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SIAMESE TWINS: THE GAS AND ELECTRIC SECTORS IN BOLIVIA

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Resumo

Pela definicao de "Siameses" (um de um paquete de gêmeos com seus corpos unidos), esta poderia ser aplicada ao setor elétrico e de gás na Bolívia.

Neste trabalho, é apresentado um modelo que simula a operação dos sistemas elétricos e sistemas de gás, em coordenação e simultaneamente Considerando a inter-relacionamento e interdependência entre ambos sistemas. Esta ferramenta foi desenvolvida por iniciativa de Transredes para ajudar na procura de soluções a um numero de temas como considerações de locação de plantas térmicas, capacidade dos dutos, linhas de transmissão, quedas de produção de gás e eletricidade, etc.

No artigo é apresentada esta ferramenta e uma descrição do setor elétrico e de gás da Bolívia, dos problemas relacionados a interdependência de ambos setores, assim como o processo para desenvolver o modelo, seus potenciais usos em operação, regulação, planejamento. No final um resumo da situação atual dos sistemas elétrico - gás a junho, 2007 assim como conclusões.

Abstract

The Definition of "Siamese" (one of a set of twins born with their bodies joined), could be applied to the electric and gas sectors in Bolivia. Significant current and increasing gas participation in power generation enhance the interdependence of both systems.

A model that simulates the operations of the Bolivian power and gas chains, jointly and simultaneously, has been developed as a tool to address a variety of issues: sitting considerations of gas-fired power plants, definition of incremental pipeline capacity, transmission lines capacity, management of gas and electricity production shortages and capacity curtailment, etc.

The paper presents a description of the gas and electricity sectors in Bolivia, the issues related to interdependency, as well as the model development process, and its actual and potential uses in operation, regulatory and planning matters. Conclusions and recommendations, derived from model simulations incorporating data up to mid-2007 are presented.

1. Introduction

The Bolivian power and gas markets are relatively small at the Southern Cone level and in relation to the Bolivian natural gas exports. However, there has been sustained growth in power and natural gas demand, 8.6% and 9.2 % in 2006.

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Historically, Bolivian power generation was primarily hydro, with sufficient reservoir capacity to handle seasonal variations in the availability of run-of-the river plants. The relative low capex of gas turbines, coupled to the low gas price (capped at 1.30 US$/MSCF since 1994, MSCF = million standard cubic feet) has resulted in a system that is currently 53% gas-fired and 47% hydro. In generation term, the thermo participation was 53% in 2006 and is estimated to exceed 65% in five years. The seasonal swing is substantial with thermal dispatch exceeding 70% of total generation in the dry season, and reducing to 38% in the wet months.

This structural change in the power generation segment has resulted in an increased demand in gas transport facilities, with limited price and locational signaling, as a consequence to the regulatory environments for power and gas. At the same time there is no long-term planning in Bolivia that can be used as a reference to define and optimize infrastructure energy investments.

Transredes S. A. is a public service company that operates over 5,600 km of natural gas and liquid hydrocarbon pipelines throughout Bolivia, under a concession regime. In 2005, Transredes contracted the development of a simulation model to represent the current (and future) gas and electricity chains in order to:

- Better understand the interactions between both systems and,
- Communicate and coordinate plans/proposals with other agents and regulators of both systems.

After analyzing the key characteristics of gas and power in Bolivia, and its impacts on the operation and expansion of the gas transportation system, the integrated gas and power simulation model will be described.

2. The natural gas and power sectors in Bolivia

Natural Gas Production and Transportation

Bolivia has developed into an important regional gas supplier exporter. Its current commitments amount to some 46 MMCMD (million cubic meters per day) but current gas production is limited to 40.5 MMCMD. The internal market takes some 6 MMCMD and has priority over exports; exports are roughly 27 MMCMD to Brazil and 6.5 MMCMD to Argentina. Total commitments for 2010 are in the order of 70 MMCMD, and will require substantial, fast-track, investments in upstream and midstream to be met. Investments are estimated at some 3 billion dollars to be invested in 3 years, in a business environment undergoing important structural changes since 2003, including a substantially higher government take, re-nationalization of assets, changes in the contracts and the regulatory frameworks, among other.

Through Transredes´ 3,000 km network flows 90 % of Bolivia’s domestic gas and 40% of export gas (30% of the exports volumes to Brazil and 100% of exports to Argentina). Transredes is the operator of the GasTransboliviano (GTB) and GasOrienteBoliviano (GOB) export pipelines to Brazil.

