A New Concept for Utility Integrated Resource Planning: "Start with the Customer"

Environmental Protection and Resources Conservation Must Also Be Considered

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EXECUTIVE SUMMARY

The competitive restructuring of the electric power industry is intensifying pressures for electric utilities to control costs through improved utilization of existing assets and by minimizing capital investment in new generation, transmission, and distribution capacity. This article introduces a new planning approach that can provide more informed business decisions, resulting in higher asset utilization, lower overall costs, and enhanced customer service.

Unlike traditional planning methods, which assumed captive customer load growth, this process starts at the customer, focusing on how the customer's energy service needs can best be met.

Experience garnered from utilities on four continents illustrates the potential of this new approach to reduce capital expenditure for energy resource additions, often at less than one-half the cost of conventional solutions. By reorienting how utilities think, plan, and are internally organized, this new approach can assist utilities in making the fundamental transition to a customer-driven industry.

Additional benefits include accurate costing of energy resources

and wheeling, reduced vulnerability to conflicts over facility siting, reduced risk in a time of rapid industry change. *The process proposed here may not be the best IRP process for utilities in the future but could be of significant benefit during the restructuring period.*

IRP CONTINUES TO EVOLVE

Integrated resource planning (IRP) is a contemporary approach to electric utility planning for future energy requirements. The goal of IRP is the identification of resources or the mix of resources for meeting near- and long-term energy needs in an efficient and reliable manner at the lowest reasonable cost. The IRP plans analyze the costs, effectiveness, and benefits of all appropriate, available and feasible supply-side and demand-side options. They take into consideration the utility company's financial integrity, size and physical capability, and consider impacts on the customer, the environment, culture, community lifestyles, the State's economy, and society.

IRP is an open and public process. The community, utility companies, and governmental agencies are provided opportunities to participate in its development.

Industry restructuring is altering the fundamental nature of the retail electricity business, and making a major impact on IRP. With wholesale and potentially retail access, electric utilities face competitive threats because customers have alternatives. Profitability and risk are becoming more important, and the return on generation, transmission, and distribution investments is becoming less certain.

Companies are responding by establishing separate business units for generation, transmission, and distribution. As a result, IRP is changing: it is evolving from a process designed to minimize revenue requirement and maximize electric system reliability to a process that 1) considers capacity additions as investments, and 2) bases service design on customer needs and profitability.

However, robust power supply plans are based on a number of forecasts and assumptions. Some of the forecasts are very complex, requiring rigorous computer simulations. Others are based on empirical trends and the best collective judgment of the analysts. Above all, assumptions and forecasts are estimates and have varying degrees of certainty and/or confidence.

One of the major parameters that drive the timing of the utility needs for additional capacity is the utility's peak load forecast. Once a need for additional capacity has been identified, the development of an optimal power supply plan depends on a number of factors, including the availability of non-generating alternatives, the capital and operating costs of the various generating options, the fuel price forecast, demand side management potential and costs, transmission capability, purchase power forecast, the utility's cost of capital and the utility's mix of existing resources. The starting point of this planning process is the *load forecast.*

THE PLANNING PROCESS FOUNDATION

Energy and peak load forecasting is the first step in the overall planning process and is the foundation upon which a set of responsive, coordinated plans are based. The forecasts are used by the utility as a basis for an integrated resource and transmission plan, corporate budgets, fuel use plan and other planning processes. The utility develops a long-term (20 year annual) forecast and a short-term (5 year monthly) forecast for the various planning processes.

The long-term forecasts of peak and energy are two key inputs to the IRP plan. In the long term, social, economic and demographic trends have had the effect of increasing the demand for electricity, without any significant reversal projected for the foreseeable future.

The projected price and availability of fuel is a critical factor in the selection of new generating units. It is very important that long-term fuel mix be diverse and flexible in order to meet the needs of electric customers in an ever changing energy and regulatory environment. There is a great deal of uncertainty regarding future prices of the various fuel alternatives. Having a diverse and flexible fuel mix will help mitigate the impact of radical price increases in any single fuel.

