



Electricity in Brazil—Part 1

Gildo Magalhães and Luiz Tomiyoshi, Guest Authors

The history of electricity in Brazil is a history of interlocking political, social, and technical forces. Although there was a public debate about industrializing the country when Brazil declared its independence from Portugal on 7 September 1822 and Dom Pedro I abdicated the Portuguese throne to move to Brazil as the first emperor, the majority of the 19th century politicians and large landowners considered the absence of significant industry as a result of some natural order. God had endowed the country with an exuberant nature that supported a strong agricultural economy with lucrative exports, especially sugar and cotton; exports could be traded for manufactured goods; industrialization was of little interest; and without industrialization, there was little demand for electrical power. However, times changed. Dom Pedro's son, Dom Pedro II, became the second emperor, and with him begins the history of electricity in Brazil.

Introduction of Electricity

In 1879, when Thomas Edison constructed the first electrical power center for public service in New York, Dom Pedro II enthusiastically encouraged Brazilian industrial development. The emperor contracted replacement of gas lamps in the Brazil Central Railway Station in Rio de Janeiro with six-type “Jablochkoff” arc lamps powered by a dynamo.

Thanks to emperor incentive and the desire to maintain independence, Brazil began its slow transformation from an agricultural to an industrial economy. In 1880, the number of industries in Brazil totaled around 150, with 60% for textiles, 15% foods, 10% chemical, and 15% others. With these industries grew the interest in using electricity.

In 1883, Dom Pedro II inaugurated the first public electric lighting system in South America, a system for the town of Campos in the state of Rio de Janeiro, with 39 light bulbs and three 52-kW dynamos driven by thermal machines. The first public-utility hydroelectric plant (250 kW, 1,000 V, 60 Hz, two single-phase generators) was built in 1889 to power a textile mill, the year in which the monarchy was replaced by the first Republic.

In 1892, a company called Ferro Carril do Jardim Botânico installed a thermoelectric plant for streetcars (called bondes, financed by an issue of bonds) in Rio de Janeiro. Also in 1892, a private mine company built the first private hydroelectric system using dc generation. A few farmers and textile owners followed with power plants to serve their loads. Electricity rapidly gained favor despite Brazil's coal reserves that were very small and of poor energy content, a significant obstacle to the development of thermal power plants. Increasingly,

Brazil looked to its rivers as sources of energy.

São Paulo and White Coal

Geography blessed the state of São Paulo with hydroresources, although the extent was not fully appreciated even in the late 19th century. Almost untouched by the white civilization, sparsely inhabited, poorly charted, and largely covered with the relatively mild (subtropical) Atlantic forests, the western area of the state was a land of hostile native Indians, while

jaguars and huge snakes were not uncommon in the scattered villages. Scientific expeditions led by São Paulo state's Geographical and Geological Commission braved these areas during the 1890s and 1910s to assess their natural

resources, including river courses and waterfalls and the correspondingly vast hydroelectric potential. These experts confirmed that the state was naturally endowed with ample white coal. The expression white coal stressed that the state's long rivers that flow from the eastern coastal mountains in a long sweeping curve to the west to form the plains of the Paraná Basin, then flow south and east to reach the ocean at Montevideo (capital of Uruguay) and Buenos Aires (capital of Argentina), a total length of more than 3,000 km. Indeed, the electric power potential of the river system could be developed.

BRAZIL LOOKED TO ITS RIVERS AS SOURCES OF ENERGY.

Social Forces

Electrification grew most conspicuously in Rio de Janeiro, the capital city of Brazil, and in the rapidly industrializing state of São Paulo, particularly in the capital city of São Paulo on the Serra and in the harbor city of Santos. The city São Paulo adapted quickly to the novelty, at first for industrial machines and streetcar traction. Soon, however, electric lights were substituted for oil lamps in houses and gas lamps in streets and gave the air of modernity; electricity became an object of desire for the entire population (about 30 million at the beginning of the 20th century, occupying an area larger than the continental United States). New working and leisure hours were thus introduced, and new habits were created.

Slavery was abolished in Brazil in 1888; in São Paulo, the workforce of freed African slaves was augmented rapidly by European (mainly Italian) and Japanese immigrants who brought their skills and increased the potential number of customers. One year later, a military coup replaced Emperor Dom Pedro II and the First (Old) Republic began. The republic had strong positivist influences (after the French philosopher Comte's philosophical system), visible even nowadays in the motto inscribed in the Brazilian flag "Ordem e Progresso" ("Order and Progress," an inscription after Comte's words)—even so, progress did not carry industrialization with it.

