The Electricity Crises of California, Brazil and Chile: Lessons to the Chilean Market

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Abstract—Many countries have deregulated their electricity markets, boosting competition and participation of private enterprises in generation. The recent electricity crises of Chile, California, and Brazil, and the problems that other countries have faced, have interrupted the development of these reforms.

In this paper the fundamentals of each market are analyzed, as well as each deregulated legislation. We also studied the crises, and the influence on them of each legislation. We found that besides circumstantial situations in each case, there are common aspects in the three crises. In all of them we found that the price signals in shortage situations were wrong, and that the performance of the regulators was deficient.

We conclude that a deregulated electricity market will not work properly in a scarcity situation if consumers are isolated from the real cost of energy, and if it does not have independent regulators, that are not influenced by short-term political interests. Finally, based on the study, we propose improvements to the Chilean electricity legislation.

Index Terms—Deregulation, electricity markets, market power, price signals.

I. INTRODUCTION

Many countries have deregulated their electricity markets, boosting competition and participation of private enterprises in generation. Different models have been adopted following two main lines; the Chilean model (1982), based on a centralized pool that makes a least cost dispatch, and the models of England and Wales, and Australia, based on centralized bid systems as a solution to resolve the dispatch issue. The recent electricity crises of California (2000-2001), Brazil (2001) and Chile (1998-1999) and the market power problems that have affected other countries, have interrupted the development of these models; particularly, the Chilean second generation reforms have been paralyzed due to the risk of new episodes of electricity shortages or market power problems.

These crises and the problems that all these countries have faced are a sample of similar difficulties that have arisen in other parts of the world, and appear as a paradigm; Chile was the first country that deregulated its electricity market and its model was relatively conservative; on the other hand, California’s and Brazil’s were the last reforms and were very different in the magnitude of the change. California’s reform was quite radical, while Brazil’s was more conservative. However, all three markets have faced serious shortage problems in recent years. While it is true that not all the troubles are explained by the regulatory reforms and that every crisis has its own particular origin, it’s also true that the study of the three cases mentioned, leads to common aspects that hindered the proper development of these markets.

Particularly, in this paper we focus in two aspects that have been relevant in the magnitude of each crisis; the mistaken price signal of each model in shortage situation, and the defective performance of the regulators.

II. CHARACTERISTICS OF THE MARKETS OF CALIFORNIA, BRAZIL AND CHILE

In the three studied markets, generation, transmission and distribution have been split, introducing free competition in the generation level. Additionally, in California and Brazil the new legislation created the figure of an energy trader.

A. California

Generated energy has grown permanently in California in the last decade, reaching 284,132 GWh in 2000. From this, 58% was thermal generation (38% with natural gas), 15% was hydraulic generation and 15% was nuclear generation. Imports from other states accounted for 11% of the energy that year and alternative sources only contributed 1%. Fixed capacity to supply California’s market is estimated in 54,000 MW, and has not changed considerably in last years. The ownership of this capacity is fairly spread. There are more than 200 participants in the market, none of which holds more than 10% of the system.

The distribution is held by three large utilities that together supply almost 75% of the energy consumed in the state.

B. Brazil

Electricity generation was of 322,464 GWh in 2000. Fixed capacity is estimated in approximately 68,590 MW, being hydroelectric sources the most important with 88% of the country’s generation capacity. Thermal capacity accounts for 9% and nuclear capacity accounts for the last 3%.

Brazil began a privatization process in 1997 that is unfinished and that pretends to sell all generation capacity, with the only exception of nuclear sources. The motivation behind the privatization was to resolve the government’s lack of resources to finance the expansion of the system. The ownership of the generation capacity is divided between private enterprises (20%), state owned companies (39%) and the federal electricity holding Eletrobrás (41%). Among private generators, the largest is Tractebel, which owns 8% of the country’s capacity. In the other hand, almost 70% of Brazilian distribution companies are in private hands. The distribution sector is very important, for distribution companies deliver almost 90% of the energy used in Brazil. Finally, transmission lines have not been privatized and...
mainly belong to Eletrobrás.

C. Chile

Electricity generation in the SIC, reached 29,576 GWh in 2000. Fixed capacity was 6,653 MW at the end of that year, mainly from hydraulic sources (61%). The other 39% is provided by thermal sources, mainly natural gas and coal.

