

PRE-FEASIBILITY STUDY FOR AN ELECTRON BEAM FLUE GAS TREATMENT DEMONSTRATION PLANT TO ELETROPAULO'S PIRATININGA POWER PLANT

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ABSTRACT

This paper describes the pre - feasibility study for a 50MW electron beam flue gas treatment demonstration plant at Piratininga Power Plant located at São Paulo, a big city in Brazil, around 16 million inhabitants, with serious problems concerning air pollution. This power plant belongs to Eletropaulo - Eletricidade de São Paulo S. A., a public service electric utility responsible for the supply of energy to more than 5,800,000 customers, covering an area of 21,168 km² where approximately 20,2 million people live. This plant is a 470MW, 2x100MW built in 1954 and 2x135MW erected in 1960, oil fueled (at fuel load, 2,800 ton per day). The oil is BTE low sulphur content (<1%), but the study considered the mode of operation and another options for the fuel supply, with a sulphur content from 1.0 to 5.0%. It was decided to use a medium point of 2,5% sulphur, flue gas rate of 150,000 Nm³/h for 50MW.

1. Introduction

Brazil is the largest country in South America and the fifth in the world in area, with 8,511,996 km², 146,960,141 inhabitants, an annual demographic growth of 1,9% and nowadays economic growth of 3,5%.

Its economy is the most diversified and with the challenge of modernization and international competition. The country, also, is a big exporter of agricultural products, such as soybean, coffee, sugar, tobacco and meat.

The main electric supply sources in Brazil are hydraulic power plant (around 90%) and thermal power plants are responsible for around 10% of total power supply [1].

But, there are nowadays in Brazil uncertainties concerning market growth and development of the regions with hydroelectric potential, then it is reasonable to assume that the country useful hydro potential will be depleted

in the next 15 to 25 years. The need thus arises to plan for after 2010 a predominantly thermal expansion replacing hydro growth: that situation is prevented by Eletrobras Plan 2015, the National Electric Energy Plan of Brazil among 1993 - 2015.

Expansion and operating planning for the Brazilian electric systems are carried out by collegiate bodies formed by power utilities and coordinated by Eletrobrás. These collegiate bodies seek to strike a balance between the local regional interests of power utilities and those of the country and power sector as a whole, so that the consumer market may be supplied with high reliability and at low costs.

Further, the most of thermal power plants are near great consumers located in Brazil in urban areas and industrial cities like São Paulo and despite of the Plan 2015 to prevent the use of clear sources like natural gas for the minimum thermal program to be implemented, the existing plants are mainly in oil or coal consumption fuel. Considering that the existing plants have also an important status to supply energy during dry seasons (winter in Brazilian southeast region), the air pollutants level increases critically during this period, near these regions. Then, it causes hard environmental problems like emissions of SO_2 and NO_x into the atmosphere and acid rain, combined with thermal inversion.

2. Air Quality Control

In Brazil there are laws to control pollutants emission fixed by "CONAMA", the Brazilian National Environmental Council, which establishes maximum values for emissions mainly the SO_2 . The CONAMA Resolution number 008 dated December 06, 1990 [2] affects new fixed sources of pollution that are coal or oil fuel burning: incinerators, thermal power plants and so on. According to these laws, the development of combustion gases desulfurization methods is necessary, and in a near future also the denitrification, mainly in attention to the "Agenda 21" adopted in Rio de Janeiro for environmental conservation in 1992. The established emission standards are presented in Table I.

Any economic activity producing air pollution is forbidden on first class areas that have to be atmospherically preserved. In areas to be preserved (leisure, watering, hydromineral and hydrothermal places) new fixed sources with nominal power over 70 MW are not allowed to be installed.

Eletropaulo - Eletricidade de São Paulo S. A. is the public service electric utility responsible for the supply of energy to more than 5,800,000 customers settled in the city of São Paulo and in other 78 locations, covering an area of 21,168km² where approximately 20,2 million people live.

Eletropaulo's Piratininga Power Plant is located near São Paulo downtown; this big city, in the southeast of Brazil, in São Paulo state, has around 16 million inhabitants. São Paulo city has serious problems concerning air pollution and the Plant is trying to reach the parameters established by the CETESB (Company of Environment Sanitation), a Governmental Institution responsible for the environmental control in São Paulo state. When this plant operates at full load it is the main emission source of SO_2 in the city and it had serious difficulties to operate at full load,

when necessary in 1986. This situation is occurring nowadays and the tendency increases for the next years according to the electric system needs.

