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Management of Large Projects in the Brazilian Amazon Region

Gestion de grand projets dans l'Amazonie Brésilienne

Management grosser Projekte im brasilianischen Amazonasgebiet

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SUMMARY

Brazil has one of the biggest hydroelectric potentials of the world. It is estimated to be of 213,000 MW, half of which is located in the Amazon Region. Eletronorte, a subsidiary of Eletrobrás, is the concessionary of this huge area of 4.7 million sq.km, which amounts to almost 58% of the total area of the country. This paper deals with the experience acquired by Eletronorte in managing large projects in this region from their early studies to their construction, focusing particularly the Tucurí Hydro Plant with a final installed capacity of 7,300 MW.

RESUME

Le Brésil a un des plus grands potentiels hydroélectriques du monde. Ce potentiel est estimé à 213.000 MW, dont la moitié se trouve dans la région amazonienne. Eletronorte, filiale de Eletrobrás, est concessionnaire de cette surface de 4.7 million km^2, qui correspond à environ 58% de la surface du pays. Le rapport présente l'expérience acquise par Eletronorte dans la gestion de grands projets hydroélectriques dans la région amazonienne depuis les études de sites jusqu'à la construction des usines, en particulier celle de Tucurui, qui aura une puissance installée finale de 7.300 MW.

ZUSAMMENFASSUNG

Brasilien verfügt über eines der grössten Wasserkraftpotentiale der Welt. Man schätzt es auf 213.000 MW, wovon die Hälfte sich im Amazonasgebiet befindet. Eletronorte, eine Tochtergesellschaft von Eletrobrás, ist der für dieses Gebiet zuständige Konzessionsnehmer. Dessen Oberfläche macht mit 4,7 Mio km^2 fast 58% der totalen Oberfläche des Landes aus. Dieser Aufsatz befasst sich mit der Erfahrung, die Eletronorte bei der Leitung von Grossprojekten gesammelt hat, von den Vorstudien bis zur Inbetriebsetzung. Besonders wird die Wasserkraftanlage Tucurui, deren Leistung beim Vollausbau 7.300 MW beträgt, ins Blickzentrum genommen.

1. INTRODUCTION

The geographic conditions of Brazil - its tropical climate, its large territorial area and hydrographic systems - and the country's relative scarcity of fossil fuel reserves have caused the planning of the national energy system to be based, from its very start, on the development of the nation's large hydroelectric potential.

The importance of this approach was enhanced by the succesive oil crises, which showed the dangers of being dependent on non-renewable fuels, specially if they have to be imported.

Within this policy ELETRONORTE, founded in 1973, continued the program of inventories of the Amazon Region basins, which was started by ELETROBRÃS 10 years before, and which is still going on. Up to this moment, 1,300,000 sq.km have been investigated, with 65 sites identified for hydroelectric purposes, totalling 46,000 MW. At this moment, the company has three plants under construction: Balbina, on the Uatamã river in the state of Amazonas, with 250 MW; Samuel, on the Jamari river in the state of Rondônia, with 220 MW; and Tucuruí, on the Tocantins river in the state of Pará, with a final capacity of 7,300 MW (4,000 MW in its first stage).

In order to develop this hydroelectric potential, special techniques for inventory, design and construction had to be developed by ELETRONORTE. These techniques are based on the experience of the Brazilian energy sector in power macro-planning, and on the cumulative experience with large hydroelectric plants and huge transmission systems obtained through the various projects built in the country during the last 20 years under ELETROBRÃS coordination.

In order to explain the causes of the management procedures which were created, developed and implemented by ELETRONORTE, we need to present a brief summary of the macro-geographic and environmental conditions which have determined the methodology adopted by the company.

2. BACKGROUND ON HYDRO POTENTIAL IN THE BRAZILIAN NORTH AND NORTHEAST

The Amazon river basin is one of the biggest in the entire world. It receives water from the three potamographic systems. The first of these is the West system, which comes from international basins whose headwaters are located in Bolivia and Peru. The second one is the Brazilian Extreme-North system, with headwaters in the highlands on the borders of Brazil with Venezuela, Colombia, Suriname and the Guianas. The third one is the South system, whose water comes from the Brazilian Central Plateau.

This Plateau, with altitude levels ranging from 500 m to 1,200 m above the sea level, separates the two main hydraulic basins of Brazil, namely, the Amazon basin and the Prata basin. Besides containing the headwaters of important right bank tributaries of the Amazon river, it also contains the headwaters of another important and independent basin: that of the São Francisco river, which flows into the Atlantic Ocean in the Northeast coast of Brazil, between the states of Sergipe and Alagoas. This river contains, already in operation, the Paulo Afonso and Sobradinho generation system, with an installed capacity of 5,231 MW. It also contains the 2,500 MW Itaparica plant (under construction), and the 5,000 MW Xingó plant (under study).

