

TRANSMISSION PLANNING IN THE CHILEAN ELECTRICITY MARKET

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SUMMARY

Chile was a pioneer country deregulating and privatizing the electricity sector with the enactment of the Electricity Law in 1982. Transmission expansion and planning methodologies are relevant factors on developing countries like Chile, whose electricity demand has been growing up nearly 7% per year in the last decade. The evolving conditions of the Chilean energy market driven by different private agents joined to the continuous demand growth meant the need to introduce changes to the original 1982 regulatory framework, being transmission pricing and expansion procedures among the main issues assessed in an amendment to the Electricity Law in 2004. The transmission expansion mechanism initially based on bilateral negotiations was changed to a co-operative regulated scheme with participation of all the agents participating in the energy market. New investments in the trunk system are the result of the expansion plan proposed in a 4-year Trunk System Study. Every year the system operator CDEC must update the plan according to the current market conditions, with a consultation process involving all the agents, and then recommend the transmission projects to be developed. The planning role of transmission companies focalizes on the proposition of projects that meet market requirements and reliability standards. Transmission planning is needed because of the shared characteristic of the grid and transmission owners head the process to forecast the future use of the grid under different scenarios and uncertainties. Chilean experience is unique in the world because it was a pioneering step in a small system, in tuning with the opening of the country's economy.

KEYWORDS

Transmission planning, deregulation, grid expansion, expansion strategy.

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1. INTRODUCTION

Chile was a pioneer country deregulating and privatizing the electricity sector with the enactment of the Electricity Law in 1982. The electricity market was restructured in generation and distribution companies that were successively privatized at the end of the 80's. A system operator called CDEC was created in 1985 in charge of the secure and economic operation of the generation-transmission system and the management of the energy market transactions. The first transmission company Transelec was created in 1993, as an affiliate company of the largest generation company, and afterwards in 2000 it was sold to private investors under an international bidding.

Transmission expansion and planning methodologies are relevant issues on developing countries like Chile, whose electricity demand has been growing up nearly 7% per year in the last decade. In that frame, open access to the existent transmission system and market rules to expand the transmission capacity, driven by local demand growth or new generating plants are the fundamental topics to allow competition among agents in the energy market. Figure 1 shows the demand forecast and installed capacity expected to be built by private agents in order to get the market growth in the Chilean main interconnected system (SIC). The capacity margin is explained because SIC's installed capacity is 60% hydro (with several reservoirs) and 40% thermal (coal, LNG, diesel).

