# ELECTRIC ENERGY CONSERVATION - A BAD BUSINESS TO THE UTILITIES ?

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***ABSTRACT***

*This paper presents conditions to establish a model which proves, in technical and economic bases, that conservation is a good business to the Distribution Utilities .The paper shows a methodology based in several charge models which demonstrates, even to Distribution systems, the possibility of good business to conservation programs, once it's shown that the benefits due to postpone of investments are greater than the revenues reduction from the decrease in growth of energy market . At the end, it is shown a practical example, representing a real situation involving a Brazilian utility .*

## 1. THE IMPORTANCE OF CONSERVATION IN CURRENT SCENARIO

Electric Energy Conservation is pointed as an important alternative of postpone of investments, reduction of environment impacts, increase of energetic efficiency, beyond of constituting in a modern attitude, related with increase of quality/productivity to consumers and enterprises of electric energy.

We can understand Energy Conservation as the utilization of a smaller amount of energy to obtain the same task .

Another definition of Conservation could be a rational utilization of a same amount of energy, sighting an increase in the capacity of supplying which can be obtained, basically, through the elimination of wastes, reduction of losses in the system, customs changes of consumption, utilization of equipments more efficient and/or increase of quality in productive processes.

In face of lack of recourses and the important growth rates, to supply the energy consumers of the utilities, the investments of the electric sector demanded by Distribution systems must be priorized, looking for a economy of resources and facing a gradual recuperation and reduction of losses along the period of study. We accentuate that a par of this economy of resources can be obtained with the adjustment of investments with the utilization of Energy Conservation Programs at the electric power system level as under the optics of the final consumer .Through an economic evaluation, the attraction of a conservation program might have three different optics: country, electric sector and final consumer.

The point of view of the country, we might compare the cost of implementation of a Conservation Program with the cost necessary to the expansion of the electric system looking for an optimum location of resources between the system expansion and energy conservation. In the conservation cost, it is also included the participation of society in investments, considered as the final consumer .

By the point of view of the electric sector, we compare, through the cost-benefit analysis, where the costs to execute a conservation program are associated to the reduction of the invoice of the utility . The benefits of the program, are related to the avoid investment to the system expansion, with a postpone of resources to the expansion.

With the point of view of the consumer, it is possible to make an analysis involving the profitability of the program comparing the investments effectuated by the consumer, necessary to the implementation of conservation measurement, with the respective reduction in the expense with electric energy.

So, the electric sector as an important agent to the development of the country, must have worries with the search of rational solutions to the supplying of an increase of demand, although the recessive period in which the country passes. In this way, we must encourage the rational utilization of electric energy, therefore, conservation is also an interesting business to the Sector because the applied tariff is lower than the marginal costs of expansion of the electric sector, which are crescents.

## 2. CONSERVATION PROGRAMS AS AN ALTERNATIVE TO POWER SYSTEM EXPANSION

### 2.1 Conservation Programs In Generation and Transmission Segments

Mainly at the Generation level, the Conservation Programs become in important alternatives if compared with those one traditionally used to the system expansion .The attractiveness of these programs is obtained in an ensemble of factors, like economic benefits with the postpone of great investments in construction of hydro or thermal electric power plants, reduction of environments impacts (very important nowadays), and increase of energetic efficiency levels .

At the Transmission segment, conservation programs are linked to the increase of efficiency of the power system with optimization of lines operation, reduction of losses with installation of banks of capacitor, etc .

### 2.2 Conservation Programs In Distribution Segment

The Brazilian National Program For Fighting Against Energy Wastes - *PROCEL*, in the report called "Strategies Of Electric Energy Conservation - Period 1996-1999", establishes a prevision to this period, concerning several efforts linked to some strategies to the final use : power motive; electric-thermal processes in industries; lighting in residential sector; public lighting; buildings and foment/dissemination .

