Spanish Power Exchange Market and Information System
Design concepts, and operating experience

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Abstract: Since January, 1st, 1998, the new Spanish: Since January, 1st, 1998, the new Spanish Electricity Market started operations. All generators, distributors, commercialization companies, and final consumers negotiate all power exchanges through the spot market. The Spanish Power Exchange Market Operator (Compañia Operadora del Mercado Español de Electricidad COMEL) is responsible for the management of the market and for the economic settlement of all transactions between market participants.

COMEL has developed its particular IT solution to manage the market. Its main characteristics are full use of internet technologies, security PKI authentication, communications redundancy, and a central database where all information is stored and consulted.

This paper describes in detail the Spanish market principles, the IT solution chosen at COMEL for the management of the market and the experience gathered through the design, installation and first year of market operation. The paper presents also the Spanish market results from January 1998 up to February 1999 indicating each specific market results and aggregate statistics.

Keywords: Power Exchange Market, Daily Market, Hour-ahead Market, Ancillary Services, Internet, Java, HTML, Secure Sockets Layer (SSL)

I. INTRODUCTION

Historically, the supply of electricity was carried out in Spain by a conglomerate of privately owned vertically integrated utilities. Generation, transmission and distribution were owned and managed by the same utility over a certain area. Back in 1985 a public company was created with two roles, to own, plan, maintain and operate the high voltage transportation network, and to schedule all the Spanish generation plants through a global standard per plant cost optimization process. To achieve the first objective, all the preexisting utilities sold their transportation assets to this company.

At the end of 1997, a new Electricity law (54/1997) was released. It establishes a new legal and institutional framework for the electricity sector trying to achieve a triple objective: To guarantee the electricity supply to all consumers, that this supply is made under certain quality conditions, and to reach the two previous objectives at the minimum cost for the end consumer. The law bases the achievement of the objectives on the decisions of the economic agents that are part of the electricity sector, instead of being based on the traditional cost optimization concept.

The law splits the electricity activities in two parts:

- **Non regulated activities**. Electricity generation and selling of energy to qualified consumers, where no central planing is imposed, and the market forces are expected to lead them to the most economical situation.

- **Regulated activities**: Transportation and distribution, where central planning exist to ensure that they are freely available to support the non regulated activities. Also selling of energy at regulated tariffs is maintained during a number of years, until all consumers are considered "qualified".

The law also requires that no company performs at the same time regulated and non regulated activities in the electricity sector, giving the companies that exists today up to the end of year 2000 to fulfill this requirement.

The new law started to be in operation January 1st 1998 and it establishes two privately owned companies to manage the

economic and the technical part of the electricity system respectively. This paper deals essentially with the economic management of the electricity business in Spain, although some references are made to its technical operation.

II. Spanish Electricity Production Market concept

The electricity production market is composed by four independent, although interrelated markets and processes (Fig.1):

- **The daily market**, managed by the Market Operator (MO), This is the fundamental Spanish electricity market and all the rest of the markets and processes are based on its results. The bilateral physical contracts are also integrated on it. This market also includes the technical constraints solution process that is done in cooperation by the MO and the System Operator (SO).

- **The ancillary services market**, managed by the SO that handles the necessary ancillary services

- **The hour ahead market**, managed by the MO. It gives the agents the opportunity to adjust the previous market results to the changes on the delivery/production situation.

- **The real time imbalance correction process**, managed by the SO. It takes care of the generation/load imbalances that appears on real time.

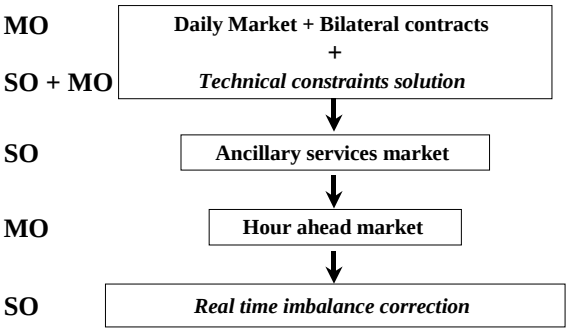

Fig. 1. Electricity Production Market and Processes

Two important characteristics of the Spanish Electricity Market are: All transactions are firm and will be settled and invoiced by the MO, and all markets and processes are paid at the marginal price fixed on the particular market or process.

