SCHEDULE DELAYS AND NEW FINANCING FOR THE ARGENTINE ELECTRICITY SECTOR GROWTH

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ABSTRACT

Apparently the electricity sector of Argentina has suffered in the past from excessive capacity planning, owing to overoptimistic forecasts of the demand growth rate. But because of the long delays involved and lack of financial backing this advantage has been progresively lost. The present official planning only provides for renovation and demographic growth, not allowing for economic growth. Therefore, the actual supply-demand balance of electricity can easily be worn away by technical obsolescence and aging process of the actual installed capacity of electricity production.

The problem behaviour arises when the timing of new capacity investment is delayed, falling behind the programmed schedule of new plants, without being able to meet the electricity demand . This could happen mainly due to political prices well below costs because of the inflation and or social subsidization, which leads, in turn, to the discapitalization of the sector, that still remains nationalized. A system dynamics model is used to explore the trade-off between construction delays (which entails costs of unsatisfied demand) and construction speed up (which entails financial costs).

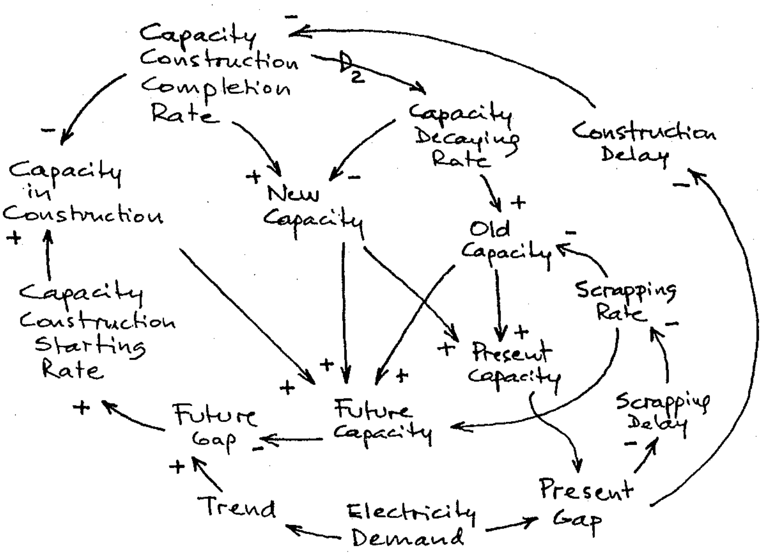
Introduction.

The prevalent opinion in official circles -shared by some from the private sector - that the actual installed capacity of electricity generation, about 12,000 Mw, was big enough to satisfy a peak demand of 8,500/9,000 Mw, giving a sufficient safety marginto the system , was corrected by the facts. The combination of unhappy circumstances, like an extremely dry winter season during 1988 and the reparation works on the Chocon Dam, lowered the hydraulic capacity generation, making clear that such hipothetical reserve did not exist, as public opinion learnt during that winter (1). Furthermore, the non reliable thermical conventional capacity, due to obsolescence has been estimated in the range of 2,500/3,000 Mw (Pescarmona, 1988), leaving the system well below the security limits. There are aproximately 5,500 Mw in the construction pipeline, which will be ready in 5 or 6 years time, taking just technical considerations into account , without financial delays. Regrettably, the big projects involved in this period, would not be ready before 1992. Which would be the picture for the next 5-10 years? Assuming a 20 years life-time for the conventional thermical and nuclear plants, and 30 years for the hydro-electrical utilities, it would be necessary to remove 500 Mw, and build up an equivalent quantity annually in order to maintain the present capacity. There ought to add up others 360 Mw more, for taking care of a 3% annual rate of demographic growth. This would entail to build between 850 and 900 Mw annually, according to Pescarmona's estimations (1988), which amount to 5,400 Mw for the next 6 years.

Definition of the system model and its formulation.

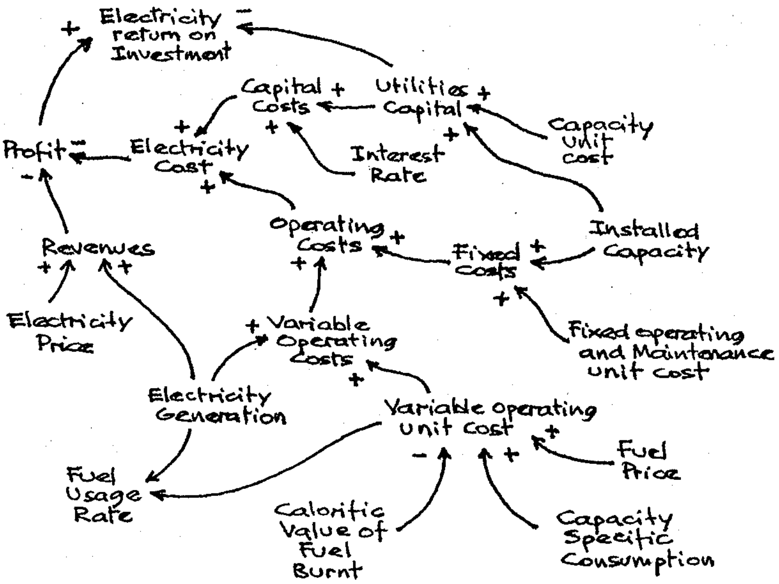
The capacity growth controlling loop, is represented in Figure 1. The forecast demand is generated, based on current demand, and compared with the expected capacity over planning horizon, which would differ from the present capacity because additions and withdrawals are expected to happen in that period of time. The difference between the forecast and the demanded capacity defines a future capacity gap, which has to be filled with new capacity orders (Rego, 1982).

