INTEGRATION OF OPERATIONAL PLANNING AND ENERGY TRANSACTIONS SYSTEMS

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Abstract

This paper describes the conceptual model and architecture of a computing system developed to carry out the data management for the short-term operation planning software and the energy transactions applications of the National Energy Control Center in Mexico (CENACE). This new system, denominated OPDMS (Operational Planning Data Management System), allows to prepare, generate and transfer operational planning data towards real-time and electricity market applications in an efficient, reliable and automatic way.

Keywords: Operational Planning, Energy Transactions, Integration.

Resumen

Este artículo describe el modelo conceptual y la arquitectura de un sistema computacional desarrollado para integrar los datos de la planeación de la operación a corto plazo y las aplicaciones de transacciones de energía del Centro Nacional de Control de Energía en México (CENACE). Este nuevo sistema denominado OPDMS (Operational Planning Data Management System), permite preparar, generar y transferir los datos de la planeación de la operación hacia tiempo real y las aplicaciones del mercado eléctrico en una manera eficiente, confiable y automática.

Palabras claves: Planes Operativos, Transacciones de Energía, Integración.

1. INTRODUCTION

CENACE is a division of the National Electricity Company in Mexico (CFE) and is responsible of the operation control, generation dispatch, operational planning and energy transactions management in the Mexican Power System.

The operation planning along with the operative strategies of security are a process of great importance for the Mexican Power System, since they produce the plans for operation and optimal use of the power resources [1]. For this, it is elaborated the hourly generation schedule daily by using a mathematical programming software denominated CHT-AU [2] (Hydro-thermal Coordination and Unit Commitment System). The purpose of the hourly generation schedule is to guarantee in any time the secure and economic operation of the electrical system.

On the other hand, the management of the energy transactions is based on the operation of an internal energy market between the producers and distribution divisions of CFE [3]. The internal energy market uses a set of computing system, named Market Systems, to calculate the nodal energy prices at which external generators sell energy output to CFE [4]. The Market Systems also calculates payments and charges at which CFE accounts for internal transfer of electricity between its generation and distributions divisions.

The Market Systems functions use CHT-AU outputs as input data. Also, CHT-AU produces information that is used in the Real Time and Control System (SITRACEN).

In order to face the necessity to manage and transfer the operational planning data to real time and market systems, the Mexican Electricity Research Institute (IIE) developed OPDMS, which provides the data with suitable format that require different applications, such as: optimal power flow, calculation of payments and charges to market participants, reliability analysis and economic dispatch. OPDMS also coordinates the store of data in an historical database, which is the core of a Web Site that publishes the market results to the different market participants and divisions of CFE.

OPDMS establishes an automated process of data preparation and transfer between the technical applications. This paper describes in detail the software modules, data flow and communication methods used to obtain the integration of the CHT-AU with SITRACEN and Market System.

2. System Architecture

The system OPDMS establishes an automated process of data collection, preparation and transfer between the operation planning software and the real time and market systems. The dataflow is illustrated in figure 1.

