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Brazil –Economic Regulation of Energy Transmission: Incentives for Innovation

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ABSTRACT

The transmission network is the first link between large power generation facilities and electricity customers. It supplies energy at high voltages to substations, where the energy is distributed via the distribution network. The transmission network today operates with a high level of reliability, but presently a variety of technologies offers the possibility of great improvement in system performance.

Sophisticated new monitoring systems may reduce the likelihood of system failures and disruptions that cause serious economic and social consequences. Emerging efficient technologies may also help to solve network expansion constraints, including difficulties to install new transmission lines and to incorporate growing participation of intermittent energy plants, like wind and solar.

This paper starts presenting the status and perspectives of the Brazilian transmission sector showing the high level of investment planned until 2024 – 60% cumulative growth of line extensions and the same 60% rate for transformation capacity.

In the second part the paper presents the emerging technologies and the potential opportunities it offer to increase, among other factors, the energy quality, O&M structure, availability and reduction of technical losses. These advantages impact not only for new assets but also for the existing ones.

Considering the existing assets the paper starts a discussion about the regulatory framework ant the right economic signals to promote investment in innovation and automation. The paper then addresses the emerging regulatory of OFGEM in UK and the existing regulatory barriers that still exists internationally and in Brazil.

The paper concludes by identifying an opportunity for developing a regulatory R&D project to deeply analyze this subject and to propose a new regulatory framework to promote an economical feasible innovation process for the Brazilian transmission sector. In the last part the paper presents the guidelines and structure of the project GESEL is starting to develop in the scope of the Brazilian ANEEL regulated R&D program.

KEYWORDS: Regulation, Electric Power System, Transmission, Technological Innovation, Brazilian Electric Sector.

1. Introduction

The purpose of this paper is to discuss the regulatory complexity of the energy transmission sector process of innovation, considering that the Brazilian Electric Sector has a continental dimension with predominance of hydroelectric power plants that are getting more and more distant from load centers and also considering also the growing participation of intermittent energy resources.

Section 2 of the paper presents the current transmission sector structure and the planned future highlighting the great increase in transmission lines and the number of substations with estimated investment.

Section 3 presents of the emerging technologies highlighting the present status of the transmission sector worldwide, showing some of the specific technical problems of the transmission sector in Brazil.

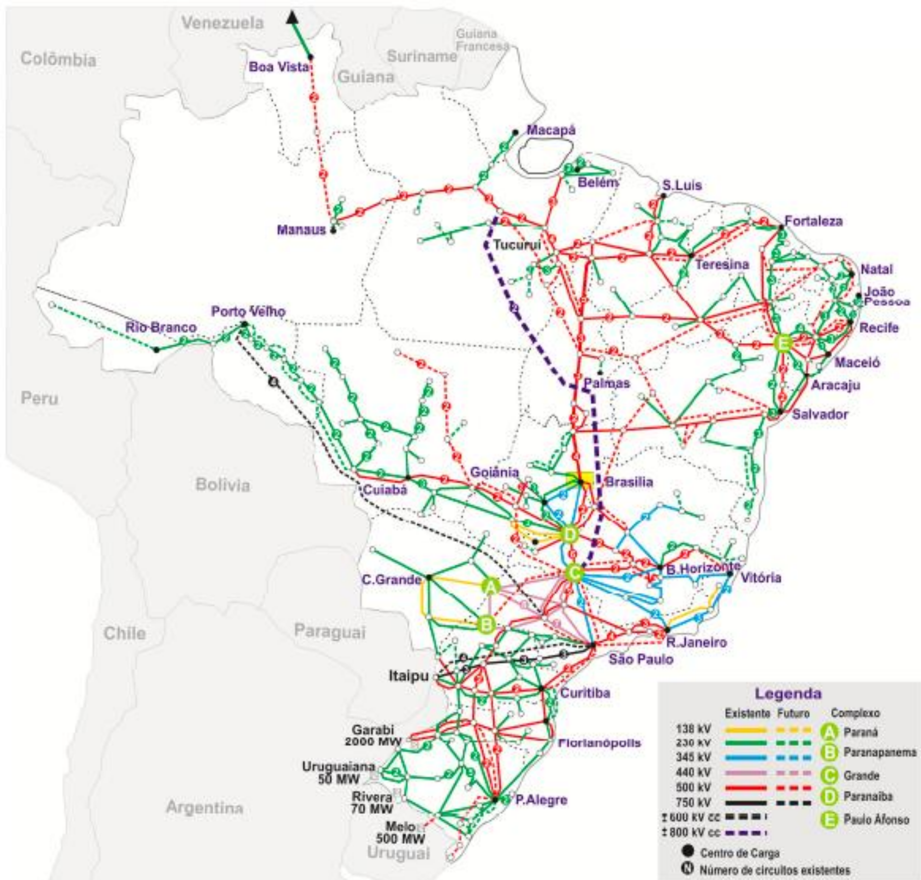
Section 4 presents the regulatory scenario of the transmission sector in Brazil and opens the discussion of how to develop a regulatory framework to motivate investors to introduce new technologies providing an economic signal for investors without creating impacts to the energy consumers.