Electricity came into the daily life of Brazilians at the decline of the empire and sped up during the first years of the republic. At first, people were curious about the novelties imported from Europe and North America, such as the telegraph, telephone, railways, and, of course, domestic electric energy. It is not surprising that the arrival of electricity sounded a prelude to what became a continuous polemic within the new republican regime: the fight around the belated industrialization of the country, which demanded energy, and for this, electrification would play a dominant role.

Economic Forces

Improvement of electromechanical generation, the invention of motors, more efficient electric light, and power transmission and distribution systems opened up the economic use of electricity. The rich soil of the São Paulo

province (later São Paulo state) proved particularly good for the coffee plantations developed during the second half of the 19th century. The continuously growing demand for the black beverage ensured a sudden richness for São Paulo, and, contrary to the usual trend, profits were invested in local industries that increased urbanization and increased interest in the use of electrical power.

The social and cultural transformations brought about by electricity had just begun in industrialized nations; less-developed areas of all continents were a sizable market for investing the capital accrued by the fast growth of industrialization. In São Paulo state, the public interest enhanced the possibility of investing gains from coffee exports. Local capitalists felt that selling electricity as a commodity was an opportunity to participate in a market that was becoming an indispensable part of the contemporary world. That said, the prospective power and light companies faced a country that was industrially poor in relation to the economically central ones and that still debated its supposed agrarian fate, something a conservative oligarchy believed to be the country's natural vocation.

From 1888 onward, small companies started operating thermoelectric generators using wood as fuel to cover commercial houses in downtown São Paulo city. Even though these predecessor companies did not last long, they showed that the region was a promising market that needed electricity for economic development.

The fast diffusion of public illumination services everywhere, including small towns and villages, spurred a demand for electric energy in São Paulo. In medium-sized cities and in the capital of the state, streetcar service also enhanced the electric market growth. Following that, there was a rapid growth of electricity participation by industrial consumers, bringing the need for new and intensive investment to increase the supply. This was the right moment to take advantage of the other factor that benefited the state: its hydroelectric potential.

Capital Investments

Considerable capital flowed to Brazil in the wake of the Napoleonic Wars when, in 1808, the Portuguese crown transferred its administrative center

from Europe to Rio de Janeiro. This financial capital, mainly British, was applied directly or indirectly to inland and external commerce, as well as to a few types of manufacturing and urban services, including transportation. Traditionally, the small national capitalist sector invested mostly in land products and cattle, establishing a pattern of local investment in agriculture while relying on foreign investment for commerce and industry. This context also explains why, during the Old Republic, the economy followed the same pattern as in the monarchy: i.e., massive heavy foreign capital affluence, first English, later on German, with increasingly American capital after World War I (WWI). The general political direction continued to favor importation of manufactured goods until 1930, when another military coup started the new era of President Vargas' nationalist dictatorship lasting 15 years as the new republic.

Two types of companies developed and marketed electric power in São Paulo from the end of the 19th century up to the 1930s. The majority were small companies, which were either municipal or regional in extent, organized by local landowners or businessmen. The second was smaller in number but far more powerful in its investment capacity, made up of foreign companies with roots in the international finance system. Small companies were unable to bring capital to build bigger dams and thus meet the fast growth in demand, so they were bought up; power production became concentrated in ever wider concession areas. During the first two decades of the 20th century, the local companies that provided public electric illumination and distributed electric power to private owners were easily incorporated by foreign investors. We will now deal with two of the best known such foreign corporations.

In 1899, a group of British-Canadian investors established the São Paulo Tramway, Light and Power Company Limited with the permit duly signed by Queen Victoria. The initial investment amounted to US\$6 million, which allowed the company (whose name was shortened by Brazilians simply to "Light") to provide both capital and engineering knowledge, incorporate all of its competitors in a short time, simultaneously provide

illumination and domestic electricity as it installed the streetcar rails crossing the city, and to expand to the neighboring state of Rio de Janeiro. In 1905, the Light group assumed services in Rio de Janeiro creating The Rio de Janeiro Tramways, Light and Power Company Limited. (In 1967, these two companies became Light Serviços de Eletricidade S.A and split again to LIGHT in Rio de Janeiro and Eletropaulo in São Paulo state.)