All the hydro potential of the country's Northeast region is located on the drop of the Brazilian Central Plateau to the Atlantic Ocean, and part of the potential of the country's North region is on the drop of the same plateau to the Amazon plain. Two companies, both of which are subsidiaries of Centrais Elétricas Brasileiras S.A. - ELETROBRÃS, have the concessions corresponding to this potential. The oldest of these is Companhia Hidroelétrica do São Francisco -

CHESF, founded in 1945; and the newest is Centrais Elétricas do Norte do Brasil S.A. - ELETRONORTE, founded in 1973.

Presently, by means of a special agreement, CHESF supplies the state of Pará, in the North region, through ELETRONORTE's pioneer 500/230 kV system, which is part of the Tucuruí project. This transmission system was anticipated in order to supply the cities of Belém and Imperatriz and the Tucuruí plant construction site with hydroelectric power, replacing local thermal generation based on fossil fuels, for both base and peak loads. As a result, the total outlay on ELETRONORTE's thermal plants, which in 1980 was 269,908 cubic meters of diesel oil and 442,832 tons of fuel oil, corresponding to a disbursment of US$ 164.2 million, has been reduced by 55% in terms of cost, through the use of the anticipated line of the Tucuruí transmission system.

The growing interest in major mining projects and electro-metalurgical industries in the Amazon Region for national development, was further increased by the possibility of transmission of the energy generated in the region to the industrial markets of the Brazilian Southeast region.

3. THE BRAZILIAN EXPERIENCE AND THE AMAZON PROJECTS

The evolution of management of design and construction within the Brazilian electric sector may be divided in three periods, the first of which corresponds to a pioneering phase, in which planning and construction were executed by foreign companies. In practice, the system covered only the areas around the cities of Rio de Janeiro and São Paulo, with local service for other state capitals. It used mixed hydro and thermal generation with short transmission lines.

The second period began in 1946, with the creation of Companhia Hidroelétrica do São Francisco - CHESF, by the Federal Government. Planning started to be done on a regional basis, and design and construction were characterized by vertical management and executive structures. This was due both to the country's stage of development at the time, and also to the specific socio-economic conditions of the Northeast region of Brazil. During this period, CHESF used its own personnel to perform all the activities of planning, design, construction and control of its hydro and long transmission lines projects.

The third period began with the creation of Centrais Elétricas de Minas Gerais S.A. - CEMIG, in 1952. This period brought about the first changes which limited the company's role in design and construction. These changes opened opportunities for private companies in the areas of consulting engineering and job contracting.

The planning policy of the Brazilian electric sector has been under application since the early sixties, when Brazil started a comprehensive and systematic study of its vast potential. This was due to the results of planning studies done by Canambra Engineering Consultants Ltd. for the South-Central and Southern regions of Brazil, which were followed by other planning studies done by the ELETROBRÁS study committees ENERAM and ENENORDE, respectively for the Northern and West-Central and for the Northeastern regions. These studies were done with the support of Brazilian enterprises.

From this point on, as a function of the long construction times and great size of Brazilian hydro projects, and using the experience of CHESF and the newer concessionaries, the Brazilian engineering private companies began to have greater participation with the studies, starting in the area of design and extending progressively to management of the main power plant and transmission system projects.

4. THE JOB TO BE DEVELOPED ON SITE UNDER AMAZONIC CONDITIONS

In order to study and build electricity generation projects in the Amazon region, ELETRONORTE has been performing, since it was created, a large study program, which includes many uninhabited and distant areas, and covers 58% of the Brazilian territory. This area has an immense potential, which is evidenced by the very large mining, metalurgical, agricultural, livestock and forestry projects which are being started in it. Of special note are the projects for developing the enormous mineral reserves of the Carajãs region, the bauxite reserves further north, and agricultural areas, mainly in the states of Rondônia and Mato Grosso.

ELETRONORTE has been studying the hydroelectric potential of the river systems in its area of activity. This potential amounts to roughly 100 GW, not including the Amazon river itself. Special attention has been given to the Tocantins river system, where the studies have indicated a potential of 25 GW, to be obtained through 15 plants whose feasibility studies have been completed. One of these projects is already being built, the immense Tucuruí hydro plant, with 4,000 MW in its first stage and 7,300 MW after its full completion. In order to attain these results, it is necessary to establish conditions which make the corresponding jobs feasible to private consultants.

