Brazil and the international electric integration: Background, Current Status and Perspectives.

Nivalde de Castro[1], Roberto Brandão[2], Rubens Rosental[3], Paola Dorado[4]

[1]*GESEL-UFRJ, Av. Pasteur 250, Rio de Janeiro, Brazil.* nivalde.castro@gmail.com
[2]*GESEL-UFRJ, Av. Pasteur 250, Rio de Janeiro, Brazil.* robertobrandao@gmail.com
[3]*GESEL-UFRJ, Av. Pasteur 250, Rio de Janeiro, Brazil.* rubens.rosental@gmail.com
[4]*GESEL-UFRJ, Av. Pasteur 250, Rio de Janeiro, Brazil.* paoladoradogoitia86@gmail.com

ABSTRACT

Electric integration is a topic discussed and promoted worldwide due to the advantages for the countries involved. In order to enjoy these advantages several countries, mainly in Europe, have created regional electricity markets. For South America countries the creation of a regional electricity market is still a distant option due to economic and social asymmetries and, especially, because of incompatibilities in the regulatory framework and in energy trading mechanisms.

This paper aims to analyze the electrical integration process in the South America, concentrating in Brazil the central focus of the analysis. The main constraints of Brazil's regulatory and electricity trading model are also analyzed, highlighting that the last restructuring process of the electric sector (2003-2004) has defined a commercial model where financial contracts of "physical guarantee" are traded and not electricity itself, and where the power plants do not have autonomy over their production. The characteristics and specificities of the Brazilian model determine boundaries and conditions that must be considered to enable international electricity trade.

The already existing integration projects are also analyzed highlighting that these projects were developed under special conditions for taking advantage of specific opportunities without the support of a strategic integration policy. Additionally, the paper addresses two other electrical integration projects that are under discussion, the binational hydroelectric power plants between Brazil-Argentina and between Brazil-Bolivia.

The paper concludes that electrical integration with direct participation of Brazil is more feasible for binational projects and short-term surplus trade because of the differences between the Brazilian market design and the other countries market design.

KEY WORDS: Electric international integration, Brazil, energy commercialization.

1 INTRODUCTION

Regional Electric Integration is a topic broadly discussed and incentivized worldwide, due to the advantages for the countries involved. Among them are: the more efficient use of energy resources for electricity generation, reduction of the wholesale prices and, specially, the reduction of its volatility, the incentive for efficiency generated by increasing the market competition, and more reliability and security for providing this service.

In order to take advantage of these benefits, many countries, especially in Europe, created Regional Electric Markets (REM) in which market competition exists for buying and selling electric energy. However, in South America the constitution of a REM, following the European model, is yet a distant option because of the existing economic and social asymmetries between the countries and, mainly, because of the adoption of different commercialization rules in each country. These factors greatly delay the electric integration process on the region.

Despite of these difficulties, Brazil has interconnections with Paraguay (Itaipu Binacional), Argentina (frequency converters in Garabi), Uruguay (frequency converter in Rivera) and Venezuela (transmission line between Roraima and Guri). These projects were developed under particular solutions for taking advantage of specific opportunities, without the support of a strategic integration policy of Brazil with the other countries.

Additionally, some electric integration projects are in the discussion agenda. Among them are:

- The construction of a new frequency converter and a transmission line to enhance the energy trade capacity between Uruguay and Brazil;
- Two binacional hydroelectric plants, Garabi and Panambi, on the Uruguay River on the border of Brazil and Argentina: these projects are at the engineering and environmental studies phase;
- A binacional hydroelectric plant with Bolivia on the Madera River: this project still at preliminary state of discussion;
- A hydroelectric plants in Peru for supplying the domestic market and selling the surplus to Brazil;
- The construction of hydroelectric plants in Guiana and in Bolivia for exporting part of the generated energy to Brazil, these projects still in preliminary state of discussion.

This paper aims to understand and analyze the electrical integration process in the South American region, positioning Brazil in the central focus of the analysis. It is divided in four sections besides this introduction. The first section examines the main electric matrix characteristics and the Brazilian potential for electric generation using just local resources. The second section analyses the Brazilian commercial model pointing out the restrictions to a full electric market integration. The third section describes the Brazilian electric integration experiences and discusses the possibilities for importing and exporting energy in the current context. Finally, the conclusions, which considers that the electrical integration with direct participation of Brazil is more feasible for binational projects and short-term surpluses exchanges due to the differences between the Brazilian business model and other South American country models.

2 THE BRAZILIAN ELECTRIC SYSTEM

The objective of this section is to present the main characteristics of the Brazilian electric sector. The electric matrix is presented as well as the expansion forecasts. Considering these elements is a key condition for analyzing the electric integration possibilities of Brazil with the other South American countries.

