ABSTRACT

The electricity sector in Mexico is undergoing a process of significant structural change. Traditional industry framework in the country has been exposed to new market structure and greater competition, and has been introduced also by changing regulations on who can generate, transmit, distribute and sell electricity.

In Mexico, the electric sector has been undergoing a process of deregulation, throughout the 1990s. The sector has been opened to private participation in generation, and policy makers and participants are studying various power sector structural models that have been implemented in other countries in order to help shape the future of the Mexican power sector.

Planning and operating problems will be more complex under this competitive environment; the uncertainty associated to private producer investments is a challenge in the development of planning strategies.

Another area in which there is particular interest is the potential for increase cross – border trade in electricity between Mexico and the United States and very recently between Mexico and Central America. Such an increase would provide economic benefits to all countries, which is of course the primary reason for engaging in trade.

Although international interconnections are now in use, the total amount of energy exchanged between Mexico and the United States is relatively limited as well as between Mexico and Central America.

KEYWORDS


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1. INTRODUCTION

In recent years many electric utilities in the world have started implementing important changes in their organization in order to promote efficiency and improve their financial situation. \(^{[1]}\) Most of the changes in the power industry are related to the introduction of competition and disaggregation of electric services. \(^{[2]}\) The unbundling of generation, transmission and distribution has altered the nature of traditional planning and operation approaches used by the vertically integrated utility. This process has started in Mexico \(^{[3]}\) where power industry is changing to a competitive integrated model.

The generation of electric energy is open to private investment for external (i.e. non-utility) production, through the ownership, design, construction, maintenance and operation of power plants. It is expected that a large portion of the generation capacity additions required to face future load demand will be met by non-utility generators. \(^{[4]}\)

2. DESCRIPTION OF CFE ELECTRIC SYSTEM

Generation Structure
At the end of 2002, the National Electric System (NES) had an estimated total of 166 power plants – 79 hydro, 88 thermal, and 1 wind-powered with 511 units. The estimated installed generation capacity is 41,177.27 MW; 56.8 percent of this total is conventional steam units, combined-cycle units and gas turbines burning fuel oil, natural gas and diesel: 25 percent is hydro units, most of them located in the southwest of Mexico; 7.5 percent is steam units using domestic coal as fuel; 5.5 percent of the capacity is dual units burning fuel oil or imported coal; 2.2 percent is geothermal plants; and less than 1 percent is wind power stations.

Electric Energy
Total estimated energy production in 2002 was 201,059 terawatt – hour (tWH), with a maximum load demand of 28.19 gigawatts (GW); 59.8 percent of this total was sales to industrial and high voltage customers; 24.7 percent was to residential users, 8.4 percent to commercial customers, 5.8 percent for agricultural irrigation, 4.6 percent for municipal services such as street lightning and water pumping, and the remaining 1.7 percent was exports to electric utilities in the US and Belize. The average number of customers served in 2002 was 37.1 million.

Transmission Structure
The national grid is formed by a transmission system based on 400 kV, 230 kV and 115 kV lines that cover most of the country. Today only Baja California Peninsula remains isolated from the main electric network. Figure 1 shows a schematic diagram of the Bulk transmission system.

![Figure 2.](image-url)
The main transmission system consists of 38,561 kilometers of high voltage lines, and total installed substation capacity is 119,707 mega – voltamperes (MVA). The bulk transmission system is made up of 400 kV transmission lines (16.5 percent), 230 kV (27.8 percent) and 161 to 69 kV lines (55.7 percent).

3. CFE ELECTRIC SYSTEM PLANNING PROCEDURES

CFE is the only organization responsible for the planning of electrical systems in Mexico [5]. Resources, generation, main transmission and subtransmission planning are handled by the Subdirección de Programación (SP) in central offices of CFE.

The Regional Distribution Centers are responsible for distribution planning in coordination with the central office. Expansion of the system is based on an integrated scheme in geography and time.

Due to the complexity of the problem, it is solved by decomposition in time hierarchy (long – mid – and short term) and by geographical hierarchy (generation, bulk transmission, regional subtransmission and distribution networks), complemented by global and marginal analysis. The scheme is shown in Table 1.

In general, planning studies are characterized by greater uncertainties as they cannot account for unforeseen future developments, thus limiting detailed analysis. The structure of the electric system can be planned in varying degrees of detail, taking into account probable scenarios involving availability and cost of resources and technologies.

