JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIQUE DU SENEGAL
SOCIETE NATIONALE D'ELECTRICITE

FEASIBILITY STUDY
ON
DEVELOPMENT OF ELECTRIC POWER SYSTEM
IN
DAKAR AREA

FINAL REPORT

OCTOBER 1986

EPDC INTERNATIONAL LTD.
TOKYO, JAPAN

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PREFACE

In response to a request from the Government of the Republic of Senegal, the Government of Japan decided to conduct a feasibility study on Development of Electric Power System in Dakar Area and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Senegal a study team headed by Mr. Hitoshi Kitazawa of EPDC International Ltd. four times during the period from August 1994 to July 1995.

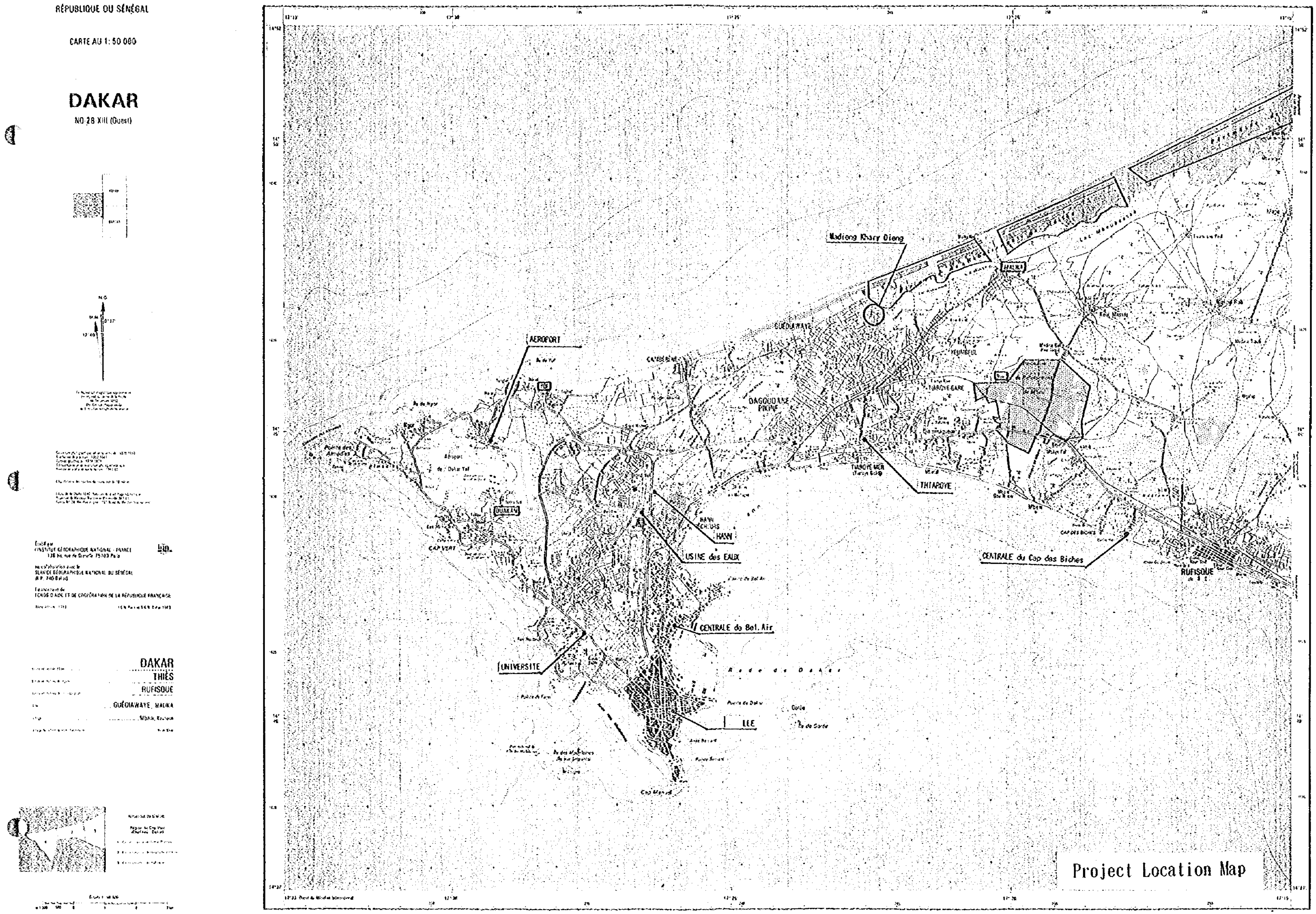
The team held discussion on the project with the officials concerned of the Government of the Republic of Senegal and Societe Nationale d'Electricite du Senegal and conducted field survey at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

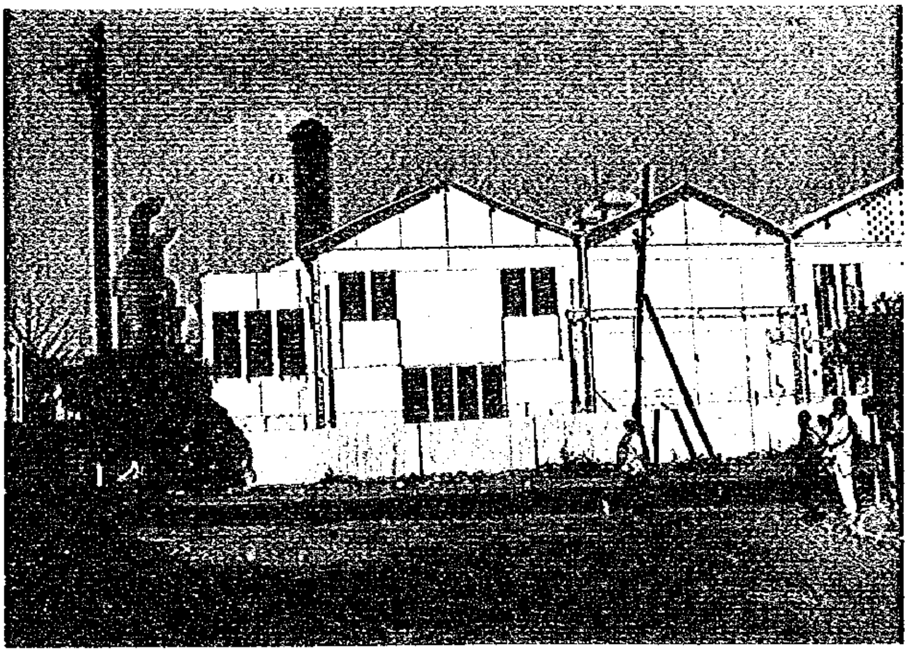
I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Senegal for their close cooperation extended to the team.

October, 1995

Kimio Fujita
President
Japan International Cooperation Agency



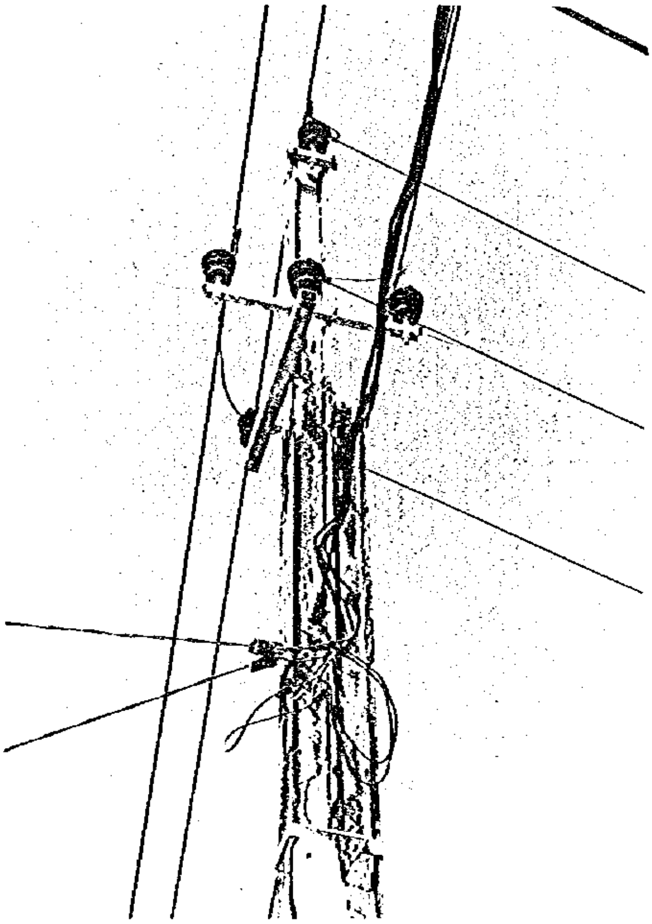
RÉPUBLIQUE DU SÉNÉGAL
CARTE AU 1: 50 000
DAKAR
ND 28 XIII (Ouest)
DAKAR
THIÈS
RUFISQUE
GUÉDIAWAYE, MALIKA
Madiong Khary Dieng
MALIKA
GUEDIAWAYE
AEROPORT
DAGOUDANE PIKINE
THIAROYE GARE
YEUMBEUL
THIAROYE MER
THIAROYE
HANN
USINE des EAUX
CENTRALE du Cap des Biches
RUFISQUE
CAP VERT
OUAKAM
CENTRALE de Bel Air
UNIVERSITE
ILE
Rade de Dakar
Gorée
Cap Manuel
Project Location Map



Bel-Air C-I Power Plant

Cap des Biches Plant Yard

Planned Area of Distribution Network
(Madieng Khary Dieng)



6.6 kV Existing Distribution Line
(Camp Penal)

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CONCLUSION AND RECOMMENDATION

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Conclusion:

The study team made three times of field surveys, August 1994, November 1994, January 1995 and discussed with the SENELEC's staffs in charge for the feasibility study on development of electric power system in Dakar area. After reviewing SENELEC's long-term power development master plan and distribution network expansion and rehabilitation master plan which were submitted to the Team in Dakar at the time of the first survey, the team prepared a development of electric power system which should be carried out immediately in a form of interim report and discussed with SENELEC in January 1995, and after obtaining their consent, the team performed a field survey for the feasibility study.

The conclusion acquired as a result of the study on preliminary design, implementation program, construction cost estimation, economic and financial analysis etc. are as follows.

(1) It is concluded that the following development of electric power system in Dakar area are reasonable and feasible from technical and economical view points.

(2) In order to alleviate the power shortage problem and make the existing system possible to apply regular maintenance and checking, two units of 5,000 kW diesel generators in Bel-Air Power Station should be installed and connected to the 30 kV busbar.

(3) In order to solve such problems as overloading in the distribution system, feeder loss, bottle neck and maintaining supply reliability etc., following programs should be executed as an urgent project.

1) Replacement of circuit breakers
2) Improvement of medium voltage distribution lines
3) Expansion of the low voltage distribution network
4) Rehabilitation of the low voltage distribution network

Recommendation:

The main reason for the power shortage currently affecting Dakar area is deemed to exist in the situation that SENELEC has difficulty to provide fund to expand the system corresponding to remarkable demand increase. Under this circumstance, they have to use the existing power generating facilities even beyond the limit of the equipment without satisfactory maintenance work resulting deterioration of equipment and decreased supply capability as a biggest problem.
The development of electric power system in Dakar area in this report has been provided as a most suitable program in spite of various problems, and it is strongly recommended to do their best to acquire the fund required and execute the project.