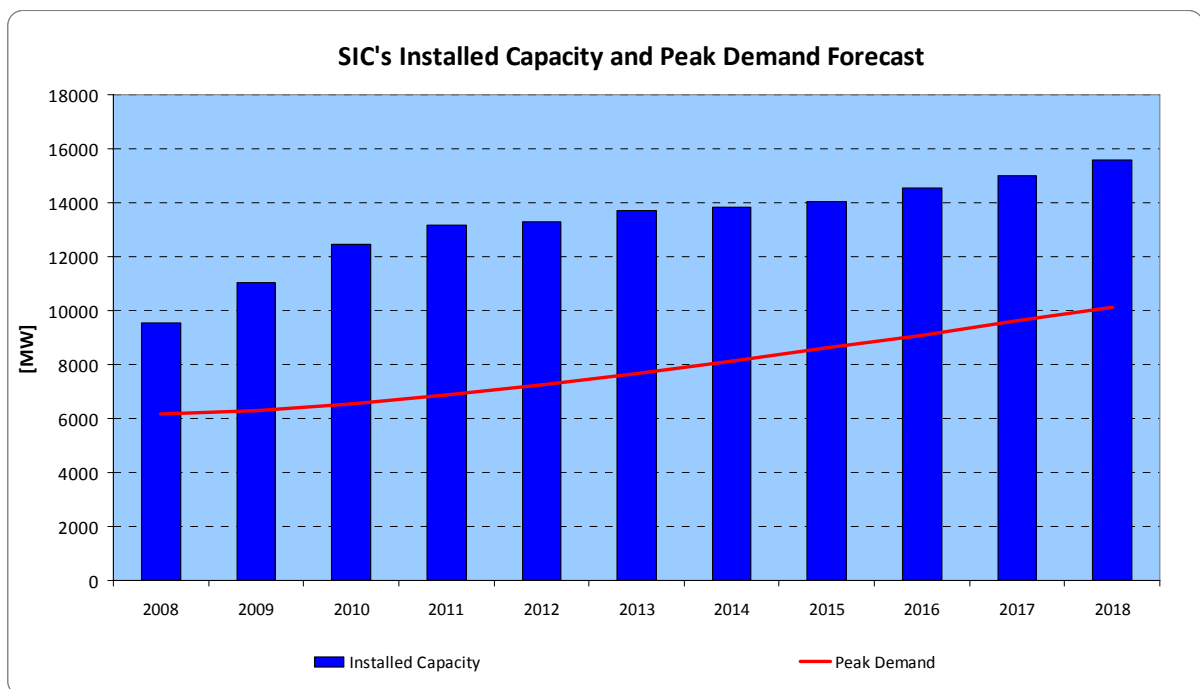


Figure 1: Demand forecast and Installed capacity 2008-2020

Transmission planning in deregulated environments does not have a common solution worldwide and most countries commit on alternatives adapted to local energy markets conditions. Transmission pricing schemes and expansion methods are closely linked to the planning strategy. The evolving conditions of the Chilean energy market driven by different private agents joined to the continuous demand growth meant the need to introduce changes to the original 1982 regulatory framework, being

transmission pricing and expansion procedures among the main issues assessed in an amendment to the Electricity Law in 2004 [1].

The March 2004 Electricity Law amendment defined new procedures to calculate transmission tolls and created a co-operative planning process to expand the trunk transmission system with the participation of all involved agents under the co-ordination of the regulator. The transmission system was separated in three segments: Trunk, Subtransmission and Additional Transmission, as shown in Figure 2.

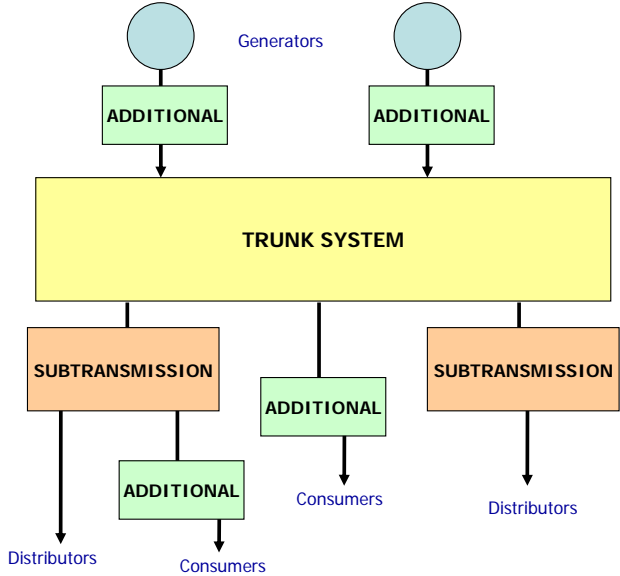


Figure 2: Transmission segments according to the new law.

Trunk system assets are those essential for competition in the energy market and are integrated by facilities over 220 kV that are economically efficient and necessary to supply the total demand. Subtransmission system assets facilitate access to consumers, regulated and non regulated prices (higher than 2 MW). Additional Transmission systems assets are those dedicated either to non regulated price consumers or to connect power plants to the system.

Trunk and Subtransmission systems are regulated with tariffs determined every four years by consultants directed by the regulator (CNE) and finally enacted after a decree of the Ministry of Economy. The Additional Transmission revenues are bilaterally negotiated between the owner and the users.

2. TRANSMISSION EXPANSION IN CHILEAN TRUNK SYSTEM

Under the 1982 Law, transmission expansion was based on free market bilateral negotiations among the transmission owner and the users that require additional capacity. That method resulted in an underinvested grid with reliability problems and the main conflicts occurred because of the allocation of the existent grid costs and free rider actuations by agents in the market [2].

