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GENERATORS GRID TARIFFS IN THE BRAZILIAN TRANSMISSION AND HIGH VOLTAGE DISTRIBUTION ELECTRIC SYSTEMS

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1. Introduction

The transmission and distribution high voltage electric energy systems are comparatively more expensive to the society in Brazil that in another countries. This reflects the continental dimension of the country and the hydraulic basis of system and affects the grid costs. In this scenario, the electricity regulator shall look to the evolution of the grid costs and its allocation as important matters. Those two issues – grid costs evolution and grid costs allocation – in last instance will allow the generation market competition in Brazil.

The grid costs evolution in long run is a planning matter. Once the grids are natural monopolies and the generation is sparse, the electric power system planning centralizes the investment decisions aiming the minimization of the global grid cost. When the system adequately planned, the society pays the minimum grid cost.

In other hand, the user does not observe this optimization because it is implicit in tariff or fee derived from a cost allocation methodology settled by the regulator. The tariff or price may have more than one objective. The primary objective is to recover the grid costs, i.e., the distribution and transmission revenues. However, the tariff can induce desired behaviors in the grid; therefore, it is common the use of more sophisticated cost allocation methodologies to propitiate these behaviors.

In Brazil, the existent transmission cost allocation methodology has a primary cost recovery function and two other objectives: it induces the best grid point connection to loads and generations and it is a vehicle to public police, e.g., the tariff discount to renewable sources. The discount to renewable sources is an explicit policy decision given by Law and determines tariff reductions to at least half of the price given. The induction of the best user connection to the grid is an attempt to minimize grid investments using different tariffs in each node of grid. Therefore, if the cost allocation methodology induces user desired behavior, the grid optimization occurs because the user has the correct incentive to connect to the optimal grid point. Hence, the correct grid tariff must be lower in the connection points that minimize the aggregated investment in grid and bigger when it does not.

In Brazil, the transmission and high voltage distribution systems costs more than US$ 5 billions per year and bring some questions that will be analyzed in this paper. It is a complex problem associated to public polices or incentives to the expansion of generation and environmental problems. Because of that, this paper will focus in one part of the problem: the generator access to grid in Brazil.

Chapter 2 will bring an overview of the organization and the relation among Brazilian institutions that deal with electricity services and the grid open access regulation. Chapter 3 will present the existent cost allocation methodologies to generators and will bring the evolution of transmission and distribution grids costs, generation and load contracts and tariffs. Chapter 4 will present regulation improvements due to generator grid tariffs and will present important aspects of grid connection regulation. Chapter 5 will assess and discuss the grid access regulation and present uncertainty perception of generation entrepreneur. Chapter 6 will bring the conclusions of the analyzed issues.

2. A general overview of the Brazilian electric power system legal structure, organization and functioning

2.1. The Brazilian institutions

The Brazilian electricity services and energy institutions are:

a. Ministry of Mines and Energy (MME);

b. National Electric Energy Agency (ANEEL);

c. National Grid Operator (ONS);

d. Energy Planner (EPE); and

e. Commercialization Chamber (CCEE);

2.1.1. The Ministry of Mines and Energy - MME

The Ministry of Mines and Energy, created in 1960, is responsible for public policies in the energy, mines and petroleum sectors [1]. The national agencies of electricity (ANEEL) and petroleum (ANP) and the companies Eletrobrás and Petrobrás and theirs subsidiaries are linked to the ministry. In 1997 the National Council for Energetic Policies - CNPE was created to propose national policies and measures to the sector. In 2004, the Law n. 10,848 creates the Monitor Committee for the Electric Sector – CMSE, to follow and assess constantly the supply security of the electric system [2].

The Law, that in some sense was a response to the 2001 blackout, introduced a new commercialization model that establishes two environments of electricity purchase or markets: the regulated, formed by distribution companies that buy energy to their consumers, and the free, formed by large consumers that freely trade and buy electricity by themselves.

Until the Law 10,848/2004, ANEEL was responsible for the electricity supply. After the Law, the MME has become responsible for the supply supported by the system planner – EPE. The main objective of the law is to permit the investments in generation, transmission and distribution in a long-term horizon. In order to achieve that, the Law established a new electricity commercialization model using auctions to buy long term regulated power agreements (15 or 30 years). The distribution companies became obligated to set the market growth and buy electricity to their entire market with a short range to error. Another interesting feature of this new regulatory act is the previous set of environmental license to power plants that will participate of the long-term energy purchase auctions.

2.1.2. The National Electric Energy Regulatory Agency - ANEEL

Created by the Law 9,427/1996 [3], ANEEL is a special agency linked to the MME with the following responsibilities: to regulate and inspect technically and economically the generation, transmission, distribution and commercialization of electric energy, to answer the user complaints and to mediate conflicts[1]. It is also under ANEEL responsibility the cost allocation methodologies and the calculation of distribution and transmission tariffs [4].

In public meetings, a board of five directors realizes the decision process of ANEEL. The processes are open to the public and subject to cross-examination. After the Law n. 10,848/2004, ANEEL remained responsible for the auctions proceedings of generation and transmission. However, the responsibility of the system planning (mainly transmission and generation, but can also includes distribution when necessary) and supply were transferred to the MME assisted by EPE.

The economic regulation and the distribution services regulation intendancies of ANEEL establish the distribution tariffs and the transmission services intendancy establishes the transmission tariff. The distribution and transmission tariffs methodologies are different and that may lead to problems associated to the economic signals offered to the market.

2.1.3. The grid operator - ONS

The control and coordination of the generation and transmission in the interconnected Brazilian electric power system are responsibility of the National Operator of the Electric System – ONS [4]. The ONS is a non-profit organization authorized by the executive branch and subject to ANEEL's regulation and inspection. The generators, transmissions, distribution companies, and larger consumers that are directly connected in the electric grid in facilities above 138 kV integrate the ONS. The ONS manages the optimal dispatch of electric energy, operates transmission lines and generators, setting up the reservoir levels of the hydraulic facilities and the fuel of the thermoelectric.

It is responsibility of the ONS, as well, the transmission services administration, including transmission grid agreements. With each transmission company, ONS signs up transmission services

[1] A special agency has partial administrative self-government and decisory autonomy, which cannot be mistaken as independence of the executive branch, once the executive indicates directors, sets ANEEL's budget and controls the number of public servants and their salaries. The autonomy implies that ANEEL's decisions are the last executive decision in Brazil, but still possible to be appealed to judiciary branch.

agreements, representing all transmission users and under regulation of ANEEL. The agreement includes the transmission installations that will be centralized operated and the revenue payment rules for the transmissions services. With the users, the ONS signs up the use agreement – CUST, that represent all the transmission companies, as well under ANEEL's regulation, and set up the conditions of the common use of the grid, the power demand that will be transported and the payment rules.

2.1.4. The energy planner - EPE

The energy planner – EPE – was created by the Law n. 10,847, in March 2004 [5]. It is a public company[2] to support the government with studies and researches in energetic planning (electricity, petroleum, natural gas, mineral coal and renewable sources). Among the EPE responsibilities, it is possible to highlight: studies and projects of the Brazilian energetic matrix; Brazil's energetic reports; identification and quantification of energetic resources; studies about optimal use of hydraulic potentials; obtention of preliminary environmental licenses of the recommended transmission and hydraulic generation enterprises; and the short and long terms expansion planning of the electricity transmission and generation. [6]

2.1.5. The commercialization chamber – CCEE

The CCEE is a chamber where commercialization, agreements declaration (register), short-term accounting and liquidation occur. The CCEE operations are externally audit, as establish in ANEEL Resolution n. 109/2004 [7] [8]. The commercialization procedures that rules CCEE activities are regulated by ANEEL, as well, and generation, distribution and commercialization companies compose the chamber. After Law 10,848/2004, the commercialization happens in two different ways: the regulated one and the free trade one. The regulated electricity purchase is applied to distribution companies that must declare to MME/EPE their load markets expansion and necessity of electricity to

[2] In Brazil public companies are governmental enterprises

supply their future markets. After that, EPE and ANEEL organize public auctions to purchase electricity for 15 or 30 years. Therefore, the generators compete to sell energy and all distribution companies that participate in auctions pay each agreement.

2.1.6. Relation among the institutions

Until 2004, ANEEL cumulates generation and transmission concessions grant and cost allocation responsibilities. After 2001 blackouts[3] and the beginning of the new[4] presidential mandate, the solution found to the structural electricity problem that Brazil faced was to set a new model of electricity commercialization, consolidated in Law at number 10,848, in 2004. The government had studied two years and proposed a new commercialization model, including the long-run planner EPE, to guarantee the necessary investments. By the new model, auctions to buy long-term electricity (15 or 30 years agreements) are offered by government to supply the load of distribution companies in a regulated manner. Once the free market represents 25% of electricity trade in Brazil, when government promotes auctions, they will be enough to guarantee the supply of 75% of the load. The other 25%, freely commercialized, are vulnerable to spot market price when CCEE liquidation happens.

Another major issue of the new electricity commercialization model is the environmental licenses. Before Law n. 10,848/04, the previous environmental licenses were not necessary to the concession grant (mainly to hydraulic power plants). When IBAMA[5] analyzed studies, after the grant, delays and even denials had occurred in some licenses [9]. That was a serious problem, not only because the environmental problems, but also because that generators have been already considered in the load supply, in accordance with the grant timetable. After the Law, the IBAMA must license the generation before the auctions. That process of previous licenses occurs under responsibility of the

[3] The 2,001 blackout was not an operational problem, like the blackout in New York in 2,003. Brazil faced a lack of energy due to the low level of the reservoirs and the insufficiency of thermal units to dispatch. In this sense, the Brazilian problem is an infrastructural problem that leads to a rationing.
[4] President Luiz Inácio Lula da Silva was elected in 2002, became president to the 2003-2006 term and was reelected in 2006 to govern until 2010.
[5] The Brazilian federal environmental agency

government that in last instance is legally in charge of the auction. That happened because the Brazilian environmental law is very modern and complex, leading the entrepreneurs to face problems and spend time and money to obtain these licenses. The framework of the Brazilian electric sector is that the MME and the EPE rules auctions, the ONS operates the grid and helps in its short term grid planning. The CCEE controls the Power Purchase Agreements and sets the short-term liquidation prices and the ANEEL regulates the agents and calculates the tariffs, but is not responsible for the supply.

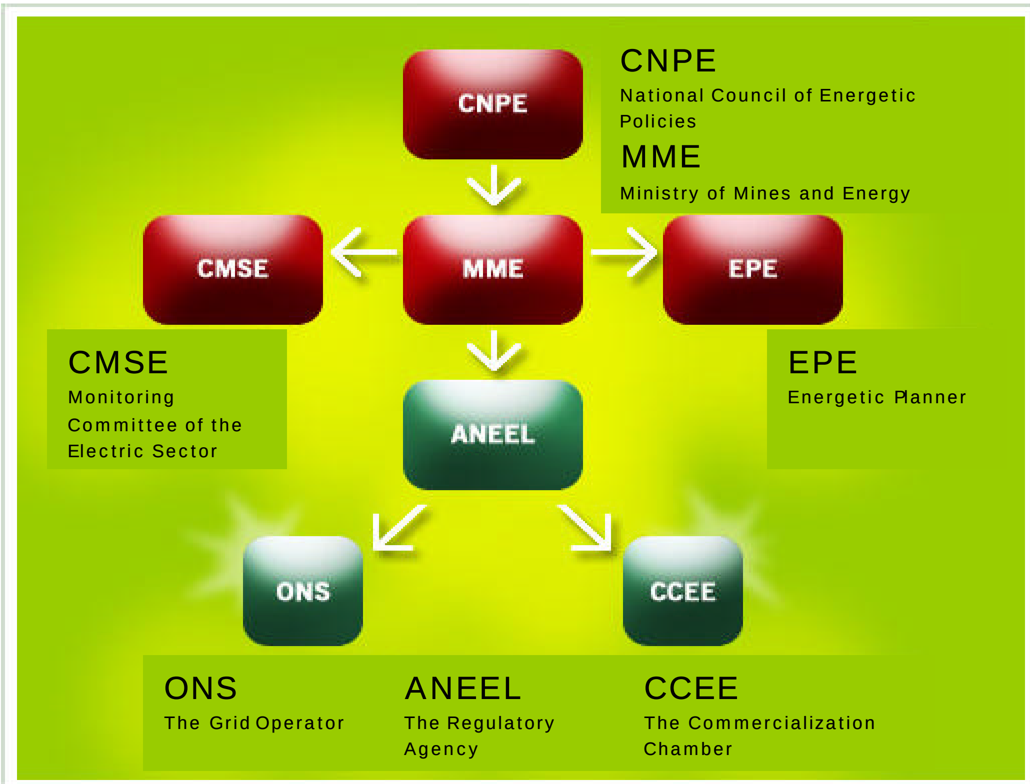


Figure 1: Relation among institutions in the Brazilian electric energy sector [4]

2.2 Regulatory issues of Brazilian open access and tariffs [10]

2.2.1. Open access regulation

The Law n. 9,074/95 [11] guarantees the open access to generators and loads. Therefore, any user that intends to access the grid may do it within regulated technical conditions. The open access right is a consequence of the electricity services separation in generation, transmission and distribution, previously offered as a whole. This separation implies that users have to pay separately by provided services. The Law n. 9,648/98 [12] provides this separation, establishing the conditions for a free commercialization market. The grids (transmission and distribution), as natural monopolies, became regulated economically and technically, in a revenue-cap with performance bonus in transmission and in a price-cap with performance bonus in distribution. ANEEL's grid access regulation is disposed in Resolution n. 281/99 [13]. The resolution sets up the necessity of two contracts to access the grid: the grid use and the connection. The connection agreement establishes the responsibility for operation and maintenance of a connection facility. The grid use agreements set up the responsibility between users and grid operators to optimal system operation, payment rules, grid access points and power demands[6].

