BASIC DESIGN STUDY (Phase II) REPORT

ON

FUEL TRANSPORTATION PROJECT

FOR

THE POWER PROJECTS

IN

THE REPUBLIC OF THE SUDAN

FEBRUARY 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of the Sudan, the Government of Japan has decided to conduct a basic design study (phase II) on the Fuel Transportation Project for the Power Projects and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Sudan a study team headed by Mr. Kiyoshi SUWA, Deputy Director, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, from November 2 to November 16, 1986.

The team had discussions on the Project with the officials concerned of the Government of the Sudan, and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

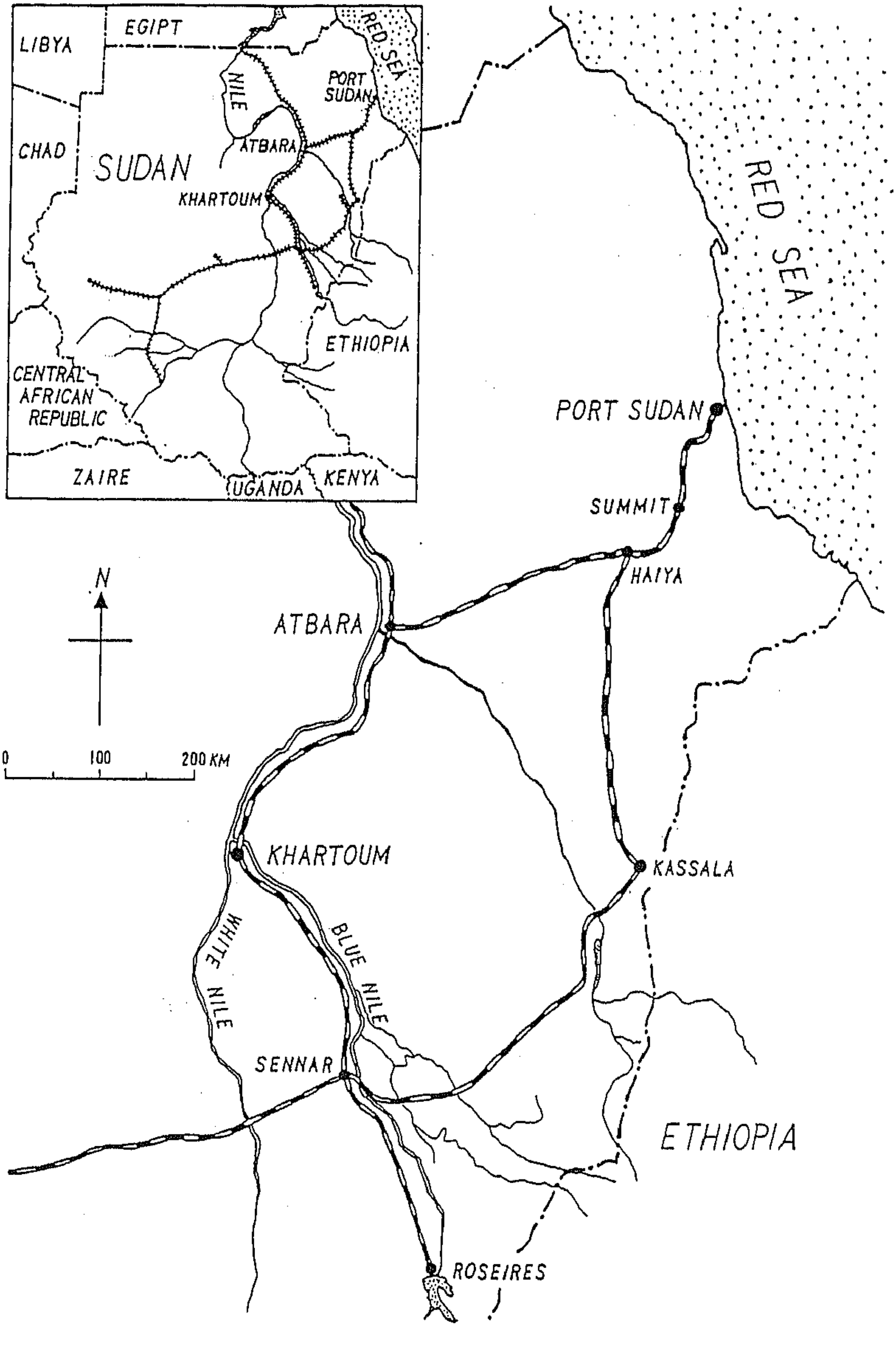
I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

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

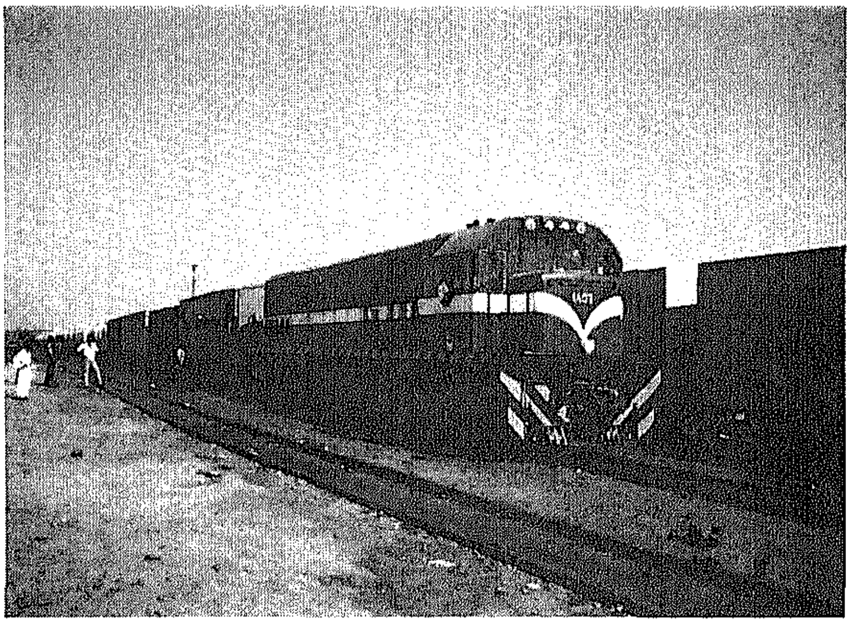
February, 1987

Keisuke Arita

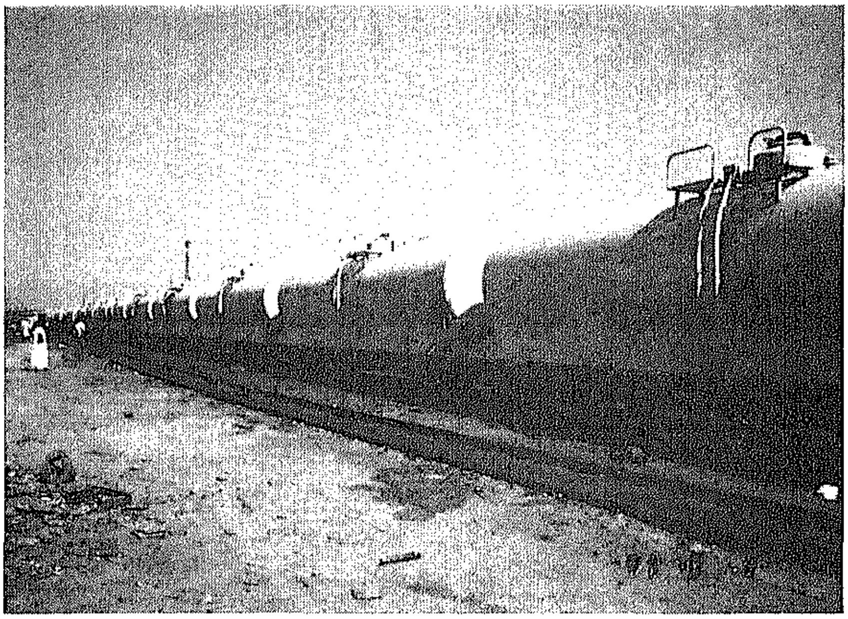
Keisuke ARITA
President
Japan International Cooperation Agency



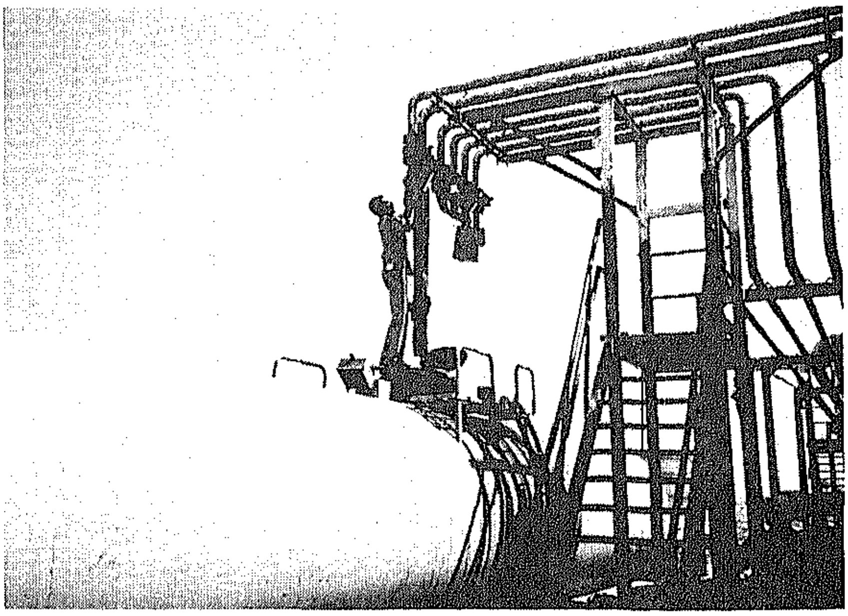
Sudan Railways – Port Sudan to Khartoum



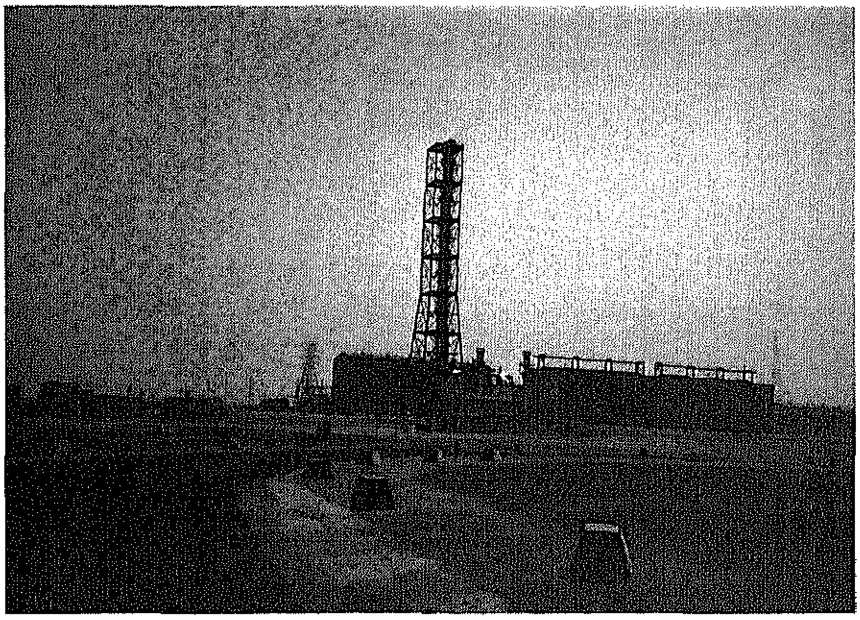
Fuel transport train (mixed)