When the expansion of power generating facilities are completed, Dakar area power supply system may have some margin and it will become possible to rehabilitate existing generators according to the schedule, utilizing the margin to make machines restore to their normal operating conditions, and maintain stable power generation within the shortest possible time.

For that purpose, deteriorated machines among the existing facility should be completely rehabilitated or retired as scheduled for the machines operating far beyond the life time and try to increase supply reliability.
Facilities in Bel-Air Power Station are especially old but the location of Bel-Air is considered to be very important even in the future for the purpose of supply reliability and system voltage regulation being located in the centre of the power demand and it should be maintained carefully.

As for the distribution expansion program, this kind of work should be done continuously as a regular work, but because of lack of fund, it became seriously deteriorated. It is hoped to rehabilitate the system as soon as possible otherwise not only precious power will be lost and become impossible to send stable power to the customers but it might result danger of electric shock or electricity leakage. By prompt execution of the project, we should do our best to share the benefit of electricity with the people as many as possible.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 General

The restrictions imposed on power supply due to the shortage of generating capacity since 1981 will not be relaxed as of January 1996 with the situation becoming increasingly worse in the face of rising power demand. This condition has very serious repercussions and the problems are so great that the intervals for the necessary plant inspection have to be extended with the result that plant efficiency keeps declining and equipment deteriorating while the fuel consumption rate increases so that the electric utility (SENELEC) is unable to meet his obligation and mission of assuring his most important users of a high quality power supply.

To improve this situation, SENELEC, the Senegal's Public Electricity Corporation, is currently reviewing the master plan for power facility improvement it has established (Medium-/Long-Term Power Generating Facility Plan for its Grid) and drawn up the following Development of Electric Power System for the facilities serving the Dakar grid and requiring urgent extension.

The present Study has been and is being conducted on the basis of the following stages:

- Review of the master plan : August, 1994 - January, 1995
- Environmental Survey : November, 1994 - December, 1994
- Feasibility Study : February 1995 - July, 1995

Following the review of the master plan and the environmental survey, the feasibility study is being carried out by a Study Team consisting of various related departments, including power generation, transmission line, distribution line, civil engineering, economics and finance. The Study Team is sent to the Senegal for explanations and discussion on the interim report. In addition, seminars have been organized to promote a far-reaching and deeper understanding among those concerned in the Senegalese government, notably SENELEC as to the content of the report and all necessary data and information required for more detailed field survey of the candidate locations for the extension of power generating facilities as well as for the feasibility study and design have been collected.

1.2 Assessment of the Problem Areas and the Project

As will be presented more fully in the subsequent Chapters, the grid system centering around Dakar presents the following serious problems which make it difficult to operate the system as a result of shortages in power generating capacity.

- Forced measures to restrict power supply due to inadequacies in the commissioning of new power generating facilities.
- Supply restriction energy resulting from bottlenecks in the distribution line facilities.

Both of these problem areas started in 1981 and because of the delay in the commissioning of new power generating facilities the existing generating facilities had to be operated beyond their capacity. As a result, the actually available power generating capacity as of 1993 dropped to a level equal to 78% of the rated output.

The results of this shortage of power generating facilities make themselves acutely felt in the peak load band with sudden rises or falls in the load. Concurrently with the problem of inadequate output in the peak load band, there is also the problem of facilities being operated for too long in order to assure the annual power generating requirement so that it is becoming increasingly more difficult to stop the power generating facilities. To overcome the present situation, it is therefore an urgent priority to commission new generating facilities to cover the minimum necessity within the shortest possible time and to implement the regular maintenance and inspection shutdowns seen as most important for the thermal power generating facilities so as to restore the facilities to its operational availability.

The bottlenecks in the distribution line facilities require measures such as the replacement of facilities with larger capacity or the re-routing of the line, seeing that in certain parts the permissible values for the series-connected facilities such as overhead lines and power cables are overloaded. These problems can be encountered in the entire system from the supply source to the line end as the demand load increases. Thus, for example, to meet the supply to new housing estates, the practice is to extend the distribution lines and increase the branching equipment. To overcome these bottlenecks, it will be essential to have a clear idea of the variations in the demand load at all times to determine the priorities for improvement of facilities so that short- and long-term improvement and renewal plans can be established on the basis of these priorities.

1.3 Scope of Investigation for the Feasibility Study

(1) Explanations and Discussions on the Interim Report

Based on the short-term power supply development plan, meetings have been conducted to explain the approach used for power demand forecast and the plans for power generating facilities based on such forecast and also to give fuller explanation on how to improve the bottlenecks in the distribution line facilities.

(2) Seminar

Seminars designed to give those concerned a fuller understanding of the details of the interim report were held in the form of a presentation of the existing problems and of question and answer sessions on these problems. The aspects that required serious consideration at each planning stage were as follows: 1. the present state of power generating facilities as seen from the perspective of gird system operation; 2. areas to be checked in view of the need for harmonization with the existing facilities; 3. plans to scrap some of the existing facilities; and 4. plans to move toward the future. In all of these considerations, the basic requirement for the installation of the new generating facilities must be integrated into the existing facilities.

(3) Details Field Survey

After the holding of the above explanation and discussion meetings as well as seminars on the interim report, a details field survey was conducted with the assistance of the SENELEC engineers. The main points of this survey are as follows.

1) Power generating facilities
   - Map of power station site complex and its surrounds
   - Arrangement drawing of power station site complex

- Cross-section drawing of power station site complex
- Detailed layout of existing equipment
- Access to project site and transport
- Climate (Annual rainfall data, wind direction, wind force, atmospheric temperature, humidity)
- Geological data
- Water supply

2) Distribution line facilities

- Data on plan, including design conditions
- Routes and surrounding environment (incl. geological conditions)
- Right of way
- Feeders
- Related existing substations (pastes) and present condition of the distribution lines
- Equipment and materials used in the existing substations (postes)
- Plan along routes
- Profile drawings and plan drawings of special locations
- Present condition of existing equipment (salt contaminatio on insulators, corrosion of steel poles, mechanical strength of conductors)

(4) Feasibility Design

With regard to the power generating plant covered by the short-term power supply development plan considered in the interim report, a feasibility design has been carried out in accordance with the following points.

1) Power generating facilities

i. Types and numbers of prime movers

- Considered were the scale of output, the types of available fuels, current fuel situation, operating and maintenance characteristics, and the economic and social impact.

ii. Installation location

Considered as candidate sites for the installation were both the Bel-Air and Cap des Biches power stations.

- Rated capacities of series-connected equipment
- Short-time current
- Maximum permissible short-circuit current
- Matching with existing plant

iii. Environmental measures

It is clear that the equipment must meet the regulatory requirements and values and take into account the influence it will have on the social environment. Consideration must also be given to ensure that the equipment will not have a seriously detrimental impact on the social environment.

iv. Important aspects for the design

Making use of the experience possessed by the consultants in the design, construction, operation and maintenance of thermal power stations both in their own countries and abroad.

2) Distribution line facilities

i. Study of basic aspects

Prior to the feasibility design consideration has to be given to the following basic aspects:

- System configuration concept, including the installation
- Pole-mounted transformer/Transformer capacity in pastes
- Wind load on support and conductors
- Types of conductors and maximum allowable current
- Design temperature
- Insulation design
- Degree of salt contamination
- Sag and tension of conductors

Following the study of the basic points, the feasibility design is carried out.

- Routes
- Voltage
- Number of phases

- Capacity and number of transformers
- Substation equipment and methods of connection
- Supports and stay
- Cable laying method
- Conductors
- Sag and tension of conductors
- Hardwares

(5) Work Schedule

Study of the procedures for carrying out the construction work on the development of electric power system and prepared the work schedule using bar charts.

(6) Construction Cost Estimation

Estimation of the construction costs for carrying out the construction of the development of electric power system both in domestic and in foreign currency to prepare the funding plans on a fiscal year basis.

(7) Economic and Financial Analysis

Estimation of the operating and maintenance costs, calculation of the return on investments (ROI) and the economic internal rate of return (EIRR), and a sensitivity analysis are carried out.

Preparation of financial documents such as sales profits and profitability estimate, profit and loss calculation, cash flow sheet and estimation of the financial internal rate of return (FIRR) and carrying out a sensitivity analysis.

(8) Evaluation of Environmental Survey

Because of the difficulties of obtaining the necessary climatic data at the time of the environmental survey, the following detailed evaluations shall be performed.

1) Assessment of the actual influence based on measurements of the magnetic field strength in areas surrounding high voltage equipment.

2) Estimation of the exhaust gas concentrations in the vicinity of prime movers for exhaust gases generated from the present prime movers of the existing power generating facilities.

3) Forecasts and studies of the effect of vibrations, noise and exhaust gas concentrations on the social environment.

1.4 Support Given by SENELEC to the JICA Study Team in the Feasibility Study Stage

The JICA Study Team conducting the investigations for the feasibility study consists of the following members:

Hitoshi Kitazawa	Team Leader
Kazuhiko Nakaoji	Power Generation
Yukiteru Takeya	Transmission line
Yoshiyuki Kudo	Distribution line
Teruhiko Tsumura	Economics/Finance
Tadayoshi Ishida	Civil Engineering
Kazuo Ando	Interpreting

The study and survey in the Dakar region by the JICA Study Team in the feasibility study stage has been carried out with the support and cooperation of the following staff members of the SENELEC counterpart, the Ministry for Economic and Financial Planning, the Ministry of the Energy and Mining Industries, and the Energy Agency.