The OFGEM regulatory framework based in the RIIO model for setting price controls for network companies is presented. It highlights the next decade challenge for the transmission companies for securing significant investment to maintain a reliable and secure network, dealing with the changes in demand and generation that will occur in a low carbon future.

In Section 5 of the paper introduces the Electric Sector Study Group (GESEL) of the Economy Institute of the Rio de Janeiro University R&D regulatory project in the aim of analyzing and discussing a new regulatory framework to push innovation for the Brazilian transmission sector.

2. The Expansion Forecast of the Brazilian Transmission Network

The Basic Brazilian Transmission System is composed of voltage lines in the range of 230kV up to 750kV. Figure 1 presents the topology of the Brazilian transmission network, highlighting the existing and projected lines.



Source: ONS

Figure 1 – Topology of the Brazilian Transmission System

The Ten-Year Energy Plan (PDE 2024), developed by the Brazilian Energy Planning Company (EPE), considered beside of the normal assumptions (mainly to increase the transmission network availability and operability) the following inputs to the transmission expansion forecast:

- Large Hydro Power Plants located in the North Region: mainly the power plants of the Tapajós River, Belo Monte and Teles Pires;
- Integration of 558 renewable energy projects, mainly wind farms, with an installed capacity of 14.000 MW. The great majority of the power plants are located in the Northeast and South region of Brazil;

- Integration of the Brazilian subsystems to take advantage of energy complementarities between the Brazilian regions;
- Integration of isolated electrical regions in the North area of the country;
- International integration with Uruguay, Argentina and Venezuela;

Tables 1 and 2 present the consolidated expansion values of the PDE 2024. Table 1 presents the extension expansion for each voltage level, and table 2 the increasing of MVA transformation capacity for each voltage level.

Table 1 – Line extension (km) forecasted in the PDE 2024

Tensão	±800 kV	750 kV	±600 kV	500 kV	440 kV	345 kV	230 kV	TOTAL
	km							
Existente em 2014*		2.683	6408	40.656	6.728	10.303	52.647	**119.426**
Evolução 2015-2024	10.055			42.783	353	1.666	20.870	**75.728**
Evolução 2015-2019	2.140			25.755	196	885	9.352	**38.328**
Evolução 2020-2024	7.915			17.028	157	782	11.518	**37.400**
Estimativa 2024	10.055	2.683	6.408	83.440	7.081	11.969	7.3518	**195.154**

