DEMAND FORECASTING AND STRATEGIC PLANNING IN ELECTRICITY DISTRIBUTION COMPANIES: A SYSTEM DYNAMICS APPROACH

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ABSTRATC

This paper presents a system dynamics based model for long-term forecasting of the demand of an electricity distribution company. Initially, the paper presents an overview of the demand forecasting in a competitive market and the concept of price-demand elasticity. The overview is followed by a description of the conceptual framework that supports the development of the computer model. Concluding the paper, an application of the proposed model is presented and conclusions are drawn from this application.

The model comprises two modules: one associated with the technical performance of the company and other associated to its managerial performance. This paper emphasizes the sensibility of the consumer as far as the price factor is concerned and shows the consequences of this factor in relation to the demand projection and the market share of the company.

The proposed model seeks to contribute in the evolution of the demand projection models, to do that, it incorporates strategic variables such as: price, demand per consumer category and market share. It is important to remember that this approach is nonexistent in the traditional methodologies, and that it can be used as a support tool in the strategic planning of a distribution company that wants to preserve, or to enlarge its consumer base.

Keywords: demand forecast, market share, price-demand elasticity.

1. INTRODUCTION

The ongoing reform in the Brazilian electric sector changed significantly the electricity market structure. In the period previous to the reforms, up to 1995, the market structure was monopolistic and regulated (rates and/or franchise area), and the market share of the distribution/retail utilities was defined by the demand in its franchise area, since all the consumers in the franchised area had no choice other than the distribution utility in charge of that area. Under this structure, the utilities forecasted the demand according to the consumption categories (residential, industrial, etc.). This demand forecast was then used to define the expansion plan, the investment needs and to forecast the energy sales.

With the reform, private electricity companies are now able to participate by the market, and the consumers are now qualified as "captive" or "free". Free consumers are those that

areable to choose a supplier other than the local distribution company, that is fred from the obligation to serve (OTS) these consumers. The “free consumer qualification will be a prerogative of the regulatory agency, based on the supply voltage and peak demand level of the consumer. The remaining consumers, not qualified as free, will continue "captive", in the sense that they will not have the right to choose a supplier other than the local distribution/retail (D/R) company. On the other hand, the D/R companiesy stiil have the OTS regarding their captive consumers.

In short, the new electricity market will have two segments: “captive consumers" and “free consumers”. This segmentation makes the demand forecasting task a tough one, since it will involve not only the determination of the overall demand in the D/R franchise area, as it is done now, but will require also the evaluation of the “free consumers”share. As a consequence, the forecasting methods and models in use shall be complemented by new models, able to determine the free consumers share of the demand. This determination will require the explicit consideration of strategic and marketing aspects in the forecasting stage of utility expansion planning.

Electricity market studies must be reformulated also to take into account that the franchise area does not contain all the demand a D/R utility will be serving. The new concept of Base of Consumers (BoC) is now needed to represent the set of consumers both within and outside the franchise area domain that the utility is apt to serve. The consideration of strategic aspects is better considered through the concept of "Market Share" (MS). A detailed analysis of both concepts is presented in [1].

Often, the strategic objectives of a company are stated in terms of goals for MS. Once established, the MS goal becames the basic reference for managerial decisions regarding the BoC. On the other hand, the BoC may be seen as the main resource for obtaining a given MS. The accomplishment of the MS goal will be conditioned by the competitive strategies of the D/R company.

In this context, this paper presents a new approach for demand forecasting, taking into account the competitive aspects previously mentioned.

2. MODEL FOR PROJECTION OF DEMAND

As a rule, the current forecasting techniques and models do not consider the price sensitivity of the demand. This means that the price elasticity of demand shall be included in the demand forecasting model in order to evaluate correctly the influence of the rates on the demand and MS of the companies.

As a consequence, the time series and econometric relationships, up to now good enough to forecast the demand, shall be complemented by models that take into account the feedback of prices on the demand of captive and free consumers. This is now a prominent charactristic of the forecasting problem and strongly recomends the application of the System Dynamics approach to this problem, as will be detailed in the next sections of the paper.