THE 7-STEP PROCESS

The steps for an electric utility integrated resource planning process (IRP) are as follows:

1. Develop Assumptions

2. Screening Analysis
3. Reliability Analysis
4. Economic Analysis
5. Sensitivity Analysis
6. Risk Analysis
7. Identify The Optimal Plan

The objective of the process is to retain customers and meet their electricity related needs as reliably and economically as possible, with due regard to deregulation, environmental, financial, regulatory and other considerations. This objective is accomplished in the process by evaluating market power, supply side, and demand side alternatives on an equal basis. The process incorporates uncertainty analysis to help identify a mix of resource options that presents the least risk to changes in major assumptions. It is an evolving process that takes into account the many changes that occur in the industry and regulatory environment.

1. The **Develop Assumptions** step involves the development and gathering of major IRP data input projections for load, fuel, market power, cogenerating facilities, as well as supply-side and demand side technology options.

2. Then perform a **Screening Analysis** of demand-side and supply-side options. Demand side management options that are determined to be cost effective are combined into packages of programs that exhibit similar characteristics in order to perform comparisons with the more sizable supply side options. Supply side options that are technically feasible and available within the required time frame are screened on an economic basis to arrive at those options that will then be compared to the demand side options.

3. The **Reliability Analysis step** is performed to identify the timing and amount of capacity needs. The utility may use a reliability target of reserve margin, Expected Unserved Energy (EUE), and/or Loss of Load Probability (LOLP) in its planning process. Other means of reducing future resource needs, such as increasing the availability of existing units, are also considered in this assessment.

4. The **Economic Analysis** step involves the identification of the least cost plan which produces lowest overall rate, and the evaluation of key uncertainties in the most influential inputs and assumptions that impact the development of an optimal plan.

5. **Sensitivity analysis** is performed to select the key uncertainties. To determine which variables to focus on, a simulation with base assumptions (highest probability) is executed to determine the sensitivity of results to each of the following variables: fuel prices, load and DSM costs. A scenario tree is then developed with combinations (futures) of these key uncertainties. The selection and performance of different planning alternatives is then quantified across these scenarios.

   The top 25 expansion plans chosen by an optimization model under each future are retained and examined for uniqueness (first resource chosen). The unique plan for each future is then fixed and simulated under every other future. Cumulative present value of revenue requirements (CPVRR) and system environmental emission levels for SO_2, NO, and CO_2 in tons are calculated and then used as a measure (attribute) by which the relative merit of a plan is determined. The attributes of the unique plans in each future then provide a basis for the risk analysis.

6. The **Risk Analysis** step evaluates the attribute information for each of the plans to assess the impacts to customers under each plan when planning assumptions change. The evaluation is performed by the trade-off method of risk analysis. Initially, all futures (combinations of uncertainties) have equal probability of occurring. The final plan could impact different groups, each with their own and sometimes conflicting interests in the outcome, in different ways, depending upon the attributes (e.g., cost, emissions) of the plan. The objective is to identify the best overall plan which maximizes:
   1. **Overall satisfaction to all customers;**
   2. **Risk-tolerance or ability to handle many uncertain future events while still remaining a relatively "good" plan.**

   Trade-offs between conflicting attributes are evaluated and plans which most evenly minimize all of them are identified.

7. The final step in the IRP process is to **Identify the Optimal Plan.** The findings of the study are reviewed and a preferred 'optimal

plan" is selected based upon its robustness or performance under a range of possible futures and flexibility while meeting the objectives of reliability and economics.

STRATEGIC CONSIDERATIONS

In developing an integrated resource plan, consideration of economics alone would fail to recognize the changing regulatory environment which will most certainly exist through time. Therefore, the expansion plan which is considered to be lowest cost may or may not be an "optimal" plan, depending on its ability to deal with other more qualitative issues. The utility believes that it is appropriate to pursue a balanced approach to meeting future needs, recognizing both economics and risk. To achieve this balance, IRP analysis includes consideration of a number of strategic factors.