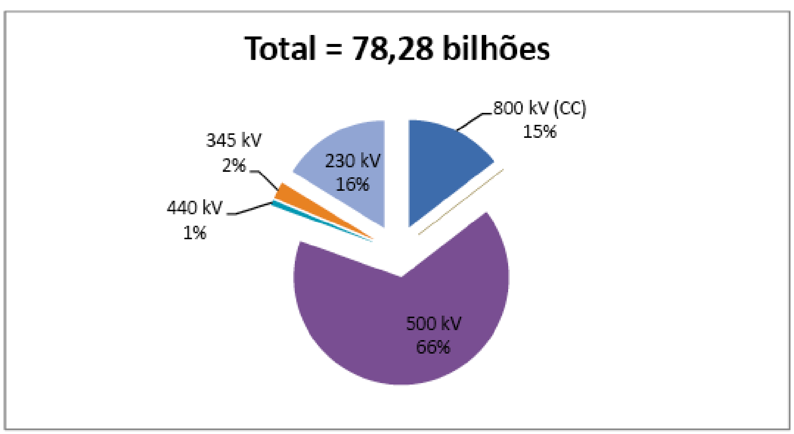
Nota: * Dados do DMSE/MME
Fonte: EPE

Table 2 – Transformation capacity (MVA) forecasted in the PDE 2024

Tensão	750kV	500kV	440kV	345kV	230kV	TOTAL
	MVA					
Existente em 2014**	23.247	129.095	23.916	49.795	79.565	**305.618**
Evolução 2015-2024	3.650	105.425	11.031	21.147	46.906	**188.158**
Evolução 2015-2019	3.650	58.339	5.081	14.747	24.933	**106.750**
Evolução 2020-2024		47.086	5.950	6.400	21.973	**81.409**
Estimativa 2024	26.897	234.520	34.947	70.942	126.471	**493.776**

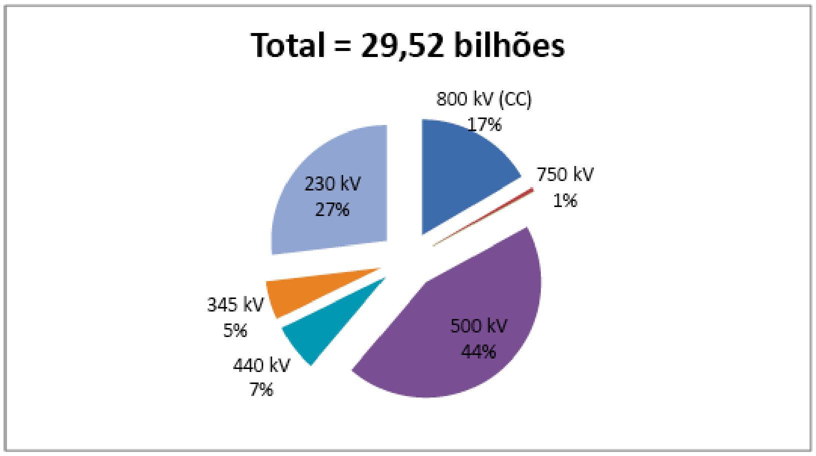
Notas: * Inclui os transformadores de fronteira.
** Dados do DMSE/MME
Fonte: EPE

Figures 2 and 3 present the forecasted investments in transmission line and substation construction.



Fonte: EPE

Figure 2 – Forecasted investment in transmission line construction



Fonte: EPE

Figure 3 – Forecasted investment in substation construction

The total estimated investment to support this expansion is of 107.8 billion Reais (approximately 25 to 30 Billions Dollars). The data presented forecast a growth of 60% in the overall line extension and transformation capacity.

The transmission expansion complexity arises from:

- The need to reconcile conflicting requirements of initial capital investment reduction (mainly because of the auction procedure) and system reliability. Conciliation of these two factors normally involves technological options (AC or DC, for example) and the need for alternative routes to the transmission lines to minimize the risk of multiple contingencies;
- The environmental constraints that limit the availability of line corridors and local provision for substations in the Amazon region and in major consumer centers (Southeast Region);
- The large number of transmission companies, with diverse backgrounds and different business characteristics, requires permanent coordination effort by the regulatory agencies, from the design phase until system operation. Due to this fact, the Grid Procedures developed by the Brazilian Independent System Operator (ONS), have to be heavily detailed and subjected to constant revision.

