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THE PROBLEM OF MANAGING A HYDROELECTRIC POWER PLANT: AN APPROACH BASED ON TRADITIONAL TECHNIQUES AND SYSTEM DYNAMICS

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ABSTRACT

The purpose of management planning is to synthesize the management's objectives and goals, and to formulate, analyze and suggest strategies that permit attaining them. So, before elaboration it is necessary to formulate the particular plans of the different component areas and immediately following, to integrate them to form an overall management plan.

The state of the art of the integration processes is, at present, almost integrally based on optimization methods that, with regard to the problem dealt with here, present some difficulties, such as:

- They are static methods, and as such, for each alteration in the initial conditions of the analysis require the repetition of the entire calculation process.
- Do not allow feedback, a characteristic involved in management planning.
- There is a large correlation between the process variables, due to which, the results provided by this methodology are only adequately precise for periods of time where this correlation does not significantly affect the results.

With this background, this Paper intends to direct the preparation of the management plans based on modeling techniques that permit the development of models that are adequate for dynamic systems. This approach proposes the solution of the management problem based on the following steps:

- The formulation of tactical plans as dynamic problems.
- The transformation of the dynamic problems into simulation models per area, and
- The integration of the area models to form an overall plan, by means of a continuous feedback process.

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The Paper analyzes the advantages and disadvantages of both methodologies and concludes suggesting the joint and simultaneous application of both techniques in more refined management planning [4].

KEY WORDS

Management Planning, System Dynamics, Competitive Market.

1.- INTRODUCTION

With the new regulation of the Brazilian electrical sector, followed by the privatization and/or dismemberment of the various vertically integrated concessionaires [8][9], new agents will participate in the electric power services: independent producers, power marketers and free consumers will join the remaining traditional generation, transmission and distribution utilities under this new regulation. The entry of these agents will motivate the creation of new business modes for the electric power production, transportation and distribution that are not considered under the present planning methodology.

In consequence, the strategy and development style of the electric system will be substantially altered, enlarging the scope and changing the focus of the planning activities, in the sense of incorporating the peculiarities of the new market structure and adapting the treatment of the uncertainties resulting from the competition in the activities involving electric power generation and marketing [7].

On the other hand, the recent advances in computer techniques (high performance processing, programming oriented to objectives, for example) and the introduction of new techniques for representing information (neural networks, specialist systems, among others) and for the treatment of uncertainties (game theory, fuzzy groups, among others), in the area of electric power systems' planning, promote unequalled opportunities for transforming the traditional planning process, normally static and hierarchical, into dynamic processes, with great facilities for interaction and the construction of models that integrate management decisions and technical aspects, promoting the participation of the managements and stimulating the creativity of the technicians.

In this manner, the present planning process will be complemented by updated approaches and supported by computational models that permit the adequate representation of the new factors that will condition the planning of the system, particularly with regard to the new organizational structures of the participants and of the Brazilian electrical sector itself [4], [5], [6].

2. MANAGEMENT PLANNING

2.1 Hierarchical Planning Levels

The planning of management activities involving a Business Unit (BU) – Hydroelectric Generation Plant (HG) – is, basically, divided into three hierarchical levels, i.e.: Strategic Level, Tactical Level and Operational Level. The Strategic Level is responsible for making the strategic decisions, that is, defining the applicable Strategies towards attaining particular corporate objectives and goals.

The second level, or tactical level, is responsible, as its name implies, for making tactical management decisions, that is, translating the strategic dispositions into tactical plans of execution; and the third hierarchical level, or Operational Level, makes the decisions related to the functions that place the tactical plans into operation.

2.2 Organizational Structure

The three above mentioned hierarchical levels – strategic, tactical and operational – can be associated with functional decisions of management, and these decisions, in turn, permit representing the organizational structure of the firm by means of the "organizational pyramid", as illustrated in Figure 2.1.

The Strategic Level is basically composed of three structures, distributed in two hierarchical levels. The topmost hierarchical level is normally designated as the Board of General Directors or Presidency, and the other two, at the immediately subordinate level, are normally known as the Technical Directorate and the Financial Directorate.