2.1 The Brazilian electric matrix

The Brazilian Electric System (SEB for its acronyms in Portuguese) had an installed capacity of 139,8 GW in 2014 (MME, 2015). The National Interconnected System[1] (SIN for its acronyms in Portuguese) has an installed capacity of 128,4 GW[2] in the same year, as shown in Table 1. The difference of the SEB and SIN installed capacity are systems installed in isolated areas mainly in the North Brazilian Region (Rain Forest).

Table 1: Installed Capacity for Generation in Brazil by source, 2014

(% of the Total and GW)

Source	SIN	Isolated System	Self production	Total Brazil
Hydro	73,1	21,7	8,8	68,0
Thermal	21,5	78,3	91,2	27,1
Nuclear	1,5		0,02	1,4
Wind	3,8		0,04	3,5
Solar	0,01			0,01
Total (GW)	**128,4**	**1,3**	**10,1**	**139,8**

Source: Ministry of Mines and Energy (MME) (2015, p.10)

[1] SIN interconnects all major consumption centers, as well as the basins where are installed the main hydroelectric plants.

[2] The remaining installed capacity is divided by: isolated systems 1,3 GW and 10,1 GW corresponds to private installations for self production, especially industries.. .

In 2014, the total energy generated in the SEB was 624,2 TWh and 566,7 TWh were consumed in the SIN (MME, 2015). Analyzing by source of generation is showed the predominance of hydroelectric generation for supplying the SIN, even considering the ongoing modification of the Brazilian electric matrix and the hydrological drought cycle that started in 2012. According to Table 2, in 2014, 71% of all energy used in the SIN came from hydroelectric power plants, meanwhile the thermal generation plants were responsible for 24,1% of the energy supplied to the SIN. This is an evidence of the increasing importance of the thermal generation in the Brazilian electric matrix.

It is still worth to consider the importance of wind energy, in 2014 this source supplied 2,2% of the SIN while the nuclear generation represented 2,7% of the SIN energy.

Table 2: Energy Generation by source, 2014

(% of Total and TWh)

Source	SIN	Isolated System	Self production	Total Brazil
Hydro	71,0	27,5	6,5	65,2
National	65,2	11,6	6,5	59,8
Imported	5,8	15,9	-	5,4
Thermal	24,1	72,5	93,5	30,3
Fossil fuel	20,1	71,8	49,1	22,9
Renewable	4,1	0,7	44,3	7,4
Nuclear	2,7	-	-	2,5
Wind	2,2	-	-	2,0
Solar	0,002	-	0,010	0,003
Total	100,0	100,0	100,0	100,0
Total (TWh)	**566,7**	**5,3**	**52,2**	**624,2**

Source: Ministry of Mines and Energy (MME) (2015, p.7)

In normal hydrology, the dispatch of the SIN usually met the demand mainly with hydroelectric plants. The difference was supplied by null variable costs plants (co-generation and wind) and power plants that has contract obligation for minimum generation (inflexibility), like the two nuclear plants (Angra I and Angra II) and thermoelectric plant with take or pay fuel contracts. Most of the time the thermal power plants were used as system backup.

However, as shown in Table 3, since 2012 the thermal generation is becoming more representative, partly due to contextual factors and partly due to structural factors.

The contextual factors refer to the hydrologic crises that Brazil is facing since 2012, which led the National Independent System Operator (ONS for its acronyms in Portuguese) to dispatch thermal plants for long periods. Since that time, the dispatch time of thermal power plants was greater than the original expected time, stated in the auction statements. For instance, between 2012 and 2014, the dispatch time of a thermal plants contracted in the 2007 auction was greater than the overall fifteen years of estimated operational time stated in the original project contract. This operational stress imposed several technical and maintenance problems (CASTRO *et all*, 2014).

The structural factors are related to the electric matrix change, due to the difficulties to obtain environmental license for the construction of new hydro power plants and because new hydro projects are *run of the river* plants with small dams that has storage capacity for just few days. The *run of the river* hydro power plants are more environmental friendly, but they also reduce the regulating capacity throughout the year because it reduces the reservoir size. This lower ability to regulate the system determines the need of complementary sources, mainly for supplying the energy demand during the dry season (CASTRO et all, 2012). In this context, the Brazilian electric matrix needs complementary sources with a greater participation of other sources in the annual energy generation, among these sources are the thermoelectric plants that uses fossil fuel, as shown in Table 3.

Table 3: Energy generation dispatched or programmed by ONS for the SIN: 2005-2014

(% of total)

Year	Hydroelectric	Thermoelectric
2005	92,4	5,1
2006	91,8	4,8
2007	92,8	4,3
2008	88,6	8,1
2009	93,3	3,7
2010	88,8	7,9
2011	91,2	5,3
2012	85,9	10,4
2013	78,7	17,2
2014	73,0	23,0

Source: ONS (2015,a)

The Brazilian transmission system has more than 100 thousand Km of high tension lines and was originally constructed to allow the optimization of hydropower generation, through the exchange of large blocks of energy over long distances. The complementary optimization hydro resources effect is one of the reasons Brazil has only one system operator.