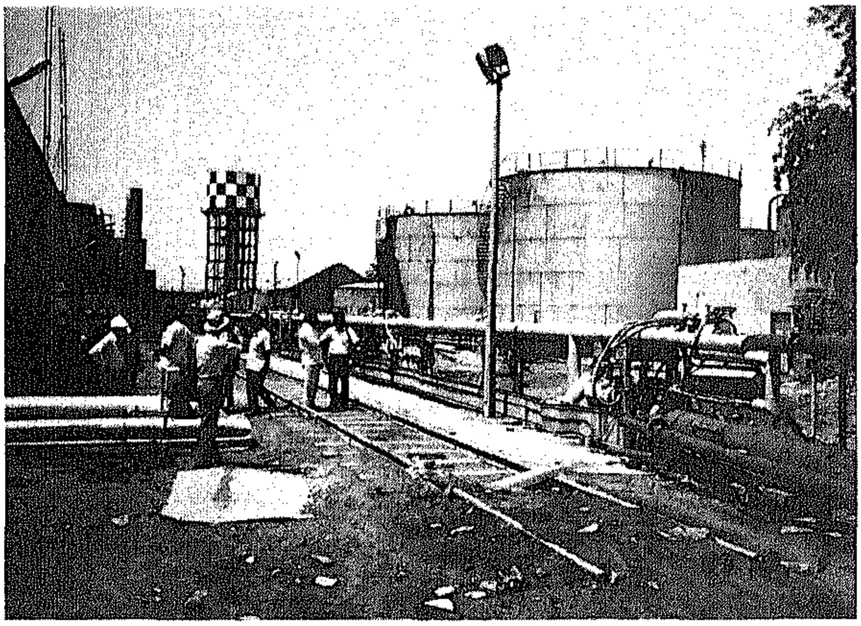
Tank wagons



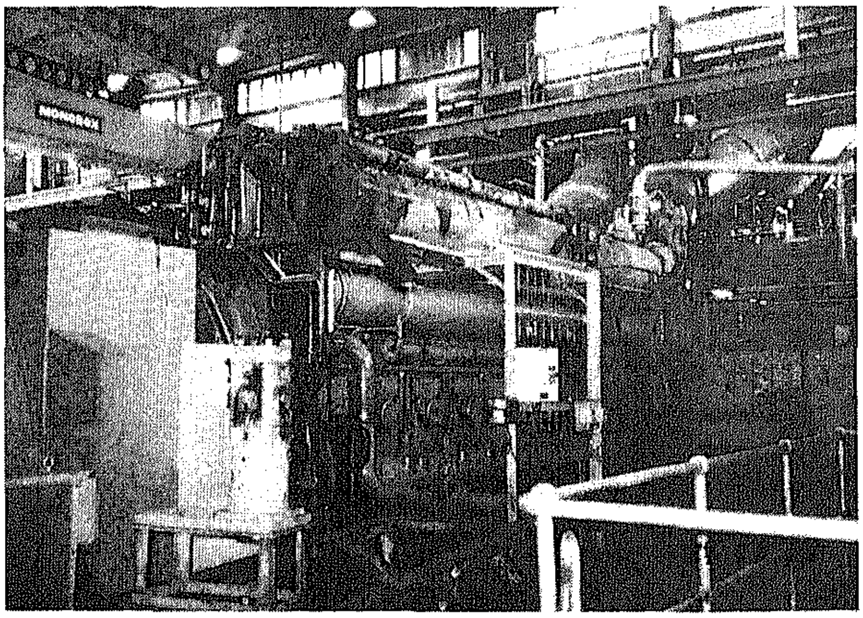
Loading facilities (Port Sudan)



Khartoum North Power Station



Burri Power Station



Diesel power plant (Burri Power Station)

SUMMARY

SUMMARY

In order to reinforce electric power generating facilities, the Republic of the Sudan has implemented, since 1961, the Power I, II, and III Projects, with the first two concentrating mainly on hydraulic power generation, and the third on reinforcing equally both hydraulic and thermal power plants, and they were essentially completed in 1985.

In spite of this, power generation capacity and generated energy per capita in the Sudan are only 23 W and 54 KWH, respectively. These figures are some of the lowest in the world.

Electrified areas consist of Khartoum, the capital, and 15 major regional cities, but in the areas electric power networks and consistent supplies of electricity exist in only 2 regions: a part of the Blue Nile River basin, including Khartoum, and a part of the Atbara River basin. As for the other cities, small isolated diesel generators are being used.

The Power IV Project consists mainly of thermal plants; accordingly, after the completion of this Project, fuel consumption at NEC (National Electricity Corporation) power plants is expected to increase sharply. On the other hand, the transportation capacity of SRC (Sudan Railways Corporation) has tended to decrease since fiscal year 1979/80, and it was judged that SRC would not be able to cope with the increases in fuel transportation.

Therefore, the Power IV Project came to include measures to improve the facilities for fuel transportation (Hereinafter these measures are referred to as Fuel Transportation Project). In fact, the limited transportation capacity of SRC became an actual problem as the Power III Project progressed, because of increases in fuel consumption from fiscal year 1983/84 due to the reinforcement of thermal plants. SRC thus became incapable of coping with the fuel transportation needs in 1984/85, and fuel transportation by road began in May 1984.

As in the case of the Power III Project, the financing of the Power IV Project was conducted with the World Bank, with a loan negotiated for the portion of the Project that showed the highest investment effect, while Grant Aid would be requested from interested countries for the other portions of the Project where the investment effects were lower. The financial assistance for the Project was discussed and decided by donor countries at a meeting held in Paris in February 1984.

Following the agreement at the meeting, a request for a grant for the "Fuel Transportation Project" was sent to the Government of Japan, upon receipt of which, the Government of Japan decided to conduct a basic design study for this Project.

The Japan International Cooperation Agency (JICA) dispatched a study team to the Sudan from September 26 to October 17, 1985. This team discussed the Project with the Sudanese officials concerned, carried out field investigations, collected data and analyzed the data in Japan.

The results of the study were summarized in the "Basic Design Study Report on Fuel Transportation Project for Power Projects in the Democratic Republic of the Sudan" in January 1986, which mainly deals with the feasibility of the Fuel Transportation Project and the basic design of the facilities for the Project.

Subsequently, it became necessary to evaluate the Fuel Transportation Project in relation to the entire Power IV Project, and at the request of the Government of the Republic of the Sudan, the Government of Japan determined to carry out another basic design study —— "Basic Design Study (Phase II)" —— and ascertain the approach and intention of the World Bank regarding the Power IV Project.

Accordingly, JICA dispatched a study team to the Sudan from November 2 to 16, 1986, to hold discussions with the Government of the Republic of the Sudan, NEC, SRC, and the World Bank in the USA, as well as to collect data and engage in field investigations. The team analyzed the relevant data after it returned to Japan.

The results of the study are summarized in the following:

(1) It was ascertained from the investigations of the JICA study team that the Government of the Sudan had a strong desire to obtain Japanese financial assistance for the Fuel Transportation Project, that the World Bank (IDA) intended to handle the Sudanese Power IV Project by resorting to the Power Rehabilitation Project (by IDA) and Power IV Project (by IDA) which was being appraised at the time, and that both the Government of the Sudan and the World Bank regarded the Fuel Transportation Project indispensable for the success of the Power IV Project (by IDA).

(2) The team investigated the background and progress of the power reinforcement plan (Power I ~ Power III) of the Republic of the Sudan and surveyed the present condition of assistance for the Sudanese Power IV Project from international assistance organizations and foreign countries. It was found that four international assistance organizations (IDA, ADB, and others) and eight countries (West Germany, Denmark, and others) are now assisting in or planning to assist in the Power IV Project with respect to reinforcement of power stations, substations, and transmission lines in the form of grants and loans.

(3) As for fuel transportation, the team investigated the present situation of railway and road transportation, and learnt the intentions of the Government of the Sudan and the World Bank, and it was ascertained that fuel transportation for the power plants should be provided by rail from the viewpoint of both economy and reliability, which is in line with Sudanese study plans.

(4) It was ascertained that the diesel locomotives requested for this Project would be owned by NEC and be used for fuel transportation exclusively, and that SRC could possibly reduce its tariff for this transportation in view of the reduced cost, since the locomotives are to be procured free of charge.

(5) As for the Fuel Transportation Project, the results of the study are as follows, these being much the same as the previous study:

① Due to the change in the target year of this project to fiscal year 1989/90 from 1988/89 (previous study) and a modification in the NEC demand forecast, the power demand was modified from 1883 GWH (previous study) to 1961 GWH (this study), of which thermal generation is to supply 761 GWH(this study) instead of 590 GWH (previous study).

② As a result of this modification, the forecast of fuel consumption was raised from 198,000 t (previous study) to 209,000 t (this study).

③ Although the consumption of fuel increased slightly, the transport scheme including composition of trains, usage of locomotives and round-trip time, were kept the same as in the previous study. As for the number of main line diesel locomotives required for this Fuel Transportation Project, it was concluded that 6 locomotives would be enough, provided that round-trip time would be shortened and equipment availability would be improved as soon as possible to reduce transportation cost.

④ As for communication equipment, the same conclusion as that in the previous study was reached, that is to say, the same type of on-board radio equipment currently used should be provided for the new locomotives, but the equipment for communicating with related organizations in and between wayside cities is not considered to be urgent.

⑤ As for the time schedule for the implementation of this Project, the same conclusion as that in the previous study was obtained; accordingly, it will take approximately 22 months, as a whole, from the E/N to the completion of this Project, which can be broken down into detailed design 4 months, tendering 2 months, and manufacturing of locomotives 16 months.

(6) As for the evaluation of the effects of this Project, the following results were obtained:

① By executing this Fuel Transportation Project, the quantity of fuel oil required for NEC power plants will be secured and this will greatly contribute to the success of the Power IV Project.

② By executing the Fuel Transportation Project, the volume of SRC freight is expected to increase by approximately 14% (in fiscal 1989/90), and this will favourably affect SRC freight transportation, which has tended to decrease in recent years.

③ Railway transportation is much more economical than truck transportation, the cost of the former being only 58% of the latter. Therefore, the reinforcement of fuel transportation by the railway will contribute to reducing the cost of implementing the Power IV Project. The execution of this Fuel Transportation Project will change the present rail/truck fuel transportation system to a railway transportation one only, reducing transportation costs, and perhaps electricity fees by approximately 1.2%.

As mentioned above, it was ascertained that the Fuel Transportation Project was indispensable for the implementation of the Power IV Project, and the Power IV Project would greatly contribute to a stable supply of electricity and some reductions in the fees for using it.

Finally, the following recommendations are made to the Sudanese authorities to enable the smooth implementation of this Project.