There are two types of consumers in the Chilean market, classified by their power requirements. Those that require 2 MW or more are considered free consumers, and can contract their supply directly with the generators. Consumers that require less than 2 MW are considered regulated consumers, and represent around 60% of total consumers. The latter are supplied by a distributor and pay a fixed tariff calculated by the regulators every six months.

III. STRUCTURE OF THE MARKETS OF CALIFORNIA, BRAZIL AND CHILE

The model established in California was considered as a paradigm of free competition in electricity markets [10]. In the other hand, the designs of Brazil and Chile were much more conservative, basically due to the high concentration of hydraulic generation in these markets.

A. California

The new Californian electricity market began its operations in April 1998. It was structured around an independent system operator (ISO) and a power exchange (PX). The ISO is responsible for the system’s security, operates the transmission system, and manages the spot market necessary to balance the system. It also manages an ancillary services market and has to assure free access to the transmission lines to all the agents. The PX is the institution where generators and distributors gather to buy and sell energy. The PX operated in two bases, one day before dispatch (DA) and one hour before dispatch. DA market concentrated between 80% and 90% of the transactions [1]. Besides, there is a third kind of institution, the Scheduling Coordinators (SC), which are intermediaries that holds contracts with generators and consumers like energy traders, but also have to schedule those loads hourly in the ISO. To the ISO, the PX is only one more SC.

Market operations are based on the auctions held by the PX, where hourly prices and operational programs are generated. The PX and all the other SC submit their programs to the ISO, who analyzes their feasibility in accordance with the transmission lines availability. If the programs are feasible, they determine the dispatch. If they are not feasible, which is very common, they are returned to the SCs with adjustment suggestions that can be accepted or rejected by them. Finally, the ISO adapts the final programs in accordance with lines availability and with adjustment bids delivered by each offerent, that show their willingness to pay for using congested lines. Thus, a feasible overall program is created.

Consumers cannot bid directly in the spot market, but they do it passively, increasing or decreasing their programmed consumption. Generators have three ways to take part in the spot market: bidding directly in it, diverting from its generation program, or bidding in the ancillary services market. The ISO run the ancillary services market separately from the energy market, which represents a peculiarity of the Californian design and will be commented ahead.

Finally, California chose a zonal transmission constraints management model. The state was separated into 24 pricing zones, two of which covered most of the territory.

B. Brazil

The new model started its operations in March 1999 and was in the implementation stage when the crisis began. It was structured around a system operator (ONS) that is in charge of a centralized and least cost dispatch system. The dispatch is made using mathematical models that optimize the reservoir’s water. Due to Brazil’s hydroelectric predominance and its large reservoirs, the coordination between different sources is essential. The decision to generate with water today always involves a rationing risk in the future [2]. Since the dispatch is compulsory and the operation of one plant can affect the conditions of other plants downstream, the regulators created a mechanism (Mecanismo de Realocação de Energia - MRE) to deal with the problems of water rights and plants remuneration. By means of MRE, the generators are paid for their firm energy and not for their real generation.

The Brazilian system was designed as a contract-based market. As a consequence, competition for contracts should be the main driver for the expansion of the system. For this reason, distribution companies are forced to contract at least 85% of their annual requirements.

To price spot energy, the regulators created a sort of wholesale market called Mercado Atacadista de Energia Elétrica (MAE). Generators, traders, and distributors constitute it, and it defines the spot price of energy with similar rules to the ones used by the ONS. As most of the supply should be contracted, MAE spot market is expected to be small, being used only to exchange the energy needed to balance the system [2]. The MAE is also the environment where contracts are traded.

As in California, regulators chose a zonal transmission constraint management model. The country was divided into four pricing zones: North, Northeast, South and Southeast/Center-West. The latter is the largest, with 58.1% of total national consumption.

Due to the experience of other countries with this type of reforms, the implementation of the new model was done in stages. For that reason, the introduction of the MAE, considered the most sensitive part of the reform, would be done gradually until January 2002. The first stage would be until September 2001, but was postponed due to the shortage problems, and during it the prices were calculated monthly in an ex-ante basis.