In Distribution segment, it is also a responsibility of *PROCEL* an elaboration of special projects of short term described in the «Work Program to 1998/99»: increase of efficiency in isolated systems of North region ; reactive compensation and meters in customers without metering .

*PROCEL* also develops important actions with the utilities that are put together in special contracts called "PROCECON". This kind of agreement establishes some projects like: specific seminars about Conservation; implementation of the "*PROCEL* in Schools of First and Second Grates", promotion, change of inefficient lamps in the public lighting of the cities, energetic diagnosis in industries, research of efficient equipments and other aspects concerning buildings and commercial magazines .

Differently from the point of view of the supplying enterprises, where the benefits from the postpone of investiments are greater than the costs of programs implementation, conservation always trouves in Distribution utilities a relative barrier to its developing, caused by the expectation of revenues reduction in concession areas .

The next sections show, through several models of charge, that, even at the Distribution sector, for specific networks parameters, the benefits obtained by the postpone of investments are greater than the decrease in revenues as a consequence of the reduction of rhythm growth of energy market .

## 3. SYMBOLOGY

Along the text, we will adopt the following symbology to the variables :

**R** - resistance of the wires of the feeder ($\Omega$ )

**V** - tension ( kV )

**D(0**) - maximum demand in the first year ( kW )

**g** - exponential annual rate of demand increase ( % )

**COS** $\varphi$ - power factor of charge

**FC** - charge factor

**CMAX** - maximum capacity of feeder transport ( kW )

**T** - useful life of works at first expansion ( years )

**1 / N** - fraction of useful life in which the system attend the charge increase ( considering the first expansion )

**I** - investment cost of works at first expansion (US$ / km )

**VA** - present value of investments cost (US$/km)

**TAR** - tariff at level A3/A4 – 69/13,8 kV (US$ / kWh )

**R** - revenues ( US$ )

**Ev** - energy sold ( kWh )

**VA**$_R$ - present value of revenues ( US$ )

**c** - annual increase rate of conserved energy increase (%)

**Pc** - economic participation of the utility in conservation program (US$)

## 4. MODELS ADOPTED FOR CHARGE EXPANSION

We describe, below, the models considered in the development of the text .

### 4.1 Model Considering Concentrated Charge At The End of The Feeder

We suppose a feeder which maximum capacity of transport is given by CMAX, supplying a charge with an specific quality of service . We admit this charge concentrated at the end of the feeder with a length L, and maximum value of demand D(t) across the year t, which increases yearly, in accordance with an exponential function with rate «g» . This charge provokes electric losses of power given by p(t). Figure 1, below, illustrates the model proposed .

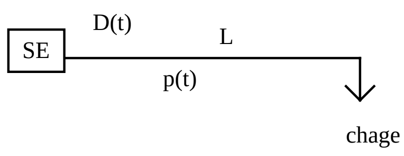



Figure 1 - Concentrated Charge Model

The feeder, in the first year of analysis, supplies the sum of the charge D (0) and losses p (0), which increases yearly. When, in a given year, this sum achieves (or transcends) CMAX, some expansions must take place in the system in order to supply the increase of charge with the same earlier quality of service . We consider $t_1$ the year when the charge of the feeder achieves CMAX . To calculate $t_1$ we have :

$$D( t ) = D( 0 ) . e^{g\,t} \qquad (1)$$

$$D(t_1) + p(t_1) = CMAX \qquad (2)$$

The losses can be obtained through :

$$p(t_1) = \frac{R \cdot 10^{-3} L}{V^2 \cdot \cos^2\varphi} \cdot D(t_1)^2 = K_1 . D(t_1)^2 \qquad (3)$$