As *the run of the river* hydropower plants are inserted in the generation capacity and considering the demand increase, the ONS will have to operate the existing dams promoting a greater variation on the dams water level in short periods of time (CASTRO et all, 2012) and, consequently, there will be greater need for complementary sources to hydroelectric plants.

2.2 **Energetic potential and perspectives for the electric matrix.**

The official planning agency named Energy Research Company (EPE-for its acronyms in Portuguese)forecasts a significant increase in consumption during the coming years[3], this demand will be supplied exclusively using domestic generation plants. Although there is a wide diversity and quantity of natural energy resources to be used in reasonable scale and with economic feasibility, Brazil will need to import fossil fuels for thermal power generation, particularly in the form of liquefied natural gas (LNG).

The expectation of the Ten Year Plan for Energy Expansion (PDE 2023), prepared by EPE, considered firstly the 30.043 MW (EPE , 2014; . p 80) projects already contracted in auctions entering in operation between 2014 and 2018. The additional energy to meet demand until 2023 (estimated at 41.044 MW[4]) would be supplied mostly with the construction of new hydroelectric power plants (14.679 MW), followed by thermoelectric plants (7.500 MW) and from alternative energy sources (wind, co-generation from biomass and small hydro plants),

The hydro potential is mainly concentrated in the Amazon biome and, therefore, the Brazilian energy frontier is expanding toward the Amazon, with the construction of large hydropower plants (CASTRO , 2007)[5]. It is estimated that by 2023 the northern part of the country will have a expansion of generation capacity of 30.504 MW over the existing 14.506 MW in 2013 (EPE, 2014; p.78). Most of this expansion will take place with *run of the river* hydropower plants that will require complementary generation.

The PDE 2023 also predicts a major expansion of thermoelectric plants, 7.500 MW between 2019 and 2023. The expansion of thermal power generation depends mainly on the availability of fossil fuels, primarily the

3 According to EPE (2014 , p. 35) , the consumption of electricity in 2023 will be 780.4 TWh , 45% more than the consumption of 535.2 TWh recorded in 2014

4 According to the EPE (2014 , p. 78) until 2023 will be added 71.087 MW , of which 30.043MW should come in operation by 2018

5 The main hydropower plants under construction are: Santo Antônio (3.150 MW) and Jirau (3.750 MW), both located in Madera River and in final phase of motorization. Belo Monte (11.233 MW) and Teles Pires (1.820 MW) on the Xingu River. There are also projects at the environmental licensing phase, the largest of them is the Tapajós complex, with a capacity of over 11.000 MW. The hydroelectric potential in the Amazon basin is estimated in more than 100,000 MW, this magnitude determines the priority of the government's energy policy to maintain strong investments in hydropower in this region. This decision is subject to obtaining environmental licenses in periods consistent with the need in order to meet the growing demand.

availability of natural gas. The supply of natural gas in Brazil depends on three factors: domestic production, imports through the Bolivia-Brazil gas pipeline and the Liquefied Natural Gas (LNG) imports.

Although the national production that is expected to increase 170% until 2023, the Fig.1 shows that the supply of natural gas in Brazil will still depend on imported resources, both from Bolivia through the pipeline as well as LNG imports.