Resolution ANEEL n. 281/99 establishes that the user access beholds to the connected system. For instance, if the grid access occurs in a facility with voltage level lower than 230 kV, it occurs to a distribution grid and the use agreement is signed with the distribution company that operates in the neighborhood. If the grid access occurs in a facility with voltage level equal or higher than 230 kV, it occurs in the transmission system and the operator (ONS) signs the grid agreement with the user. The use agreement establishes the payment rules proportionally to the power contracted. In that sense, this agreement defines the electric power transport capacity that will be reserved in the grid. As a capacity contract, the payment does not depend of the electricity commercialization or consumption, i.e., it is a take-or-pay agreement.

2.2.2. Tariff regulation

The transmission grid tariff must be locational or nodal, as established by Law n. 10,848/04, i.e., the user that minimizes the transmission system use must pay lower tariffs than the one who maximizes it. The design of a tariff methodology that will enforce the Law is not an easy task and has been object of discussion since 1,999 because the criteria set by regulator to make results feasible. The results imply different tariffs in each node of the grid.

[6] The grid classification in connection and common grid use will be detailed in Chapters 3 and 4.

The transmission tariff regulation differs methodologically from the distribution tariff regulation. The distribution grid use cost allocation methodology tries to minimize the investments in generation and the investments in grid. The generator tariff does not exist in terms of methodology in the distribution systems. The lower tariff of the distribution company is applied to generators access.[7]

The differences between transmission and distribution systems have to be carefully analyzed, mainly the relations among tariffs. If the transmission tariff is lower than the distribution tariff in a no proportional way, the consumer and the generator will tend to migrate to the transmission system. Otherwise, if the tariff is lower in the distribution than that in the transmission system, the loads and generators will tend to migrate to distribution lower voltage levels. It is always possible to create regulation barriers to avoid that to the already connected user. However, it is much more difficult to control connection of new users' accesses and probably the system will face optimization problems.

The difference in tariff methodologies has its origin in electricity services separation. The economic and technical regulations of these two economic sectors (transmission and distribution) are different and leaded to different allocation cost methodologies. For instance, a public tender in an inversed auction aggregates a transmission installation to the grid by the smallest annual revenue. There is no uncertainty in the user's payment because each transmission company invoices all users and every user pays to all transmission companies. The grid use agreements reflect that payment mechanism. The distribution high voltage lines, connecting the distribution to the transmission, are aggregate to grids in a different way, by the distribution companies planning to supply the load and eventually the generation. The distribution revenue, differently of the transmission one, is regulated by tariffs and the investments are recognized each four years in a tariff review process. During the period between tariff reviews, investments and market growth are problems of the company.

[7] ANEEL have proposed a methodology in the beginning of 2008 to calculate the generator tariff to the high voltage lines connections – 138 kV and 88 kV.

The difference in methodologies and regulations have been leading to problems in generators and load connections to grids due to the applied prices, principally in the boundary of the transmission and distribution systems.

3. Grid Cost allocation in Brazil

As established in section 2.3, Brazilian regulation separates the grid open access in two components: grid connection and grid use. In a simple manner, the grid connection exists to permit the user access to a common grid. In that sense, the grid connection payment is due to the demanding user. Beyond the connection point, the common grid investment and maintenance are responsibility of a grid company and the costs are allocated by tariffs to all systems users.

In that manner, the differentiation of when any installation is a connection and when it is part of the common use grid is one of the biggest problems in Brazilian regulation. The problem is not the property of the assets, which is indifferent to the regulator[8], but cost allocation. Connections, as said before, are specific installations and so the user is responsible for costs. Eventually, the user may outsource the construction and even the maintenance, but the cost will remain allocated to him.

It is common the user attempt to share its connection costs by forcing a share connection with other user to have recognized the condition of common grid, instead of a connection facility. It happens because the cost allocation methodologies in many times are not able to return the correct price for the common use grid. If the grid cost allocation methodologies indicates that are cheaper to pay the connection through tariffs than by the connection, the new users will be stimulated to go to transmission and distribution companies to share their connection costs with other users. If the prices returned were correct, that will be indifferent to pay as a connection or by tariffs. Therefore, it is

[8] The property remains important in the sense of civil responsibility

necessary to establish a way to allocate correctly the costs among users, giving the economic signals through the tariff and stimulating the correct grid connections that minimize the global costs.

Because the hydraulic basis and the grid investments, the load tariff has components due to seasonality and modulation that tries to stimulate the user's behavior, applying a bigger fee in dry seasons and in peak hours than in wet seasons and off-peak hours. But that does not make sense to generators that does not control the dispatches (ONS does because the same hydraulic basis demands a coordinated and centralized operation that results in an economy due to the optimization of the water in hydraulic power plants reservoirs and the fuel in thermoelectric facilities).

The generators tariff (only the grid one) is calculated once a year and applies to all day and seasons. Despite that, Brazil has two cost allocation methodologies to generators: the locational for the transmission system and the postage-stamp methodology for distribution systems.

3.1 The postage-stamp cost allocation methodology and the distribution methodology used in Brazil [14]

In the postage-stamp cost allocation methodology the tariffs are calculated based on the sum of the costs in the grid, including the operation and maintenance costs and the capital costs, divided by the total demand contracted in the system leading to a cost in [$\$/MW$] equal to each agent. The postage-stamp tariffs are:

$$Charges_i / D_i = TC / D_{total} \quad [\$] \tag{1}$$

where: TC = Total Cost to be allocated [$\$$]; D_i = Contracted Demand of the user [MW]; and D_{total} = Total Demand in the system [MW].

As said in [14], the main advantage of this method is its inner simplicity. Because of that, United States and other European countries use it. However, the simplicity does not permit the use of interesting features. The main disadvantage to generators is the indifferent treatment in relation to their geo-electrical location. The methodology exhibits an ignorance of the physics laws that the operation of an electric power system must obey and because of this, there is no economic rationality observed[9].

The distribution cost allocation methodology applied in Brazil uses the marginal cost theory, based in load curves and its impacts in grid expansion to determine the load tariffs that are equal per voltage level and modulated in peak and off-peak periods[10]. However, the costs in grid buses are the same per voltage level in each distribution company. After establish the revenue per voltage level and per consumption period, it is possible to allocate the cost among the market as a postage stamp. In that kind of method, the regulator use the marginal theory to sets how to split the revenue into a tariff group and the resulting tariff is common to each group.

The distribution use tariff in Brazil is denominated TUSD, and the generator TUSD tariff is denominated TUSDg, and settled as the smallest tariff calculated to the load due to a lack of methodology. Hence, there is no meaning to consider the method as an economic signal to generators. In that sense, the cost allocation to generators market culminates in a postage stamp tariff methodology with *ad hoc* distribution revenue set by regulator.

3.2 The nodal methodology and The Brazilian Nodal Transmission Cost Allocation Methodology [15]

The Law n. 10,848/04 determines two drivers to the transmission tariff calculation: to guarantee enough resources to cover the costs; and to use the **locational signal** to allocate bigger charges to the agents that demand more investments from the system.

ANEEL's way to enforce the law is a variant of the long-run marginal transmission cost, as presented in chapter 3. The marginal methods arose in 80`s and are related to spot prices [14]. The spot price in a system node corresponds to the marginal cost of production of one additional *MW* in an

[9] Section 5.1 brings an example of economic rationality that the postage-stamp methodology disregards.
[10] In Brazil, each distribution company sets the peak time interval, within three consecutive hours.

instant of time. The efficiency of the system is due to the given economic signal that can induce the grid user behavior. The quality of the given economic signals lead researchers to develop more sophisticated methodologies to considerate the long run marginal cost, by including in the methodologies not only the operation and maintenance costs but also the grid expansion and improvements. These methods, known as long-run marginal cost or nodal methodologies, reflect the cost variation of the system expansion necessary to attend one more *MW*, or the marginal increment in the demand.

The nodal methodology used by ANEEL considers the set of transmission lines, transformers, generators and loads in each node of the transmission grid. Due to the system expansion, the tariffs calculation occurs yearly and includes the new generators, loads and installations. The nodal methodology reflects the long-run marginal transmission cost.

The classical problem of grid expansion optimization has as variables the circuit costs, the investment decisions, the grid topologies and the loads and generations in each node or bus of the system. The result is a non-linear mixed integer optimization problem with a very difficult solution. Therefore, some hypotheses that simplify the problem have been adopted. The simplified problem results in a linear optimization problem. From the formulation, it is possible to derive the following transmission tariff equation:

$$?_{j} \; ? \; ?_{i?1}^{n} ? \frac{c_i}{\overline{f}_i} ? ??_{ij} \qquad (2)$$

where: c_i is the annualized cost of one installation that has to be paid by the tariff. The cost is standardized; $\overline{f}_i$ is the capacity of the installation *i*; $?_{ij} = ? Fi / ? I_{ij}$ is the sensitivity that measure the variation of the power flow in circuit *i* into relation an injection in the node *j*, and is function of the grid topology, the loads and generations. The product of the unitary cost, $?_j ? c_i / \overline{f_i}$ by the sensitivity, $?_{ij}$, represents the fraction of i installation that is used when one MW is injected in node j. Therefore, it is possible to observe that the nodal tariffs recover only the used part of the installation, i.e., the ideal grid, which differs from the total use of the installation when the circuit is not fully used. Operationally, a linear load flow solution determines the flow directions in the transmission equipments and the signals of the $?_{ij}$ elements. The tariff calculation results equal tariffs with opposite signals to generation and load in each node of the system, i.e, $?_{Lj} = -?_{Gj}$.

As observed, the nodal tariffs recover only the ideal grid and return the relation among tariffs in each node. Therefore, it is necessary to add a last equation (with the total revenue) to recover the missing cost. This step has two functions: to guarantee the recover of the total revenue and, as can be mathematically proven [13], to transform a linear dependent system into an independent one, converting the tariff relations into absolute values or final tariffs.

The methodology adopted by ANEEL to calculate the transmission tariff contemplates few modifications to deal with the Brazilian electric system. The two most important modifications are the weighting factor and the stabilization mechanism. The weighting factor, or ramp, inserted in equation (2) to weight the tariff impact, diminishes the nodal tariff impact in less loaded installations. By inserting the factor, the formulation becomes:

$$?_j \; ? \; ?_{i?1}^{n} ? \frac{c_i}{\overline{f}_i} ? ? ?_{ij} \cdot FP \qquad (3)$$

The factor attenuates the sensitivity in low flow levels circuits, reducing the volatility of the nodal signal between tariff cycles and increasing the precision of the tariff.

The stabilization mechanism, inserted since 2004 [16], diminishes the tariff volatility as well. The Law 10,848/2004 had changed the commercialization model and 8 years agreements were established to the existing generators. The generators pointed that the transmission tariff volatility had remained a problem that would harm the long-run commercialization. Therefore, ANEEL decided set up a stabilization mechanism that kept the nodal price fixed for the duration of the contracts, but guarantees the transmission revenue.

3.3 Evolution of transmission and distribution grid costs

After the market opening in 1,999 and the blackout in 2,001, the government planning pointed the expansion of the transmission grid as one of the solutions to guarantee the supply. That happens because the hydraulic basis of the Brazilian power system. The transmission lines in Brazil can be used into two different manners. The first and simpler are to connect the generators and loads. The other and more implicit is to optimize the system operation by minimizing the fuel consumption of thermoelectric facilities and maximizing the reservoir levels of the hydroelectric power plants.

