Competitive Electricity Markets

Energy, Ancillary Services Prices and Asset Evaluation

Energy markets need a structural model for price forecasting.
Time-series models are prone to significant errors.

Power Market Simulation Using UPLAN

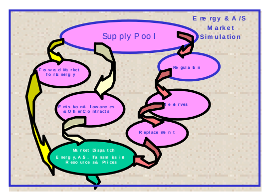
⇒ **Forward Market Model**

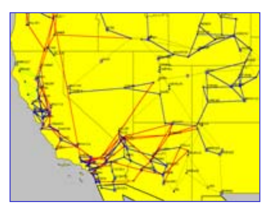
- **Simulates Regional Energy, Ancillary Service and Emission Allowance Markets.**
- **Determine System Resources and Network Constraints for Energy Dispatch.**

⇒ **Network Power Model**

- **Fast Monte Carlo method for chronological simulation of generation and Transmission.**
- **Security-constrained Optimal Power Flow (OPF) for hourly Flow & redispatch.**

An Example of Power Market
Western System Coordinating Council





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Energy, Ancillary Services Prices and Asset Evaluation

In recent years, forecasting of electricity prices and asset evaluation has acquired an unprecedented significance in the industry. In response, attempts have been made to use time-series analysis to forecast electricity prices and their volatility. In general, regression or Black-Scholes types of analyses have not met with success. This lack of success of time-series analyses can be attributed to the following reasons.

Electricity is a unique commodity. Forecasting prices requires a structural model.

- Price swings in the market for electricity is mainly due to the need to balance demand and supply at every instant. Moreover, electricity can not be stored to absorb the instantaneous imbalances.
- The conditions that prevailed in the market in the past are unlikely to be repeated in any consistent manner in the future. For instance, the flawed market rules and price caps in California, and the failure of the counterparty guarantee in ECAR are unlikely to recur predictably.
- In coal-dominated regions like SERC and ECAR, the electricity prices will depend to a large extent on the emission rules and the penetration of emission reducing technologies. Price projections based on historical data can not incorporate the structural, technological and regulatory changes in the energy industry.
- Prices for energy, ancillary services (A/S), emission allowances (EA) and other products interact with each other. It is not possible to forecast energy prices without estimating the impact of A/S and EA on the market participants and electricity prices.

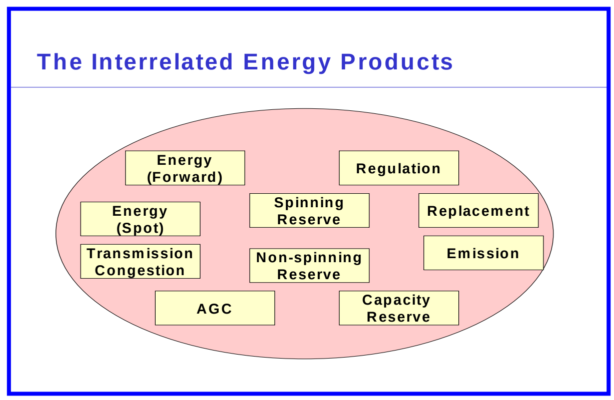

Figure 1. Products interact and modify participants' behavior and prices

- Superposition of the volatility of individual products ignores the correlation between the products and has often produced unacceptable results.
- Experience has shown that in a structured market like California, the participants' bidding strategies are influenced by the presence of multiple product markets.

- The history of the competitive market is very short and can not provide sufficient information for reliable forecasts.
- The electric system is subject to extreme price swings due to the confluence of unusual demand, unexpected generator outages and transmission deratings.

To avoid the shortcomings of historical analyses, one must recognize that electricity prices are strongly related to fundamental physical drivers such as loads, hydrological conditions, fuel prices, unit operating characteristics, emission allowances, and transmission capability. Also, the interaction between markets must be captured for consistent forecasting across a range of products.

In addition to the market protocol, regional and system-wide reliability policies influence the operation and energy interchanges. The energy, ancillary service and allowance markets interact with each other and hence, impact the bidding behavior of the participants; these factors must be included in the forecast.

The interaction between Energy, Ancillary Services and the fundamental drivers must be captured for consistent and accurate forecasting of energy prices and plant valuation.

California, New York, New England, Ontario and PJM have markets for ancillary services like regulation, spinning, non-spinning and capacity reserves. An Independent System Operator (ISO) or Power Exchange (PX) auctions these products. For other markets such as ECAR, the ancillary services are traded over the counter as a Capacity charge, or subsumed in the firm energy price.