Currently, YPFB (State owned gas and oil company) commercializes the oil and gas for the internal and export markets, and ships these products on the Transredes system. Pipelines are economically regulated via a return on net assets system, and companies are allowed a rate case every 4 years. A rate case has been pending since 2005 for Transredes. Capacity is contracted on a firm and interruptible basis. Only in 2006, in the context of a significant capacity expansion, it was possibly to move a substantial fraction of the internal market to firm contracts.

The gas transportation internal market tariff is capped and subsidized by the export transportation tariff. The internal market gas prices are substantially lower than the export prices: power generators pay up to 1.30 US$/MSCF and industrial users up to 1.70 US$/MSCF. The gas producer netback for gas sold to gas distributors (attending the industrial, CNG (compressed natural gas), commercial and residential segments) is 0.57 US$/MSCF. This results in a substantially distorted signal for supplying the internal market.

Electricity

The Sistema Interconectado Nacional (SIN) is the electric system that connects major population centers and represents 83 percent of installed capacity. A number of private companies operate in the generating, transmission and distribution activities. The grid extends over 2,000 km and covers the central and southern parts of the country. The population in the northern and western parts of the country remains largely unconnected to the national grid, either served by isolated systems or having no access to electricity at all

Natural gas continues to gain market share in generation in Bolivia consequent to the lower capex, low gas price and easier licensing that hydro. In 2006, the SIN had 1.1 GW of installed electricity generating capacity. The bulk of this capacity consists of conventional thermal plants, with hydroelectricity providing the balance. The SIN generated some 4,500 GWh gross to meet 4,200 GWh of power demand in 2006.

The system is regulated as unbundled generation, transmission, and distribution activities. The law forbids any single company from operating in more than one of these activities. The SIN is operated centrally by the dispatch (CNDC) that also serves as clearing house. The system is effectively operating on a spot basis.

End user tariffs are effectively capped since 1994. A large high-load free customer can benefit from monomic (´all-in´) prices in the order of 25 US$/MWh.

After a period of overinvestment between 1996 and 2000 followed by fierce price competition in generation that benefited the end-user, the clearing system is now running a debt of more than 10 MMUS$ (´stabilization fund´) to generator and transmission companies, while substantial investments are necessary to meet demand. The debt is estimated to grow at a 10 MMUS$ / year rate.

3. What is the problem for the gas pipeline company?

The performance of a gas pipeline company in the Bolivian internal market depends primarily of its understanding of the requirements of the distribution and power markets, and of the regulatory discontinuities.

Market issues

Gas distribution demand follows a steady growth, mainly driven by industrial and CNG demand. The gas for power demand is much more volatile, showing significant daily and seasonal variations in the load curve (Figure 1). Daily variations reflect a limited industrialization level: there is a demand increase of around 35% over 30 minutes, at the peak load hour (7:00 pm), due to residential consumption and public lightning.

The power market spot operation (in price and power production allocation) limits the willingness of generators to contract firm gas supply (and transportation contracts) as exist severe problems with pass-through of contractual costs.

Under these conditions the objectives of the power generator and of the pipeline are opposed. The generator would like 100% on demand capacity to be paid on a ´as used´ basis only for plants located near the demand centers. The pipeline would like to provide transportation service to near field power plants, with electricity then being transmitted cross-country to reduce investments, or to make sure that the generator pays firm contracts for 100% of its demand.

This is not a theoretical problem. Its real and current outcome is that capacity shortages exist in gas transportation, power generation and power transmission.