Figure 1. Capacity Growth Controlling Loop and Pressure of the Current Gap on the Construction Delays and Scrapping Rates.



The accounting sector of the model, shown in Figure 2, is extremely simple and keeps track of the costs incurred when generating electricity. The operating cost are the area under the load duration curve weighted at each time interval by the operating costs per unit of energy output, and the output of each kind of power station operating in such interval. The overall performance of the sector is evaluated by its return on investment, comparing the assets value with profit, for every interval simulation time.

Figure 2. Accounting Sector.



The approach to the model formulation is one which, in spite of knowing that the problem adressed in this paper is a short-term one, on the 5-6 years horizon, the model should, however, be able to handle short and long-term trade-offs. Also it was sought simplicity and economy in its formulation. To this purpose the programme was written taking full advantage of the macro and arrays facilities availables in DYNAMO Plus. It has the ability to handle repeated structures of a system using array variables. Doing so, the modeller has to define every variable of the repeated structure in a generic way, using subscripts, as it has to be done in most computing languages, when a variable, e.g., is defined inside a repeating loop. This facility is used for the formulation of the power generating capacity, which varies according to the ageing stage and the kind of utility that generates the electricity. The double subscripted variable cap(stage,kind) represents simultaneously the capacity of every type - nuclear, hydro-electrical, oil and gas-fueled; and every stage -capacity in construction pipeline, installed normal capacity, and capacity operating beyond its economic life, that is a 3x5 array.

There are different modelling traditions for the planning of the electricity generation, like dynamic programming, linear and non linear programming or integration of the load duration curve. The system dynamics model used and presented in this paper follows the last alternative. The cheapest way to meet the demand at any point in time is to run the stations with the lowest operating cost. The system operator tabulates the power stations in ascending order of marginal operating cost and loads and unloads the stations sequentially as the demand rises and falls (merit-order operation). For clarity the system is aggregated in five representative power stations: they are nuclear, new fossil, hydro, old fossil and gas turbines. The power demand varies throughout the day and throughout the year. To simplify the calculation of operating costs the load duration curve is constructed from the daily demand curve rearranging each load for each time interval to occur in descending order of magnitude. Thus the load duration curve makes integration of costs less difficult because it can be represented by simple functions. This curve characterizes the fraction of time the electrical load is equal to or greater than a given output level. For example, an x percent on the horizontal axis indicates that the load was u mw or higher for x% of the year. The load duration curve is analytically aproximated by an exponential function, where α is the parameter that represents the rate of decreasing of the exponential aproximation to the load curve. p is the peak power demand, m means the minimum power demand and x is the fraction of the year (Ford, 1982).

$$u_1=(p-m)e^{\alpha\ln(1-x)}=x_1(1-x1)^{\alpha}$$

$$u=m+u_1$$

In order to obtain the total annual demand, given by the area under the load duration curve, it is convenient to express the value of x duration as function of the load demanded, in Figure 3.

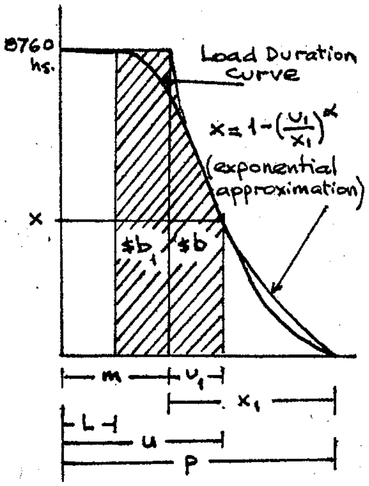
$$u_1/x_1=(1-x_1)^{\alpha}$$

$$x=1-(u_1/x_1)^{(1/\alpha)}$$

The integral of function $x_1=f(u_1)$ is then

$$\text{Integral } f(u_1)=u_1-(1/(x_1^{(1/\alpha)})\ \alpha\ u_1^{(1+\alpha)/\alpha})/(1+\alpha)+C$$

Figure 3. The Load Duration Curve and the Portion of The Electrical Demand Evaluated by Dgen Macro (After Ford, 1982).