(1) To the Government of the Sudan:

① To clearly define the responsibilities of the related organizations for major aspects of the Fuel Transportation Project, including fuel procurement, loading and unloading, reliable train operation, provision of additional installation, and operation and maintenance of facilities, and to monitor their performance at all times, giving necessary advice and guidance to them.

② To guide SRC towards a tariff reduction for fuel transportation for NEC power plants, taking into account transportation costs, and to guide NEC towards suppressing electricity fees due to lower fuel transportation costs.

(2) To NEC:

① To control the utilization and maintenance plans of these diesel locomotives, receiving useful advice from SRC.

② To upgrade unloading facilities (station tracks, heating facilities, storage tanks) as planned.

③ To provide exclusive shunting locomotives.

④ To carry out efficient loading in consideration of the capacity of the oil companies, thereby minimizing loading time.

(3) To SRC:

① To render NEC useful advice concerning the utilization and maintenance plans of these diesel locomotives, and to fulfill the operation and maintenance requirements.

② To secure the budget for spare parts and other costs required for efficient rolling stock maintenance, to upgrade worker skills, and carry out reliable inspection and maintenance.

③ To provide shunting locomotives with facilities for efficient fuel loading and unloading through discussions with NEC.

④ To review present train operation diagram and improve the scheduled speed. In particular, to reconsider the necessity of inspecting tank wagons and to shorten stopping time at way stations.

As mentioned above, the Fuel Transportation Project will have a significant role to play in the Power IV Project and will contribute greatly to a stable supply of electricity and social progress. Therefore, it is highly important and effective to implement this Project with the Grant Aid and the early realization of this Project is expected.

CONTENTS

ABBREVIATIONS

MFEP	Ministry of Finance and Economic Planning
NEA	National Energy Administration
SRC	Sudan Railways Corporation
NEC	National Electricity Corporation
STC	Sudan Telecommunications Corporation
GPC	General Petroleum Corporation
BNG	Blue Nile Grid
EG	Eastern Grid
ID	Isolated Diesel
IBRD	International Bank of Reconstruction and Development
IDA	International Development Association
ODA	Overseas Development Administration (UK)
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit (West Germany, Ministry of Economic Cooperation)
EIB	European Investment Bank
ADB	African Development Bank

Power IV Project:	Power IV Project that is planned by NEC (Total amount US$ 458million, foreign currency US$ 348million)
Power Rehab. (IDA) Project:	The power project that is now being financed by IDA as the contingency parts of "Power IV Project". (Total amount US$ 40million, foreign currency US$ 30million. The main project is investment in Burri Power Station, 2 diesel plants)
Power IV (IDA) Project:	The power project that is now being studied by IDA, and is in its appraisal stage, for several parts of the "Power IV Project". (Total amount US$ 93million, foreign currency US$ 76million. The main project consists of investment for the Khartoum North Power Station, 2 steam turbine plants)
FTS report:	Fuel Transportation Study, Final Report June 1984, by Sir Alexander Gibb & Partners Merz and Maclellan

CHAPTER 1. INTRODUCTION

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In the Republic of the Sudan, the power development programs called the Power I and II Projects mainly focused on hydroelectic power, while the Power III Project concentrated on having hydro and thermal at almost equal levels of capacity. These programs were initiated in 1961 and essentially completed in 1985.

However, the per capita power generating capacity and power generated in 1985 in the Republic of the Sudan were 23 W and 54 KWh, respectively. These figures are some of the lowest in the world.

Khartoum and 15 major regional cities are electrified. However, a systematic power supply forming power grids, exists in only two areas — a part of the Blue Nile River basin including Khartoum, and a part of the Atbara River basin. In other areas, small isolated diesel plants have been installed independently.

In view of this situation, the Government of the Sudan prepared the Power IV Project, and a part of this program is being implemented with financial aid from the World Bank (IDA).

Hydropower generation has almost reached its limit due to problems of water shortages in the dry season and heavy siltation. To cope with increasing power demand in the future, it is inevitable that the nation's power supply capability be reinforced. Therefore the Power IV Project, mainly consisting of thermal power development, was established. This includes the Fuel Transportation Project, which contemplates transporting fuel required for power generation by rail from Port Sudan to Khartoum. It was judged that SRC would not be able to cope with the required level of fuel transport demand, because its transportation capacity has almost reached its limit.

The Government of the Sudan requested foreign governments and international agencies for financial aid, and a meeting for donor countries was held in Paris in December 1983.

Based on the meeting, the Government of the Sudan made a formal request to the Government of Japan to provide diesel locomotives and telecommunications equipment under the grant-aid program. In response, the Government of Japan decided to conduct a basic design study on the Fuel Transportation Project and the Japan International Cooperation Agency (JICA) sent a study team headed by Mr. Tetsuya Yamagata (Department of Foreign Affairs, Japanese National Railways) to the Sudan for a period between 26 September and 17 October, 1985.

The study team held discussions with the Government of Sudan (Ministry of Finance and Economic Planning), National Electricity Corporation (NEC) and Sudan Railways Corporation (SRC), and collected data and information on the following items, as well as conducted field investigations on major facilities.

(a) Present state of power generation and future demand

(b) Implemented and planned power source improvement projects

(c) Operating system, rolling stock, track conditions, telecommunication/signalling facilities of SRC.

(d) Locomotive depot and workshop of SRC and work carried out at these facilities

(e) Fuel loading and unloading facilities

(f) Diesel locomotives and telecommunications equipment requested under the grant-aid program

A report that includes the study result and analysis in Japan was prepared in January 1986, and submitted to the Government of the Sudan in February 1986. Afterwards, the Government of the Sudan requested that an additional study be carried out to evaluate the appropriateness of the project as a part of the Power IV Project. The Government of Japan then decided to carry out the Basic Design (Phase II) of the Fuel Transportation Project, as well as to confirm the policy of the World Bank (IDA) for the Power IV Project. JICA sent a study team headed by Mr. Kiyoshi SUWA (Ministry of Foreign Affairs) to the USA and the Sudan from November 2 to 16, 1986.

The study team held discussions with IDA in Washington, as well as with the Government of the Sudan (MFEP), NEC and SRC in Khartoum, and collected data and information. The Minutes of Discussions covering the study results were signed by the study team and the Sudanese side on November 12, 1986 in Khartoum.

The following items were studied:

① Policy of IDA and the Government of the Sudan for the Power IV Project and the Fuel Transportation Project

② Background information of Power Projects (I ~ IV) and foreign financial assistance for the Power IV Project.

③ Actual situation and means of fuel transportation

④ Operation of diesel locomotives and fare policy

This report, "Fuel Transportation Project in the Republic of the Sudan (Phase II)", was prepared based on the above mentioned field study results and analysis in Japan.

CHAPTER 2. BACKGROUND OF THE PROJECT

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2-1. General outline of the Republic of the Sudan

The Republic of the Sudan is the largest country on the African continent, with a total area of 2.51 million square kilometers (about 6.6 times that of Japan), and is situated in the northeastern part of Africa, bounded by the Red Sea in the northeast, and has borders with 8 countries; Egypt and Libya in the north; Chad and the Central African Republic in the west; Zaire, Uganda and Kenya in the south; and Ethiopia in the east.

The country has a population of 20.95 million (as of the year 1983), with a growth rate of 3.2%, of which Arabians account for 75% and African negroes 25%. Khartoum, the capital, has a population of 330,000 (1983).

Topographically, the Sudan is generally situated on a flat plateau with elevations of 300 ~ 500 m, except for the Red Sea Hills in the northeast. The country consists of the Nubian Desert in the north, irrigated farmland and grassland in the center, and vast swampland and tropical forest created by the meandering White Nile in the south.

The White Nile, originating at Lake Victoria and flowing in a northery direction, joins the Blue Nile, originating at Lake Tana (Ethiopia), at Khartoum located in the center of the Sudan to become the Nile, which then flows into Egypt. In addition, tributaries of the Atbara and the Sobbat join the Nile in the Sudan.

The Sudan has a variety of climates: from a desert in the north to tropics in the south. The temperature is generally high throughout the year: the highest is 52.5°C in the north, 47.7°C in the capital and 42.5°C in the south; the lowest is 16°C in the north and 29°C in the south.

The rainy season also varies from region to region: June - September in the north and April - November in the south. The mean annual rainfall is 25 mm in the north and 1,400 mm in the south.

In Khartoum, winter is between November and March and is the most comfortable season of the year with relatively low temperatures (25°C mean). The mean temperature in April and May is about 36°C and there are relatively high temperatures at night. The rainy season between June and August is subject to high temperature and humidity along with rain and sandstorms (haboobs). The sandstorms sometimes stop road traffic and blow a few centimeters of sand into a house. The period between September and October is called the second summer and is characterized by high temperatures without wind or rains.

Table 2-1 Monthly Temperature of Khartoum City

Month		1	2	3	4	5	6	7	8	9	10	11	12
Temperature (°C)	Maximum	31.7	33.2	37.0	40.1	41.9	41.6	38.1	36.2	38.4	39.3	35.8	32.3
	Minimum	16.5	16.7	19.9	23.0	26.3	27.1	25.7	24.8	25.6	25.2	21.2	16.9
Precipitation (mm)		—	—	—	—	5.0	5.0	55.0	72.0	25.6	5.0	—	—

The Sudan is an agricultural country with 76% of the total labor force engaged in this sector. Major agricultural products include cotton, peanuts, durra (cereals), gum Arabic, sesame and livestock. Cotton and livestock are major export items, representing 63% of the total value of exports in 1983/84. Export of livestock, durra, gum Arabic and sesame have grown steadily, while cotton exports vary with price fluctuations in the world market; cotton exports in 1982/83 decreased to 21% of the amount of 1979/80 (Table 2-2).

On the other hand, the Sudan imports raw materials (for example petroleum), manufactured goods, chemical products, machinery, foods (tea, coffee, sugar, etc.), and drinks and tobacco (Table 2-3).

Table 2-2 Commodities exported

Unit: US$ million

Commodities	1979/80	1980/81	1981/82	1982/83	1983/84
Cotton	333.4	182.0	69.4	174.5	344.2
Groundnuts	32.1	96.4	69.8	38.0	46.8
Sesame	40.6	38.6	46.2	51.3	68.9
Dura	65.7	69.8	64.5	87.4	31.6
Gum Arabic	41.5	34.3	43.2	47.5	64.6
Livestock	35.6	85.0	89.7	120.4	120.2
Other	32.6	31.7	39.2	53.7	55.9
Total	581.5	537.8	422.0	572.8	732.2

Note: The fiscal year of the Sudan is from July 1 to June 30 of the following year.

