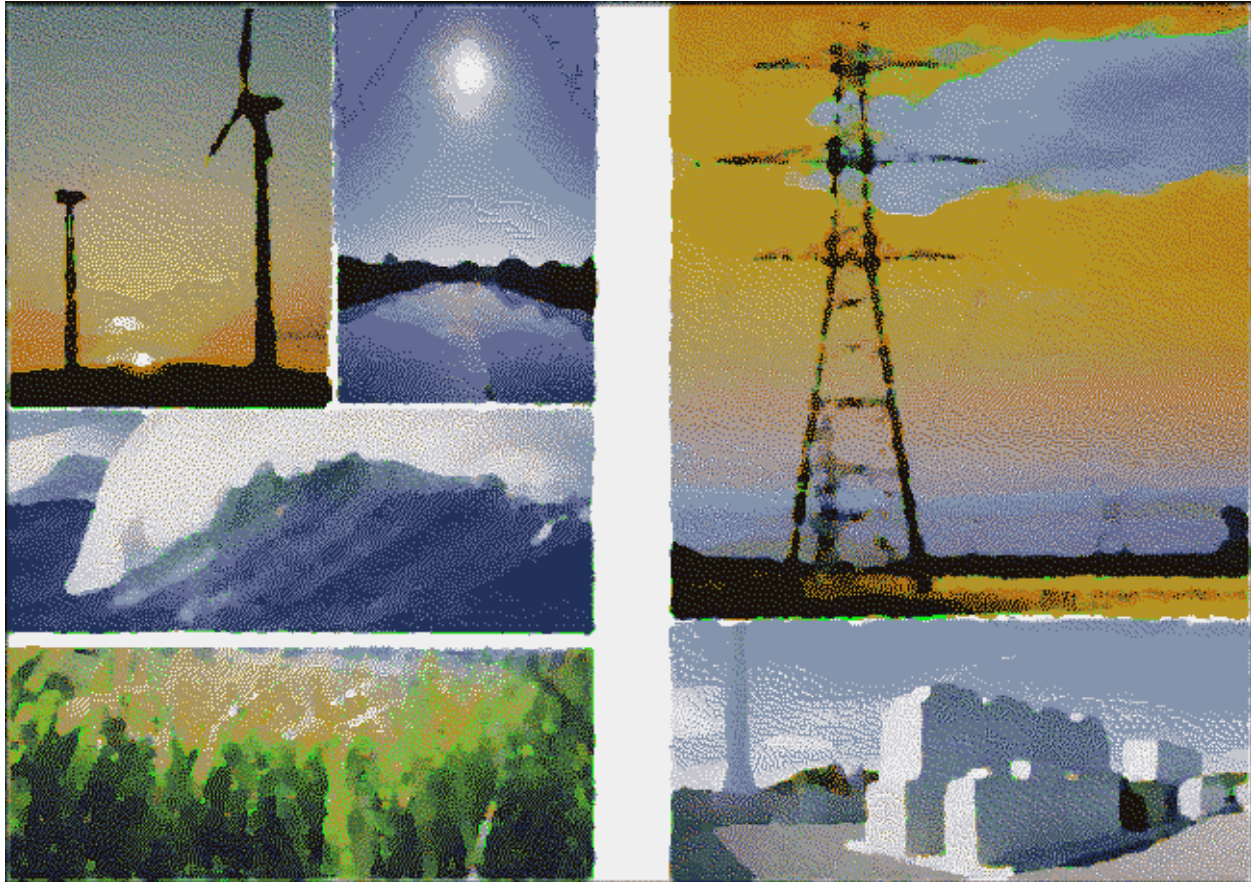


# PROMAXLT™



## **LONG-TERM ENERGY & TRANSMISSION MARKET SIMULATION SOFTWARE PACKAGE**

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## ProMaxLT<sup>TM</sup> – Executive Summary

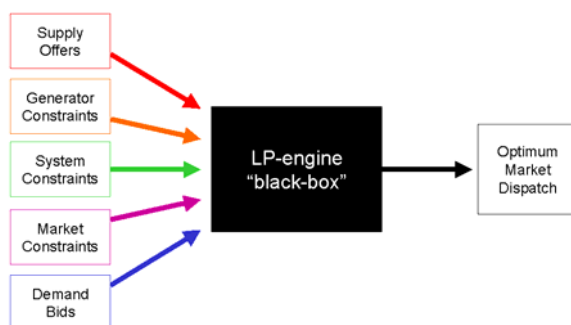
ECCO International, Inc., (“ECCO”) has developed and implemented a comprehensive long-term market simulation package, called ProMaxLT<sup>TM</sup>, to assist ISOs/RTOs and Market Participants in understanding the complexities of the competitive electricity market, and provide accurate simulations of market behavior for a multitude of applications. The many features incorporated into the standard design of ProMaxLT<sup>TM</sup> makes it, we believe, the best value-for-money product available.

ProMaxLT<sup>TM</sup> has been successfully used by various Market Participants as a market analysis and forecasting tool, especially for long term applications.

Typical ProMaxLT<sup>TM</sup> applications include:

- Reliability studies, LOLP calculations, etc.
- Market simulation studies, market price forecasting, etc.
- Congestion forecasting
- CRR (Congestion Revenue Rights) strategic evaluation and analysis
- Transmission flow forecasting
- Loss factor forecasting
- Generation plant revenue and profit forecasting, investment evaluation
- Generator bid strategy evaluation
- Integrated Plant Expansion plan, where multiple plant expansion options are considered, automatically selecting the best set of options via dynamic programming.