Table 1. Power System Planning Procedure Scheme

<table>
<thead>
<tr>
<th>Term</th>
<th>Network Studies</th>
<th>Generation Studies</th>
<th>Bulk Transmission</th>
<th>Subtransmission</th>
<th>Distribution</th>
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<tr>
<td>Long Term</td>
<td>N</td>
<td>Guidelines for Site</td>
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<tr>
<td>Year N+10</td>
<td>N+10</td>
<td>Generation Allocation</td>
<td>Expansion of Power Plants</td>
<td>Site Allocation of Generation Plants</td>
<td>Transmission Program</td>
</tr>
<tr>
<td>To N+30</td>
<td>N+10</td>
<td>Generation Program</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Transmission Program</td>
</tr>
<tr>
<td>Mid-Term</td>
<td>N+5</td>
<td>Generation Program</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Transmission Program</td>
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<tr>
<td>Year N+5</td>
<td>N+10</td>
<td>Generation Program</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Site Allocation of Substations and Bulk Transmission</td>
<td>Transmission Program</td>
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<tr>
<td>To N+10</td>
<td>N+10</td>
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<td>Site Allocation of Substations and Bulk Transmission</td>
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<td>Transmission Network Design and Decision Adjustment</td>
<td>Subtransmission Program Decision Adjustment</td>
<td>Distribution Program Decision Adjustment</td>
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<td>Year N+3</td>
<td>N+5</td>
<td>Generation Decision</td>
<td>Transmission Network Design and Decision Adjustment</td>
<td>Subtransmission Program Decision Adjustment</td>
<td>Distribution Program Decision Adjustment</td>
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<td>To N+3</td>
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<td>Subtransmission Program Decision Adjustment</td>
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<tr>
<td>Year N</td>
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<td>Subtransmission Program Decision Adjustment</td>
<td>Distribution Program Decision Adjustment</td>
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<tr>
<td>To N+3</td>
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<td>Current Year</td>
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With the locations, sizes and dates determined for the hydroelectric and thermal plants several models are used for planning the required electrical network. [6,7,8]

The planning scheme is aimed at minimizing the expected investment and operational costs, which are subject to the technical and economic constraints that usually arise in large interconnected systems comprised of thermal and hydroelectric power.

4. ELECTRICITY SECTOR RESTRUCTURING DEVELOPMENTS

Modernization for structural change

On June 2, 1999 CFE undertook a formal corporate transformation project consisting of creating business units with greater management autonomy and technical – economic results centers, as well as simulating an internal power market which would allow the company – without making any amendments to the existing legal framework – to operate within a competitive framework that will result in greater operational and financial effectiveness. [9]
Since August 2000, the Corporate Transformation Program (CTP) has already achieved, the following goals:

To project CFE towards its transformation into a modern entity with administrative and operational processes that are transparent and cost effective, in addition to providing a more flexible structure by decentralizing its functions and strengthening its services.

To foresee CFE’s possible opening to investors in order to increase electric power generation, through the design of an internal power market that would in turn, assess the company’s results within a market environment and to correctly assess its generation assets.

Competitiveness among business divisions is necessarily reflected in better transactions prices and sales to the NES. This will insure in long run benefits for the consumers.

Therefore, since August 2000, a structure was projected in which CFE would act as the corporate entity evolving into a series of divisions in charge of generation, the operations system and electric power dispatch and transfer and distribution, except for the isolated electric systems of Baja California (see Figures 1 and 2).

Based on the foregoing, the following basic criteria have been established for the transformation process.

- Maintaining the operational stability and integrity of the NES.
- Ensuring technical and economical feasibility.
- Creating a shadow power market.

5. EXISTING BORDER INTERCONNECTIONS BETWEEN MEXICO AND THE US.

There are 13 electrical interconnections between the US and Mexico, as illustrated in Figure 3. Total transfer capability is less than 900 MW, including 150 MW which is operated in a normally open mode.

The two 230 kV interconnections between San Diego Gas and Electric (SDG&E) and CFE can handle 800 MW. Two interconnections between CFE and El Paso Electric Company (EPECO) are 115 kV with a combined capacity of 200 MW. Three interconnections between CFE and Central Power and Light (CPL) are 138 kV with a transfer capability of 150 MW but operated in a normally open mode. Recently CFE and Central and South West Corporation (CSW) installed an asynchronous electrical tie using HVDC light technology. [10,11] The tie is rated at 36 MVA at 138 kV and allows an interchange of power between US and Mexico in both directions under open access without interfering with the surrounding system, enabling the parties to trade electricity with each other in a mutually beneficial way.
Finally there are four 69 kV interconnections with a total transfer capability of 120 MW, and two distribution connections with a combined capacity of only 14 MW. Minor improvements could be made to expand emergency services but a material increase in cross border trade will require significant expansion of existing transmission capacity.

6. US/MEXICO BORDER GENERATION INTERCONNECTION STUDY

The evolving power supply problems in California have prompted many proposals for short – and mid term solutions to this growing energy crisis. In the short term, the CFE and SDG&E are evaluating opportunities for increased power and energy exports from Mexico to the US.

In the mid term, several major power plants, most notably the Otay Mesa (558 MW) and Sempra (600 MW) projects are proposed for development in the border area (see Figure 4).