3. Improvements in the existing Transmission System

At a global level, the existing transmission system is being continuously challenged to anticipate and prevent blackouts or unexpected shutdowns, increase the transmission capacity, improve its availability and quality, reduce maintenance time, improve controllability, restoration and operability, implement mechanisms for load management, reduce losses and increase the ability to interconnect an increasing amount of intermittent generation (mainly wind energy) with high levels of reactive power.

Some Brazilian characteristics increase complexity:

- The tropical climate constraints imposed to the transmission assets (high temperatures, high humidity and high level lightning activity);
- The variability of high energy blocks flow during the year, stressing the regional interconnections;
- The highly concentrated consumption of energy in the southeast region while the new generation assets are mainly located in the North and Northeast areas;
- The economic and financial feasibility of introducing innovation in the already existing transmission system due to the Brazilian regulation framework.

3.1 Technological Innovation and System Reliability

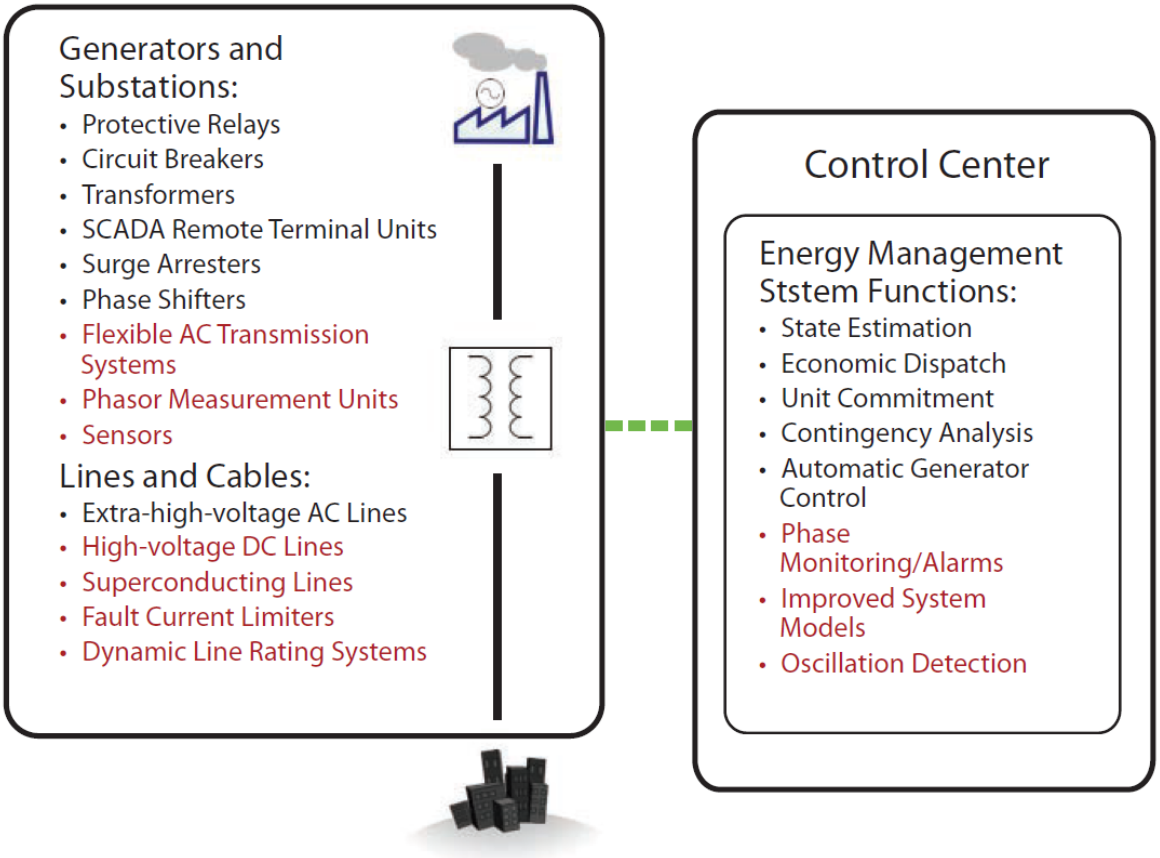
One of the technologies being studied and applied with greater emphasis focused on improving the quality of systemic operation worldwide is the PMU (Phase Monitoring Units).