Special consideration has to be given to the difficulties of conducting technical activity in a jungle environment, including topographical geodesical, geological, hydrological and ecological studies,with their requirements of equipment, personnel, food and other supplies. This in turn leads to complex logistics, including land, air and water transportation, and also requires radio communications and other items in order to provide a link between field and office project activities.

It must be considered that these activities take place at sites which are from 1,500 km to 2,000 km distant from Brasília, São Paulo and Rio de Janeiro, where the main consulting companies, which have the technical ability and financial capacity to perform these studies, are located. Sometimes the field studies have the appearance of complex military operations, involving planes, helicopters, motorboats, and special vehicles which are able to cross swamps and uneven lands. All of this takes place in the region which has the lowest level of economic activity in Brazil, with a population density of 1.1 inhabitants per sq.km, while the rest of the country has a density of 30 inhabitants per sq.km.

5. THE EXPERIENCE OF ELETRONORTE

ELETRONORTE has always reserved for itself the general coordination of the planning phase of its projects, and considered that their operation should be its main statutory objective. It has reserved for private companies the execution of the planning phase of the projects, and their design and construction. It was able to profit from the experience of its older congenerous companies in order to establish a new line of action, which is adapted to its special responsibilities as the concessionary for the generation and transmission of large amounts of energy in the Amazon region.

The environmental conditions of the area, added to its long distances and lack of population,with the attendant problems of isolation and logistics, have led ELETRONORTE to the formulation of principles which are based on the precept of "unity of responsibility with maximum delegation".

5.1 The Meaning of this Precept

The various risks which have to be taken during the execution of any project in the Amazon region, certain special difficulties which will be commented in later paragraphs, the need to offer private consultant firms stimulating conditions

for participation, and the need, above all, to be sure of receiving the best possible service, have led ELETRONORTE to adopt this precept, which in practice translates into: "The ones that do the inventory should also do the design and oversee the construction with the maximum participation of the consulting companies". In this way, all the steps are carried out under constant and rigorous supervision by ELETRONORTE,which counts with strong participation of consulting firms from the very beginning of the projects. In this way, these companies have a strong incentive to execute each of these steps-inventory, feasibility, and basic studies, which precedes the public licitation for construction - in the best possible way, and to conclude them on time, as prescribed by the contracts.

On the other hand, the use of consulting companies to perform these activities, instead of ELETRONORTE's own staff, avoids the surpluses of technical personnel within ELETRONORTE which would occur between the conclusion of each project and the beginning of the next one.

The optimization of design and construction is garanteed by the ELETRONORTE people, as the former of these is accompanied, and the latter supervised, by them. In practice, this leads to the creation of two areas within the group in charge of the project, which are inter-related, and which complement each other in the following ways:

- The inspection group, which demands that blueprints and specifications of high quality be sent on time, in order to avoid loss of time due to their lack;

- The design group, which demands that the field group follow the specifications as closely as possible.

This interaction forces the group as a whole to achieve a greater degree of efficiency, under the principle of "unity of responsibility".

5.2 The Application of the Principles

This principle is in full application in all ELETRONORTE's projects. These projects are listed below, together with the symbol (1) for projects under construction, (a) for projects whose feasibility is being studied, and (b) for projects in the basic studies stage:

PROJECT	INSTALLED CAPACITY (MW)	RIVER	STATE
(1) Tucuruí	4,000 plus 3,300	Tocantins	Pará
(1) Balbina	250	Uatamã	Amazonas
(1) Samuel	220	Jamarí	Rondônia
(a) Babaquara-Kararaô	14,000	Xingú	Pará
(b) Santa Isabel	2,400	Araguaia	Goiás
(b) Porteira	1,400	Trombetas	Amazonas
(b) Manso	210	Manso	Mato Grosso

5.3 The 7,300 MW Tucuruí Power Plant on the Tocantins River

The main example of the application of these principles is Tucuruí, which is the second largest power plant in Brazil, located on the Tocantins river, 300 km south of Belém, which is the capital and most important city of the state of Pará. The principles are being applied by ELETRONORTE with a consortium formed by Themag Engenharia S.A. and Engevix Engenharia S.A. (both consulting companies) and the civil works contractor Construções e Comércio Camargo Corrêa S.A.

The main characteristics of the Tucuruí project may be described shortly as: final capacity of 7,300 MW with 330 MW units, under a nominal head of 60.8 m; - 45.8 km^3 of total accumulated volume in the reservoir, with 25.4 km^3 of useful volume; - 576 m^3/s of turbine flow under nominal head with 83.7 rpm; - 94,500 m^3 of ordinary and back fill excavations; - 5,700,000 m^3 of concrete

and 19,000,000 m^3 of coffer dams.