The Dgen macro gives the area under the load duration curve between the two ordinates L and U and is a modified version of macro Demgen presented by Ford (1982). The internal variable $b evaluates the area over the minimum demand and $b1 variable calculates the base load area, under the line of minimum demand. The present formulation is based on the solution previously found to the integral of function $f(u_1)$.

```
macro dgen(p,m,l,u,α)
a $l1.k=max(max(l.k,m.k)-m.k,1e-37)
a $u1.k=max(max(u.k,m.k)-m.k,1e-37)
a $x1.k=max(p.k-m.k,1e-37)
a $a1.k=(1/α.k)
a $a2.k=(1+α.k)/α.k
a $a3.k=(1+α.k)
a $b2.k=($u1.k-(1/$x1.k**$a1.k))*α.k*(exp($a2.k*logn($u1.k))/$a3.k))
a $b3.k=($l1.k-(1/$x1.k**$a1.k))*α.k*(exp($a2.k*logn($l1.k))/$a3.k))
a $b.k=$b2.k-$b3.k
a $b1.k=min(u.k,m.k)-min(l.k,m.k)
a dgen.k=($b.k+$b1.k)*8.76
mend
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Now it is possible to follow a merit order in the electricity generation. The nuclear available capacity, which appears at the head of the proposed rank, becomes one of the arguments of the dgen macro, which evaluates the electricity generated (nuclear) at the base of the load duration curve, that represents such nuclear capacity. Once that capacity was full employed, a second band of energy is generated by all the available new oil-fueled utilities and so on.

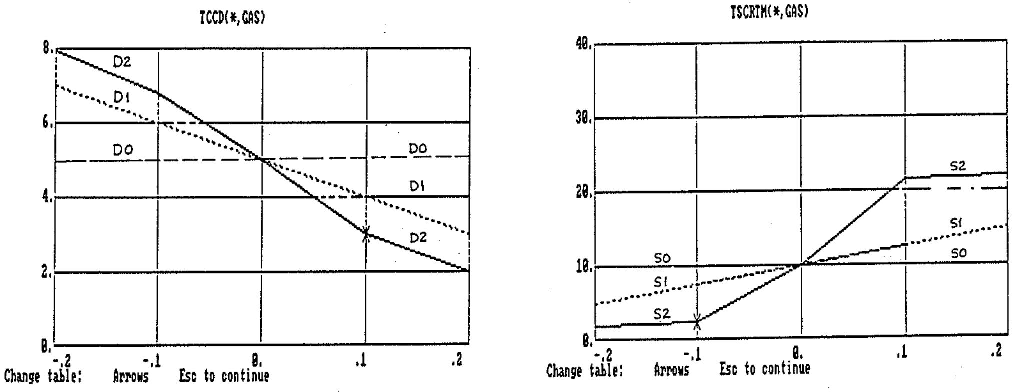
The sort of questions adressed by this paper has normally difficulties in formulating the initial conditions of the system, in particular the amount of capacity still in construction pipeline. The built-in macro delays availables in DYNAMO Plus have the convenient ability to initialize all their internal levels by themselves, so that the inflow rates and their delayed outflows are in equilibrium at the beginning of the simulation (Richardson, Pugh; 1981). But this does not happen in the Argentine case, so it is necessary to built a dely6p macro where it would be possible to assign the actual capacity in the construction stage into the corresponding internal levels, according to the construction stage of each kind of power generation. The output Delay6p is a sixth-order exponential material delay.

Policy Analysis.

To become a truly System Dynamics Model it should lose its rigidity, giving the possibility to the system to improve its self-control. Something can be said to this respect about the role of the actual gap between actual capacity and demand capacity; this is the one perceived by the clients of the system, and failure in closing such gap is sanctioned by the public opinion, putting pressure on the management. Construction delays would have to hurry up and scrapping would be delayed, as shows Figure 1.

There are now two gaps to monitor simultaneously: one concerned with the long term investment policy, which is the future gap, and another one related to the day to day operation of the electric grid, this is the present capacity gap. From the modelling point of view, it is worthwhile to comment that the construction time delay, usually a constant argument of the macro delay which was called, becomes a variable itself in this model. Such construction delay depends on the value which takes the present gap. In a similar way the scrapping time is no longer a constant but a function of the same gap. The current capacity gap relative to the power demand ranges from -5% to 10% in the low demand scenario, and from 5% to 15% in the normal scenario so that it is convenient to use -0.20 and 0.20 as the lower and the upper limits of the independent variable current gap, used in the table functions representing the proposed policies. This relative gap becomes the argument of the corresponding table functions, to pursue the policies above described. The shape of the functions connecting both variables with the current gap appears in figure 4. This figure presents two alternatives to the originals S0-S0, D0-D0 for each function used in the base runs. Those alternatives ranked by its agressiveness are S1-S1, S2-S2, D1-D1, and D2-D2.