2.1 Elasticity Price-Demand of Electric Energy

According to Ferguson [2], the price elasticity of demand is the variation of the demand in face of the variations of the market price, in other words, the price elasticity is the proportional variation of the demand divided by the proportional variation of the price. Mathematically, the coefficient of the price elasticity of demand is represented by the equation (2.1).

$$\eta = [- \Delta q/q] / [\Delta p/p] \qquad (2.1)$$

Where:
$q \rightarrow$ demand
$p \rightarrow$ price

According to the "Demand Law" of Economics, the demand and the price varies inversely, i.e., a positive variation of the price will be accompanied by a negative variation of the demand. Therefore, to obtain a positive price-demand elasticity coefficient, a minus sign should be introduced in the equation (2.1). Depending on the value of this coefficient, the demand may be classified in:

- $\eta > 1$, the demand is said elastic - a variation in the price will result in a larger variation in the demand;
- $\eta = 1$, the demand has unitary elasticity, that is, price and demand vary proportionately;
- $\eta < 1$, the demand is said inelastic – a variation in the price will result in smaller variation in the demand.

In the available electricity market literature, the price elasticity of the demand is seldom mentioned, therefore, it is not possible to have a precise definition for its value. However, studies conducted at the Brazilian electricity market (refs.[3] and [4]) claim that the price elasticity varies according to consumers class and time horizon (short and long term).

Reference [3] presents an analysis of the price elasticity taking into account all consumers classes from1970 to1990. It indicated that the demand of the residential, rural and public services is almost inelastic and is not sensitive to the time horizon. The industrial demand is relatively inelastic and sensitive to time horizon (-0,24 and -0,65 for the short and long terms, respectively). Reference [4] gives the price elasticity of the demand for the industrial class, according to the values in Table 2.1. The average rate along 1984-1988 and the period 1989-1993 was respectively of US$ 61/MWh and US$ 49/MWh. Taking as reference the rates shown in Table 2.1, we realize that the demand is inelastic when the rates are low and it is elastic when the rates are higher.

Table 2.1 - Price Elasticity of the Industrial Class

	Price	
Period	Short term	Long term
1970-1994	-0,09	-0,57
1970-1988	-0,29	-1,95

In a market characterized by homogeneous services, as it is the case in the electricity market, the price becomes the decision variable used by consumers to choose their energy

supplier. Accordingly, it becomes the strategic variable to enlarge the BoC's of the D/R companies.

The current Brazilian legislation entitles most industrial costumers the right to choose their electricity supplier. Therefore, the maintenance or enlargement of a BoC, and the consequent MS increase, depends strongly on the choices made by industrial customers. Therefore, the present paper takes the industrial rate as the base for the decision rule of the forecasting model that is described in the next section.

2.2 Conceptual Modelling

The concepts described in the previous sections were implemented in a computer model to support the demand forecast of a D/R company. The model comprises two modules: the technical module and the managerial module.

The technical module performs the forecast of the demand per consumer class: residential, commercial, industrial, and other classes. The "other classes" category subsumes rural costumers, public illumination, public services and the consumption of the utility itself (premises, losses), that are relatively small in themselves. Moreover, if current legislation is enforced, these classes are poised to keep captive. The technical module has another important function: the classification of overall demand into captive and free consumers. The free consumers category includes basically the industrial class. For this reason, the technical module forecasts the industrial demand by voltage level. The forecast of the other classes follows the traditional methodology.

The managerial module defines the investment and price policies for captive and free consumers. As illustrated in Figure 2.1, these policies are implemented in the technical module and the results evaluated by the managerial module. A mechanism feeds the results of the technical module back to the managerial module, that compares these results with the goals and determines if new policies are necessary to fill the strategic gap.

An hypothesis adopted in the current version of themodel is that free consumers' supplier choice is determined only by the price level. If a company, other than its present supplier, offers a lower price, the consumer switches suppliers. Therefore, the revenue lost by the incumbent supplier will be earned by the entrant supplier [1].

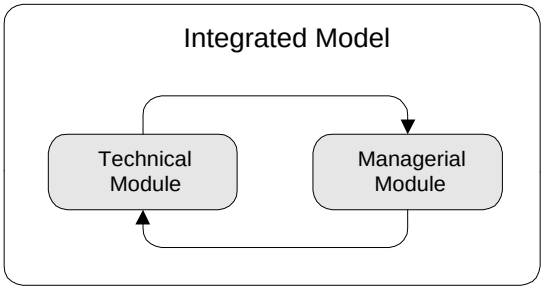

Figure 2.1 - Model Proposed

Figure 2.2 shows the influence of the price over the demand forecast. Starting from the demand forecast per class and voltage level, for a given price structure, the expected revenue is determined and a program to manage the BoC is defined. The implementation of a program involves several costs: energy purchase, distribution assets, consumer service centers, maintenance teams, human resources and marketing, among others. These costs must be recouped through the rates to both free and captive customers, if the company does not want to reduce its current level of revenues.