Some of the strategic factors which are considered in the planning process are listed next. (A more comprehensive discussion of each follows.)

Customer retention and customer choice

Protection of the environment

Conservation of natural resources

Economic risk to the customer

Fuel switching flexibility

Flexibility to respond to changes in demand growth

Operational flexibility

Financial integrity of the utility

Regulatory uncertainty

Customer Retention And Customer Choice

Consideration must be given to the uncertainties introduced by the awareness of the customer to the choices offered in an increasingly competitive environment. This environment necessitates the introduction of options which allow the customer to choose a desired level of service at a corresponding price. Options such as load management are an important part of the integrated resource plan to meet customer needs.

Protection Of The Environment

One of the most important considerations in the development of an integrated resource plan is environmental impact. Existing environmental regulations and emerging environmental issues must be carefully analyzed in evaluating generating options (Figure 1). While two integrated resource alternatives may be economically competitive, their effects on the environment may be quite different. Utilities recognize that the impact of a resource plan goes well beyond the direct cost of electricity to the end user.

Conservation Of Natural Resources

The conservation of natural resources, such as coal, natural gas and oil, must be an objective of integrated resource planning. Conservation of these resources requires both supply side efforts to maximize the efficiency with which such fuels are used in the production of electricity, and demand side efforts to increase the efficient use of electricity.

Economic Risk To The Customer

Alternative expansion plans are often compared on a total present value of revenue requirements (PVRR) basis. It is important, however, to compare not only the "bottom line," but also the year by year economics of alternatives. A plan which is lower cost in year thirty, but does not produce savings until year twenty-nine, may not present the best economic choice to the customer. Particularly when savings are predicated on fuel price differences, results should be carefully examined before a decision is made. Reliance on fuel savings to offset higher capital costs introduces a high degree of risk to both shareholders and customers. **An expansion plan must therefore carefully consider the risks associated with relying on fuel savings to offset initially higher capital costs.**

Fuel Switch Flexibility

Fuel price and availability projections influence the results of the integrated resource planning study, affecting both the type and timing of new generating units. Integrated resource plans are developed based on, among other factors, projected long-term price relationships between various fuels. But during the last twenty years, there have been significant and often unexpected swings in fuel prices, and it is anticipated that fuel prices will continue to exhibit volatile behavior in the future. Therefore, in evaluating integrated resource options, one must allow for pos-

Figure 1. Electric Utility Power Plant Environmental Criteria

1. Capability of Cooling System Development
2. Proximity to Load Center
3. Land Availability
4. Compatibility of Land Use
5. Resource Consumption
    a. Water Consumption
    b. Land Utilization, Amount
    c. Land Utilization, Critical Environmental Importance
6. Accessibility
    a. To Rail Transportation
    b. To Highway Transportation
    c. To Water Transportation
    d. To a Port
7. Suitable Soil Foundation Conditions
8. Environmental Impact
    a. Water Quality Impact
    b. Terrestrial Biological Impact
    c. Aquatic Biological Impact
    d. Threatened or Endangered Species
    e. Construction Effects
    f. Aesthetics
    g. Air Quality Impact
    h. Noise Impact
    i. Transmission System Routing
    j. Impact on Fuel Delivery Corridors
    k. Archaeological/Historical Impact
9. Site Development, Transportation and Transmission
10. Service Water Supply
11. Population Density
12. Socio-Economic Impact
    a. Community Services
    b. Area Economy
13. System Compatibility
14. Multiple Use Potential
    a. Land
    b. Water
    c. Process Flow

sible changes in the future price relationships of competing fuels.

The projected fuel market conditions, on which the selection of an integrated resource plan is based, often change after the plan is implemented. A plan that incorporates the ability to switch fuels in response to an unexpected change in fuel price relationships that alters significantly the relative economics of the integrated resource plan benefits both the utility and the ratepayer. Therefore, one of the features of an effective integrated resource plan is the flexibility to respond to changing fuel price conditions. It is important to have a diversified fuel mix, so that even a significant change in the price of any one fuel does not radically affect total system economics.