The Technical Directorate is associated with defining the strategic actions for optimizing, on a time basis, the operation of the hydro-hydraulic complex of the installations. In other words, its actions are guided by the search for strategies for coordinating the operation of the reservoir with that of the electric power generation facilities and the facilities for delivering the power generated.

The Financial Directorate is associated with defining the strategic actions involving the economic-financial management of the firm. Its activities are primarily oriented to generating the resources for attending the economic requirements of the different internal areas, such as how to fulfill the financial obligations associated with the payment of interests and principal of the plant's debt.

The maximum hierarchical level, or the Board of General Directors, is responsible for the preparation and feasibility of the overall strategies of the plant,

that is, it undertakes either independently or jointly with the other two directorates, to transform the departmental strategic actions into global actions of the firm. The Board of General Directors constitutes the natural organ for representing the firm before higher hierarchies, such as regulatory organs, government secretariats, etc.

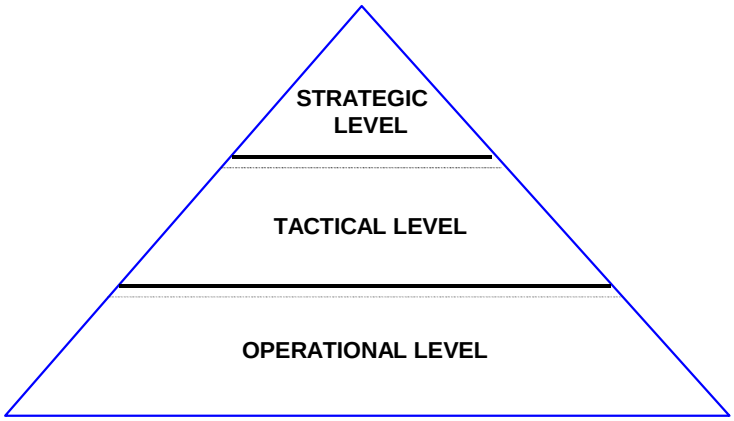


Figure 2.1 – Organizational Structure of a BU-HG

The second hierarchical level of corporate management, the Tactical Level, is responsible for optimizing certain areas of the plant. Therefore, it works with the discrimination of the objectives, strategies and policies established in the strategic plans. The tactical level of a hydroelectric plant is normally constituted by Superintendencies, whose principal objective is forecasting the resources required for attaining previously fixed goals, following a predetermined strategy.

The third level of management, or Operational Level, can be considered the level of formalization, mainly through written documents or digital means, of the methodologies established for development and implementation. This level is operational and normally comprises the Departments or Divisions whose principal purpose is the preparation of plans of action or operational programs that implement the guiding directives received from the higher tactical level. The present Paper will not be going into the details of this area, but its principal functions will be added to those of the hierarchical level situated immediately above.

2.3. Types of Planning

From items 2.1 and 2.2, it can be concluded that the three hierarchical management levels of the firm can be associated with three different types of planning, to wit:

(a) Strategic planning;

(b) Tactical planning;

(c) Operational planning.

These three types of planning can be linked to the levels of the "organizational pyramid" of Figure 2.1, as shown in Figure 2.2.

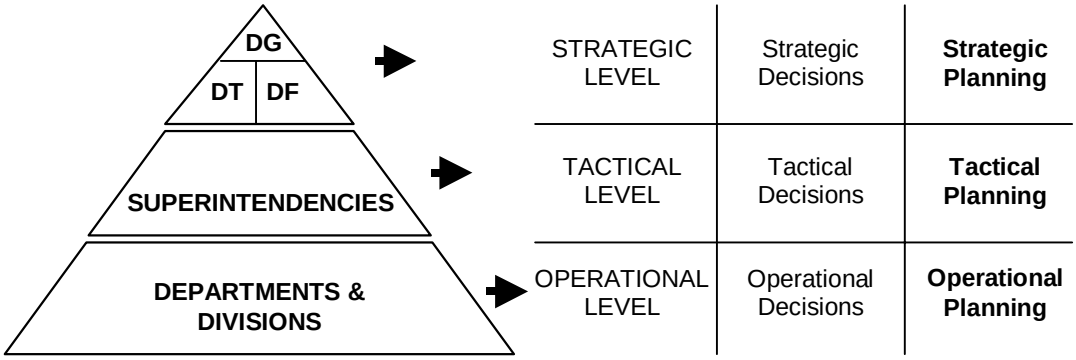


Figure 2.2 – Types of planning and levels of decision

The **strategic planning** is conceived as a management process that permits the executive to establish the direction to be followed by the Business Unit with a view to obtaining an optimum level for its internal functions and in the relationship between the firm and its environment.