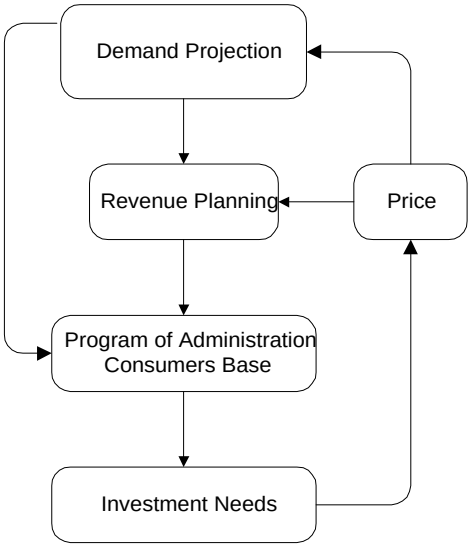

Figure 2.2 - Conceptual Modelling

On the other hand, the rate increase may induce free consumers in the top of the rate scale to choose another supplier, if a one with smaller rates is available. Therefore, the rate increase, that in the short term alleviates the financial burden, may aggravate the longer term financial position of the company, as well as may effect negatively the BoC and MS of the company.

Figure 2.3 presents the causal loop diagram (CLD) that relates free and captive consumers demand and the MS of a D/R company. This CLD shows that if *Demand* goes up, *Investment Needs* increase and this will be transformed in *Investments* depending on the available *Capacity of Invest*, that is influenced by *Revenue Level*. The increase in *Investments* enhances the quality of the energy supply to both captive and free consumers, but raises also the supply costs of the company. If the current *Revenue Level* is to be kept, a new rate increase is necessary, thus a new increase in *Price*. On the other hand, the *Price* growth increases production costs and decreases consumer competitiveness. As a consequence *External Migration* increases, that is, the number of customers that switch supplier increase, thus reducing the *Free Demand* of the company.

Captive consumers may reduce the impact of the rate increase with two measures: energy conservation and/or changing rate class. Energy conservation may be achieved through the efficient use of electricity, reducing the *Demand Captive* of the D/R company. Switching to another rate class is translated into *Inner Migration* between rate classes. Inner migration reduces income of the D/R in the short term, but helps to keep its BoC in the long term. The

migrating consumers increase costs in the short term (investments in transformation, for example), but may reduce their production costs in the long term.

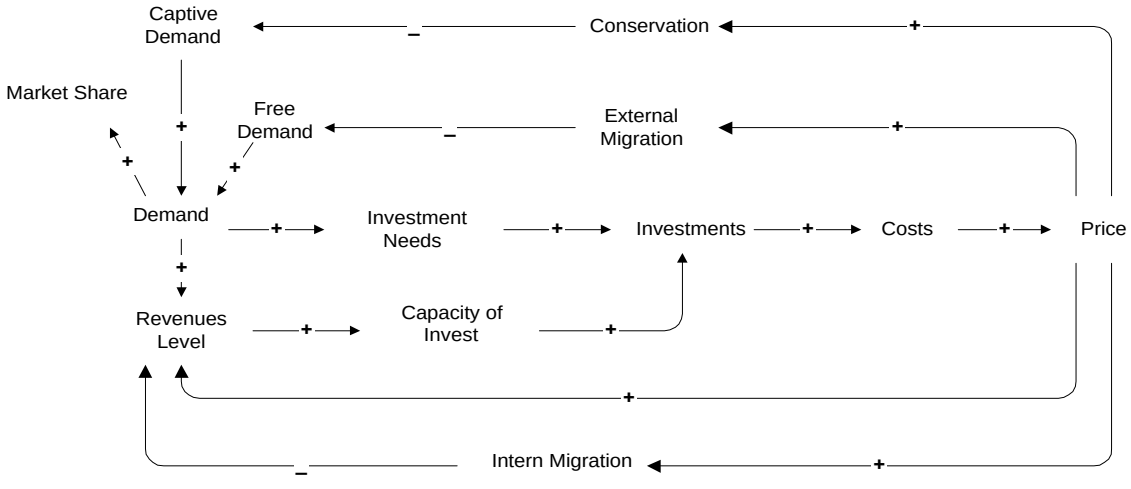

Figure 2.3 - Causal Diagram of the Proposed Model

2.3 Computer Modelling

A computer model was implemented in the Powersim shell that simulates the evolution of the free BoC of a D/R company. It calculates the MS of the utility and checks if the MS goal is reached with the current rate policy. Otherwise, it changes the rates and calculates the new captive and free demands from the present BoC and corresponding MS.