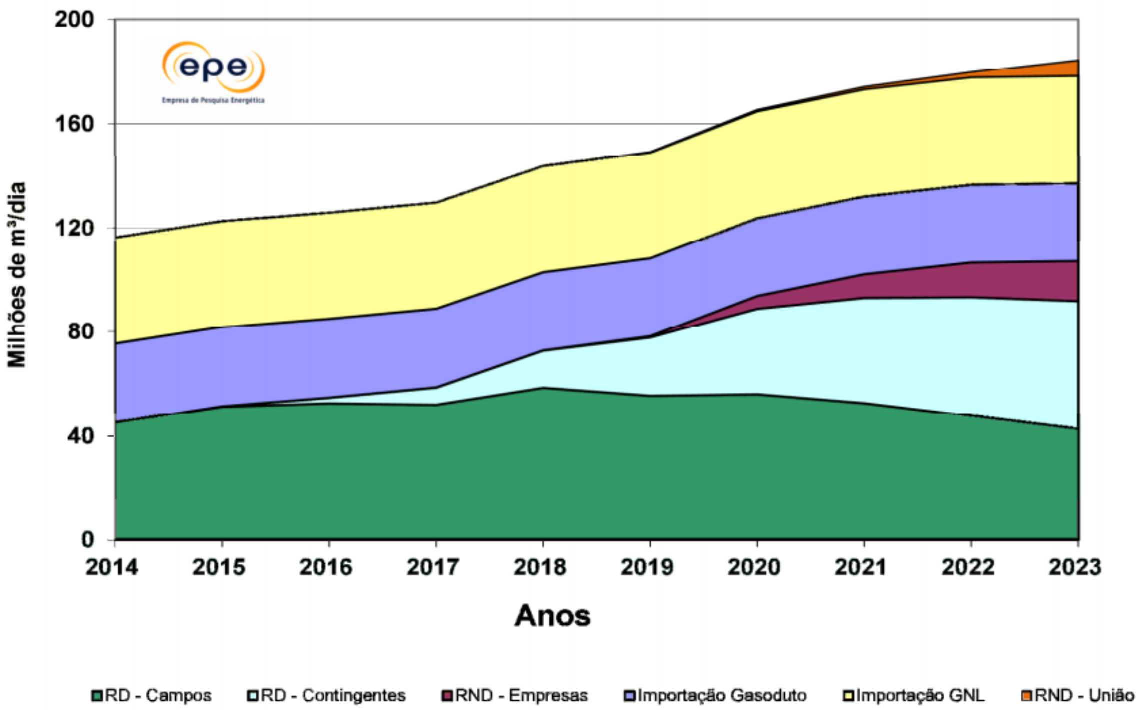

Figure 1: Natural gas supply for the integrated network in Brazil: 2014- 2023

EPE (2014, p. 293)

The increase in power generation using natural gas is not only a feasible alternative but is a must, considering the changes in the Brazilian electric matrix where thermal generation will have a key role. As an example of the importance of thermal sources, in the auction held in April 2015, to be available in 2020 (referred to as A- 5 Auction), a thermoelectric plant of 1.515MW which uses imported LNG[6], obtained a supply energy contract offering electricity with price of 70,63 USD/ MWh[7] (ANEEL, 2015,a)

In relation to other renewable sources, the EPE forecast an important increase of wind participation in the electric matrix. Since 2005, Brazil began to explore its great wind potential, estimated in 350GW (IEA, 2014,p.391), and the costs reduction has exceeded the most optimistic forecast. The wind projects have revealed the competitiveness of this source. Brazil auctions have already hired more than 7.000 MW of installed capacity of wind power to start its operation between 2016 and 2020 (ANEEL, 2015 a). Given the current price scenario and the existing wind potential in Brazil, the trend is that the hiring of wind project will remain intense in the coming years.

In addition to hydropower, thermal with natural gas and wind, Brazil also has another option with competitive costs. It is the co-generation using residual biomass from sugar cane. The technical potential for generating electricity using this source would allow to offer 7.7 GW until 2023, from which 1.4 GW will start its operations until 2018 (EPE, 2014; p. 90)

For solar energy, the installed capacity is still very small. However, there is a growing interest in developing the necessary conditions to the participation of this source in the Brazilian electrical matrix. In fact, on the auction

[6] The thermal power plant will be installed in Porto Sergipe with an estimated construction cost of R $ 3.2 billion. The project includes the construction of a regasification terminal for the operation of the thermoelectric (GENPOWER GROUP, 2015).

[7] Using the exchange rate of December 25, 2015 informed by Brazilian Central Bank, 3,95 R$ per US dollar.

held in October 2014, were contracted 889.6 MW of solar energy with an average price of 54,51 USD/ MWh[8] (ANEEL, 2015 a)

The PDE 2023 does not consider any increasing in the electricity importation. However, this position does not mean that international projects involving energy imports cannot be developed[9]. These projects may be incorporated into the planning but would be directly conditioned to negotiations that will allow the hiring of firm energy by the Brazilian market. Until now, there is not consistent study to enable medium and long-term import contracts in the current Brazilian regulatory environment.

3 THE BRAZILIAN BUSINESS MODEL

The Brazilian business model, unlike other countries in the region, does not allow the trading of physical energy. The trading of energy is through financial mechanisms that not necessarily involve physical delivery of energy from the generation company. The agents must buy or sell contracts representing a guarantee a "physical guarantee" and not energy itself. The logic behind this mechanism is that an individual generator does not have the responsibility to meet consumer demand, because it does not have the empowerment over its own generation unit. It is the responsibility of the Brazilian ISO (ONS) to dispatch all the generation assets in an optimal and centralized way[10].

This business model was designed to deal with the singularities of the Brazilian electric system, predominantly hydroelectric, in a business environment that, from the nineteen’s, went through a liberalization process with the introduction of market mechanisms for energy trading.