In the coming stages the prices will be calculated more periodically and finally they will be calculated each hour in an ex-ante and ex-post basis.

\[ There are two main electricity systems in Chile, the SIC and the SING. In this paper we are interested only in the largest one, the SIC (Sistema Interconectado Central), which supplies almost 93% of Chilean population. \]

\[ The MAE, differently than the ONS, does not consider transmission constraints to calculate the spot prices. \]
C. Chile

The Chilean market was the first that was reformed (1982). It is structured around a system operator (CDEC) that controls the transmission system, determines a centralized dispatch based on least cost criterion and on rules that optimize the use of reservoir’s water. It also calculates the spot price of energy for each hour of the day. Main generation and transmission companies constitute the CDEC.

The market has three different prices for the energy. Free consumers negotiate its own free price with the generators or distribution companies. Regulated consumers pay a fixed tariff, called node price, plus a charge for distribution. The node price is fixed every April and October by the regulators, and has two components, for energy and power remuneration. The energy component corresponds to the average of the expected marginal cost of the system in the next four years. The power component corresponds to the cost of capital of the most efficient technology to add power to the system, which currently is a gas turbine. Node prices should have a maximum deviation of 10% respect to the free prices. Finally, transactions between generators in the spot market are priced at spot price, which is settled hourly by the CDEC and comes from the audited marginal cost of the plant that supplies the system’s peak.

Chilean legislation considered a capacity payment to the generators that hold the system, which is not subject to real generation. Besides, the regulators promote a certain level of over capacity in order to maintain the security of the system. This is done with a parameter called Theoretic Margin of Reserve (MRT) that is fixed by the regulators. The MRT is used every year in the annual balance of power capacity that the CDEC makes, where the deficits and surpluses of capacity of each generator with respect to its compromises are settled. Thus, there is an annual market of capacity that results in payments for transfersences of capacity between generators [3].

To manage shortage situations, the model gives the government some important attributions. Its main tool is the rationing decree, which provides special powers to decrease consumption and force generators to compensate their regulated consumers for the energy they are not able to supply. These compensations consist in payments for each non-served KWh priced at the difference between the non-served energy price and the node price. Non-served energy price is fixed by the regulators and represents the cost that faced the consumers for not receiving energy. Compensations have a double effect: they prevent the generators from signing contracts that they cannot fulfill and they expose the consumers to the real cost of energy in shortage situations, in the sense that by means of the compensation the alternative cost faced by the consumers is the non-served energy cost.

IV. Supply Crises

The three studied crises have a fundamental difference. California suffered a capacity deficit, while Brazil and Chile suffered an energy deficit.

A. California

The Californian crisis is explained by a combination of circumstantial factors that raised the wholesale prices more than expected, and by some unfortunate regulatory measures that hindered the market’s adaptation to the new conditions. Among the factors that raised the wholesale prices are: significant demand growth (12.7% in June 2000) due to an extremely hot summer, unexpected increase in natural gas prices (more than 10x between 1999 and 2000), increase in NOx emission permit prices and considerable reduction in energy importations due to the low level of the reservoirs in the Northeast of the country. In the other hand, investments in generation capacity almost disappeared in California as a result of the long and uncertain reform process that started in 1994 and finished in 1998 [4].

These factors were responsible for part of the price increase; the rest is attributable to market inefficiencies and to the exercise of market power by some generators. However, all this does not explain the occurrence of blackouts in a supposedly deregulated market. At this point become visible the flaws in the regulatory framework established in California, and particularly the effect of two transitory measures designed to help the utilities to recover their stranded costs and to assure competition in the short-term.

The first of these measures was to freeze the retail price in 0.06 US$/KWh for four years, whereupon the regulators supposed that the utilities would have huge profits in this period. The second transitory measure was to ban the utilities from signing contracts to ensure their supply, being forced to buy all their required energy from the PX and ISO markets.

Thus, when the prices started to rise and surpassed the price at which the utilities sold the energy, they started to lose money for each KWh delivered. This situation dragged one utility to bankruptcy, and has the other two in a fragile condition. As the utilities lost their credit capacity, in January 2001 the state’s government began to buy energy directly from the generators, in order to supply the regulated consumers. The effects of the transitory measures were disastrous for the market. The retail price’s rigidity was the main cause of the collapse of the system, because it inhibited the market from giving proper consumption signals. The prohibition to sign contracts did not allow the utilities to cover themselves from the inherent risk of the electricity business and exposed them to the volatility of daily prices.