Regarding fuel switching capability, it is important to consider the magnitude and timing of the capital investment required to make the unit "fuel switchable." For example, a coal unit that is inherently capable of utilizing fuel oil or natural gas may offer greater fuel switching flexibility than a combined cycle unit that can be modified to use (gasified) coal. However, in constructing a combined cycle unit a large portion of the capital investment necessary to enable the combined cycle unit to burn coal may be deferred until conditions warrant a conversion, while in the case of the coal unit, almost the entire capital investment is committed up front, whether or not the alternate fuel (oil or gas) is ever used.

Flexibility To Respond To Changes In Demand Growth

Uncertainty over demand growth must also be considered when an integrated resource plan is developed. Options with short installation/construction lead times and modular construction allow the utility to respond to changes in the demand forecast. Options which have long lead times introduce significant risk into a plan by making it more difficult to respond to change. In many cases, this will also impact the financial risk associated with the plan. Modular construction, meaning the unit can be constructed in "pieces" enhances the utility's ability to respond to changes.

An example would be a combined cycle unit, which consists of one or more combustion turbines and a steam turbine generator. These components can be "phased in" to match the pattern of demand growth. Demand side management programs are also easily tailored to meet changes in demand growth, capable of accelerated or decelerated implementation, as needed.

Operational Flexibility

When a number of diverse alternatives are compared, consideration needs to be given to the operational requirements of the system. Particularly where **non-utility supply sources** and demand side management are evaluated, the following factors should be accounted for in the analysis of the utility system:

1. Unit dispatchability and limits on use
2. System voltage regulation
3. System reactive requirements
4. Transmission constraints
5. Cycling requirements and varying degrees of effectiveness due to changing load patterns

Financial Integrity Of the Utility

Financing and rate relief are major considerations that must be analyzed before a plan is adopted. Any integrated resource plan requires a financial analysis to determine if adequate financing can be expected to be available at a reasonable cost. The availability of financing is dependent on the financial integrity of the utility, which is reflected in its debt coverage ratios, return on equity and capital structure.

In the electric utility business, investors must perceive that their investment will earn a rate of return comparable to that available from companies of similar risk. Adequate revenues producing a fair rate of return on the investment are essential to attracting investment to the utility. Such investments are needed to meet the following facility requirements:

1. Replacement of existing lines, poles, cables and power plant components as they wear out or become obsolete

2. Environmental control equipment

3. Capital improvements to facilities to enhance efficiency

4. Investment in fuel stocks to achieve supply security and stability

5. Demonstration projects for new technology

6. Capital investment to provide flexibility to deliver and use a diverse mix of fuels

7. New facilities to accommodate load growth.

A utility's ability to finance future projects and the cost at which it finances those projects are influenced by the technologies and resources it plans to add. For example, an over-reliance on purchased power may have a detrimental impact on utility costs of obtaining financing.

Regulatory Uncertainty

Regulatory considerations represent significant issues in the integrated resource planning process. As a result of a myriad of regulatory requirements, numerous uncertainties are created in the overall planning process. These uncertainties can impact the cost and timing of potential options. One of the main responsibilities of the integrated resource planner is to obtain input on existing and proposed Federal and State regulations in order to develop an expansion plan that properly addresses these considerations.

Both nuclear and fossil generating plants have to meet State and Federal regulations. On the Federal level, there are several agencies, such as the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA), which have approval authority over the design and construction of power plants. Likewise, on the state level, generation additions have to meet the standards set forth by the State Department of Environmental Regulation (DER) and other state, regional and local agencies. Also on the state level, the State Public Service Commission (PSC) must make a determination of need for any proposed power plant larger than 75 MW.