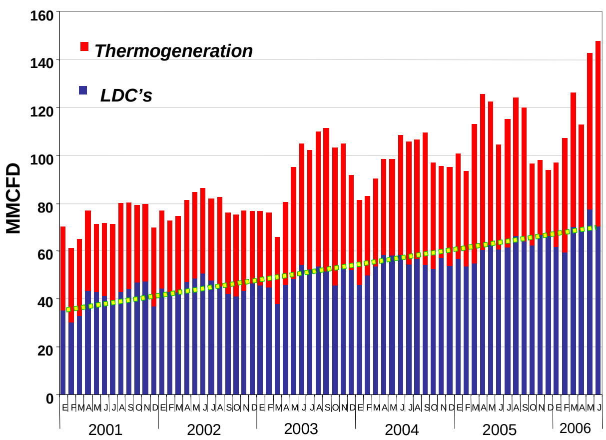

Figure 1. Internal market demand for natural gas

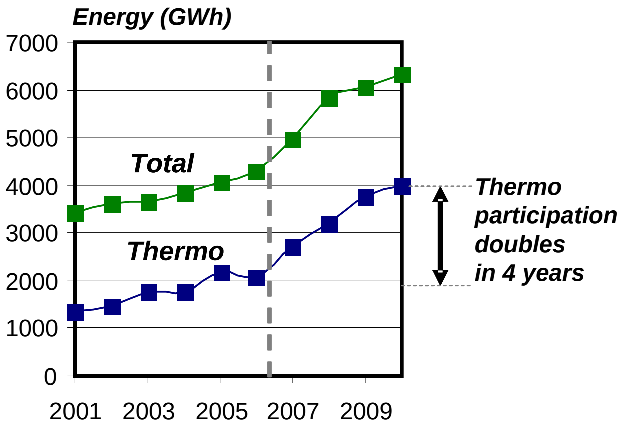

Figure 2. Historic and projected power generation

Thermal power generation (Figure 2) is expected to double over the next 4 years leading to substantial investment in gas transportation and/or power transmission investments.

Energy policy and regulatory issues

Gas and power in the internal market are fully linked on a day-to-day basis but operate with different short term and long term views. They are as if ´Siamese twins´ sharing digestive and circulatory systems, but with two heads sending very different signals to each twin. The consequences become particularly evident when capacity restrictions start to take over in either the gas or the power sector, or in both.

Currently, the central power dispatch programming does not consider gas supply and gas transport restrictions in its economic dispatch. Plants which do not have gas available are dispatched on economic grounds (lower variable cost declaration). Agents owning these plants then level complaints to the regulator and the pipelines trying to force expansions in gas pipelines, without having to bear the full costs.

The pipeline counters with strong regulatory rights that the expansions have to be fully backed by firm contracts to be rational and prudent investments, as required by law and regulations.

The lack of coherence of the regulatory systems is evident but is difficult to be acknowledged for political reasons, particularly as there are costs that are not fully recognized in the provision of the public services of gas and power. In the case of gas transportation, the ´hidden variable´ is the cross-subsidy to the export transport tariff. In the case of power, the ´hidden variable´ is the stabilization fund.

Using the price as an accounting variable and not as a signal for the long term costs of providing service is known to be extremely detrimental to supply and demand in systems with ´long-lag´ type of investments. The most recent case in point is Argentina, struggling with gas and power balance during winter.

To avoid philosophical discussions it is important to have a common understanding of the situation. This requires that the people in the gas business/regulator have a deeper understanding of the power business and vice versa. As the problem is technical, a technical representation is needed for the current situation and future outcomes. Acknowledging that the systems are ´Siamese´, then describing them as ´Siamese´, may help in reaching an agreement on how to best integrate the operational and investment policies.

In a centralized planning environment, the optimal solution for the integrated system would be relatively easy to find: For a power supply to a point B, multiple possible solutions exist to transport gas, generate power and transmit power:

Gas wellhead		Demand
A	**C**	**B**

Power Plant in A + transmission line from A to B

Power Plant in B + pipeline from A to B

Power Plant in C + pipeline from A to C + transmission line from C to B

A low cost solution exists, but how and who will find it in the current Bolivian environment? How costs will be allocated along the chain? And, who will decide about the allocation?

4. A gas and electricity integrated model as means to discuss integrated infrastructure solutions

In order to be able to objectively discuss these technical and regulatory issues, and their interactions, Transredes decided to develop an integrated simulation model that could address simultaneously gas exports, market projections, supply alternatives, fuels availability, etc. in the gas an power sectors.

Planning models are well established in the power sector; integrated gas and power at the country-scale are less common. Transredes selected Quantum[1], a well-known consultant in the region, that had already formulated a gas and electricity model for Argentina..

Model development was carried in approximately one year in a collaborative effort:

[1] Quantum, Expertos en Regulación de Servicios Públicos, consultants located in Cordoba, Argentina. Quantum had previously developed a gas & electricity model for the Argentinean system (www.quantumamerica.com)

- The consultant provided a project manager, a gas specialist, an electricity specialist and other analysts for programming and data organization. They contacted and collected electricity data from the Bolivian load dispatch center (CNDC).
- Transredes provided a project manager and specialists, to collect and organize data from the Bolivian gas production and transportation systems, including the non-Transredes systems.

Objectives, methodology and technical characteristics were defined from the outset, to assure that the model would simulate the behavior of both markets, its agents and the interactions.

Objectives

To establish a methodology that generates short and long term economic signals in the natural gas and electricity markets, through the optimization of integrated costs of gas transportation and electric transmission.

