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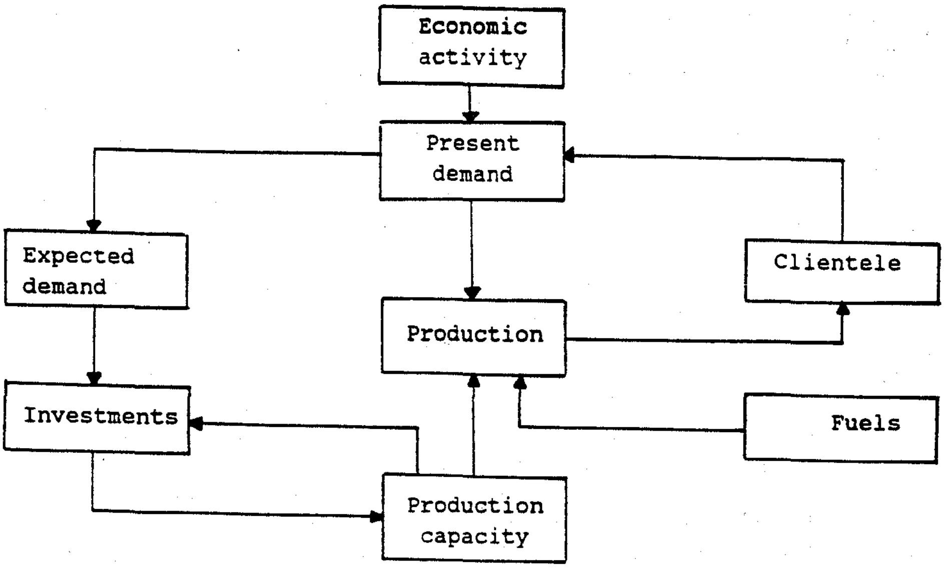
# SYSTEM DYNAMICS APPLICATIONS IN THE SECTOR OF ELECTRICITY

## INTRODUCTION

As for as we know there are relatively few examples of application of System Dynamics in the electric power Industry. Some of them are nonetheless of high interest. We can mention the program of the Bonneville Power Administration that had been presented in a previous Conference of the System Dynamics Society. Our purpose at Electricité de France was to scan the areas in which System Dynamics could be helpfull to our company

## MAIN FEATURES OF THE ELECTRIC SYSTEM

Before any further discussion, we need a comprehensive view of the electric power industry.
Clearly, there is no question of drawing up a complete causal diagram of a system of such enormous complexity; At this stage, we are forced to rely on a few highly aggregated variables and, for the time being, to overloook certain aspects that are rather more than mere details.




In this diagram, a variable such as "production" covers transport and distribution, and is made up of quantities as well as prices. The other variables are similarly complex. Economic, financial and tariff aspects are not specifically mentioned, but are nonetheless omnipresent and essential to the operation of the mechanisms that regulate the system.

This diagram could certainly apply to many industries. The characteristics of the electricity system that we have to mention are :
- The high cost of transmission
- The technical difficulties to stock electricity
- The cost of investments.

Honever electric power Industries have developped around the world under different regulations, the electric utilities have generally got more or less a monopoly in there areas. At least they got a monopoly as suppliers but very often they are in charge of nearly all their production.

In many respects, decision making is an optimization problem and is based on few mathematical tools, mainly mathematical programming or statistical models.

The phenomenas involved at this level of the diagram are those included in the large-scale models that have been developed by electricity specialists for forecasting load curve, investment planning, unit management optimization, etc. The loops involved in this diagram are fairly insignificant, relate to relatively long time constants and are reasonably well controlled by one actor.

Running mathematical models in series generates good results measured according to widely accepted criteria. The phenomena develops slowly enough for it to make possible to avoid high-level iterative procedures. The process can be controlled by revising objectives on a yearly basis. Above all, system dynamics could play an important role as a forecasting tool in the study of long-term developments or in analysis of the main disturbances that can occur in an electric power system.

At a more macroscopic level, other loops appear, but this time the size of the enterprise becomes insufficient. In this way, our fossil fuel purchasing policy has only a negligible effect on the price of these commodities. A dynamic model of the fuel market following the example of those used by oil companies would be a useful tool but would be limited in that it would not provide a basis for influencing the development of the system in any significant manner. In such cases, system dynamics is a particularly useful way of understanding the mechanisms behind developments and helping to make forecasts, but it does not play a direct role in preparing the implementation of a plan of action.

## APPLICATIONS OF SYSTEM DYNAMICS

Finally, it would be of interest to make a brief analysis of some of the myriad specific questions that would be amplified out of all proportion in the diagram above. This type of question was tackled in the studies on the regulation of the load curve by remote control, or on the developpment of bi-energy applications.

### Régulation of the load curve

The problem addressed here is to examine how undesirable consumption peaks develop between tariff periods, and to determine how to monitor and reduce these peaks through application of appropriate tariffs combined with 188 Hz remote control. This problem is a good example of system dynamics featuring a major feedback effect :

- The tariff has an influence on consumer behavior;
- Consumer behavior determines the load curve and peaks in that curve;
- The load curve is used to set the tariff.

Topics of this type are fraught with difficulties. The effects that we are seeking to analyze are partly results of the large-scale mathematical models above mentionned. The system dynamics approach is interesting, but in this specific problem it very quickly becomes necessary to take sophisticated mathematical models into account in our analysis, and this requires a great deal of skill. It would not be fair to claim that the subject is unsuitable for a system dynamics approach, but it is true that it is too complicated to be used as an introduction to the subject.

## Bi-energy applications

The use of electricity through bi-energy processes, i.e those which can alternatively use electricity or another source of energy is obviously interesting in some cases.

In the french electrical system for instance, some of these devices can be operated seasonally, using electricity in the summer and a fossil fuel when electricity cost is higher during other seasons.

This kind of opportunity can be used for many appliances, such as boilers producing hot water and steam, which still play an important part in the industrial equipment devoted to energy conversion.

The advantages that the bi-energy approach to electricity offers users depend to a very large extent on the price of competing fuels (fuel oil or coal). In certain periods, fluctuations in the price of fuel oil can bring the development of the bi-energy approach to a virtual standstill, and can discourage boiler manufacturers from remaining in such an unstable market. Is it possible, therefore, to define a tariff policy that attenuates the risks to the user of investing in bi-energy, at the same time as ensuring the survival of bi-energy equipment manufacturers ?

This topic is somewhat less difficult to deal with than the load curve regulation example discussed above, but it is also less interesting as a test bed for system dynamics in that it is considerably less complex and feedback effects have turned out to have less influence that was throught at the outset. It has shown that when we are dealing with parameters that are merely appendages to the basic variables in the overall diagram, the feedback effects are diminished and rarely play a crucial role.

## CONCLUSION

The system dynamics approach has nonetheless made it possible to reach a more operational stage and to address practical questions related to decision-making aids. A lot remains to be done before we can make a clear distinction between the questions that can be analyzed through a dynamic approach and those that it is still possible to examine with non-retroactive models. Nevertheless, problems that are less complex than the electric power system as a whole will provide the basis for using system dynamics as a decision-making aid.