FM) in order to obtain a conversion factor.

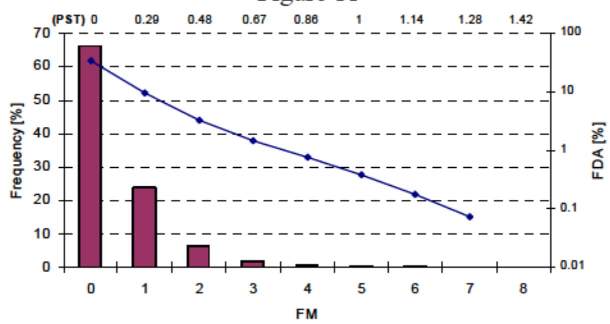
To demonstrate the foregoing, Figure 10 shows a flicker metering at a particular point of the campaign. As a comparison, the graphic has two axis of ordinate, one in FM units and the other in PST. The same was done with the rest of the Figures.

Figure 10



The procedure utilized for the analysis of the flicker results is complete, the same as the one used for the harmonics. The only exception to take into account is that, due to the low resolution of the equipment, the calculated P_{95} values are only indicative. In Figure 11, the histogram and the accumulated distribution curve of FM for all registers is shown. The mean value of the sample is 0,52 and P_{95}, 2. Of all registers, 0,8% exceeds the FM=5 value, which is approximately 1 in the PST scale (maximum value admissible for this parameter in BT [Low Voltage] pursuant to Res. .ENRE 465/96).

Figure 11



Figures 12 y 13 show graphics similar to the foregoing but which take each of the 1025 measurements individually. Figure 12 represents each measurement by the average of all its registers, mean value being 0,52 and P_{95}, 1,6. Of all measurements, 0,1% exceeds FM=5 value. In Figure 13 each metering is represented by the P_{95} of all its registers, resulting in a mean value of 1,7 and in a P_{95} of 3,9. A 4,4% exceed the maximum value permitted.

Figure 12

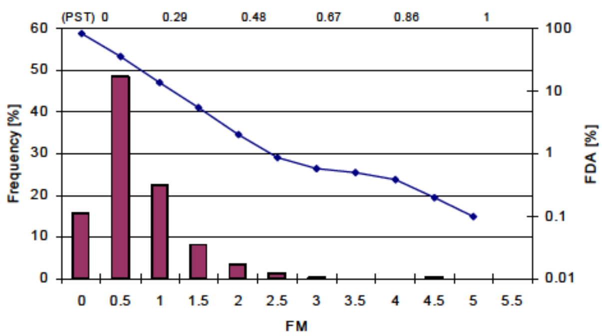
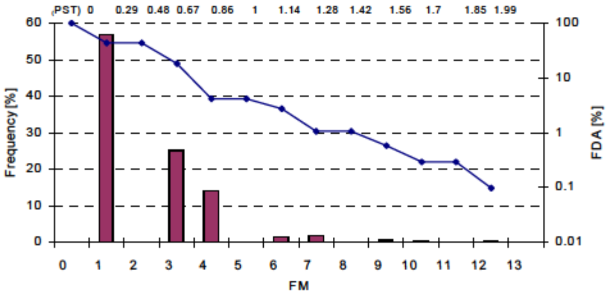
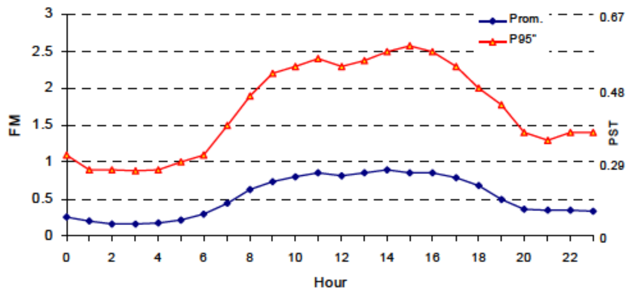


Figure 13



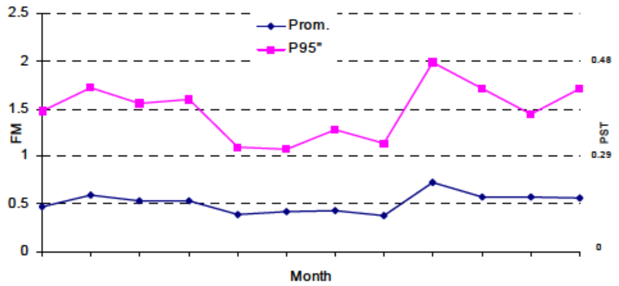
As with harmonics, Figure 14 represents the flicker along a typical day, taking into account the average and the P_{95} fo registers present in an hour. It is apparent that the highest FM values appear approximately between 6 a.m. and 8 p.m., while they stay below this level during the rest of the day.

Figure 14



In Figure 15 we make a similar analysis but along the year; noticing that, as in TDT, there is little relation between FM and the time of the year; we can see values slightly lower during the coldest months of the year.