The end effect of these regulatory requirements is the creation of uncertainties in the planning process with regard to capital costs, lead times for site selection and plant construction. The capital costs of a new generating plant may be increased by additional equipment necessary to meet regulatory requirements. For example, sulfur dioxide and nitrogen dioxide particulate controls are now required on new coal fired power plants. Future legislation may result in even more stringent requirements that would significantly increase the costs of new generating units.

The lead time, or time for construction of a new plant, has also been significantly affected by regulations. A plant that might have been built in five years in the past may now take eight to ten years to site, license, design and build, due to more comprehensive licensing procedures and required studies. Longer lead times increase the uncertainty of timely completion of generation projects and thus affect the overall reliability of the system. In addition, extended lead times increase the financial risk of a project, as well as the possibility of cost overruns.

Until 1987, the Power Plant and Industrial Fuel Use Act (FUA or Act) prohibited the use of natural gas or petroleum in new electric power plants unless an exemption was obtained from the Department of Energy. In 1987, the Act was amended to remove all restrictions on construction of peak and intermediate load power plants and to allow construction of base load power plants using natural gas or petroleum if the plants are also coal capable. Under the definition of coal capability provided in the Act, a base load power plant need not be capable of burning coal immediately upon operation. The power plant must have inherent design characteristics to permit the addition of equipment necessary to render the power plant capable of using coal in the future and not be physically, structurally or technologically precluded from burning coal. The alternative generation technologies considered by the utility satisfy these requirements.

Recently passed legislation, as well as foreseeable international, federal and state environmental laws and regulations, have and will continue to impose stringent environmental controls over the life span of electric power plants. It would be unwise for utilities to knowingly invest in resources which will have to be abandoned or require expensive emission control retrofit. The consideration of environmental impacts in utility decision making may help to avoid additional costs for needed future environmental controls as well as help to reduce the level of uncertainty associated with utility resource plans.

STATE AND REGIONAL CONCERNS

Consistency with Statewide Needs

The generation additions in the base plan are compared with the statewide needs identified by the state power coordinating group. This comparison is designed to ensure that the plans of individual utilities are generally consistent with statewide needs.

Coordinated Planning Efforts

In addition to its internal planning process, utilities also participate in several regional planning efforts which plan to provide the most efficient and economic development of the future energy supply for the ratepayer. These regional planning efforts are coordinated through the following:

Bi-Lateral Studies between Utilities

The purpose of these studies is to determine if there are sufficient potential benefits to both electric utilities to warrant joint participation in generation and transmission projects.

National Electric Reliability Council (NERC)

The National Electric Reliability Council (NERC) consists of nine regional councils. Each utility is a member of a subregion and adheres to the NERC planning guidelines established to augment further the reliability of bulk integrated resource in the areas serviced by its member systems.

TRANSMISSION PLANNING PROCESS

The Electric Utility Transmission Plan is a key function of the system load forecast and the integrated resource plan. The primary purpose of transmission planning is to provide adequate transmission facilities in order to reliably serve the forecast loads and to integrate the planned resources into the power system.

The development of a transmission plan that answers these questions must consider three key elements: **reliability, economics and regulatory requirements.** These three considerations are not always complementary. Therefore, it is often necessary to seek a satisfactory balance between them.

Transmission Reliability

The utility assesses the reliability of its transmission system through the use of computer-based power system simulation techniques. The transient and steady state response of the system to electrical disturbances is evaluated under varying levels of system load, power interchange and generation dispatch. The computer models used to perform risk analysis are updated regularly to reflect changes in load forecast, transmission configuration and supply plans.

Just as in the generation reliability area, various industry organizations and reliability councils publish suggested study guidelines to evaluate the degree of internal reliability of the transmission system. Due to the nature of the interconnected transmission network, each individual system is dependent on its neighbors to a large degree and the network is studied as a whole for reliability purposes. Thus, transmission reliability evaluation involves the development of a set of internal and regional study guidelines and the testing of the composite and the individual utility's plans against them.