Where, $$K_1 = \frac{R \cdot 10^{-3} L}{V^2 \cdot \cos^2 \varphi} \qquad (4)$$

Replacing (3) in (2), we have :

$$K_1 . D^2(t_1) + D(t_1) - CMAX = 0 \qquad (5)$$

$$D(t_1) = \frac{-1 + (1 + 4. K_1 . CMAX)^{1/2}}{2 . K_1} \qquad (6)$$

We make $K_2 = D(t_1)$ . With $K_2$ , we calculate $t_1$ in this way :

$$D(t_1) = D(0) . e^{g t_1}$$

$$t_1 = \frac{\ln(K_2 / D(0))}{g} \qquad (7)$$

When conservation actions are taking place, there will be a change in the year when the expansions will be necessary, considering that the charge supplied by the feeder will be in relative terms yearly smaller and the achievement of CMAX will occur in an year later than $t_1$ . We define $t_2$ this year and c as the yearly rate of exponential increase of the conserved power . These situations are illustrated in Figure 2, where the slopes I e II represent the demand evolution with and without conservation .

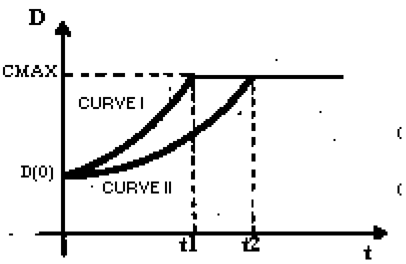



Figure 2 - Demand Evolution

Then, we'll have ,

$$D(t_2) = D(0) . e^{(g-c) t_2} \qquad (8)$$

To $t_2$ we can write :

$$D(t_2) + p(t_2) = CMAX \qquad (9)$$

$$p(t_2) = \frac{R \cdot 10^{-3} L}{V^2 \cdot \cos^2\varphi} \cdot D(t_2)^2 = K_1 . D(t_2)^2 \qquad (10)$$

Replacing (10) in (9), we have :

$$K_1 . D^2(t_2) + D(t_2) - CMAX = 0 \qquad (11)$$

Then ,

$$D(t_2) = \frac{-1 + (1 + 4. K_1 . CMAX)^{1/2}}{2 . K_1} \qquad (12)$$

We can conclude,

$$D(t_1) = D(t_2) = K_2 \qquad (13)$$

$$t_2 = \frac{\ln(K_2 / D(0))}{g - c} \qquad (14)$$

In this way, if $\Delta t = t_2 - t_1$ , results :

$$\Delta t = \frac{c}{g.(g-c)} . \ln(K_2 / D(0)) \qquad (15)$$

### 4.2 Model Considering Distributed Charge Along The Feeder

In this model we admit that the charge is distributed across the length L of the feeder, in accordance with the Figure 3 .

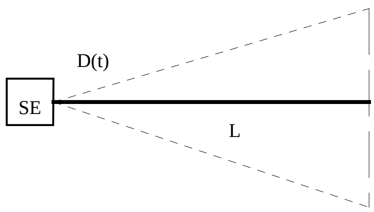



Figure 3 - Distributed Charge Model

In an identical way described in the last topic, the losses can be obtained to an instant t, by :

$8. R .10^{-3} L$

$$p(t) = \frac{\quad}{15 \cdot V^2 \cdot \cos^2 \varphi} \cdot D(t)^2 = K'_1 \cdot D(t)^2 \qquad (16)$$

Where,
$$K'_1 = \frac{8 \cdot R \cdot 10^{-3} L}{15 \cdot V^2 \cdot \cos^2 \varphi} \qquad (17)$$

If we make :

$$K'2 = D(t_1) = \frac{-1 + (1 + 4 K'_1 \cdot CMAX)^{1/2}}{2 \cdot K'_1} \qquad (18)$$

We will have, like (15) :

$$\Delta t = \frac{c}{g.(g-c)} \cdot \ln ( K'_2 / D(0) ) \qquad (19)$$

**4.2.1 Generalization For a Distribution Substation .** If we admit a power substation with N feeders, the expression (16) will be changed to :

$$p(t) = \frac{8. R .10^{-3} L}{N .15.V^2 \cos^2 \varphi} \cdot D(t)^2 = K''_1 \cdot D(t)^2 \qquad (20)$$