Figure 15



TECHNICAL SERVICE

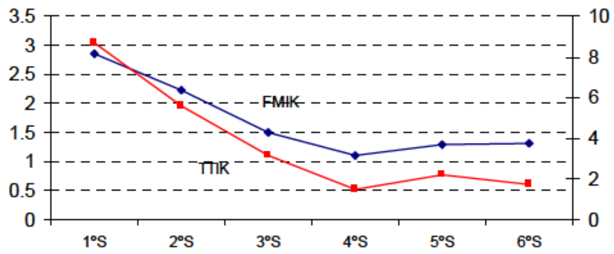
This issue refers to the degree and duration of the interruptions that affect customers. In September 1993 controls were put into place to monitor Quality of the service by means of global indicators of the Average Interruption Frequency and Interruption Total Time. As a consequence of the companies' failure to comply with admitted limits, penalties were imposed wich returned to customers in proportion to the power consumed by each of them, which amounted to M. US$13,7 in three years.

In Figure 16 the FMIK (Frecuencia Media de Interrupción por kVA) [Average Interruption Frequency by kVA] and TTIK (Tiempo Medio Total de Interrupción por kVA) [Average Total Interruption Time by kVA] evolution for one of the companies monitored is shown. There appears an improvement of said measures along the time in respons to the economic signals received via the fines imposed.

FMIK (Frecuencia Media de Interrupción por kVA) [Average Interruption Frequency by kVA]

TTIK (Tiempo Medio de Interrupción por kVA) [Average Total Interruption Time by kVA]

Figure 16



Later, in September 1996, control of interruptions affecting each customer individually begun. For the sake of this, distribution companies had to make a careful survey of the relation customer-net, develop complex computer systems and incorporate new management techniques to the net, so as to accurately identify the affected customer during an interruption in any part of the net. If, during the monitored semester, a customer suffers more interruptions (longer than 3 minutes) than established, and/or lacks service supply during more than the permitted time, he should receive from the distribution company, a credit in his invoices for the semester in question.

The limits for interruptions, over which the Power Not Supplied will be determined, depend on the Type of Customer and are the following:

Type of Customer	Frequency per Semester	Duration per Interruption
High Voltage	3	2
Medium Voltage	4	3
Low Voltage / ≥ 50 kW	6	6
Low Voltage / < 50 kW	6	10

Power not supplied (not received by the customer) is calculated as follows:

$$ENS(kWh) = \cdot \sum \frac{EA \cdot Ki}{525.600}$$

Where:

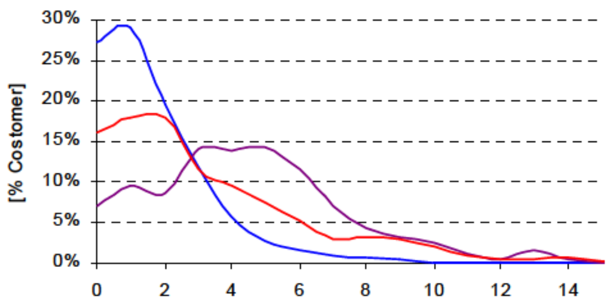
Σ : Sum of "i" minutes of customer's lack of service over the pre-established limits.
EA : Total energy invoiced to the customer during the last twelve months.
Ki: Factor representing the charge curves of each rate category.

Finally, the power not supplied is valued according to the rate category of each customer, varying between 1.40 US$/kWh and 2.71 US$/kWh.

The total amount of discounts to customers during the first semester is around U$S 2 million, for one of the Distribution companies monitored.

If we analyze the information obtained during this stage, we can see that the Service Quality, as perceived by the customers, differ considerably from one Area to another, even among different areas of the same Distribution company. From this we can infer that it would pose limitations and produce distortions for the regulation authority to send economic signals if global indicators are kept for the whole company. As an example, the following Firgure shows the percentage of customers affected, with respect to the number of interruptions of three areas of a Distribution company. Where the percentage of customers is a proportion of the total customers of each area analized, thus allowing thier comparison

Figure 18



If we analyze the whole universe of customers who have to receive discounts (excluding those who receive service quality within the admitted limits) from the Distribution companies due to poor service quality, we can see that the amounts to be discounted are distributed proportionally to the requirement level established for each customer affected and to the annual power invoiced. The following Table shows how affected customers and amounts of discount are distributed per Small Demand (SD), Medium Demand (MD) and Large Demand (LD) within a Distribution company.

	% of Customers	% Discount
SD	98.5 %	25 %
MD	1.0 %	5 %
LD	0.5 %	70 %

Considering all interruptions longer than three minutes occurred during the first semester of the monitored period, we have calculated the following management indicators.: SAIFI (Frecuencia Media de interrupción en el Sistema) [System Average Interruption Frequency Index] and CAIDI (Duración media de Interrupción por Usuario) [Customer Average Interruption Duration Index], for the two Distribution companies with the greatest number of customers in Great Buenos Aires. The following table shows the values obtained:

CAIDI	SAIFI
108 minutes	2.9
90 minutes	5.6

From the analysis of the values we can observe that CAIDI falls within international standars, while SAIFI is significantly higher.