After the enactment of the 2004 Law, transmission investments in the trunk system are the result of the expansion plan proposed in the Trunk System Study (TTS), developed every 4 years. The expansion plan is determined through a planning process that has got the following inputs:

- Nodal demand forecast prepared by CDEC.
- Generation expansion scenarios prepared by CNE.
- Fuel prices projection.
- Transmission projects proposed by the participants.
- Reliability criteria according to the Security and Quality of Service Technical Norm [3].

The trunk expansion plan is the set of transmission projects that minimizes the present value of transmission investment, system operation and outages costs over a 10 years period. Figure 3 represents the economic evaluation of transmission investment and system costs in the situation without and with a transmission project. If a transmission project can demonstrate that the reduction of operational costs in the energy market (congestions) and improvement on reliability (minimizing outages) overcome the project investment and O&M costs, then the project is added to the plan.

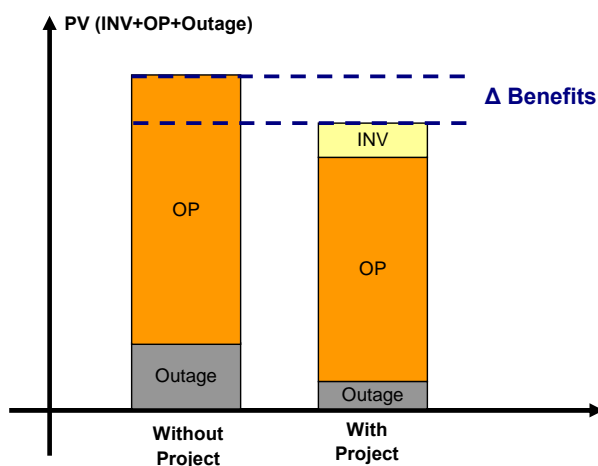


Figure 3: Economic evaluation of transmission projects.

Once a year, the system operator CDEC must revise the trunk expansion plan according to the current market conditions, particularly demand and effective generation development, with a consultation process including all the involved agents in the energy market. Then CDEC recommends the resultant set of trunk transmission projects to the CNE. Afterwards the CNE has 30 days to release the expansion plan of the Trunk System with the projects that must initiate construction in the next 12 months. The participants can, once again, challenge the expansion plan and raise discrepancies to be resolved by a special tribunal called the Expert Panel, created by the 2004 Law to solve any controversy in the electricity market. Figure 4 shows the sequence of steps to get the approval of a transmission project and then start up the bidding process, construct and finally commission.

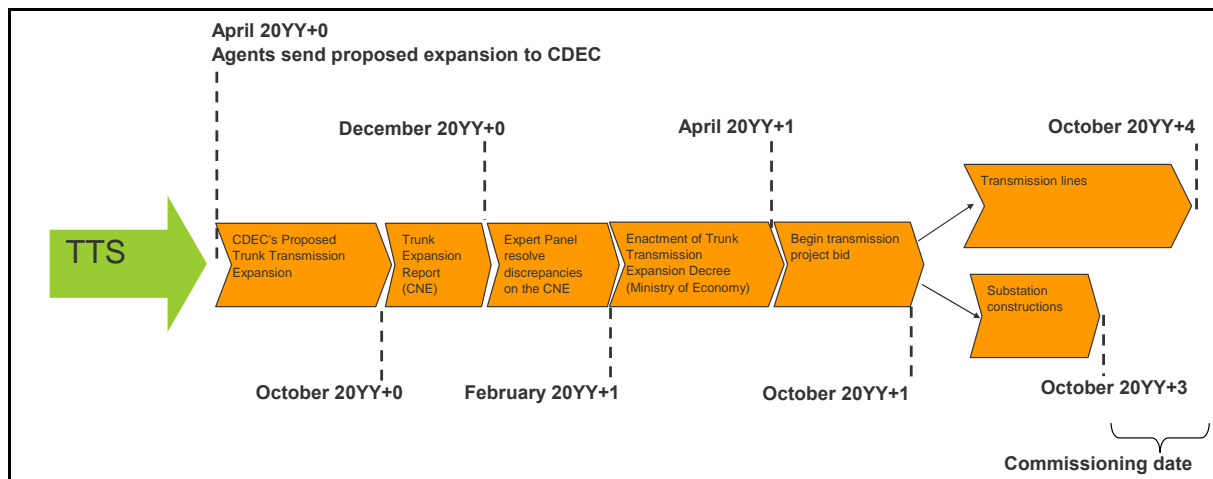


Figure 4: Annual approval sequence of the trunk expansion plan.