These characteristics imply that once a transmission line aggregation to the system is planned, two things must be observed: first, the direct gain of the integration of two areas, e.g., the connection between two regions and/or diminishing of losses, and second, the operation optimization gains. The planners have analyzed the aspects of the system since 1999 and decided to guarantee the supply by expanding the generation and the transmission. In that sense and within limits, that is a way to expand the power availability without expanding generation. Due to the environmental licenses, that are much more difficult to obtain to generation than to transmission lines, it is possible to observe that the transmission grid are expanding in a faster ratio than the generation and even the distribution systems. Table 1 shows the evolution of the transmission revenue and the increasing ratio of transmission in the electricity chain, also representing the increase in the transmission tariff.

Another characteristic that leads to a conclusion that the transmission tariffs are increasing in Brazil is the relation between the increase in grid use agreements and the grid cost, during the years. Figure 2 illustrates that situation.

The increase ratio differences of the generation and load agreements and the transmission revenue leads to a change in the transmission tariff that is a relation of the costs (transmission revenue) and the aggregated power demand of generators and loads.

Table 1 – Evolution of transmission revenues and participation in electricity market

Period	Transmission system annual revenue [R$]	Participation in electricity chain
1999/2000	1,764,206,694.00	5.70%
2000/2001	2,115,192,485.00	5.93%
2001/2002	2,442,187,083.00	6.83%
2002/2003	3,372,368,821.00	7.48%
2003/2004	4,942,627,920.00	9.56%
2004/2005	5,911,644,611.00	10.3%
2005/2006	7,238,877,495.26	11.2%
2006/2007	7.902.492.545,89	12.2%

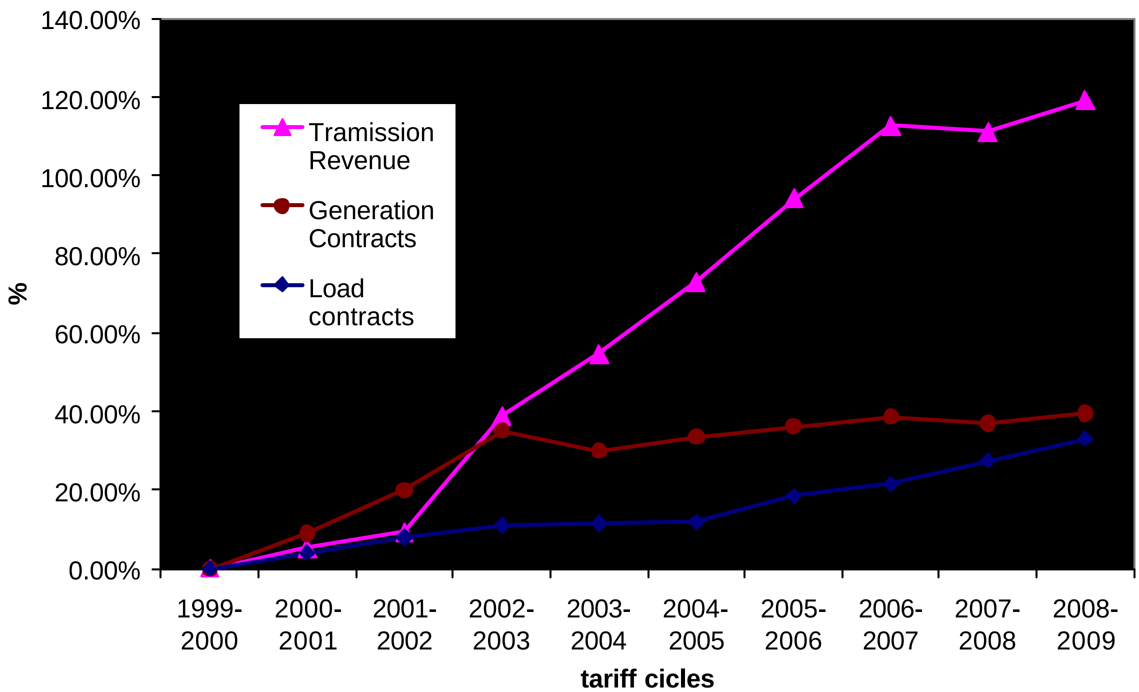


Figure 2: Increase in Transmission Power Agreements and Cost Evolution

3.4 Tariff evolution and volatility

Besides the tariff growth due to the investments in the grid during the years, another characteristic is problematic in the transmission cost allocation: the volatility of the nodal or locational price applied. As an example, figure 3 shows the nodal price in Coxipó Substation in Cuiabá, the capital of Mato Grosso State, an emblematic point of the transmission system, where a thermoelectric facility is connected and many hydraulic generation flows from the inner regions of the Mato Grosso state to the loads of the systems. It is possible to see in figure that the nodal tariff varies due to the changes in the parameters, as the grid costs (Table 1) and topologic changes.

As a developing country, Brazil has significant economic growth and the electricity consumption has reflected that. The increase of consumption leads to investment in generation and transmission that culminates in the change of the relation of payment in the grid, i.e., the price. For instance, the implementation of a new transmission line changes the marginal price that the nodal tariff tries to reflect, leading to tariff volatility in every region that a transmission investment is required. Figure 3 shows the tariff volatility due to the beginning of the operation of the 500 kV transmission line between Coxipó and Rondonópolis.

In the distribution grid, the tariffs are set up for each company. Figure 4 illustrates the tariffs for two distribution companies that attend regions in São Paulo State. As it is possible to see in Figure 4, the existent distribution cost allocation methodology results in different tariffs for each distribution grids, even when they have the same characteristics and are near each other, as the example. The Appendix brings the generators distribution grid tariffs for the distributions companies that operate in Brazil in the year 2008.

Besides the existent distribution allocation cost methodology does not indicate the correct connection point, it gives erratic economic signals to generators by lower tariffs, even when it causes more investment in grids. The identification of the problem associated to the lack of methodology leads ANEEL to propose another way to calculate these tariffs. In chapter 4, it will be presented.

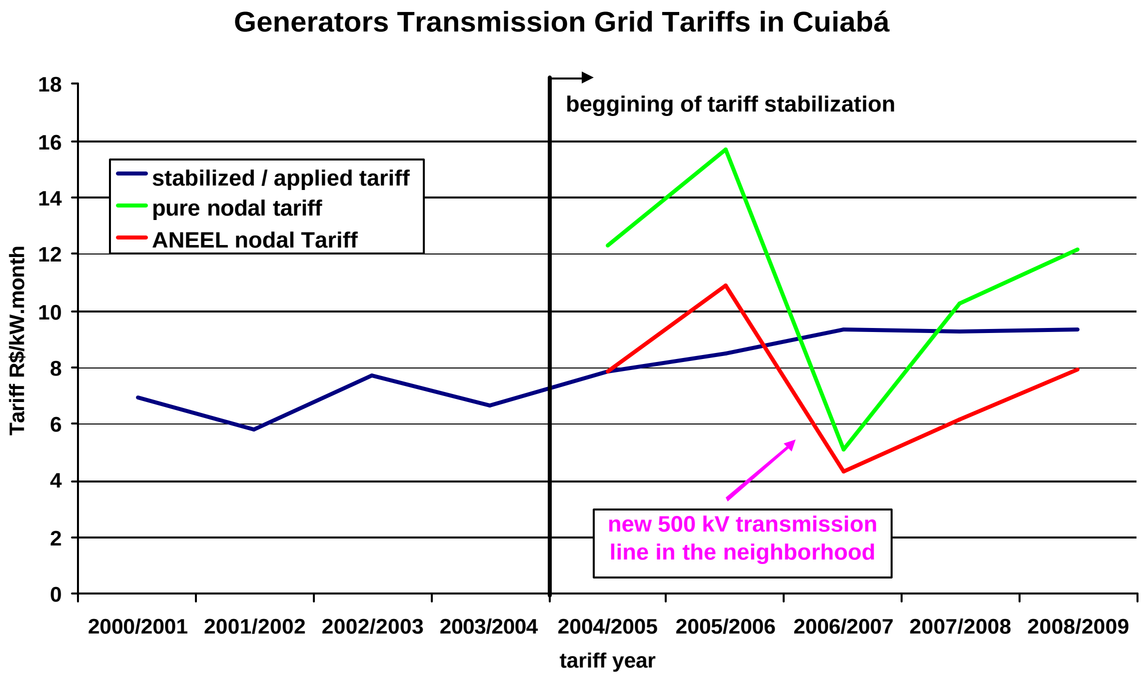


Figure 3: Transmission tariff volatility due to topology change (price reference-jun/08)

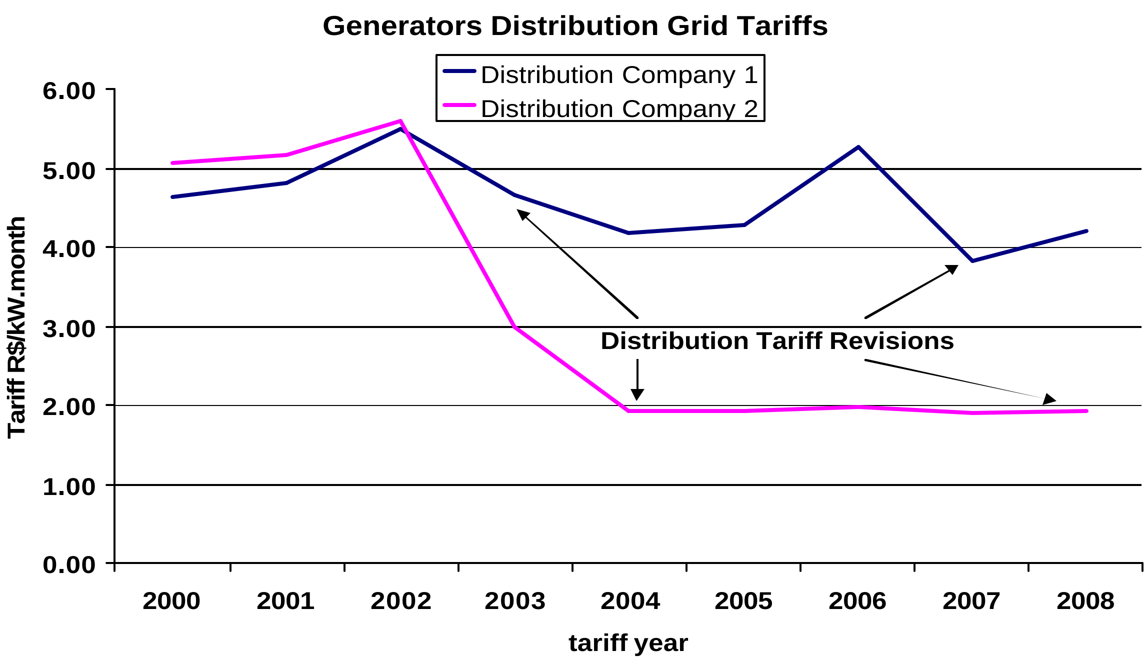


Figure 4: Evolution of generation distribution tariffs for two distribution companies that supply contiguous areas (price reference: 06/2008)

4. The regulation improvement for generators

In previous chapters, it was presented the regulatory framework of the free access in Brazilian electric power systems. It was presented the difference between the two existent grids, the transmission and the distribution. They are regulated in different manners economically and technically that leaded to different cost allocation methodologies and consequently, different grid use tariffs. The difference in tariffs had become a problem because induces erratic behavior of the users. The differences had led to unnecessary migration between the systems that decreased the cost to the user who migrated but increased the cost for remaining users.

Despite that, marginal methodologies seem to fit with the necessities of the society and the market because the significant economic signals provided and because it involves the entrepreneurs and the existent generators and consumers in the planning process.

In Brazil, as said in the very beginning, the transmission and distribution electrical high voltage energy systems are relatively more expensive to the society that in another countries because the generation basis. It implies that the grid costs evolution tends to be centralized because of the multiple gains provided by the grid expansion. Then, when the fee that has to be paid by users is derived from the long-run marginal cost, it implies that more and significant players are in the process participating, in a process of checks and balances.

As result of this participation, the regulator faces in daily basis the complaints of the regulated users. In one side, the consumption complaints about the total costs that increases. In the other side, the generation complaints about the regulation stability and the uncertainties to the entrepreneurs. In this chapter, it will be presented the state-of-art in the grid access and fees regulation in the Brazilian electricity market as the way that ANEEL tries to mitigate uncertainties looking to the tariff moderation.