The major strength of ProMaxLT<sup>TM</sup> is the precision of the model which ensures consistency of results between studies and this precision has been proven over again in many market study audit situations, where the results of ProMaxLT<sup>TM</sup> have been independently checked. This precision and consistency is a result of ProMaxLT<sup>TM</sup> using a nodal configuration which optimizes network flows (and constraints) with dynamically calculated limits; Monte-Carlo based plant outage consideration; LP-based optimization; and discrete hourly modeling. The major blocks of ProMaxLT<sup>TM</sup> are shown below.



ProMaxLT<sup>TM</sup> may also be used to perform sensitivity studies of different plant expansion options, fuel price scenarios, load forecasts and transmission expansion options. These sensitivity studies may be used in investment risk analysis and evaluation.

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## 1. Introduction

ECCO International, Inc., (“ECCO”) has developed and implemented a comprehensive long-term market simulation package, called ProMaxLT™, to assist Market Participants in understanding the complexities of the competitive electricity market, and provide accurate simulations of market behavior for a multitude of applications. The many features incorporated into the standard design of ProMaxLT™ makes it, we believe, the best value-for money product available. The strengths of our product stem from the following three key attributes:

- **Comprehensive Accurate Database:** ECCO has performed the data collection and validation to establish a database for the system to support the calculation and forecast of MCPs/LMPs. The database also includes the full unreduced network model with proper limits, generation with accurate price profiles and scheduling point price forecasts. These models have been benchmarked against the actual operating scenarios to verify prices and instances of congestion.
- **Precision:** A full unreduced nodal configuration which optimizes network flows (and constraints) with dynamically calculated limits; Monte-Carlo based plant outage consideration; LP-based optimization; and discrete hourly modeling. This precision will be of considerable benefit in the delivery of forecasts relevant to your assets. Forecasts can focus on averages, and or volatilities, and sensitivity studies may be readily performed to provide an accurate risk profile.
- **Versatility:** It uses a robust ODBC database storage mechanism for all input data, and output data created. The algorithm we have developed is applicable under different market conditions. You can apply ProMaxLT™ to the delivery of forecasts under a wide range of different market assumptions and scenarios. Output results may be readily formatted into graphical and tabular reports using standard software packages such as Excel and Access.

## 2. ProMaxLT<sup>TM</sup>

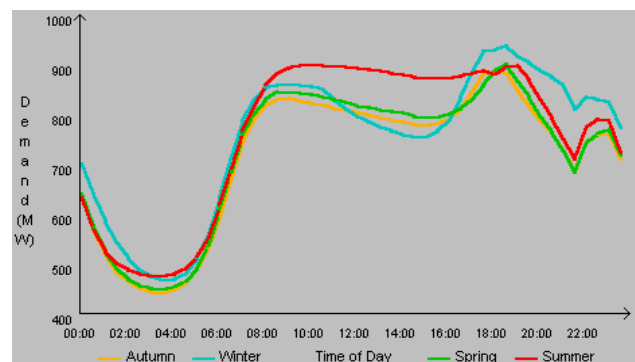
### Delivering Precision

In the development of ProMaxLT<sup>TM</sup>, several key features have been included in order to provide you confidence in the precision of the forecasts generated. Several of these are explained in the following pages.

### Discrete Hourly Modeling Capability

You're no doubt well aware that electricity demand is not constant. Indeed, you know that demand varies on the basis of:

- Time of day;
- Day of week;
- Month of year; and
- From one year to the next.



**Figure 1 – Seasonal Demand Curves**

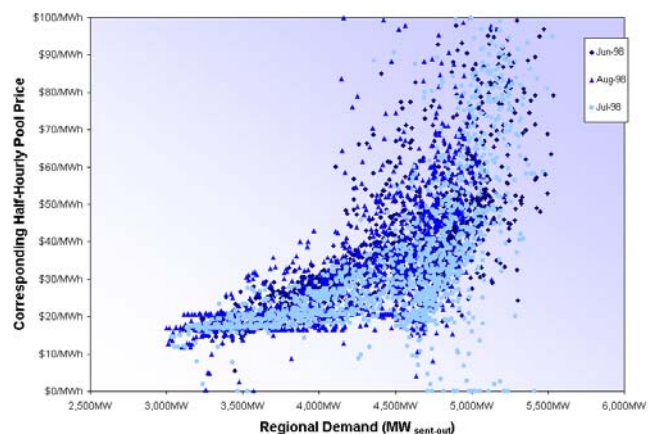
Because of this variation, the competitive electricity market must be dispatched on a time-sequential basis. During peak-times, the higher priced generators will be dispatched to meet demand – hence, price volatility can be experienced from one hourly period to the next, by virtue of these changes in demand.

For you, this volatility is probably very important to your considerations:

- High prices spread over a small % of time can have a big impact on average outcomes;
- The volatility will also impact on your risk position (based on how your own energy purchase/sales requirements vary over time).

It stands to reason that, given that the real market exhibits such volatility on an hourly basis, your forecasting of the future should also operate on this basis.

ProMaxLT<sup>TM</sup> incorporates as a standard feature the consideration of all 8,760



**Figure 2 – Scatter graph**

discrete hourly periods in any given year. This means that the results delivered to you will display true reflection of the natural randomness in prediction of key market variables (prices, production volumes and network transfers).

This, in turn, means greater precision of the results.

### 3. LP/MIP-based optimization

The electricity spot market is dispatched many times during a given day, week and year.

The actual dispatch of the market is performed using a complex optimization process that can only be solved (with confidence in the results) through the consideration of a large number of independent and interdependent sets of constraint equations. These constraint equations relate to a wide range of physical and commercial parameters within the market.

Over the past 20 years, linear programming (LP) has emerged to be the most tried, tested and trusted mechanism by which such complex, sparse-matrix problems can be solved. A diagram representing the spot market operation has been provided here.