The Market Operator (MO) company functions: The main responsibility of the company is the economic management of the system. As part of this responsibility, the daily market and the hour ahead markets are operated by the MO, together with the settlement of all the non regulated activities of the electricity sector.

The main functions of the MO are:

- Receive and accept energy bids.

- Determine marginal prices and energy assigned on each market.
- Settlement of all the MO and System Operator (SO) transactions.

- Publish information regarding market results

- Propose enhancements to the market rules

All the MO Electricity Market actions are done according to the market rules that are public and available to any agent or potential agent (downloadable from the MO public WEB site www.mercaelectrico.comel.es)

Agents in the Spanish Electricity Production Market: Agents are those companies or qualified consumers that can act in the Electricity Production market (Fig. 2). The agents are:

Generators: All the generators bigger that 50 MW, that have not contracted the unit (totally or for the contracted part) in a bilateral physical contract, must present bids every day to the daily energy market. Smaller generation units can also participate, if they decide to do so, on the market.

Distributors: Those are the only agents authorized to sell energy at the regulated tariff. They have to purchase all energy in the market and can not get it from bilateral physical contracts. They can not sell energy to "Qualified consumers".

Commercialization or reseller companies: They submit bids to the market to purchase the energy. The energy that a commercialization company obtains in the market could be sold to another commercialization company or to an end "qualified consumer".

Qualified consumers: For a consumer to be considered "qualified" he must have an annual consumption above a certain limit. This limit will decrease with time, until all consumers are considered "qualified". Right now the limit is 5 GWh and by this October only 1 GWh will be required. This type of consumers can purchase energy in four ways, at their choice, mixing them if they want:

- While the regulated tariff exist; from the tariff.

- Through a commercialization company.

- From a generator by the means of a physical bilateral contract between the two parties.

- Directly from the electricity production market.

External agents: Agents from other countries can act in the Spanish Production Market, if they obtain the administrative authorizations that will be granted based on reciprocity conditions. Once they are authorize they will act as generators, commercializators, or qualified consumers.

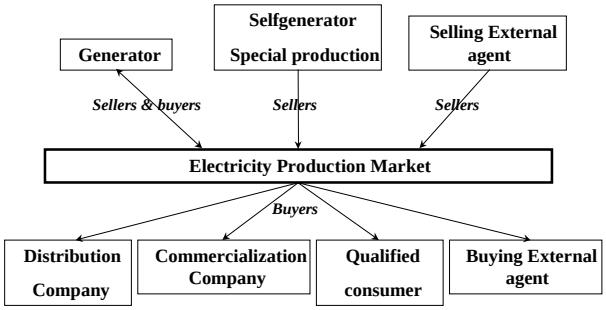

Fig. 2. Agents in the Spanish Electricity Production Market

III. POWER EXCHANGE MARKET

As already indicated, the two main markets operated by the MO are the day ahead market (Daily Market) and the hour ahead market.

A. Daily market organization: The market is organized as a day ahead market, therefore, prior to 10 a.m., each day, all the energy bids for the following day must be presented by the agents to the MO. The market is organized on an hourly basis so the bids and the energy assigned will be in hourly energy blocks. The results are given to all participants prior to 11 a.m. including the daily energy values that the parties of the bilateral contracts communicate to the market that they will execute.

Selling bids are presented to the daily market by generators for all their available capacity, and for every hour (except the capacity that is dedicated to a physical bilateral contract on each hour). Independent selling bids are presented, and scheduled later on, for each physical generation unit, except in the case of Hydro units where all the units that have to be scheduled in a coordinated way due to the water flows in between them, can be presented as a single bidding unit.

Purchase bids are presented by distribution companies, commercialization companies, generators, and qualified consumers.

In the daily market sellers and buyers present only one bid per bidding unit.

Each daily market bid could be divided in up to 25 hourly energy blocks for each hour of the next day (the maximum number of energy blocks that a bidding unit can submit is 24x25). During the energy/marginal price determination process (matching process) there will be no interpolation between the blocks and they will be treated independently. For selling bids the price of the blocks need to be increasing with the energy bided on the hour, and for purchasing bids the price of the blocks need to be decreasing with the energy requested on the blocks.