Piratininga Power Plant is a 470MW - plant, 2 x 100MW, built in 1954 and 2 x 135MW, erected in 1960, which are oil-fueled. The consumption at full load is 2,800 ton per day (full load). The oil is BTE low sulphur content (< 1%).

Eletropaulo has been worried with air pollution problems since seven years ago, when it started, together with IPEN-CNEN/SP, studies concerning electron beam technology for flue gas treatment, which has the following advantages: efficient simultaneous removal of SO_2 and NO_x ; dry process without waste water treatment, producing a valuable fertilizer by-product; easy to operate with an easy system start-up and shut-down; lower capital investment and competitive operation costs; minimum space requirement and possibility of using in retrofit installations [3].

3. Piratininga Power Plant

Piratininga Power Plant is located at São Paulo municipality, and was erected in 1954 (unit number 1 and 2, 2 x 100 MW) and 1960 (units number 3 and 4, 2 x 135MW) generating a total of 470 MW.

It is oil - fueled, pumped by pipeline and have a storage capacity of 100,000 ton, sufficient for 1 - month operation at full load.

The steam conditions in units 1 and 2 is 61 kgf/cm², 500°C and 395 ton/h each unit and in units 3 and 4 is 133 kg/cm², 538°C and 427 ton/h each unit.

The fuel oil consumption is shown in Table II.

The turbo generators are General Electric Co. and the Boilers are manufactured by Baboocok and Wilcox (Canada & USA).

The Fig. 1 shows the Piratininga Power Plant Localization and the Fig. 2 shows the drawing of the plant with all the units.

4. Eletropaulo Project

The IPEN has been collaborating with Eletropaulo in the project entitled "Conversion of pollutants parts from combustion gases of thermal power plants in raw material for fertilizer". The Piratininga Power Station, with 470MW power, normally works in cases of energy peak and burns fuel oil with 1% sulphur content (see attached 6). The staff of Eletropaulo have been studying the possibility to use fuel oil 20% cheaper with 3% sulphur content, if they can use some dessulfurization method.

In this study we estimated the cost of a 50MW power demonstration plant for flue gas treatment with electron beam accelerator. The preliminary calculation was carried out with the help of the IAEA expert visitor, Dr. Norman Frank. We also discussed about accelerators, and the sizes that would be required. Dr. Frank brought information from Nissin High Voltage Co. It appears we can use a standard 300kW machine for the proposed project. The following input conditions were assumed:

- Temperature into process: 374 °F;
- Water in flue gas: 9%;
- Temperature of inlet spray water: 80 °F;
- SO₂ concentration: 2200 ppmv;
- NO_x concentration: 400 ppmv;
- Temperature of gas existing in process vessel: 167 °F.

The considered output conditions are shown in the Table III.

This project proposal has as objectives:

- Installation of one pilot plant, in commercial scale, 50MW, for flue gas treatment by electron beam accelerator, in the Piratininga Thermal Power Plant;
- To reduce the atmospheric pollution because of the Piratininga operation;
- Study of the technical and economical feasibility of the process in Brazil;
- Determination of the removal efficiency of SO₂ e NO_x for the burn of fuel oil up to 3% sulphur content, using the pilot plant;
- Obtain usable byproducts what represents one contribution part for the society;
- Data acquisition to extend the process for the total power of Thermal Power Station, 472MW;
- Human resources capability in environmental area, with experience in flue gas treatment process;
- Demonstrate to the future users in Brazil (Thermal Power Stations, steel industries, incinerators, chemical industries, industries of paper and cellulose) the viability of the process.

The executive plan consists of:

Activity 1: Collecting data about the Thermal Power Station, such as: gas flow, temperature, velocity, moisture and pressure, concentration of SO₂ e NO_x, O₂, CO₂, CO and particulate materials;

Activity 2: Environment legislation data collection;

Activity 3: Preparation of the report EIA/RIMA;

Activity 4: Preparation of the basic engineering project, including the purchase technical specification and the procedures for legal approval;

Activity 5: Equipment acquisition;

Activity 6: Preparation of the executive project for each component of the demonstration plant;

Activity 7: Building services;

Activity 8: Installation of the pilot plant;

Activity 9: Operational preliminary assays;

Activity 10: Preliminary assays and optimization of the process using fuel oil with until 3% of sulphur content;

Activity 11: Preparation of the final report with the feasibility study for large scale application.