Table 2-3 Commodities imported

Unit: US$ million

Commodities	1979/80	1980/81	1981/82	1982/83	1983/84
Foods	266.2	314.4	371.2	253.6	165.5
Drinks and tobacco	9.8	23.1	23.5	23.8	23.7
Raw materials	259.0	311.2	368.9	344.4	330.4
Chemical products	12.5	139.3	129.6	140.2	148.1
Manufactured goods	240.5	325.1	294.5	266.6	233.4
Machinery	234.2	231.1	273.1	263.3	195.3
Transport equipment	137.7	140.2	227.1	167.0	154.4
Textile	69.0	55.7	56.3	43.5	31.0
Other	0.1	0.2	29.8	13.6	91.9
Total	1,339.0	1,540.3	1,774.0	1,1516.	1,373.7

Source : IMF (International Monetary Fund)

Especially, the Republic of the Sudan relies on imports for more than 95% of its energy, which according to the statistics of 1983, amounts to 1.3 million t of oil (equivalent to 1.8 million of coal). All of the imported fuel consists of oil and is processed by the Refinery of Port Sudan, the only refinery in the country (established in 1964 by Shell and BP), into kerosene, light oil, furnace oil, petroleum gas, and other products, to be transported to the Khartoum area.

Of the total energy consumption, 60% is used for transportation, 15% for industry, 10% for agriculture and 8% for generation of electricity. The general public obtains most of its energy requirement from such biomass as wood, charcoal and agricultural wastes.
The GNP per capita in 1983/84 was US$ 360.

[Note] BP : The British Petroleum Co.
IMF : International Monetary Fund

2-2. Electric power situation

2-2-1. Generating equipment

The total installed capacity for the general supply of electricity in the Sudan in 1985 was 520 MW (23 W per capita), and energy generation was 1,233 GWh (54 kWh per capita). In Table 2-4, these two indices (kW per capita and kWh per capita) of the electrical situation for 1982 are compared with those of other developing countries, showing that the Sudan has some of the lower figures in the world.

Table 2-4 Electricity in developing countries (1982)

Country	Population ($\times 10^3$)	Annual energy generation (GWh)	Installed capacity (MW)	Annual energy generation per capita (kWh/ps)	Installed capacity per capita (W/ps)
Sudan	19,450	1,010	313	52	16
Egypt	44,670	17,720	3,782	397	85
Ethiopia	32,780	679	319	21	10
Kenya	17,860	1,806	556	101	31
Zaire	26,380	4,412	1,716	167	65
Nigeria	82,390	7,500	2,770	91	34
Ghana	12,240	4,981	1,060	407	87
Morocco	21,670	6,057	1,593	280	74
Algeria	20,290	7,180	2,006	354	99
Tunisia	6,670	3,088	929	463	139
Libya	3,220	6,000	1,180	1,863	366
Iran	40,240	17,500	5,300	433	131
Indonesia	153,030	7,365	2,860	48	19
Philippines	50,740	19,406	5,003	382	99
Thailand	48,490	17,220	4,935	355	101

(Reference)

Country	Population ($\times 10^3$)	Annual energy generation (GWh)	Installed capacity (MW)	Annual energy generation per capita (kWh/ps)	Installed capacity per capita (W/ps)
Japan	118,690	618,100	159,232	5,208	1,342
USA	232,060	2,367,637	674,947	10,203	2,909
UK	55,780	232,162	69,191	4,162	1,240
France	54,220	281,589	83,958	5,193	1,548

Note
1. Annual energy generation and installed capacity are extrapolated from the "Overseas Electric Power Industry statistics 1985" (Japan Electric Information Center, Inc.)
2. Population : estimated by the UN
3. Annual energy generation includes both electric utilities and independent generation.

The present public electricity supply in the Sudan is handled by NEC, established in 1982, which supplies the electricity generated at BNG and EG to consumers. As already stated, IDs are maintained and operated by regional governments.

BNG is an important electric power grid that covers the economic development area of the Sudan, including the capital, Khartoum. The main power stations consist of the hydropower stations of Roseires and Sennar on the Blue Nile and a group of four thermal power stations in the Khartoum area including Burri, Kuku, Kilo X and Khartoum North, which account for 85% of the country's total installed capacity. These power stations are interconnected by transmission lines of 220 kV, 110 kV and 66 kV, totaling 1,260 km, and related substations have a total capacity of 1,000 MVA.

EG, along the Atbara River, has the Khashm el Girba Hydropower Station and small-scale diesel plants, which account for only 5.0% of the total generating capacity. Diesel power plants (with outputs from 100 to 800 kW) are installed in 15 cities (with inhabitants from 50 thousand to 200 thousand each) scattered throughout the country. However, these small diesel generators produce energy at only approximately 40% of their capacities, so these cities are not completely electrified.

The power generating facilities of NEC, regional governments and the whole of the Sudan are shown respectively in Tables 2-5, 2-6 and 2-7, and the NEC power grid in Fig. 2-1 and 2-2.

● Towns with existing supplies

—— Existing grid

Fig. 2-1 Existing power systems

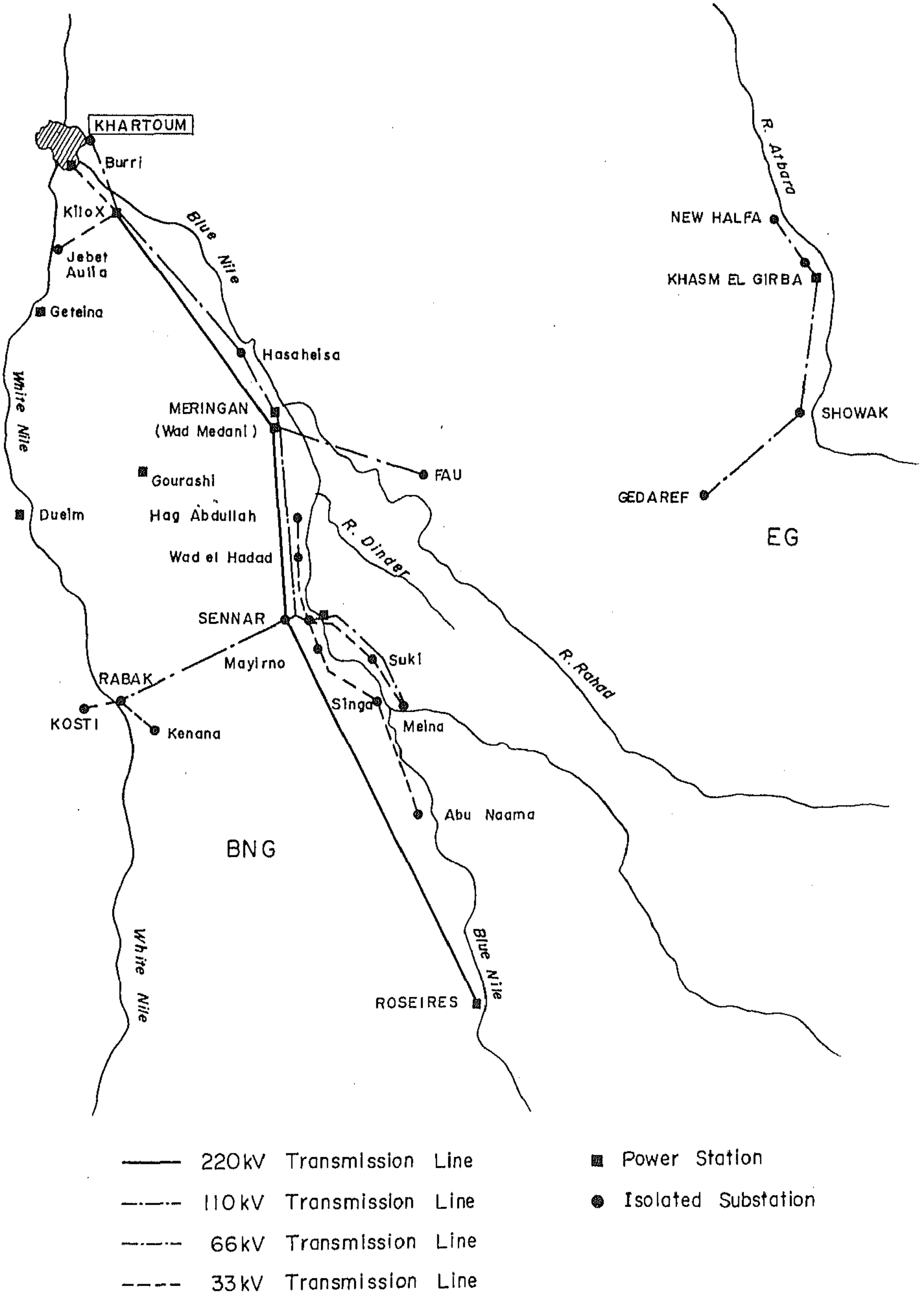

Fig. 2-2 General layout of BNG and EG

Table 2-5 **Public electricity: installed capacity of power stations owned and operated by NEC (1985)**

Power station	Type of prime mover	Date of commissioning	No. of units	Installed capacity (MW)	Actual capacity (MW)
A. Blue Nile Grid (BNG)					
Roseires	Hydro	1971~72	3	90	90
	Hydro	1979~84	3	120	90
	Hydro	1966	2	2	0
	Diesel	1963~82	3	0.5	0.4
Sennar	Hydro	1962	2	15	14.5
Burri	Steam	1956~61	4	26	16
	Diesel	1966	5	15	2
	Diesel	1981	3	15	12.5
	Diesel	1983~84	4	40	32.0
	Gas Turbine	1984	1	15	14.0
Kilo X	Gas Turbine	1969	1	14	13
Kuku	Gas Turbine	1984	2	23	20
Khartoum North	Steam	1985	2	60	60
Wad Medani	Diesel	1954~55	2	1.0	0
	Diesel	1967	2	5.8	1.5
BNG Total				442.3	365.9
B. Eastern Grid (EG)					
Khashm el girba	Hydro	1961~63	5	12.6	10
	Diesel	1961	3	4.2	2
Kassala	Diesel	1956~80	15	5.6	-
	Diesel	1982	4	4	3.6
EG Total				26.4	15.6
NEC Total				468.7	381.5
of which Hydro				239.6	204.5
Thermal				229.1	177.0
- Steam				86.0	76.0
- Gas Turbine				52.0	47.0
- Diesel				91.1	54.0

Table 2-6 **Public electricity: installed capacity of power stations transferred to regional governments (ID)**

Power station	Type of prime mover	Date of commissioning	No. of units	Installed capacity (MW)	Actual capacity (MW)
A. Isolated stations in the area served by BNG					
El Gourashi	Diesel	1962	4	0.7	0.6
Ed Dueim	Diesel	1957	5	1.4	0.7
	Diesel (mobile)	1978	1	0.5	0.4
	Diesel (mobile)	1980~82	2	0.4	0.1
				3.0	1.8
B. Northern					
Atbara	Diesel	1955~78	10	13.0	0.8
Dongola	Diesel	1972~82	10	4.7	2
Shendi	Diesel	1959~82	10	4.6	3.5
Northern Total				22.3	6.3
C. Southern					
Juba	Diesel	1953~65	8	1	0.3
Malakal	Diesel	1961~70	5	1	0.03
Wau	Diesel	1969~83	10	1.9	1.5
Southern Total				3.9	1.83
D. Red Sea					
Port Sudan	Diesel	1964~78	6	10.8	2.0
E. Darful					
El Fasher	Diesel	1958~82	9	2.8	2.1
Nyala		1976	6	1.5	1.3
Darful Total				4.3	3.4
F. Kardofan					
El Obeid	Diesel	1980~82	5	5.0	2.7
Um Ruaba	Diesel	1976	5	1.3	0.8
Kardofan Total				6.3	3.5
TOTAL FOR A ~ F				50.6	18.83

Table 2-7 Public electricity: installed capacity in the Sudan (1985)

Owner	Installed capacity (MW)	Actual capacity (MW)
NEC (BNG, EG) Regional Government (ID)	468.7 50.6	381.5 18.83
Total for the SUDAN (Installed Capacity of Public Electricity)	519.3	400.33
Private Owned	100	
TOTAL for the SUDAN	619.3	
of which Hydro Thermal - Steam - Gas Turbine - Diesel	 239.6 379.7 86.0 52.0 241.7	

2-2-2. Power demand

According to NEC's Annual Report (1984/85), energy generated and sold during 1978/79 ~ 1984/85 are as indicated in Table 2-8.