Selling bids are allowed to incorporate to the bids two different kinds of complex conditions:

- Conditions to single blocks (undivisible block)

- Transversal conditions that impose restrictions for the whole daily bid of the bidding unit (minimum income for the bid) or for some blocks (maximum ramp rates between hours)

In order to preserve the transparency and the fair consideration of all agents, irrelevant of their size and the number of units that they own, the complex conditions are handled by the matching algorithm in such a way, so as to insure that never a complex condition will make the bid to match more energy than the same bid considered as simple.

B. Daily market price determination (matching process): The objective of this process is to provide marginal prices for each hour and energy assigned each hour to each biding unit. The solution to the daily market, including the hourly marginal prices is the unconstraint solution, without taking into account the network situation. These hourly unconstrained prices will be the ones fixed for the daily market and it will be the prices paid by all buyers and earned by all sellers in each hour.

market.

To obtain the results the sellers and buyers curves are formed (actually they are step curves) and the marginal price will be determined by the point where both curves cut.

The matching algorithm for an hour in which there are only simple bids is represented in Fig.3.

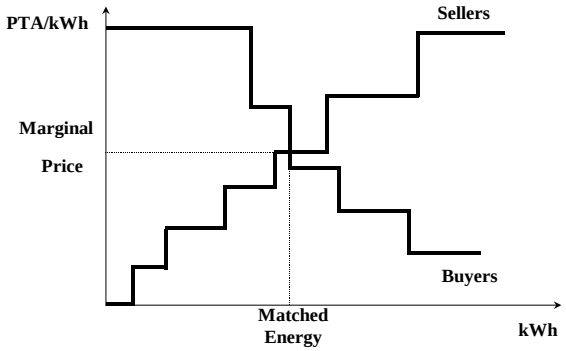

Fig. 3. Each hour Simple Matching Process

The complex bid conditions are satisfied in the way described in the following steps, ensuring always to reach a viable solution, if it exists. The matching algorithm does not try to optimize the solution; it simply tries different combinations but keeping always in mind that a complex condition should never help to allocate more energy to the bid, as compare to the energy assignment that the bid will get without the complex conditions (Fig. 4).

- Step 1. Simple price setting

All bids are considered as simple ones, without any complex condition. A solution (the simple solution) is obtained.

- Step 2. First Viable Solution

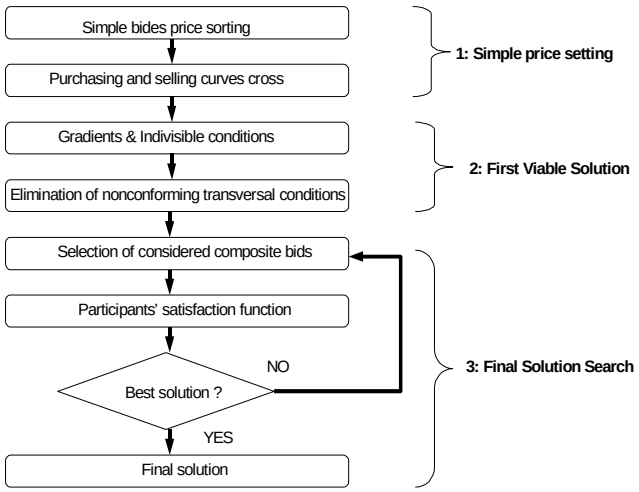

Fig. 4. Daily Matching Algorithm

Starting from the former solution, complex conditions are considered. Energies allocated to each unit are modified to fulfill their complex conditions. At the end of the process, a solution which meets all such restrictions is obtained.

- Step 3. Search of the Final Solution

Once a viable solution has been obtained, the algorithm searches in the solutions space for another viable solution which increases the participants satisfaction with the results. The participants satisfaction has been measured as the minimization of the benefit that the units out of the solution would obtain at the solution market prices. The final solution is the one on which no unit out of the solution would fulfill its complex conditions at the solution's market prices (benefit obtainable equal to 0). When searching in the solutions space, the solutions first tested are those which show, at the previous market prices, the minimum distance to the final solution (minimal benefit obtainable at such prices by the units which are out of the solution).