Figure 2.2 illustrates that the strategic planning is the responsibility of the highest levels in the firm: the General Directorate (DG), Technical Directorate (DT) and the Financial Directorate (DF). This planning involves both formulating the objectives and selecting the courses of action to be followed for attaining them.

The Strategic Planning has to be formulated taking into account the internal and external conditions of the plant. As regards the external conditions, it considers the basic premise which states that the plant forms part of an interconnected system focused on global optimization. The optimization is carried out by external regulatory organisms, in consequence, their instructions constitute an obligation for the firm.

The **tactical planning** is also conceived as a management process that permits sector managers to establish the direction to be followed by the areas for which they are responsible. As the planning does not involve the overall corporate vision, conflicts of interest may arise between areas of the same business unit; however, these are dealt with and resolved by the planning of higher hierarchy.

The **operational planning** corresponds to an assembly of homogeneous parts or subdivisions of the tactical planning, that is, although they can be

formulated in an independent manner, they must all take into account the basic premise dictated by the tactical planning.

Table 2.1 presents some examples of types of planning associated with a hydroelectric power generation firm. Observe in this figure that the strategic planning considers the firm as a whole, and that the tactical and operational planning efforts are, in effect, dismemberments of the former, and are associated with particular well defined areas.

Table 2.1 – Types and Levels of Planning in the Generation Plant

TYPE					LEVEL
Strategic Planning					**Strategic**
Operational Planning	Maintenance Planning	Engineering and Works Planning	Materials and Purchases Planning	Economic – Financial Planning	**Tactical**
Plant operation plan	Electrical equip. maintenance plan	Technological update plan	Purchasing management plan	Rates and economic financial plan	**Operational**
Electrical study plans	Mechanical equipment maintenance plan	Installation improvement plan	Stocks management plan	Contract control plan	
Hydrological study plans	Maintenance of transmissión equip. plan	Works plan	Inspection and Test plan	Financial operations plans	
Statistical studies plans	Laboratory operation plan	Centralized archives plan	--	General accounting plan	

Figure 2.3 presents the principle of integrated planning in the firm, that is, it illustrates the basic dynamic cycle established between each of the planning efforts. It shows that, with the intention of formulating overall planning for the firm, it is necessary for the various levels to present their respective sectarian planning efforts, and that all of them be subsequently integrated.

From the analysis of Figure 2.3, it is also possible to conclude that the strategic planning, by itself is insufficient for forecasting the corporate management. This becomes clearly evident upon considering that it establishes objectives over the long term, and that the lack of tactical and operational planning results in a nebulous situation since there are no more immediate actions to turn them into operation.

Figure 2.3 also illustrates that the route for the evaluation of outside instructions on the management of the firm shall be traveled after determining the influence on the strategic planning, followed by the reflections on the planning of the different areas of the firm. This mode of evaluation constitutes a critical problem in the management of hydroelectric generation firms since if nothing is done, the problems will only be detected after they are incorporated.

An adequate tool for the analysis of these influences would be the one that permits detecting the problems before they are incorporated; in other words, it would be a tool that allows the executives to test the influence of their strategies on the management of the firm before they are implemented.