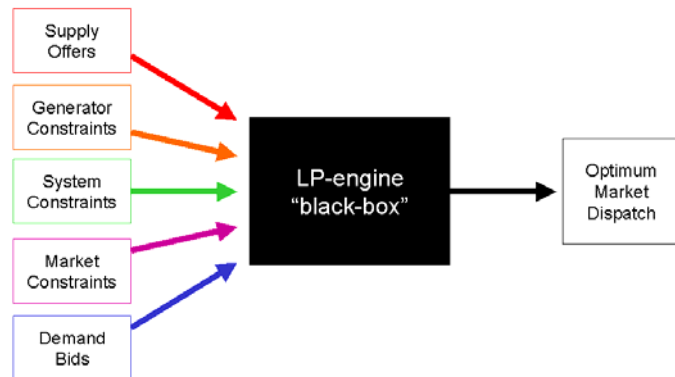


Figure 3 – Inputs and Process

LP-engines can be used in all situations where all inputs can be written in the form of linear equations. For the electricity market, this means that they can be applied in all cases except where full AC load flow modeling is assumed.

ProMaxLT™ includes a sophisticated LP engine for nodal analysis and LMP pricing. It can model any time period from a single time period to typically 30 years ahead at half hourly intervals. Annual simulations are generally run for 50 to 100 simulation years per year of the study to ensure price and production convergence. Multiple iterations of the Monte-Carlo (complete with LP optimization) are performed to provide the added benefit of true convergence to the most likely outcome (in terms of averages, totals and volatilities).

To take into account Unit Commitment constraints, such as start-up costs, ramps, minimum up constraints and minimum down constraints, ProMaxLT™ also includes an advanced MIP-based Unit Commitment solver to clear the market and perform nodal/zonal analysis and LMP/zonal pricing. The Unit Commitment software iterates with a full SC load flow model to model losses and compute prices that reflect the cost of losses in addition to the cost of energy and the cost of congestion.

ProMaxLT™ is configured to optimize many hourly time periods one-after-the-other, whereas most other similar software are focused in optimizing the next immediate five-minute dispatch period. It is structured such that LP/MIP iterates several times within each hour to take into consideration:

- a) System reserve requirements,
- b) Dynamic limit equations, and
- c) Dynamic inter-regional loss equations.

The outcome of the constrained LP/MIP solution for each time period provides the LMP/zonal prices, together with all line flows and generator outputs. The LMP/zonal prices are calculated from the LP dual variables of the bus equality constraints. For large case studies, the ProMaxLT™ execution is managed by MySQL server and is parallel processed on several dual core machines as described above. The price in a given time interval (e.g., half hour or an hour) is an outcome of the application of the market rules to the simulated market clearing dispatch. Also the generation is dispatched in order to meet a security constrained dispatch. This detailed integrated approach provides a more realistic forecast of the LMP/zonal prices because it allows evaluation of the system under a variety of unit-forced outage scenarios. It truly captures the effects of congestion on marginal prices and provides a realistic LMP/zonal price forecast that can be used to assess the potential revenue from various hedging plans.

The model can also be calibrated against historical LMP/zonal price levels. The calibration process usually works as follows. LMP/zonal price duration curves are built using actual, historical LMP/zonal prices. These duration curves are compared with LMP/zonal duration curves calculated by ProMaxLT™. Differences between the two distributions are analyzed and assumptions are validated. In this process we focus on historical bidding patterns, tie flows, loads, network model, limits, hydro profiles, and generation outages. Actual and forecast data are compared on a statistical basis with ease (see first diagram below), since backcasted and forecasted data is collected and processed in the same data format. Modifications of this data are made, if necessary, to achieve the best calibration results. The calibrated model based on historical data will result in the same distribution of prices as that of the “real” world. The calibrated model can now be used for statistical analysis of LMP/zonal prices for future studies.

However, where calibration is not feasible (i.e., market and LMP/zonal actual prices do not exist), the network is modeled from the bottom up (load, generation, transmission) and does not need to be calibrated. The model can provide any level of modeling detail from a single area, single price to a regional or full nodal model.

Once LMP/zonal prices are available, ProMaxLT™ will provide the capability to execute queries and produce for each location LMP/zonal probability distribution functions, LMP/zonal cumulative distribution functions, and LMP/zonal duration curves. This wide range of statistical data on future LMP/zonal prices for each location is provided as part of the standard output of the ProMaxLT™.

## 4. Full Monte-Carlo Based Outage Modeling

All generation units in the market will periodically experience outages, which will remove them temporarily from service. These outages may be the result of any of a number of phenomena:

- Planned full and partial maintenance outages;
- Forced outages (due to plant breakdown);
- Partial forced outages
- Forced outages (due to other issues, including fuel supply disruptions and industrial relations disputes).

Under the previous, centrally planned industry regime, complex statistical parameters were developed in order to describe such outages. These could then be applied to forecasting to allow consideration of the impact of plant outage. Various techniques were developed. The most advanced of these was based on (Monte-Carlo based) randomization of unit outages. This technique delivers a true reflection of the natural randomness that occurs in relation to these events and hence delivers a more precise forecast.

ProMaxLT™ is stochastic in nature; it uses a Monte-Carlo random outage scheduler to create full and partial outage states for both generation and transmission. Maintenance and forced outages are prepared from the best available data in each market. The Monte-Carlo forced outage event modeling in ProMaxLT™ allows the true impact of multiple coincidence outages to be forecasted across multiple iteration of the same scenario.

A Weibull Distribution is used to randomly determine the outage and repair times for each unit. Using a computer generated seed, the random number generator is used to randomly generate a number between zero and one and the Weibull distribution is then used to convert the number to an outage and repair time for each unit. Four Weibull Distributions are used: a) Full Time to Failure, b) Full Time to Repair, c) Partial Time to Failure, and d) Partial Time to Repair. As a result of this process the simulated failure and repair patterns are determined.