The problem by that time refers to the short-term prices of energy in a system that produces electricity essentially with fixed costs, basically hydropower plants. It is easy to demonstrate that a price equal to zero can occur in industries where production is based on fixed costs and where the products are traded in a competitive market. Prices may be zero because: (i) in competitive markets price is always equals to the marginal cost of the least efficient producer; and (ii) the marginal cost of an industry that produces only based on fixed costs is zero. In this sense, if the Brazilian business model were based on a spot energy market, prices would be, for large periods, very low or even zero, becoming significant only in times of water shortages. If generator revenues were formed based on spot market prices they would not be enough to pay all the production costs for long periods, especially when hydrology were favorable.

During the 2001 and 2002 water shortage the above mentioned problem was intensifies and the business model was corrected with the reform of 2003 and 2004. The new business model ensures and encourages competitiveness for power generation. However, the competition focus is not in the physical power market, but in a market for financial contracts of "physical guarantees"[11]. The new dynamic for energy auctions makes the long-term contract prices to converge to the average cost of energy. Additionally, by offering long-term contracts with highly predictable revenues and indexed to inflation, the National Bank for Economic and Social Development (BNDES for its acronyms in Portuguese) offers long-term financing using project finance mechanisms for all the winning projects. The main guarantee of the financial contract is the future cash flow of the project based in the produced energy.

The "physical guarantee” that is the fundamental characteristic of the SEB. There are not energy contracts, but energy guaranty contracts. This way, each power plant, regardless of the source, receives from the Ministry of Mines and Energy (MME) certificates that can be traded with consumers through contracts. These certificates represent, using a specific rule, the entireness or a fraction of the energy that the power station could produce. The certificates are calculated by an official methodology that consists in modeling the optimized operation of the SIN, with all the projects already contracted and the new projects that want to participate in an auction. The aim of this model is, in a first step, to calculate the highest load that the system (critical load, or system physical

[8] Using the exchange rate of December 25, 2015 informed by Brazilian Central Bank, 3,95 R$ per US dollar.

[9] From the planning mechanics point of view, with a horizon of ten year will be easy to include a forecast for the energy importation in case of the projects move forward, because every year the EPE review the planning for the next ten years.

[10] The centralized and optimized management of water resources in a system with the scale and size like the Brazilian, reduces the dependence that hydropower has with respect to the local hydrology uncertainties and, therefore , makes it possible to meet a higher electric load compared to what would be possible with an uncoordinated system operation

[11] On the one hand, there is an obligation of the agents to have 100 % of it consumption backed by financial contracts of "physical guarantee". On the other hand, all the needs of the regulated market must be contracted in long-term contracts (30 years). Hiring energy for the regulated market is done through new energy auctions organized by the government on behalf of the distributors, thereby creating a monopsony buying structure.

guarantee) could meet given a safety criterion (5% deficit risk in any given year) and other conditions for an economic operation.

In a second step, the critical load of the system is divided between all the modeled production units. The share corresponding to each generator is their "physical guarantee", which corresponds to the energy certificates that can be traded with consumers through contracts.

The business model has proven to be adequate for ensuring the correct operation of the Brazilian electric sector, it gives economic signals for capacity expansion at low costs using the auctions to expand the supply for the regulated market.

The entire model is based on the concept of "physical guarantee ", which is consistent when the generation units are represented as a closed system, operated in an optimal and centralized way. No other country in Latin America adopts a business model similar to the Brazilian one.

Given these technical and commercial characteristics, the Brazilian electrical integration with neighboring countries will not occur, using the same model as in Europe, which consists of a common energy market responsible for defining the generation of each plant, the energy prices and the energy exchanges. In fact, the Brazilian model does not makes sense if it is not possible to represent the generation resources and the energy demand in a closed system, optimized in a centralized form.

Although Brazil has abundant alternatives for generating electricity using domestic resources and has a model that allows to expand the supply minimizing the costs. Even considering the difficulties and limitations for implementing a truly integrated energy market in South America, the growing need of firm energy and the present shortage of national natural gas create opportunities for energy integration.

On the one hand, seasonality of water flows between the hydrological regimes in the Southeast / Midwest (where are localized the dams with greater water capacity) and the hydrological regime in the south and the Amazon region (EPE, 2014; p. 84) enhance the economic feasibility of binational projects with Bolivia[12] and Argentina[13]

On the other hand, the growing need for natural gas at competitive prices has created opportunities for importing LNG for supplying electric generation. In addition, some neighboring countries companies with gas availability[14] has showed interest in investing in the Brazilian electricity market by building fired power plants.

4 ELECTRIC INTEGRATION

In this section are analyzed the existing experiences of electrical integration between Brazil and its neighboring countries, also are pointed out some future electrical integration possibilities.