There are two types of transmission projects determined in the expansion plan:

- New trunk projects that are independent of the existent grid are awarded via an international bidding process conducted by CDEC. The transmission company that offers the minimum annual tariff will be the winner. This value will be kept by four tariff periods (20 years) after which the asset will be valued in the corresponding Trunk System Study.
- Upgrades of the existent trunk grid that are allocated on the corresponding owner, who has to bid the project under an open and competitive process. Bids are allocated to a construction company that offers the minimum Value of Investment (VI), with a cap equal to the referential VI plus 15%. If the bidding is unsuccessful the owner must require a study by an independent consultant that explains the causes and, if it is justified, the Ministry of Economy is entitled to release a decree with a higher VI, in order the owner can perform a new bidding process.

In this new context, three trunk transmission expansion processes have occurred [4]:

2.1 Immediate construction works in 2004

This was a 'fast track' expansion plan included in the 2004 Law in order to improve the system security of supply via urgent trunk projects for immediate construction. These projects had to cover the trunk system expansion between 2005 and 2008, just in time to coordinate with the first set of projects to be determined by the Trunk System Study. According to this mandate CDEC proposed to CNE a set of projects in May 2004 and CNE enacted the decrees in September 2004.

Three new projects with a VI of around US\$ 90 Million were bided by CDEC in the beginning of 2005 and 2006, with three new entrants that competed with Transelec to win the bids. Transelec won two of the three international bids. Additionally, six upgrade projects with a VI of US\$ 85 Million were defined and allocated to Transelec, as the owner of the existent assets to be upgraded.

2.2 First trunk expansion plan in 2007

The trunk expansion decree was enacted in November 2007, after CDEC revised the first expansion plan determined in the Trunk System Study. One new project with a VI of around US\$ 47 Million was bided by CDEC in the beginning of 2008, with four new entrants competing with Transelec, who finally won the bid. Additionally, 23 upgrade projects were defined, 22 allocated on Transelec and 1 on another company. Only 5 projects were awarded at the first auction and the rest were awarded after a new VI was settled. Some are still waiting for a new VI in 2009. Upgrades under construction have a VI of US\$ 76 Million. Figure 5 presents the trunk annual investment, according to the commissioning date, awarded as new projects or upgrades as a result of the Immediate Construction process (2005-2008) and the First Trunk System Study (2009-2011).