In the 1920s, the Brazilian census confirmed that large areas of São Paulo state were rapidly becoming industrialized. This attracted another major investor in 1924, the American and Foreign Power Co. (AMFORP) from Bond and Share Co. (linked with General Electric), which started operations in 1927 in the Midwest of São Paulo state. This company also bought up several smaller local businesses and expanded to the neighboring state of Minas Gerais. By the end of the Old Republic in 1930, São Paulo had 166 power plants—13,500 kW thermal and 318,000 kW hydroelectric, more than 50% of Brazil's capacity concentrated in just one of the nation's 20 states, mostly in the hands of these two foreign companies, placing them in a position to control commodity prices. [Today, AMFORP is known as Companhia Paulista de Força e Luz (CPFL)]. Soon the two companies owned 80% of the power concessions in Brazil, a situation that continued until 1960. It was then that the state decided not only to increase its regulatory capacity but also to start investing heavily in new hydroelectric plants.

Governmental Regulations

In 1903, the Brazilian federal government published its first regulations related to the use of hydraulic (water) power and electrical distribution. Later, in 1930, as a result of a revolution (known in Brazil as "revolução de 1930"—revolution of 1930), the government established administrative controls that changed conditions of services previously defined only by contracts with the foreign companies. This marked the beginning of solid government regulation. It led to the creation of government power companies and to the acquisition

of stock in existing foreign companies. (Government involvement will be addressed at greater length in Part 2 of this column.)

Engineering Achievements

For a country as vast and diverse as Brazil and in a history article as brief as this one, it is impossible to describe even a small part of the innumerable, significant engineering achievements. The reader is asked to accept a description of just a couple of outstanding engineering accomplishments in Brazil, to give a sense for these achievements.

Six generators totaling 24 MW, powered by turbines operating under a

THE BEGINNING
OF WWII IN
SEPTEMBER 1939
MARKED THE
END OF
NORMAL
SUPPLY OF
ELECTRICAL
EQUIPMENT.

brought out to the switchyard at 132 kV.

Cubatão Powerhouse in the state of São Paulo is located at the foot of Serra do Mar, just a few kilometers from the port of Santos. The city of São Paulo lies on the Serra itself, close

head of 370 m and with an overload rating of 36 MW, went on line at Fontes in 1908 to serve the Rio de Janeiro system. Over the years, Fontes grew, to 63-MW installed capacity in 1913 then to 221 MW in 1939. After WWII, major changes to the system included incorporation of an underground powerhouse that is approximately 24 m wide, 114 m long, and 33 m top to bottom. Power is



The Perfect Electrical Design Software

One-Touch Electrical Design and PDC Tools Now Available in EasyPower
What used to take hours or even weeks can now be accomplished in seconds!

SmartDesign™ | Automated Design for Low-Voltage Systems

EasyPower SmartDesign completely automates equipment sizing in the design process, saving countless hours of manually rerunning calculations to verify code compliance. It also generates comprehensive reports to alert you to possible problem areas, giving valuable insight. SmartDesign does this and more!

SmartPDC™ | Protective Device Coordination Made Easy

EasyPower SmartPDC fully automates the tedious, labor-intensive work of setting protective devices — just highlight an area to coordinate, and one click completes the task for you. Includes reports and detailed descriptions!

Arc Flash, Short Circuit, Power Flow and more...

EasyPower, the most automated, user friendly power system software on the market, delivers a full lineup of Windows-based tools for designing, analyzing, and monitoring electrical power systems. EasyPower's ease of use and integration increases your productivity 3X over all other software products!

Download a free demo, or watch our 3 minute EasyPower video at www.EasyPower.com.

Power made easy

intelligent | intuitive | instantaneous
power system software

www.EasyPower.com | 503-655-5059 x35

to the crest. Diversion dams on the outskirts of São Paulo direct water of the upper Tieté River to pumping stations that lift the water approximately 30 m to a reservoir and head works, providing the powerhouse with a head of 718.5 m. This installation too is much larger now.