4.1 Integration Experiences of Brazil

There are a consistent technical and economical reasons that pushes the international integration of electrical systems. For example, the integration of different generation matrixes and different seasonal consumption profiles allows the optimization of available resources, offering benefits for all the parties involved. Even the simple shared use of sources can allow economy of scale. However, the technical benefits of electric integration are maximized only when it is possible to establish common and solid trade rules. The harmonization, or at least the compatibility, of regulatory and trade rules is the basic assumption for a joint optimization of electrical resources between countries.

Regarding Brazil´s position in the regional electrical integration process, as previously analyzed, has to be consider that the energy trading mechanisms were designed in a closed format, and also planed and operated in a centralized way. Therefore is not suitable for a full-integrated market scheme.

Even considering these structural constraints, Brazil developed special business model to import and export energy with Paraguay, Argentina, Uruguay and Venezuela.

[12] On July 17, 2015 was signed the Addendum to the Memorandum of Understanding in the field of energy between the Ministry of Mines and Energy of the Federative Republic of Brazil and the Ministry of Hydrocarbons and Energy of Bolivia (signed on 17 December 2007) , which aims to facilitate the studies of financial viability, and technical and environmental studies for building a binational hydroelectric dam on the Madeira River Basin

[13] Since 2012, the company *Unión Transitória de Empresas*, obeying the request of Eletrobrás (Brazil) and Ebisa (Argentina), has been developing engineering and environmental studies as well as a social communication plan for the hydropower plants of Garabi and Panambi located on the Uruguay River in the binational stretch between Brazil and Argentina (ELETROBRAS, 2010).

[14] This is the case of the National Electric Energy Company of Bolivia (ENDE for its acronyms in Spanish), which has weighted the possibility of building a thermal power plant to supply the Brazilian market using Bolivian gas as a key resource.

The electric integration experiences between Brazil and its neighbors have been designed in its operational and commercial aspects to function properly in the Brazilian model. For example, although Itaipu was built long before the new model has been established (2004), the trade of energy for this plant had to be adapted to the new logic of the business model. Thus, Itaipu Binacional is part of the optimized dispatch of energy on the Brazilian system, which includes not only the supply of the domestic market, but also Paraguay's energy needs, which has different market arrangements than Brazil.

The original energy import contract from Argentina through CIEN also fit the Brazilian model, represented as a "frontier thermoelectric", which is dispatched when the hydrological situation required thermal energy complementation. In both cases, Itaipu Binacional and CIEN, the import of energy was possible because the commercial mechanisms adopted allowed the exporter to fit in the Brazilian operational logic . However, recent experiences of energy trade with Argentina and Uruguay followed a different logic.

When the importation of energy from Argentina, via CIEN, was unilaterally interrupted because of the energy crises in Argentina, finishing 20-year export contracts with Brazilian distribution companies, the frequency converters localized in Garabi began to be used occasionally to export power from Brazil to Argentina. These frequency converters are also sporadically used to allow the export of energy to Uruguay, passing through the Argentinian transmission system.

This energy export modalities practiced with Argentina and Uruguay are occasional. There is not a Brazilian commitment to export certain fixed amount of energy.Most of the time, the existing interconnections remain idle

Imports has a more complicated situation. The import of power by Brazilian agents is very difficult to be incorporated into the current trade model. Currently, besides the exchange of surplus of hydropower generation to be returned without involving any cash transaction, there is also the interruptible energy import from Argentina[15] and Uruguay[16]. This type of importation involves weekly energy offers on the border of Brazil[17] aiming the sell the energy in the spot market and being paid according to the Settlement of Differences Price (PLD for its acronyms in Portuguese). This energy can only be traded in the spot market because the generators do not have a certificate of “physical guarantee” in the Brazilian market, which prevents them to obtain incomes through sale contracts.

The integration method adopted with Argentina and Uruguay, which involves the export and import of energy in an interruptible basis without long-term contracts and taking advantage of short-term opportunities with relatively simple rules of commercialization, has shown the benefits of intensifying the trading of energy surpluses for all the parties. Contracts aiming the exportation / importation of firm energy are also possible if the certain conditions are created. These conditions must give effective legal certainty for such commercial arrangements.

In order to allow the exportation of firm energy through long-term contracts to the Brazilian market, it will be necessary to develop a technical and commercial arrangement to match energy imports to a power plant operating in an optimal way within the Brazilian system.

4.2 Outlook for import and export of electricity in Brazil

There are negotiations between governments for using the water resources on the border, particularly with Argentina on the Uruguay River (hydropower plants of Garabi and Panambi) [18] and with Bolivia in the Madeira River[19] basin, with a similar scheme used for Itaipu Binacional. However, any agreements for the construction of binational hydroelectric plant between Brazil and other partner should consider trade mechanisms consistent with the current model adopted in SEB.