6. THE TUCURUÍ POWER PLANT CONSTRUCTION MANAGEMENT

The management activities for the construction of the Tucurui power plant are characterized by the fact that the consultant has been present since the early phases of the project. All work is done under ELETRONORTE supervision and control, and this process has resulted in a light management structure. The process itself is described by the flowcharts in this chapter. The content of these flowcharts can be summarized as follows:

6.1 Flowchart I - Engineering Studies

This flowchart shows the procedures for initial approval of the feasibility studies under the coordination of ELETRONORTE's Planning Department, their final approval by ELETROBRÁS, and also the corresponding procedures for the initial and final approval of the basic design under coordination of ELETRONORTE's Project Department.

6.2 Flowchart II - Civil Works and Electromechanical Assembly

This flowchart outlines the main aspects of technical and administrative control for civil works and electromechanical assembly. It begins with the establishment of technical specifications by ELETRONORTE, which led to the choice of the main civil works contractor, and also to a state protocol signed by the Brazilian Government and the French Government for the acquisition of electrical and mechanical equipment. The fact that 20% of the equipment is made in France and 80% is made in Brazil has resulted in the inspection and quality control structures shown by the flowchart, which also presents the areas of responsibility of the consultant and of ELETRONORTE when changes in design are needed after the execution of the whole project has started.

6.3 Flowchart III - Purchase of the Power Plant Equipment

This flowchart shows the main relationships between ELETRONORTE and the consultant in the purchase of equipment. It defines the main responsibilities in cost control, quality control and transportation, based on equipment specifications prepared by ELETRONORTE.

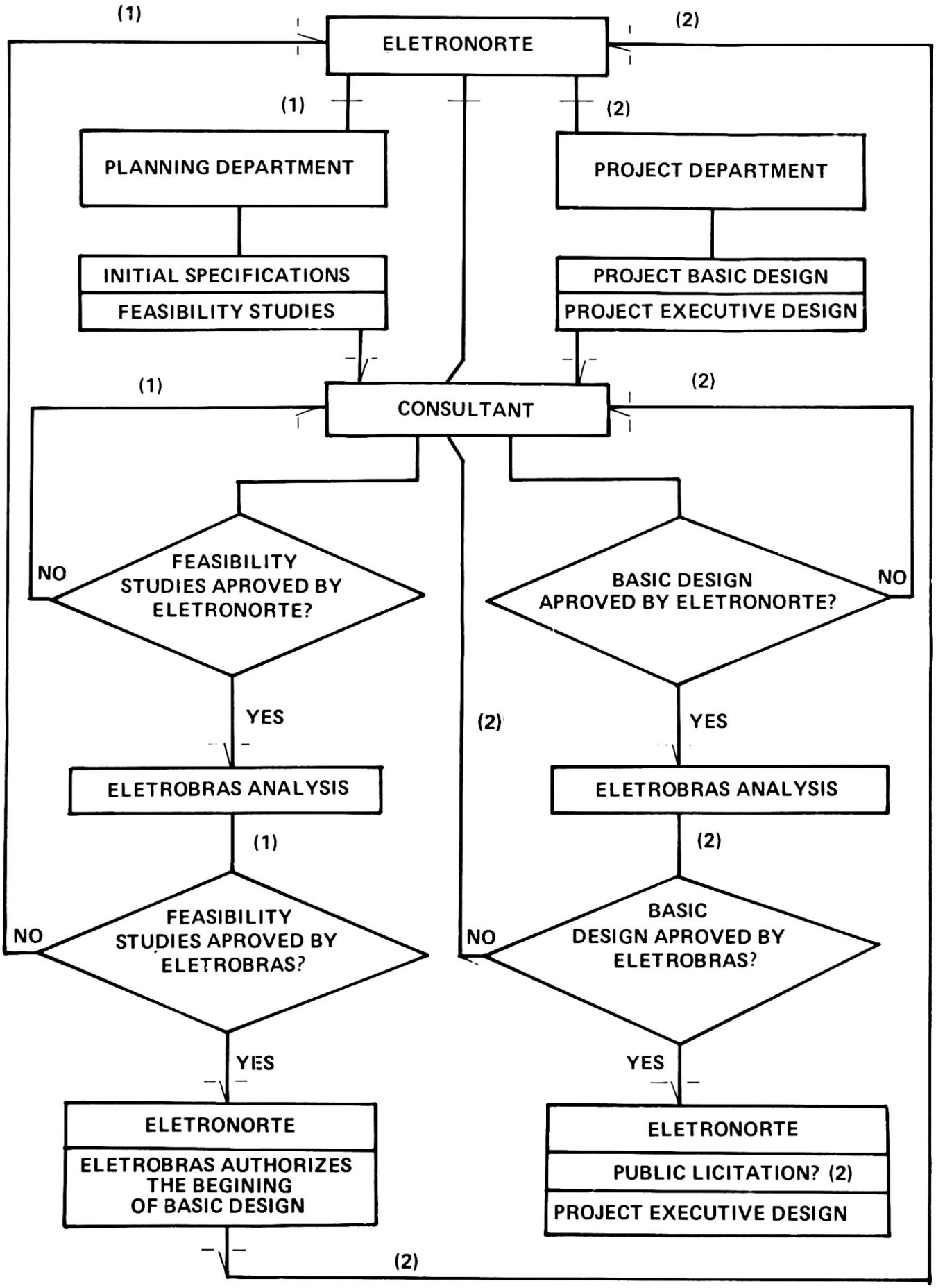
7. THE PRACTICAL APPLICATION OF THE PRINCIPLES