Mr. Diatourou NDIAYE	Responsable du Secteur Secondaire - Energie, Industrie
Mr. Mamadou DIANKA	Directeur de l'Energie
Mr. Mochel DIEME	Chef Division Planification
Mr. Alassane NDIAYE	Chef Division Economie d'Energie et Energie Renouvelable
Mr. Mbague MBODJ	Assistant de la Diretion de l'Energie
Mr. Abdourahmane NDIR	Directeur Général

Mr. Abudoulaye NDOYE	Directeur de Contrôle de Gestion
Mr. Zaul NDIAYE	Adjoint au Directeur Général
Mr. Moustapha LO	Chef du Service Planification
Mme Moimouna SECK	Ingénierur Cellule Planification Moyens Production
Mr. Issa Mare DIAW	Chargé de Projets Réseaux Electriques
Mr. Babacar GUEYE	Directeur de l'Exploitation
Mr. Pana Ndiame DIOP	Chargé de Projects Réseaux Electriques
Mr. Waly NDIAYE	Chargé de Projects Réseaux Electriques
Mr. Babacar MAME	Coodination Centrales Régionales et Secondarres
Mr. Tdiane BARRY	Directeur de l'Equipement
Mr. Birane KHOULE	Chef de Service Mouvements d'Energie et Conduite
Mr. Makha CAMARA	Chef du Département CI/CII Bel-Air
Mr. Laurent DIENE	Chef Division Préparation
Mr. Oumar DIAM	Chef Division Condute
Mr. Papa DIOP	Chef de Centrale
Mr. Idrissa NIASS	Chef de Service Exploitation
Mr. E. C. SOW	Chef de Service Entretien
Mr. Senigne Mohamadou DIOP	Chef de Centrale Diesel Cap des Biches
Mr. Bamar SAMARA	Chef de Service Entretien
Mr. Basirou GAYE	Chef du Service Exploitation et Entretien, Départment Transport d'Energie
Mr. Abdoulaye NIAUY	Chef de Poste
Mr. B. NDIAYE	

CHAPTER 2

GENERAL SITUATION IN SENEGAL

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2.1 Natural Conditions

The Republic of Senegal, which is situated approximately at 11 degrees north latitude and between 11 and 17 degrees west latitude, lies on the northernmost tip of the African continent. Extending about 600 km from the east to the west and about 400 km from the south to the north, the size of the land is 196,722 km^2. In the north, the country is bordered by River Senegal with Mauritanie, a Moslem Republic; in the east, it is bordered by the Republic of Mali with River Famele branching out from River Senegal; and in the south, it is bordered with Guinee and Guinee Bissau. The land can be divided into four areas based on topographical, geological factors and climatic bands, that is, the low flatland of the Senegal river delta belonging to dry or semi-dry zones, the central plateau mainly composed of the wide sands, the highland in the southeast and the lowland tropical rain forest zones, as well as the Cap Vert peninsula which protrudes into the Atlantic Ocean with its hills and bare rocks. As its topographical features, except some hills stretching 300 to 400 meters here and there in the southeast, Senegal consists mostly of flat lands no higher than 200 meters. Especially, the area about 100 km wide along the Atlantic Ocean from Saint-Louis to Gambia in the north is extremely low with its altitude of 15 m above the sea level. In the valley of the River Gambia which flows from the east to the west, the Republic of Gambia surrounded on three sides from the east to the west over 300 km is shaped into a wedge, thus creating a special form of border line.

The climate, which is tropical, is divided into the rainy and dry seasons. During the dry season, the inland is remarkably dry due to the Harmattan wind; however, the coastal area is not too dry due to the humid oceanic monsoon. The rainy season is from June through October; however, the rainfalls are concentrated on the three months between July and September. The average annual rainfall in the Casamance State in the south is 1,000 mm to 1,500 mm. However, moving up further to the north, the rainfall is gradually reduced: the basin of the River Senegal in the north, it is dropped to below 300 mm. The temperature is generally high: the temperature in the basin of the River Senegal in the north exceeds 40 degrees Celsius immediately before the rainy season sets in. The highest temperature along the coastal area is around 30 degrees Celsius.

As was previously mentioned, Dakar, the capital city of the Republic of Senegal, is stretched out in the shape of a belt from the northwest to southeast direction for the length of about 12 km along the Cap Vert peninsula, which is the westernmost part of the African continent. According to the national census taken in 1988, about 22 % of the total population of the country reside in and around Dakar; the fluctuation in this ratio was minimal even in 1994. The capital city is expanding rapidly along the roads of Dakar, Cap-des-Biches to Bargny in the direction of the suburbs included in the Government's city plan which includes industrial complexes and others.

Dakar has an international airport which connects the three continents of Europe, Africa and America, handling many arrivals and departures of airplanes from various countries. It also has a well-equipped port as an important point for the marine traffic of west Africa, handling a large number of fishing boats, cargo boats and passenger boats from various countries.

2.2 Social Conditions

The national population of Senegal in 1994 is assumed to be about 8.15 million. The rate of population increase is nationally 2.76 % and around Dakar 3.63 %. It is estimated that, by the year 2,000, the population will exceed 10 million; and, by the year 2,010, it will exceed 12 million. Such a rapid population increase is becoming a significant problem to the Senegal society.

Regarding employment, the economic activities of the country are still generated by the traditional industries of the local areas despite rapid urbanization in recent years. Therefore, increase in unemployment and incomplete employment in recent years is becoming a serious problem, together with the population increase.

In Senegal, there are about 10 races, each of which has its own unique language. However, racial conflicts are not visible and people seem to live in a good harmony with each other. However, the Zolaqq race which relies mainly on rice farming in the Kazaman's region in the south is continuing its campaign of independence from the central government, feeling unsatisfied with apparently unfair treatments. Although a truce agreement was made with the government in 1991, a final solution is still not in sight, with armed conflicts by some radical groups still taking place sporadically. Regarding the conflict with Mauritanie in the north which occurred in 1989, efforts are being made by the authorities to produce a solution; however, it is regarded that the problem of compensating for the residents who were forced to move to other places due to the conflict will be difficult to solve. Therefore, it will take some time until the angry emotions being felt by the residents living in the vicinity of the border subside.

2.3 Economic Conditions

At the time of independence, Senegal was the most developed country and a center among the French-speaking countries in west Africa, enjoying a better infrastructure, more diversified industries and a higher educational level, etc. than neighboring countries. However, its economy was centered on the agriculture, which was based on peanut production which started from the colonial rule by France. Although the country has aimed at industrialization since its independence, it has suffered reduced agricultural production due to frequent droughts; sharp price falls of peanuts which are a major export item; deterioration in the trade balance due to increased import of raw materials and food; and financial deficits.

Therefore, receiving deferment of debts as well as supports from the World Bank and the IMF since 1981, the country announced mid-/long-term economic and financial structure plans (1985-1992) and drew up the 7th four-year plan (1985-1989) to tackle structural adjustment and economic rebuilding. And, the structural adjustment in 1985 through 1988 is estimated to have been smooth. The country continued to draw up the 8th economic and social development plan (1989-1995)(VIII eme Plan de Development Economique et Socia), which placed the highest priority in continued improvement of the national productivity and is proceeding with the plan to achieve various goals.

However, the structural adjustment was placed in a standstill by the sharp decline in the agricultural production due to the rainfall shortage in 1988-1989 as well as by the political installability in 1988. In 1990, the reduced tariff revenue and the insufficient restraint on public expenditures, etc. made compliance with various conditions impossible; thus, in 1991, causing delay in the advance of funds by the IMF and the World Bank. The actual growth rate in 1992 was mere 2.3 % - lower than the population increase rate of 2.76 %. The structural adjustment policy saw some progress in privatization of public enterprises and so on; however, with regard to liberalization of the agricultural sector, compression of the salaries of government officials, reduction of financial deficits, and revision of labor acts, etc., no concession was made between the World Bank and the IMF and the Senegal Government, thus suspending the expenditure of the third term of the fourth structural adjustment loan by the World Bank in 1993. On January 12, 1994, Senegal carried out a large-scale currency depreciation, together with other 12 countries using the same currency. This was done to promote export and introduction of foreign currencies and suppress trade and financial deficits. Through this depreciation, the "1 FF = 50 FCFA" rate which had been maintained since 1948 was reduced to "1 FF = 100 FCFA", thus halving the exchange value of the local currency. The currency depreciation affected the domestic prices as well: currently, various prices have risen sharply, thus inviting economic instability. The real GDP was as low as 2.3 % in 1992. However, when looked at together with the 1.1 % in 1991 and 3.7 % in 1993, the trend during the past three years definitely shows signs of proportional growth; and it is hoped that a stable growth will continue in the future as well.

For the economy in Senegal, the assistance from foreign countries plays an important role for the financial side of the country. The ex-colonizer France is the largest aid country for Senegal, followed by Japan, ex-West Germany, and the United States. Being one of the Islamic countries, Senegal receives a large amount of funds from oil-producing Arabic countries as well.

2.4 Electric Power Conditions

2.4.1 History of Power Supply

In 1897, the power supply in Senegal started in Saint-Louis, which is situated 150 km northeast of the current capital Dakar. Presently, the power supply in Senegal are conducted by the state-run Societe Nationale d'Electoricite (SENELEC). The developmental process of the power supply since its start in 1898 up to the present time can be viewed in terms of four periods as follows:

(1) 1st Period (1897 - 1929): Starting period of power supply

In Saint-Louis, where the government and the "Port Maritime et Fluvial" at the time had their offices, the electricity was supplied by the CARPOT company (Etablissement CARPOT) until 1922, when it was absorbed into the "Compagnie Africaine d'Electricite (CAE)."

In 1925, CAE not only started the power supply in Louga but also the operation of a power station in Kaolack. In Rufisque, which used to be the center of commercial and agricultural products, electricity was supplied by the municipal's public organization until 1928, when the public power facilities were bought up by the "Compagnie d'Electricite du Senegal (CES)."

The CES above is a French electric utility established in Dakar on January 4, 1910 with the capital of one million francs. The power supply in the Dakar area was started in 1910.

(2) 2nd Period (1929 - 1966): Developmental period of power supply

In 1929, both the CES which had been supplying power to Dakar and Rufisque and the CAE which had been supplying power to Saint-Louis, Louga and Kaolack until then were dismantled to be absorbed into the "Compagnie des Eaux et Electoricite de l'Quest Africa (EEOA)" which was newly set up in that year.

During this period, the EEOA made a very smooth development through healthy management. The criteria for power facility operation formulated at EEOA's initial stage are continued unchanged to the criteria for electric works, which were newly enacted in 1967.

The annual power demand in 1945 through 1952 increased by 15 % on the average; and 85 % of Senegal's national generated energy was consumed in the Dakar area. (As of 1993, 63 % in terms of the electric energy; 97 % in terms of the electric power.)

(3) 3rd Period (1966 - 1971): Starting of regional electrification

This period is characterized by the will of Senegal Government to actively participate in the management of power supply in the future, thus making it possible to provide various legal grants especially for individual power supply in the regions suffering from serious financial management problems.

(4) 4th Period (1971 - 1982): Establishment of SENELEC

Using the independence in 1960 as an opportunity, conferences were repeated between the French-national private electric utility EEOA, which has been monopolizing Senegal's domestic supply, and the Senegal Government on how to nationalize the electric utility. As a result, all of EEOA's power generating, transmission and distribution line facilities came to be purchased by the Senegal Government through bank loans.

Based on the arrangement above, two new companies were established in January, 1972. One of them is the completely state-owned "Electricite du Senegal (EDS)"; the other is the "Societe Senegalaise de Distribution d'Energie Electrique (the predecessor of SENELEC)", which was jointly financed and set up by the Senegal Government and the EEOA at 50 % respectively.

Based on the capital participation by EEOA and as the owner of the power generating, transmission and distribution line facilities, the former EDS had loaned them to the previously described Societe Senegalaise de Distribution d'Energie Electrique and allowed it to manage them until 1981 in accordance with the contracts.

All the 50 % of the previously described power distribution company stocks above owned by EEOA were handed over to the Senegal Government by December, 1981. As a result, based on Act 83-72, the EDS and the Senegal power distribution company were dissolved and then integrated to set up the "Societe Nationale d'Electricite (SENELEC)" on July 5, 1983, which is continuing until today.

2.4.2 SENELEC

(1) Organization of SENELEC

1) Head-office organization

SENELEC has its head office in Dakar; its regional organizations such as branches and agencies in major cities including Saint-Louis, Kaolack, etc.; and its sales branches in towns and villages. The total number of employees was 2,340 as of 31, 1991. Fig.2.4.2-1 shows the organization chart of SENELEC.