Where,
$$K'_1 = \frac{8 \cdot R \cdot 10^{-3} L}{N .15. V^2 \cos^2 \varphi} \qquad (21)$$

If we make :

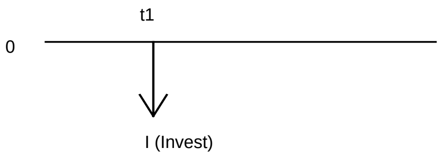
$$K''_2 = D(t_1) = \frac{-1 + (1 + 4 K''_1 \cdot CMAX)^{1/2}}{2 \cdot K''_1} \qquad (22)$$

We will have, like (15) and (19) :

$$\Delta t = \frac{c}{g.(g-c)} \cdot \ln ( K''_2 / D(0) ) \qquad (23)$$

**4.3 Present Value of Costs Variation**

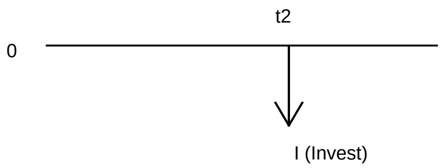
**4.3.1 Expansion Without Considering Conservation Actions in Final Use of Energy .** For expansion, we suppose that in $t_1$ the maximum capacity of the feeder is achieved, making necessary a work to construct a new feeder.




We have, in present value :

$$VA_1 = I \cdot e^{-a.t_1} \qquad (24)$$

**4.3.2 Expansion Considering Conservation Actions in Final Use of Energy .** With conservation actions, the instant of time to execute a work is postpone to $t_2$




We have, in present value :

$$VA_2 = I \cdot e^{-a.t_2} \qquad (25)$$

As $t_2 = t_1 + \Delta t$ and replacing in (25) :

$$VA_2 = I \cdot e^{-a. \Delta t} \qquad (26)$$

Considering $\Delta VA = VA_1 - VA_2$ , we'll have :

$$\Delta VA = I \cdot e^{-a \cdot t_1} \cdot ( 1 - e^{-a \Delta t} ) \qquad (27)$$

**4.4 Variation Of Revenues In Present Value**

We admit that this system (considering the expansion) supplies the increase of charge during a period of T/n years after the implementation of a new expansion (where T/n corresponds to a one part of the useful life) .

In this analysis, after this period and till the end of the useful life, the charge is supposed constant to the system, although we see that, in reality, this fact is not completely true, once the characteristics of increase in the consumption of energy, will carry to an increase of charge in influence area considered after the first expansion.

We will restrict our analysis to the first expansion, also considering that the repercussion of the implementation of works to a long term and the next variations of the charge supplied by the system, after this year, will have a little influence in terms of present value . And more, if we prove that it is advantage the gain in the postpone of investments at the first expansion, with more reason it will be to the expansion in a long term .

**4.4.1 Income Without Considering The Conservation Actions in Final Use .** The expressions are :

$$R_1 = E_V \,.\, TAR \qquad (28)$$

$$VA_{R1} = 8760.\ FC.TAR.\ D(0)\ .\Big( \int_0^{t_1+T/n} e^{g.t} . e^{-a.t}\, dt$$

$$+ \int_{t_1+T/n}^{t_1+T} e^{g.(t_1+T/n)} . e^{-a.t}\, dt \Big) \qquad (29)$$

**4.4.2 Income Considering The Conservation Actions in Final Use .** We can write :

$$VA_{R2} = 8760.FC.TAR.\ D(0).\Big( \int_0^{t_2+T/n} e^{(g-c).t} e^{-a.t}\, dt$$

$$+ \int_{t_2+T/n}^{t_2+T} e^{(g-c).(t_2+T/n)} . e^{-a.t}\, dt \Big) \qquad (30)$$