Separate random number generators are used for all generator and transmission elements. This ensures that outage sequences of all plants are independent. All random number sequences are chosen to be dependent of the single seed which is independent of the time clock. In that way, if the same seed is used in a repeated simulation at another time, the study can be reproduced exactly. The reference time for each unit is chosen to be at a fixed reference time in the past, so that multiple runs with different input parameters may be performed with the same outage sequence. This is an important requirement for sensitivity runs.

The Weibull Parameters are determined from long-term historical outage statistics. An example of the Weibull distributions is shown in the figures below:

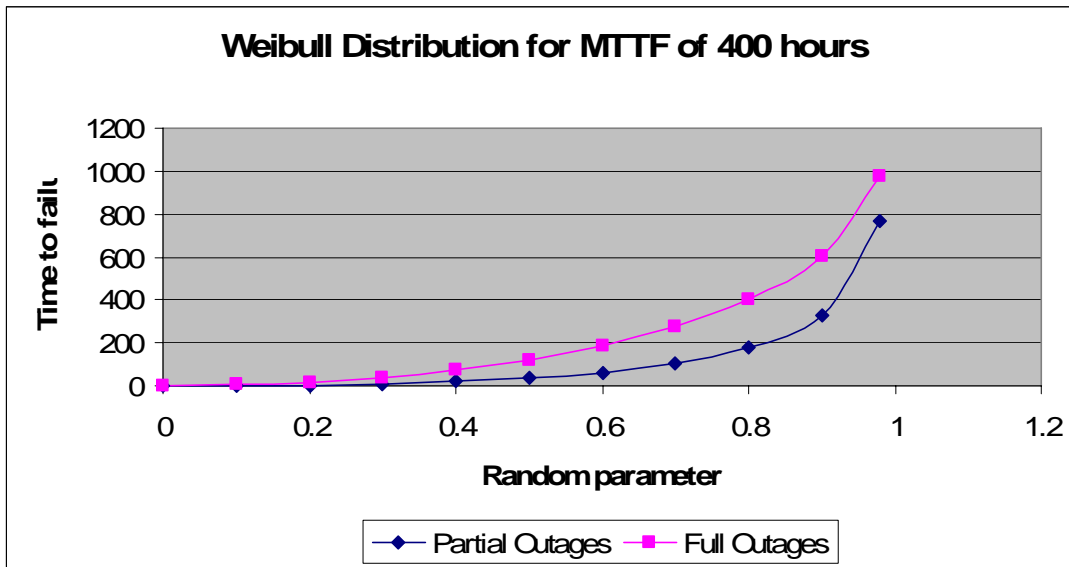


Figure 4 - Sample Weibull Distribution for Unit Failure Time

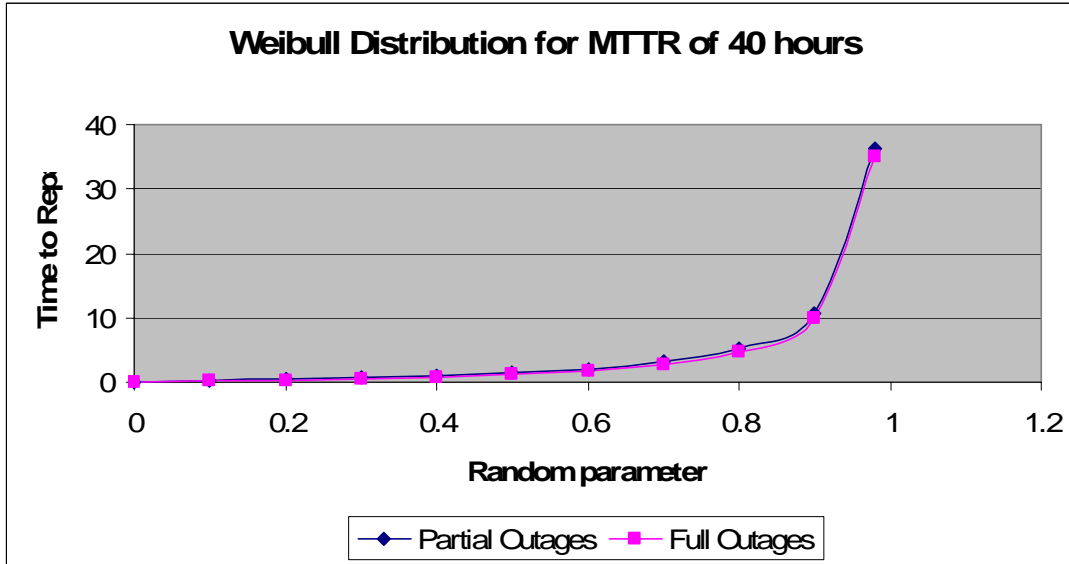


Figure 5 - Sample Weibull Distribution for Unit Repair Time

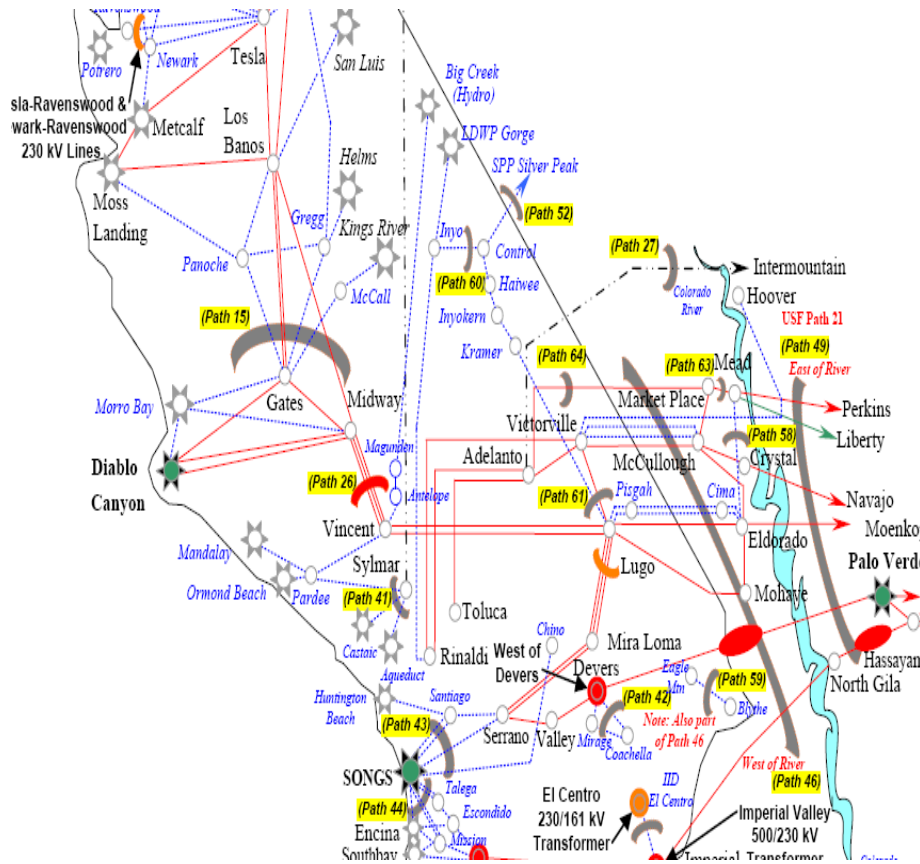
ProMaxLT™ is capable of incorporating an accurate transmission model with a nodal configuration which optimizes network flows and constraints with dynamically calculated limits on an hourly basis. The model is built bottom up, with every generating unit modeled in terms of its capacity, bidding pattern, maintenance plans and forced outage rates. Every transmission line or group of lines is modeled in terms of its electrical properties (particularly reactance for dc load

flow modeling), and transmission limits. Specifically the software reads the susceptance matrix of the network from a power flow solution file and converts the susceptance matrix into LP constraint equations. The power flow equations are explicitly modeled in the LP solution. The bidirectional line limits on each line are also read into the database and converted to constraint equations. The load is modeled on an hourly basis through the year(s), based on reading in historical load curves and scaling for peak load and energy growth rates.

Contingency constraints are also explicitly represented by adding additional constraints that express the flow in the constrained lines as a set of linear shift factors of the generation output levels. These shift factors for the contingency constraints are derived directly from the network admittance matrix with the outages as specified by the contingency set incorporated into the study case.

