DETERMINING THE COST OF FAILURES IN ARGENTINE ELECTRIC DISTRIBUTION

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ABSTRACT

It is of the essence to know the value of power interruptions by appraising Energy Non supplied (NSE) when it comes to providing guidance for investments geared towards the development of electric grids, both at the level of National Economy as well as for Electric Energy Distributors.
The paper is based on the consideration of the cost of ENS, bearing in mind the difficulties generated by interruptions in the supply of electric energy to consumers in our country. Unlike what happens with Industrial and Commercial Customers, who are quite precisely aware of the cost the lack of energy has in their economic equation, for Residential consumers a specific method of surveys was resorted to where all the answers needed in order to appraise non supplied KWh were obtained by means of an indirect questionnaire.

INTRODUCTION

With the aim of optimizing the investments which need to be made so as to expand and strengthen the electric system, it is of the essence to know the cost of failures, expressed in monetary terms, which the economy of the country has to bear in case an outage of the electric system occurs.
This cost can be evaluated pursuant to three different criteria:
1º.-From a GLOBAL point of view, with macroeconomic methods: for example, based on the ratio between the Gross Domestic Product (GDP) and the total consumption of electric energy.
2º.- From the point of view of SUPPLIERS of electric energy, based on lesser income due to the lack of sales of electric energy.
3º.-From the point of view of CLIENTS or USERS, based on the cost of the "nuisance" or "discomfort" that the latter have to put up with.
Whereas the first two criteria can be analyzed starting from the data made public by the National Institute for Statistics and Census and by internal statistics provided by Distributors, for the application of the 3rd criterion, the most widely used methodology is the performance of interviews or surveys, so as to obtain the data and the knowledge needed to evaluate the cost of failures.
For the present study, the cost of failures seen by clients is the one that has been taken into consideration, based on the results of a campaign conducted in Argentina in order to gather data, which included a sample of over 1000 clients.

Methodology

The typology of clients is very varied, both from the point of view of dimensions as well as from the uses that each client gives to electric energy.
Although for synthesis reasons we will analyze only the residential clients, we could do a first segmentation into five major categories:

- Residential clients
- Large industrial clients
- Smaller industrial clients
- Clients from the tertiary(or service-related) sector
- Remaining clients

The criterion used for the subdivision was the capacity for the supply of electric energy and the capacity limit was set up at 200 kV.
For each of the first four categories of clients formerly mentioned, market research was conducted with the purpose of determining the cost that clients have to bear in case a failure in electric supply takes place.

Sampling Method

For each category of clients considered, a stochastic sample of clients was taken into consideration, that is to say, a sample where each of the clients had a chance of being included in the known sample before being drawn; so that the data might be projected to the whole category from the same sample. Only in the case of larger clients, with consumption of over 50 annual GWh , was a total study conducted, that is, of each and every client for that category.

Interrupted Energy

The cost that an outage of electric supply creates in clients, generally refers to the energy that this same interruption has not been able to provide; this is expressed in U$S per kWh that have not been supplied.
It should be pointed out that both the cost in U$S as well as the energy that has not been supplied are both variables, strictly, non measurable; they refer to the confrontation between a first situation in which electric supply is regular and a second situation in which the supply is interrupted; such situations cannot coexist simultaneously and, therefore, they can never, actually, be perfectly confronted.
From another point of view , it can be said that the damage in currency can never be deducted from an accounting entry and that the energy that has not been supplied cannot be measured by an instrument.
In order to add the cost of failure of all the clients in the sample and obtain the total cost of a failure , D, it will be necessary to multiply the specific cost , di, in U$S/KWh regarding the client, times the energy Ei that has not been

supplied to this same client.

$$D = \sum_i d_i E_i$$

The cost of the relative, average, specific failure regarding all clients would be

$$d = D / E$$

where E is the energy that has not been supplied to all clients: $E = \sum_i E_i$.

That is to say:

$$d = \sum_i d_i \frac{E_i}{E}$$

With respect to the energy ei, which has not been supplied, it is typical to assume that the kwh that have not been supplied should not be proportional to the consumption of electric energy, for the same duration in outages. This hypothesis , if the rate of failures does not relate to the cost per kwh corresponding to each client, does not introduce any distortion in the estimation of the average failure cost for all clients.

This hypothesis is almost forced, since it is rather difficult and costly to obtain estimations of the quantity of energy that has not been supplied for each client.

From the hypotheses of proportionality mentioned above, we can infer that

$$d = \sum_i d_i \frac{E_i}{E} = \sum_i d_i \frac{W_i}{W}$$

where Wi is client consumption, i, and

$W = \sum_i W_i$ is total consumption.

Based on such a formula ,the cost of the total failure can be estimated without knowing the quantity of energy that has not been supplied.

In order to evaluate the cost of the failure in currency which, as we have said, cannot strictly be measured, we count with several methods depending on the sector of clients.