Table 2-8 Energy generated and sold

Fiscal Year	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1983/84
Energy generated GWh	724	822	833	873	934	1,014	1,233
Energy Sold GWh	609	608	630	681	662	790	990
Loss GWh	115	214	203	192	272	224	243
Loss factor %	16	26	24	23	29	22	25
(1) MW Max. power generated	136.9	144.7	157.8	157.5	157.8	(2) 193	(2) 235
(1) Load factor %	60.3	64.8	60.3	62.8	67.5	(2) 60	(2) 60

Note: (1) is from Power Rehab. (IDA) Project.
(2) is estimated including extention of Roseires (40 MW) and Burri (40 MW).

In this table, a noteworthy fact is the abnormally high loss factor and fluctuation of the load factor. The abnormally high loss factor, according to the IDA Report, is attributable to unmetered consumers or uncollected bills and pilferage. It is technically considered that the normal loss factor should be 15 to 16%, indicating that there should be improvement in billing and metering customers. The fluctuating load factor implies that power output does not correspond to the increasing demand and that peak demand is being curtained.

According to the IDA Report, energy demand and supply were balanced from 1970/71 to 1976/77, but from 1977/78, with the rapid introduction of air-conditioning equipment, the rate of demand grew to 11.6% per year until 1982/83. During that time, increases in capacity consisted only of Burri II (15 MW) in 1981, resulting in output not satisfying increasing demand, meaning many consumers were not supplied with the energy required.

Further, NEC's Annual Reports (1983/84 and 1984/85) state that programmed power reductions were carried out according to the priorities of the consumer. The reason for such power reductions is a shortage in the output and capacity of transmission and distribution lines. Also, according to the Reports, interruptions in supply due to failures occurred 33 times in 1983/84 and 13 times in 1984/85, most of them concentrated in the flood season. The cause of these interruptions were due to drifting logs and decreases in the water head by releasing flood flows.

In order to cope with this inbalance in the demand and supply of electricity, the Government of the Sudan, following the Power I, II and III Projects, has set up the Power IV Project, which includes expansion of the transmission and distribution system, as well as addressing generating capacity and personnel training. A part of this Project is being implemented with financial aid from IDA and various foreign countries. Details are given in Chapter 3.

2-3. Power reinforcing projects

2-3-1. Power I Project

Full-scale power generation development of the Sudan was undertaken by the CEWC (Central Electricity and Water Corporation), which was created in 1966. It can be said that CEWC commenced with the development of the Roseires and Kilo X Power Stations.

Three (3) sets of hydraulic turbine-generators with a capacity of 30 MW each were installed at the Roseires Hydropower Station on the Blue Nile, and a gas turbine generator of 14 MW in capacity was installed at the Kilo X Thermal Power Station with financial aid from IBRD. This was the Power I Project.

The Roseires Dam was constructed for irrigation purposes in 1962 with the financial aid from IBRD. Water is stored behind the dam during the rainy season from July to September and released to irrigate agricultural land along the banks of the Blue Nile during the dry season from October to March.

Because of this irrigation, the inherent problem of reduced generating capability arises in April and May when power demand is high. The Blue Nile is most suitable for hydropower generation and an electric power reinforcement project centering on the expansion of the Roseires Hydropower Station was carried out. The water resources of the Republic of the Sudan are the Blue Nile, White Nile, Atbara River and the main stream of the Nile, as indicated in Fig. 2-3 and Table 2-9.

The Power I Project was virtually completed in 1973 and the amount financed by IBRD, including IDA's contribution (for a 2 MW water turbine generator for Roseires Hydropower Station as a power source for irrigation pumps), was 69.1 million dollars.

Table 2-9 Flow of the Nile River

(Unit: 10^9 m^3)

Location	Annual mean discharge	Monthly mean max. discharge	Monthly mean min. discharge
Bahr el Jebel (Upper Sadd Swamp)	29.3	3.0 (August)	1.9 (Feb)
White Nile (Upper Sobat River)	15.5	1.4 (Oct)	1.2 (June)
Sobat River (Flows into White Nile)	13.7	2.0 (Oct~Nov)	0.3 (April)
White Nile (Khartoum)	25.7	3.2 (Oct)	1.4 (July)
Blue Nile (Roseires)	50.7	15.6 (August)	0.3 (April)
Main Nile (Lower Khartoum)	76.7	16.9 (August~Sept)	2.2 (April~May)
Atbara River (Flows into Nile)	12.1	5.6 (August)	0.1 (Dec~Jan)
Main Nile (Egyptian border)	86.4	21.8 (Sept)	1.9 (May)

Note: For the period 1912 ~ 1967, except for Main Nile (Egyptian border) from 1912 to 1964.

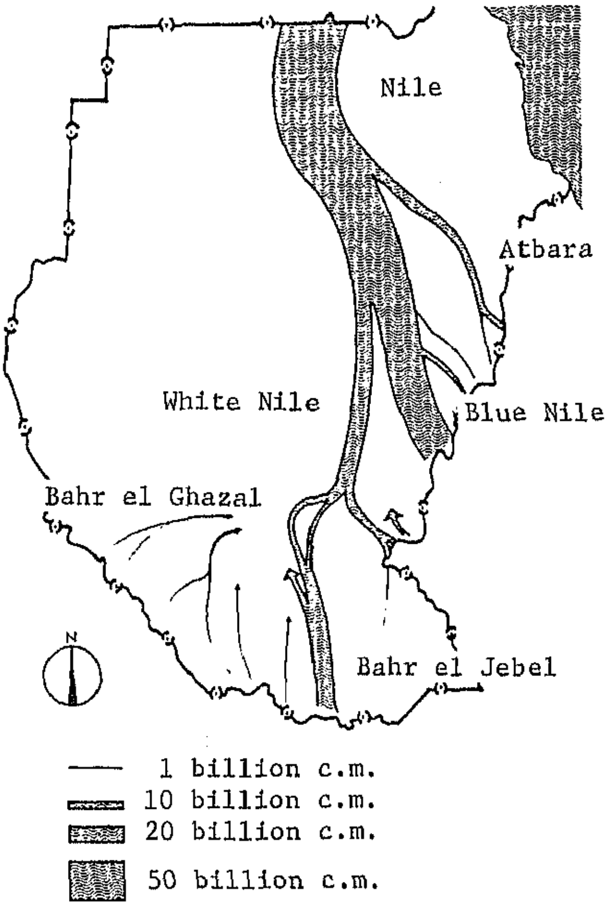

Fig. 2-3 Annual mean runoff of Nile River Basin

2-3-2. Power II Project

The Power II Project was implemented by PEWC (Public Electricity and Water Corporation – CEWC until 1975), and one (1) set of 40 MW water turbine generators was added to the Roseires Hydropower Station, three (3) sets of 5 MW diesel generating plants to the Burri Thermal Power Station in Khartoum, and one (1) set of 5 MW diesel generating plants to Juba. Excluding Juba which belongs to ID, 55 MW of power generating capacity was added to BNG. The Power II Project also included the expansion of 220 kV transmission lines and the related substations, which were completed in 1981. IDA provided financial aid of 23 million dollars for the Power II Project.

2-3-3. Power III Project

The Power III Project was originally planned and promoted by PEWC. However in 1982, the electric power department of PEWC was split in two and NEC (National Electricity Corporation) was created, which then promoted the Project first undertaken by PEWC.

The Project consisted of installing two (2) additional sets of 40 MW water turbine generators at the Roseires Hydropower Station, two (2) additional sets of 30 MW steam turbine generators at the Khartoum North Thermal Power Station, four (4) additional sets of 10 MW diesel generators at the Burri Thermal Power Station, and expansion work on 220 kV transmission lines and related substations.

In 1980, IDA appraised the Power III Project and estimated its total cost including interest during construction to be 290 million dollars. Seventy percent of this fund, that is, 204 million dollars, including all of the foreign currency portion and a part of the domestic currency portion, was financed by funds made available by IDA, ODA and BMZ: IDA 65 million dollars, ODA (England) a 114 million dollar grant, and BMZ (West Germany) a 25 million dollar grant.

Increases in capacity at the Roseires Hydropower Station and Burri Thermal Power Station were completed in 1984 and at the Khartoum North Thermal Power Plant in 1985, concluding the Power III Project.

2-3-4. Power IV Project

The Power IV Project was formulated based on the report "Power IV Project Feasibility Study, July 1983" prepared by British consultants Sir Alexander Gibb & Partners, and Merz & Mclellan. According to this report, the Power IV Project, mainly for reinforcing thermal power generation, consists of expansion of steam turbines at the Khartoum North (90 or 180 MW), water turbines at the Roseires No. 7 and gas turbines (30 MW) at the Kilo X, to meet a demand forecast of an annual growth rate of 13.4% for 6 years from 1983/84. This was the initial Power IV Project.

Transportation of fuels required for thermal power generation will rely on SRC, however, SRC's transportation capacity has been decreasing since 1979/80. Economic studies on fuel transportation under the Power IV Project were performed by the same consultants. The report was submitted in June 1984. Thus, a reinforcement project for fuel transportation facilities was included in the Power IV Project from its initial stage.

In actuality, power demand was lower than the forecasted figure in the initial Power IV Project. Therefore, the initial project was revised and the present Power IV Project formulated as described in Chapter 3. Also the inbalance between power supply and demand improve, but was not solved in 1983/84 and 1984/85 at the final stage of the Power III Project. According to NEC's Annual Report, it was obliged to enforce programmed power reductions and supply interruptions, which occurred 30 and 13 times in 1983/84 and 1984/85, respectively.

Considering the electrical power situation, IDA, which has been contributing much to the financing and formulation of electric power reinforcement projects, drew up the Power Rehabilitation Project in June 1985. It includes enlargement of the Burri Thermal Power Station (10 MW × 2 : diesel) and rehabilitation of the Roseires and Sennar Hydropower Stations. IDA has provided US$30 million to this project, which is now under way to be completed in 1988.

The Government of the Sudan considers the Power Rehabilitation Project as a part of the Power IV Project. Meanwhile, IDA has taken up some of the projects of this Power IV Project into its own Power IV Project, with Project appraisal being conducted by IDA, which is considering a co-financing scheme of US$38 million by IDA and Us$38 million by ADB (total US$76 million) for the enlargement of the Khartoum North Power Station (45 MW × 2 : steam turbine).