The technical goals:

Goal 1: Acquisition of large technical knowledge about all the necessary parameters for the project and installation of the pilot plant in order to attend the environmental legislation;

Goal 2: To get experience in project and operation of the flue gas treatment installation;

Goal 3: Building services;

Goal 4: To obtain experience in installation and operation of the flue gas treatment system from the burn of fossil fuels;

Goal 5: Technical evaluation of the electron beam process for fuel oil burn with 3% sulphur content for future utilization in Piratininga Power Station in order to substitute the 1% sulphur content fuel oil, and comparison with the conventional processes;

Goal 6: Enable the professionals of energetic companies to be monitors / instructors of the acquired know-how, passing on the concepts, procedures and the technology.

The estimated cost for this installation is shown in the Table IV.

5. Comments

According to Brazil's National Electric Energy Plan (1993-2015) for the next years a minimum thermal program must be implemented to ensure the country's technological development in this area using coal, natural gas, oil products, fuel oil and biomass [1]. Also, the existing thermal power plants have an important status to supply energy during dry seasons, once most of electrical energy in Brazil comes from hydraulic source and also to supply energy in emergency situations such as transmission problems. These plants are usually near great urban centers with all the environmental problems common to these centers: emissions of SO_2 and NO_x into the atmosphere causing air pollution and acid rain.

In this study it was discussed the mode of operation for the plant and various options that we have for fuel supply, with a sulphur range of 1.0 to 5.0%. It was decided to use a medium point of 2.5% sulphur, since the process is capable of handling swings in the SO_2 content. It was also decided to look at a size of about $150,000\text{Nm}^3/\text{h}$. This is equivalent to about 50MW. Electron beam accelerators and the sizes that would be required were also discussed. Dr. Frank brought information from Nissin High Voltage Co. So, we can use a standard 300kW machine for the proposed study.

For this evaluation, we considered some gas input condition and we obtained an output condition for the process of 80% SO_2 removal for different flue gas flow rates. The estimated implantation cost for flue gas rate of $150,000\text{Nm}^3/\text{h}$ is around 240US\$/kW.

Besides, if Eletropaulo uses this process burning only 4400 ton of fuel oil per month, equivalent to operating with 18MW, with high sulphur oil content (2.5%) that is cheaper than BTE low sulphur, it will save US\$ 1590000 per year. So, it pays the project in around eight years.

The Japan Consulting Institute - JCI, has approved the support for a Feasibility Study for a Commercial scale Plant of the electron beam flue gas treatment process in the Piratininga Power Plant. In a further discussion, Eletropaulo has decided to ask this study for a 100MW single unit, with estimated flue gas of $320,000\text{Nm}^3/\text{h}$, considering three alternatives to remove: 70%, 80% and 90% of SO_2 and the correspondent NO_x .

Acknowledgments

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6. References

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Table I. Maximum levels of air pollutants in pollution fixed sources according to CONAMA 008, Dec./06/1990 expressed in weight of pollutants by caloric power (g/Gcal).

TYPE OF FACILITY	TYPE OF POLLUTANTS	CLASS OF	AREA
		I	II / III
NOMINAL POWER	PARTICLES	120	350 OIL / 1500 COAL
< 70 MW	SO ₂	2000	5000 NOMINAL
NOMINAL POWER	PARTICLES	---	120 OIL / 800 COAL
> 70 MW	SO ₂	---	2000