Preventing or anticipating and reducing the magnitude of blackouts undergo a systemic view of the transmission network. In this regard has been increasingly applied the so-called WAMS (Wide Area Measurement Systems) which are collected from notable points of network data with high sampling rates, through PMU (Phase Measurement Units). These data are transmitted to the control center where they are processed in order to identify abnormal network conditions. The implementation of a WAMS System is normally regarded as a systemic initiative to be conducted by the System Operator (ONS).

To increase the capacity of the lines mainly three types of constraints has to be considered: thermal, voltage stability and transient stability. In Brazil with the increasing distances between power plants and the major load centers, new transmission technologies in extra high voltage and direct current (HVDC) have been studied and used. The emphasis on this subject is to implement or to increase the monitoring, actuation, automation and control algorithms and applications associated with the existing assets. The transmission company that owns the assets normally conducts this type of activity.

With the increase use of long lines, the need for reactive power compensation by means of series capacitors and static compensators so-called FACTS devices. These devices having a more elaborate technology makes the operation and maintenance more complex and determines the need to develop knowledge and technical training to deal with this new reality. The transmission company that owns the assets normally conducts this type of activity.

Figure 4 shows different technologies that can be used to upgrade the transmission network.



Note: Existing technologies and functions are listed in black; new and emerging elements are shown in red.
SCADA = Supervisory control and data acquisition.

Figure 4 – Technologies to improve the transmission network

The increasing degree of automation and technological innovations in the transmission system associated with investment in research and development are key elements to increase the overall quality of the transmission system.

3.1.1 Highlighting to the PMU (Phasor Measurement Unit) technology

WAMS consists of measurement devices, communications networks, and visualization software; the most critical is an enabling technology called the phasor measurement unit (PMU). The key issue of the PMU is that the measurement is taken at a very high sampling rate and that the time tag is associated with each measurement. This provides for asynchronous transmission of the information from the different locations and enables the correlation of data between these locations.

The PMU technology - **P**hasor **M**easurement **U**nit presents several advantages, such as:

Table 3 - Advantages of Technology - PMU - Phasor Measurement Unit
Improves the models simulating the behavior of major interconnections and power plants.
Simulates the transmission system behavior with mathematical models that predict how a power plant and transmission assets will operate under various normal and abnormal conditions.
Supports operators to supervise and coordinate the active reliably knowing operating limits and analyzing in real time, thus avoiding errors and blackouts.
Supports software applications to aggregate and to analyze the PMU data and produce actionable information for system operation or planning are critical to realizing the full benefits of PMUs.
Measures defining characteristics of voltages and currents at key substations, generators, and load centers, such as cities.
Supports state estimation algorithms with the use available measurements, such as the magnitudes of system voltages and currents, to estimate the system state. The system operator uses the state information to optimize power system operation. System optimization includes contingencies and corrective actions. State estimation algorithms read system measurements to determine the state of the system within a predetermined error. Traditional system state estimation takes around 10 minutes. Synchronized phasor measurement takes approximately 100 msec to calculate the system state, 6,000 times faster than the traditional approach.

