Abstract: Private investment in generation plants in Ecuador has been null over the last 10 years due to several political and economical factors. The only important hydro plant over that period, a 250 MW plant, was constructed by the Ecuadorian State. At present, the Ecuadorian State and the Ministry of Electricity are the only ones initiating the construction of new hydro plants of significant capacity for the country. This reveals the failure of the existing competitive market model that has been in place for the last 10 years, particularly in relation to incentive to private investment. Arguments are being raised to return to a centralized mandatory planning scheme, under government direction, where the important hydro investments are made by the State and private investors are left with the thermo projects and small hydro. The presentation will discuss the hydro developments and future prospects.

Index Terms— Power system expansion, energy matrix, hydroelectric plants, energy policy.

I. INTRODUCTION

Currently the Ecuadorian State is reactivating many important hydro projects such as: Coca Codo Sinclair (1500 MW), Sopladora (500 MW), Mazar (180 MW), Toachi Pilatón (320 MW), Minas La Unión (380 MW). The entrance of these projects will have an important impact in the power matrix of Ecuador, its energy prices and the electricity transactions with neighboring countries.

The panel presentation will provide a technical and economical analysis of the impact of the entrance of the hydro power plants in the operation of the Ecuadorian electrical system. For the analysis, technical tools for expansion planning (OPTGEN) and operation simulation (SDDP) will be used. Results will be analyzed and the main conclusions presented in order to obtain a long term vision respect to the power matrix and the electrical operation of the Ecuadorian Power System.

II. ECUADORIAN ELECTRIC POWER SYSTEM

Ecuador’s area is 256,370 km²; its population is around thirteen million. It is crossed by the Andes Mountains, this characteristic origins three different natural areas: Coastal Region, that represents one fourth of the country’s area and which includes nearly 50% of the population; Highlands, that represents another one fourth of the country’s area and which includes less than 50% of the population; and finally, Amazon Region, that represents the rest of the country’s area and which includes around 5% of the population. Also, Galapagos Islands are part of the Ecuadorian territory but the electric service is provided by an isolated system.

Since April, 1999, the Ecuadorian Wholesale Electricity Market (MEM) started, based on the Ecuadorian Electricity Law (LRSE) leaving a vertically integrated model, regulated by CONELEC (Ecuadorian Electricity Council). Appendix A provides statistical information on the Ecuador electricity market.

By December, 2006, MEM was composed by 17 generation agents (8 of them privately owned, 8 State owned and 1 temporally administrated by a government agency), 1 transmission company and 20 distribution companies (18 pertaining to the interconnected grid-SNI- and 2 isolated systems). All distribution companies belong to government organizations.

I. GENERATION INFRASTRUCTURE

From 1997 to 2006, the hydroelectric generation to total generation ratio has decreased from 55 % in 1997 to 48% in December, 2006, as shown on figure 1. This variation is considered adverse from economical, energetic and environmental points of view.

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The considered future hydro projects are the following:

1. Mazar. 190 MW plant located upstream of Paute plant. Mazar will be capable of producing approximately 871 GWh per year, and reinforce the energy production of Paute plant, summing up to 6,380 GWh per year both plants. It is considered that Mazar will begin operation by the second semester of 2009. Energy produced by this plant will substitute an estimated of over 100 million gallons of fossil fuels.

2. Sopladora. 320 MW plant located downstream of Paute plant. Sopladora will contribute with approximately 2,700 GWh per year. Its commercial operation is estimated to begin in the first semester of 2011.

3. Toachi Pilatón. This 228 MW plant production will be around 1,120 GWh per year and is considered to begin commercial operation in the second semester of 2012.

4. Coca Codo Sinclair. Considered as a priority project, this 1,500 MW plant is estimated to begin commercial operation in the first semester of 2014. The energy production is estimated to be around 10,370 GWh per year.

5. Minas & La Unió. These two projects, Minas of 300 MW and La Unió of 80 MW are estimated to begin operation in the first semester of 2012.

The largest hydroelectric plants lie in the Amazon watershed, where rainy season occurs usually between April and September and the dry season is between October and March opposed to the Pacific watershed. That is why the maintenance of the hydroelectric plants is programmed for dry season and the maintenance of the thermoelectric plants for the rainy season. Figure 5 shows the energy contributions of the new considered hydroelectric projects, and also the energy expected to be produced by existing plants.

