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Operation of the Brazilian Renewable Energy System

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Abstract. This article describes in detail the operation of the Brazilian renewable energy system that is maybe the largest one in the planet. The Brazilian hydropower system is a system unique in the world because it has continental dimensions. Brazil has an 8.5 million square kilometers area. There is a complex net that is capable of delivering the country up to 104 GW (total power), among which about 84 GW are coming from hydroelectric power. More than 92% of the annual TWh consumed come from these hydro power plants. Coordinate the operation of this system is a somewhat singular task. That's what is presented here.

Key words

Hydroelectricity; Brazilian power system; Interconnected system.

1. Introduction

Among others like Russia, China, Canada and USA, Brazil is one of the largest countries in the world in extent [1]. Two hundred million habitants live in 8,502,728.26 km2. Brazil has a 2.09 trillion dollars economy (GDP) that is sustained by an annual electricity consumption of 506 TWh. The country managed to create the greatest renewable energy system on the planet. This is due to its hidrography.

- Brazil has the most extensive river system of the globe, with about 55,457 km2.
- The Amazon basin - is the largest river basin in the world with 7,050,000 km ².
- Brazil has the largest hydropower potential of the Earth; about 13% of all fresh water on the planet is in its territory.
- Because it has such a large territory, Brazil is considered a continental country, which means a country whose physical dimensions have the proportion of a continent. Its territory covers 5.7% of Earth's land area, 20.8% of the surface of the Americas and 47.3% of the surface of South America [1].

And it is precisely for these reasons that hydropower is the most important primary source of electricity generation for Brazil.

It must become clear how works this great electrical interconnected system.
Before actually dissecting the subject it is important to know some more details of this system. The figure showed below, may best exemplify the dimensions of the Brazilian electrical system.

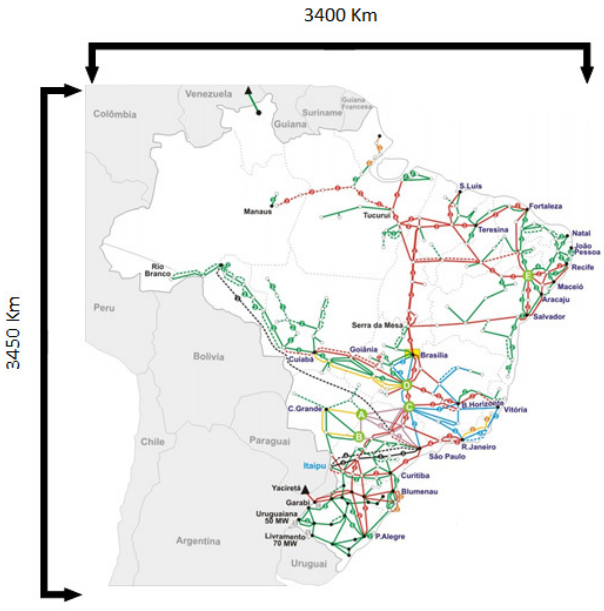

Fig.1- Map of the National Interconnected System (SIN)

The Brazilian hydroelectric potential is confirmed at around 260 GW of which at about 104 GW are now effectively utilized [2].

A unique feature of the Brazilian National Interconnected System (SIN) is its continental size giving it more complex operating systems when compared to those of other nations.

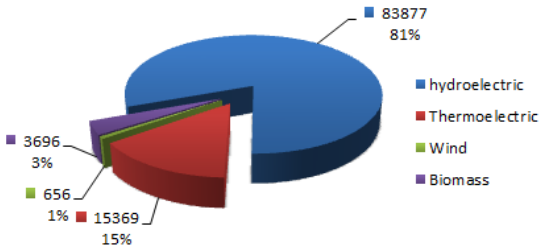

Fig.2 - Map of the Installed Capacity on National Interconnected System of Brazil (MW)

The graph below gives us a bigger picture of the size of this system. It shows an approximate overlap of the Brazilian electric system on the map of Europe. The real distances are preserved.

Fig.3 – Brazilian National Interconnected System overlaid on the Europe Map.

With size and features that allow one to consider it worldwide, the system of production and transmission of electric energy in Brazil is a large hydrothermal system, with a strong predominance of hydroelectric and multiple owners. This is the SIN (National Interconnected System). Currently, hydropower accounts for more than 90% of energy produced annually in SIN. Only 3.4% of electricity production capacity of the country is out of SIN - in small isolated systems located mainly in the Amazon region but future should also be integrated. [4]

2. Interconnections between the subsystems and watersheds of the SIN.

It is these interconnections that allow the complementarity of the hydrological regions which is explored through the exchange of energy. It works like a transposition of basins, since there is the use of an energy surplus in another far region. It can be said that the transmission lines “carry water” from one basin to another, and no electricity.