A meeting for donor countries was held in Paris in December 1983 where financial assistance for the Sudanese Power IV Project, including reinforcement of fuel transportation, was discussed. Table 2-11 shows the initial and present Power IV Project and loans provided by foreign governments and international financial instructions. The Power IV Project is described in detail in Chapter 3.

Table 2-10 Electric power supply enterprises and power reinforcement in the Sudan (Nov. 1986)

Year	Organization and power project	Summary of electric power reinforcement	Finance (10^6 US$)
1908	Commenced electric power supply in Khartoum		
1925 1956	SLPC (Sudan Light and Power Company) was established	· Replacement of steam piston generator by diesel engine generator · Commissioning of Burri Thermal Station 30 MW (7.5 MW × 4, steam turbine)	
1960 1962 1963	CEWA (Central Electricity and Water Administration) was established	· Commissioning of Sennar Hydro Station 15 MW (7.5 MW × 2) · 110 kV Transmission Line (Sennar~Khartoum) · Completion of Roseires irrigation dam (installed 2 MW water turbine)	· IBRD, IDA 38.8 (1961, 1963)
1966 1969	CEWC (Central Electricity and Water Corporation) was established, incorporating CEWA and regional electrification areas	· Enlargement of Burri Thermal Station 15MW (3 MW × 5, diesel) · Commissioning of Kilo X Thermal Station 14 MW (gas turbine)	
1971 ~ 1972	<Power I Project>	· Commissioning of Roseires Hydro Station 90 MW (30 MW × 3) · 220 kV Transmission Line (Roseires~Khartoum)	· IBRD 24.0 (1967)
1975	CEWC changed its name to PEWC (Public Electricity and Water Corporation)		
1979 1981 1982	<Power II Project>	· Enlargement of Roseires Hydro Station unit 4 40 MW · Enlargement of Burri Thermal Station 15 MW (5 MW × 3, diesel) · 220 kV Transmission Line (Roseires~Sennar)	· IDA 23.0 (1975)
1982	PEWC was split in two and NEC (National Electricity Corporation) was established.		

Table 2-10 (Continued)

Year	Organization and power project	Summary of electric power reinforcement	Finance (10^6 US$)
1984		· Enlargement of Burri Thermal Station 40 MW (10 MW × 4,diesel)	· ODA 114. grant (1980)
	<Power III Project>	· Enlargement of Roseires Hydro Station unit 5 and 6 40 MW × 4	· IDA 65.0 (1980)
1985		· Commissioning of Khartoum North Thermal Station 60 MW (30 MW × 2,steam turbine)	· ODA (included above)
		· 220 kV Transmission Line (Sennar~Kilo X)	· BMZ 25.0 grant (1980)
1987		· Enlargement of Khartoum North Thermal Station 40 MW (20 MW × 2,gas turbine)	· Italy 16.0
1988	<Power IV Project>	· Enlargement of Burri Thermal Station 20 MW (10 MW × 2,diesel)	· IDA 30.0 (Power Rehab. Project)
		· Enlargement of Roseires Hydro Station unit 7 40 MW	· EIB 12.0
		· Diesel Locomotive for Fuel Transportation (10 units)	·
1989		· Eastern Grid Reinforcement 15 MW (5 MW × 3,diesel)	· Holland 12.5 grant
1990		· Enlargement of Khartoum North Thermal Station 90MW (45 MW × 2,steam turbine)	· IDA,ADB 38+38 (Power IV IDA Project)
		· Electrification of Regional Cities 10.5 MW (several diesels)	· Holland 6.0 grant Denmark 17.6 grant

Table 2-11 **Summary of the Power IV Project and financing**

Fiscal Year	Initial Power IV Project: Load forecast Power gene.	Instal capa.	Power reinforcement program	Present Power IV Project: Load forecast Power gene.	Instal capa.	Power reinforcement program	Finance (10^6 US$)
1982/83	(GWH) 920	(MW) 235		(GWH) 934	(MW) n.a.		
83/84	1,130	263	kilo X 30 MW gas	1,014	193	(Burri 10 MW×4)	
84/85	1,329	294	Roseires #7 Hydro plant	1,233	235	(Roseires 40 MW ×2)	
85/86	1,544	323		1,218	n.a.		
86/87	1,760	352	Khartoum North 60 MW × 2 steam	1,593	303	Khartoum North 20 MW × 2 gas	Italy 16.0 grant
87/88	1,974	384	Khartoum North 60 MW × 1 steam	1,714	326	Burri 10 MW × 2 Diesel Roseires #7 Hydro plant 10 Diesel Locomotives	IDA 30.0 soft loan (Power Rehab.) EIB 12.0 soft loan Japan grant
88/89	2,184	419	Sennar 30 MW Hydro plant	1,839	356	EG 5 MW × 2	Holland 12.5 grant
89/90	2,413	456		1,961	373	Khartoum North 45 MW × 2 steam	IDA.ADB 38+38 (Power IV (IDA))
90/91	2,610	496		2,095	385	Regional Cities 10.5 MW	Holland 6.0 grant Denmark 17.6 grant

[Note] Power Gene. : Power Generation
Instal Capa. : Installed Capacity
( ) : Power III Project

2-4. Present state of Sudan Railways Corporation

Sudan Railways Corporation (SRC) is one of the oldest railway organizations in Africa, having been incorporated in 1875. It first began operation between Wadi Halfa and Saras near the Egyptian border in the lower reaches of the Nile River, and gradually extended until most of the present-day sections were in place by 1928.

2-4-1. Organization and staff

The organization and staff of SRC are summarized in Fig. 2-4 and Table 2-12, respectively. SRC has its head office in Atbara and five regional offices.

- Board of Directors
  - Internal Auditor
  - General Manager — Deputy General Manager
    - Chief Mechanical Engineer
    - Chief Civil Engineer
    - Signalling and Telecommunications Engineer
    - Personnel and Training Director
      - Personnel Director
      - Training Director
    - Traffic Manager
    - Chief Accountant
    - Planning and Economic Research Director
    - Controller of Stores
    - Eastern Regional Manager
    - Northern Regional Manager
    - Central Regional Manager
    - Western Regional Manager
    - Southern Regional Manager
    - Fire Brigade Office
    - Social Services Director
    - Chief Police Officer
    - Public Relations Director

Fig. 2-4 Organization of SRC

Table 2-12 SRC Staff (Oct. 1985)

Section	Number of employees
Head office	816
Mechanical/electrical	11,455
Facilities	8,231
Transportation	7,226
Stores	1,047
Security	2,003
Accounting	929
Total	31,707

2-4-2. Tracks

Track length and rail type in each section are shown in Table 2-13.

Table 2-13 Track length and rail type by section

Section	Length (km)	Rail type (lb/yard)
Port Sudan – Atbara	475	90
Atbara – Khartoum	313	90
Haiya – Kassala	347	75
Kassala – Sennar	455	75
Khartoum – El Obeid	698	75
Er Rahad – Babanusas	363	75
Atbara – St No. 10	270	75
St No. 10 – Wadi Halfa	341	50
St No. 10 – Karima	222	50
Babanusa – Nyala	335	50
Babanusa – Wau	444	50
Sennar – Ed Damazin	227	50
Total	4,481	—

The percentage of 90 lb/yd (45 kg/m), 75 lb/yd (37 kg/m), and 50 lb/yd (25 kg/m) out of total track are 18%, 50%, and 32%, respectively. The section between Port Sudan – Atbara – Khartoum, since it will be used for fuel oil transport in this project, is the most important section and thus will use 90 lb/yd (45 kg/m) rails. On the other hand, the alternative route Haiya - Kassala - Khartoum uses 75 lb/yd rails, which also permits an axle load of 16.5 t. Most of tracks are unballasted and not well maintained, thus limiting the maximum train speed to around 60 km/h.

2-4-3. Rolling stock

Rolling stock owned by SRC is listed in Table 2-14 and the types of main line locomotives and their operating status are summarized in Table 2-15. (As of October 1, 1985)

Table 2-14 Rolling stock owned by SRC

Type	Use	Number
Steam locomotive	Main line	89
	Shunting	10
Diesel locomotive	Main line	169
	Shunting	76
Passenger carriage	For general use	491
	For business use	606
Freight wagon	For general use	5,613
	Tank wagon	746

Table 2-15 Types of main line locomotives and their operating status

(as of Oct. 1, 1985)

Type	Class	manufac-turer	Power / Axle layout	Number total	Number oper-ated	Number sus-pended	First year in service	Remarks
SL	——	——	——	89	6	71	——	o.serv. 12
DL	1000	English Electric	1875 HP Co-Co	62	9	42	1960~1969	abandn. 3 others 8
	1500	Hitachi	1500 HP A1A-AIA	20	0	17	1969	o.serv. 3
	1600	Hen./GM	1500 HP Co-Co	10	4	4	1982	others 2
	1700	GE U15	1650 HP A1A-A1A	10	6	2	1975~1981	others 2
	1800	GE U22C	2250 HP Co-Co	20	15	3	1976	others 2
	1850	GE U22C	2250 HP Co-Co	10	7	2	1985	other 1
	1900	Hen./GM	2250 HP Co-Co	20	3	12	1975	others 5
	1950	GM JT22LC-2	2250 HP Co-Co	10	4	0	1981~1985	others 6
	DL Total			172	48	82	——	(42)

(Note) GM : General Motors o.serv. : out of service
GE : General Electric abandn. : abandoned
Hen./GM : Henschel/GM

Most of the diesel locomotives for the main lines are out of service due to the unfavorable environment (sand and high temperatures) as well as to a shortage of spare parts; only 48 locomotives (28%) were in working condition as of 1 October 1985.

Although 10 locomotives were procured with US Government aid in August 1985, three of them are under repair due to a compressor failure and an accident. The situation has not changed much since then, and the operating status of main line locomotives in the second survey (in November 1986) is as follows ;

Table 2-16 Types of main line locomotives and their operating status

(as of Nov. 1986)

Type	Class	manufac-turer	Power / Axle layout	Number: total	Number: oper-ated	Number: sus-pended	First year in service	Remarks
SL	——	——	——	89	6	71	——	o.serv. 12
DL	1000	English Electric	1875 HP Co-Co	62	19	32	1960~1969	abandn. 3 others 8
	1500	Hitachi	1500 HP A1A-AIA	20	0	17	1969	o.serv. 3
	1600	Hen./GM	1500 HP Co-Co	10	0	8	1982	others 2
	1700	GE U15	1650 HP A1A-A1A	10	2	6	1975~1981	others 2
	1800	GE U22C	2250 HP Co-Co	20	15	3	1976	others 2
	1850	GE U22C	2250 HP Co-Co	10	7	2	1985	other 1
	1900	Hen./GM	2250 HP Co-Co	20	0	15	1975	others 5
	1950	GM JT22LC-2	2250 HP Co-Co	10	4	0	1981~1985	others 6
	DL Total			172	47	83	——	(42)

(Note) GM : General Motors o.serv. : out of service
GE : General Electric abandn. : abandoned
Hen./GM : Henschel/GM

Since locomotives in working condition are constantly in short supply, a utilization program cannot be established for them. As a result, locomotives are being used on an unprogrammed makeshift basis.