In principle, these projects need to meet the same model of Itaipu Binacional, which is operated within the Brazilian model logic. In this sense, there are not major problems related to the use of this model in binational plant projects, especially for the quota of 50 % that will be owned by Brazil.

[15] Through the frequency converter of Garabi (MME, 2015- Portaria N°81).

[16] Through the frequency converter of Rivera and the future frequency converter of Melo (MME, 2015 – Portaria N° 82),

[17] The weekly energy offer to the ONS can be adjusted to the daily dispatch schedule.

[18] This project has significant progress with the hiring, in 2012, of the engineering and environmental studies, and also with the communication plan

[19] The addendum to Memorandum of Understanding in the field of electricity between Bolivia and Brazil was signed on July 2015 , which aims to enable the bi-national studies on the Madeira River

Building a hydroelectric plant dedicated in whole or in part to export energy to Brazil and use it in accordance to the Brazilian system operating logic will probably impose restrictions on the energy optimization needs. To consider the local demand of the exporting country and make a joint optimization of the system, would be required that consumers of the neighboring country were indeed part of the Brazilian market by acquiring financial contracts of "physical guarantee~~.~~". Although this hypothesis, which is equivalent to the adoption of the Brazilian business model by another country, cannot be ruled out, it is unlikely to be achieved in the short or medium term.

In the case of exporting thermal energy to Brazil, it would be possible to structure a similar contractual modeling to the original scheme of import of CIEN, but with greater legal certainty. For this, from the formal and contractual point of view, the signing of an International Treaty would be needed, raising the energy commercialization to a relationship between countries and not between electric companies, as was the case of CIEN. Presently there is not any plan for Brazil to import thermal power from neighboring countries

Due to the economic, political and energy asymmetries between Brazil and the other countries in the region, the major and faster opportunities for electric integration and international trade of electricity involving Brazil are the import and export of surpluses. The current contractual arrangements for energy trading adopted by Brazil with Argentina and Uruguay have used this logic and could be extended to other power plants. Important to notice that there is already a transport infrastructure to the Argentinian market and a large interconnection with Uruguay is being built.

Although there are functional mechanisms for trading energy surpluses using the existing interconnections, it is essential to create a legal, regulatory and commercial framework enabling the energy exchange of larger blocks of energy and with long-term contracts.

5 CONCLUSIONS

The energy integration process of Brazil, with respect to the electric sector can be divided in~~to~~ two phases. The first phase , which began in the 1970s , being the central focus the construction of the then largest hydroelectric of the world, Itaipu Binacional, which had a double and strategic goal: to ensure greater national supply with competitive costs.

The second phase of the integration process starts in 2003 and 2004, when Brazil redefined its strategic policy of regional economic integration, focused on Latin America. It is also important to highlight the role of power sector restructuration on 2003-2004. This process included: the recovery of state planning with the creation of EPE; use of new energy auctions as the main instrument for expanding the supply, formatting a new and consistent institutional framework and the BNDES role in financing the generation and transmission projects through the use of project finance mechanisms, directly linked to the auctions. This new model allowed Brazil to gradually return to exploit the hydroelectric potential, as well as creating a support for investments in wind energy, biomass from sugar cane and in generation from natural gas.

The business model was structured according to a unique and fundamental characteristic of the Brazilian power sector, the high prevalence of hydroelectric generation in the matrix. In this sense, the Brazilian model has specific characteristics that clearly distinguish it from the commercial arrangements prevailing in other Latin America countries. It is a model where energy itself is not traded, but financial contracts of "physical guarantee ". The electricity generating plants do not have contracts of physical energy and they do not have autonomy over its own production, being this determined by the ONS according to an optimization logic or all the electricity generation units.

In this sense, the electrical integration through the import and export of electricity in Brazil must respect the Brazilian business model. The characteristics and specificities of the Brazilian model determine boundary conditions that need to be observed in order to allow international trade of electricity. This involves, excepting for binational hydropower projects such as the project in the Madeira River with Bolivia and the hydropower plants of Garabi and Panambi with Argentina, that energy integration projects will depend on regulatory setting in order to adhere to the Brazilian business model. Especially for projects focused on exporting big blocks of electricity with long-term contracts and at competitive prices to the Brazilian electricity market.

In this sense, the dynamic of the electrical integration in South America with direct participation of Brazil is restricted to four possibilities. The first and simplest one, is the construction of binational hydroelectric plants based on the Itaipu Binacional successful experience. The production of a binational power plant is 50 % for each country and it is possible to define in the International Treaty that will endorse the trade agreement, the conditions for the trade of energy surpluses as was done with Paraguay in relation to Itaipu Binacional.