UPLAN models all the energy products simultaneously, performs a real-time dispatch and determines the volatility using fundamental drivers.

A structural model like UPLAN, which can take into account the presence of multiple energy products, is a must for accurate forecasting and asset valuation.

The UPLAN integrated system consists of the following functional components.

- *Forward Market Model for energy and ancillary service auctions and bilateral sales.*
- *The Real-time Dispatch Model using AC - Optimal Power Flow (OPF) for congestion management and real-time prices.*
- *The Volatility Model for asset valuation, bidding strategies, options valuation and risk management.*
- *The Merchant Plant Model for assessment of new entrants and their impact on future prices.*

We highlight below some of the salient features of the functional components of UPLAN.

UPLAN's Forward Market Model simulates the energy, ancillary services and emission allowance markets simultaneously.

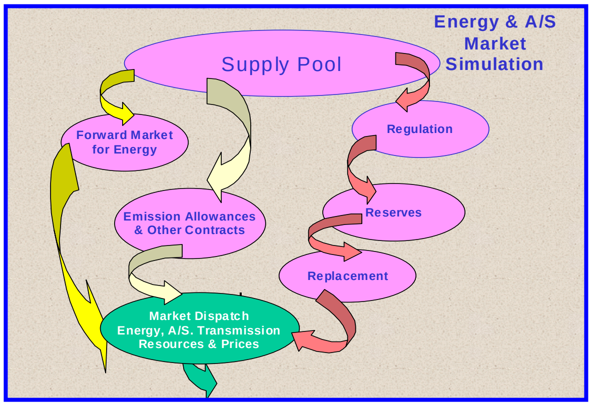

Figure 2. UPLAN Forward Market Model maximizes participants' profit

For bid-based markets like ISO and PX, a bidding strategy incorporated in UPLAN is based on the notion that sellers are likely to choose to participate in the market that maximizes their profits. This strategy influences the bids and offers for all the energy product markets and provides the market-clearing price (MCP) for ancillary services, as well as the quantity that clears the market.

An optimal AC power flow program carries out dispatch of the resources cleared through the forward market.

In regions where a bid-based ancillary service market does not exist, capacity reserve prices may be estimated from the volatility of energy prices. Capacity reserve is intended to maintain adequate resources during emergencies and is treated as a physical hedge in UPLAN.

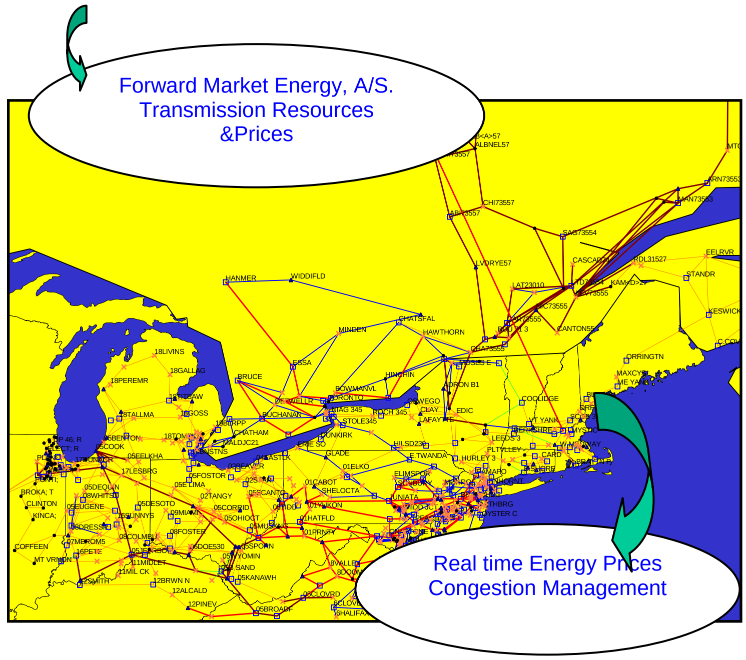

Figure 3. UPLAN OPF model determines the real time prices

The built-in AC-Optimal Power Flow model, which continues from the results of the Forward Market Model, determines the spot prices, congestion costs and generator revenues.

The results of the Forward Market Model and the AC-OPF model are utilized by the volatility simulation component of the system for the valuation of options and the analysis of hedging strategies.

Determination of volatility requires a structural model for consistent evaluation of options.