Then, the revenue variation, in present values will be :

$$\Delta VA_R = VA_{R1} - VA_{R2} \qquad (31)$$

If we substitute expressions (29) e (30) into expression (31), we'll have :

$$\Delta VA_R = 8760.FC.TAR.D(0).((B1+B2) - (E1+E2)) \qquad (32)$$

where :

$$B1 = \frac{e^{(t1+T/N)(g-a)} - 1}{g - a} \qquad (33)$$

$$B2 = \frac{e^{g\,(t1+T/N)} \left( e^{-a(t1+T)} - e^{-a(t1+T/N)} \right)}{-a} \qquad (34)$$

$$E1 = \frac{e^{(t2+T/N)(g-c-a)} - 1}{g - c - a} \qquad (35)$$

$$E2 = \frac{e^{g-c\,(t2+T/N)} \left( e^{-a(t2+T)} - e^{-a(t2+T/N)} \right)}{-a} \qquad (36)$$

## 5. ANALYSIS OF THECNICAL AND ECONOMICAL FEASIBILITY

The analysis is based in a comparison of expressions (32) and (27) that describes the gain with postpone of investments in face of implementation of conservation programs and the lost revenues verified by the rhythm reduction of consumption increase. In this way, the relation «Benefit-Cost - B/C» will be :

$$B/C = \frac{\Delta VA - Pc}{\Delta VA_R} \qquad (37)$$

If the rate B/C is greater than the unit, the development of the conservation program is interesting to the utility .

## 6. FLOWCHART - STAGES OF CALCULATION

Figure 4 shows all the stages of calculation described before .

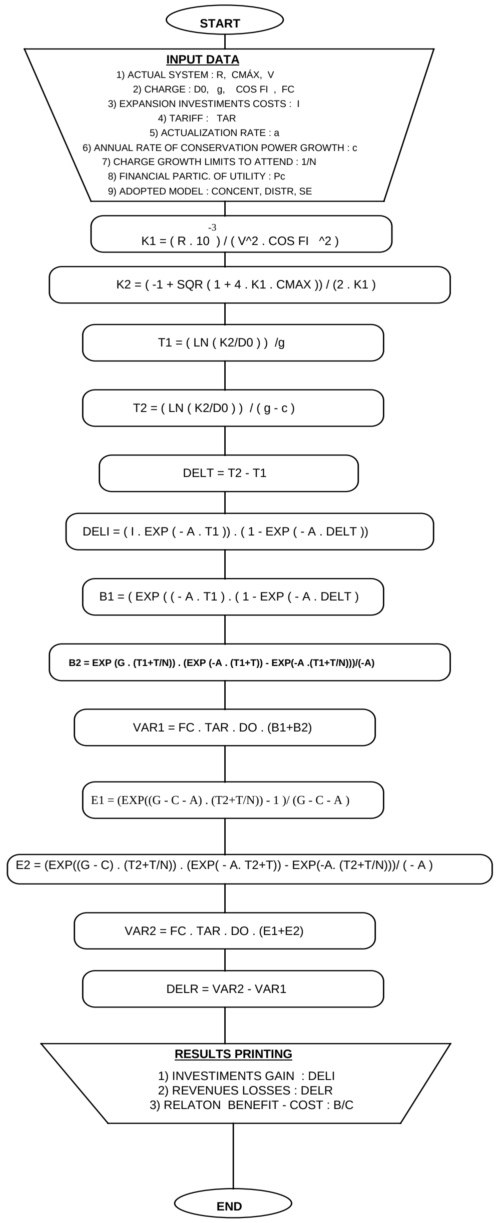



Figure 4 - Stages Of Calculation

## 7. METHODOLOGY APLICATION - EXAMPLE OF CALCULATION

We present one example which describes a real situation for a Brazilian utility .

### 7.1 Example

An utility of Northwest region of Brazil develops a conservation program with support of PROCECON (resources at lost fund), developing energetic diagnosis, replacing incandescent lamps by mercury ones and making seminars about energy conservation to promote the program. These actions are mainly developed in an specific area of a feeder with wires 1/0 AWG - CA, with exponential annual increase of charge about 5 % . These programs are modifying the expectations of increase in energy consumption in this feeder, where the reduction of the annual increase rhythm is about 20 % .