2) Head-office structure

Under the board of directors, SENELEC's head office consists of the President, the vice President, the power generation and management division, the distribution line and procurement division, the research, development and training division, and the management/accounting/ information system division. Under the President, the head office is further branched out into the Presidential secretariat, the comprehensive inspection, and the internal audit organizations. Under the vice President, there are the secretariat office, the experts section, the consultation section, the formality section, the general affairs section, the legal affairs section, and the procurement section. The board of directors, which is the highest decision-making organ of SENELEC, has 14 to 17 regular members, who are selected from those experienced in the energy field and appointed in accordance with a government ordinance. As of 1990, the representative of the constituting members is the representative of the Presidential Office, the representative of the Industry Ministry, the representative of the Finance Ministry, the representative of the Construction Ministry, the representative of the regional public bodies, the representative of Farming Village Development Ministry, the member nominated by the parliamentary members, or the consumer representative nominated by the President.

3) Power system operation organizations

The organizations which operate RGI power systems include the load dispatching office responsible for operating transmission line facilities of at least 90 kV and power generating facilities and the control center responsible for operating distribution line facilities, both working 24 hours a day based on shifts.

The load dispatching office and the distribution control center are both placed in the Hann substation. The former uses the PLC system and the latter uses the VHF wireless telephone system for control between remotely-controlled stations, information collection and liaison.

4) Power station operation organizations

Operation of the SENELEC's power station falls broadly into two sections, i.e., the operation section and the maintenance section; and each section consists of two parties. The operation section consists of the operation party which works on shifts and the technical party which performs adjustments of equipment and routine checks. The maintenance section consists of the preparation party which repairing (in the repair plant) faulty equipment and the ordering/implementation party procuring equipment and materials.

(2) Financial Situation

SENELEC's financial situation has been operating in the red by failing in the balance between the revenue and the expenditure which was increased due to aging of the facilities in general. The financial situation from 1982 until 1991 is shown below.

Year	Operating fixed assess (kFVDA)	Net profit (kFCFA)	Earning rate
1982	26,581,641	-1,868,089	-7.08%
1983	86,686,156	-4,221,121	-5.23%
1984	82,239,920	-4,883,699	-59.4%
1985	81,031,148	-3,596,461	-4.44%
1986	80,866,648	-2,838,478	-3.51%
1987	81,975,685	-3,579,260	-4.37%
1988	86,741,690	-4,503,356	-5.19%
1989	103,270,141	-4,267,188	-4.13%
1990	106,773,131	+2,806,623	+2.63%
1991	110,039,177	+1,775,202	+1.68%

As can be understood from the table above, SENELEC's financial situation has turned to surplus ever since 1990, showing earning rates of +2.63 % in 1990 and +1.68 % in 1991 respectively.

(3) Power Facilities

1) Senegal's power system

Senegal consists of ten administrative regions, i.e., Dakar, Zinguinchor, Dioubal, Saint-Louis, Tambacounda, Kaolack, Thies, Louga, Fatick, and Koida, each of which in turn is comprised of three areas.

The power system connecting the areas above is being managed by Senegal's electric power corporation SENELEC, which consists of the Reseau Interconnect (RI) and the Sentress Secondaries. As of 1993, the former supplies power to major cities (in the Dakar region, the Rufisque area, the Thies and Taiba areas) facing the Atlantic Ocean of the country; the latter to the other areas scattered all over the country. Their relationship is shown below.

```
RI systems              ──┬── Dakar area ─────────┐
(Reseau Interconnect)     │                        │
                          ├── Rufinsque area       │
                          ├── Thies area ──────────┼── RGI system
                          └── Taiba area ──────────┤
                                                   │(Interconnected
Independent systems ──┬── Saint-Louis system --│ in 1994)
(Sentress Secondaries) │                          │
                       ├── Kaolack system -----│(Interconnected
                       │                            in 1997)
                       ├── Ziguinchor system
                       ├── Tambacounda system
                       └── Other system
```

The RI is also called the Reasou General Interconnect (RGI) by including the Saint-Louis system and the Kaolack system. The former is planned to be interconnected during 1994 and the latter in 1997. Fig.2.4.2-2 shows the power system diagram of the whole country. Fig.2.4.2-3 shows the power system diagram of the Dakar region.

The transmission voltages of RGI system are 30 kV, 90 kV, and 225 kV. Although, as of 1993, 90 kV is the basic transmission voltage, an international system interconnection plan is in progress at SENELEC to connect a 225 kV transmission line up to the Manantali hydropower plant in the River Senegal joint development project by three countries Mauritanie, Mali, and Senegal.

The 225 kV transmission line plan will interconnect between the Cap des Biches, Tobene, Sakal, Richard-Toll, Boghe, Matam, Kidira through Manantali hydropower plants, thus the total length exceeding 1,000 km - a long transmission line. Therefore, it is important to take measure to maintain the stable transmission voltages at both the heavy load and the light load. Furthermore, the 225 kV transmission line plan is intended for interconnecting between, Tobene, Kahone, Tambacounda, and Kidira as well.

Fig.2.4.2-4 shows the potential hydraulic power plant development distribution in the River Senegal area, of which three countries Mauritanie, Mali and Senegal Are proud and in the basin of the River Gambie, of which Guinee and Senegal are proud.

All the power generating facilities of the RI systems consist of heat engine generating facilities (such as steam turbine, gas turbine and diesel), producing the rated output of 226,700 kW as of 1993 and actual limit output of 176,500 kW. The actual limit output is 78% of the rated output. The power consumption of RI system occupies about 63 % of that of the entire country; and about 97 % of the maximally generated energy.

2) Generating facilities

The breakdown of the generating facilities of RGI systems at the time of field survey in August, 1994 are shown below.

Bel-Air power station:

Generator No.	Type	Rated output	Actual limit output (kW)	Commissioning year
G101	Steam	12,800	5,000	1953
G102	Steam	12,800	9,000	1955
G103	Steam	12,800	11,000	1959
G104	Steam	12,800	5,000	1961
G105	Diesel	5,000	5,000	1991
G106	Diesel	5,000	5,000	1991
	Sub-total	61,200	40,000	

Cap des Biches power station:

Generator No.	Type	Rated output	Actual limit output (kW)	Commissioning year
G301	Steam	27,500	27,500	1966
G302	Steam	30,000	20,000	1975
G303	Steam	30,000	15,000	1978
TAG1	Gas Turbine	16,500	15,000	1972
TAG2	Gas Turbine	21,500	19,000	1984
G401	Diesel	20,000	20,000	1990
G402	Diesel	20,000	20,000	1990
	Sub-total	165,000	136,500	
RGI system total		226,700	176,500	

3) Transmission line facilities

The total length of the 90 kV transmission line as of 1993 was 169 km; 5 km between Bel-air and Hann, 18 km between Hann and Cap des Biches, 60 km between Cap des Biches and Tobene, 43 km between Cap des Biches and Thies, 30 km between Thies and Tobene, and 13 km between Tobene and Taiba. The 225 kV transmission line, which is 123 km between Tobene and Sakal, is currently operated at 90 kV.

4) Substation facilities

Excluding the step-up transformers for generator of RGI systems (Saint-Louis and Kaolack excluded), the total capacity of 90/30 kV stepdown transformers is 226 MVA, that of 30/6.6 kV stepdown transformers is 121.9 MVA, that of 6.6/6.6 kV interconnecting transformers is 40 MVA, and that of 6.6/30 kV stepup transformers is 15.95 MVA.

5) Distribution line facilities

The distribution line voltages of SENELEC include 30 kV, 6.6 kV, 380 V, 220 V, and 127 V. Regarding the distribution voltages of 220 V and 127 V, efforts are currently made to gradually changeover them to 380 V and 220 V respectively. The lengths of the distribution lines in the whole country as of 1989 was: 2,244 km for the 30 kV lines, 641 km for the 6.6 kV lines, and 634 km for the low voltage lines.