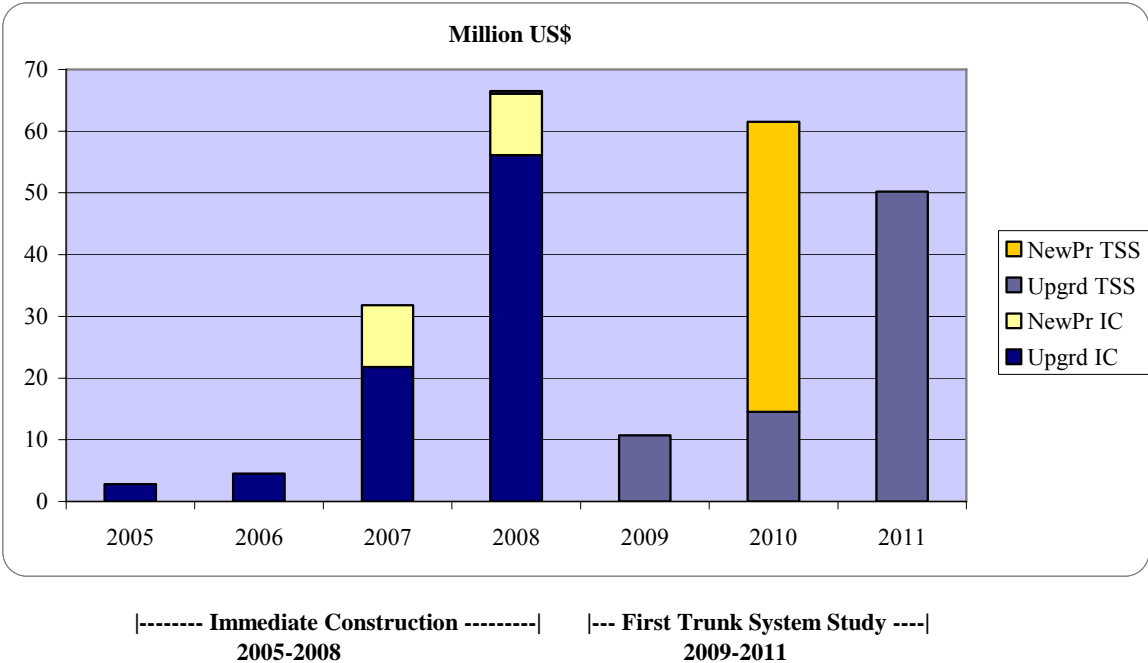
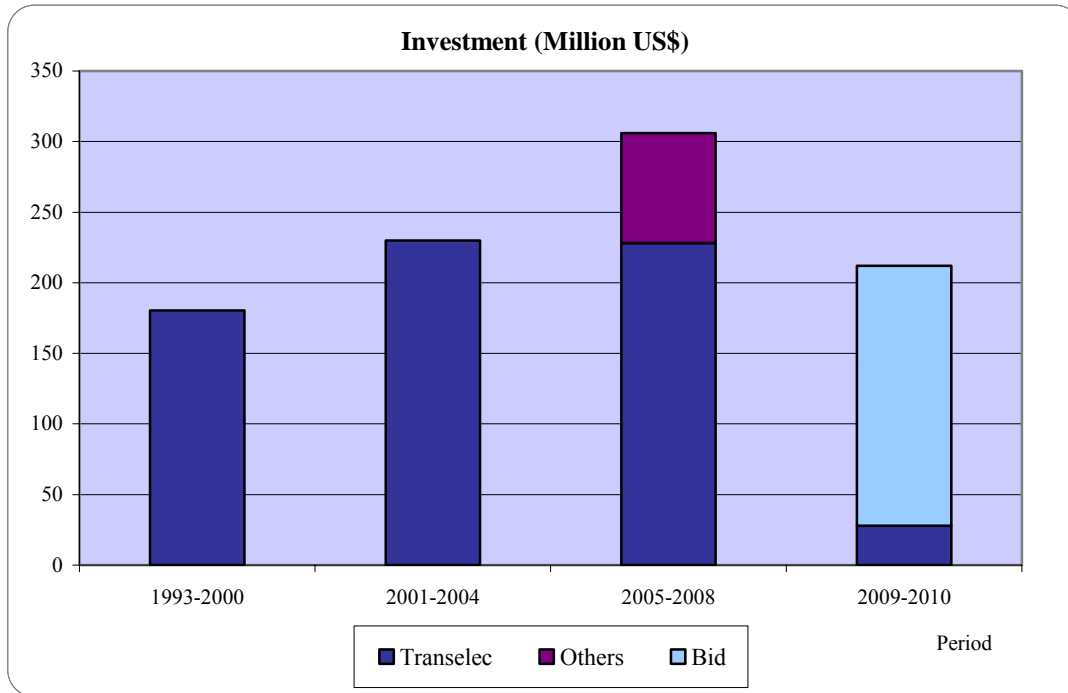


Figure 5: Trunk investment 2005-2011 (new projects and upgrades).

2.3 Expansion plan revision in 2008

The last trunk expansion plan was enacted by the Ministry of Economy in May 2009 after CDEC sent its revised proposal of projects to CNE in November 2008, they released the expansion plan in January 2009 and the Experts Panel resolved the discrepancies in March 2009. It contains one new project with a VI of US\$ 184 Million and three upgrade projects with a referential VI of US\$ 13 Million.

In the period 1993 – 2010, the annual trunk transmission investment has grown up, as shown in Figure 6. This is the result of demand growth and construction of new power plants in the SIC that required transmission expansions plus the improvement in the co-operative planning and expansion regulation with the 2004 Law.



Average Inv per year	22,6	57,5	76,5	106,0
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Figure 6: Trunk transmission investment (1993-2010).