Source: Tab. 01 - US Department of Energy – August 2014 – Smart Grid System Report to Congress

The Phasor Measurement and Control Units (PMCUs) located at different parts of the power system make synchronized phasor measurements that provide a "snapshot" of the power system using absolute time reference. For example, we can obtain voltage phasor information across the power system to determine the power system operating state.

4. Regulatory innovation to encourage the use of new Technologies

As previously presented there is a strategic importance to give the economic signals to push innovation in the existing transmission system. This type of discussion is being held internationally. The key question is: How economic regulation can provide adequate and consistent economic signals for agents to invest in automation and technological innovations in countries that adopt liberalized models with emphasis on low tariffs?

Solving this issue is important to convey the desirable investments from a social point of view with the investor economic perspective. Some authors and regulatory agencies such as the UK OFGEM, show that the traditional tariff regulation can send an imperfect economic signal for transmission agents with negative effects on the quality and safety of the electrical system.

One important effort to overcome this problem is being developed in the UK OFGEM (Office of Gas and Electricity Markets) that is developing a new regulatory framework focusing what they termed RIIO (Revenue = Incentives + Innovation + Outputs- Products). The starting point is the recognition that over the next decade the transmission companies will face an unprecedented challenge of securing significant investment to maintain a reliable and secure network, and dealing with the changes in demand and generation that will occur due to a low carbon future.

The goal is to ensure that the energy is delivered at a fair price for consumers. RIIO is designed to encourage network companies to:

- Put stakeholders at the heart of their decision-making process;
- Invest efficiently to ensure continued safe and reliable services;
- Innovate to reduce network costs for current and future consumers;
- Play a full role in delivering a low carbon economy and wider environmental objectives.

Investments focused on increasing the level of automation of the transmission network and / or introduction of technological innovations may involve:

- The replacement of not yet depreciated assets presenting low technical performance;
- The installation of new equipment not envisioned in the original design;
- The reduction in operating costs due to higher degree of automation; and
- The application and software development that can provide greater reliability to the system.

In order to evaluate the impacts of the innovation process we must consider some components of the problem:

- Capital Investment: considering a transmission company with regulated tariff, as several Brazilian transmission companies that renewed the concession agreements in 2013, the replacement of equipment not yet fully depreciated poses a reduction in the remuneration regulatory base and therefore a reduction in the tariff associated to the previous investment. Of course, the new investment will be recognized for tariff purposes, but the net effect in terms of increase will be reduced to the extent that the asset decommissioned leaves the remuneration equation. This situation gives a negative economic signal to invest in innovation even if it brings advantage for the transmission system.
- Operational Costs: Regulatory agencies resist compensating investments related to process improvements that result in cost reductions. The basic issue is: Does it make sense to include the remuneration base - and therefore pay – for investment that will result in reduction in operating costs and thus increase the profit potential? The answer to this question is complex but without solving it, the result is a negative economic signal to investment in transmission efficiency. Additionally even if the company decides to invest there is a risk that the improvements do not pay back in a single tariff cycle, and the operational benefit be captured by the consumers in the next cycle.

The Brazilian regulatory framework has started to address those issues in the auctions for new transmission networks. It was created a mixed regime where most of the concession revenue is set during the auction for the construction and operation of a new transmission installation, but part of the revenue of the regulated tariff will be pay for expansions and upgrades authorized by the regulatory agency (ANEEL).

5. GESEL R&D Regulatory Project

In order to address consistently the above-related topics, the Electric Sector Study Group (GESEL) of the Economy Institute of the Rio de Janeiro University started a regulatory research and development project to be developed in the framework of the regulatory agency (ANEEL) R&D program. Figure 5 presents the basic structure of this project.