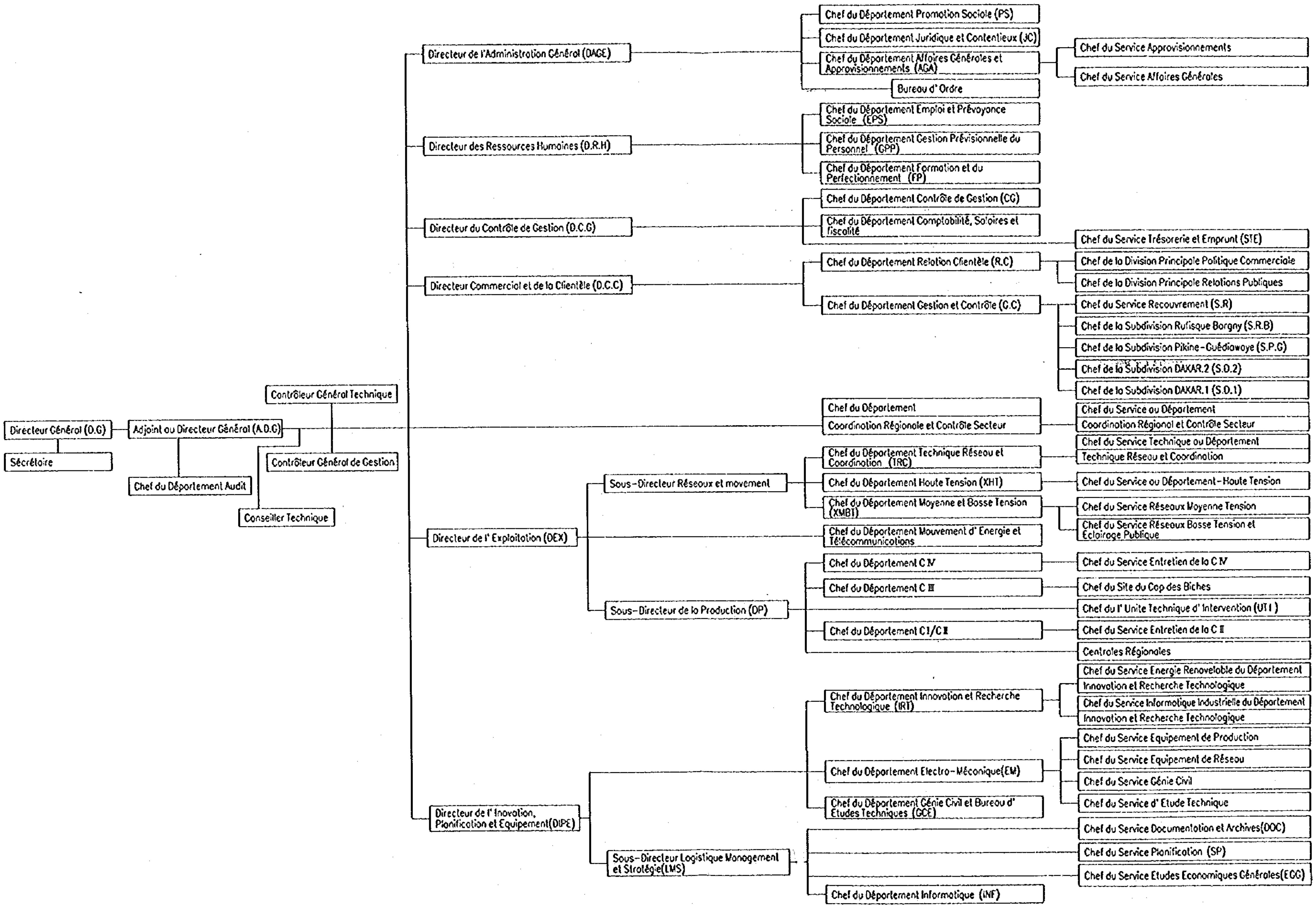


Fig. 2.4.2-1 Organization of SENELEC

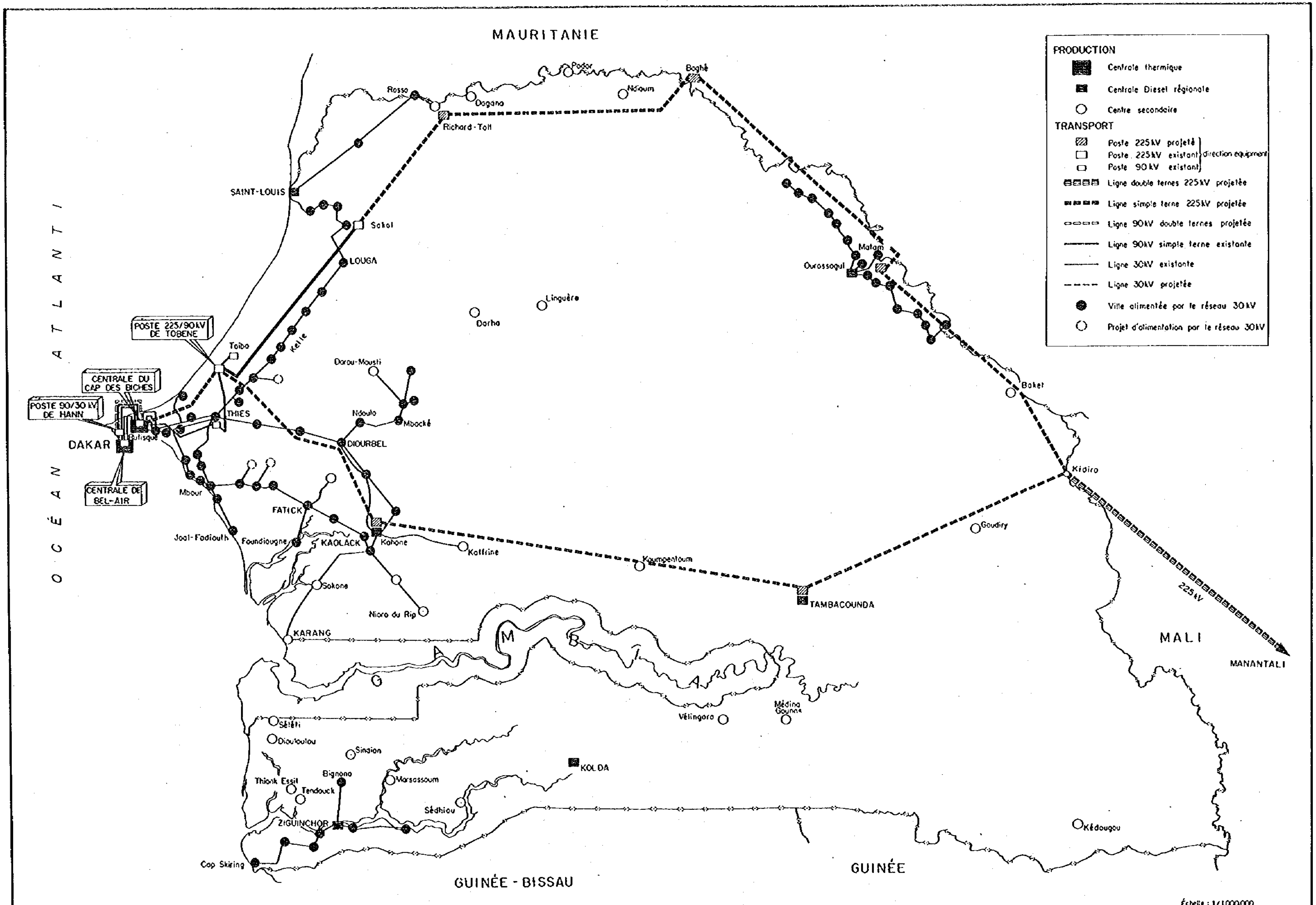


Fig.2.4.2-2 Power System Map

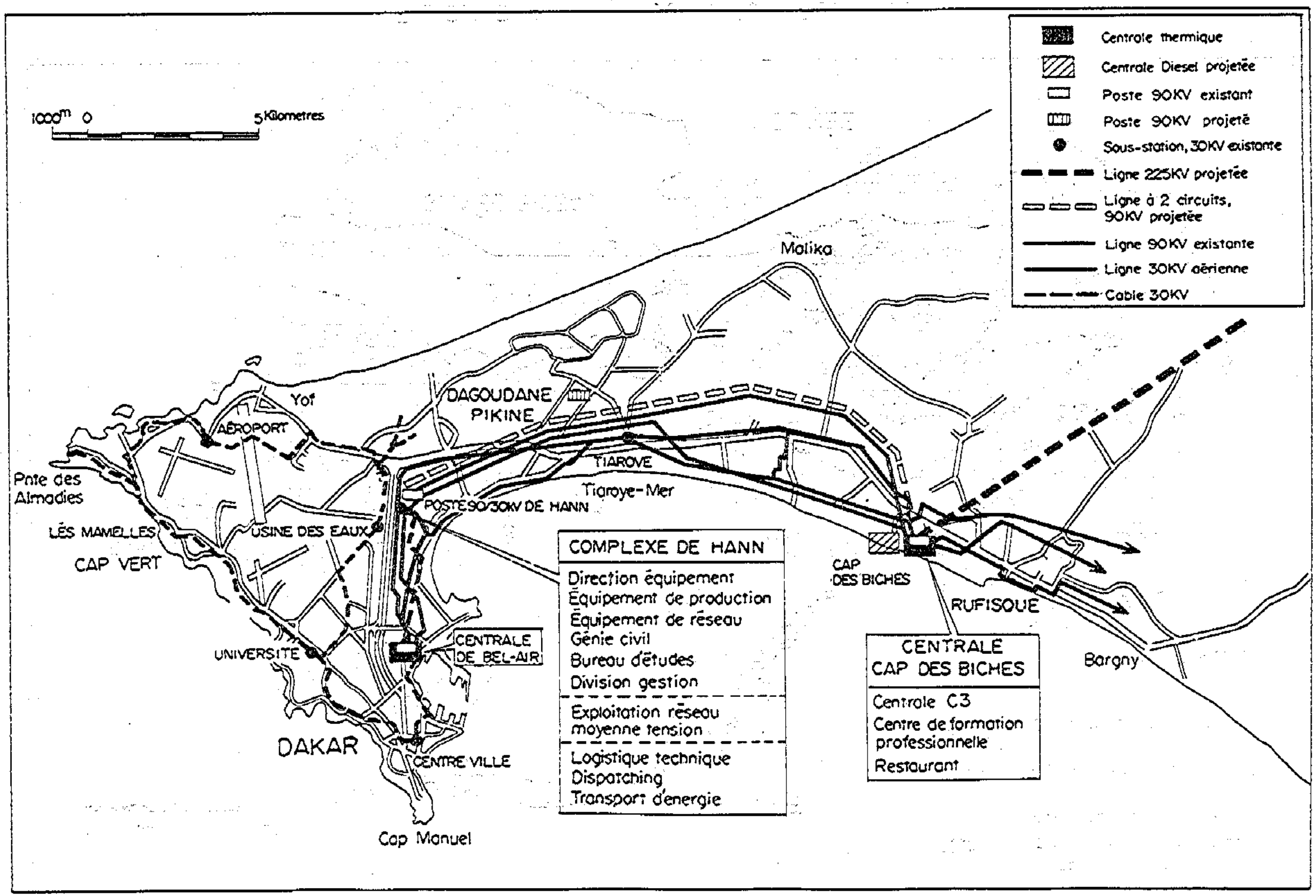


Fig. 2.4.2−3 Power System Map of DAKAR Area

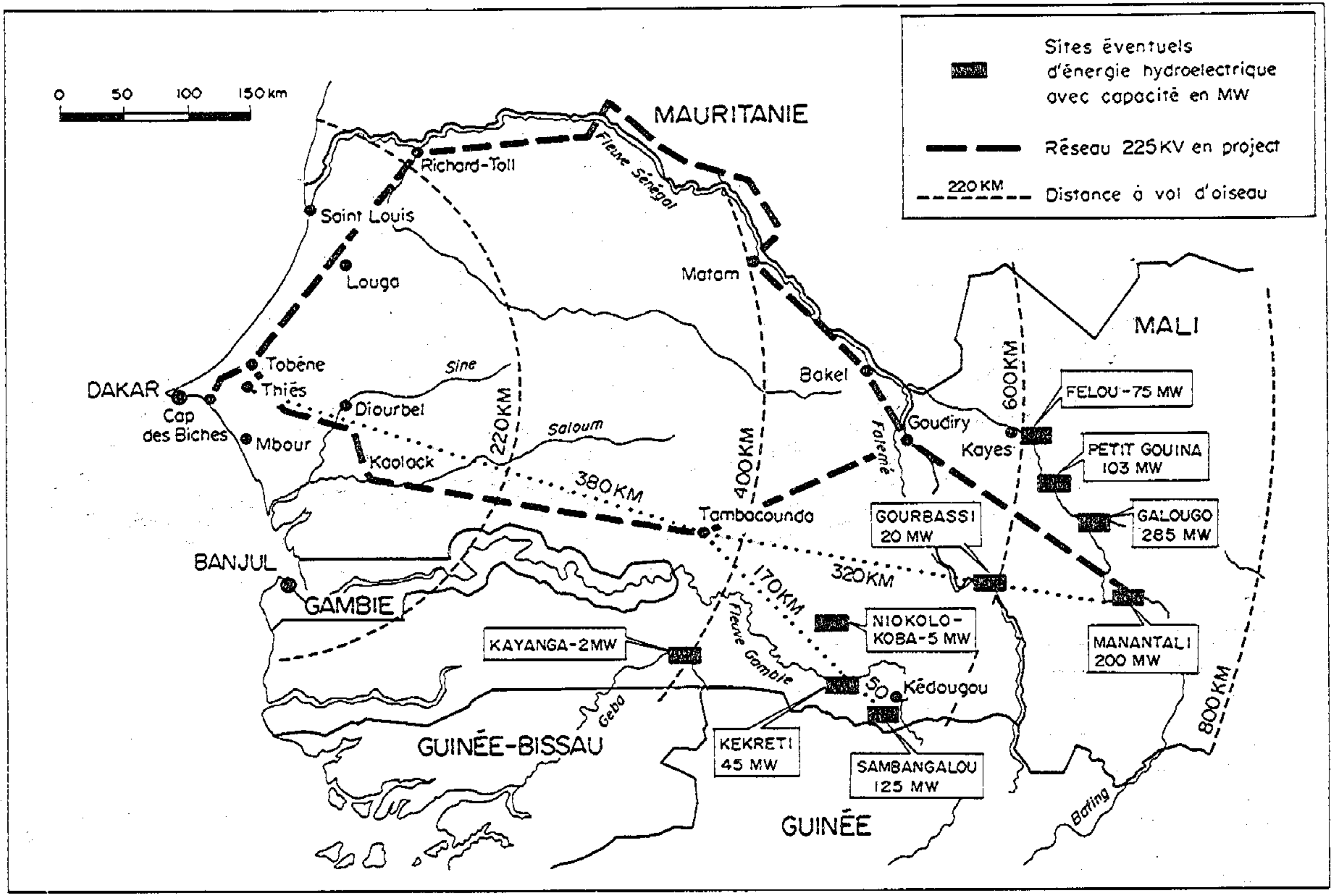


Fig. 2.4.2-4 Hydroelectric Potential

CHAPTER 3

PRESENT SITUATION

OF

EXISTING POWER FACILITIES

CHAPTER 3 PRESENT SITUATION OF EXISTING POWER FACILITIES

To understand the present situation of power facilities in detail and set up the most suitable power generation plan, the following facilities in the Dakar area were surveyed.