In the other hand, there are several regulatory aspects that proved to be inadequate. Zonal management of transmission constraints over-simplified the transmission problem, eliminating the incentives to avoid congestions within a zone. It also forced special arrangements with some generators that where considered non-replaceable due to transmission constraints. These generators did not have incentives to bid their energy in the PX or the ISO since they where called to generate outside the market with over-market remunerations.

The separation of the energy, transmission and ancillary services markets proved to be inadequate in California, since the results of the separated optimization of these markets was inefficient. Finally, the rule that forced the SC to program balanced schedules (generation-demand) in the ISO was unnecessary. Its origin is based on the principle that the ISO should not modify the arrangement of two private parties. However, while aggregated balance of supply and demand is necessary by electricity’s nature, the individual balance that each SC makes is artificial and unnecessary, often inefficient and sometimes unfeasible [5].
B. Brazil

The Brazilian government has pointed out the lack of rain as the main cause of the country’s electricity shortage. It is true that the drought that some regions suffered was hard, but it does not fully explain the severity of the electricity shortage [6]. The shortage situation is explained almost exclusively by the lack of investments in generation and transmission capacity in the last decade. Since 1980, the growth of the generation capacity is less than the growth of demand.

To maintain the system with a security level of 95%, the regulators annually make an indicative construction plan with a 10-year horizon. 1999’s plan pointed out that even with all the proposed constructions and with an average hydrology, the system’s risk of shortage in 2000 was close to 10%. This shows that the gap between supply and demand was previous to the instauration of the new model, from where we can conclude that the government and the institutions in charge of the energy policy are responsible for the energy crisis, and not the new structure of the market.

The direct causes of the crisis were the high-risk level of the system in 2001, the lack of rain, the delays in the construction of new plants and a deficit in the transmission capacity. If more transmission capacity had existed, it would have been possible to transfer energy from the South, which was not affected by the drought, to the consumption centers in the North, relieving the situation. To face the crisis, the regulators created different measures that included penalties and compulsory blackouts for consumers that increased their consumption, and rewards to those that decreased it. The official target was to reduce consumption by 20%.

The new market structure has not helped in boosting new investments either, mainly as a result of three factors: the effect of the initial contracts scheme, the currency exchange risk at which the thermal generators are exposed, and finally, the lack of consistency and order of the reforms.

By means of the initial contracts scheme the distributors signed contracts that guaranteed 100% of their supply until the end of 2002. After that, the contracted supply would decrease by 25% a year, so as to have a completely free market for new contracts in 2006. The idea behind this scheme was to achieve a competitive market gradually, but the direct consequence was that as 100% of the consumption was already contracted and new capacity would have to compete only for new consumptions, there were no incentives to add new capacity to the system. Initial contracts were issued by ANEEL, the energy governing institution, and required guarantee certificates that ensured their ability to cope with their obligations at a confidence level of 95%. However, it is now evident that those certificates were too optimistic, because there was no capacity to ensure that level of confidence in the system.

The currency exchange risks at which the thermal generators are exposed arise from the fact that thermal generators consume natural gas that comes from Bolivia and that is priced in US dollars. The energy sold in Brazil is priced in reais, and does not include satisfactory adjustment components, thus exposing the profits of the companies to the depreciation of the Brazilian currency, which have been important in recent years and is related with the unstable regional situation.

Finally, the electricity sector reforms have not been completed yet. There are many aspects that have not been tested and others that have not been defined [6]. As the free market will truly begin to operate when the initial contracts scheme ends, these definitions are not crucial now, but have certainly discouraged investments, as the failed attempts of privatization recently proved. In the other hand, the electricity reform has not been coordinated with other energy sector reforms, such as oil and natural gas restructuring, despite the fact that they are closely related.

C. Chile

The central regions of Chile went through the hardest drought of the century in 1998. Given the mainly hydroelectric composition of the SIC, the deficit of energy that the country suffered does not sound strange. In fact, there are annalists that argue that deficits are inherent to any hydroelectric dominated system in certain periods [7]. However, that does not mean that in those periods blackouts must take place. The blackouts in the SIC in 1998 and 1999 show that the model did not work, and that it was not able to assign the energy more efficiently. The reasons behind this are diverse and the members of the market interpreted them differently.