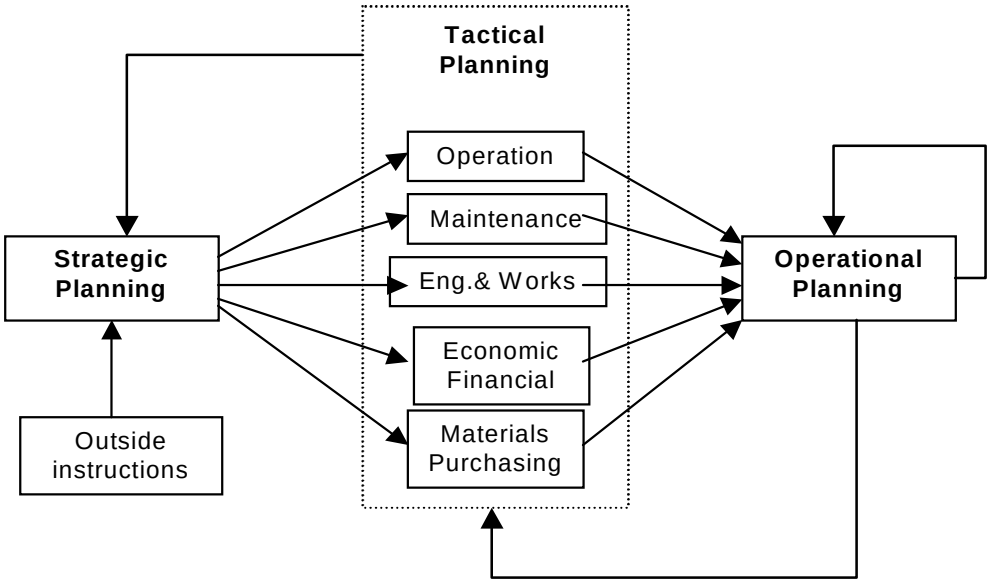


Figure 2.3 – Cycles of the Integral Planning

2.4 Differences between the Types of Planning

With the purpose of providing a good notion of the concepts involved in the preparation of the three types of planning, Table 2.2 presents four basic parameters of temporal and managerial characterization. From this table, for example, the principal differences of strategic planning with regard to tactical planning can be summarized:

1. A longer term, since it must consider aspects such as long-term bilateral contracts, uncertain hydrological forecasts, debt payments, and the survival itself of the firm in the market.
2. Greater amplitude, because it considers the firm as a whole.
3. Greater risk, due to its greater amplitude and the greater time for its realization.

4. Less flexibility, basically for two reasons; first, because it considers the firm as a whole, and in consequence must harmonize sectarian interests that are often conflicting; and second, due to the work of harmonizing the interests of the firm with the interests of its environment.

Table 2.2 – Differences Between Types of Planning

PARAMETERS	STRATEGIC PLANNING	TACTICAL PLANNING	OPERATIONAL PLANNING
Term	Long (1 to 5 years)	Medium (annual)	Short (monthly)
Amplitude	Firm	Areas	Sectorial
Risks	High	Medium	Slight
Flexibility	Little	Medium	High

The same principle and reasoning can be applied to the differences existing between the tactical planning and operational planning, observing, however, the fundamental premise that states: tactical planning covers different operational areas possessing common objectives.

2.5 Considerations for Formulating Strategic and Tactical Plans

In the formulation of strategic and tactical plans for the BU-HG, there may be some difficulty in distinguishing between them in time, since the mathematical formulation of tactical plans can, with small alterations, become enlarged into being considered as a strategic plan.

However, an easy manner to differentiate between them is to consider that tactical plans are the dismembered parts of overall plans prepared on the basis of deterministic parameters, and that the strategic plans, apart from integrating and projecting them into the future, allow considering some of them as strategic parameters.

In the formulation of tactical plans, difficulties of a practical nature may also be encountered, since operational plans of different kinds must be integrated for them to be formulated. However, this difficulty can also be overcome if it is considered that a tactical objective exists in the area and that the influences of the operational plans can be translated into restrictions to this common objective.

An additional difficulty faced by the strategic and tactical plans of the generation firms in the new Brazilian power market, is related to the influence of

outside instructions concerning the plans being executed. In order to confront this new reality, the firms should work with various alternative scenarios, or else grant priority to the celebration of bilateral contracts that permit maintaining their generation within foreseeable limits.

2.6 Approaches for Formulating a Corporate Management Model

The process of formulating a corporate management model consists of the integration of the tactical planning efforts into an overall plan. The state of the art of the integration processes at present offers two possible alternatives, one based on methods of optimization and the other based on methods of simulation.

2.6.1 The optimization approach

Corporate Management Planning constitutes an instrument associated with the strategic decision areas of the firm, with the objective of providing the different tactical areas with directives for the preparation of their individual planning efforts.