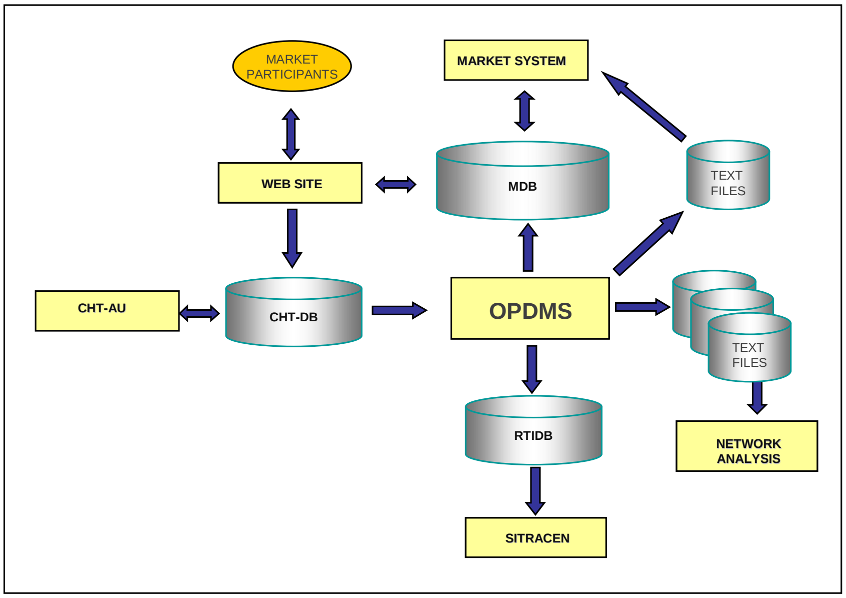

Figure 1 OPDMS architecture

The input data and results of CHT-AU are stored in the planning database (CHT-DB). OPDMS extracts, prepares and inserts planning data in both Market Database (MDB) and Real-Time Interface Database (RTIDB) using embedded SQL routines.

OPDMS also prepares and generates text files in required format that are used as input data for optimal power flow, load flow and reliability studies. This text files are transferred in an automatic way via *ftp* to the market server and some personal computers.

Market Systems obtains most of planning data from MDB. Some market applications such as optimal flow program obtain data from text files in an appropriate format. Market results data such as energy prices, generators payments and purchaser charges are also stored in MDB. In a similar way, SITRACEN obtains the required planning data from RTIDB, but it has their own databases for its real-time applications.

The Web Site publishes market results stored in MDB to market participants. It also has a module that receive generators offers and transfers that data to CHT-DB.

3. OPERATION PLANNING MODULE

The operation planning module (CHT-AU) along with the operative strategies of security produce the hourly generation schedule for a planning period up to 7 days. CHT-AU identifies which both thermal and hydro-electric units are planned to be dispatched to meet demand at the minimum cost, taking into account several operation constraints. This includes which units are to be started or shut-down, and the expected MW level of energy output of each unit.

The hourly generation schedule, depends on generator offers, load forecast and the own characteristics of the network, as well as the control strategy established for their operation. The solution technique takes into account several system and device constraints such as:

- Regional spinning reserve limits
- Generators offers
- Generator upper and lower limits
- Minimum up time and down time
- Unit initial states
- Must run units
- Different types of thermal units: coal fire, oil-fired, gas-fired, mixed fuel, combined cycle plants
- Transmission limits between network zones
- Gas consumption limits for different operative sectors
- Reservoirs upper and lower limits
- Availability fuel (oil, coil, diesel)
- Time delay between reservoirs

A stochastic dynamic programming algorithm is used as a solution technique in the unit commitment:

- First, it determines the optimum scheduling of units, i.e., which units are online for each interval.
- Second, the algorithm performs more detailed allocation using the schedule of the first stage.

A great amount of results are generated and stored in the operation planning database (CHT-DB). These results can be consulted through a graphical user interface and serve like indicators of the feasibility to carry out the proposed operation plan. At this point, the operation planning personnel can decide on accept the plan or make some modifications to the planning data and return to obtain a new operation plan. Once the plan is accepted, OPDMS prepares, manipulates and transfers operational planning data from CHT-DB to the market and real time applications.

4. MARKET SYSTEMS

CENACE is the responsible of the operation of an internal energy market between the producers and distribution divisions of CFE. The internal energy market uses a set of computing systems named Market Systems to calculate the nodal energy prices at which external generators sell energy output to CFE. The Market Systems also calculates payments and charges at which CFE accounts for internal transfer of electricity between its generation and distributions divisions.

The energy market allow and encourage efficient entry of private generators to meet Mexico's need for electricity without losing the benefits of the integration present in the existing system and without imposing large additional costs. It also gives CFE market-based incentives for production and investment. As a means to meet these objectives, the market was designed to ensure that CENACE can operate the system in a reliable manner and that generators have an incentive, through market prices, to follow CENACE instructions.

The principle characteristics of the market design are:

- CENACE is the responsible for both system and market operations.
- Scheduling and dispatch of generators are based on offers received by CENACE.
- Energy prices are calculated for every node of the transmission network, in every hour. The nodal prices are determined based on the marginal cost of supplying energy to each node.

- The settlement is based on the operation of two markets: a Day-Ahead Market and a spot market known as Balancing Market. Separate prices are calculated in the Day-Ahead Market and the Balancing Market for each hour. Most power is sold in the Day Ahead Market. Differences between planned and actual output are paid for at prices calculated in the Balancing Market.