Table II. Fuel oil consumption in Piratininga Power Plant

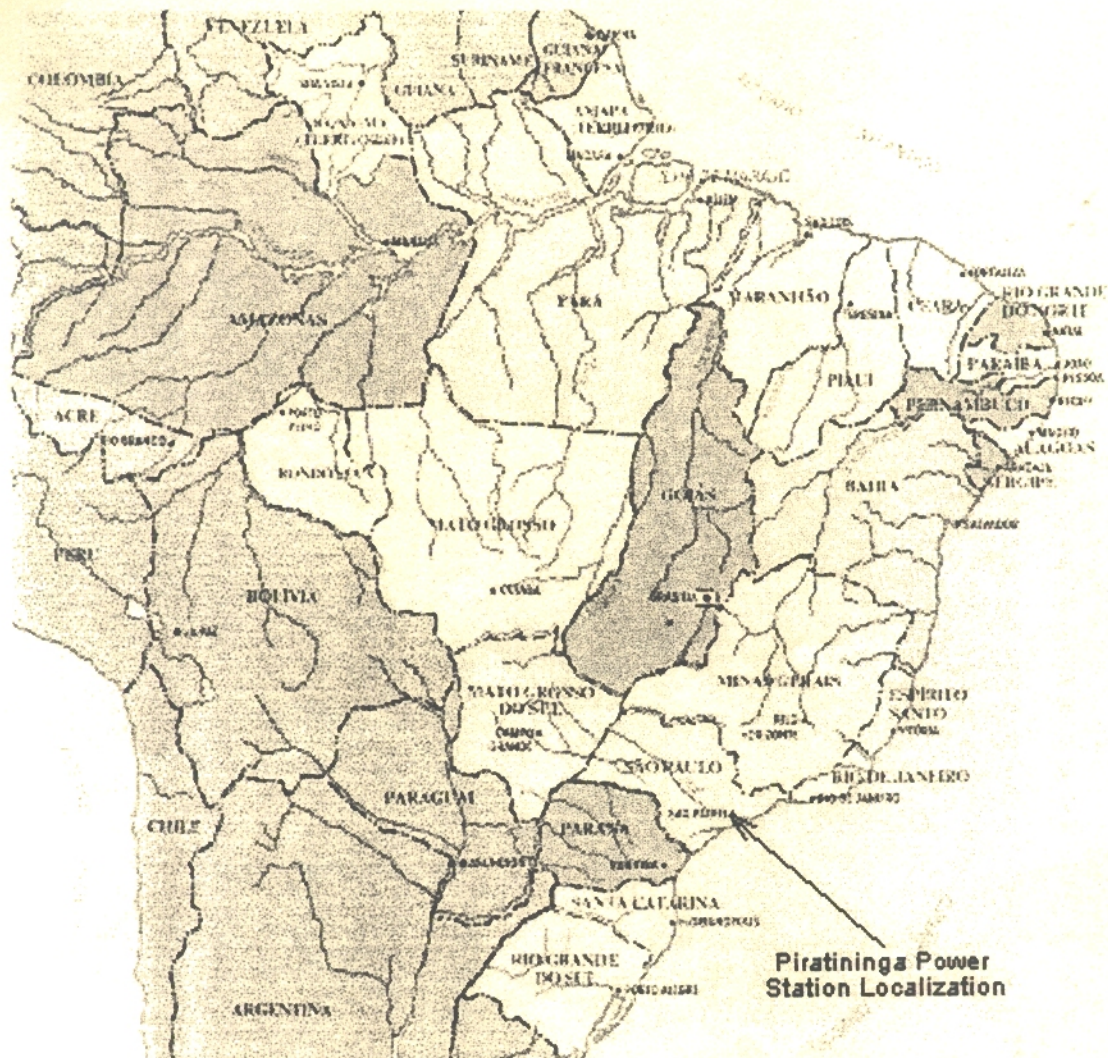
FUEL	OIL	CONSUMPTION
	UNITS 1 AND 2	UNITS 3 AND 4
FULL LOAD (T/h)	26,5 (100 MW)	32 (136 MW)
MINIMUM TECHNICAL VALUE OF LOAD (T/h)	6,7 (20 MW)	8,6 (30 MW)
EFFICIENCY AT FULL LOAD	30,8%	34,6%

Table III. Assumed output conditions for a 50MW demonstration plant.

	80% OF REMOVAL	80% OF REMOVAL	80% OF REMOVAL	90% OF REMOVAL
Flue gas flow rate (Nm ³ /h)	120.000	172.500	225.000	120.000
Minimum Dose (Mrad)	0,41	0,41	0,41	0,67
NO _x Removal & dose (%)	40	40	40	50
Electron beam power (kW)	208	300	392	340
NH ₃ required (l/h)	705	1009	1337	792
Byproduct (t/d)	33	47	62	37
No. of zones	1	1	1	1

Table IV. Estimated cost for a 50MW demonstration plant.

ITEMS		ESTIMATED COST (US\$)
1	Accelerator Installation	2.500.000,00 300.000,00
2	Spray cooler	400.000,00
3	Electrostatic precipitator	1.800.000,00
4	Byproduct handling system	500.000,00
5	NH ₃ storage	500.000,00
6	Analyzers, monitoring, control systems	800.000,00
7	Accelerator building, construction, reaction chamber	1.500.000,00
8	Flue gas duct work	8000.000,00
9	Electrical system	500.000,00
10	Ventilation system, cooling system (accelerator room)	500.000,00
11	Engineering, supervision, training	1.200.000,00
12	Contingency	1.200.000,00
Total		12.500.000,00



**Piratininga Power
Station Localization**

Figure 1. Piratininga Power Plant localization.

ELETPAULO
Eletrônica e Eletrotécnica

UNITS Nos 3 and 4

UNITS Nos 1 and 2

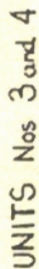


Figure 2. Drawing of the Piratininga Power Plant.

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