Once the marginal prices and the schedules of the unconstraint solution are obtained, the schedule is sent to the SO for the technical side of the constraint solution phase. The SO makes use of a contingency analysis program to find the periods of time on which there could be an overload or voltage problem in the network, giving as a result the production units which must increase or reduce their production to avoid these possible problems. Production involved in bilateral contracts is considered in the technical constraints solution in a proportional way with the production assigned in the market. Once security schedule modifications have been decided by the SO, they go back to the MO to balance again the daily energy schedule. Both processes, the technical and subsequent balancing are done respecting the economic merit order of the daily bids, but without any modification to the daily marginal prices. The merit order is obtained by sorting the bids sent to the market, accordingly to their energy block prices. In this processes, again, production involved in bilateral contracts is treated in a proportional way with the energy assigned in the market. At the end of this process the "technically viable daily schedule" is published, and the ancillary services bids are requested and assigned by the SO. It is important to note that this way of solving technical restrictions in the network is working reasonably well in Spain since the network has very little, almost none, embedded constraints. If other countries have a situation where a permanent congestion or technical restriction exist, this simplified procedure may not work and it could distort the solution of the daily market results.

C. Hour ahead market organization: Once there is a technically viable daily schedule published, the MO starts to run several sessions of the hour ahead market, to provided the agents with a market in which to negotiate the voluntary adjustments that they wish to. The hour ahead is a voluntary market where no agent has the obligation to participate.

The intention is to run a session of the hour ahead market each hour, but at the end of February 1999 there are only 5 sessions with the following time horizons (28 hours, 24 hours, 19 hours, 14 hours and 10 hours). The number of sessions will be increased when the procedures are optimized and simplified, and the agents request more sessions.

In any of the hour ahead market sessions, any of the agents (sellers or buyers on the daily market) can participate making several bids (selling or buying energy). The only condition is that distribution companies, commercialization companies and qualified consumers, should have participated in the corresponding session of the previous daily market.

The bid structure and the matching processes of the hour ahead market are similar to the daily process except for the fact that the solution will be added to the previous market results, and that some of the complex conditions, like gradients as an example, need to be applied over the complete schedule (previous market plus the current hour ahead result).

Each bid to the hour ahead market could be divided in up to 5 hourly blocks and, as already indicated, any agent could present as many bids as he wants for the same unit, mixing selling and purchasing bids.

D. Hour ahead market price determination (matching process): The objective of this process is to obtain marginal prices for each hour of the session horizon and the corresponding bid energy assignments. As in the daily market, the solution will not take into account any network constraints. The matching process is similar, but it is important to note that in order to fulfill a complex condition of the hour ahead assignment, it is not possible to remove any of the previous markets assignments since, as indicated, all transactions are firm in all markets and processes.
Once the unconstrained hour ahead market results are encountered they are sent to the SO to check the viability of the transactions. The SO will eliminate from the result the nonviable transactions and will balance the schedule again, respecting the economic merit order of the hour ahead bids.

IV. POWER EXCHANGE INFORMATION SYSTEM (PEIS)

A. Design principles

When the Spanish Power Exchange Market started its operation the 1st of January, 1998, it was the first European market implemented after the 96/92/EC directive, although prior to the EC directive, the England and Wales and Nordic markets, were established . The Spanish regulatory law had just been put into effect and some of the market areas were still not fully defined. There was a need to look for a fast-to-implement and easy-to-maintain and to evolve solution for the application to be developed.

This solution should at least include the following functionalities:

- Receive purchasing and selling bids
- Obtain the market price for each of the considered periods
- Provide market agents with all information needed
- Produce all settlements and clearinghouse activities
- Interchange information with external bodies (SO, mainly)

At the same time, the market was expected to accept in a short time a huge number of potential agents, most of them, demand side customers, not used to operating in the power system and with little experience and knowledge on the IT field. A simple, reliable and easy to maintain solution was therefore needed for the agent's client side.

Moreover, and due to the special importance of the information transmitted (offer bids, acceptance information, etc.) and its economic consequences, special measures had to be considered regarding the security and confidentiality of the information transmitted and the application reliability.

As a consequence of the above points, internet technology was chosen as the cornerstone of the chosen solution. All system accesses are done through the use of an standard browser without requiring any special software product at the agent side. Table 1 shows the encountered problems at the design phase and the chosen solutions. Fig 5, presents the resulting system configuration.

PEIS is built on a star configuration. All external agents accesses to the system are done through the Web Server cluster.

The server connects to the database for introducing or accessing information. All information related to the market is stored in the database. A double firewall protection ensures system security.