In figure 6, energy contributions of hydroelectric projects without considering Coca Codo Sinclair plant are presented. The high contribution of new Pacific watershed projects is appreciated.

In figure 7 the percentage composition of hydroelectric generation considering Amazon watershed and Pacific watershed including future projects is presented. Figure 8 shows the same composition but not including 1500 MW from Coca Codo Sinclair project.

### III. TECHNICAL AND ECONOMICAL ANALYSIS OF FUTURE HYDRO POWER PLANTS IN ECUADOR

Demand forecasted for the analysis in given in Appendix B.

In 2007, 88% of hydroelectric power capacity is covered by the 5 largest plants: Paute (1,075 MW), San Francisco (230 MW), Marcel Laniado (213 MW), Agoyán (156 MW) and Pucará (74 MW). Four of them are located in the Amazon watershed and only Marcel Laniado plant is located in the Pacific watershed.

The considered future hydro projects are the following:

- 230 kV tie line with Colombia, 250 MW, 2003.
energy balance is shown. Additional 300 MW of thermal generation or an equivalent on energy imported from Colombia are needed to cover the possible deficit. Starting 2012, this thermal generation effect begins to decrease, caused by the entrance of new hydro projects like Sopladora, and getting to a minimum by 2015, when Coca Codo Sinclair gets fully functional.

The evolution of marginal energy costs for both cases is presented on figure 11. The 2 year delay on the entrance of Coca Cod Sinclair project will cause a significant increase on energy prices due to the thermal energy needed. This delay will cause not only energetic but also economic inconveniences, fossil fuels consumption will increase significantly, on figure 12 the estimated consumption for diesel, fuel oil and bunker if Coca Codo Sinclair project entrance delays for 2 years. An increase of about 150 million gallons is expected, the difference is shown on figure 13. The increase in fuel consumption represents an estimated of $80 million considering today fuel prices to keep constant.

An analysis considering a possible 2 year delay on the entrance of Coca Codo Sinclair project was made, the objective was to detect possible energy shortages needed to be covered by additional thermo electric energy. In Figure 10 the resulting energy balance is shown. Additional 300 MW of thermal...
V. FUTURE EVOLUTION OF COSTS AND ELECTRICITY RATES

The evolution of future average generation costs is analyzed to provide an outlook of how future energy contracts prices will evolve. Average production cost for each generation unit is separated in fixed and variable costs. An 11.2% discount rate is used.

Resulting average generation costs are shown on figure 14. Their evolution presents a decreasing rate, starting on $37.84 per MWh in 2008 to $32.24 per MWh in 2017.

The Spot Market bill includes: purchased energy in spot market to accomplish contracts, power, reserves, etc. Also, the power to be compensated in the contract market is cleared off in the spot market. It is important to clarify that the distribution tolls are not considered.

The average energy price in MEM was 6.14¢/kWh as a result of the following:
- 9.64¢/kWh in the Spot Market; and,
- 3.66¢/kWh in the Contract Market

The Transmission Grid transported 14,439.06 GWh with 3.1% of power losses. The Transmission Company billed $103.41 million and the unit price was 0.716¢/kWh.

Total MEM income for exported energy during 2006 was $49.71 thousand. Total charges for imported energy were $124.98 million.

III. APPENDIX B. - DEMAND PROJECTIONS

Forecasted power and energy demand considering a medium increase scenario is shown, yearly on table 1 and monthly in figure 16.

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<th>Year</th>
<th>Non Coincident Maximum Demand (MW)</th>
<th>Maximum Demand (MW)</th>
<th>Energy (GWh)</th>
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<td>2,939</td>
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<tr>
<td>2009</td>
<td>3,073</td>
<td>2,980</td>
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<tr>
<td>2010</td>
<td>3,208</td>
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<td>2011</td>
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<td>2017</td>
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<td>24,168</td>
</tr>
</tbody>
</table>

Table No. 1 Demand and energy forecast
Figure 16. Monthly demand forecast 2007 - 2017

VII. BIBLIOGRAPHY


VIII. BIOGRAPHIES

Gabriel Salazar, graduated as Electrical Engineer from Escuela Politécnica Nacional of Quito, Ecuador and Doctorate in Electrical Engineer from Instituto de Energía Eléctrica of San Juan, Argentina. He is presently the Director of Electrical Tariffs in the Electric Regulator of Ecuador. He is professor of the Electrical Sciences Magister program in Escuela Politécnica Nacional of Quito, Ecuador.

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