Since each tactical area comprises operational sectors with particular objectives, in spite of being common to all when viewed as a whole, the tactical plans can be prepared with the assistance of the decomposition techniques, employing for the solution, for example, the methods based upon the Benders.

On the other hand, the tactical areas, as a whole, differ from each other regarding well-individualized objectives, to the point of being able to draw their own objective functions. From this fact, the alternative for resolving the problem of optimized overall planning again obliges utilization of the decomposition techniques in the search for solutions.

The mathematical formulation of a problem, in accordance with the decomposition technique, demands a single objective function, which represents its final goal and is subject to certain restrictions imposed by particular objectives. On applying this concept to the overall planning of the BU-HG, it is necessary to formulate an objective function that represents the interests of the firm as a whole (servicing the contracted demand, ensuring shareholder profits, for example), and that is subject to tactical objectives like restrictions (maintenance programs, operational restrictions on the operation, availability of stocks of materials, for example). Figure 2.4 presents the structure of the problem with a view to the integration of the tactical plans in an integral model of corporate management.

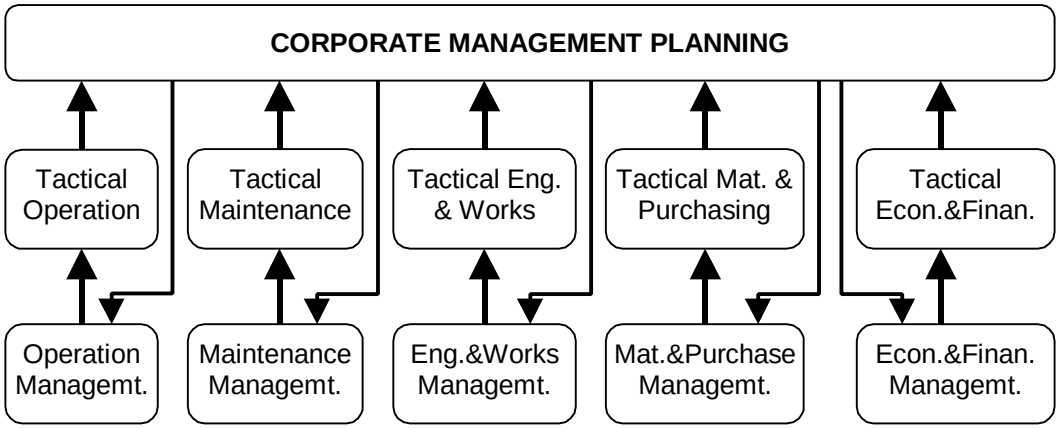


Figure 2.4 – Integration of tactical planning efforts through methods of optimization

The proposal for using optimization methods, although apparently feasible, becomes quite complicated upon consideration of the following facts:

- The enormous difficulty in determining the corresponding Benders. As well as this, the method is static, that is, each different strategy must generate a different Bender.
- The multiplying factor of the corporate strategies. For example, if we consider that a strategy is distributed in a different manner for 5 areas, i.e., it is transformed into 5 instructions of the tactical areas, within the tactical areas, each one of the instructions can, once more, generate at least three operational instructions.
- Upon accounting the values of the previous point, a single strategy under the optimization focus, can generate at least 15 different Cuts of Benders. If the number of corporate strategies is amplified to 10, the number of Cuts of Benders would increase by at least 150, without taking into consideration the crossed influences that could raise it to an even greater number.

From the above, it will be found that in practice there is great difficulty in the application of the optimization methods. In consequence, this imposes a search for alternative solutions based on other approaches, such as the formulation of the model of corporate management based on simulation methods. This is the next approach to be analyzed.

2.6.2 The Dynamic Simulation Approach

The basic outlines of the search for a solution to the corporate management problem, based on this approach, primarily consist of the following steps:

- the formulation of the tactical plans as dynamic problems;

- the transformation of the dynamic problems into simulation models per area;
- the integration of the area models to form an overall plan, through a continuous feedback process.

Figure 2.5 illustrates this process.