Four alternative communication means have been introduced:

- Analog phone lines
- ISDN lines
- Internet
- Extranet (direct lines)

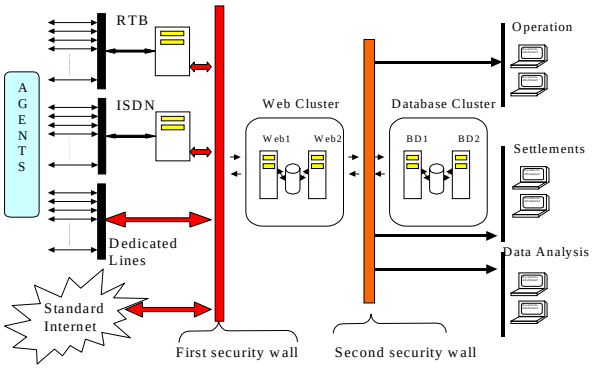

Fig. 5. System configuration

Table 1

DESIGN CONSTRAINTS

Requirements	Answers	Solutions
Unlimited number of agents	Modular design	Internet technology
Minimal needs for agents	Standard software	Avoid special products
Universally accessible	Standard communications	Use available communication facilities:
Controlled security	Up to date security	Firewalls, Smart cards, SSL
Potential agents increase	Scalable solution	All modules expandable
Single fault tolerant	Redundancy	Duplication of all equipment

Each agent, depending on its particular needs, may choose the mean which better adapts to his needs, from communicating through a standard internet connection, to a private direct line. All communication channels and equipment are duplicated and switch automatically in case of failure.

A Public Key Infrastructure (PKI) system, based on smart cards with authentication certificates is used to ensure security during data transmission and data privacy between agents. The application makes extensive use of secure http protocol following the Secure Sockets Layer (SSL3) standard.

B. System Architecture

PEIS has been built as a database centered application. Every action performed in the system is done through the database, which keeps a log of the time and its actor. All market processes (price setting, settlements, etc.) store there their obtained results. All information needed by the agents is accessible through established queries to the same database.

Fig. 6 presents the graphical representation of PEIS's architecture. It includes five main subsystems:

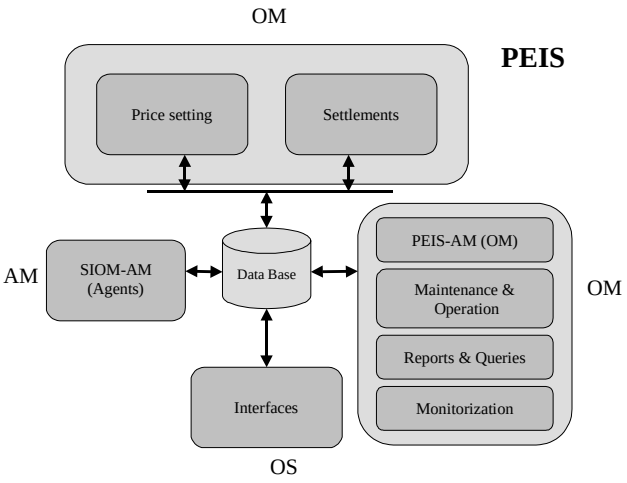

Fig. 6. System architecture

Agents client application. It provides the client application for the agents. It allows them to submit bids and related information to the market and provides agents with an easy-to-use interface to access all market results and settlement information

Price setting subsystem. Responsible of producing the matching between the purchasing and selling bids for both the daily and hour-ahead market.

Settlement subsystem. Responsible of producing all market economic annotations, including the direct market ones and those produced in the ancillary services managed by the SO. It also takes care of the whole market billing process.

External Interfaces. In charge of providing all market with relevant information to the related bodies (SO, specially) and receiving information from them (schedules, measurements, etc.).

Operation & consultations subsystem. Which provides the facilities to operate the market, continuously access to the produced results, monitors the correct functioning of all infrastructure and applications, and includes facilities for producing value-added information from the database.

C. Agent-Client Application

The Agent client application is fully based on internet technology making use of dynamic HTML pages, JAVA and JavaScript code and specific plugins. At the client side, the agent only needs an standard browser to communicate to the market. Specific parts which must be run at the client side (plugins, Java code) are downloaded from the server. Fig. 7 presents the application interface at the agent's side. It includes three main information Frames.