The Cubatão underground powerhouse is approximately 27 m wide, 114 m long, and 39 m top to bottom. An interesting sidelight is that power is brought out to the switchyard at 230 kV by pipe-type cables designed specifically for this application by Okonite and trademarked as Oilostatic cables. These are single conductor, 500 mcm copper, with each set of three conductors in an 8-5/8 in O.D. steel pipe with 1/4 in wall, filled with oil, with a working pressure in

the order of 275 psi. The Ohio Brass potheads, also of special design, were designed for a 900-kV basic impulse level (BIL) in accordance with AIEE Specification 48. Unfortunately, construction of the Cubatão underground was delayed despite the pressing need for generation. Obtaining necessary water rights took longer than anticipated, so equipment orders had to be cancelled. The Korean War intervened before the situation was resolved, with equipment deliveries much longer for the reinstated orders and prices significantly higher.

The Rio de Janeiro system operates at 50 Hz and the São Paulo system at 60 Hz. The two were interconnected at Aparecida using a frequency converter rated 57.5 MW, located about halfway between the

two powerhouses, a distance of 330 km.

World War II

The beginning of WWII in September 1939 marked the end of the normal supply of electrical equipment. Accelerating demand for electrical services in Brazil could not be met, construction was delayed, electrical staffs improvised, equipment ran overloaded, outages took their toll, and rationing came into being. After the war, pent-up demand strained manufacturing capabilities throughout the world, prices increased, and deliveries remained long. The situation improved until the Korean War and then slipped back again. This tumultuous period marked the end of more than half a century of progress in Brazil. (Part 2 of this column will describe the sharp changes that followed.)

Acknowledgments

This article touches on just a few aspects of the history of electricity in Brazil. It does not pretend to be comprehensive. Insights were collected from the items listed below as well as from other sources. Readers who are interested in learning more may wish to refer to these references as well as to other literature on the subject.

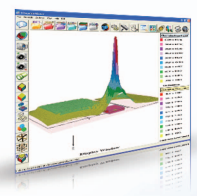
References

- [1] Eletrobras. (2010). Available: <http://www.memoria.eletrobras.com/historia.asp> (in Portuguese, English, and Spanish).
- [2] *A Energia Elétrica no Brasil*. Rio de Janeiro, Brazilian Army Editor, 1977.
- [3] A. R. Barbalho, Ed., *Energia e Desenvolvimento no Brasil*. Rio de Janeiro, Brazil: Memória da Eletricidade, 1987.
- [4] R. F. Dias, Ed., *Panorama do Setor de Energia Elétrica no Brasil*. Rio de Janeiro, Brazil: Memória da Eletricidade, 1988.
- [5] R. Jatobá, Ed., *A Cidade da Light (2 v.)*. São Paulo, Brazil: Eletropaulo, 1990.
- [6] G. Magalhães, *Força e Luz*. São Paulo, Brazil: UNESP, 2000.
- [7] "Aproveitamentos Hidroelétricos Para o Sistema do Rio de Janeiro," Internal publication of "Light," ca1950.
- [8] "Heightening the Lages Dam, Rio de Janeiro," *Eng. News Rec.*, July 1 and 8, 1949.
- [9] "Revista Light, Segundo Numero," Internal publication of "Light," 1952
- [10] Dominion Engineering Company Ltd., *Dominion Eng.*, vol. XXVI, no. 3, 1959.

IAS

**THE INDUSTRY STANDARD SOFTWARE PACKAGES
IN GROUNDING AND
ELECTROMAGNETIC INTERFERENCE**

Are now more powerful with the addition of new standard components such as arbitrary transformers and cables.



Classical Equipotential Grounding

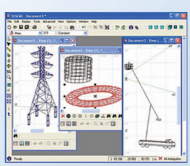
Multiple grounding systems having any shape, in simple or complex soils, including any number of layers or heterogeneous soil volumes.

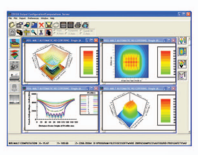
- AutoGroundDesign
- AutoGrid Pro
- AutoGround & MultiGround

Complex Frequency Domain Grounding, Interference Analysis & Environmental Impact Assessment

Perform fast, yet complex and accurate, Interference analyses on pipelines, railways, etc. Examine electromagnetic impacts to the environment.


- SESTLC
- Right-Of-Way
- MultiLines & SES-Enviro
- MultiGroundZ





Frequency & Time Domain Arbitrary Network Analysis

Upgrade to the full power of MultiFields or CDEGS to tackle any electromagnetic problem involving aboveground and buried conductor networks including lightning or switching surge analysis.



World Leader in Grounding & EMI
www.sestech.com

800-668-3737 450-622-5000