The consumer's classification in captive and free is in accordance with the standards of a typical Brazilian Electric Distribution Company, as shown in the following tables:

- ***Free Consumers***

Tension	Demand	Validity
≥ 69 kV	≥ 10 MW	immediate
≥ 69 kV	≥ 03 MW	2000
≥ 30 kV	≥ 02 MW	2003

- ***Captive Consumers***

Other consumers, of any consumption class, independently of tension characteristics and it demands.

Once classified the consumers, the technical model calculates the additional demand (MWh/year), considering the growth of the captive, free demand and inner migration. The new demand is calculated multiplying the demand of the previous year by the annual rate of growth.

The managerial module defines the investments (R$/year) and the rates (R$/MWh), taking into account the demand (MWh/year) supplied by the technical module. The costs (R$/year) are calculated according to the investments. The model calculates the cost of the offer increment according to the gross domestic product (GDP).

In the current version of the model, the consumer decision to switch supplier is based only on the price. They will choose the D/R company that offers the lowest price - company A or company B. The customer response to an increase in the price is quantified through the price elasticity of the demand. The hypothesis used for the rate of external migration is that price increases move the external migration rate up by 1% per year.

Most parametesr are embedded in the model, but the user may change part of these parameters, during a simulation run, to simulate different price polices. A flight simulator cockpit is available to the user, through which the rates may be changed. In the beginning of the simulation it is possible to choose the price-elasticity within the following range: 0,5%; 0,57%; 0,65%; 1,7% and 1,95%. The evolution of the free BoC demand, of the MS and of the prices may be observed during the simulation runs through graphs in the control panel of the flight simulator.

The model has a "Module of Market Share" that calculates the market share of the D/R companies, based on the following variables:

- DaL _CB _A: level variable that accumulates the additional free demand from the consumers list of the company A. The rates of this level are the growth of free demand and free demand lost by Company A. The growth of the demand is given by the annual growth of the free demand plus the free demand gained from the competitor. The demand rate lost by company A is the rate of the demand gained by company B. This rate is the result of the price policy of company A.
- DaL _CB _B: level variable that accumulates the additional free demand from the consumers list of the company base B. The increase or decrease rate of the level are respectively the growth of the free demand and the free demand lost by the company B. It has the same structure of the level variable described previously for the company A.
- Gain _ A: auxiliary variable that calculates the free demand gained by company A. This variable represents the rate of demand lost by company B due to its higher price. The price of the company B is higher than the price of the company A, in other words, this result is determined by the comparison between prices practiced by the companies in the period, and also of the price elasticity coefficient.
- Gain _ B: auxiliary variable that calculates the free demand gained by the company B. This variable has the same structure of the Gain _ A.
- MS _A: auxiliary variable that calculates the market share of the company A from the information of the levels of additional demand of the companies.

Depending on the results obtained in the simulation, the company can reformulate its price strategy to reach its goal in market share terms.

3. RESULTS

To evaluate the performance of the model, a market division was simulated between two hypothetical distribution companies, denominated company A (**A**) and company B (**B**), along the period 1995 - 2005. The hypothesis adopted in the example are the following:

- The consumers are located in the area where both companies operate, and also the initial demand for both companies are the same.
- The minimum price to be practiced is 50 R$/MWh (cost recovery), and the maximum price is defined by the market.
- In the first year, 1995, the model assumes that both companies have 50% of market share and that the price is 60 R$/MWh.
- Company A has as strategic objective to increase its BoC with free consumers from the company **B**.
- To reach this objective, company A defines as a goal to gain 6% of the market along the next nine years, starting from 1996.
- To reach this goal, company A will try to gain **B** free consumers through a policy of price adjustments. This strategy consists of maintaining its price lower than the price practiced in the previous period, maintaining the same service quality and the same reliability of the company B.
- Company B has as strategic objective to preserve its BoC and to keep its MS at 50%.

With these hypothesis, the model was run to simulate two price policies of company B. The policies were simulated considering a price elasticity of 0,57%.

Case 1

Company B wants to preserve its present BoC and to keep its MS around 50%. To reach this goal, its price policy consists of reducing its price around 3% in relation to the value practiced in the previous year by company A, starting from 1997. The level of investments is kept along the period, even with reduction of the revenues. The Figure 3.1 presents the results obtained from the simulation, for the additional free demand of the company A (A) and of the company (B) and their respective market shares.