4.1 Risk factors to generators on grid access and grid use

The Law 10,848/2004 was established to improve the commercialization process and to promote the reduction of uncertainty factors in the electricity supply. The reduction of uncertainty factors to generators had not been restricted to the construction, which involves the electricity trade. It also had affected the transmission and distribution services regulation. ANEEL had improved four changes in grid use and access regulation to diminish the uncertainty perception for generators:

a) The long-term transmission tariff methodology for new generators;

b) The improvement in the transmission and distribution access rules;

c) The regulation of the shared connection; and

d) The nodal tariff methodology to generators in high voltage distribution grids;

4.2 The mechanisms to minimize uncertainty factors

4.2.1 The long-term transmission tariff for new generators [17]

The commercialization model brought by Law n. 10,848/04 set up new power purchase agreements with 30 years term to hydraulic plants and 15 years for thermoelectric plants. The agreements are established with fixed and unchangeable prices, but are indexed by inflation. Those long-term agreements fulfill the necessities of the Brazilian society for the supply and show the government focus in the long-run supply. This second point is important because without the long-term commercialization model the system planning becomes weaker. The long-term price-fixed contracts had showed that the generators costs may become a problem because the electricity price is fixed and the costs are variable. The major costs of a generation facility are the plant construction and system access. After the building, the bigger costs are fuel (to thermoelectric plants) and grid use tariff. The uncertainty problem is aggravated by the transmission cost allocation methodology, as explained before. The methodology brings volatility to the tariffs that can vary significantly from one period to another. Therefore, because the evolution of the grid and the cost allocation methodology, the grid cost to the generator are unpredictable. Obviously, the uncertainty affects the price.

ANEEL studied the problem and some made some conclusions. If the generators know the grid tariffs before the auction, it diminishes the uncertainty perception in the long-term commercialization. The problem is that it will be impossible to set up the tariffs for the duration of the agreements due to the lack of grid planning in such horizon. The transmission evolution plans are available for a 10 years horizon and the distribution plan even less time. Therefore, the focus had changed to the transmission grid where the bigger generators will be connected and the planning is available.

ANEEL implemented a regulation that minimizes part of the problem by establishing the tariffs for a ten-year horizon to new generators that win auctions. The regulation consists in tariff calculation based in the long-term transmission grid planning (transmission lines with voltage equal and above 230 kV). The planned transmissions investments are transformed into annual revenues and the equipments are modeled into the existent tariff program. The distribution companies and EPE estimate the future load for a ten years horizon. The future generators are estimated and the power balance is done. Hence, it became possible to calculate the long-run tariffs in each grid point for the planning horizon.

Because of the construction time, the auctions are realized three to five years before the generation connection. During the construction time, the tariff estimation cannot be applied and the estimation became restricted to seven or five years of utility operation. ANEEL considered this time insufficient and defined that the tariff must be established for 10 years.

Because of the lack of information, it becomes impossible to use the methodology to estimate the generator tariff after the planning horizon. The regulation overcame this problem by the replication of the last estimated tariff. In grid cost allocation terms, this assumption implies that after the planning horizon the loads and generations aggregated to the grid are enough to pay the new costs of transmission. It is obvious that this tariff estimation application will cause a mismatch in the transmission cost recovery. The load will pay this mismatch. The payment of the mismatch by the generator would return the very uncertainty that the methodology proposes to eliminated. The figure 5 and table 2 illustrates the methodology:

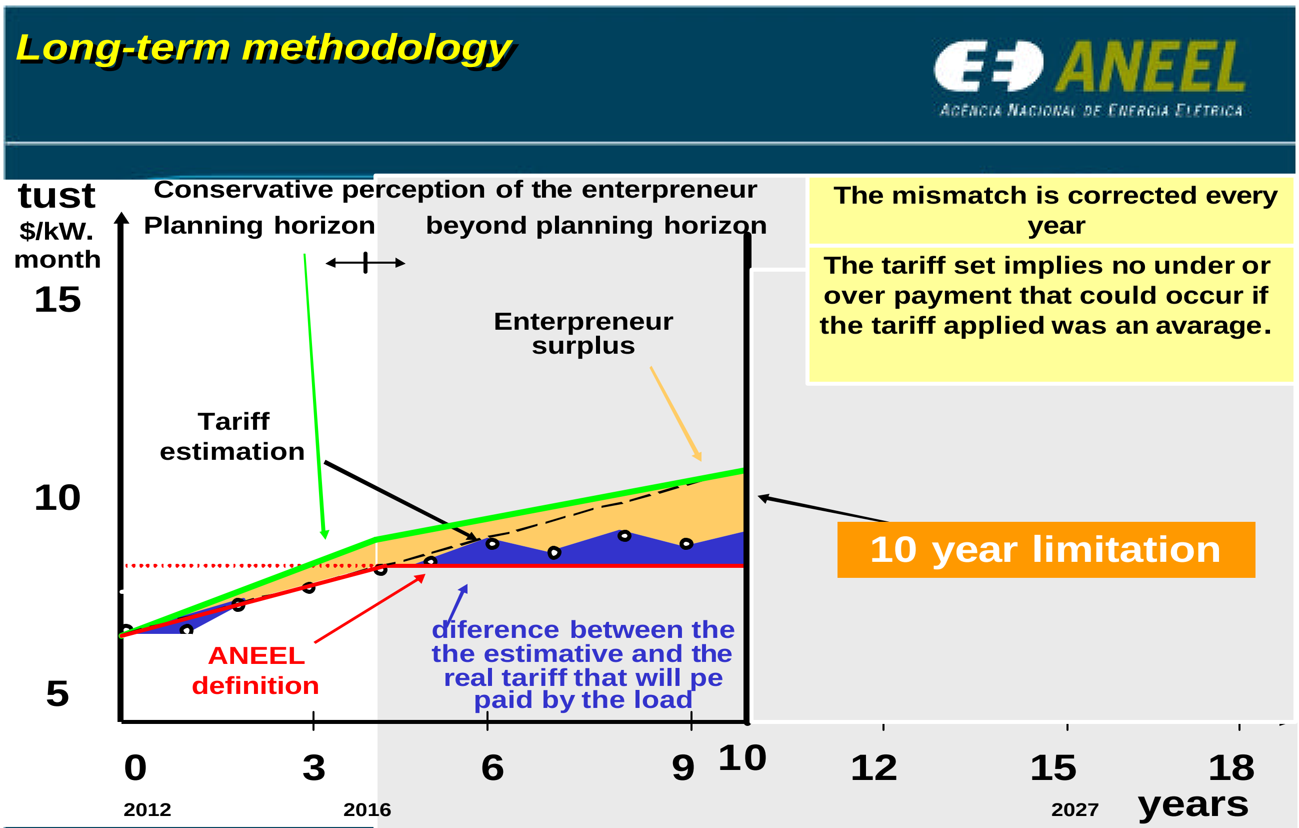


Figure 5: Long-term transmission tariff methodology.

Table 2: Tariffs calculated with the long term methodology [18] [19] [20]

Generator		MW	State	Transmission System Use Tariffs (TUST) R$/kW.month					
				From 7/1/2011 to 6/30/2012	from 7/1/2012 to 6/30/2013	from 7/1/2013 to 6/30/2014	from 7/1/2014 to 6/30/2015	from 7/1/2015 to 6/30/2015	After 7/1/2016
TU[11]	Viana	171	Espirito Santo	0,526	0.472	0.418	0.364	0.310	0.310
HU	Foz do Chapecó	855	Rio Grande do Sul	3,874	3,838	3,801	3,765	3,729	3,729
HU	Estreito	1,087	Maranhão	4.488	4.506	4.524	4.542	4.560	4.560
HU	Jirau[12]	3,300	Rondônia	-	13.377	12.533	11.688	10.844	10.844
HU	Santo Antônio	3,150	Rondônia	11.162	11.296	11.431	11.565	11.700	11.700

[11] TU – Thermal Unit; HU – Hydraulic Unit

[12] The tariff variation reflects the cost allocation methodology. Once the generators in Madeira River (Jirau and S, Antônio) are more than 1,500 miles away from the load center, they have a bigger tariff than Viana unit that are in the load center.

4.2.2 Regulatory issues of generator's grid connection

The necessity of improvement on generators connections leaded ANEEL to propose adjustments in the existent grid connection regulation to transmission and high voltage distribution grids. The realized improvements try to reduce uncertainty factors in generators connections to transmission and high voltage distribution grids. Three improvements can be listed: the end of grid owner exclusivity in the connection implementation; the increase in ONS responsibility to promote conflict solutions among the users and grid owners through mediation and eventually by setting up the connection; and the possibility to generators to share the connection with other generators.

The grid owner exclusivity to build up the connection had brought generators complaints due to high prices settled by the transmission and distribution companies. Once the grid owner had the monopoly and the prices were not regulated, it became a problem. In fewer situation the problems was the very high and disproportional settled prices. Nevertheless, in most cases it is a market problem (the user had said that it was possible to find lower connection prices in the market than the one settled by the grid owner). ANEEL, therefore, had changed two resolutions to permit the user to build the connection in the grid owner standard.

Another common complaint about the connection regulation was the grid connection point established in the studies. In the transmission system the grid operator has control to set the best possible connection point because the necessary electric studies that impose restrictions to operate the grid. However, in distribution grids some problems occur when generators try to connect. Many connection solutions unfold in huge distribution investments. In those cases, the grid owner predicted investment return problems and indicated connection points far away the generators location. To solve that kind of problem that leads also to grid optimization problems, ANEEL establish that the grid operator will supervise the high voltage connections in distribution grids (in a mediation process) and when necessary points out the best solution.

The generators shared connection problem is new and very interesting. In the running to improve sustainable energy sources, incentives has been given to that kind of generation[13] and a lot of investments in sugarcane biomass have been implemented. The special feature of this energy source is that it is spread in the farms. The electricity has to be collected and then transported to the grid and there is no regulation for that.

ANEEL had studied the problem and found two different solutions to solve the problem. In distribution systems, the distances are small and agreements among generators are possible. So the first user build the connection and ANEEL set up a rule of shared connection cost allocation, that is proportional to the electric power of the generator and the point of access in the shared connection. Therefore, it solves the free-rider problem. In the transmission system, the investments are higher, the distances are longer and the planner has to be involved. The solution was a specific regulation that will be presented in section 4.2.3.

4.2.3 The regulation of the shared connection [21]

The environmental concern resulted in policies to incentive the expansion of renewable electricity sources. Among them, it is possible to highlight the sugarcane biomass expansion in Brazil. The sugar cane bagasse generator is not new, but with the new high-pressure boiler technology, the electric power of each generator unit increased, as the use of biofuels in Brazil and in the world, expanding the harvest area. The total power aggregated to the grid is bigger than the local distribution load and are sparse in numerous farms. EPE has studied these characteristics and concluded for the grid expansion through a **shared connection** of generation to the transmission system. Therefore, a regulatory problem arose due to the treatment of the generators accesses that are small alone but bigger than the local load when the small units are summed. In this case, it is observed a change in the

[13] The hydraulic power plants, the biomass, the Aeolic, the solar among others are considered renewable sources, but in Brazil, the incentives apply only to generation with installed power inferior than 30 MW.

paradigm of distributed generation. In any sense that generation could be considered distributed. It is so huge that the planner studies indicate many transmission lines to export the energy to the load center.

This expansion solution had brought a problem: the articulation of the shared connection among the generators. The core business of the biomass entrepreneurs are alcohol and sugar and they have being treated are small units in electric grid. They argued that they do not have the knowledge to develop jointly the grid connection and in addition, they have become competitors for the same market and capital goods, like boilers.

ANEEL's solution of the problem was a regulation that integrates common grid lines and generators connections in one auction driven to aggregate the generation, leaving the construction, operation and maintenance to the transmission company that won the auction and the costs allocated to the generators. The main characteristics of the regulation are:

a) the connection will be maintained and operated by the transmission company that wins the auction to build up (preserves competition among generators);

b) only the generators will pay the connection, avoiding distribution companies' participation in the process (permits the correct cost allocation);

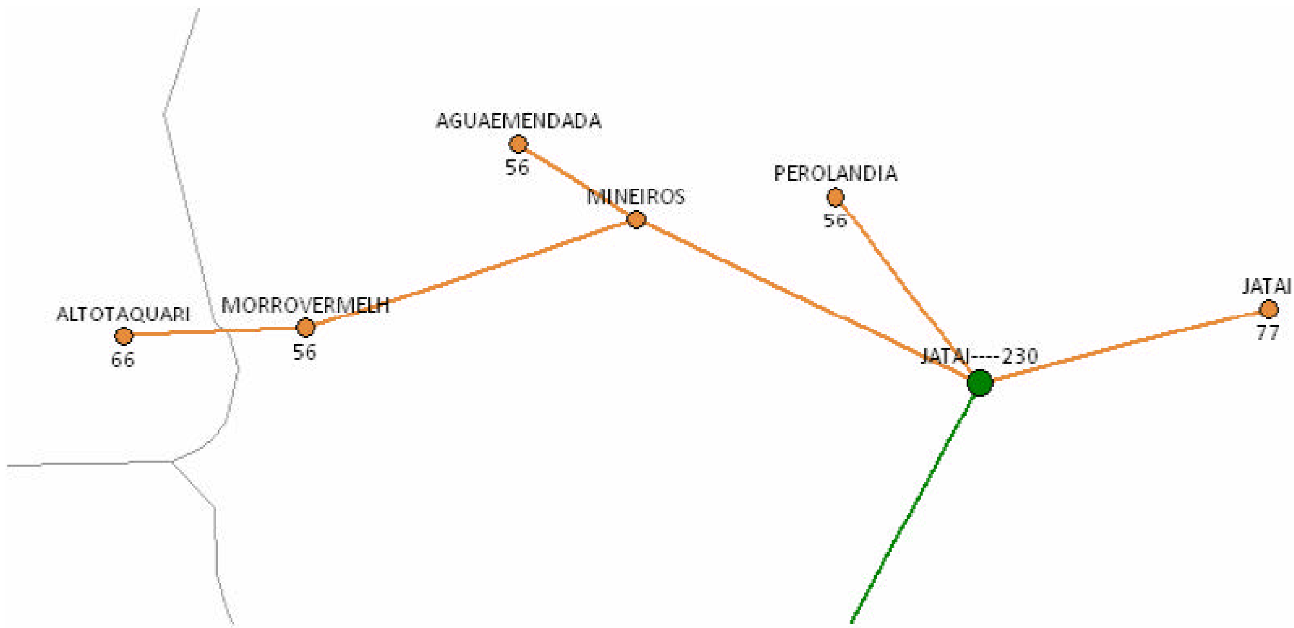
c) The generators will share the costs proportionally to the power and the connection point (locational cost allocation method in the connection);

d) It will be optional to generators to choose if the transmission company will also build the individual connection (permits the free market); and