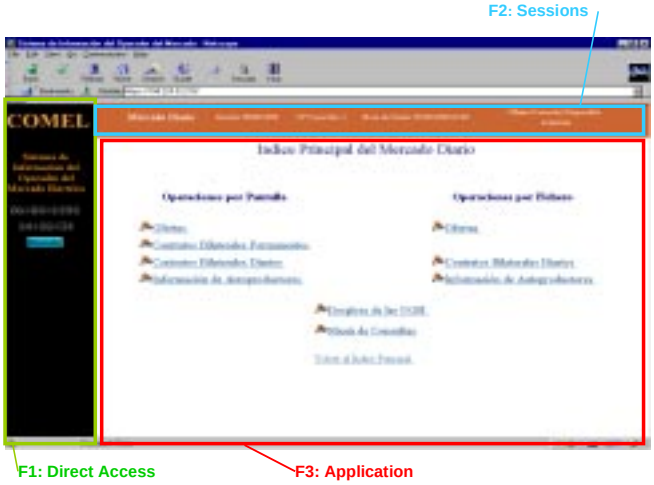

Fig. 7. Agents Client Application

Frame 1, the Direct Access Frame continuously presents the user with the official market time. This time is obtained at the server side through a GPS and is transmitted to all clients when they connect to the market. This frame also introduces a dynamic direct access menu with links to the most frequently used application screens.

Frame 2, the Session Frame, introduces information about the market session (daily, hour-ahead) in operation at that moment. It presents the state of the session (open, close) and its closing time. It also gives information about information availability and information messages produced by the market.

Frame 3, the Application Frame, where the interaction with the application takes place. Through it, agents introduce the market bids and access the market results making use of standard navigation procedures.

Special care has been taken in relation to application usability considerations. Following this path, most common functions and queries are accessible form the direct access menu and all market relevant information may be downloaded from the server as an HTML page or as a formatted easy-to-treat file.

D. Price Setting Algorithm

In spite of its complexity, the algorithm is capable of finding a solution in about 10 seconds for each session. During the months in operation, in no occasion this time has gone above 3 minutes.

V. FIRST FOURTEEN MOTHS RESULTS

The Spanish Power market behavior during the first fourteen moths of operations can be considered very positive. All the scheduled sessions have taken place and prices and energy schedules have been produced according to market rules every day. Despite a few volatile prices during the first days of the market, the prices and the energy schedules could be considered very reasonable. During the last months new comerzialization companies have appear in the market and new qualified consumers are starting to obtain their energy in the market.

In the next graphics (Fig. 8 and Fig. 9) the results of the daily market are represented indicating the market energy volumes and average daily prices. The results are represented in Figure 8 on a daily basis. Prices are represented in PTA/kWh, at an exchange rate of 1$=150 PTA, 5PTA/kWh=3,333 $cents/kWh.

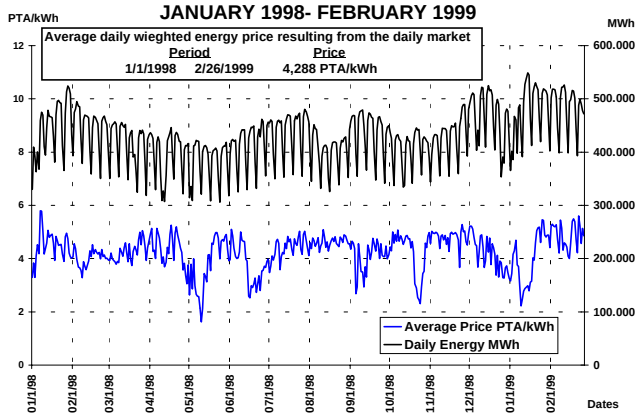

Fig. 8 Daily Market Prices (January 98- February 99)

The differences between the maximum and minimum hourly prices are in the order, as an average, of 2-3 PTA/kWh. As indicated before, the market results are published daily on the company public WEB site.
Fig. 9 represents the amount of energy produced each month with the different technologies.