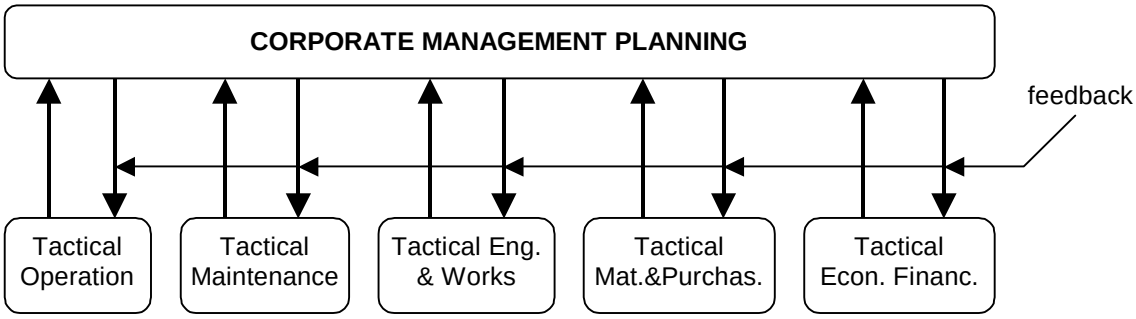


Figure 2.5 – Integration of tactical plans through simulation methods

In this methodology there is a continuous exchange of information between the tactical plans and the overall planning (as also between the operational plans and the tactical plans), i.e., at every instant the overall planning considers the needs and the objectives of the different areas, and of how the *feedback* provides information of its reflection and applicability in the integration process.

The greatest difficulty in the application of this methodology resides in the dynamic formulation of the tactical plans, but once this stage is surmounted, its principal advantage is linked to the rapid reevaluation of the planning efforts for different alternatives or management scenarios.

2.7 Implementation Aspects

The state of the art in the planning area has at its disposal, at present, a great quantity of models developed to preferentially attend the specific technical requirements of each area. The advances in this direction result from the new challenges imposed by the present business environment, which demands its adaptation in order to transform it into management plans that integrate new disciplines, such as managerial and environmental aspects.

In an initial stage, the present models could continue being utilized for obtaining results from areas; the necessary integration only being effected on the basis of the results. In a later stage, when new techniques, such as Specialist Systems, System Dynamics, etc., are perfectly consolidated within the planning area, the present models could be integrated into a single methodology.

In this way, the research developed in the present Paper demonstrates that the techniques of System Dynamics (DS) are particularly attractive as tools for integration; this statement is based on its major feature, which consists of the capacity to contend with feedback mechanisms between the parts of a system. Apart from this characteristic, the DS techniques offer other facilities for modeling, such as the following:

- the possibility of dealing with long and short term aspects in the same model;
- the representation of complex and non-linear relationships;
- the possibility of representing variables involving decisions, social and environmental factors;
- the facility for testing corporate management policies through the use of the "Dynamic Simulator".