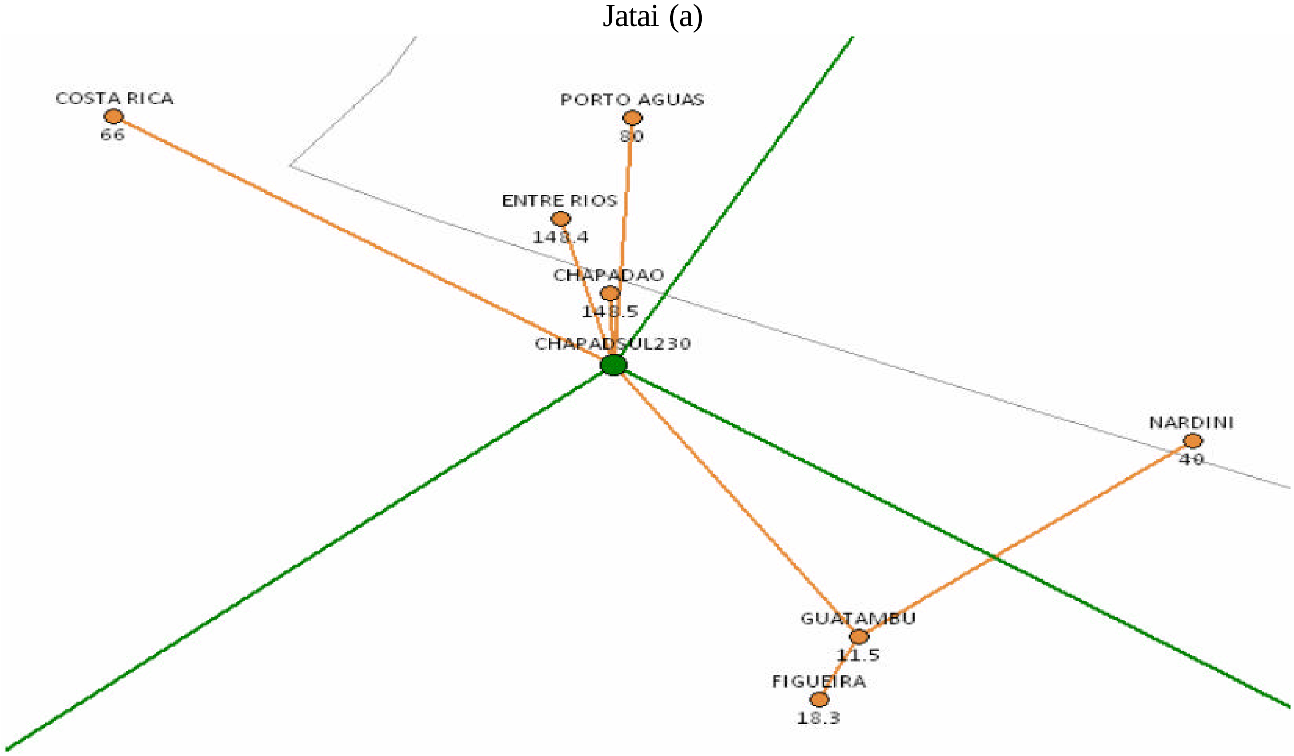
e) The generators will guarantee by insurance in a public call[14] the connection contracts before the transmission auction (reduces the uncertainty to the transmission company).

[14] **Resolution ANEEL no. 320/2008, art. 3º** ANEEL will realize a public call to the generators interested in shared connection. The public call has the follow objective: 1) enroll the generators with securities; 2) set up the generators start operation dates; 3) subsidizes the planning; and 4) point out the grid access point and set up the injected electric power.

The first public call resulted in 27 generators and 1,954.3 MW that will be aggregated to the grid. As example, the following figures and table depict the planned topology and costs:



Jatai (a)



Chapadão do Sul (b)

Figure 6: examples of the result of the 1st public call of generators interested in share connections to the grid (stations of Chapadão do Sul and Jataí) [22]

Table 3: Access cost using shared connections [23]

Generator		Electric Power [MW]	Beginning of operation date	Grid access point 230 [kV]	Shared connection access point 138 [kV]	Individual Access R$/kW. month	TOTAL Connection R$/kW. month	TOTAL Connection R$/MWh[15]	TOTAL grid use tariff + connection R$/MWh
HU	Guatambu	11.5	7/1/2010	C. do Sul	Guatambu	1.603	6.904	13.924	23.924
HU	Figueira	18.3	7/1/2010	C. do Sul	Guatambu	3.010	8.311	16.762	26.762
TU	Nardini	40.0	7/1/2010	C. do Sul	Guatambu	3.248	8.550	17.243	27.243
TU	Costa Rica	66.0	7/1/2010	C. do Sul	C. do Sul	3.020	5.084	10.253	20.253
TU	Porto Águas	80.0	7/1/2010	C. do Sul	C. do Sul	1.757	3.458	6.975	16.975
TU	Chapadão	148.5	4/1/2011	C. do Sul	C. do Sul	0.580	1.498	3.020	13.020
TU	Entre Rios	148.4	4/1/2012	C. do Sul	C. do Sul	1.003	1.921	3.873	13.873
TU	A. Taquari	66.0	7/1/2010	Jataí	M.Vermelho	1.548	12.572	25.356	35.356
TU	M. Vermelho	56.0	7/1/2010	Jataí	M.Vermelho	0.329	11.353	22.898	32.898
TU	A Emendada	56.0	7/1/2010	Jataí	Mineiros	1.558	6.131	12.365	22.365
TU	Jatai	77.0	7/1/2010	Jataí	Jataí	2.117	3.294	6.643	16.643
TU	Perolândia	56.0	5/1/2011	Jataí	SE Jataí	2.265	3.443	6.943	16.943

In November 2008, ANEEL had realized the first shared connection auction.

4.2.3 The nodal tariff to generators in high voltage distribution grids [24]

As showed in Chapters 2 and 3, Brazil has two tariff methodologies for generators, one for distribution grids (postage stamp) and other to the transmission grid (locational). Obviously, these two different methodologies results in different tariffs. For example the tariff applied to generators of a distribution company in Brazil in 2,008 was R$ 4.200/ kW.month. This tariff is applied to each generator accessing this distribution system in 138 kV or lower voltage levels. If the generator connection occurs in transmission level (230kV or higher) in the vicinity, it will cost between R$1,696/kW.month and R$2.742/kW.month[16].

Once there is no link between the methodologies, it can be observed grid migrations, leaving the distribution costs to the remaining users. The regulator will probably establish barriers to avoid this, but the problem source is the different tariff methodologies.

[15] The cost / MWh is an approximation based on the ratio electric energy / installed electric power.
[16] The tariffs vary because the locational methodology used.

ANEEL studied the problem and proposed to change the postage–stamp methodology to a nodal methodology, but respecting the difference and the legal separation between the distribution and the transmission systems. The proposition has not become a resolution yet, but it is in final analysis.

By the methodology, every generator that access the 138 and 88 kV[17] distribution grid will have the tariff calculated by a specific nodal methodology, which will observe the adequate costs to be allocated, being lower to generators that diminishes the grid investments. The methodology will also consider the tariffs convergence, process that tries to fit the tariff result with the right economic signal to the generators, avoiding the migration trials. The proposed methodology is almost the same that has been applied to the transmission system. The differences are related to the following considerations:

a) the transmission methodology uses the power balance among generators and loads to allocate half the cost to the generators and the other half to the loads (distribution companies and free consumers). It is not possible to use the same consideration to allocate half of the distribution cost to the generators. For instance, there exist grids with one generator and many loads that are more than ten times higher than this generator. Therefore, the methodology will consider the size of the generator in the distribution system; and

b) When the sum of generator power injection is bigger than the load in the area, the distribution grid will export. In that case, the existent transmission cost will be captured and applied to the generator as extra fee;

c) The costs and data that have to be used to set up the tariffs became from the distribution costs and data in 138 and 88 kV and from all installation used to supply the distribution systems that are not in the transmission system (e.g.: the power transformers in the boundary of transmission and distribution systems); and

[17] It will be very difficulty to apply the methodology to generators access up to 88 kV due to problems of modeling the low levels networks. ANEEL has limited then the locational tariffs to the accesses in 138 and 88 kV that achieve more than 95% of the generation in the distribution system.

d) The lowest tariff is equal to zero, i.e., it is not allowed negative tariffs.

All other considerations applied to the calculation of the transmission tariffs are valid to the distribution proposed methodology. Therefore, it is possible to affirm that the differences between the methodologies are minimal, only to guarantee the correct calculation of the tariff. The results of this methodology are shown in the following figure:

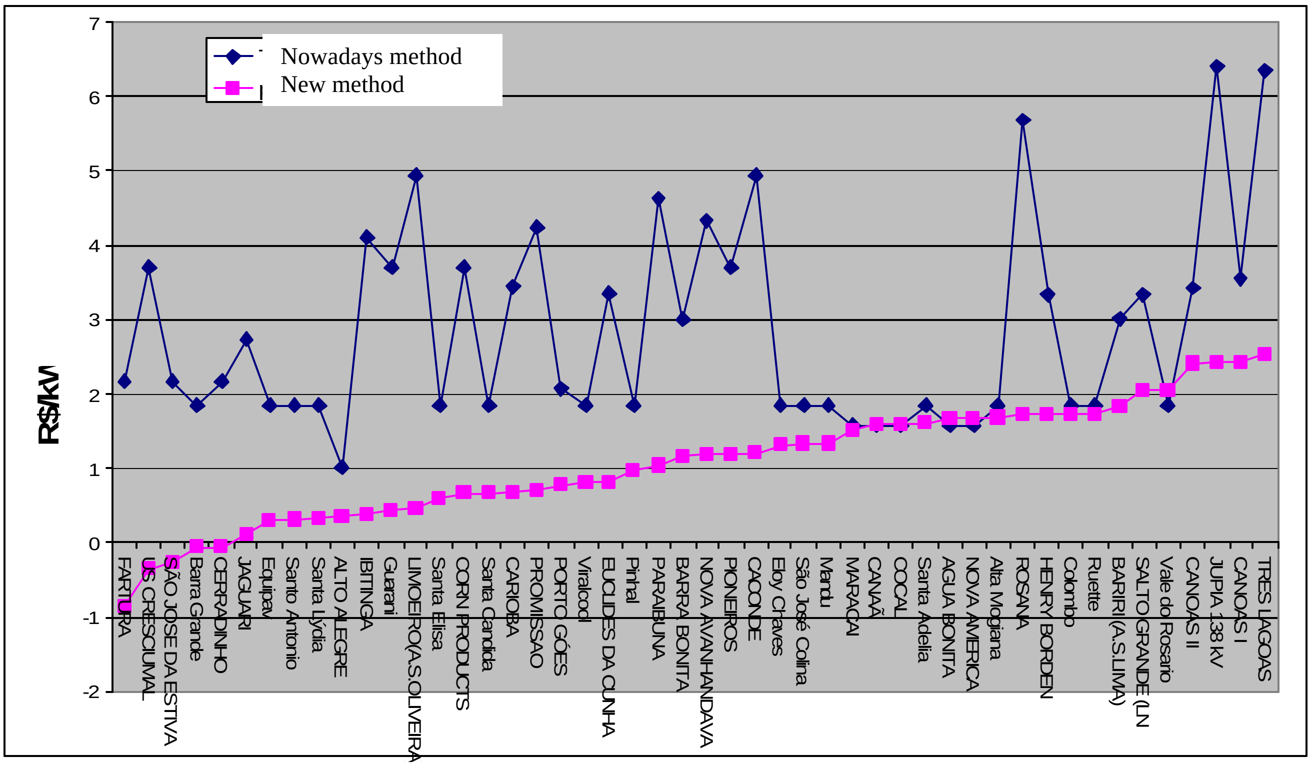


Figure 7: New distribution grid tariff

5. Generator's uncertainty perception due to regulatory framework on grid use and access

As presented in chapter 3 and described in [14], it does not exist only one cost allocation methodology or one way of regulate. It is possible to see that each country tries to apply the methodology the best fits with the electricity commercialization. In Brazil, the transmission and distribution electrical high voltage energy systems are relatively more expensive to the society that in another countries because the hydraulic generation. It implies that the grid planning tends to be centralized and has to be carefully analyzed. The grid access and grid use regulation in Brazil are settled to charge the generation in two ways: the grid connection and the grid use.