Regardless of the mistake which is implicit in the whole evaluation, the great variability of the magnitude considered can be added: we know that the cost of a failure can vary according to:

- The day and the time on which the outage took place;
- The duration of such outage;
- The fact that the power cut may or may not have been previously announced by electric utility companies.

The cost of the specific failure, that is to say, the cost which refers to the energy that has not been consumed, is a value which, as it has been said, varies with time, since it is a relationship between two magnitudes, both variable at the same time. It has been considered timely to take into consideration only the cost the average failure produces in each client due to a one-hour cut which is verified at any point in time during the year and its average hourly consumption; in such a way, the need to know the load curve of the client being considered has been avoided.

The need to know the annual average value of a failure cost remains to be analyzed, taking into consideration the hypothesis that the outage that produces the cost may occur by chance at any moment in time,

Such a temporal average value was obtained with several methods pursuant to the type of clients being considered.

For residential clients, a special question was resorted to so as to verify, for each client, the relative importance of interruptions which occur during several periods in a single day.

For industrial clients, due to the fact that the verification of the level of activity at the various periods of the day, for each establishment, was considered excessively complex, an approximate formula was resorted to; the latter, however, was created in such a way as to make it exact in those cases – which comprise ,nevertheless, most industries- in which the establishment practically ceases its activities from one workshift to another one , or else work at a constant pace during three shifts.

In general, the cost of a failure suffered by the establishment is a function of the moment on which the outage occurs, for which reason the annual failure cost turns out to be:

$$Da = \int a(t)\, dt$$

where a (t) is the cost of the failure at t time.

We can notice immediately that if "a" has a constant D value during time L (working hours of the establishment) and is null in the rest of the time, the result is:

$$Da = D\, L ;$$

And we can infer that such a formula is also valid in the case in which L covers the whole year.

Residential Clients

The cost of the failure suffered by residential clients was estimated in monetary terms based on data gathered through a survey conducted by sampling within that sector of clients.

From the sample, all the clients whose consumption was lower than 1.000 kWh/year were left out, since it was deemed untimely to ask clients having very low consumption levels all the questions planned in the questionnaire .The results of the survey were extended, nevertheless, to all residential clients, and the same cost of failure per kWh determined for clients with consumption immediately above that level, that is, between 1.000 and 1.500 kWh/year was attributed to clients with an annual consumption lower than 1.000 kWh. The mistake which has been made in this way cannot be , but of a reduced value, given the fact that the total consumption of clients with less than 1.000 kWh/year represents a small percentage of the consumption of the whole residential sector.

It should also be taken into consideration that the consumption of residential clients includes , as well, the consumption of the supply of electric energy which feeds electric applications utilized jointly by several families, such as elevators, stairway illumination, water pumps, heating installations, etc. The cost of failure per kWh regarding such supplies has been considered in the same way as the one estimated for the supplies of each of the

families.

Sampling

From the files of the main Distributors in the country, a sample of 600 clients was drawn. In order to assign the quantity of clients to each of the Companies, the following two conditions were taken into consideration:

- the assignment of clients from the sample should be made in a way which is proportional to the quantity of clients and
- a minimum of 80 interviews

The questionnaire used for gathering data included inquiries made to each client on the following:

- the division of the working day into six periods pursuant to the main family activities: beginning of the day and breakfast, rest of the morning, lunch, afternoon, dinner and family gathering, night rest;
- the scale of importance that can suffer from an interruption in the supply of electric energy in each of the periods formerly mentioned;
- if the last time that all of the members of the family went out together, went to the cinema or to eat out and the corresponding cost of such an activity;
- the existence of household appliances;
- the quantity of family members and their activity;
- the tendency to give up their free time in order to perform an extraordinary job;
- the quantity of rooms in the housing unit;
- the level of studies of the head of the family;
- the monthly income of the family;

In addition, the interviewer evaluated the socio-economic level of the family interviewed and the Distributors contributed with data on the consumption of electric energy for each client of the sample.

Alternative activity method

With this method, we are assuming that the failure cost should be identical to the alternative activity that the client would be performing in order to obtain the same level of satisfaction that the activity - which the client has been unable to carry out due to the power cut - would have rendered to him.

Since it became very difficult to identify the alternative activity of the client with a direct question, it was possible to find out, through an indirect question, what kind of activity the client and his family typically carried out , when they go out for pleasure , and the cost related to such outing.

Taking into consideration that the most frequent activities developed were "to visit relatives and friends" , "to go to the movies", "to eat out", and "sports activities", the question raised to the client in the final questionnaire made reference only to these four activities.

The failure cost per hour which is born by the client was estimated pursuant to the following formula:

$$C_{haa} = h \times (c_{alt}/2) \times P$$ where:

C_{haa} = cost of failure per hour according to the alternative activity method ;

h = 1 if the activity indicated is to go to the movies ,

= 0.5 if it is to go to a restaurant;

indeed, in this case, the costs that are not sustained by the meal at home are substracted: food supplies, beverages , time to clean and wash up, detergent, hot water, etc.

c_{alt} = cost born by the client for the alternative activity. Such a value is subdivided in two because the alternative activity has been considered to last an average of 2 hours, whereas the formula only refers to the cost per each hour.