The day-ahead prices must be calculated immediately after the generation schedule has been determined. They are calculated for each hour of the following day and for each node on the electric system representation. The calculation of the day-ahead prices uses the same offers and demand forecast as CHT-AU. The nodal prices are calculated with an optimal power flow program.

5. MARKET DATABASE

The market database (MDB) is the core of the energy market. It serves as a central historical data repository for market data. It resides in a data server running the relational database management system Informix 9.

Everyday, OPDMS and the different market calculating functions interface to MDB to store in an historical way the whole operation planning results and market data such as generation schedule, energy prices, participant payments and charges, network data, etc. This is made by using embedded SQL programs.

MDB is set up in a client-server configuration where it is easily accessed via JDBC by the Market Web Site where market results are published. It is also access via ODBC by various user front end applications developed in Microsoft Access and Excel. These last applications allow market operators generate several reports for presentation or further analysis.

6. WEB SITE

The Web Site is an application that works through the CFE private intranet and whose main functions are the following ones:

Generator offers. This module allows generators to send theirs offers to CENACE. The internet browser presents several templates that generators have to fill. The offers are received, validated and processed by the Web Site. If errors are found, they are reported back to the generators, otherwise, the offers are registered in CHT-DB.

Market information publishing. This module publishes the market information to the market participants. This information includes generators offers, generation schedule, nodal prices, generator payments, purchaser charges, and statistical graphics related to market results.

The development of the Web was made using Java technology based on servlets. The Web Site is constructed in architecture of three layers; the first layer is the internet browser that allows market participants to interface to market systems; in the second layer, the Web server receives the information requests by market participants, and constructs in a dynamic way the HTML pages; finally, in the third layer, the data server received information request by the Web server and extracts or inserts the required information in the corresponding database.

7. DATA MANAGEMENT MODULE

Operational planning data must be manipulated and transformed into the form that is applicable in the Market and Real-Time Systems. OPDMS gives the facilities to collect, prepare, manipulate and transfer operational planning data from CHT-DB to the market and real time applications.

Everyday, when the hourly generation schedule has been determined, OPDMS runs an automatic process that includes the following tasks:

- **Data collection**

  The first task of OPDMS consists on data extraction from the different data tables of CHT-DB. The data extracted correspond to the hourly intervals of the day-ahead. Due to CHT-AU is not a relational database, it was necessary to develop Fortran routines instead of embedded SQL routines. The collecting data is temporarily stored in memory arrangements.

- **Estimation of equivalent hydroelectric cost models.**

  Equivalent cost models of hydroelectric units are estimated for each hourly interval so that they can be considered as thermoelectric units in power systems analysis and market applications; the water cost is used as the fuel cost of these units.

- **Estimation of equivalent cost models of combined cycle plants**

  Equivalent cost models of combined cycle plants are estimated for each hourly interval so that they can be considered as single units in power systems analysis and market applications.

- **Nodal load distribution.**

  System load forecast is organized using load scenarios. A load scenario contains nodal factors that correspond to a specific season, day of the week and hourly interval. Nodal loads are estimated from area load forecast using the corresponding nodal factors.

- **Interface to Market System**

  Operational planning data is transferred to the MDB. This information includes the necessary data for the programs that are used in the market to determine energy prices, payments to generators and charges to purchasers. The transferred information is shown in the following table:

Data group	**Detail**
Operation planning results	Generation schedule (unit status, unit energy output)
Network	Buses, transmission lines and transformers parameters, shunts, etc.
Generators models	Maximum/minimum MW output, offers, heat rate curves, start up costs, minimum up time and down time, equivalent cost models for combined cycle plants, equivalent cost models for hydroelectric plants, etc.
Operation constraints	Spinning reserve and transmission limits.
Relation of nodes and generators with regional subsystems or CFE divisions	Relationships of nodes with area control centers and distribution divisions, relation of generators with plants, generation divisions and areas.
Load forecast	Nodal loads and scheduled interchanges between areas.