For a system work well with these dimensions and with the inherent complexity, it is necessary a Centralized Operator to coordinate and solve all possible problems in real time. This central operator exists and it is named ONS (National Interconnected System Operator).

Fig.4 - Water Basins of Brazil and Interconnected Electric System.

3. The ONS

The ONS is responsible for coordinating and controlling the operation of existing generation and transmission of electricity in the National Interconnected System (SIN), under the supervision and regulation of the National Agency of Electrical Energy (ANEEL). The operator consists of associate members and participating members. [4]

Associate members are the agents of generation plants with centrally dispatched the agents of transmission, distribution agents members of the SIN, as well as importers and exporters and free consumers with assets connected to the Basic Network. [4]

Participants are members of the Granting Authority by the Ministry of Mines and Energy, the Consumer Council; centrally dispatched generators are not distributors and small (below 500 GWh/year). [4]

The main studies and actions undertaken by the ONS in the coordinated operation of the centralized SIN can be grouped into different macro processes:

- Operating in real-time SIN
- Extensions and reinforcements in the Basic Network;
- Assessment of Future Conditions of the Transaction;
- Evaluation of Short-term operation;
- Results of Operation;
- Analysis of Energy and Demand Charge;
- Performance Indicators of the SIN;
- History of Operation;
- Integration of the New Facilities SIN;
- Transmission Services Administration;

The ONS is part of a complex network of institutions and actors, playing different roles in the Brazilian electric sector. The following figure illustrates the main institutions of the current model of the sector:

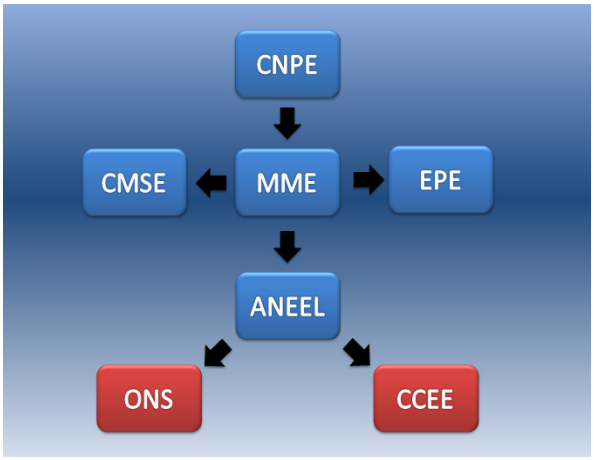

Fig.5 - Main Institutions of the current sector model

NEPC - National Energy Policy Council Advisory body to the President of the Republic for the formulation of national policies and guidelines of energy, focusing, among others, the use of natural energy resources of the country, periodically review the energy matrix and establishing guidelines for specific programs.

MME - Ministry of Mines and Energy
Charged with formulating, planning and implementing actions of the Federal Government under the national energy policy.

MCPS - Monitoring Committee of the Power Sector
Monitor and continuously assess the continuity and safety of the electrical energy supply throughout the country.

CEEC - Chamber of Electric Energy Commercialization
It is intended to facilitate the sale of electricity in the National Interconnected System - SIN. Manages the purchase and sale of electricity, its accounting and settlement.

NESO - National Electric System Operator
Legal entity of private law, non-profit, under the regulation and supervision of ANEEL, aims to carry out activities to coordinate and control the operation of generation and transmission under the SIN.

NAEE - National Agency of Electric Energy
Authority on the special scheme, linked to the MME, with the purpose of regulating the control the production, transmission, distribution and sale of electricity in accordance with the policies and guidelines of the Federal Government.

The activities performed by the National Electric System Operator produce benefits for all industry players. They also have effects on consumers and, more generally, on society as a whole. Some key benefits that ONS provides are:

1. For sector agents: optimization of generation resources in the use and reliability of the transmission network. Guarantee of free access to the transmission grid for the purchase and sale of energy. Supply of reliable and updated information about the operation of SIN signaling and technical-economic conditions of future care. Viability of a healthy market power, acting with integrity, transparency and fairness in the technical relationship with agents.
2. For consumers: Ensuring adequate standards of quality and supply continuity. Warranty, reliability and lower cost of electricity. Technical informations for the choice of supplier by free consumers.
3. For society: Reduced risk of power electric failure. Increase of the efficiency of electricity service, contributing to raising funds for investment by investors. Increase of the competitiveness in all economic activities that use electricity as a relevant input.