Furthermore, the market rules are also read into the model. Even though the data preparation will be completely automated, the development of a valid solution, especially for a large number of nodes, will require an extensive level of data checking. Maintenance and forced outages are prepared from the best available data with NERC GADS data as the default. The forced outage event modeling in ProMax™ allows the true impact of multiple coincidence outages to be forecasted across multiple iteration of the same scenario.

## 5. Detailed Nodal Configuration



**Figure 6 – Nodal map**

a range of different investment or operational strategies.

We're also periodically enhancing our nodal configuration to provide you greater detail and precision.

We have already outlined how the use of LP/MIP-based optimization can deliver greater precision. Special notice is made here of the use of the LP-engine within ProMaxLT™ to take account of (both *intra-regional and inter-regional*) transmission constraints.

When transmission constraints occur, suppliers on the upstream side of the constraint simply can't get their power to market. Not only does this have a big impact on their business, transmission constraints also have a big impact on the operation of the market as a whole.

A precise market model must have, as one series of inputs, constraint limitations on links between major supply and demand centres (or nodes). These links will occur both within regions and between regions.

The incidence of and impacts due to transmission constraints can be very significant. With dynamically calculated transmission limits and meshed transmission system flows evaluated ProMaxLT™ produces a high level of detail in the forecasts results.

In ProMaxLT™ we provide the facility to precisely consider the impact of transmission constraints between all the nodes we have defined.

This will be significant in your consideration of the merits of

## 6. Delivering Speed

We have outlined above the steps we have taken to deliver greater precision in the market forecasts delivered by ProMaxLT™.

## 7. ProMaxLT Delivering Versatility

The competitive electricity market will be subject to many changes in the coming years:

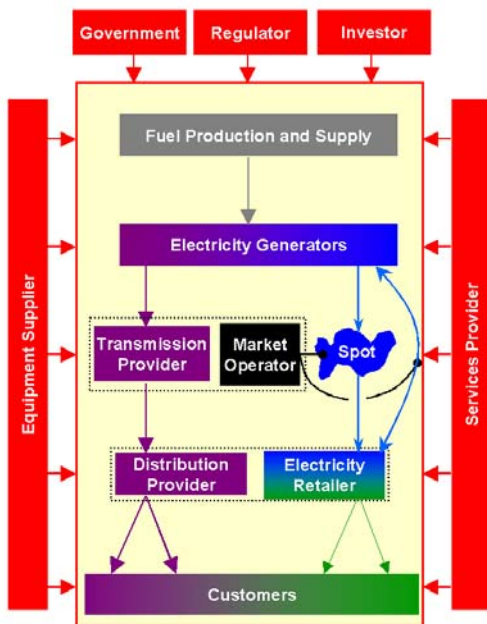
- Changes to the supply side;
- Changes to the demand side;
- Changes to the delivery system;
- Changes to the market rules; and
- Changes to the external environment.

Our staff has gained considerable understanding of, and experience in, the development of competitive energy markets around the world.