P = ponderation quotient which takes into consideration the relative importance of each hour of the day in which the power cut occurs.

Method which refers to the non functioning of household appliances

With this method, the failure cost born by clients is estimated as the cost of the services that have not been rendered (for instance, washing machine) or as a reduction in the value of merchandise produced by the fact that household appliances are not working (for instance, food supplies inside the refrigerator).

The cost of failure per hour born by residential clients was estimated for the following equipment: refrigerator, freezer, TV set, washing machine, air conditioning, "lighting and others".

The hourly failure cost born by each client interviewed was estimated as the addition of the cost of the hourly failure cost of each type of household appliance present in his/her home.

The average value of all residential clients was taken as average value, taking into consideration the various durations of power cuts and the various times of the day at which the latter occur.

An hourly failure cost per person was estimated; the basis for such estimations was a family of four people and a two-hour power cut.

In the case of refrigerators, the assumption was that the contents were to lose half their value in the case of a 24-hour power cut , since they must be consumed or cooked quickly before they begin to deteriorate.

Acknowledging that the magnitude of the failure cost were proportional to the duration of the power cut, the average hourly failure cost related to the non functioning of the refrigerator was estimated at 0,05 U$S per person. For the freezer, using identical reasoning, the estimation was set at 0,16 U$S per person.

Based on research conducted in Italy, the daily use of the TV set was estimated in 5 hours, therefore the hourly failure cost was estimated at

0,06U$S per person.

The washing machine is used, pursuant to Italian data, an average of 3,5 washes per week. It was also estimated that , in order to wash outside the home, 0,90 U$S is spent, on average, per person.

The hourly average cost corresponding to this was, therefore, 0,02 U$S per person.

The air conditioner for average Argentine weather

conditions is used approximately two months per year; during this period, it was estimated that the air conditioner works some 8 hours per day.
With this assumption, the hourly failure cost was estimated at 0,06U$S per week.
For lighting and smaller appliances which have not been considered earlier, the wide range which they imply does not allow us to perform an analytical evaluation of their failure cost.
The average failure cost , which results from household appliances examined earlier in full detail and to which two thirds of domestic consumption correspond has been considered to also be extended to "lighting and other appliances", to which group, one third of the overall domestic consumption of electric energy corresponds.
As a result of this, the average hourly failure cost obtained was 0,02 U$S per person.

Family income method

With such method, the failure cost per working hour is considered to be identical to the income per hour of work which the family obtains, as a whole. This method is based on the hypothesis that each worker, for each working hour, should accept to renounce to his/her free time in exchange for the hourly salary. Likewise, one hour of electric energy interruption prevents the worker from enjoying such free time. When applying this method, it has been naturally taken into consideration that the value of the cost of the electricity failure is different during the various hours of a single day. For a quantitative estimation of this circumstance, the quotient which has already been determined for the alternative activity was used.
The failure cost per hour born by a client has been estimated pursuant to the formula:

Chif = Ih x P x a , where:

Chif = cost of failure per hour pursuant to the family income method;

Ih = hourly family income, estimated as the ratio between the monthly income and the average number of hours for monthly work;

P = ponderation quotient which takes into account the relative importance of each hour of the day on which the power cut occurs

a = quotient which evaluates the importance that each person attributes to free time. Such a factor has been estimated based on how prone the person is to perform an extraordinary job.

Determination of Average Failure Cost

For each of the three methods mentioned, the failure cost per KWh has been estimated, establishing the ratio between the hourly failure cost and the average hourly consumption of electric energy. The average of these three values was taken as the failure cost per kWh.

RESULTS

The range of the sample enables to project the results obtained to the whole universe with an acceptable sampling error.
The cost per kWh, for a lack of energy lasting an hour, produced , for **residential clients,** a cost equivalent to **2,70 U$S.** By analyzing the following tables, it can be noted that the three methods mentioned used for the evaluation of this cost have yielded analogous results:

Electric energy interruption lasting 1 hour

Method	interviews	Failure cost
Alternative activity	406	3,30
No use of appliances	586	2,64
Family income	586	2,31
Total	586	**2,70**

From the analysis of annual consumption of electric energy, a trend can be noted indicating that the cost of kWh is reduced when consumption increases.

Electric energy interruptions lasting 1 hour

Annual consumption (kWh)	interviews	Failure cost
Up to 1500	166	3,48
1501-2 000	195	3,18
2001-3 000	155	2,44
3001-4 000	48	2,04
over 4 000	22	1,70
total	586	**2,70**

As final information on nuisances produced by electric energy outages, the results obtained showed that 60% of clients consider that four half-hour power cuts in several days are less serious than a single two-hour interruption; in both cases, reference was made to outages that occur without any prior notice during the period of the day in which such interruptions produced the maximum failure cost for clients.

CONCLUSIONS

For all clients, the failure cost was 2,82 U$S/kWh, understood as the average value for any one hour power cut which might occur at any time during the year.

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