It should also be noted that all DL class 1600's, which had been in service since 1982, and DL class 1900's became unoperable. (DL class 1900's and 1950's suffered from pinion troubles in the traction motor in FY 1983/1984.)

However, rehabilitation of 10 DL class 1000's was accomplished with assistance from the EEC. The EEC donated a grant totalling US$11 million, providing spare parts for rehabilitation of diesel locomotives.

The operating status of shunting diesel locomotives (as of November 1986) is shown in Table 2-17. The number of locomotives available, "13", is half that of October 1985, "26". Thus, SRC now has a serious shortage of diesel shunting locomotives. SRC is coping with the problem by using main line locomotives for shunting as an emergency measure. (Main line diesel locomotives with light axle loads are used for shunting fuel tank wagons between Khartoum and Khartoum North Power Station.)

As shown in Table 2-17, diesel shunting locomotives in operation are mainly Japanese made (KSK), and SRC hopes to prolong their activity as long as possible. The Railway Emergency Recovery Program (RERP), planned by the World Bank, includes the procurement of spare parts for these locomotives.

Table 2-17 Operating status and types of diesel shunting locomotives

(as of November 1986)

Class	manufac-turer	Number			First year in service
		total	oper-ated	sus-pended	
100	EE	6	0	6	1970~
460	Hen./GM	20	3	17	1968~
600	KSK	23	10	13	1975~
700	Hen./GM	20	0	20	1962~
Total		69	13	56	——

(Note) EE : English Electric
Hen./GM : Henschel/GM
GM : General Motors
KSK : Kawasaki

2-4-4. Operation

(1) Operation control

Operation control is done from six dispatch offices listed in Table 2-18.

Table 2-18 Dispatch offices and control sections

Dispsatch office	Control section	
	From	To
Port Sudan	Port Sudan	Haiya
Atbara	Haiya	Atbara
	Atbara	Khartoum
Khartoum	Khartoum	Sennar
Sennar	Sennar	Gedare
Kssala	Gedare	Kassala
Kosti	Sennar	Kosti
	Kosti	El Obeid

(Note) : Other sections are not controlled from a dispatch office.

(2) Timetable

Although a standard train timetable (one train per 1 – 2 hours for each direction) is established for the section between Khartoum and Port Sudan, actual train operations are carried out in accordance with weekly timetables.

The average number of runs each day is 5 round-trips for the section between Khartoum and Atbara, and 3 – 4 round trips for the section between Atbara and Port Sudan (1984/85).

An example of a standard timetable is shown in Table 2-19 (inbound : Port Sudan to Khartoum, outbound : Khartoum to Port Sudan).

Table 2-19 Standard Timetable of inbound and outbound trains (goods train)

pos.	Station	Train No. 52		pos.	Station	Train No. 83	
km		Ar.	Dep.	km		Ar.	Dep.
787	Port Sudan		00 : 54	0	Khartoum C.		21 : 10
758	Sallom	01 : 55	02 : 05	4	Khartoum North	——	21 : 25
740	Obo	02 : 57	03 : 08	18	Kadaru	——	21 : 45
711	Assot	04 : 33	04 : 49	83	Jebel Querri	——	23 : 25
691	Gamateb	05 : 42	05 : 55	107	El Miga	23 : 59	00 : 30
682	Gebeit	06 : 17	06 : 37	172	Shendi	01 : 49	02 : 10
674	Adit	06 : 54	07 : 05	189	Taragma	02 : 33	02 : 45
658	Summit	07 : 37	08 : 12	239	Mahmiya	03 : 53	04 : 13
628	Baraseet	09 : 02	09 : 17	299	Ed Damer	——	05 : 28
				313	Atbara	05 : 50	07 : 50
584	Haiya	10 : 19	10 : 49				
547	Shediyeb	——	11 : 42	329	Zalata	——	08 : 16
501	Musmar	12 : 48	13 : 17	413	Ogrein	10 : 13	10 : 40
454	Togni	14 : 21	14 : 25	433	Siyeteb	——	11 : 08
433	Siyeteb	14 : 53	15 : 05	454	Togni	11 : 41	11 : 43
413	Ogrein	15 : 32	15 : 52	501	Musmar	12 : 50	13 : 10
329	Zalata	17 : 40	17 : 56	547	Shediyeb	14 : 26	14 : 31
				584	Haiya	15 : 35	16 : 05
313	Atbara	18 : 20	21 : 00				
299	Ed Damer	21 : 21	21 : 35	600	Tahamiyam	16 : 35	16 : 45
280	Ez Zeidab	22 : 00	22 : 10	619	Erheib	17 : 22	17 : 35
239	Mahmiya	——	23 : 03	628	Baraseet	——	17 : 56
189	Taragma	00 : 10	00 : 47	658	Summit	——	19 : 05
172	Shendi	01 : 10	02 : 13	682	Gebeit	19 : 41	20 : 24
132	Wad Ban Naqa	03 : 05	03 : 25	699	Erba	20 : 50	21 : 05
83	Jebel Querri	04 : 33	04 : 45	729	Okwat	21 : 51	22 : 05
18	Kadaru	06 : 14	06 : 35	758	Sallom	——	22 : 49
4	Khartoum North	06 : 55	07 : 10	765	Tisiamti	22 : 59	23 : 30
0	Khartoum C.	08 : 20		787	Port Sudan	00 : 05	

* pos. : position

Train No. 52 (inbound goods train) takes 31 hours 26 minutes from Port Sudan to Khartoum. Excluding stoppage time of 9 hours 54 minutes, the actual run time required is 22 hours 32 minutes (average speed 34.4 km/h). On the other hand, Train No. 83 (outbound goods train) takes 26 hours 55 minutes. Excluding stoppage time, the actual run time required is just 20 hours (average speed 39.4 km/h). It is a little faster due to a less rising gradient.

(3) Locomotive depots

Location of locomotive depots and their responsible sections are shown in Table 2-20.

Table 2-20 Locomotive depots and responsible sections

Locomotive depot	Responsible section
Atbara	Khartoum – Atbara – Port Sudan Atbara – Karima, Atbara – Wadi Halfa
Khartoum	Khartoum – Sennar Junction
Kassala	Old Sennar Junction – Haiya Junction, Haiya Junction – Port Sudan
Sennar Junction	Sennar Junction – Ed Damazine
Kosti	Sennar Junction – El Obeid
Babanusa	Babanusa – Er Rahad, Babanusa – Kyala, Babanusa – Wau

(4) Operating performance

The operating performance in 1984/85 is shown in Table 2-21.

Table 2-21 Operating performance (1984/85)

Section / Operating pf.	Khartoum – Atbara		Atbara – Port Sudan	
Punctual operation	1,892	52.3%	1,334	50.9%
Delay over 30 min.	1,723	47.7	1,287	49.1
Over 30 min.	103	2.9	20	0.8
Over 1 hour	449	12.4	130	5.0
Over 3 hours	363	10.1	143	5.5
Over 5 hours	478	13.2	395	15.0
Over 10 hours	330	9.1	599	22.8

(Note) Punctual: Delay within 30 minutes
Operating pf: Operating performance

As seen from the table, about 50% of the trains operated on the Khartoum – Port Sudan section were delayed 30 minutes or more. Of these delays, 20% were 30 minutes to 5 hours long and 30% longer than that, indicating a high percentage of lengthy delays. On the Atbara – Port Sudan section, in particular, 40% of its delays were more than 5 hours long, much higher than its 10% for delays of 30 minutes to 5 hours. This is because the section relatively long with steep and poorly maintained track on the Port Sudan side, which requires a lot of time when a locomotive that fails on the way has to be saved with a rescue locomotive from Atbara.
Thus, to maintain reliable fuel oil transport, an adequate backup system for locomotive failures (multi-hauling or appropriate positioning of rescue locomotives) should be provided.

2-4-5. Rolling stock maintenance

Maintenance of diesel locomotives is carried out at the locomotive depot and workshop in Atbara. These facilities are equipped with the necessary machines, equipment and buildings, and the employees appear to work efficiently.
Nevertheless, prompt repairs cannot be done due to the high rate of failure caused by severe operating conditions (sand and high temperatures) and shortages of spare parts owing to the financial condition, resulting in an extremely low rate of operation. For instance, 20 diesel locomotives procured from Japan in 1969 are out of order and cannot be repaired due to a lack of spare parts. To avoid such a situation in this Project, the continuous provision of spare part and technical assistance will be needed.

2-4-6. Signalling and communications equipment

(1) Signalling equipment

Important signalling equipment owned by SRC is listed in Table 2-22. Since all SRC lines are single-tracked, operations are done with tablet block system. All the points are manually operated, except for spring loaded points at some stations.
Signalling is done with semaphores and interlocking devices are of the mechanical type.

Table 2-22 Important signalling equipment operated by SRC

Item	Equipment	Remarks
Block device	Tablet block device	Key-token
Signal	Semaphore	
Interlocking device	Mechanical interlocking device	

(2) Communications equipment

A) Transmission lines

Shortwave radio is used for long distance communications between dispatch offices, and overhead bare wires for short distance communications between a dispatch office and each station as well as between neighboring stations (See Table 2-23).

Table 2-23 Transmission lines by type of communications

Type of communication	Transmission medium	Remarks
Long distance	Shortwave radio and overhead bare wire	Used for telegraph (Morse) and calls
Short distance	Overhead bare wire	Owned by STC, 5 lines leased to SRC

Note : STC – Sudan Telecommunications Corporation

On the section between Khartoum and Port Sudan, there is a dispatch office in Khartoum, Atbara and Port Sudan to conduct systematic train operations. These dispatch offices are far away from each other: 313 km between Khartoum and Atbara and 474 km between Atbara and Port sudan. Communications between them is made possible by shortwave radios or overhead bare wires leased form STC.

Overhead wires are used for short distance blocking, telephone communications between neighboring stations and dispatch telephones. Also they are used for long distance telegraph communications between dispatch offices. However, they break down frequently (800 – 1,000 cases each year for all the sections) making communications unreliable, and their repair is always delayed since STC, which is responsible for maintenance, operates its own microwave network, leaving them little time for repair. Once, communications were interrupted for 50 days because of a failure in an overhead wire.

The overhead wires are used in the following manner.