The grid connection is characterized as the grid part individually used or used by a small group that jointly need to access a grid. The common grid is characterized by its multiple purposes, for instance, optimize the system and attend loads and generation. Once settled the boundary (which is not an easy task), the cost allocation problem remains only for the common grid, once the connection costs are allocated to the demanding user.

The marginal methodologies seems to be adequate to allocate the common grid costs once they provide economic signals that leads to the involvement of the entrepreneurs and the existent generators and consumers in the planning process, in a multilateral process that ends up in a discussion of the central planning. Among the marginal methods, the long run or nodal methodology appears to be adequate because the generation basis and the capital cost in a developing country. The grid operation and maintenance costs represent 2 to 3% of the total investment cost and the capital cost represents 14%. Therefore, the important and expensive to the country is not the system operation or the short-run, but the investments. In that sense, the tariff will guarantee in a bigger part the return of the capital costs and in a smaller part the return of operational costs. However, the tariff will also bring to the new user the correct marginal cost allocation signal, pointing higher prices in equipments that are operating near the capacity, near the necessity of expansion or investment.

5.1 Assessing the existent nodal methodology

The generation is one of the electricity services and not a user of the good provided. Then, when one speaks about grid tariffation of generators, it has to be seen as a cost that will be accounted in the electricity sales price. Therefore, it is possible to argue that it is not necessary to apply tariffs to generators, once the consumers will pay the generators grid cost through the grid tariff or the electricity price. However, other problem arises because the consumer cannot choose the less expensive generator if the transportation costs are not included.

The grid cost allocation to generators is the way of better assess the total electricity cost by adding to the generation cost the transmission cost caused by that generation. In that sense, the grid charge of generators is important to force the rational grid expansion. Then, the solution provided by the cost allocation methodology is to leave to the generators their connection cost (solely caused by them) and charge a small part of the common grid that are used by all generators and loads. As the complexity of the transmission system increases, the cost allocation becomes more important and more complex because the economic signals that it reflects. For instance, the transmission use tariff of the Santo Antonio power plant in Madeira River (see Table 2) is R$24.64/MWh and the energy price is R$78.87/MWh. Only the grid use represents approximately one third of the energy price. If the cost allocation methodology was postage-stamp, the tariff would have been R$ 8.12/MWh and the other generators would have to pay the difference, what prejudices the generation competition[18]. Even with the highest transmission tariff in Brazil, the Madeira river power plants were competitive and the two power plants will be implemented in Brazil up to 2,013.

As can be seen, the purpose of the cost allocation methodology is not to prohibit new grid expansion, but rationally shows and charges the costs incurred. In the case, the purpose of the cost allocation methodology was achieved (to allocate more cost to the one's that implies more investment) and to the consumer it was provided a better assess, composed by the generation and transmission cost.

It would be very difficult to the consumer assess the transmission cost and choose among all possibilities the cheapest generator, considering the grid connection and grid use, without the existent

[18] The tariff calculated using the postage stamp methodology is R$ 4.173/kW.month which represents the mean cost of one kW transported in Brazilian transmission grid. Therefore, Santo Antonio transmission tariff is almost three times more expensive than the mean tariff.

regulation. Obviously, the decision would have to be made by the centralized planner in the planning studies, in a more vulnerable way than an existent *ex ante* regulation of cost allocation. Therefore, in the conception of the electricity services, the laws brought the necessity to charge the generators to protect market competition.

Once it is necessary to use a more sophisticated cost allocation methodology, as the nodal one used in Brazil, the regulator had a difficult task to set the intensity of the prices in two characteristics: **proportion and intensity**. It happens because the methodology approximates the long-term marginal cost in relation to a pre-defined system bus, setting the relation among the buses for the injection of each MW in the grid. However, these relations recover only the ideal grid[19] relatively to the reference bus, witch tariff is set as zero. The recovered cost is not the necessary one and the missing cost has to be added to the tariffs, preserving the tariffs relation and recovering the necessary cost.

The proportion characteristic is an intrinsic cost allocation problem. Despite the total transmission cost is given, the allocation between generation and load is not. In Brazil, the regulation determines half of the grid cost to be allocated to generators. Does not exist a study about these fixed proportion, only the feeling, in the beginning of the open access (1997) and the foundation of ANEEL, that the new (at the time) transmission segment cost would be equally divided between load and generation. However, once the rule was defined, it became very difficult to propose any other allocation proportion without break contracts or the competition in the market.

The second characteristic (the intensity), is a more empirical problem. Some assumptions of the method leads to unfeasible solutions, e.g., very big and volatile tariffs for few generators and negative tariffs to others, even after the addition of the unrecovered cost. Therefore, ANEEL proposed an

[19] As said before, the nodal methodology uses the concept of ideal grid, which implies that the grid is capable to transport the exact flows that are in lines, leaving no transport capacity without use. Unfortunately, this strong assumption never happens because the system is composed by standard equipments and faces reliability of demand supply, hydrothermal optimization problems that lead the system to have over capacity.

implicit limitation in the locational signal by introducing a factor that weights the signal by the circuit use rate. The impact of the final nodal tariff in the summation of the equation (2) bringing the tariff results to feasible solutions (see figure 3).

The nodal prices that have been applied to generators observe two characteristics: the range is wide and the distribution approximates to a normal curve, as depicted in Figure 8. In the 2007-2008 tariff period the highest tariff applied to a generator was R$ 9.806/kW.month and the lowest was R$ 0.132/kW.month (range of 75 times).

Despite those characteristics of tariff application, more studies are necessary to validate the division 50-50% of the transmission costs between generation and the load, which is an input data of the cost allocation methodology and determines the final tariff level. If a new division is not possible to the already connected generators (because the existent agreements), the argument does not hold to new contracts that have a separated long-run tariff methodology.

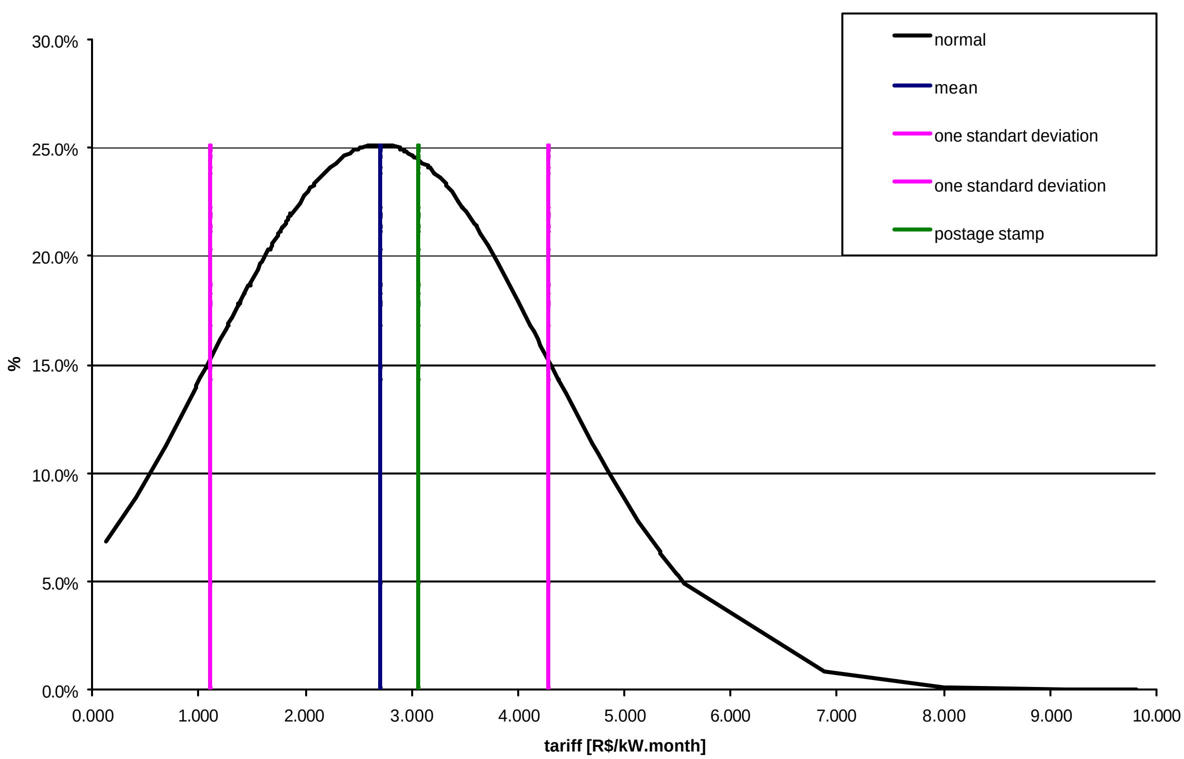


Figure 8: Normal curve of the applied transmission tariffs in Brazil.

The nodal methodology increases the Brazilian uncertainty to generators because the economic nodal signal is unpredictable beyond the 10 years planning horizon. If the existent generator cannot predict the tariff, it is a uncertainty that has to be covered in the energy sales tariff or will be object of discussion with the regulator. Since 1999 the methodology is known and appears to be solid and will not be changed in short-run because it had recently been object of a public hearing when ANEEL decides to keep the methodology to the existent generators and improve the predictability to new one's.

5.2 Assessment of the long-run transmission tariff methodology

The long-run nodal methodology was settled by ANEEL in 2007. The methodology was conceived to minimize uncertainty of the generation entrepreneur due to temporal volatility of the transmission nodal tariff that is not compatible with the fixed long-run price settled in the power purchase agreements, as determined by Law 10.848/04. The points that need to be assessed are:

a) The measurements of the diminishing uncertainty perception;

b) The sufficiency of the ten years estimative;

c) The problems in the planning changes; and

d) The impacts caused in the distribution systems and in the free market, once the methodology is not applied in these environments;

Entrepreneurs see all unpredictable changes in costs, rules or behaviors in the regulated market as uncertainty. The uncertainties of the generation plant construction have to be allocated to the entrepreneur that in this case is the best to assume the uncertainty. However, other uncertainties as change in regulations and regulated costs are observed as externalities and are uncontrolled by generation entrepreneurs. The concern about tariff regulation is the volatility of nodal prices despite the regulator's efforts to minimize it. The regulator solution to diminish such uncertainty has been the long-run tariff calculation. It diminishes the uncertainty once there is a strong regulation that fixes the generator cost for the period.

Figure 9 illustrates qualitatively the regulation benefits in comparison to its absence. The figure shows the generation entrepreneur perception of grid cost evolution in three scenarios. The pessimistic one can be used to set the reference in the electricity sale tariff as the one that most minimizes the generators perception of uncertainty (red line).