UPLAN's Volatility Model performs systematic evaluation of price volatility due to the uncertainty associated with fundamental drivers such as fuel prices, hydrological conditions, electricity demand, generator and transmission outages, new entrants to the market, and any other critical variables that impact electricity prices. The evaluation is based on Monte Carlo sampling from the probability distribution of the fundamental drivers that contribute to the volatility of energy and ancillary service prices. Some of the output of the model and examples of their uses are described below.

- The probability distribution of prices of energy and each of the ancillary service components are determined.
- Intrinsic and extrinsic values of calls and puts options for energy, A/S and transmission basis differences are reported.
- It provides an alternative calculation of capacity reserve prices as a physical hedge for energy.
- The buyers' premium and sellers' risk across the entire spectrum of strike prices are reported.

The options value, the sellers' risk and buyers' premium are essential for bid evaluation and valuation of new assets.

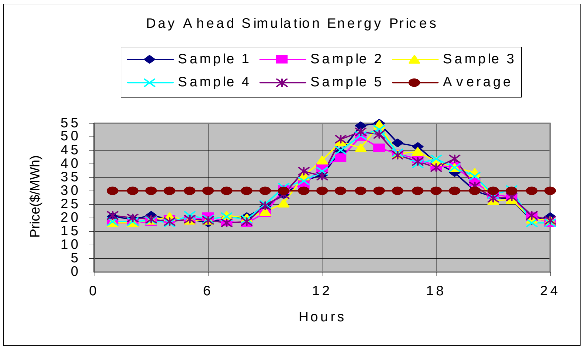

Figure 4. Five UPLAN sample pathsfor day-ahead prices

Figure 4 and Figure 5 respectively show a few UPLAN simulations of the day-ahead energy prices and the corresponding call and put options values at various strike prices. The call and put premiums for any strike price reflect the value of the risk to which buyers and sellers are exposed at that strike price.

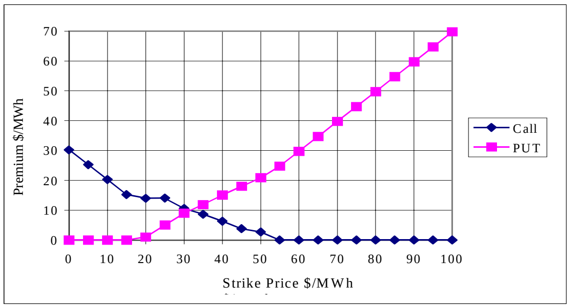

Figure. 5. Hedging strategies for the day-ahead market

The intersection of these curves provides a fair market value of the risk exposure that the buyers and sellers will experience that day.

For example, if a pump storage operator offers energy at $25 (Fig. 5, Call), then he is expected to make an additional $13.40 and operate for 13 hours (Fig. 6, Call). The pump storage is off-line for the remaining 11 hours of the day (Fig. 6, Put) and the operator avoids a potential loss of $7 (Fig. 5, Put) by his bid. Obviously, this is an optimal bid if the storage has only 13 or less hours of energy.

The options curves provide a powerful tool for day-ahead bidding. A similar analysis on a monthly basis provides in-depth insight into the capacity market.

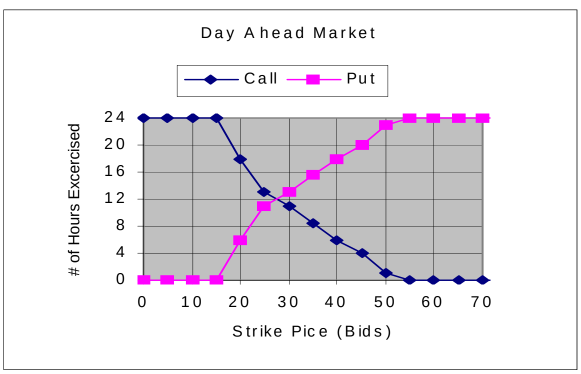

Figure 6. Number of hours a successful bid is exercised in the day-ahead market

New entrants to the market significantly influence the prices in the long-term forecast.

The UPLAN Merchant Plant Analysis (MPA) model is an optimization program that identifies the location and timing for installation of new units that meet the required investment criteria over the operating time horizon.