Studies are conducted individually as well as with other utilities. Joint studies aim to determine such things as: 1) Adherence to reliability agreements; 2) Coordination of long range plans; 3) Potential of propagation of intra-system disturbances into neighboring systems; 4) Interconnected transfer capability; and, 5) other considerations of mutual concern.

The utility merges the results of these individual and joint studies with its right-of-way, environmental, regulatory, engineering and construction considerations and then develops various alternative ways of delivering the generation to the load.

Transmission Economics

Another element considered in the development of a transmission plan is economics. Alternative plans for total cost are evaluated. Total cost consists of two components: 1) Capital investment for right-of-way and construction of the facility; 2) Energy losses plus other significant operating expenses.

The capital costs arise from the construction of the facility (i.e., labor, materials, etc.). The energy losses in the transmission network are directly influenced by variations in the dispatch of generation and by the distance the electrical energy must travel over the transmission system.

Regulatory Requirements

Transmission plans, like integrated resource plans, must satisfy guidelines established by federal and state agencies. On the federal level, for example, the NRC evaluates the reliability of the transmission network to supply off-site power to nuclear units during emergency conditions. Other federal agencies (e.g., the Federal Aviation Administration, U.S. Army Corps of Engineers, U.S. Department of the Interior, etc.) may evaluate the effects of a transmission line depending on its route and its impacts.

On the state level, transmission directly associated with a power plant is licensed under the Electrical Power Plant Siting Act. A brief summary of the certification process for this Act is as follows:

1. The State Public Service Commission makes a determination of need based on system requirements.

2. The State Department of Environmental Regulations (SDER) and other agencies review the environmental impact. The SDER administers the processing of applications, including conducting hearings.

3. The Governor and Cabinet are responsible for certifying the power plant site and its associated facilities, including transmission lines.

In addition, any proposed transmission line designed to operate at 230 kV or above, (not directly associated with a power plant) which crosses a county line and is at least fifteen miles in length, undergoes a similar certification process under the Transmission Line Siting Act. A brief summary of the certification process for the Act is as follows:

1. The State Public Service Commission makes a determination of need for the project.

2. The State Department of Environmental Regulations and other agencies review the environmental impact. The SDER administers the processing of applications, including conducting hearings.

3. The Governor and Cabinet are responsible for certifying the transmission corridor.

Regulatory requirements impact the transmission planning process in the same manner as they affect the integrated resource planning process by adding to the planning lead time. However, the Transmission Line Siting Act provides the benefit of a defined framework and schedule for licensing transmission lines. The process provides a generally predictable procedure and set of review criteria.

Transmission planners assess the impact of regulatory requirements and incorporate these considerations in the development of comprehensive transmission expansion plans.

In 1989, some states adopted standards governing electric and magnetic fields that apply to new distribution, transmission and substation facilities. New transmission line and transmission substation projects are designed to comply with these standards.

THE SITE SELECTION PROCESS

The utility initiates new power plant projects through a review of its integrated resource plan. Once the potential need for a new facility is identified, a number of factors are considered to determine the general area of the state in which a detailed site selection study must be performed.

The utility's Environmental Affairs Department has the responsibility of identifying and evaluating alternate sites. The Environmental Affairs Department works with the Engineering and Technology Department (which is ultimately responsible for plant design) to determine the basic requirements for the site, such as size, water requirements, etc.