To analyze the economic viability of expansion projects for the natural gas transport and power transmission systems. The integrated model allows for analyzing multiple options and identifying the expansion plan that minimizes the cost in both natural gas and power sectors in an integrated manner.

Methodology

The use of an integrated model opens a wide array of possibilities to operate the gas and electricity systems in a country or in a region. Optimizing each system separately will not necessarily result the most cost effective, but is simpler to represent. Computing options that reflect both systems integrally allows finding a global optimal option, which could be different to the optima found by modeling the gas and electricity separately.

The optimization model can be run as short-term and long-term simulations. In short-term simulations, the decision variables are the gas production and the supply of the demand (power plants, residential, commercial and industrial clients). Given a restriction of production and/or natural gas transport, the model decides how best to meet the thermal power plant demands to avoid a shortage of electric generation, to minimize generating energy with diesel fueled turbines, and/or meeting the other demands while minimizing penalties for undelivered gas penalties. Cost drivers in the short term simulation are related to gas production and fuel consumption in diesel turbines.

In long-term simulations, the model also features the capability for expanding both gas and power systems. Cost drivers in long-term case, are the annuity costs of expanding generation and electric transmission and transport of natural gas. Gas production costs and liquid hydrocarbon production credits could be incorporated in the analysis, but are not yet featured.

Technical characteristics

The model uses a real variable linear programming algorithm and is composed of four parts: data inputs, linear programming, model administrator and model results.

The model consists of an objective function to minimize, and a group of restrictions to the variables that will limit the range of the minimization solutions.

Objective Function:

FO = Gas Production * Price Gas + Diesel Consumption* Diesel Price
+ Gas pipeline expanded capacity * Expansion Cost
+ New Gas Pipelines * Construction Cost
+ New capacity of Thermo Generation * Cost of Installation
+ New Transmission Lines * Cost of Installation
+ Penalties for Undelivered Energy + Penalties for Undelivered Gas
+ Penalties for area restrictions
+ Penalties for maximum and minimum reservoirs throughput
+ Penalties for maximum and minimum reservoirs volumes

Gas - Gas Balance by node (restriction):

Gas Production + GNS + incoming Flow = Clients Demands clients
+ Power Plants Demands + outgoing Flow + retained Gas

Electricity - Energy Balance by node (restriction):

Hydraulic generation + Thermal Generation + Undelivered Energy + Incoming Power Flow = Electric demands + Outgoing Power Flow + Power Losses in transmission lines

Hydro - Water Balance by node (restriction):

Incoming flow (rivers) + Volume Poured upstream + Turbined Volume upstream +ΔVolume = Volume Poured downstream + Turbined Volume downstream

Input Information of the Model

All the information related to the natural gas system used in the model, is given by TRANSREDES.

All of the information related to the Bolivian Electric Market was obtained directly from the Load Dispatch Center Committee (Comite Nacional de Despacho de Carga - CNDC).

The general input data to the model is:

- Gas and Electricity Demand (five year period)
- Programming Parameters
- Natural Gas System data:
    - Gas demand projections by node
    - Capacity and prices projections at different gas basins
    - Retained gas by compressor
    - Pipelines capacity
- Electricity System data:
    - Power demands by node projections
    - Power plants (thermal and hydraulic)
    - Transmission lines capacity
    - Forced and programmed unavailability.
    - Thermal plants: specific consumption, fuel types, alternative fuels availability, generating capacity, % forced and programmed unavailability by year and period.
    - Hydraulic power plants: hydraulic efficiency, generating capacity, maximum and minimum acceptable volume dammed, turbined and poured water,% of forced and programmed unavailability by year and period.
    - Electric characteristics of the transmission system.
    - Future plants and/or lines incorporations.
    - Historical water flows chronics.
- Technical and economic information of:
    - New pipeline expansions to evaluate
    - New pipelines to evaluate
    - New power plants to evaluate
    - New transmission lines to evaluate
- Costs of Undelivered Gas and Undelivered Energy

Output information

One aspect to enhance in the model is the fact the results are presented in schemes for each system, which makes it friendly to handle the information. Main schemes are showed in Figures 3, 4 and 5.