Table I. Transferred data to Market Systems

- **Interface to Real Time System**

  Operational planning data is transferred to the RTIDB. This information includes the necessary data for the economic dispatch, and the programs that determine the planned reservoir sensitivity coefficient. The transferred information is shown in the following table:

Data group	**Detail**
Operation planning results	Unit MW schedule, unit status, interchange schedules, hydro reservoir schedules, operating cost, reserve zone MW required, merit list.
Hydraulic data	Planned water value, planned reservoir elevation, forecast natural water inflow
Network	Buses, transmission lines and transformers parameters, shunts, etc.
Generators models	Maximum/minimum MW output, offers, incremental heat rate curves, start up costs, minimum up time and down time, equivalent cost models for combined cycle plants, equivalent cost models for hydroelectric

	plants, operating, maintenance & transportation cost etc.
Operation constraints	Transmission limits, availability fuel schedules (hourly, daily, etc.)
Load forecast	Nodal loads and scheduled interchanges between areas.

Table II. Transferred data to Real-Time Systems

- **Text files exportation**

IEEE text files are prepared and exported to the market server and some personal computers for be used as input data in power system analysis programs such as load flow, optimal power flow and reliability analysis. These files include data of electric network, generator models, generation schedule, operating system constraints, nodal loads, etc.

8. HARDWARE ARCHITECTURE

The different modules of operational planning and market systems reside in several computer servers that work through the private CFE intranet. These computer servers are denominated as follows:

- Market Server
- Operational Planning Server
- Web Server
- Data Server

Figure 2 shows an overview of the hardware structure adopted for the integrations of operational planning and market systems.

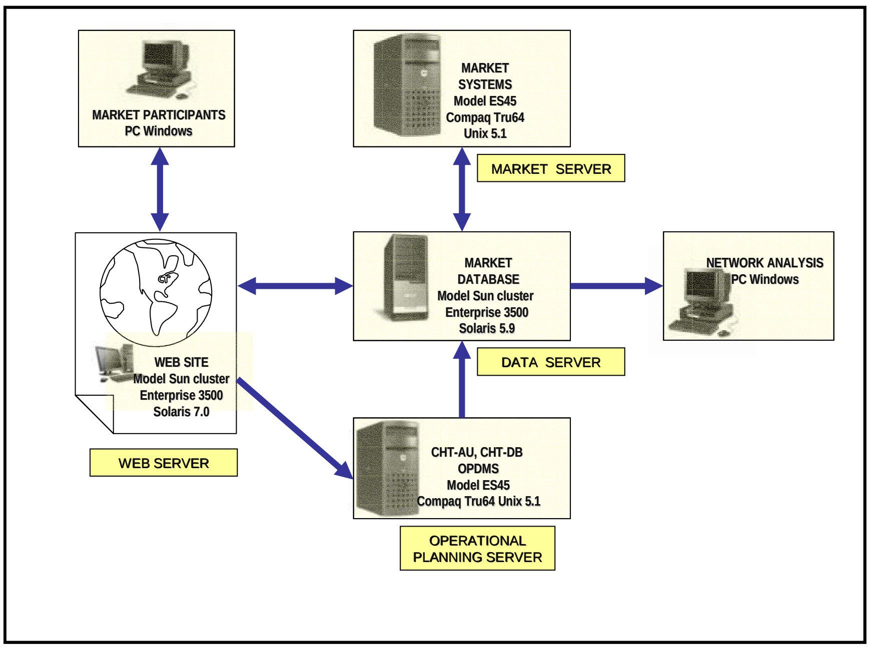

Figure 2 Hardware Architecture

9. CONCLUSIONS

This paper presented the conceptual model and architecture of OPDMS, a computing system developed to interfaces the short-term operation planning software to transactions applications and real-time systems of the National Energy Control Center in Mexico. There were described the software modules developed to collect and manage great amount of modeling data from a proprietary operational planning database and exchange that data to market and real-time applications. There also were presented the data flow and the hardware architecture adopted to integrate these applications, as well as tables with detailed description of data exchanged .

Nowadays, OPDMS is one of the key tools used daily at CENACE to carry out the operation of the internal energy market and real-time operation, because allows to prepare, generate and transfer operational planning data towards market and real-time systems in an efficient, reliable and automatic way.

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