- Power generating facilities
- Transmission line facilities
- Distribution line facilities
- Substations facilities
- Communications and control facilities
- Work shop for maintenance and repair

3.1 Power Generating Facilities

3.1.1 Electric Power System of Senegal

The electric power system of Senegal is being managed by Senegal's electric power corporation SENELEC and consist of the Reseau Interconnect (RI) and the Sentress Secondaries. The RI is also called the Reseau General Interconnect (RGI) by including the Saint-Louis system and the Kaolack system. The former is planned to be interconnected during 1994 and the latter in 1997. All the generating facilities of RGI consist of thermal power generating facilities (such as steam turbine, gas turbine and diesel), producing the rated output of 251,200 kW (RI: 226,700 kW) as of the end of 1993 and actual limit output of 201,000 kW (RI: 176,500 kW). Table 3.1-1 shows the specifications of the boilers and turbines of the power generating facilities installed in Bel-Air and Cap-des-Biches. Table 3.1-2 shows the generator capacity, fuel consumption rate, lubrication oil consumption rate and commissioning year of the generating facilities installed in RGI as of the end of 1993. Table 3.1-3 shows the evolution of existing power generating facilities of RGI system. Graph 3.1-3 shows the yearly evolution of power generating facilities of RI system. The ratio of RI system as of 1993 as to the actual limit output of the peak load (generating end) is 85.3%. However, this ratio is even higher from the viewpoint of the reality of the supply restrictions to be described in section 4.4. In defining the capacity of the power generating facilities, SENELEC has four ways, i.e., the rated capacity, the economical capacity, the actual limit capacity and the short-time capacity.

- Rated capacity: Refers to the installed capacity.

- Economical capacity: According to the explanation by SENELEC, the economical capacity refers to "about 90 % of the rated capacity - a capacity which indicates the most efficient fuel consumption rate. " Even actual operations are performed in this capacity or higher. The nameplate does not show the value of the economical capacity. However, in view of the change by the fuel consumption rate and load ratio of the 4-cycle diesel generation oriented, it can be said that SENELEC's power generating facilities have the characteristic of showing the lowest fuel consumption rate at about 90 % of the load capacity.

- Actual limit capacity: Indicates the capacity which can be output at the present point.

- Short-time rating: Applied to diesels to refer to the capacity which can be operated exceeding the rated capacity. The time allowed for continuous operation is taken 1 hour.

The power systems for other areas are called Centres Secondaries and available in a large number all over the country. Among them, the Ziguinchor power system and the Tambacounda power system comparatively large in power scale.

3.1.2 Power Generating Facilities of SENELEC

The power generation facilities of SENELEC as of 1993 are as follows:

(1) Reseau Interconnect (RI)

The power generating facilities in RI system include the Bel-Air power station in the Dakar region and the Cap-des-Biches power station in the Rufisque area.

a. Bel-Air power station
The steam power generating facilities were installed from 1953 till 1961 and the diesel power generation facilities were installed with grant aid from Japan in 1991, thus the total generating capacity reaching 61,200 kW at the rating, 49,000 kW

at the economical operation, and 40,000 kW at the actual limit operation. Even the oldest facility which has already the performance records of 42 years (as of 1994) exceeding the service life is still in operation due to delay in commissioning of new generating facilities.

The buildings housing the steam power generating facilities are extremely old (oil leakage on the basement floor, corrosion on steam pipes, etc.) and reduced in their outputs (with G101, the actual limit output is 5,000 kW as to the rated capacity of 12,800 kW); therefore, it is recommended that they are stopped operation as soon as possible.

The electric facilities for outdoor switchyard are also observed oil leakage from main transformers as with power generating facilities, occurrence of rust on surface of copper conductors, and sand dirt deposited on equipment. The generator transformer installed is SEM Brown Bouveri's Auto-Transformer commissioned in 1965. The upper limit of the voltage is 7,375 V, the medium voltage 6,860 V, and the lower limit 6,345 V with 11 steps - a standard tap.

Fig.3.1-1 shows the plan drawing of this power complex.

b. Cap-des-Biches power station

This power station has the steam power generating facilities installed from 1966 till 1972, the gas turbine units installed in 1972 and 1984, and the diesel units installed in 1990. The total generating capacity is 165,000 kW at the rating, 148,000 kW at the economical operation, and 136,500 kW at the actual limit operation. As with the old-type facilities at the Bel-Air power station, even the oldest facility which has already the performance records of 29 years (as of 1994) exceeding the service life cannot be stop the operation due to delay in commissioning for new generating facilities and is still taking the responsibility of a very important power supplying base of the SENELEC in the Dakar area.

The electric facilities for outdoor switchyard are observed especially oil leakage from main transformers, occurrence of rust on surface of bare copper conductors, sand dirt deposited on devices.

Fig.3.1-2 shows the plan drawing of this power complex.

(2) Saint-Louis Power System

This system is equipped with four high-speed diesel generating facilities using the diesel oil as the fuel, which were installed from 1979 till 1980. The total generating capacity is 10,500 kW at the rating, 9,450 kW at the economical operation, and 10,500 kW at the actual limit operation. After being interconnected to the RGI system in 1994, the Saint-Louis power system has been playing the role of substitute operation of the gas turbine generating facilities.

(3) Kaolack Power System

Four medium speed diesel generating facilities which were installed from 1982 till 1988 are equipped with the Kahone power station. The total generating capacity is 14,000 kW at the rating, 12,600 kW at the economical operation, and 14,000 kW at the actual limit operation. In 1997, it is going to be interconnected to the RGI system by the 225 kV designed transmission line (operated at 90 kV) between Tobene and Kahone. After the linkage, this system is going to play the role of the substitute operation of the old facilities of the Bel-Air power station.

(4) Sentress Secondaries

No investigation of generating facilities was carried out in this project stage.

3.1.3 Site Environments of Power Station

a. Bel-Air power station

The Bel-Air power station faces the Felix Eboue street of the

Industry Zone. The circumference of power station is surrounded by factory buildings and is situation near coast crowding port facilities.

The diffusion of exhaust gas and incompletely burnt components caused operation of steam turbine which looks out toward neighboring factories is seen depending on the direction of the wind.

b. Cap des Biches power station

The Cap des Biches power station is located on the coast of the Atlantic Ocean in Rufisque zone, approximately 20 km east from the Dakar city center. As with the Bel-Air power station, the odorous exhaust gas generated from operation of boilers and produced through low chimneys is a matter of great concern, although no private houses are nearby.

3.1.4 Fuel Supply

Heavy oil supply to both power stations above of RI system is made directly through pipe lines from the SAR (Societe Africaine de Rafinage). However, the light oil is transported by truck.

The maintenance of buried pipe lines for fuel transportation is done by SAR.

3.2 Transmission Line Facilities

3.2.1 Outline of Power Supply Systems

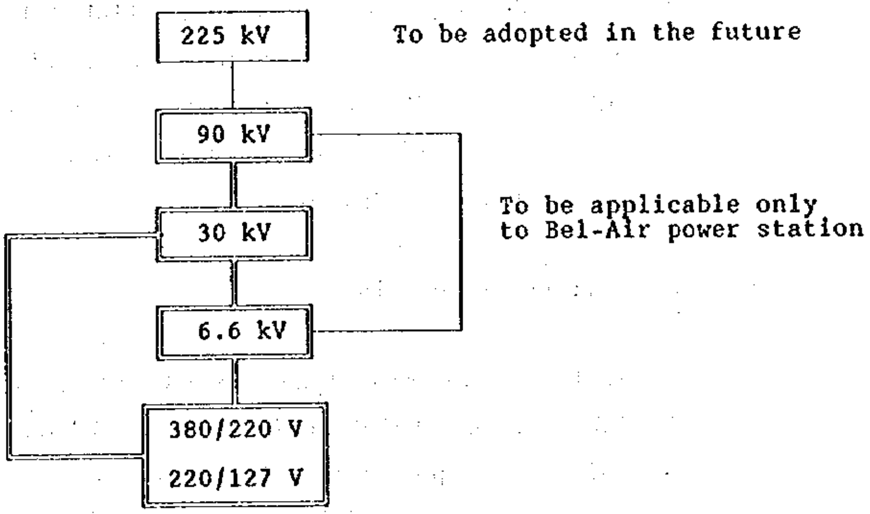
As stated in 2.4.2.3 "Power Facilities", the power systems of SENELEC are divided broadly into such two categories as the Reseau General Interconnect (RGI) that includes Dakar, the capital city, and other local cities, Saint-Louis and Kaolack as its nucleuses, and the Centres Secondaires that comprises twenty countrywide local regions to which each independent power system supplies the power.

In the Reseau General Interconnect, the power is supplied to the cities fronting on the Atlantic such as Dakar, Rufisque, Thies, Taiba, Saint-Louis and Kaolack. In particular, the system that connects Dakar, Rufisque, Thies and Taiba by 90 kV transmission lines is called the Reseau Interconnecte (RI).

The transmission line between Tobene and Sakal is operated with the voltage of 90 kV at present, and planned to operate at 225 kV due to its design condition.

As for the Saint-Louis and Kaolack regions, the power is supplied to these regions by 30 kV transmission lines respectively. However, despite the linkage with the Dakar system by 30 kV transmission line, power supply to these regions is carried out entirely independently without any power interchange with the Dakar system like from Dakar to Saint-Louis and Kaolack or the reverse.

The transmission and distribution voltage by SENELEC is as follows:



Note) The 30 kV line is classified into the distribution line in the Dakar region while it is classified into the transmission line in other regions.

3.2.2 Transmission Line Facilities

(1) 225 kV Transmission Line

A 225 kV transmission line is planned to be constructed along the borders in a joint venture project to be undertaken by Senegal, Mauritania and Mali. The purpose of this project is to construct a facility to supply the power, which will be produced from the 200 MW hydroelectric power station presently under construction at Manantali in the Republic of Mali, to those three countries. This facility is scheduled to be completed in 2000. Fig. 3.2-1 shows the related transmission system by Manantali joint project.

In view of the above, SENELEC has started construction of a two-circuit 225 kV transmission line between Tobene and Sakal aiming at linkage with the above-mentioned transmission line. As of September, 1994, one of the two-circuits of the subject 225 kV transmission line was completed and temporarily being operated with the voltage of 90 kV.