Once the planning phase of hydroelectric project is finished, the execution of the project requires that its basic components, namely,engineering design, choice of equipment, public licitation and signing of contracts for construction and assembly, be started at the same time.

7.1 The Graphic Representation of the Process

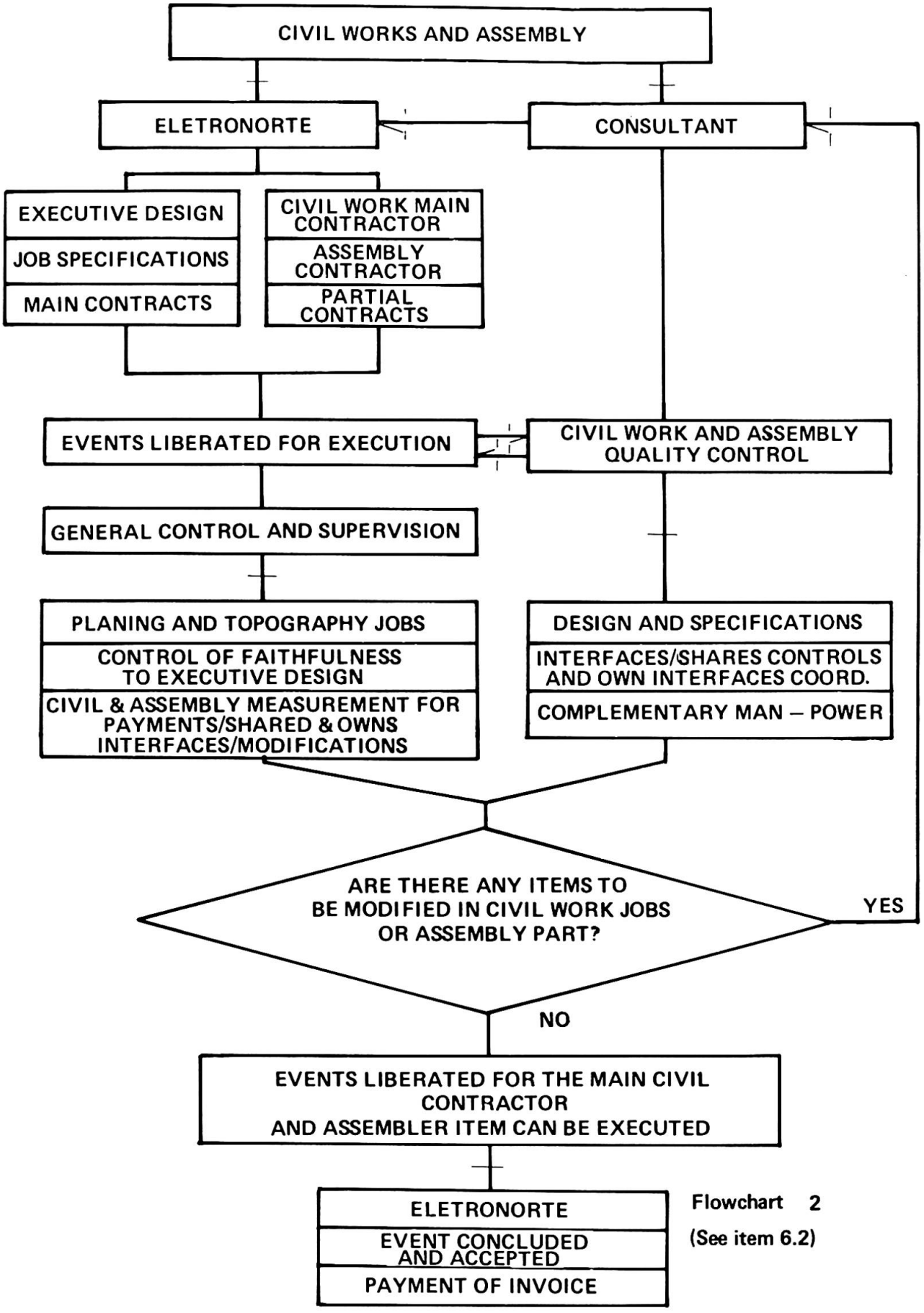
Using Prof. Ladi Biezus' notation, the management of the Tucuruí project can be represented by the five circles in figure 1. The outermost circle represents planning. Inside this circle are three other circles, denoted "P", "O" and "E". The "P" circle represents engineering design activities; the "O" circle, civil works and assembly activities; and the "E" circle, activities related to the equipment. These three circles have areas in common, as the corresponding activities do during the execution of the project. The innermost circle (shaded area in figure 1), represents internal activities, corresponding to actual construction and services.