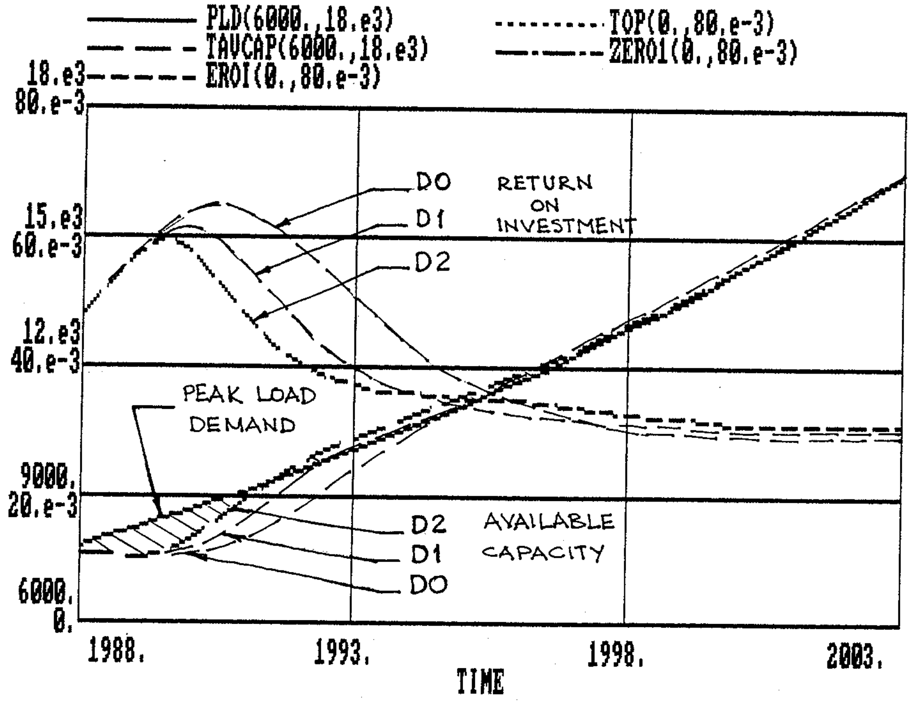
Figure 4. Scrapping Time and Construction Delay Table Functions.



As it can be seen in Figure 5, the acceleration of the construction programme, which is an obvious solution to the deficit of electricity supply, reduces such a shortage at the expense of the financial position which becomes worse and worse as the construction time is shortened. This, of course, compromises the viability of the proposed solution and this not mentioning technical dificulties implied by the acceleration programme itself. One of the problems is that the extra profit generated through the reduction of deficit capacity is not big enough to cover the heavy capital expenses incurred in the acceleration of the construction programme. Its consequences are similar in both and high demand scenarios, with the undesired effect in the low case that the system will have to cope with an excessive capacity for a longer period of time.

The scrapping policy which consists in being accelerated when there is capacity excess and being delayed when there is shortage, has shown its lack of effectiveness, at least as it has been modelled. Actually, the lengthening of the old capacity lifetime, only reduces the investment in the new capacity in the high and low scenario improving the financial performance in both cases. It must be said that this happens because the capital cost of the old capacity is considerably lower than the new one. The results could change dramatically when the costs of enlarging the lifetime are properly taken into account which is something not done in this preliminary version of the paper. Improvement of the model in such a direction is under study. As it is this policy cannot reduce the deficit. Perhaps what should be done is to introduce in the model a conversion rate which translates old capacity into new capacity which is also something being considered.

Figure 5. Supply-Demand Capacity Balance and Financial Performance Speeding up the Construction in the High Demand Scenario.



Conclusion.

The electricity demand in Argentina is expected to dissatisfied for the next five years or so, if that grows at the f per cent historical annual rate. Simulating with a prelimin version of a System Dynamics model of the electricity supply sec show that if new financing is available, which is represented by assumption that payments for capacity additions are done not dur the construction process but simultaneously with the incorporation the new utilities to the grid, there will be some relief to financial position of the sector, shown by an improvement of return on investment in the next five years. But such effect is s worn down by the payments. With regard to the power capacity defi the model's control policies achieve the capacity-supply balance af five years in the base case run. Such time can be shortened if capacity construction is speeded up, but at the expense of financial position. The extra revenues coming from such advance the schedule would not compensate the required capacity paymen This is probably the reason why this would not happen, rather contrary.

Notes.

1. "La Nación" Journal, Buenos Aires, 15th August 1988, p. 1.

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