CFE is cooperating with SDG&E to evaluate the ways and means to increase the rating of Path 45 so as to deliver up to 1,600 MW to California by 2005.
7. Potential Near-Term CFE/ERCOT Interconnections

The Comisión Federal de Electricidad (CFE) and the Electric Reliability Council of Texas (ERCOT) have a long history of emergency assistance across the México/United States border. The recent study continues that tradition by performing a contemporary analysis of the CFE and ERCOT transmission systems to determine the short-term (Phase I) and long-term (Phase II) opportunities for interconnections. The study is separated into phases as follows:

**Phase I:** immediate consideration of support to the ERCOT transmission system along the Texas border where older inefficient generation is no longer economical to operate. In addition, synchronous ties may allow new block load support in remote areas where lengthy transmission additions are required. Phase I alternatives leverage the existing interconnections and infrastructure that do not require lengthy regulatory review.

**Phase II:** will evaluate opportunities for long-term interconnections that can support additional economic transactions and emergency assistance between CFE and ERCOT. Phase II studies will not be constrained by infrastructure limitation, and they are likely to involve new transmission improvements for higher transfer capabilities.

In both phases, both high voltage synchronous and asynchronous transmission interconnections will be considered, but the primary effort is focused on asynchronous interconnections that utilize Flexible Alternating Current Transmission Systems (FACTS) technology to allow the scheduling of power transfer between the electrical grids.(see Figure 5).

![CFE and ERCOT Systems along the México and United States Border](image)

**Figure 5**

8. TRANSMISSION PLANNING MODELS.

The purpose of transmission planning is to identify a flexible, robust, and implementable transmission system that reliably facilitates commerce and serves loads in a cost-effective manner.

Meeting this planning goal requires both technical analysis of different transmission system configurations and economic analysis of different transmission projects.

Different models are used by CFE for steady-state, dynamic, and short circuit analysis, and then recommend the most cost-effective projects as part of the transmission plan.
9. KEY PLANNING ISSUES AND COMPLEXITIES.

Reliability against commerce.
Traditionally, vertically integrated utilities planned their transmission systems with two goals in mind:
- Meet reliability requirements.
- Ensure that the outputs from the utility’s and non-utility’s generation could be transported to the utility’s customers.

Today, transmission systems are called on to do much more. They must serve dynamic and rapidly expanding markets in which the flows of power, into, out of, and through a particular region vary substantially over time.

As a consequence, it is not clear whether transmission planners should focus exclusively on the Planning Standards in assessing alternative transmission projects or whether they should also consider enabling competitions to occur over large geographic regions.

Congestion Costs.
Traditionally, vertically integrated utilities integrated their transmission and generation planning and operations.

This coordination recognized any generation redispatch costs associated with the prevention of congestion during real-time operations.

In competitive electricity markets, with generation separated from transmission and system control, congestion pricing can offer valuable information on the potential benefits of new transmission investment.

Decisions on whether to build new transmission are complicated by uncertainties over the future costs of congestion. These uncertainties relate to load growth, the price responsiveness of load, fuel costs and therefore electricity prices, additions and retirements of generation capacity, and the locations of those generators.

Assessment Criteria.
The electricity industry and its regulators would benefit from objective assessment criteria that can be applied to the transmission planning process and to the resultant plans.

Transmission plans should be low in cost, robust, and feasible to implement. To achieve these three objectives, the plan must consider a wide range of transmission and nontransmission alternatives relative to a variety of future load and generation scenarios.

The assessment must consider compliance with reliability standards as well as commercial uses of the grid.

Because of these many disparate factors, it is unlikely that the preferred plan will be the lowest-cost solution. Instead planners should choose plans that are robust across a range of future scenarios, which means they may be least-cost for none of the scenarios.

9. CONCLUSIONS

New laws and regulations have started the transformation of the electric power industry in Mexico. Two state-owned electric utilities had a monopoly in generation, transmission, and distribution of electric energy in the country. Electricity market has been opened in the long term generation business and competition between CFE’s generation units and private non-utility generators has been introduced.

Planning and operating problems will be more complex under this competitive environment; the uncertainty associated to private producer investments is a challenge in the development of planning strategies.

The evolving power supply problems in California and Texas have prompted many proposals for short-term and mid-term solutions to this growing energy crisis. In the short term CFE, and ERCOT are evaluating opportunities for increased power and energy exports from Mexico to the US.
In the mid-term several major power plants are proposed for development in the border area. CFE is cooperating with ERCOT to evaluate the ways and means to increase the existing rating of 138 kV paths so as to deliver up to 300 MW to Texas by 2005.

The introduction of the electricity market has resulted in new frames and considerations in transmission network planning. As more and more countries are liberalizing the electricity sector, a number of questions have been raised regarding the transmission network planning.

A number of key issues have been listed and classified as the most important due to the changed conditions. The most important ones are:

- Uncertainties in electricity prices (market prices).
- Uncertainties in regulation and transmission pricing.
- Possibility of financing new interconnections.
- Uncertainties in development in international markets.

These uncertainties call for a new planning approach.

**BIBLIOGRAPHY**