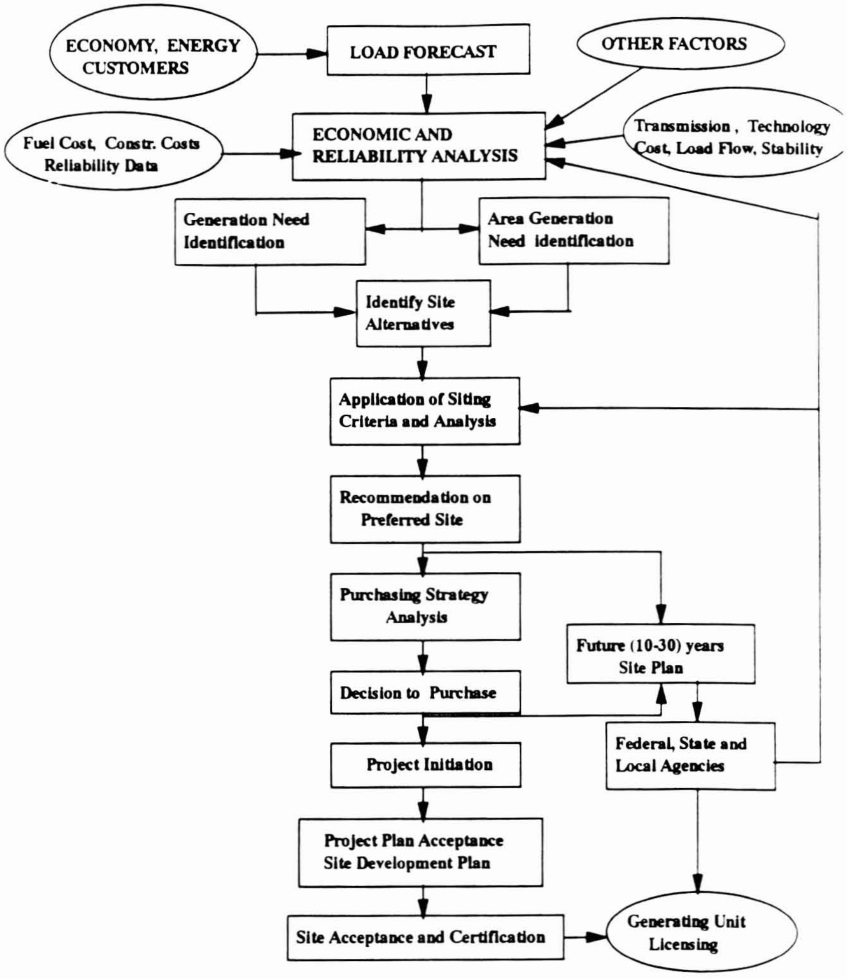
The Environmental Affairs Department identifies possible alternative sites in the general study area by means of an extensive screening process (Figure 2). These sites are then evaluated against a series of Power Plant Environmental Siting Criteria and by means of cost analyses. This evaluation is based on criteria considered fundamental in the selection of a site. Each criterion is assigned a weighted value for each site so that a quantitative evaluation can be made.

Furthermore, a separate cost analysis is performed for the sites in order to identify cost impacts for each alternative. The cost analyses typically incorporate site development, fuel transportation and transmission costs. This evaluation leads to the decision to purchase or acquire options for a future site.

In some cases, sites are purchased but active plans for development are delayed due to factors such as cost, the availability of other sources of power or changes in regulatory requirements.

Figure 1 lists general environmental siting criteria for a power plant. Siting criteria may be added or deleted based upon the nature of a particular project.

Figure 2. Power Plant Site Selection



CONCLUSIONS

The introduction of competition for customers is reshaping the business of electricity generation, transmission and distribution. Uncertainties as well as opportunities are being created by deregulation and unbundling of services. In a competitive environment, the price of electricity will be determined by the market, transmission access and availability of competing generating resources.

IRP strategies will play a central role in determining the market share and profitability of electric utilities. In this new environment, a sophisticated multi-area optimization modeling approach is required for effective IRP. A lack of one, universal, general optimization method has led to the situation, that there exists diversity of very narrow restricted optimization methods, which are applicable only to specific problems.

For optimization targeted on simulation this situation is not satisfactory. We need methods which on the one hand can cope with specific features of a goal function specified by a simulation model, and on the other hand are general enough to be applicable for a diversity of simulation model characteristics. Properties of the goal function is a black box function, highly complex, frequently non deterministic and non-linear. The number of possible solutions is vast, and the search space is very large, causing a challenge for development of new optimization techniques.

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