The second possibility is to model the energy imports by Brazil as a thermoelectric at the border, as happened with CIEN contract. This option is ideal for the import of thermal energy and its viability requires an understanding between countries, probably with an International Treaty to give legal certainty to commercial arrangement.

The third alternative, more complex, is the construction of hydroelectric plants (and the respective segments of transmission lines) in neighboring countries, and define the conditions for export to Brazil the portion of the energy production that won´t be consumed by the country of origin. The difficulties are great because the generating unit would have to submit to the Brazilian trade rules and to optimal and centralized dispatch criteria.

The fourth possibility is to trade energy surpluses in trade patterns that Brazil is already practicing, although sporadically, with Argentina and Uruguay. Selling and buying surpluses of power through short-term contracts that may be signed without a profound regulatory harmonization between the businesses models of the countries involved. In this case, each country seeks to ensure security of supply on its own market, counting in addition with the surpluses from a neighboring country and alternatively, with the option of selling the surpluses power. This type of integration has great scope for expansion, especially with countries with which Brazil already has interconnection.

REFERENCES

ANEEL (Agência Nacional de Energia Elétrica). (2015). Editais de Geração. Site Institucional. Brasilia, Brasil: Agencia Nacional de Energia Elétrica. Disponível em: http://www.aneel.gov.br/area.cfm?idArea=53 Access on August,1; 2015.

CASTRO, N. J. (Abril-Maio 2007). O destravamento ambiental do setor elétrico brasileiro. Custo Brasil. N°8, 68-73. Disponível em http://raceadmv3.nuca.ie.ufrj.br/buscarace/Docs/njcastro83.pdf Access on August, 3; 2015.

CASTRO, N. J., BARA NETO, P., BRANDÂO, R., & DANTAS, G. d. (Maio de 2012). Expansão do Sistema Elétrico Brasileiro e o Potencial Hidroelétrico da Região Amazônica. TDSE N°50. Rio de Janeiro, Brasil: GESEL-UFRL. Disponível em: http://www.gesel.ie.ufrj.br/app/webroot/files/publications/53_TDSE50.pdf . Access on August, 5; 2015.

CASTRO, N. J., HUBNER, N., & BRANDÂO, R. (Maio de 2014). Desequilibrio econômico e financeiro das usinas termoelétricas frente à persistência da crises hidrológica: 2012-2014. TDSE N°61. Rio de Janeiro, Brasil: GESEL-UFRJ. Disponível em: http://www.gesel.ie.ufrj.br/app/webroot/files/publications/20_TDSE%2061-%20Crise%20das%20UTE%20(1).pdf Access on August,10; 2015.

ELETROBRAS. (2010). UnE Garabi-Panambi. Site institucional. Brasil.: Disponível em: http://www.eletrobras.com/elb/data/Pages/LUMIS39833F64PTBRIE.htm . Access on August, 15; 2015.

EPE (Empresa de Pesquisa Energética). (2014). Plano Decenal de Expansão de Energia 2023. Brasilia, Brasil: Ministério de Minas e Energia. Disponível em: http://www.epe.gov.br/PDEE/Relat%C3%B3rio%20Final%20do%20PDE%202023.pdf . Access on August, 2; 2015.

GENPOWER GROUP. (Maio de 2015). Category Archives: Leilão A-5 . Site institucional. Brasil: Disponível em: http://www.genpowergroup.com.br/pt/category/leilao-a5/ . Access on August, 6; 2015.

IEA (international Energy Agency). (2013). World Energy Outlook 2013. International Energy Agency. Disponível em http://www.worldenergyoutlook.org/publications/weo-2013/ . Access on August, 22; 2015.

MME (Ministério de Minas e Energia). (2015). Resenha Energética Brasileira. Exercício 2014. Brasilia, Brasil: Ministério de Minas e Eneria. Disponível em: http://www.mme.gov.br/documents/1138787/1732840/Resenha+Energ%C3%A9tica+-+Brasil+2015.pdf/4e6b9a34-6b2e-48fa-9ef8-dc7008470bf2 Access on August, 3; 2015.

MME (Ministério de Minas e Energia) (25 de Março de 2015). Portaria N°81. Diário Oficial da União N°58, Seção 1. Disponível em: http://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=26/03/2015&jornal=1&pagina=60&totalArquivos=80. Access on September, 10; 2015

MME (Ministério de Minas e Energia) (25 de Março de 2015). Portaria N°82. Diário Oficial da União N°58, Seção 1. Disponível em: http://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=26/03/2015&jornal=1&pagina=60&totalArquivos=80. Access on September, 5; 2015

ONS (Operador Nacional do Sistema Elétrico). (2015, a). Histórico de Operação. Site institucional. Brasil: Operador Nacional del Sistema Elétrico. Disponível em: http://www.ons.org.br/historico/geracao_energia.aspx . Access on August, 23; 2015.