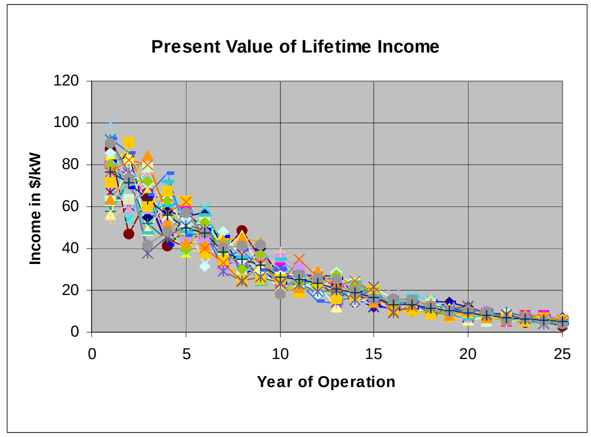

Figure 7. Some sample trajectories of net income accrued to new assets simulated by the Volatility Model.

In particular, UPLAN's MPA model provides the following analyses:

- Net present value of income over the operating horizon of the asset.
- The distribution of net income for multiple scenarios sampled by the Volatility Model.
- The options value of premiums and risks for the plant at strike prices of interest. These strike prices correspond to $/kW investment in the asset.
- The value of new investment and the risk-reward structure (Fig.8) of the investment over the spectrum of possible outcomes.

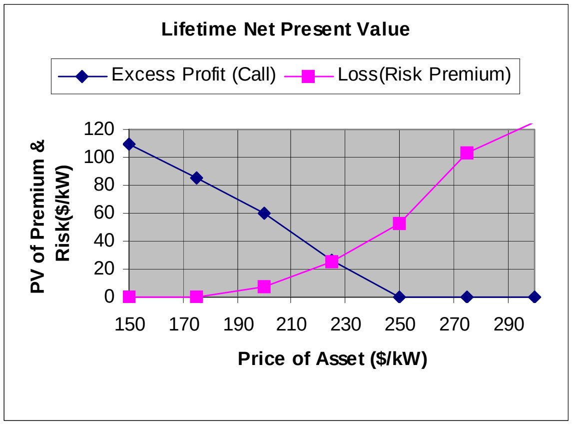

Figure 8. The risk-reward structure of new assets. The call and put value of the asset is the PV of all income over 25 years of operation of the generator

- Percent of time the investment is in the money, i.e., the net value of revenue is greater than the strike price (Fig. 9)

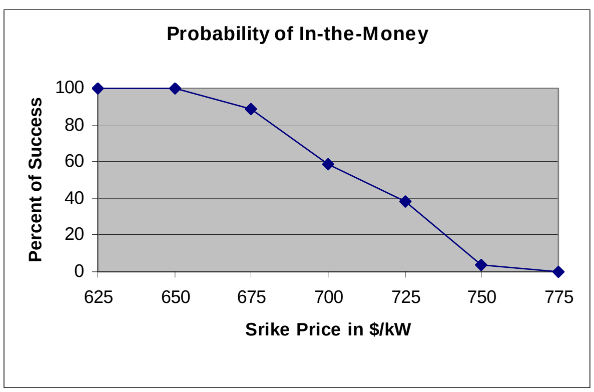

Figure 9. Percent of time the investment is in-the-money

Calculation of costs and revenues of a new unit using time series analyses is not only subject to inaccuracies of estimation as stated earlier, but also takes no notice of the impact of transmission congestion. Moreover, such calculations, when used for the evaluation of peakers, are unable to capture the revenue from price spikes and the impact of their intermittent operation. The electricity price spikes account for large parts of the revenues of the peakers.

The Merchant Plant model incorporates revenues from price spikes, capacity and operating reserve and trading emission allowances in determining the income of new units.

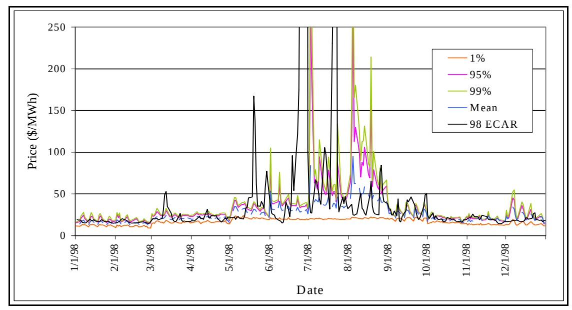

Figure 10. Daily on-peak price volatility for ECAR

Figure 10 shows the actual ECAR prices for 1998, along with price distributions obtained from UPLAN's volatility simulation. Note that UPLAN can capture the frequency and duration of the price spikes using the volatility simulation of the structural variables.

The price spikes are rare occurrences and take place when several unusual events occur simultaneously. Point forecasts based on random walks are quite ineffective in identifying these unforeseen events. Although these spikes are infrequent, their contribution to the economic viability of peaking units and the liquidity of the options market is substantial.