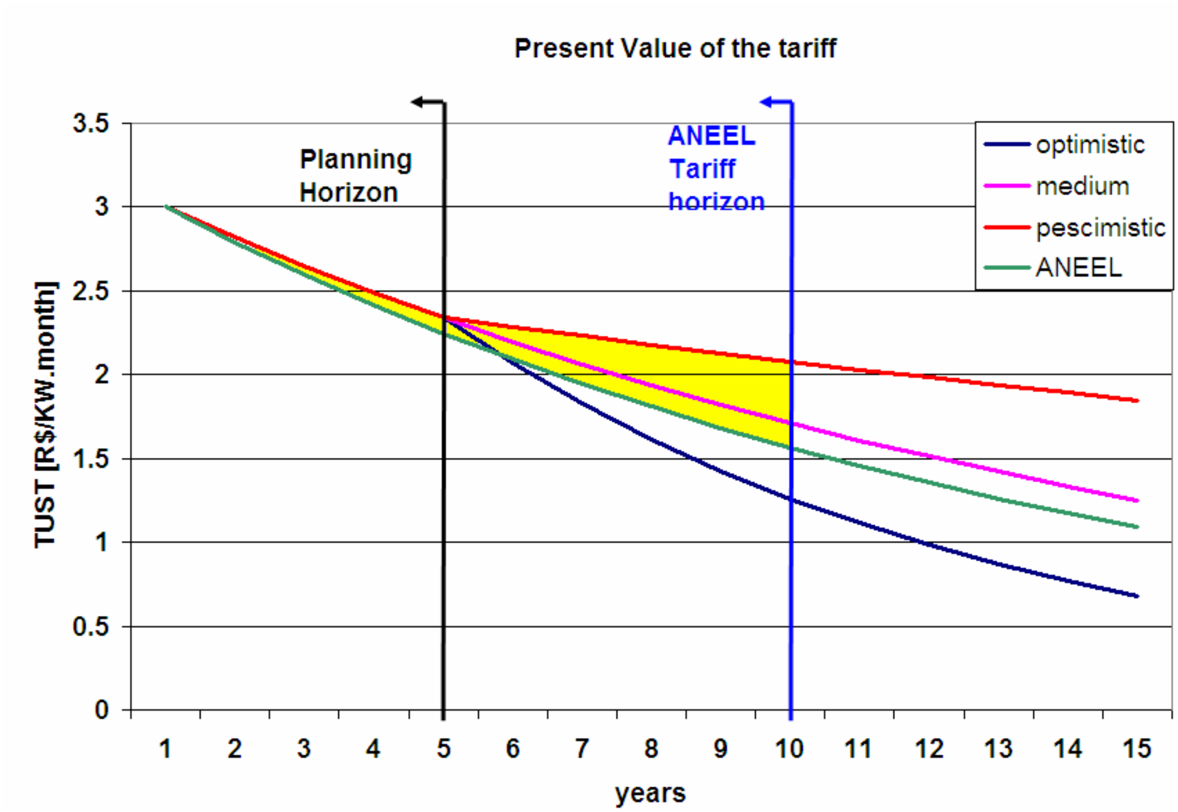


Figure 9: Present Value of the transmission tariff for three qualitative scenarios.

The generator estimative was divided in two slopes that imply two different uncertainty perceptions, one in the planning horizon, and one after the planning horizon. The uncertainties in the planning horizon are given by smaller slope of the curve in relation to the after planning horizon. The bigger slope in the left side of the graph implies that the uncertainty perception increased and the generator estimative of uncertainty is bigger and reflected in the tariff estimation that is higher. The

ANEEL's line represents the realized tariff, where the 10 first tariffs were established using the long run methodology and the others are yearly calculated. The uncertainty perception reduction can be quantified by the yellow area in the figure, or the difference between the pessimistic line and the ANEEL's long run tariff methodology line.

Once the regulator settled the tariff, there is no necessity of uncertainty estimation during the first 10 years of operation. For instance, in figure 9 the pessimistic tariff increases 1% a year after inflation in the planning horizon and 5% after the planning horizon[20]. If the analysis is realized for a 15-year contract, the impact of the ANEEL long-run methodology reduces 44% the perception of generators uncertainty in comparison to a 100% of uncertainty in its absence.

Keeping all other variables constant, the uncertainty perception increases to longer agreements, once the absence of planning is bigger and the regulator's long-run tariff methodology applies to a reduced proportion of the contract time. In spite of that, it is possible to affirm that the long-run tariff methodology reduces the tariff uncertainty perception to generators.

The methodology limited the calculation time to 10 years after the beginning of the generators operation. ANEEL's argument is that the time is the maximum possible due to the planning horizon, 10 years. These argument holds for the first 5 or 7 years when the planning is used to calculate tariffs, but it does not hold for the period after the planning horizon, when the tariff estimative remains the same, i.e., there is no real growth after the planning horizon.

The observation of the figure 9 will leads to the conclusion that the expansion of the tariff calculation should be thought, at least to the 30 years contracts because the uncertainties due to

[20] The real growth of 5% in the transmission tariff implies that the transmission system will be expanded in a bigger ratio than the generation and load that support the transmission costs. The relative or real growth of the transmission system in this case is 70% in 15 years with 12% increase in the planning horizon (first five years of generator's operation)

volatility remained significant. Nevertheless, this kind of expansion leaves the uncertainty to the load and to the regulator in the future.

Another way to diminish the uncertainty perception is to permit revisions in the long-run contract. These revisions could be restricted to the regulated prices that generators are subjected, like the grid tariffs. In that case, the tariff calculation horizon could be fitted to the period between revisions, and the grid tariff uncertainty will be eliminated.

New versions of the long run planning are yearly made by EPE and are a source of uncertainty to the generation. When the 10 years plan varies a lot among each other it became a problem. Obviously, the generator that has long run tariff calculated is protected during the application of the long-run transmission tariffs, but the changes in plans affect the others and the uncertainty volatility perception of the period after the long-run tariff calculation, reducing the benefits of the methodology.

The impacts caused in the distribution systems and in the free market because the regulation does not apply to them are significant. The generator that access distribution grids with higher tariffs than the nearest transmission grid tries to change its connection point to the transmission system. The solution to this is to expand the nodal methodology to distribution grids, and after that, expands the long-run regulation as well.

5.3 The assessment of shared connection regulation

In the beginning of chapter 5 and section 5.1 the generators connection was presented as a problem existent before the establishment of the grid access point. After that, it becomes easy to regulate once the generator will have to pay the allocated costs directly. However, to establish the grid access point may not be so easy. It is easy to see the grid connection point when one generator will access the grid, which is already constructed. There is also true in most countries that have a thermoelectric generation basis (near the load) and in developed countries because the grid does not expand to unattended regions. All those conditions apply to the majority of generators accesses in Brazil as well, but to one kind of generation access it does not: to generation located in unattended area. In the nearest past that happens at least 3 times in Brazil: the Madeira river power plants connection to the grid, the Dardanelos and small hydraulic power plants in Mato Grosso state and the biomass integration in Goiás and Mato Grosso do Sul states. Figure 10 illustrates the generation facilities position in the Brazilian map indicating the absence of grid.

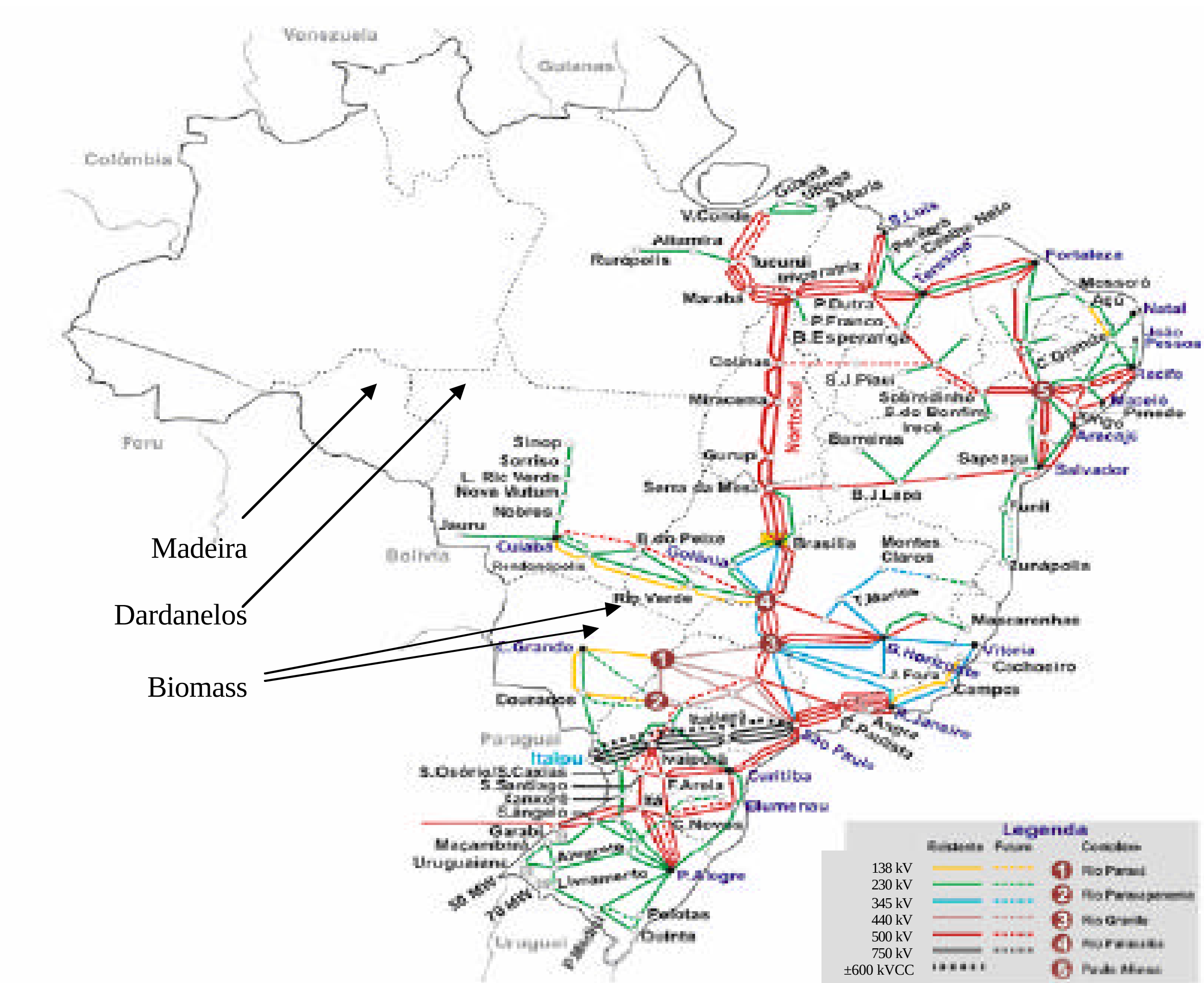


Figure 10: The Brazilian grid [4]

In those cases, it is much more difficult to set the connection point once neither the connection nor the grid exists. Two things may happen: the generation is not viable because the connection cost or the framework is incomplete. In all cases, long-term planning shows the existence of other players as loads or other generation in the same regions of the generation.

The ANEEL resolutions n. 320/08 and 312/08 [25] established a new manner to characterize the deepness of the generators connection when they permited shared connections. In future, as a result of the regulation, it is expected the access point will not be defined due to the number of users as before, but by the function that the installation has in the system, which is more rational.

It is a positive change that tries to avoid subsidies to the connection cost, which harms the generation competition.

Nowadays the resolutions have allocated the connection costs to the generators. Despite the allocation benefits, the regulation increased the uncertainty perceptions to the generators in a shared connection and brought a problem of source restriction.

The ANEEL resolution n. 320/08 derives from the Presidential Decree n. 6,420/08 [26]. The Decree establishes that the Ministry of Mines and Energy will determine the implementation of shared connections as the ones illustrated in figure 6 to new unattended region. That mechanism exists to limit the transmission auctions, what is positive, because they are cost full. Despite that, the Decree brought also a restriction that only small hydraulic, biomass, Aeolic and solar power plants can participate of the shared connection that will be built by a transmission company.

The link between grid expansion and energy source follows the same logic: avoid the increase of transmission auctions to generators that can build alone or with others the connection. Possibly, it will lead to problems in grid optimization. For instance, if a thermoelectric plant minimizes the system global cost by sharing a connection in a biomass field, it will be impossible to permit the auction or the participation of that generator because the Decree forbid[21].

In fact, the regulation tries to guarantee the correct cost allocation and the optimization of the grid, once it permits the generators together and in a cheaper way to implement or pay to the implementation of the connection to the grid. The police arose because the shared connection promotes a return to scale and diminish the cost to aggregate the generation. In that sense, the prohibition of any kind of source leads to optimization problems. In other way, it works as a policy to improve renewable sources competitiveness.

The regulation also brought a uncertainty to the generator in sharing the connection. Before the regulation, the connection cost is fully allocated to the generators and they control the connection costs. The costs are bigger but more predictable. With the shared connection solution, problems with one generator that share the installation became a problem to the others. If one generation fails in payments, or worse, if it fails into access the system after the transmission auctions, the cost of the transmission company will be reallocated to the remaining users of the connection, i.e., the remaining generators. That uncertainty has to be analyzed before the option to get into a shared connection in a cost benefit analysis.

5.4 The differences between transmission and distribution nodal prices for generators

The ANEEL's proposition to calculate the distribution grid tariff to generators is a tentative to apply a nodal price to the already connected generator and to stimulate the correct allocation of new ones. The methodology was conceived to permit the tariff convergence between distribution and transmission grids in high voltage levels of 138 and 88 kV. The methodology needs many data to

[21] The Decree do not restrict the other sources to build up the connection by their own, only restricts the public auctions to renewable sources.

modeling the grid and costs in a nodal program including the equipment and transmission lines in distribution level and the total distribution revenue in grids. The methodology intends to finish with the lack of regulation of the generation tariff in the distribution grid that has been postponed for 10 years.

The methodology results seems to be grid tariffs that recover the allocated costs and promotes an nodal economic signal (figure 7). The methodology also gives a solution to a regulatory problem in the distribution grids that have excess of generation, like Mato Grosso State (bigger power demand than the distribution load) by charging transmission costs in exporting distribution grids.