The SIN is scaled according to the criterion of N-1 security, or even with the loss of any element (single contingency), the system should be able to continue to operate without interruption of power supply, loss of system stability, rape standards of electrical quantities (frequency, voltage, within the operating range) and without reaching overload limits of equipment and facilities. [4]

4. Sindat

The Geographic Information System Registration SIN - SINDAT provides relevant information system, integrating digital maps in the same environment, formed by vector graphics data with alphanumeric data Technical Base.
It is based on GIS - Geographic Information Systems, and provides access to always updated information about the topology of the network operation of the ONS, in an easy, fast and interactive. [4]

The National Electric System Operator develops a series of studies and actions, which are based on two fundamental inputs.
a) Network Procedures: These procedures are a set of standards and technical requirements that establish the responsibilities of ONS and Agents Operating in what they refer to activities, inputs, outputs, deadlines and procedures for operation of the SIN and other assignments Operator. These documents are prepared by the ONS, with the participation of agents and approved by ANEEL.
b) External Information: ONS needs to receive from the industry, especially the MME and ANEEL, agents and owners of facilities that make up the SIN for the execution of their activities. [4]

The main studies and actions undertaken by the ONS in the coordinated operation of the centralized administration of SIN and transmission services in the basic network (facilities with voltages equal to or greater than 230 kV) can be grouped into different macro processes, as described below.

5. Load data

The daily bulletins reporting the entire operation of the system for a specific period of time can be of type: Special Bulletins, Daily, Monthly and Yearly. These reports feed a database that allows the ONS to rebalance the system in the short, medium and long term. They also have a documentary function that can later be statistically observe the behavior of the whole interconnected system.

6. Energy operation planning

The Operation Planning Energy - PEN, prepared on an annual basis and subject to revision when the relevant facts, presents assessments of the conditions of service to the market power of the National Interconnected System, a horizon of 5 years ahead, analyzing scenarios of supply and demand. [4]

PEN represents the instrument of Operation Planning of Energy National Electric System Operator-ONS that, based on the criteria of the warranty service electrical power consumption can be recommended to the Monitoring Committee of the Power Sector - CMSE and Research Company Energy - EPE, agencies coordinated by the Ministry of Mines and Energy - MME, decisions of anticipation and/or deployment of generation/transmission, to increase the margin of safety on the operation of the SIN. [4]

7. Special protection systems – SPS

The Special Protection Systems that include the Emergency Control Schemes and Safety Schemes Control, automatic control systems are deployed in generating stations, transmission and distribution of electricity in order to: allow greater use of systems generation, transmission and distribution, increasing the reliability of operation of the interconnected system, providing additional protection from electrical system components, improve system security by preventing both the spread of cascading outages and large disturbances. [4]

The SEPs receive information of the electrical instrument transformers (PT and CT) of the network topology and positions of electrical circuit breakers, isolators, selector switches and other devices and act commanding opening or closing of transmission lines, generators, transformers and others, and reducing or lifting power generators, relief or restoration of loads, among other actions. [4]

This database presents the essential characteristics of protection systems to embedded generation facilities, transmission and distribution of the Brazilian Interconnected System.

They are also used by the ONS several other bug tracking systems such as the study of short-circuit impedance diagrams and optimization of controllers.

The National Interconnected System (SIN) has various control equipment, in which adjustments can have a major influence on the dynamic behavior of the system. The controllers are available in the electrical system, for example, automatic voltage regulators (RAT), additional signals stabilizers (PSS), speed regulators (VR); controllable series capacitor (CSC), static compensators (EC), and so on [4].

8. Resetting the system

Although the likelihood of widespread power outages occurs, they have quite a few times, either in the Brazilian Interconnected System, or elsewhere.
Reassessment of the reset of the SIN is an ongoing activity at ONS, and several actions are done on a regular basis taking into account the following aspects:
a) Monitoring the balance between load and generation in the areas of self-healing and self-healing features to the plants that are part of the main loop of the SIN;
b) Monitoring the entry into operation of new equipment enabling the improvement of the process of restoration;
c) Review of operational procedures on the basis of studies and expanded in the SIN.