The area which is not shaded in figure 1 represents conceptual activities, coordination activities, and management activities.



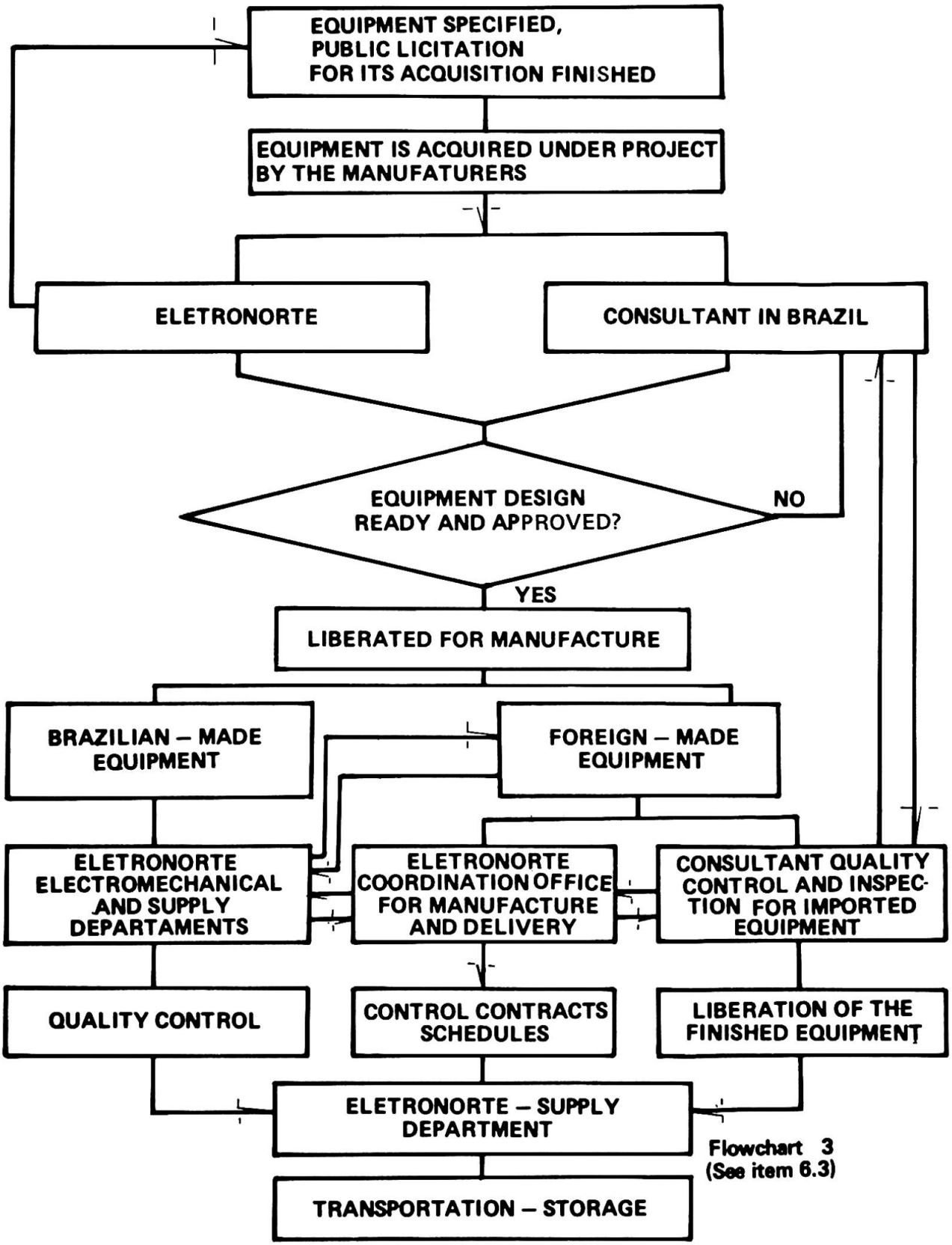
TUCURUI POWER PLANT
APPROVAL OF FEASIBILITY AND DESIGN

Flowchart # 1
(See item 6.1)