The methodology controversial points are the complexity and the tariff environments, the tariff volatility between cycles and tariff convergence.

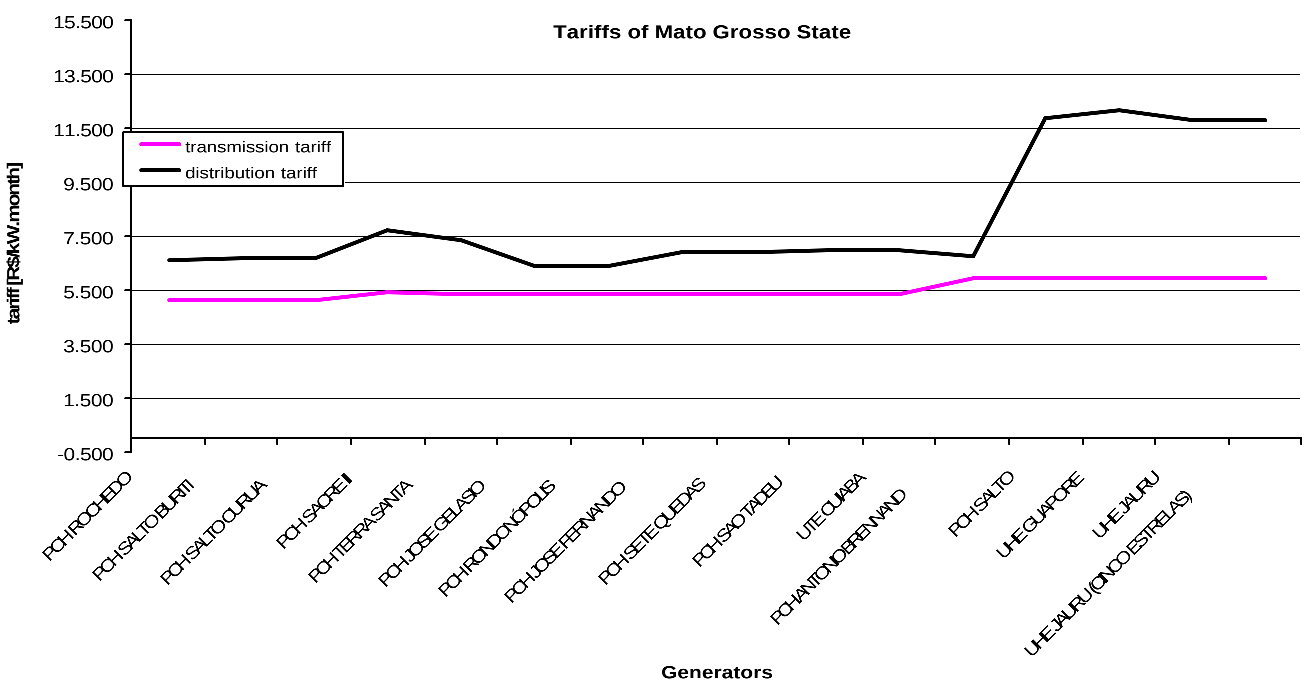
It is possible to affirm that exists a much simpler way to apply nodal tariffs in distribution systems by simply modeling the distribution grids in the existent transmission nodal program and run the tariffs in each point of the system. Despite that, there is a command in Law that separates the grids in transmission and distribution into two different economic regulations and the methodologies integration may lead to legal problems.

Despite the legal problems, it has been showed that existent differences in cost allocation methodologies leads to users' erratic behavior due to access and may cause grid optimization problems. Therefore, if it is not possible to solve the tariff problem with one methodology, it is possible to do it with two methodologies that interact with each other, but are restricted to each economic environment.

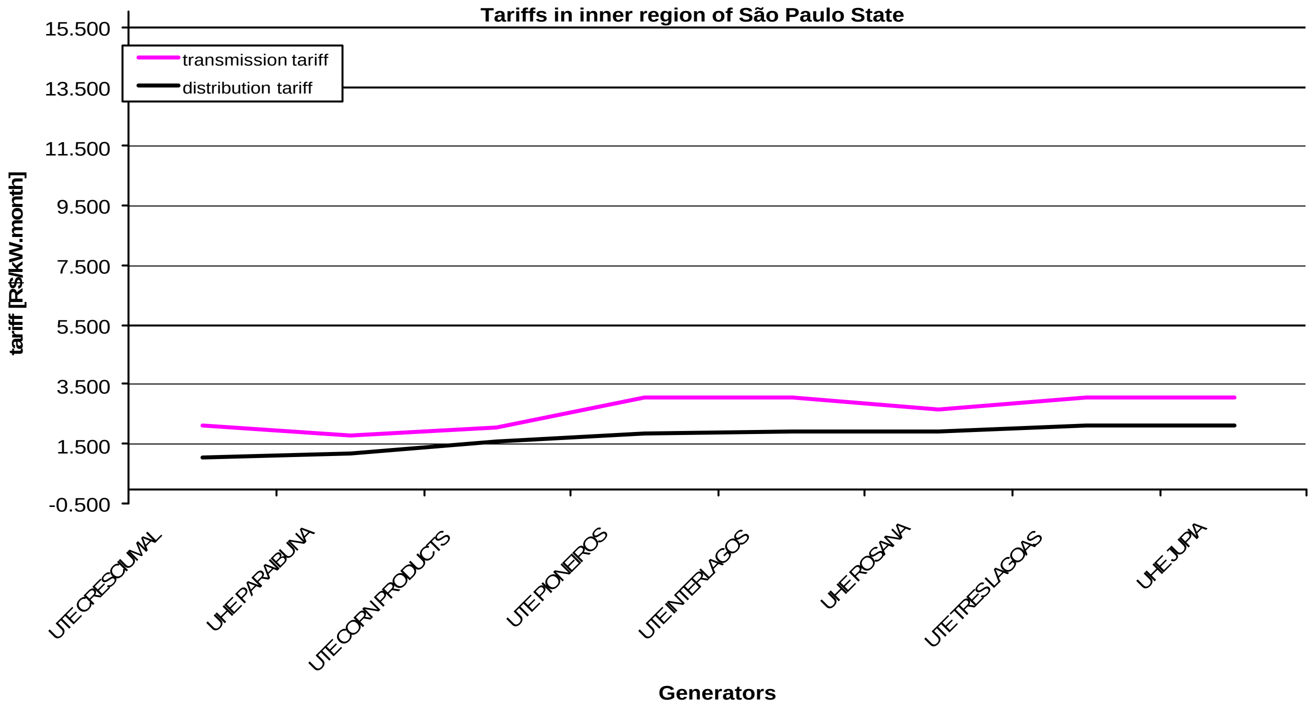
Another current problem of the nodal tariffs is the volatility. The nodal distribution tariff will face the same problems of the transmission nodal tariff. However, it is probable that ANEEL will apply the same mechanisms in use to the transmission tariff, e.g., stabilization.

In the uncertainty perspective, the volatility of the future tariff cannot be assessed yet and when compared to a change in tariff methodology that is happening now may be considered a minor problem. The worst that can happen in the uncertainty perspective is a change in cost allocation methodology because there is no way to predict what will become the next tariff.

The convergence between the transmission and distribution nodal tariffs is not guaranteed methodologically, but implicitly it can be obtained by the use of the same methodologies in the two grid cost allocation and the same assumptions. Figure 11 shows the result of the distribution and transmission nodal prices for generators in two regions: São Paulo (importer distribution grid) and Mato Grosso (exporter distribution grid).



(a) Exporter region



(b) Importer region

Figure 11: nodal distribution tariffs for importer and exporter regions

As it is possible to see, the results of the tariff comparison appears to approximate to the premises of convergence.

6. Conclusions

The fundaments of the grid access (connection and use) in the Brazilian transmission and distribution systems were presented. An overview through the up to date regulation was realized and the investment environment to generators due to grid access were established.

Brazil has separated the generators grid costs in two: connection and use. The first one is allocated to the generation and is related to the installations that permit the generators access the common use grid. ANEEL have done some improvements in grid connection regulation, highlighting the regulation of shared grid connection.

The grid use costs are allocated to generators in different ways in transmission and distribution systems. The grid costs are allocated in the transmission system with a nodal methodology that uses the marginal cost theory, leads to tariffs in each node of the grid and gives economic signals to the generation entrepreneurs. The grid costs are allocated in the distribution system with a postage-stamp methodology that is a transient cost allocation methodology and does not return economic signals to the generators.

The cost allocation methodologies and the grid connection regulation were assessed in two forms: analytically, indicating the controversy about the used arguments and the generation uncertainty assess, indicating points that implies uncertainty perception to generation.

The analysis leads to the conclusion that the regulator has been doing the optimization of the cost allocation methodology to improve the quality of the generation nodal price and at the same time have been trying to reduce the uncertainty perception of the generation, as assessed in chapter 5.

ANEEL's biggest change in regulation will be the high voltage distribution grid cost allocation methodology to generators. With respect to the existent Law, a methodology that leads the nodal price to the distribution grid was proposed using the same principles applied to the transmission grid and described in chapters 3 and 4. It was showed that the methodology has a tariff convergence with the transmission one, despite this has not been explicitly imposed by the proposed methodology. Figure 11 illustrated the new prices that will be given to generators connected in distribution systems that are adequate to the already given transmission nodal prices.

About the long-run transmission tariff methodology, the regulator found a mid-term solution between short-run volatility of nodal prices and complete elimination of transmission tariff uncertainty. Despite that, the regulator has already identified that the generator is not the best uncertainty-taken to the tariff volatility uncertainty. In that sense, one of two things can be done to eradicate the tariff volatility: the extension of the tariff stabilization to the horizon of the power purchase agreement (15 or 30 years) or the permission to price revision of the power agreements time-to-time and its synchronization with the tariff calculation horizon to each revision.

The regulator implemented a new rule that permits auctions to connect more than one generator to the transmission system. This solution permits the expansion of renewable electricity sources but increased the uncertainty to generators, because they become dependent from each other. Hence, a possible give up of one generator increase the costs of the remaining ones. Once the connection is an installation that exists only to permit the generation access to the grid, the regulator left the decision to share the connection to the entrepreneur and increased the competition in the generation market.

Finally, the Brazilian grid connection and grid use regulation reflect the institutional arrangement, constructed to permit competition in generation and long-run power purchase agreements. It is very sophisticated as consequence of the grid costs and conditions imposed to the transmission and distribution systems by the hydraulic generation basis in a large and developing country.

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8. Appendix

8.1 Generation Grid Tariffs of Distribution Companies in 2,008

	Distribution Company	Tariff R$/kW.month		Distribution Company	Tariff R$/kW.month		Distribution Company	Tariff R$/kW.month
1	AES SUL	2.750	23	CER	0.000	45	DEMEI	0.000
2	AMPLA	4.360	24	CEAM	7.890	46	ELEKTRO	3.440
3	EBE	2.160	25	COELCE	5.500	47	ELETROPAULO	2.570
4	BOVESA	7.010	26	CEMAR	8.350	48	EDEVP	1.940
5	CAIUA	1.770	27	CEPISA	6.700	49	EEB	0.000
6	CEB	2.510	28	COSERN	3.070	50	ENERSUL	4.370
7	CEMIG	4.440	29	CEEE	2.700	51	ENERGIPE	5.170
8	ELETROCAR	0.000	30	CFLCL	6.880	52	EFLJC	2.540
9	CERON	5.150	31	CFLO	6.320	53	EFLUL	2.540
10	CELPA	3.730	32	CHESP	3.340	54	ELFSM	0.000
11	CEMAT	3.430	33	CJE	1.560	55	ESCELSA	2.440
12	CELESC	2.540	34	CLFM	4.250	56	FORCEL	2.820
13	COCEL	5.110	35	CLFSC	2.670	57	I ENERGIA	2.540
14	ELETROACRE	5.510	36	CNEE	2.400	58	LIGHT	2.480
15	CEA	4.140	37	CPEE	0.000	59	MESA	2.340
16	COELBA	3.620	38	CPFL PAULISTA	1.690	60	MUX ENERGIA	0.000
17	CENF	5.100	39	CPFL PIRAT.	2.010	61	UHENPAL	2.540
18	CELTINS	7.220	40	CSPE	2.620	62	RGE	3.200
19	CELB	5.470	41	SULGIPE	6.800	63	SAELPA	6.530
20	CEAL	6.850	42	COOPERALIANCA	8.180	64	HIDROPAN	0.000
21	CELG	2.640	43	COPEL	2.290			
22	CELPE	0.920	44	DMEPC	0.000			
MEAN VALUE = 3.424								
STANDARD DEVIATION = 2.280								
HIGHEST TARIFF = 8.350								
SMALLEST TARIFF = 0.000								