9. Hydrology

The hydrologic study developed for planning the operation of the National Interconnected System covers the hydraulic lifting operational restrictions, planning and programming of the flood control operation, business forecasting inflow and the replenishment of natural flows in the power plant site. Quantitative information on these processes, which constitute an important phase of the hydrological cycle, is used to solve numerous problems involving the management of water. management of water.

10. Meteorology

Weather and climate information relevant river basin and subsystem, observed and expected precipitation in the basins of interest to the National Interconnected System and temperature due to the major load centers.

11. Intercâmbio de Energia entre as Regiões

One of the main functions of the ONS is to manage the energy exchanges between the regions. For the Brazilian electrical system, these regions are divided into: South, Southeast / Midwest, northeast and north.

12. Operation Results

Completing the chain of activities consisting of the sequential evaluation of future conditions of operation, the evaluations of short-term support with their studies and daily schedule of the operation, one comes to the real time operation of the SIN.

The real-time operation tries to follow the rules and operating instructions and meet the program guidelines and recommendations, aligning the requirements of continuity, security and economy of supply. The actions undertaken by the National Center Operating System, and the Regional Centers of System Operation under him, make monitoring and correction of operating conditions as a function of load variations and status of equipment that make up the SIN every moment.

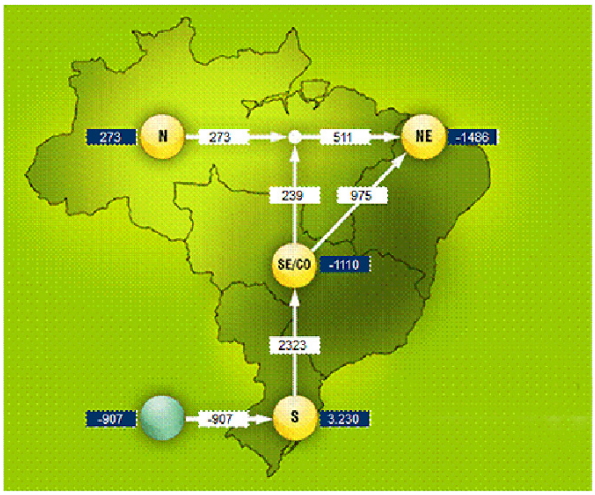

Fig.6 - Daily Electric Energy Exchange between the regions.

13. Performance indicators for SIN

Of the total 2670 disturbances cleared over 2010 in these 291 (10.9% of total) were observed cutting load. However, it is noteworthy that in only six (0.2% of total) load cut were above 1000 MW. With respect to disturbances with loss of load greater than 500 MW, there were 10 such events (0.4% of total). With regard to disturbance in which there was load shedding more than 100 MW, there were 91 cases (3.4% of total 2670).

Safety in electrical service can be reached in 2010 translated by the performance indicators of the SIN. An indicator is fairly representative of robustness, because disturbances in the SIN relates to the supply to the loads. The value of this indicator is given by the ratio between the number of disturbances without loss of load and the total number of disturbances.

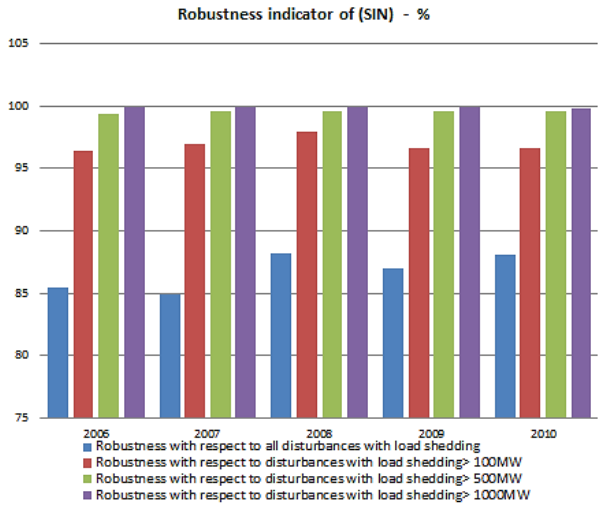

Fig. 7- Robustness Indicator of (SIN) - %

14. Conclusion

A vast country with continental dimensions like Brazil requires great and efficient solutions. The ISO (Independent System Operator) governed with great efficiency and creativity an electrical system composed of predominantly hydroelectric generators. This is all due to its geological and geographical location on the globe. Its geological formation naturally creates a mesh basin with natural tendencies to such exploitation. Its geographical position creates climatic conditions favorable for the formation of large reservoirs. For this reason, Brazil in the world today is a world-class technology of building large dams, and is also the largest renewable electric energy system of the planet.

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