There were four main aspects that hindered the proper functioning of the market: an extremely rigid price system, the slow and ineffective performance of the regulators, conflicts between the generators in the pool, and finally the lack of independence of the system operator.

The cost that regulated consumers face in Chile is the node price plus a distribution charge. The node does not reflect the real cost of energy in every moment, as mentioned before. For that reason, to face scarcity situations, the legislation has the compensation for non-served energy already mentioned. However, if some year was drier than the driest year used in the hydrological sequence used to calculate the node prices, the legislation foresaw that there should be no compensation, without giving any other alternative mechanism to solve the situation. As a result, the market remained without any price signal for its consumers. Even more, due to the arrival of natural gas to the market and to a regulator’s optimistic plan of entrance of new thermal plants [13], the node prices in the SIC decreased almost 20% during the shortage period. Thus, the consumers faced a smaller cost for energy just when it was scarcer.

At the beginning of the crisis, divergences arose in the pool related with the price at which the energy traded among generators should be valued. Despite each position, the real issue was that the authorities did not solve these divergences, as they were obliged to do with the attributes they had, resulting in the market without a spot price for more than four months. Chilean legislation gives the authorities great responsibilities in shortage periods, specially the decree regarding the rationing situation. In September 1998, the government was advised about the convenience of declaring it, but mainly due to the political damage that this could have caused, the authorities did not decree the rationing until November 1998, when some blackouts had taken place and it was unavoidable.

Finally, the CDEC was questioned due to the quick and incautious use of the reservoir’s water, given the conditions of the system. Although the dispatch was made in accordance with the system’s rules, the planning was obstructed by delays in the
entrance of new thermal plants and by the divergences inside the pool. All these issues raised concern about the governance and independence of the CDEC.

V. CONCLUSIONS

Deregulated electricity markets have worked reasonably well when there is no scarcity. However, legislations are proven when supply is tight and should be designed to face these situations. Many of the problems that have been analyzed in this work are intrinsic to the nature of electricity as a commodity; difficult to store, relatively inelastic short-term demand, high variation of demand associates to weather, etc. [12]. For this reason, it is even more important for deregulated markets to have proper mechanisms to adapt to these effects. Prices that reflect the real conditions of the market are the first condition needed for a market to adapt properly to tight supply conditions. Regulators that fulfill their responsibilities and react timely with technical criteria are other necessary condition for a market to overcome a shortage period successfully.

A. Price Signals

Regulated markets have a central control that indicates the goods’ prices, level of consumption, level of investments, etc. When a market is deregulated, this control is replaced for the essential mechanism of any free market: the price. The prices indicate the investment level required, the production level, etc. [8]. However, it is hard to find a single electricity market where prices can properly fulfill these functions.

In the three markets studied, consumers do not experiment the real cost of energy, which explains why their consumption patterns do not agree with the scarcity level of the markets and makes forced blackouts necessary to maintain the reliability of the system. Fixed prices hinder the supply-demand equilibrium and facilitate the possibility of the generators to exercise market power. When retail prices are fixed there is no demand elasticity, so the generators can raise wholesale prices without experimenting any change in consumption [9], as happened in California. The crises make clear that markets require more flexible retail prices to adapt to tight supply conditions. Besides, due to the nature of electricity, deregulated markets need contract schemes to hedge agents against the intrinsic volatility of spot prices.

Fixed retail prices were the main cause of the collapse of Californian electricity market. They have driven consumption to increase instead of decreasing it, they have dragged utilities to serious financial troubles, and they have collaborated to worsen the mentioned market power problem.

In Brazil, despite energy scarcity, consumers did not see significant changes in energy prices. Regulators preferred to face the problem socializing the deficit by means of a compulsory plain rationing rather than adapting the retail prices to market conditions. In the other hand, free contracts were thought to be plain rationing rather than adapting the retail prices to market conditions. The fact that the contracts have to fit to the VN and not the contrary makes the deregulation lose sense, because it does not allow prices to play their role.