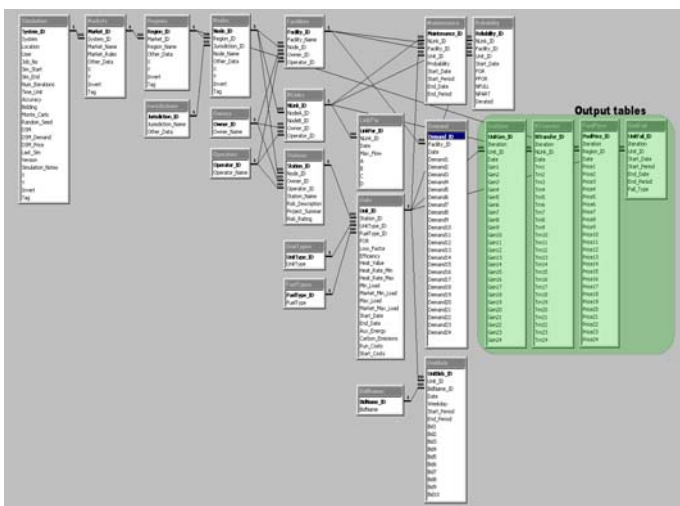
Additionally, our staff is involved with the application of modern software development techniques.

On this basis, we have included in the design of ProMaxLT™ several key concepts that will deliver, for you considerable versatility in the modeling of these potential changes in the market.

Such features include:



**The New Competitive Market Model**  
**Parallel, Interactive Systems**



**Figure 7 - Processes and relational diagram**

- Robust ODBC-database design for storage of all simulation data (input and output);
- Application of LP/MIP-engine for dispatch optimization;
- Time-sequential design;
- Incorporation of all energy market rules in the clearing.

## **8. Delivering Simplicity**

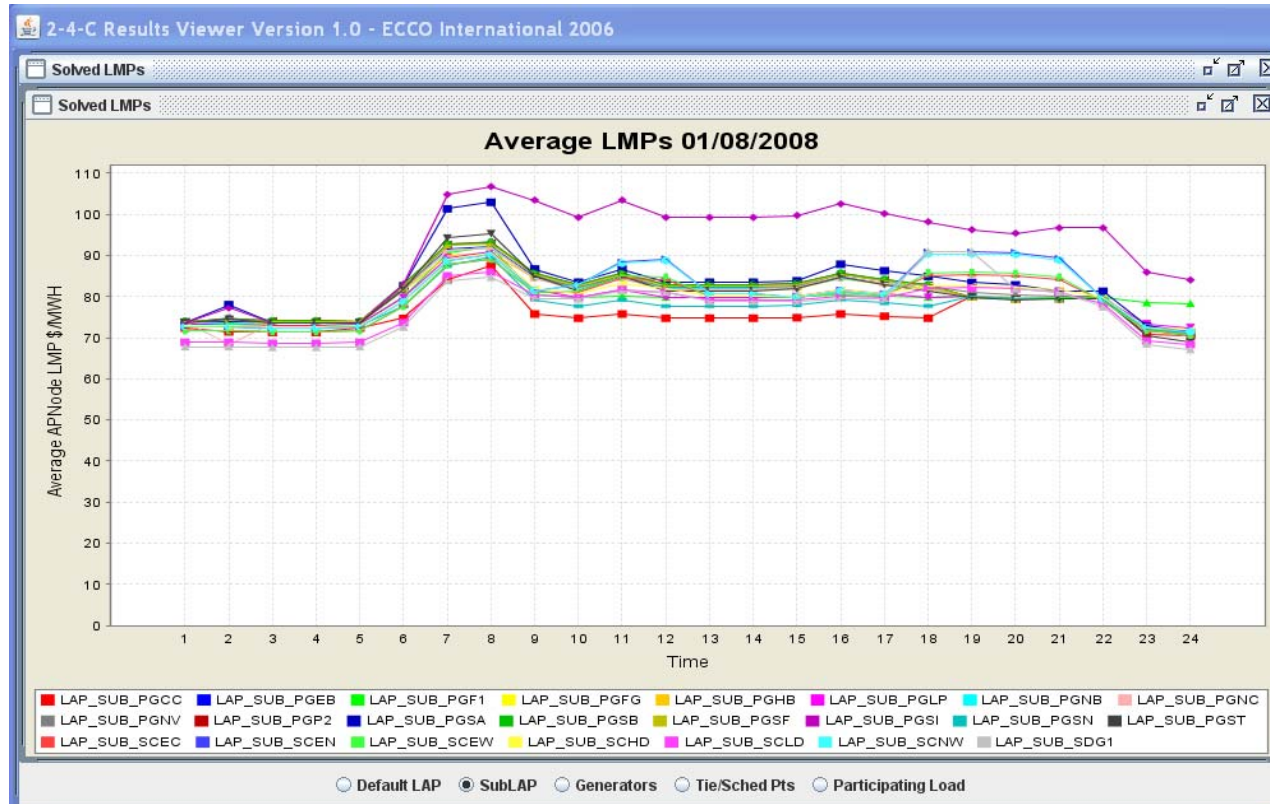
ProMaxLT™ has been specifically designed to deliver an exceptional combination of precision, and speed while keeping the product simple to operate.

This is not as easy as it might seem, given the huge degree of versatility designed into ProMaxLT™.

ProMaxLT™ - By including a standard reporting feature in Excel, and including provision for export of all (half-hourly or hourly) results, we're ensuring the forecasts can be viewed and used widely in your organization (at any time in the future, and on any PC).

## 9. Sample Output Data

The following are some samples of the output we are currently calculating related to the California Market using ProMaxLT™.