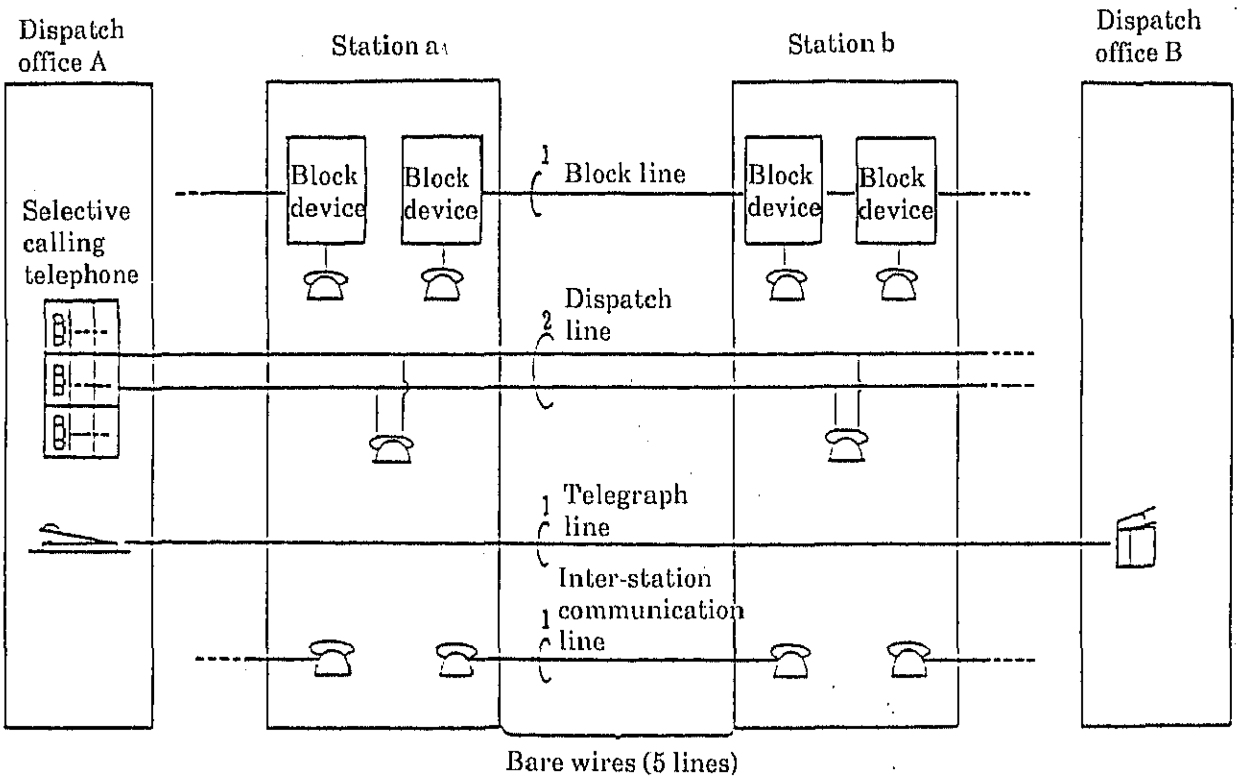

Fig. 2-5 Use of overhead lines

Each dispatch office is equipped with one set of shortwave equipment. Ten frequencies (146 ~ 174 MHz, band, 2 MHz width, 12 frequencies are possible) are used in radio communications since the effective distance of shortwaves varies with time.

B) Radios for communication between trains and a nearby station

Radios are used for communication between train crews and nearby stations, and are installed on the section between Khartoum – Port Sudan and Haiya – Kassala sections. There is radio equipment at 32 stations (24 stations between Khartoum and Port Sudan), with two units each including a standby. Antennas are put up on 35 – 40 m high steel towers. Stations having radio equipment are listed in Table 2-24.

Table 2-24 Stations with radio equipment

Port Sudan – Khartoum

Location	Spacing
Port Sudan	
Sallom	29
Kamob Sanha	37
Gebeit	39
Summit	24
Barameiyu	19
Erheib	20
Haiya Jn	35
Kas	26
Talquhari	27
Musmar	30
Sigadeit	25
Siyateb	43
Hadiga	43
Hudi	46
Atbara	31
Ezzidab	33
Mahmiya	41
Kabushiya	30
Shendi	37
W. Ban Naga	40
J. Ouerri	49
El Geili	36
Khartoum N.	43

Haiya – Kassala

Location	Spacing
(Haiya Jn.)	
Imasa	43
Tehella	41
Delai	39
Ungwatiri	52
Amadam	56
Mitatib	46
Akala	37
Kassala	33

On-board radio equipment (fixed type) is installed in the operator cabs (both sides) of locomotives: one unit is used while the other serves as a standby. At present, there are 70 units of on-board radio equipment in 35 locomotives.

The radio communication system, made by Storno in Denmark, is being effectively used for communication whenever there is engine trouble or an accident.

C) Other communications equipment

SRC owns 4 telephone exchanges as shown in Table 2-25, which are interconnected with STC lines.

Table 2-25 Telephone exchanges owned by SRC

Line capacity	Number	Location
400 lines	1	Atbara
50 lines	3	Port Sudan, Kassala, Kosti

2-4-7. Passengers/freight carried and operating revenues/expenses

Passengers and freight carried by SRC are shown in Table 2-26.

Table 2-26 Passenger/freight carried by SRC

Year	Passenger traffic		Freight traffic	
	Passenger carried	Passenger-km (10^3 psgr-km)	Tonnage carried	Ton-km (10^3 t-km)
1979/80	2,310,293	1,061,058	2,135,743	2,003,207
1980/81	2,041,017	1,169,580	1,720,400	1,594,306
1981/82	2,675,016	1,148,646	1,690,874	1,608,389
1982/83	2,212,941	1,031,025	1,353,842	1,215,183
1983/84	1,524,380	729,899	895,292	836,000

[Note] psgr : passenger

As seen in Table 2-26, both passengers and freight carried by SRC have been decreasing gradually; in particular, they decreased to 70% of the previous year's totals for 1983/84. This is probably due to insufficient transport capacity caused by the shortage of locomotives in working condition rather than a decrease in traffic demand.

The revenues/expenses of SRC are shown in Table 2-27. SRC has shown a deficit in most of the years, except for fiscal 1981/82 when a profit was realized as a result of a rate increase.

Table 2-27 Operating revenues/expenses

Item	Year	1979/80 ×10³ LS	1980/81 ×10³ LS	1981/81 ×10³ LS	1981/83 ×10³ LS
Revenue	Passengers	10,140	9,620	13,190	17,830
	Freight	42,700	46,450	73,630	65,820
	Other	190	180	190	130
	Total	53,030	56,250	87,010	83,780
Expense	Labor cost	36,020	44,590	47,640	50,910
	Fuel cost	5,520	5,640	8,090	9,130
	Other	14,120	14,070	17,260	24,130
	Total	55,660	64,300	72,990	84,170

Freight fares had been frozen since 1979, then went up by 57% in FY 1981/82, 73% in December 1983, and finally 50% in April 1985. Compared with the high price rise in the Sudan, this rate of increase is not extraordinary as can be understood from Table 2-28.

Table 2-28 Price escalation rate and freight fare

Fiscal Year	1980	1981	1982	1983	1984
Price index *)	100	124.6	156.6	204.5	301.8
Price escalation rate (%)	24.6	25.7	30.6	47.6	—
Freight fare index	100	100	157	157	275
Escalation rate (%)	–	0	57	0	73

*) Source : Annual of Mideast and Africa

2-4-8. Assistance program of the World Bank (IDA)

IDA recognizes the status of SRC, i.e., annual decrease in traffic volume due to a shortage of operable locomotives. IDA is now planning to implement the Railways Emergency Recovery Program (RERP) with a total investment of US$70 million, which would include :

① Materials for high priority emergency track repair

② Spare parts and essential equipment and material replacements

③ Training

④ Technical assistance

IDA's first pre-appraisal mission visited the Sudan in September 1985.

Afterwards, a meeting for donors was held in the Sudan to discuss what amounts were to be borne by who (expected amount : US$10 million by the Sudan, US$20 million by IDA, US$10 million by Saudi Fund).

IDA sent the pre-appraisal mission to the Sudan twice in 1986 (totalling three times) ; however, the schedule for the final appraisal mission has not yet been decided because of a delay in the preparation of data on the Sudanese side, which will be essential for evaluating the Project.

2-5. Present situation of fuel transportation

2-5-1. Fuel transportation by railway

NEC consumes the following four types of fuel at thermal power stations.

① Gas oil (for gas turbine) : Used at the gas turbine plants at Burri, Khartoum North and Kilo X Power Stations

② Light oil (for small diesel) : Used at small diesel plants in local towns

③ 1,500 sec. Furnace oil (for diesel) : Used at diesel plants (10 MW ×2) at the Burri Power Station

④ 3,500 sec. Furnace oil (for diesel and steam turbine) : Used at diesel plants (10 MW ×2) at the Burri Power Station and steam turbine plants (30 MW ×2) at the Khartoum North Power Station

White oil (① and ②) is sent by GPC pipelines, while black oil (③ and ④) is transported by train. Table 2-30 shows the amount of furnace oils transported until FY 1985/86 and its forecasts up to FY 1990/91.

Table 2-30 Fuel oil transportation by SRC

Fiscal year		1981/82	82/83	83/84	84/85	85/86
Furnace oil (3,500 sec.)	(t)	–	–	–	46,616	82,689
Furnace oil (1,500 sec.)	(t)	33,932	41,003	61,565	45,226	45,020
Quantity	(t)	33,932	41,003	61,565	91,842	127,709
Fiscal Year		1986/87	87/88	88/89	89/90	90/91
Quantity	(t)	134,000	167,000	176,000	209,000	224,000

In April 1984, a third diesel power plant was added at the Burri Power Station as a part of the Power III Project. With the inauguration of the new plant, NEC's fuel oil consumption began to increase very greatly FY 1983/84. On the other hand, FY 1983/84 saw a sudden increase in troubles of SRC's main line diesel locomotives (classes 1900 and 1950, cf. Table 2-16), resulting in a transportation capacity decrease (30% less than that of the previous year, both for freight and passengers : cf. Table 2-26).

Until this fiscal year, all furnace oil (1,500 sec) used at thermal power station had been carried by SRC's tank wagons. As an urgent and temporary measure to compensate for the gap between increased transportation demand and decreased capacity, tank trucks were introduced to transport fuel oils (in May 1984).

In FY 1984/85, diesel power generation unit No. 4 (10 MW) at the Burri Power Station and steam turbine plant unit No.s 1 and 2 (30 MW each) at the Khartoum North Power Station were completed under the Power III Project. These plants consume 3,500 sec furnace oil, transportation of which was commenced in FY 1984/85. Having a high viscosity, this furnace oil needs to be heated to be loaded in the winter; otherwise, it would take much more time for loading. Shell is the only petroleum company, out of four, which has a steam heating plant at loading facilities. In addition, since few tank wagons are equipped with heating coils, loading/unloading troubles might occur especially in the winter.

In FY 1984/85, SRC only transported 40% (37,000 t) of NEC's total fuel requirements, which was less than the quantity transported in the previous year, (Tank trucks transported 55,000 t of fuel.) The quantity of fuel transported from FY 1981/82 to 1985/86 is shown in Table 2-31.

Table 2-31 Quantity of fuel transported

FY	1981/82	82/83	83/84	84/85	85/86
Train (t)	33,932	41,003	61,565	(37,000)	(64,000)
Road (t)	——	——	——	(55,000)	(64,000)
Total (t)	33,932 *1	41,003 *1	61,565 *1	91,842 *2	127,709 *2

Note : *1 1,500 sec furnace oil only
*2 1,500 & 3,500 sec furnace oil

In Fy 1985/86 SRC, transported 64,000 t of furnace oil, which is more than that for FY 1983/84, recovering its 50% share of transporting fuel for NEC. It is presumed that a grant from the USA (USAID supplied SRC with 10 diesel locomotives class 1850) contributed to this recovery. At the same time, the quantity of fuel transported by tank trucks increased to 64,000 t.