3. TRANSMISSION PLANNING AND THE ENERGY MARKET

Under the new regulated environment for expansions, the planning role of a transmission company like Transelec is concentrated in the early identification and proposition of trunk system projects that meet market requirements and reliability standards.

Users of the trunk transmission system are generally generating units and consumers, mostly large ones, directly connected to the trunk system. Changes in the energy market are mostly related to competition among generators in order to capture the market opportunities related to demand growth (distribution companies, large industrial or mining companies) and supply contract renewal by existing consumers, where the most efficient and opportune generator is the winner. Those are the main reasons why the transmission system must be expanded.

In addition to demand growth forecasting, the main issues that challenge the definition of a transmission expansion plan are related to the new generation power plants to be commissioned under a competitive energy market. The following questions arise:

- What kind of technology will be used in the new generation plants?
- When will the new plants being connected?
- Where are the new plants going to connect to the grid?
- How much capacity is being connected?

Under a deregulated scheme there is freedom to answer all these questions and then the investment decision concerning the expansion of the grid takes the form of an “expansion strategy” instead of an “expansion plan”. This strategy must determine the set of transmission projects that allow the best solution to the energy market participants, minimizing the total cost to the users.

Transec’s experience in transmission planning can be summarized in the process shown in Figure 7, displaying the flow chart of data, technical and economic studies and activities to be carried out for determining the trunk transmission expansion strategy under different market scenarios.