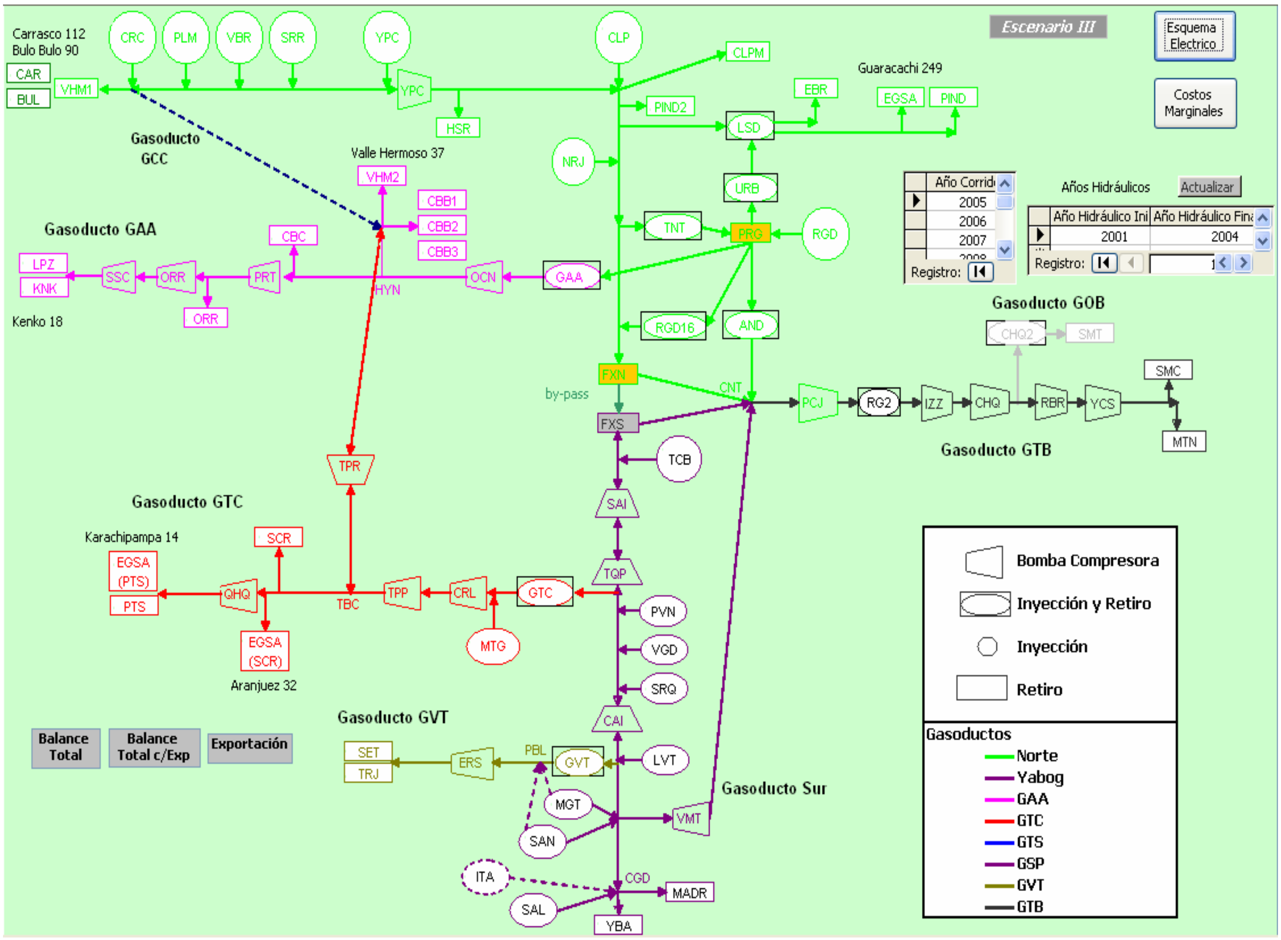

Figure 3. Natural gas system diagram

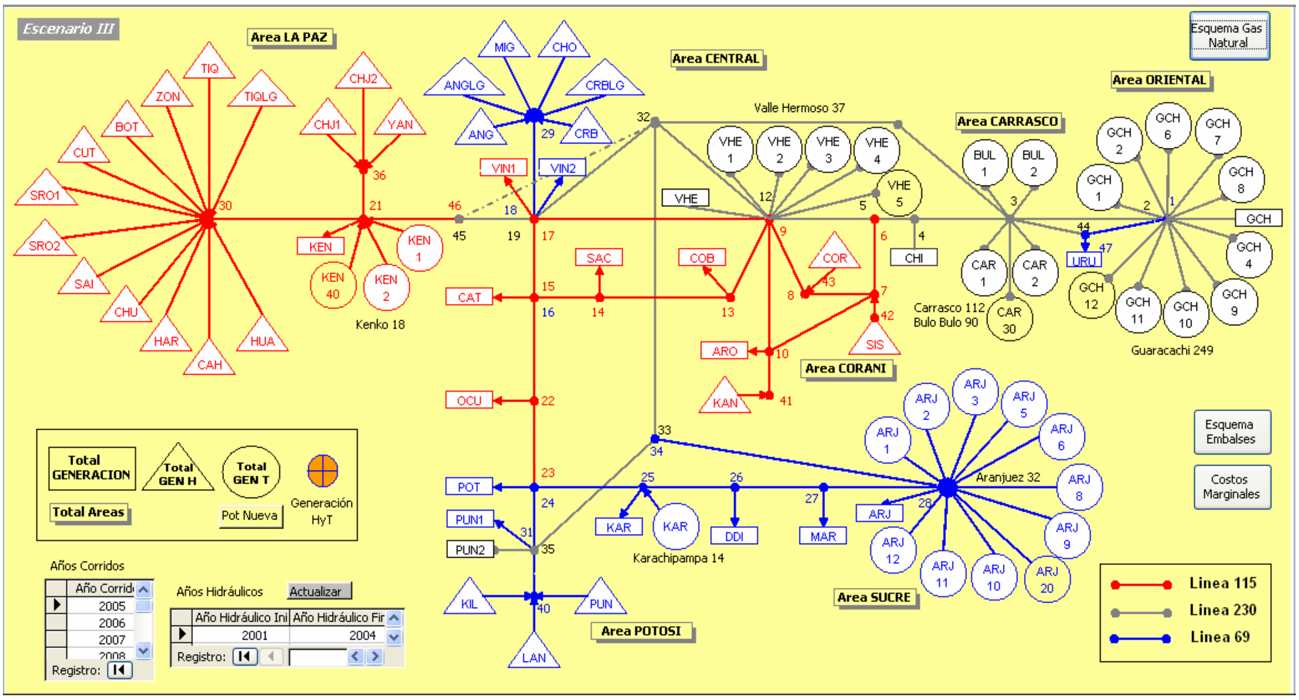

Figure 4. Power system diagram

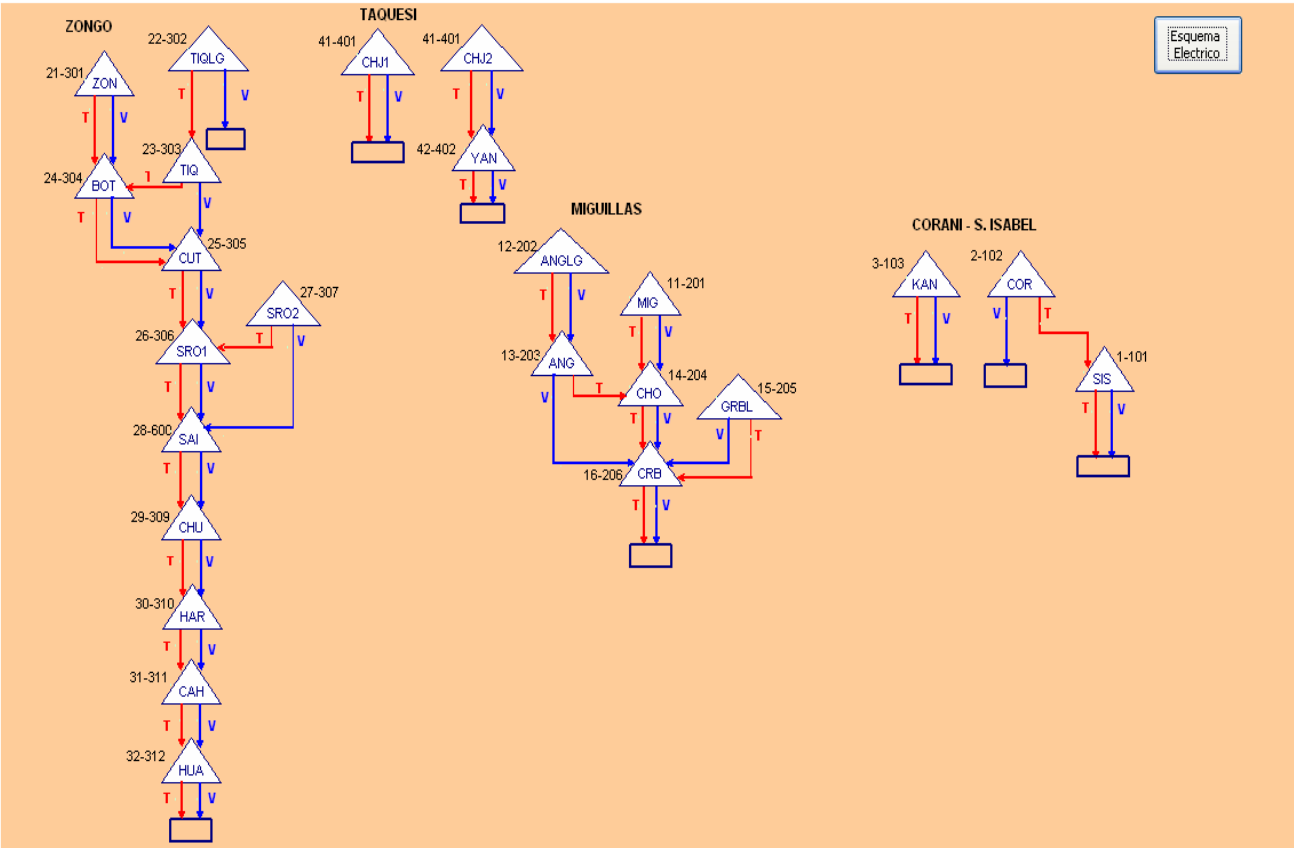

Figure 5. Hydro power generation diagram showing all plants and water streams

A simple click on any of the elements (power plant, transmission line, electricity demand, gas basin, gas transport pipeline, etc) of the scheme, one can see the graph related to the element in terms of MW or MMcf/Day for a five years of study period as follows:

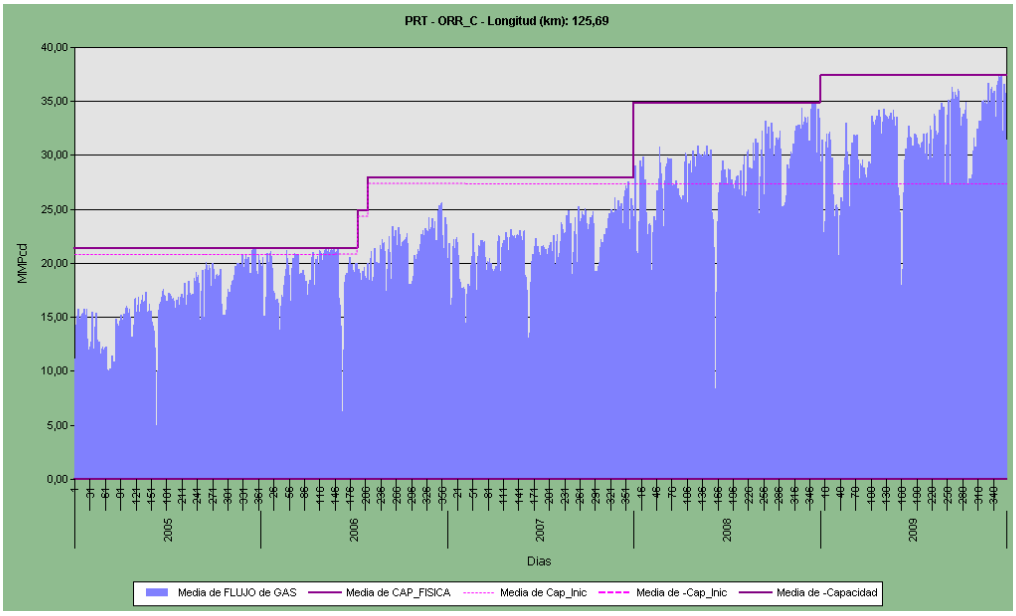

Figure 6. Model output: pipeline capacity and daily gas throughput

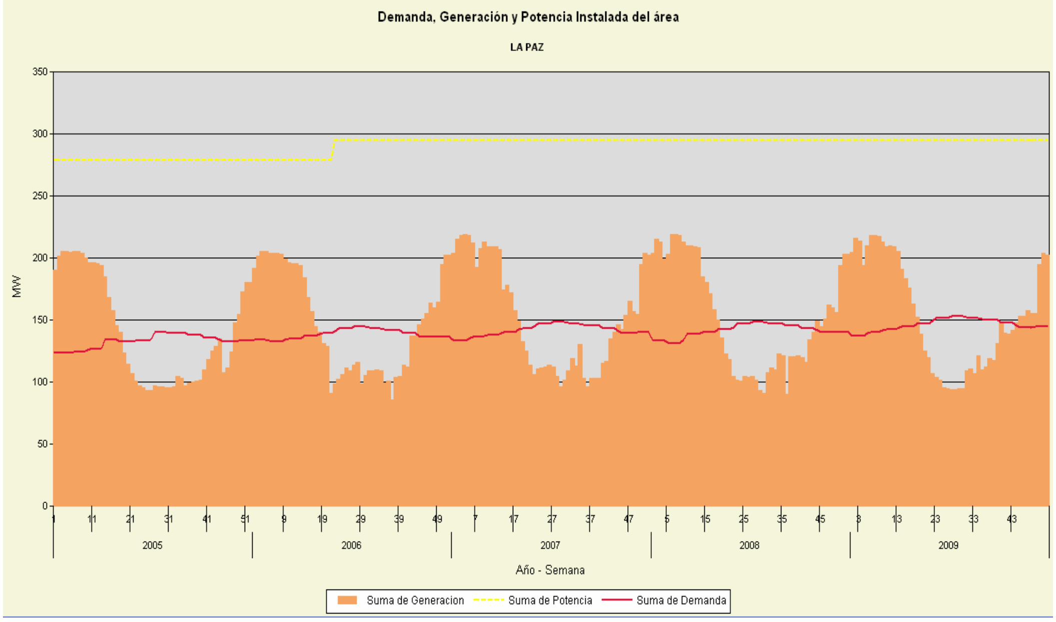

Figure 7. Model output: installed power generation capacity, supply and demand.

5. Problems in the Bolivian gas and electricity sectors are confirmed/identified

Simulation of a number of scenarios shows what agents in the gas and power sectors perceive. The problems will materialize in the short, medium and long term, and are structural.

- The gas system is restricted mainly at production level. Investment requirements are significant and need to be done quickly. Gas shortages are foreseen to deepen in 2008 and 2009.
- Natural gas availability for domestic market (electricity, industrial, residential and others) is not a production concern. Consistent with regulation, the model simulates highest priority for this market. Gas availability for exports to Argentina and Brazil is reduced, if there is no significant further investment in production. Government take reduces.
- Domestic gas markets are constrained by transportation capacity. Pipelines capacity expansions include a new pipeline linking the northern gas fields with the city of Cochabamba to feed western Bolivia. This new asset will free-up capacity on the existing system.
- The model alerts to significant investment in new power plant preferably at or near the big loads, given the sustained growth and the transmission limitations. The model provides solid ground to estimate power investments of at least 150 MW (15% of the current capacity) in the short term.
- The competition for gas in western Bolivia between the growing distribution and power requirements under restricted delivery, further constrains availability of gas and power. Having identified the issue, the best curtailment policy can be identified to reduce the overall impact on gas and power delivery and the economy.

6. Achievements

Transredes is promoting model utilization in the sector and with government authorities to guide operational and network planning decisions. The model performance is highly dependent on data quality, and thus performance depends on the cooperation of agents. The natural owner of the model is a national planning agency that would coordinate data acquisition with agents and results dissemination. Results have been presented to government and regulatory authorities, and to gas and power agents generating good acceptance and valuable suggestions that are being implemented.

