Integrated Model for Energy System Planning: A System Dynamics Approach

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INTRODUCTION

This paper describes a new approach and outlines a SD based model, both designed to support the strategic planning process of a large electric utility in Brazil. The model will be used for analysis of strategic issues. It computes several performance indices while considering the regulatory compact for the electricity supply industry, the response of the consumers and the values of prospective investors.

This model is part of a framework for implementation of a Value Based approach to business planning at utility level. The Value Based Planning (VBP) approach contrasts with the traditional (least) Cost Based Planning (CBP) concept that permeates most of electric utility investment planning, so far.

TRADITIONAL PLANNING METHODOLOGY

The basic objective of power system planning may be defined as the determination of the commissioning dates of generation and transmission facilities, in order to supply the electric energy market at minimum cost, for a given reliability level.

As a consequence of the complexity of the planning problem, it is usual, in power sector utilities, to make staged planning studies, according to the decomposition rules illustrated in Table 1, where N indicates the current year.

Table 1 - Structure of the Planning Problem

TIME FRAME	ACTIVITIES	RESULTS
Long term studies (N+15 to N+30)	Energy resources evaluation Conceptual planning Technological forecasting	Reference configurations Selected technologies Long-term marginal costs
Medium term studies (N+5 to N+15)	G/T system planning Project dimensioning Plant siting	Reference expansion plan Selected plant sites Medium-term marginal costs
Short-term studies (N+3 to N+5)	Reliability evaluation Project financing schemes Financial planning	Project building schedule Operating constraints Short-term marginal costs

At any time range, the solution of the planning problem involves a compromise between a desired reliability level and the costs incurred to obtain it. This compromise has been traditionally expressed as the minimization of the total cost to supply a given demand forecast. The total cost is the sum of investment, operation and failure costs. The failure costs express the economic penalties associated to the expected energy not supplied. This formulation of the planning problem leads naturally to a mathematical programming problem, as follows:

$z = \text{Min}\ [c(x) + d(y) + p(x, y)]$ (1.a) subject to: (1) $A\ (x)\ b$ (1.b) $G\ (x) + H(y)\ e$ (1.c) $0\ x\ N$ (1.d) $0\ y$ (1.e)	where: *x* vector of investment variables (integer) *y* vector of operation variables (linear) *b* vector of investment resources *e* vector of operation resources *A* matrix of investment constraints *G, H* matrices of operation constraints *N* upper bound on investment variables *c()* investment costs *d()* operation costs *p(,)* failure costs

The solution of this complex programming problem usually is done by a decomposition scheme, able to break down this large-scale, mixed-integer stochastic programming problem into two subproblems: a mixed integer decision subproblem and a linear operation subproblem, as shown in Figure 1.

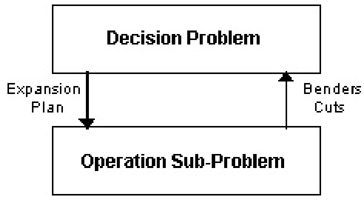

Fig. 1 - Structure of the Strategic Model in the Cost Based Planning Framework

VALUE BASED PLANNING

The optimization approach to the planning problem has worked well under slow or negligible environmental change in the electricity supply industry. Today, by contrast, the utilities live in an era of growing competition, where the external environment is highly complex, unstable, and unpredictable. In response to the changing utility environment, utilities now recognize the need for improved planning approaches and tools. As a result, it is envisioned that the planning process will evolve gradually from the traditional (least) Cost Based Planning (CBP) concept to a new Value Based Planning approach (see Fig.3), that takes into account the market value of the utility, as well as the value of the electricity services for the utility customers. The main characteristics of both approaches are synthesized in Table 2.

Table 2 - Characteristics of Planning Approaches

	COST BASED PLANNING	VALUE BASED PLANNING
Prospects	Market Forecast	Market Share
	Minimize Costs (Customer, Utility)	Create Value (Customer, Investor)
	Comply with Standards (Regulated)	Manage Quality (Customer Choice)
	Energy Balance (System wide)	Offer Services (Client specific)
	Franchised Area (Monopoly)	Market-Product Matrix (Competition)
Process	Yearly Planning Cycle	Event Based Planning
	Expansion Plan	Business Plan
	Hierarchical (top-down)	Openness and Inclusion
	Mathematical Bias	Behavioral Bias
	Search for Least Cost Supply	Competitive Strategies and Policies

The implementation of the VBP in the utility planning process requires a new strategic framework (see Fig. 2), whose construction must take into account the ongoing CBP process, in order to avoid disruptions in the workflow (see Fig. 3). A staged implementation process is necessary also to create the strategic information base and to establish the performance monitoring indices. The Business Environment Analysis activity (see Fig. 2) will be based on intensive use of the integrated planning model, described in the next section.