**Figure 8 - Output prices for various LAPs**

In the figure above we present the LMPs over a 24-hour period shown for each California ISO defined sub-LAP (Load Aggregation Point). We can also show information such as duration curves for two different annual load curves, a typical climatic year and an

extreme climatic year. This LMP statistical information is important to accurately evaluate LMP profiles and LMP volatilities under a variety of system conditions.

In the figure below we present a sample of an LMP duration curve over a three month period shown for a particular pair of California ISO aggregated price nodes. We can also show information such as duration curves for two different annual load curves, a typical climatic year and an extreme climatic year. This LMP statistical information is important to accurately evaluate LMP profiles and LMP volatilities under a variety of system conditions.

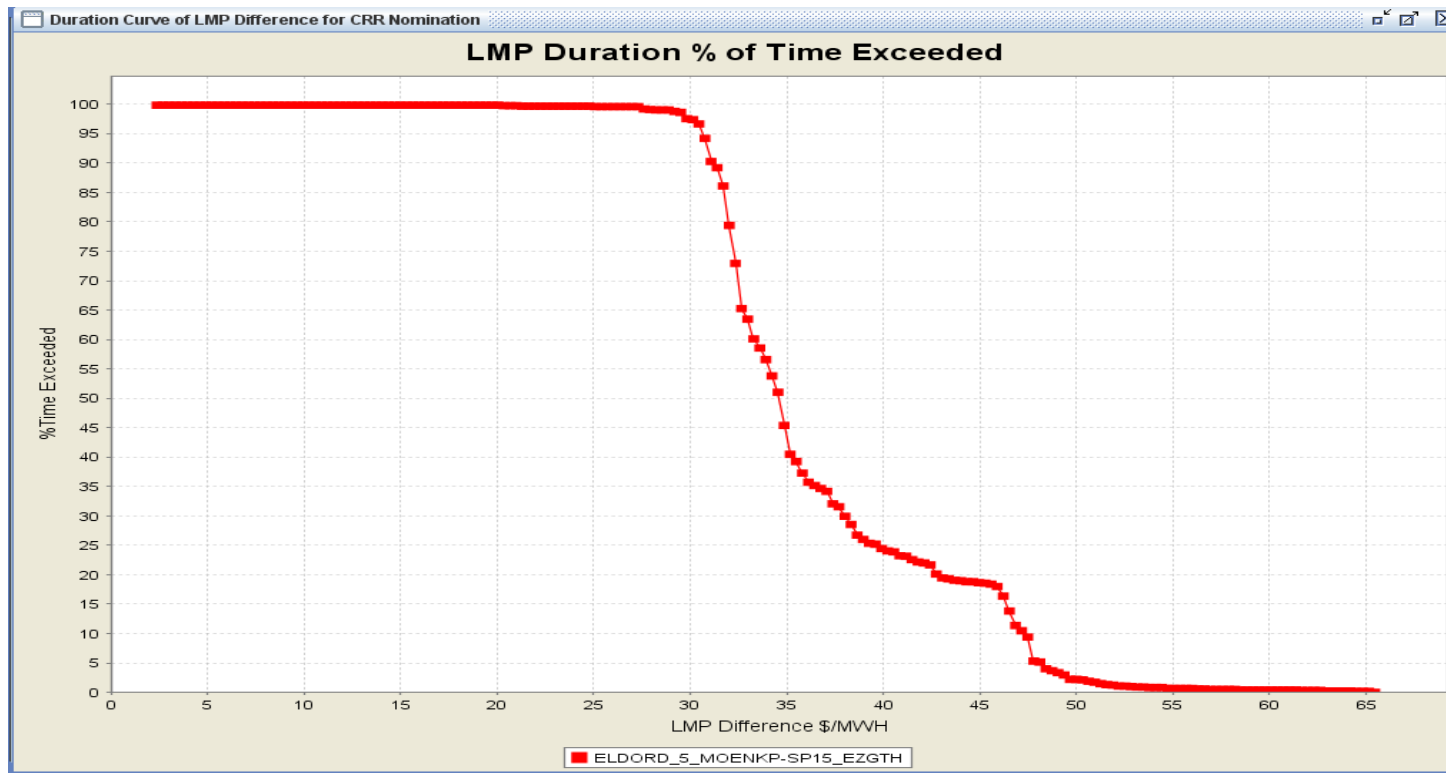


Figure 9 - LMP Duration curve

Other studies may be performed to evaluate the effect of possible variations in scenarios for effects such as:

- Sensitivity of LMP statistical forecast to delays in major transmission projects such as the Palo Verde transmission line upgrade and the Sunrise Powerlink transmission upgrade
- Sensitivity of the LMP statistical forecast to scheduling point prices
- Sensitivity of the LMP statistical forecast to fuel price forecasts
- Sensitivity of the LMP statistical forecast to alternative new entrant plant scenarios or delays in commissioning of new entrant plant.