Flowchart 2

(See item 6.2)



Flowchart 3
(See item 6.3)

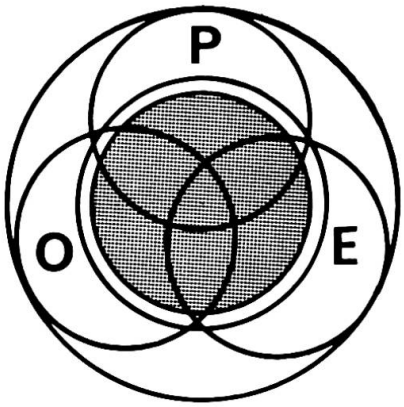


Figure 1

A good coordination of all these phases and management functions is necessary for the sucess of the project. In order to achieve it, the corresponding management activities are shared by ELETRONORTE and consultant companies as described in the next items, which treat the areas of inspection; of coordination of interfaces; and of general planning and control.

Fig.

7.2 Division of Management Activities - Inspection

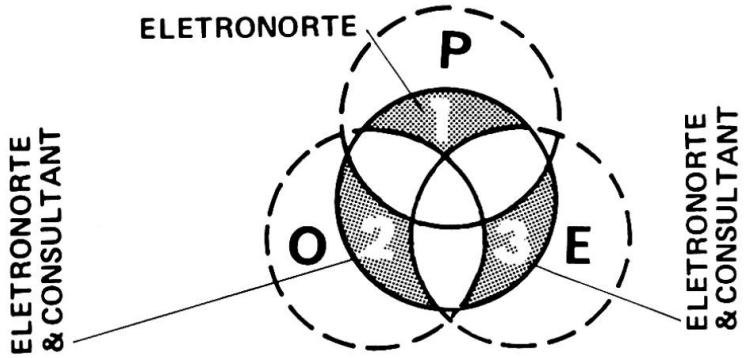


Figure 2

There are three kinds of inspection activities, corresponding to the shaded areas 1, 2 and 3 in figure 2. Shaded area 1 represents project control; shaded area 2 represents supervision of construction and assembly; and shaded area 3 represents inspection of equipment. These activities are shared by ELETRONORTE and the consultant as follows:

7.2.1 Project Control

This activity is done by ELETRONORTE. It includes:

- Quality control of design;
- Faithfulness of executive project to basic design;
- Comparisons between quantities as measured during construction and corresponding forecasts in the executive project;
- Inspection of progress of civil works;
- Approval of changes in the executive project due to conditions which appear during construction.

7.2.2 Supervision of Construction Work and Assembly

This activity is shared by ELETRONORTE and the consultant companies in the following way:

- ELETRONORTE is responsible for:
. Utilities for construction site (both workshop and residential areas - during the peak of the construction phase there are 28,000 workers, who, with their families, total 55,000 people living in these areas), including their maintenance and community services.
. Supply of the larger items of materials and equipment.

- The consultant is responsible for:
. Quality control of civil works and assembly.
. Supply of small items and of additional personnel when required by ELETRONORTE.

7.2.3 Inspection of Equipment

This is also shared by ELETRONORTE and the consultant, as follows:

- Specifications - ELETRONORTE
- Oversee manufacturing - in Brazil - ELETRONORTE
  - other countries - consultant
- Quality control, testing, quantity control for payments, internal transportation, shipping and storage:
  - in Brazil - ELETRONORTE
  - other countries - consultant
- Transportation which demands special procedures or special vehicles: ELETRONORTE.
- Insurance, customs, taxes - ELETRONORTE
- Technical personnel for tasks which are of ELETRONORTE responsibility, when unavailable at ELETRONORTE - consultant.

7.3 Coordination of Interfaces

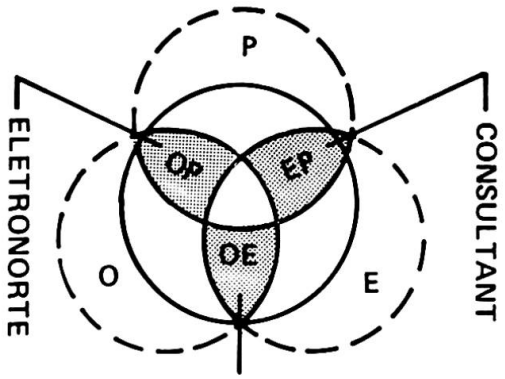


Figure 3

During the execution of a project, the many contacts between the technical staff of the consultant companies and that of ELETRONORTE tend to create a good relationship between the companies, which in turn is useful in solving the problems caused by the interfaces between the various areas.