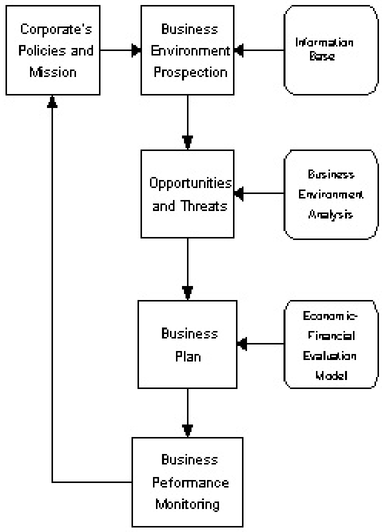

Fig.2 - Structure of the VBP

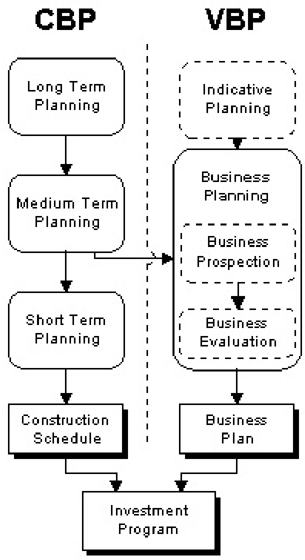

Fig.3 - Transition from CBP to VBP

INTEGRATED RESOURCES PLANNING MODEL

The integrated resources planning model follows the trends of the SD based models developed for electric utilities and is intended to be used as a learning tool, besides supporting the formulation and evaluation of competitive strategies. It consists of a series of sub-models representing the major activities of a utility and its interaction with the external environment (customers, regulators, investors, suppliers, society at large). These submodels are: electricity demand, capacity expansion, energy production, financial planning and regulatory aspects.

The model represents the activities within these sectors at a relatively aggregate level of detail. The electric demand submodel takes into account the consumers reaction (price feedback), depending on the real price of electricity and the short-term price elasticity, among other factors. The energy production submodel is "driven" by the demand submodel and also is used as the basis for new capacity orders in the capacity expansion submodel. The capacity planning and construction takes into account the discrete nature of hydro plants, as well as the lead times required by each plant. The financial planning submodel satisfies the demand for funds by using retained earnings, raising debt, preferred, or common equity. The regulatory submodel calculates the required charges and allocates it among the several classes of customers, taking into account regulatory lags.

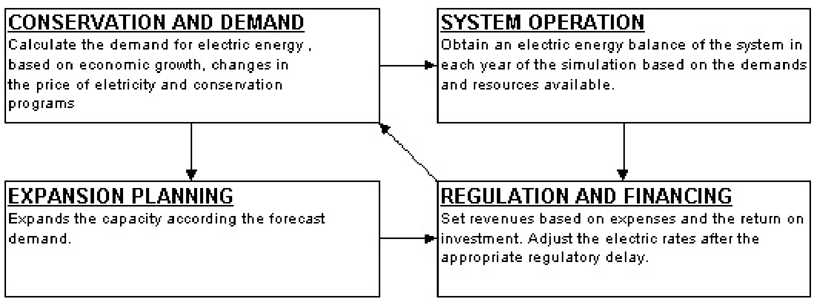

Fig.4 - Structure of the Strategic Model in the Value Based Planning Framework

CONCLUSION

The VBP approach and the integrated resources planning model are being developed under a research project involving a utility and a university. As such, it is envisioned that the results of the research will benefit not only the utility, but will bring additional insights to update the Electrical Engineering curricula at the university. It is expected that the complete model will be used by the utility to learn about the new business environment. It is expected also that a simplified version of the model will be used at the university as a practical tool to prepare new engineers and managers to cope with the complexities of the competitive environment.

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