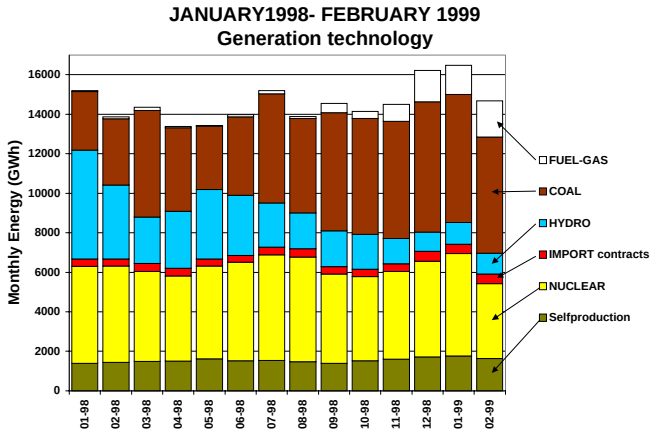

Fig. 9. Generation technology on the daily market (January98- February 99)

The PEIS behavior can be reported as very positive. All market sessions have taken place without problems. A few minor application problems have certainly occurred in some sessions, but the modularity of the system has always allowed for a fast solution, without compromising the market.

In a typical daily market session, about 20,000 simple (energy block) bids integrated in the order of 300 complex bids are submitted. In a typical hour ahead market, this number is reduced to about 6.000 simple bids, but, in this case, around 400 complex bids are received. All bids, specially in the hour ahead market, are generally received in the last fifteen minutes of the session. The matching price algorithm takes about 2 minutes to produce the final results.

Communication design decisions have shown to be a significant success. Main participant agents opted for the connection to the system through direct lines, with a common internet connection or a modem as a back-up. Small agents opted generally for a common internet connection with an analog modem as a backup. Both solutions have proved to be highly satisfactory without presenting performance problems.

Internet technology has proved to be robust enough and specially suitable for a fast changing application like PEIS. In these 14 months, the market definition and requirements have evolved from an initial daily market to the current 5 sessions of the hour-ahead market and the participation of PEIS in the network restrictions solution. These continuous modifications have had to be introduced in PEIS while the system had to maintain its proper operation. As all those changes have only been introduced locally at COMEL's site and the agents have accessed them without having to introduce any change at their site, this process has been done smoothly. There are certain doubts that these changes could have been introduced so fast at COMEL's site, not givingif thethe agents enough time to manage their specific client application modifications at their sites.

Finally, the use of a database as a center of all generated information in the market used for the settlement process, has also produced very positive results. Its position as the only information center has eased the needed modularization of the whole application. Database oriented validation processes have minimized the risks associated to incoherent incoming data. Moreover, all stored information has proved to be a very powerful source of information for obtaining conclusions about the market operation and the different technologies and agents behavior.

VI. FUTURE

Several changes are expected to be introduced in the Spanish Power Production Market, and in the information system in the near future. Mainly:

- As new agents, especially consumers and commercialization companies, operate in the market, new requirements will have to be introduced. The legal

framework already states that the demand participation on the market could incorporate more options.

- New market requirements. The Spanish market may still suffer modifications in the future, specially in relation to new possibilities not implemented yet. An electricity market based on options, or futures may be put in operation in the near future.
- Integration with other countries market. So far, Spain is the first European country which has put in operation a Power Exchange Market after the 96/92/EC directive. In the near future, all European countries will follow this path. Some questions and practical problems will have to be solved for the interaction between these markets.
- Introduction of a full function back-up system. At the moment, PEIS includes a backup system situated at the same company site. A new site has been found with full independent communication capabilities. The challenge lies in the needed coordination between both systems.
- Introduction of Data Warehouse facilities. The current operation database is starting to be almost continuously dedicated to the market activities. There is a plan to add a separate consult-driven database for data analysis.

VII. BIOGRAPHY

Jose Javier Gonzalez. has obtained his Civil Engineering degree from the Madrid Polytechnic University and his M.S. from the Massachusetts Institute of Technology in 1975 and 1977 respectively. He has worked for a consulting company, and for Red Electrica de España, where he was head of the Energy Management System Department. At present, he is the director of bids and energy assignment at "Compañia Operadora del Mercado Español de Electricidad", the Spanish power exchange organisation.

Pedro Basagoiti. .Pedro Basagoiti received his BS in Electrical Engineering and his Phd in Computer Sciences from Madrid Polytechnic University in 1986 and 1989 respectively. He has worked for Madrid University and several consulting firms, in the field of IT applications for electricity utilities. At present, he is the director of information systems at "Compañía Operadora del Mercado Español de Electricidad", the Spanish power exchange organisation.