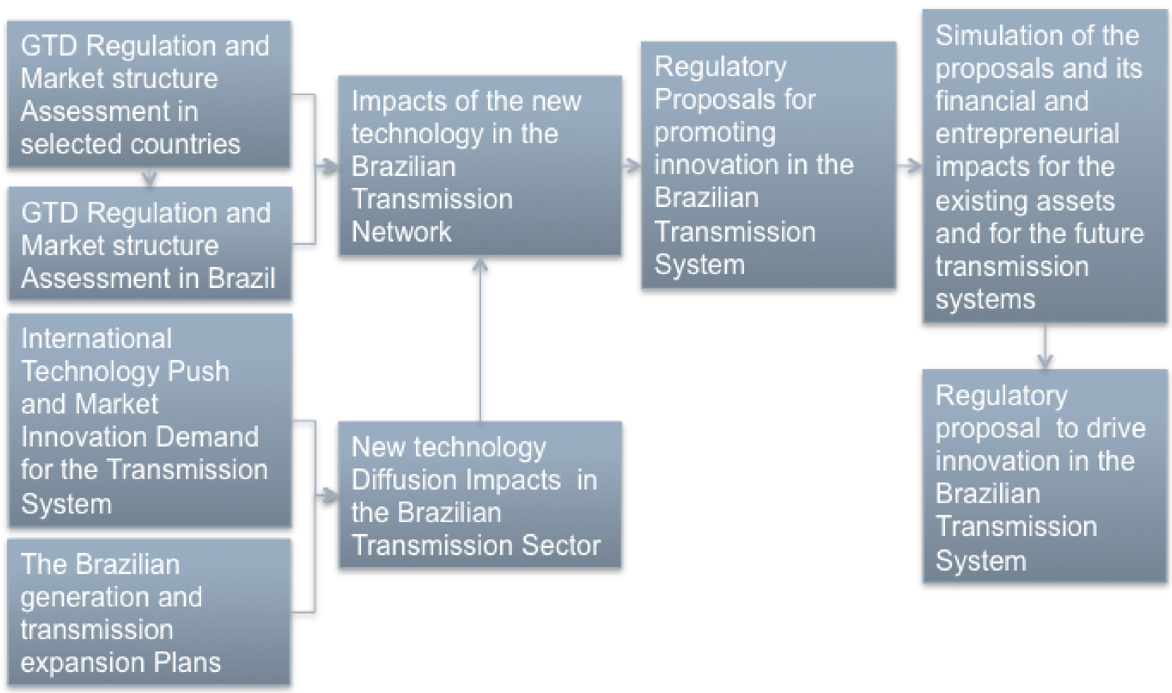


Figure 5 – Basic Structure of GESEL Regulatory R&D Project

The project was divided in six phases:

I. Assessment and comparison of international and national regulation for promoting innovation in the transmission sector;
II. International technology push and market innovation demand in the transmission sector and opportunities and impacts in the Brazilian transmission sector;
III. Developments of scenarios for technology innovation and diffusion in the Brazilian transmission sector;

IV. Based on the developed scenarios, propose regulatory innovations to promote innovations;
V. Simulation of the qualitative and quantitative impacts of the proposed regulations considering the expansion plan;
VI. Discussion of the proposed regulation with the main stakeholders (regulators, electric companies, association, government institution).

6. Conclusions

The profound technological evolution of the electricity sector is strongly linked to the dynamics of innovation.

Simultaneously, it is recognized that all the innovation process is conditioned by the transmission sector economical regulation in order to present clear indications to promote public and private investments. The main guideline is to consider elements of economic theory and trends of the technological diffusion to conceive the appropriate conceptual framework for balancing investment; the quality of energy and the cost the society is willing to pay for the energy.

In the Brazilian transmission regulation model, it can be identified some conflicts that can delay the adoption of technological innovation: one major example is the commitment to achieve the lowest tariffs that may conflict with the implementation of technological innovations during the life cycle of the projects.

GESEL is committed to develop a deep analysis of the subject considering the ongoing evolution of the worldwide regulatory framework and the Brazilian sectorial condition in order to make regulatory proposition and to promote discussions. The goal is to conceive what could be a regulatory framework to promote innovation on the Brazilian transmission sector without impacting the energy consumers.

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