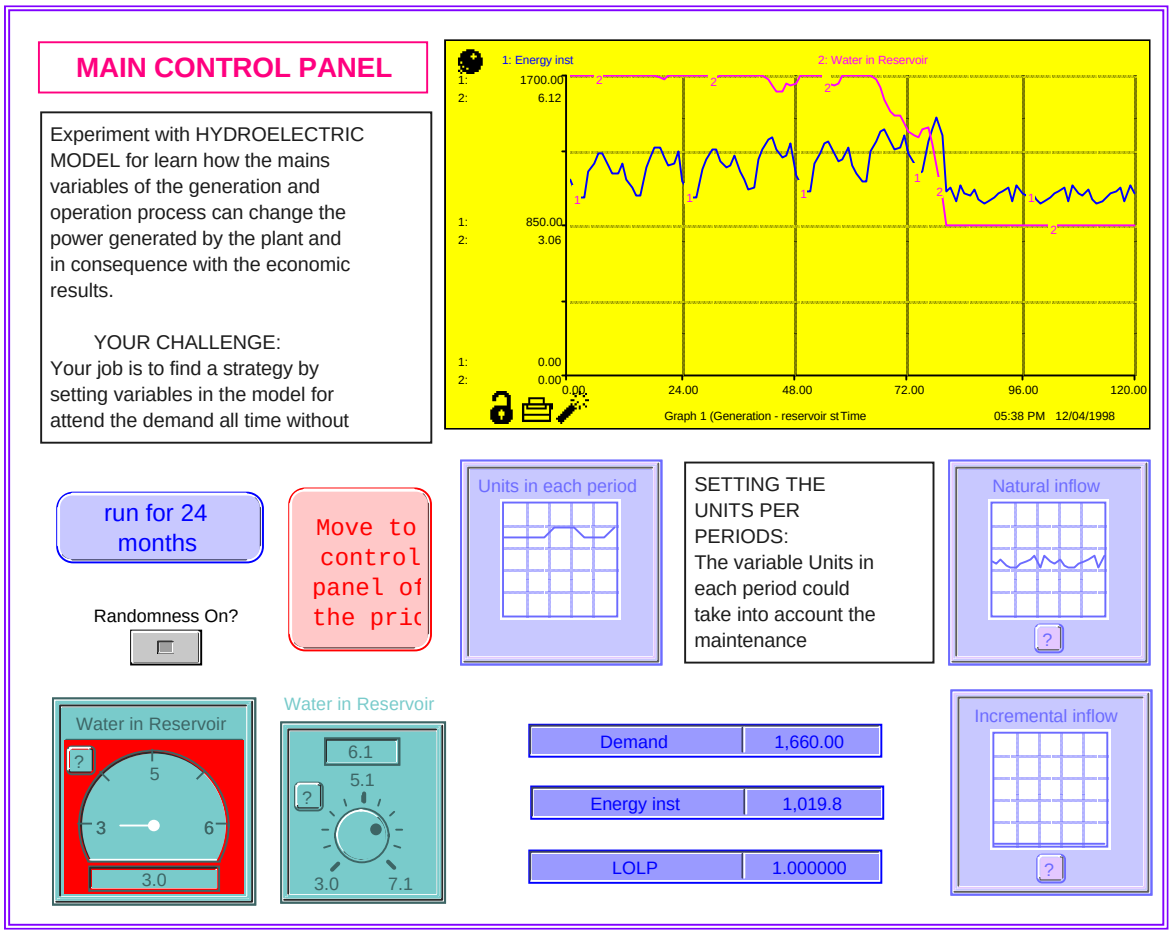
The following section presents the main features of a Dynamic Simulator that is adequate for studying the corporate management of a BU-HG.

2.7.1 Dynamic Simulator

System Dynamics provides the facility for constructing an auxiliary model that is very important for the practice of simulations; this model is called a "Flight Simulator", and for which the present Paper adopts the name of "Dynamic Simulator" [1],[4].

Figure 2.6 presents a dynamic simulator built to analyze strategic aspects of the management of a power generation plant. It comprises two control panels: the first designated as the **Main Control Panel**, and the second as the **Financial Control Panel**. By means of both panels, the user can perform individual or combined tests for different hypotheses, for example, on:

- Rates;
- Percentage on investments;
- Percentage on the amount to be applied to debt payment;
- Estimated costs of the technical, financial and support areas;
- Hypotheses on variations in the demand;
- Hypotheses on natural and incremental inflows;
- Maintenance plans;
- Initial value of the water stored in the reservoir.