The next information complete the input data for analysis . If we admit the concentrated charge model, we ask : In economic terms, is it interesting to the utility, in medium/long terms the implementation of these conservation program ?

INPUT DATA

1) SYSTEM DATA

RESISTANCE OF THE FEEDER WIRES (OHMS) : 5.3
MAXIMUM TRANSPORT CAPACITY OF THE FEEDER (KW) : 3000
TENSION (KV) : 13.8

2) CHARGE DATA

MAXIMUM CHARGE DEMAND IN THE FIRS YEAR (KW) : 2000
ANNUAL EXPONENTIAL RATE OF CHARGE DEMAND INCREASE (%) : 9
POWER FACTOR : .85
CHARGE FACTOR : .4

3) ANOTHER DATA

INVESTIMENT COSTS OF WORKS IN FIRST EXPANSION (US$/KM) : 160000
USEFUL LIFE OF WORKS AT THE FIRST EXPANSION (YEARS) : 20
MEDIUM TARIFF (US$/KWh): 0.0025
LIMIT TO ATTEND THE INCREASE OF CHARGE (% OF USEFUL LIFE): 20
ACTUALIZATION RATE (%) : 10
EXPONENTIAL ANNUAL RATE OF CONSERVED POWER INCREASE (%) : 1
MODEL ADOPTED : CONCENTRATED
UTILITY PARTICIPATION (US$ - PRESENT VALUE) : 0

RESULTS

PRESENT VALUE OF THE GAIN IN INVESTIMENTS (US$) : 12308.63
PRESENT VALUE OF INCOME LOOSEN (US$) : 7087.157

**BENEFIT/COST RATE : 1.736751**

The rate benefit/cost shows clearly that the Programs implementation gives a good profitability to the utility .

## 8. SENSIBILITY ANALYSIS OF THE RESULTS OBTAINED AT EXAMPLE 1

Chart 1 establishes a sensibility analysis of the behavior of the rate benefit/cost as a function of the variable " c " (annual increase rate of conserved power), concerning the data of example 7.1 .

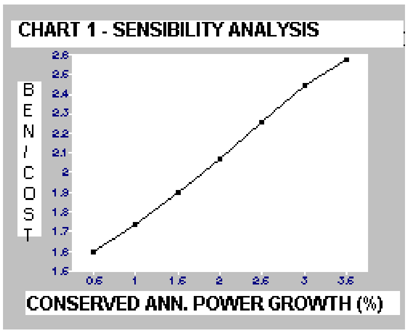



Chart 1 - Sensibility Analysis

## 9. CONCLUSIONS

* It is possible to create conditions to make an technical & economical analysis of conservation programs feasibility, even at Distribution segment ;

* For typical values used in Distribution networks, it is proved that the conservation programs can be very interesting to Distribution utilities ;

* The belief that still exist in electric sector that energy conservation is a bad business to the utilities is, mainly, in face of the expectation of decrease in the revenues obtained from the energy sales . Meanwhile, this is, essentially, a short term optics without looking at the medium/long terms. For greater horizons, the gain obtained with postpone of works is greater than the loss of revenues verified across the time ;

* Then, it is recommended to the utilities the development of conservation actions in their electric power systems and respective energy consumers due to the attraction of these programs, "awaking" the energy clients to problems related to an increase of energetic efficiency of processes and productive means .

* At last, the experience obtained with conservation programs implementation allows to confirm one important conclusion of the "International Seminar of Energy Conservation Strategies – EFFICIENTIA 98", taken place at Rio de Janeiro in October of 1998 : *"More important than sell an specific product is make sure that always there will be «someone» to supply it . In this case, the product is the electric energy and the «someone» is the own planet that we live ".*

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[2] H.S. Geller, *Efficient Electricity Use - A Development Strategy For Brazil*" , Rio de Janeiro (1990), pp 67-78.