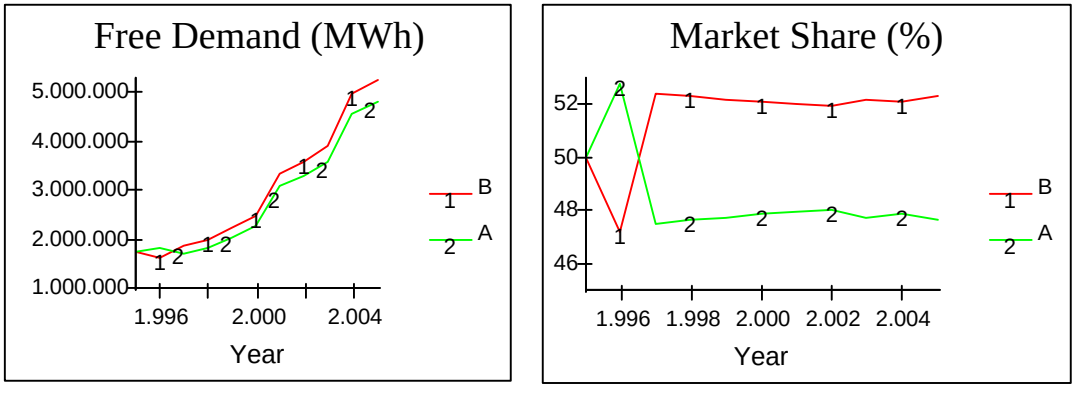

Figure 3.1 - Results of the Case 1

The results of the Case 1 show that the price policy used by company **B** is effective, because it meets the expectation of a larger MS, around 2,2% along the period, and blocks the penetration of company A. Company B increases its free demand and its BoC with the

consumers it got from **A**. On the other hand, **B** reduced its revenues to maintain the level of investments in order to guarantee the quality of the services offered.

Case 2

To maintain its revenues and level of investments, starting in 1997, company B increases its annual price in around 5% per year. The results presented in Figure 3.2 show that the policies used by **B** reduced its participation, along the period, on an average of 6,06%. In consequence, there was a reduction of its BoC and of its free demand maintaining the level of revenues. On the other hand, company A met its participation goal arriving at the end of the period with 57,42% of market share and an increase in its BoC.

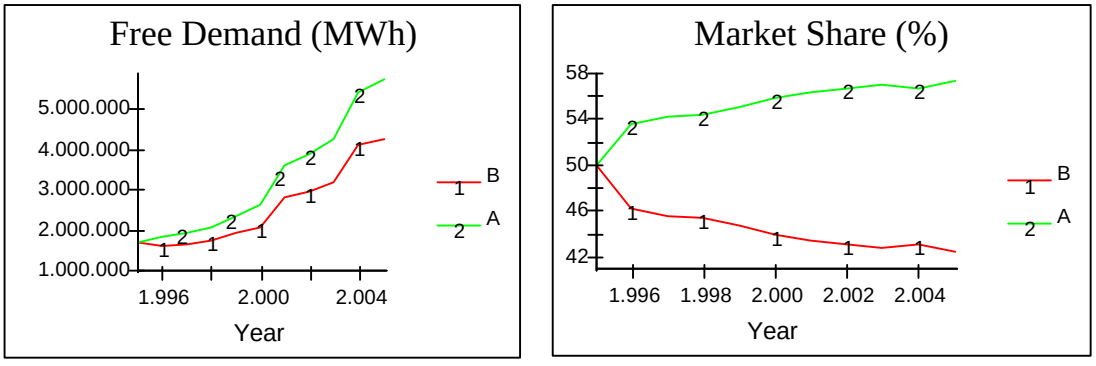

Figure 3.2 - Results of Case 2

4. CONCLUSIONS

Consumers response to price variation depends on a complex group of causal and interrelated factors that have been the object of research in the UFSC. However, the example presented has shown the need to better understand consumers behavior, concerning price sensitivity.

It has shown also the dynamics of the Base of Consumers and of the market share of D/R companies in the electricity sector. The example indicates some strategic options. Other strategies may be designed within the limits of the model.

System dynamics proved adequate as a tool for modelling the complex technical and management aspects involved, given the complex causal relationships and feedback loops among the variables of the problem.

Summarizing, the model presented in this paper contributes for:

- The evolution of electricity demand forecasting models, since it takes into account strategic variables such as price and additional demand of the Base of Consumers and market share, not considered in the traditional methodologies.
- A support tool to strategic planning of a distribution/retail company that wants to preserve or to enlarge its consumer base.

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