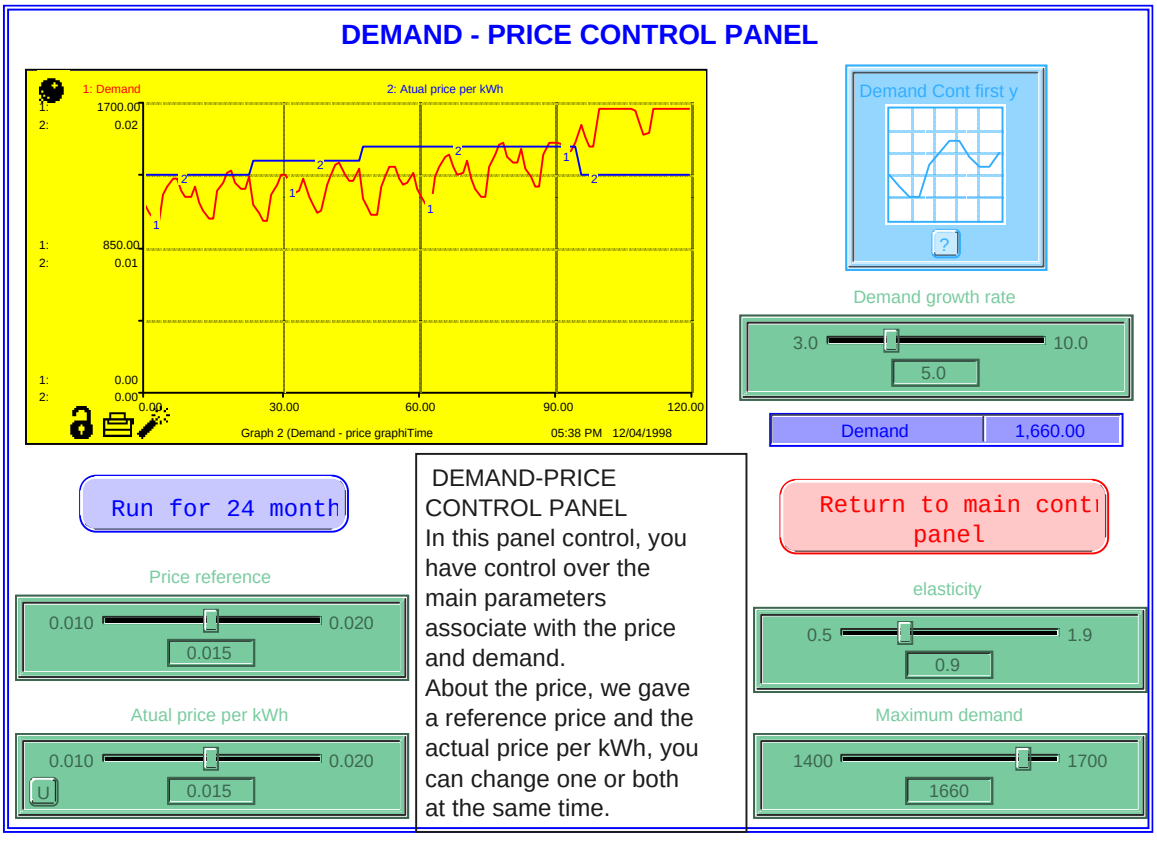


Figure 2.6 - Dynamic Simulator

The control panels are complemented with other facilities for the users, such as:

- Systems to alert the user to the variation in the volume of water stored in the reservoir: it first presents the risk situation and subsequently the danger of total disaster.
- Provides graphic displays that can be defined by the user, depending on his area of interest.
- Provides counters of variables that permit the user to immediately know the values at the end of the simulation.
- Presents explanatory text that allows the user to easily operate the control system without needing to know the mathematical structure of the problem.
- Includes navigation facilities that permit agile and easy transfer between control panels.

The Dynamic Simulator can be particularly adapted to each type of necessity. In consequence of this, it offers a great facility for interfacing with the user; in a short time it will become the preferred tool for use by managers, planners and technicians in general.

3. CONCLUSION

In concluding, it is worth stressing some relevant aspects concerning the proposed planning methodology. The planning of the electric power utilities has been one of the most important areas of application of the operational research methods. This is due not only to the nature of the problems in this area, in general well structured, but always challenging and linked to the minimization of costs associated with improvements to operational procedures, but also to the technical guidance provided by the managers and the ample availability of data and information.

As the power generation firms move towards a competitive environment, the planning methodology and models must be adapted or even changed to confront a wider range of objectives, that are not only strategic, but also financial and behavioral. In this context, the uncertainty and risk become dominant, now caused by the elements of competition, as well as, naturally, the uncertainties associated with the market, fuel prices and the regulatory system. The possibilities

of management failure, previously nonexistent, now tend to accentuate with the increase in competition.

In consequence, the models will become less specified, the analyses of scenarios will be more frequent and, what is most important, the decision makers, managers and analysts will be more involved in the modeling process. The culture of the present concessionaires, based on the viewpoint of engineering and management reports, must be replaced by a corporate culture, in which models for supporting decisions, that are interactive, will assist the organizational learning process and facilitate comprehension of the strategic questions.

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