The price system in Chile was obstructed by the limitation of the compensations and the undecided behavior of the authorities. To minimize social impact, the deficit was managed through rotary blackouts, without considering that some free consumers contracted with non-deficitary generators could have been paying for a better quality of service. As a result of the crisis, the electricity legislation was modified in order to eliminate the compensation’s limitation. Although technically the problem was solved, this solution implies that the generators will be required to pay compensations in years with less rain that the ones considered in the calculation of their remuneration, which does not seem reasonable.

B. Regulators’ Performance

Regulators’ performance was a crucial factor in all the crises studied. The existence of so many federal and state agencies in California was not enough to solve the problem. The responsibility was diluted among them and nobody took the necessary measures to relief the situation: to raise retail prices, to allow utilities to enter into contracts with generators and finally, to monitor the market properly.

In Brazil, the lack of investments that caused the crisis is fully explained by the incapacity of the authorities to plan and carry out an orderly and coherent privatization and deregulation process that would boost investments instead of discouraging them. Particularly in the crisis, the regulators proposed several emergency plans, but no one was finally carried out.

The regulators performance was not so relevant in Chile as in the other cases, but it also was slow and in spite of having some tools to manage the situation, they did not make use of them [10]. Political considerations influenced the authorities to delay the decree of the rationing situation, which is crucial in the Chilean electricity structure, and for similar reasons they did not solve the disputes inside the CDEC, leaving the market without spot prices for more than four months.

In the three cases the agencies in charge of the electricity sector were not independent from the government, and that explains why political short-term criterions prevailed over the technical and economical criterions that should have been applied. Appropriate measures to solve these crises are commonly contradictory with government political short-term interests, and for that reason it is not likely that government’s dependent institutions will provide the necessary long-term outcomes to solve an electricity crisis.

One important lesson from the crises studied is that deregulation of electricity markets is a dynamic process, that requires independent and flexible institutions, capable of reacting fast and efficiently to face different market conditions [4]-[10]. To achieve that, institutions in charge of energy polices should be independent from the government.

C. Proposals to Improve the Chilean Electricity Market

Although the compensation system is theoretically well designed, it has never operated and requires a lot of regulator’s calculated prices to work properly. Moreover, it requires active participation of the authorities. For these reasons, we consider that it is recommendable to go further in giving more flexibility to the node prices, in order to gradually subtract importance from the compensation system. If node prices are closer to real prices, the importance of compensations is significantly reduced. In [11],
the economic loses associated to the price inflexibility in the Chilean market are estimated, resulting in a range of 5-10%. They also show that current price system in Chile requires 30% more capacity than if it were more flexible. For this reason, we suggest that node prices be updated monthly, and that the way they are calculated be modified in order to increase the importance of current conditions of the market and to reduce the weight of estimated future conditions. Additionally, we propose the introduction of improvements in the retail price system, in order to have different retail prices along the day (dynamic pricing). This would allow to shift demand from peak hours to other moments of the day when overall demand is less. As a result, less capacity is needed and the overall cost of the system would be cheaper [12].

There is consensus in Chile around the idea of decreasing the relevance of node prices. For that reason, the regulators proposed an increase in the number of free consumers by gradually decreasing the level of required capacity that characterizes them from 2 MW to 200 KW. This measure, along with a reduction of the deviation margin of the node prices respect to free prices from 10% to 5%, would reduce the arguments around the tariff decrees.

In relation with the disputes inside the CDEC, we propose to solve them by means of private arbitrations or permanent committees, in order to release the regulators from their role of arbitrator in private conflicts. We also propose the creation of payment guarantees that support the exchanges between generators into the pool. Additionally, we recommend that the organism in charge of energy polices (Comisión Nacional de Energía), should be freed from the government and should be established as an independent body, with its board elected by the Congress for fixed periods.

To ensure system backup we suggest restoring the MRT to 15%, as it was until 1997, when the government decreased it to 6.27%. We also recommend that the MRT be established as a fixed number, in order to avoid a political misuse of it. MRT is a signal, and it would be clearer if nobody can change it.

Finally, as of measures for shortage situations, we propose to raise tariffs to customers that increase their consumption within these periods and to apply plain rationing only to regulated consumers, in order to induce free consumers to contract with reliable generators.

VI. REFERENCES


VII. BIOGRAPHIES

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