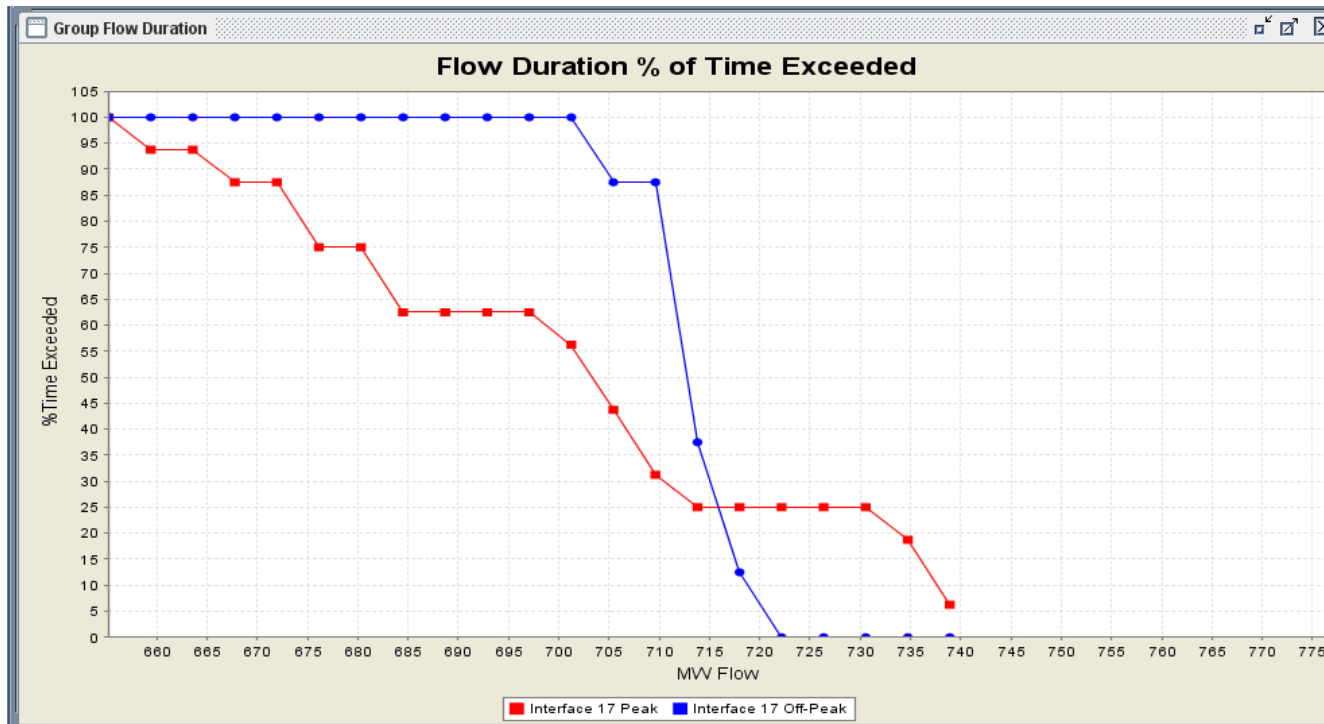


Figure 10 - Flow comparison curves

## 10. Sample Average LMP differences for key APNodes

APNode	season	tou	5 Iterations	High Load	Low Load	High SP Prices	Low SP Prices	Base
HIDSRT_2_UNITS	4	1	0.379592	0.429328	0.407543	0.00378278	0.708209	0.3342234
MEAD_2_WALC	2	1	6.839619	6.476759	5.983339	3.764273	11.80497	5.71266
NP15_EZGTH	4	1	-7.69065	-7.89246	-6.71906	-7.266185	-5.89844	-7.07326
PVERDE_5_DEVERS	4	2	12.16983	12.56576	11.90522	11.22936	17.3156	11.7512
ZP26_EZGTH	1	1	0.234724	0.089145	0.016668	0.7292358	0.02561	-0.1248213

**Figure 11 – LMP differentials**

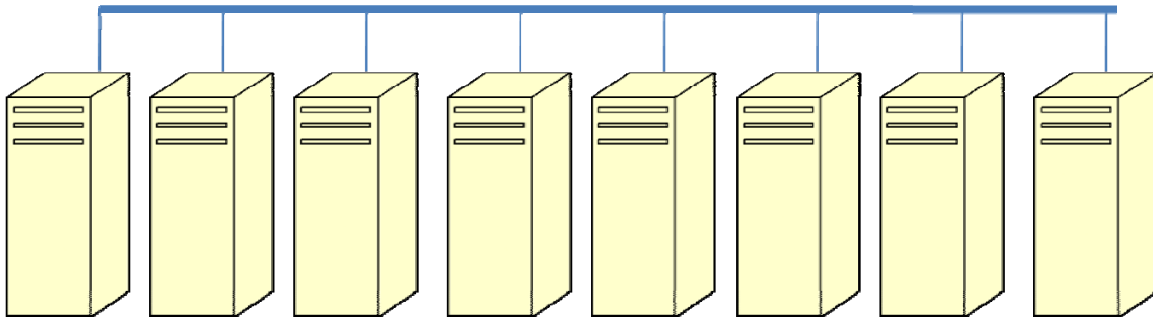
The above is a small sampling of a summary of the LMP differences obtained from studies for key APNodes (Aggregate Points) to illustrate some of the data provided for analysis. A more comprehensive set of results could be provided separately in the form of CSV files containing hourly LMPs and LMP differences. An MS Access Database is also available for each case that contains the LMP difference duration curves and 30%, 50%, 70% and 90% percentile values for each APNode LMP difference. The APNode configuration used by the ECCO programs for the simulation studies is provided by the California ISO.

## 11. ProMaxLT™ Computational Facilities

In order to meet the intensive computation requirements for studies of this nature, ECCO has a server farm facility specifically configured for market simulations. ECCO recognizes that the proposed market simulation studies will require very powerful, intensive computation facilities and has already invested in the hardware facilities to offer this capability. The computational requirements of the study result from the need to execute large scale simulations without deploying any modeling approximations coupled with the large scale California transmission grid and long study periods.

The ECCO server farm facility consists of a main Simulation server which hosts a relational database. This database contains the simulations input and output results. The server farm also includes a number of computation nodes which can be used to perform individual yearly simulations in parallel. This parallelization is critical to reduce the substantial time required to perform and execute a large number of scenarios for the study.

The configuration of the ECCO server farm facility is depicted in the Figure below.



**ECCO Simulation Server Farm**  
**8 X Dual CPU – Intel core duo e6700 CPU**

Figure 12 – ECCO Server configuration