ELETRONORTE reserves for itself the general coordination of the solutions to these problems, but it usually shares the corresponding management work between its own staff and that of the consultant companies.

In general, the work is divided as shown in figure 3:

OP interface (between design and construction work): ELETRONORTE
EP interface (between design and equipment): consultant
OE interface (between construction and equipment):ELETRONORTE and consultant (mixed group)

These interfaces are very important and complex. The solutions to the problems they pose are usually worked out by the corresponding departments in ELETRONORTE and in the consultant companies, but sometimes they involve decisions which must by taken by the boards of directors of both companies.

Figure 4 shows the mechanism by which decisions are taken. The autonomy of the resident staff must be compatible with the great distances of the Amazon region. Global management problems and their consequences are usually detected first by the resident staff, which takes decisions at its own level and communicates them to the relevant departments of ELETRONORTE and of the consultant companies, thus starting the procedure represented by figure 4, which is used for making any changes that may be needed.

With this mechanism, ELETRONORTE resident headquarters has local executive power for matters related to the execution of the project, with a direct link to the corresponding departments. Thus, it can contact the project area of ELETRONORTE in anything that relates to the actual execution of the project, specially when local conditions force changes of design. In the same way, it can contact other areas for solving management problems as they appear.

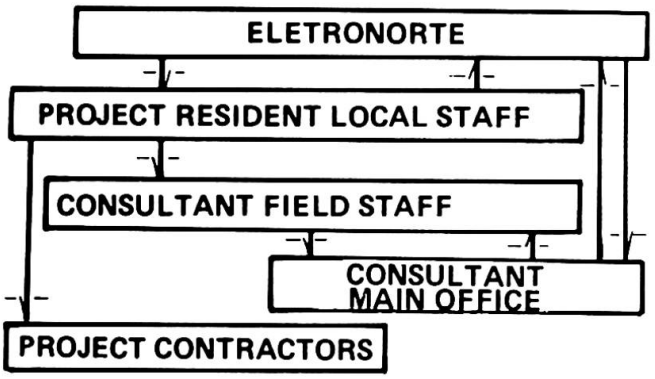


Figure 4

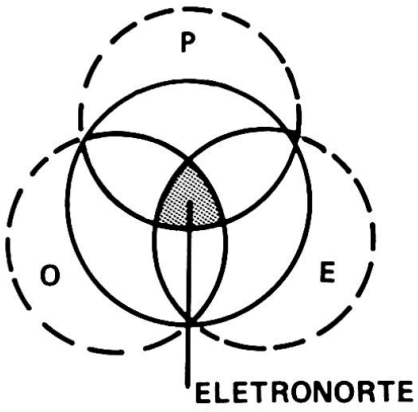


Fig. 6

Figure 5

7.4 General Project Planning and Control

ELETRONORTE, as a subsidiary of ELETROBRÁS, must follow the objectives determined by the central planning of its holding company. Subject to this condition, the planning and general control of the Tucuruí project is done internally by ELETRONORTE (Figure 5). Within the objectives which are programmed and specific instructions which are issued by ELETROBRÁS, specially those concerning financial matters, ELETRONORTE establishes its own annual objectives for the project. It then gives to the resident staff the task of preparing detailed objectives for the year, for both the consultant companies and the contractors. Thus, a qualitative and quantitative program is established and the corresponding tasks are given to the consultant companies, so that they can program their own personnel and other requirements for the year.

7.5 The Management Staff

The management of the execution of the Tucuruí project, whose main aspects have been summarized, involves 610 people, of which 34 are employees of ELETRONORTE and 576 of the private companies, whose activities are:

ACTIVITY	UNIVERSITY DEGREE WITH	WITHOUT	TOTAL
Command of Field Staff	1	4	5
Concrete Quality Control	14	121	135
Earth and Rock Moving	12	134	146
Electromechanical	12	27	39
Complementary Activities	22	166	188
Administrative Activities	1	22	23
SUBTOTAL	62	474	536
Staff Support - Brasília	5	19	24
Staff Support - São Paulo	9	7	16
Complementary Activities	-	-	-
TOTAL	76	500	576

For the Tucuruí transmission system management,during the construction of its 1,200 km, 500 kV/230 kV lines, ELETRONORTE had, at most, 25 employees directly assigned to it, while at same time a total of 5,600 persons were involved with the project.

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