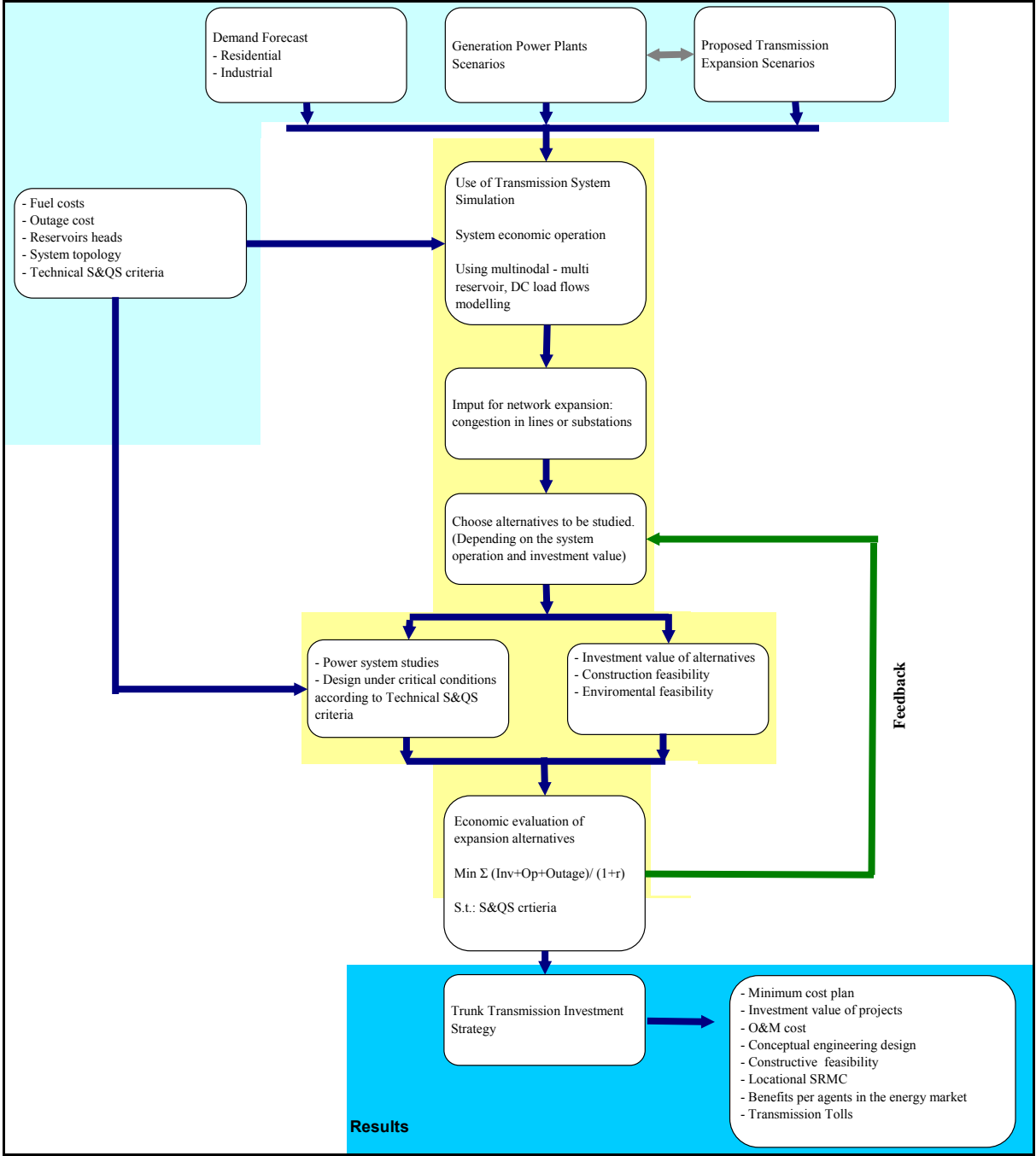


Figure 7: Transec’s planning process.

Among the tools used in the economic operation system studies it is important to remark the hydro-thermal characteristic of the Chilean SIC that determines the use of multi-node and multi-reservoir simulation models. In the last ten years, models using Stochastic Dynamic Dual Programming [5] have been introduced for the operational simulation over long term horizons. Fast models to calculate the economically adapted network are useful to have preliminary analysis [6]. Nevertheless AC load flow analysis is performed using standard models. Figure 8 presents the main range of tools in use depending on the kind of study to be developed in the planning process.

	Name	Methods	Characteristic	Studies
Use of Transmission System Simulation	PLP	Stochastic Dynamic Dual Programing	Economic Operation Multinodal - Multireservoir	DC Load Flow analysis Adequacy analysis Congestion diagnosis Economic Evaluation
	MRO	Lineal Programing	Economically Adapted Grid	
	PLEXOS	Lineal Programming/ Mixed Integer	Economic Operation Multinodal	
Power System Studies	Digsilent	AC Load Flow	System Operation (intact and contingencies)	AC Power flows Transient stability Short circuit
	PSS/E			

Figure 8: Main planning tools in use.

4. MAIN CHALLENGES

Transmission planning is always a need because of the shared characteristic of the transmission assets and transmission owners head the process to forecast the future use of the grid under different scenarios and uncertainties. Transmission planning is a co-operative work and it requires regulatory support to avoid free rider attitude by some market agents and blockage to transmission projects that are not commercially convenient for them.

Then main challenges identified in transmission planning are:

- Anticipation in the transmission investments decision (with uncertainties in the effective generation projects to be built) versus an increasingly more difficult environmental and rights of way processes.
- Construction period of some thermal and wind power plants are lower than the transmission project construction period (including environmental approval and rights of way negotiation).
- Competition of existent generators in order to create entry barriers to new entrants through underinvested transmission grid in certain zones.
- Sustainable development of the grid requires a long term vision that provides the regulatory signals in order to avoid bottlenecks in the future and minimize the amount of new transmission corridors.
- Connection of renewable generation (especially wind) that will require grid expansions and mechanism to mitigate voltage quality problems.

- Interconnection of large and far south hydro power plants that will require the development of long HVDC transmission systems.
- Introduction of FACTS in the grid to improve quality of supply and improve the efficient use of the transmission system.

In order to face these challenges planners must diversify its traditional technical role in the design of the grid architecture, integrating the economic variables to support investment decisions in front of market agents and regulatory agencies. One of the more important aspects is the early consideration of environmental issues in planning studies to avoid that transmission projects can be delayed or rejected by local communities or land owners.

5. CONCLUSIONS

Chilean experience is unique in the world because it was a pioneering step in a small system, in tuning with the opening of the country's economy. There are still things to improve from planning point of view, like the way the expansion plan considers the uncertainties like demand growth and the location, size and technology of future power plants. One relevant issue today is the way to front the incremental difficulties to get the environmental approval and complete right of way negotiations for the use of private land.

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