(2) 90 kV Transmission Line

The power stations and substations linked by the 90 kV transmission lines are such two power stations as Bel-Air and Cap des Biches (and one substation as Hann) located alike in the Dakar region, and such two substations as Thies and Tobene. Fig. 4.1.2-1 shows the 90 kV transmission line diagram.

(3) 30 kV Transmission Line

The 30 kV transmission line connects the major three systems, namely, the Dakar system, Saint-Louis system and Kaolack system. Nonetheless, each of these major systems is regularly operated entirely independent of the other systems without any power interchange among them.

3.2.3 Outline of the Facilities

(1) Outline of Transmission Line

The 90 kV transmission line connects Cap des Biches power station and Hann grid substation, and Hann grid substation and Bel-Air power station.

The outline of the 90 kV transmission line facilities in the Dakar region is as follows:

1) Cap des Biches power station to Hann substation

	C.D.B to Hann (1)	C.D.B to Hann (2)	C.D.B to Hann (3)
a. Commencement of operation:	1959	1970	1990
b. Line length :	18 km	18 km	18 km
c. Number of circuits :	1 cct	1 cct	2 cct
d. Kind of conductor :	ACSR(*)	-Ditto-	-Ditto-
e. Size of conductor :	288 mm^2	288 mm^2	366 mm^2
f. Kind of overhead ground wire :	Aluminum -clad steel wire	-	Aluminum -clad steel wire
g. Size of overhead ground wire :	94.1 mm^2	-	94.1 mm^2

2) Hann substation to Bel-Air power station

	Hann to Bel-Air (1)	Hann to Bel-Air (2)
a. Commencement of operation:	1953	1990
b. Line length :	5 km	5 km
c. Number of circuits :	1 cct	2 cct (1 circuit is not connected yet.)
d. Kind of conductor :	ACSR(*)	-Ditto-
e. Size of conductor :	288 mm^2	288 mm^2
f. Kind of overhead ground wire :	Aluminum -clad steel wire	-
g. Size of overhead ground wire :	94.1 mm^2	-

Note: ACSR(*); Aluminium Alloy Cable Steel Reinforced

(2) Supporting Structure

As supports of 90 kV transmission lines in the Dakar region, steel towers (one circuit or two circuits assembly) are used in ordinary areas while twelve-cornered mono-poles are adopted in densely populated areas or where it is difficult to acquire the construction land. The minimum conductor height above ground is set at 8.5 m. Fig. 3.2-3 shows the existing steel tower configuration drawing.

(3) Insulator

250 mm suspension insulators and 330 mm aero-type insulators, both of which are made of glass, are adopted.

(4) Measures to be taken Against Salt Contamination

The 90 kV transmission line routes from Cap des Biches power station to Hann substation and from Hann substation to Bel-Air power station are situated very close to the seashore thus posing trouble that salt is often deposited on the surface of the insulators. To cope with it, cleaning of the insulators is performed at least once a year.

3.3 Distribution Line Facilities

The power is supplied to the distribution poste located in each area from respective distribution substation through 30 kV and 6.6 kV 3-phase, 3-wire distribution lines, and then supplied to consumers after being transformed to medium-voltage or low-voltage power.

As regards the descriptions given in this report, the terms related to the substations (Poste) are understand as follows:

a. Grid substation
- Bel-Air (90 kV/30 kV/6.6 kV)
- Hann (90 kV/30 kV)
- Cap des Biches (90 kV/30 kV)

b. Distribution substation (30 kV/6.6 kV)
- Usine de Eaux
- Thiaroye
- Aeroport Yoff
- Centre Ville
- Universite

c. Distribution Poste
Distribution Poste means all Poste that supply 30 kV/low-voltage and 6.6 kV/low-voltage power to the ordinary consumers.

(1) Medium-voltage Distribution Networks

1) 30 kV distribution line

Fig. 3.3-1 to 3.3-2 show the 30 kV distribution line networks in the Dakar region as of December, 1994. The 30 kV feeders at respective grid substations are as follows:

a. Bel-Air grid substation
- Hann
- Sipl
- Centre Ville

b. Hann grid substation

- Amerger
- Hann Pecheurs
- Centre Ville
- Bel-Air
- Hlm Patte d'Oie
- Hann Labo
- Universite
- Aeroport Yoff
- Soprim

c. Cap de Biches grid substation

- Rufsac
- Sies
- Villa Cap des Biches
- Km22
- Rufisque Nord

The 30 kV feeders of SENELEC in terms of overhead line and underground cable are as follows:

Overhead line	148.84 km
Underground cable	141.74 km
Total	290.58 km

The breakdown of the above is shown in Table 3.3-1.

2) 6.6 kV distribution line

Fig. 3.3-3 to 3.3-5 show the 6.6 kV distribution line networks in the Dakar region as of December, 1994.

The 6.6 kV feeders of SENELEC in terms of overhead line and underground cable are as follows:

Overhead line	124.54 km
Underground cable	192.70 km
Total	317.24 km

Table 3.3-2 shows the length of 6.6 kV feeders and to what categories, i.e. the overhead line or underground cable, they belong.

(2) Distribution Poste

1) Type of distribution Poste

The 30 kV or 6.6 kV power is transformed at respective distribution Poste to the supply voltage (380 V/220 V, 220 V/127 V) to the consumers. The distribution Poste are divided into the following three categories depending upon the owners:

a. Exclusive use by SENELEC
b. Exclusive use by consumers
c. Common use by SENELEC and consumers

Number of distribution Poste in terms of owners are as follows:

	Exclusive use by SENELEC	Exclusive use by consumers	Common use use by SENELEC & consumers	Total
30 kV/low-voltage	136	130	2	298
6.6 kV/low-voltage	370	420	40	830
Total	506	580	42	1,128

Table 3.3-2 and Table 3.3-3 show the details of the above number and Fig. 3.3-6 shows the single-line diagram of each of the above Poste.

2) Configuration of distribution Poste

The distribution Poste are divided into old and new types depending on the configuration of buildings.

The Poste with a layout where the lead-in insulators are installed on the exterior wall of a tall building (because of its height) is called the old type while the Poste with a layout where a leading-in pole is built next to the building on the

Poste side thus allowing the building to be built comparatively low is called the new type.

3) Transformer capacity

Table 3.3-4 shows the number of distribution transformers owned by SENELEC and being connected to respective distribution substations as of 1992. Table 3.3-5 shows in terms of capacity the number of transformers installed.

(3) Low-voltage Distribution Line

The electric power is supplied to the consumers with 3-phase 4-wire system. As for the voltage, the following two types are mixedly supplied:

B1 type....... 3-phase, 4 wire, 220 V/127 V
B2 type....... 3-phase, 4 wire, 380 V/220 V

B1 type is the old type which is now widely used in the most part of the urban areas of Dakar where the electrification has been implemented since early days. Presently, however, the B1 type is being replaced with the B2 type by SENELEC aiming at substantial decrease in the distribution loss and increase in the supply power.

The distribution lines consist of the overhead lines and underground cables, of which some overhead lines are still bare conductors which are however being replaced with insulated cables one by one currently.

(4) Distribution Line Route

As for the 30 kV distribution lines, the underground cables are mostly used in the city of Dakar with the exception of the line between the Cap des Biches power station and Hann grid substation where the overhead line is partly adopted.

As regards the 6.6 kV distribution lines, the overhead lines and underground cables are mixedly used in the city of Dakar. However, the replacement work has already been started by SENELEC in order to replace the overhead lines with the underground cables.

(5) Support

The followings are employed by SENELEC as a support of distribution lines:

- Concrete pole
- H-shape steel
- Wooden pole

The concrete poles are mostly used for the 30 kV distribution lines with the exception of the use in part for the 6.6 kV distribution lines. The H-shape steel is used for the 6.6 kV and low voltage distribution lines in the city of Dakar as well as the suburbs while the wooden poles are only adopted in the suburbs.

(6) Conductor

Small sized conductors have been used for the existing distribution lines by SENELEC thereby so far causing the following problems:

- Increase in the distribution loss
- Excessive voltage drop
- Insufficient supply capacity of the feeders

In order to solve these problems and improve the situations, rehabilitation works are underway by SENELEC currently.

(7) Insulator

The insulators adopted for the 30 kV and 6.6 kV distribution lines are as follows:

	30 kV	6.6 kV
Suspension set	250 mm suspension insulator (4-5 discs)	Pin insulator
Tension set	250 mm suspension insulator (4-5 discs)	250 mm suspension insulator (2-3 discs)

(8) Others

1) Repair and calibration of watt-hour meter

Repairs and calibration of the watt-hour meters are undertaken by the Instrument Section. After completing the calibration work, the watt-hour meters are sealed with the attendance of representatives from the Instrument Section and Economical Control Section. The specified permissible tolerance to be used for the calibration is ±3%.

a. Watt-hour meter for ordinary consumers
The calibration of the watt-hour meters installed for the ordinary consumers is not performed periodically with the exception of the following cases:

- When requested so from the consumers.
- When watt-hour meter is in failure.
- At the time of sampling inspection.

b. Watt-hour meter for large industrial consumers
As a rule, the calibration of the watt-hour meters installed for the large industrial consumers is performed once a year plus whenever requested so from the consumers.

2) Cable connection

To protect the cable from the lightning surge, arcing horns are attached to the tension insulator strings at the connection of the overhead lines of the 30 kV transmission lines and underground cables and thus the lightning arresters are not provided.

3) Pilferage (fraude)

In order to cope with the pilferage, such measures are taken by SENELEC as to completely stop supply of the electricity.

To cope with the pilferage, the following measures are taken by SENELEC:

- To seal watt-hour meters.
- To provide a key on instrument panels.
- To provide a key on housing boxes for instrument transformers.

3.4 Substation Facilities

In this report, as stated in the previous article "Distribution Line Facilities", major substations in Dakar area are taken as the three grid substations while the subsequent five substations are regarded as the distribution substations.

(1) Outline of the Facilities

Table 3.4-1 shows the outline of the facilities and years of commencement of operation as regards the above three grid substations and five distribution substations.

(2) Single Line Diagram

Fig. 3.4-1 (1/5) to 3.4-1 (5/5) show the single line diagrams of respective substations.

(3) Operation of Transformers

1) Standby transformer

In the SENELEC's power facilities, it is planned to install one unit of standby transformer at each substation as a rule.

2) Operation of transformers

Individual operation (1 unit operation, others are for standby) system is applied for main transformer except in Thiaroye substation. In Thiaroye substation, two units of main transformers are being operated at the same time due to the insufficient transformer capacity (7.975 kVA) caused by load increase.

The changeover between transformers is done in every month by non stoppage power changeover.

3) Voltage adjustment

The voltage adjustment of main transformer is conducted in such a manner that the primary voltage (high voltage side) is adjusted with automatic voltage regulator (LRT).

Secondary bus voltage is maintained within the specified level for both peak load and off-peak load duration. As far as the voltage adjustment, no remarkable problems exist because of the controllable fluctuation of automatic voltage regulator.

(4) Bus Pperating System

Bel-Air, Hann and Cap des Biches grid substations are considered to be large-scale substation with double bus system, however single bus operation system is employed for these substation.

It is recommended to adopt double bus system for substation operation to minimize the influence to the power system at the fault, because of the big influences against the power system due to the fault on bus conductor or transformers.