Transredes´ commercial and operational processes have also benefited from the improved knowledge of the gas and power systems and their interdependency, a closer operational coordination with the power dispatch, and better supporting evidence for network expansions.

7. Conclusions and recommendations

Joint optimization of the gas and power systems of Bolivia is possible using data readily available from the agents. The combined analysis provides an improved framework for decision making, and prioritization. This represents clear benefits and opportunities in policymaking and regulation, optimal expansion of networks, and access to new markets.

A number of potential model improvements and additions have been identified, including:

- To interconnect gas export requirements for Argentina in the Transredes/Bolivian model with the corresponding import requirements in the Argentina gas and power model[2]. A similar approach can be followed with Brazil
- To model the gas basins depletion.
- To improve the expansion planning module.
- To model the liquids transportation system interaction with the gas transportation system

Going back to the Siamese twins metaphor, the model has clearly showed us that the much smaller electricity twin is getting bigger and it now takes quite an effort to provide food (natural gas) to it. The twins, even though naturally joined, knew little about each other. This is now changing.

8. Acknowledgements

The authors acknowledge the support of management of Transredes & Quantum that were part of the project.

9. References

- Quantum **INTEGRACION DE LOS SISTEMAS GAS NATURAL Y ELECTRICO BOLIVIANOS, Informe Final, November 2006, 69 p.,** www.quantumamerica.com
- Comité Nacional de Despacho de Carga, RESULTADOS DE OPERACIÓN DEL SISTEMA INTERCONECTADO NACIONAL GESTION 2006, **www.cndc.bo**

[2] Quantum has recently updated the model for Argentina System. The idea is to use the result in one model for the other model and vice versa.