Single bus system is employed in the distribution substations, and the bus is sectionalized by disconnecting switch not circuit breaker so that system operation such as changeover of transformers becomes complicate.

3.5 Communication and Control Facilities

3.5.1 Communication Facility

The power system control of the Dakar area, which forms a major part of the RI system, is in the hands of the load dispatch center which monitors and controls the transmission line network of 90 kV or more as well as of the distribution control center which monitors and controls the distribution network of no higher than 30 kV.

The communication facility of the load dispatch center is based on the PLC system while the distribution control center is based on the VHF wireless telephone circuit system. Both are used for load dispatch operation and maintenance telephones.

(1) PLC System

All the 90 kV transmission lines are equipped with the PLC system. Communication lines using this are for the following uses.

- For load dispatch telephone
- For transmission line protection relay equipment
- For station information transmission equipment

Fig. 3.5-1 shows the PLC communication line network of SENELEC.
Fig. 3.5-2 shows the details of the PLC communication line diagram.
Fig. 3.5-3 shows the PLC frequency allocation.

a) Load dispatch telephone

The load dispatch telephone facility is made to be able to make contacts between the load dispatch center and the distribution control center and their respective remotely-controlled stations.

b) For transmission line protection relay equipment

The carrier protection relay equipment is used as the protection relay equipment of 90 kV transmission lines and is assigned with channels so that the single-phase reclosing and 3-phase reclosing are possible.

c) For station information transmission equipment

The information transmission line indispensable for achieving a reliable system operation is connected to the load dispatch center information transmission device of the Hann substation equipment. The line is used for processing the information acquiring from the remotely controlled stations as well as for transmission of the outgoing control information.

The specifications for the PLC equipment (ABB) coupler of the Bel-Air power station equipment are as follows:

Capacity of coupling condenser	:	10,000 pF
Primary impedance Z1	:	240 Ω
Secondary impedance Z2	:	75 Ω
Frequency	:	F1=52 kHz F2=500 kHz

(2) VHF Wireless Remote Supervisory Control System

Among 1,251 distribution poste in the Dakar area, 34 postes are remotely monitored and controlled by the distribution control center installed on the premises of the Hann substation by means of the VHF wireless remote supervisory control system.

The remote supervisory control system connects the information transmission line, which is based on the 170 MHz band VHF wireless line, with the information processor of the distribution control center and the remote terminal unit installed in the remotely controlled distribution substation, to monitor the acquiring information and transmit the outgoing control information. If the wireless line is VHF, it may be interfered by other lines due to changes in the radio wave's propagation characteristics, thus allowing faulty operations to be caused by faulty signals. However, by using a special cord, it is said that this type of faulty operation has never taken place since 1990.

The VHF wireless line has the advantages of being able to communicate with parties by trans-horizon propagation. Its problem is that, in the case of the substations installed in the Dakar city, not enough field strength is obtained due to skyscrapers, thus often making communications impossible.

(3) Dakar Area VHF Wireless Telephone System

This system consists of 170 MHz band VHF wireless telephone lines connecting the load dispatching center and distribution control centers with the power stations and substations, mobile vehicles, and portable telephones in the Dakar area via the Les Mamelles switching office (installed on a mountain top along the coast northwest of Dakar). One of the two telephone line channels of the press-to-talk system is for maintenance of low-voltage (380 V and 220 V) distribution lines; the other is for maintenance of transmission lines and medium voltage distribution lines.

(4) Regional (surrounding the Dakar area) VHF Wireless Telephone System

This system consists of 170 MHz band VHF wireless telephone lines connecting the load dispatching center and distribution control centers with the power stations and substations, mobile vehicles, and portable telephones in the Dakar area as well as a telephone line channel of the press-to-talk system.

3.5.2 Control Facilities

(1) Load Dispatching Center

Load dispatching center installed on the premises of the Hann substation, which is the only one load dispatching center in the RI system of SENELEC, and control of the 90 kV transmission lines and load dispatching instruction for all power stations are made from this center. As remotely controlled stations, there are three, i.e., Bel-Air, Hann, and Cap des Biches, in the project area; and two in other areas, i.e., Thiona and Tobene.

1) The load dispatching center is equipped with two work stations with 19-inch color CRTs, several printers (making hard copies as well), simplified system monitoring panels, recorder panels and desks.

a. Workstations

The operating information of equipment obtained from the information transmission line is managed in the file management system (transmission line file, power generation file, etc.). Many screen displays easy for the operator to understand are made available to enable rapid processing. Data collection items are as follows:

Analog information
Effective power, reactive power, voltages and frequencies

Digital information
Circuit breakers, disconnecting switches, line earthing disconnecting switches, fault signals

Pulse data
Pulse data has not been collected.

b. Printers
The printers are of dot-impact type.

c. Simplified system monitoring panels
Not automatically lighting type but manually operated type.

d. Recorder panel
Most of the recorders installed on the recorder panel are stopped.

e. Monitoring desk
Equipped with a telephone panel and writing space.

2) Tasks of the load dispatching center

The most important tasks of the load dispatching center are to make coordinations for economical power generation and to perform economical power transmission. The remote control is used to operate the circuit breakers and turn on/off the protection relay equipment of the unmanned substations Thiona and Tobene. The major tasks of the load dispatching center include the following.

a. Automatic system frequency control
No automatic frequency control operations are available. Instead, based on the standards listed below, the load dispatcher makes a telephone contact with Bel-Air and Cap

des Biches while observing the frequency meter to send instructions on increasing/decreasing the generator output for economical power generation. On the power station side, the output of the generator is manually adjusted as instructed and the frequency is returned to the default value.

- System frequency : 2% (49 - 50 Hz)
- Transmission line voltage: ±10 %
- Distribution line voltage: ±10 %

b. Power generation schedule

The power generation schedule of the following day is drawn up in accordance with the principle of "operating from the most cost-effective power generating facility" and transmitted by Fax to Bel-Air, Cap des Biches, Kahone, and Saint-Louis. On the power station side, the operating schedule is executed as instructed in the Fax transmission. Fig. 3.5-4 shows the power generation schedule of August 27, 1994.

c. System voltage adjustment

The system voltage adjustment function is not available. At each power station, the system voltage is maintained within the specified value by manually adjusting the generator voltage. Fine adjustments are made with the LRT (on-load automatic voltage regulator) installed at each power station.

d. System configuration

In principle, SENELEC's system configuration is based on the single bus bar operation method. The popularly used bus bar operation method is the double-bus bar operation except in cases of work and special reasons so that, if one bus is involved in an fault for any reason, it can be disconnected to allow the other one to continue the operation. As the systems increase in number in the future, it is recommended that this double-bus bar operation method be applied.

e. Maintenance of the file management system

Various types of files are managed.

3) Trend of the RI system

The trend in the RI system can be observed through the overview display made available on the control system of the load dispatch center. Fig. 3.5-5(1) shows the operating status of the Bel-Air power station. Fig. 3.5-5(2) shows the operating status of the Cap-des-Biches power station. Fig. 3.5-5(3) shows the trend status of the Hann substation. Fig. 3.5-5(4) shows the trend status of the RI system.

a. Power factor of generator

The operating statuses of the generators at the time (11:58) of our survey of Bel-Air in August were as follows:

- G105: Effective 4.1 MW, reactive 2.7 MVar, power factor 83.5 %
- G106: Not operating
- G102: Effective 8.2 MW, reactive 4.5 MVar, power factor 87.7%
- G103: Effective 10.5 MW, reactive 4.3 MVar, power factor 92.5 %
- G104: Effective 5.0 MW, reactive -1.3 MVar, power factor -97.7 %

The statuses at Cap-des-Biches are as follows:

- Gen.1: Effective 20.8 MW, reactive 0 MVar, power factor 100.0 %
- Gen.2: Effective 18.3 MW, reactive 8.5 MVar, power factor 90.7 %
- Gen.3: Effective 11.3 MW, reactive 0 MVar, power factor 100.0 %
- Gen.4: Effective 11.3 MW, reactive 5.7 MVar, power factor 89.2 %
- Gen.5: Effective 8.8 MW, reactive 17.3 MVar, power factor 45.3 %
- Gen.6: Effective 15.4 MW, reactive 1.6 MVar, power factor 99.4 %

As shown in the previous page, the power factor of generator is no less than 80% except in the special case of Gen.5 (45.3%) in Cap des Biches. Although this may be also be so because the data at the time of peak load is unclear, it is considered by load dispatchers and station operators that the voltage maintenance of the RI system generally is made possible by adjustment of the generator voltage. As far as the distribution line network of the Dakar area is concerned, the reasons affecting this may include the long distance of the underground cables installed, the comparative easiness of voltage maintenance, and the sufficient capacity of the 90 kV transmission line.

b. Bus voltage

When the performance results are viewed as to the normal value of 90 kV, the bus bar voltage at the Bel-Air power station is 91.7 kV, that at the Cap-des-Biches power station is 92.0 kV, 92.6 kV at the Hann substation. Thus, it is understood they are being operated at higher voltages. When related to the description in a. above, it is predicted that the RI system will eventually need the phase modifying equipment for the Hann substation.

c. System frequency

The system frequency is maintained within 1 Hz through manual adjustment in accordance with SENELEC's standards. The performance records of some representative days in 1993, which experienced remarkable fluctuations, are shown in Fig. 3.5-6. The following is the summary of this chart.

- The changes in the midnight band are minor.

- The load changes in the peak load band are generally divided into the cyclic load ranging from zero to several minutes; the fringe load ranging from several to 10 minutes; and the sustained load of no less than 10 minutes. According to the frequency chart, however, the cyclic component is about ±0.4 Hz (about ±5 MW in terms of the load); therefore, as the number of systems increase in the future, the fluctuation width is also expected to increase. The demand for governing operation by power generating facilities equipped with excellent frequency responsiveness such as gas turbines is effective as a measure for absorbing the sharply fluctuating system load into the peak load band and its importance is felt increasingly strongly. At the same time, it is considered necessary to conduct research on the adaptability of operating the governing operation at the Manantali hydro power plant, which is expected to be interconnected after the year 2,000.

- The fluctuation (between 10:00 to 11:00) due generator fault is remarkably large and manual adjustment is extremely difficult. Therefore, although the declined frequency can be recovered immediately through load shutoff, the high frequency is made to stay for a long period of time for lack of measures such as system splitting circuits against frequency rise. This measure will become a very important item in the future when a large capacity of units are introduced into the system.

- The supply shutoff is determined at about 19:20 and 20:55, clearly aimed at the frequency recovery in a straight line. Based on the size of the recovery frequency, it is determined that the load of about 1 Hz and 15 MW is shut off.

(2) Distribution Control Center

One distribution control center is set up on the premises of the Hann substation as SENELEC's RI system to control and collect information on the circuit breakers of remotely controlled substation not exceeding 30 kV.

As major devices, the center has a monitoring desk equipped with a workstation with 19-inch color CRT as well as a printer. It does not have the monitoring panel and the recorder panel.

a. Workstation

The workstation is able to perform management of operating information of equipment (especially, remote measurement of amperes on behalf of watt-hour meter) by various file management systems, remote control of circuit breakers by the distribution line network management system, turning on/off of the protection/control device, and control of on/off of the load limiter. It can also handle fault management on the CRT.

b. Printer

The printer is of the dot-impact type.