No. 56

MASTER PLAN AND FEASIBILITY STUDY
ON
EXTENSION AND REINFORCEMENT
OF
POWER TRANSMISSION AND DISTRIBUTION SYSTEM
IN KATHMANDU VALLEY
IN
NEPAL

FINAL REPORT

DECEMBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Kingdom of Nepal, the Government of Japan decided to conduct a Master Plan Study and a Feasibility Study on Extension and Reinforcement of Power Transmission and Distribution System in Kathmandu Valley and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Nepal a study team headed by Mr. Yoshiaki Miyagawa, General Manager of Plant Engineering Department, Overseas Consulting Administration, Nippon Koei Company, Ltd., 3 times between October 1990 and December 1991.

The team held discussions with the officials concerned of the Government of Nepal, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

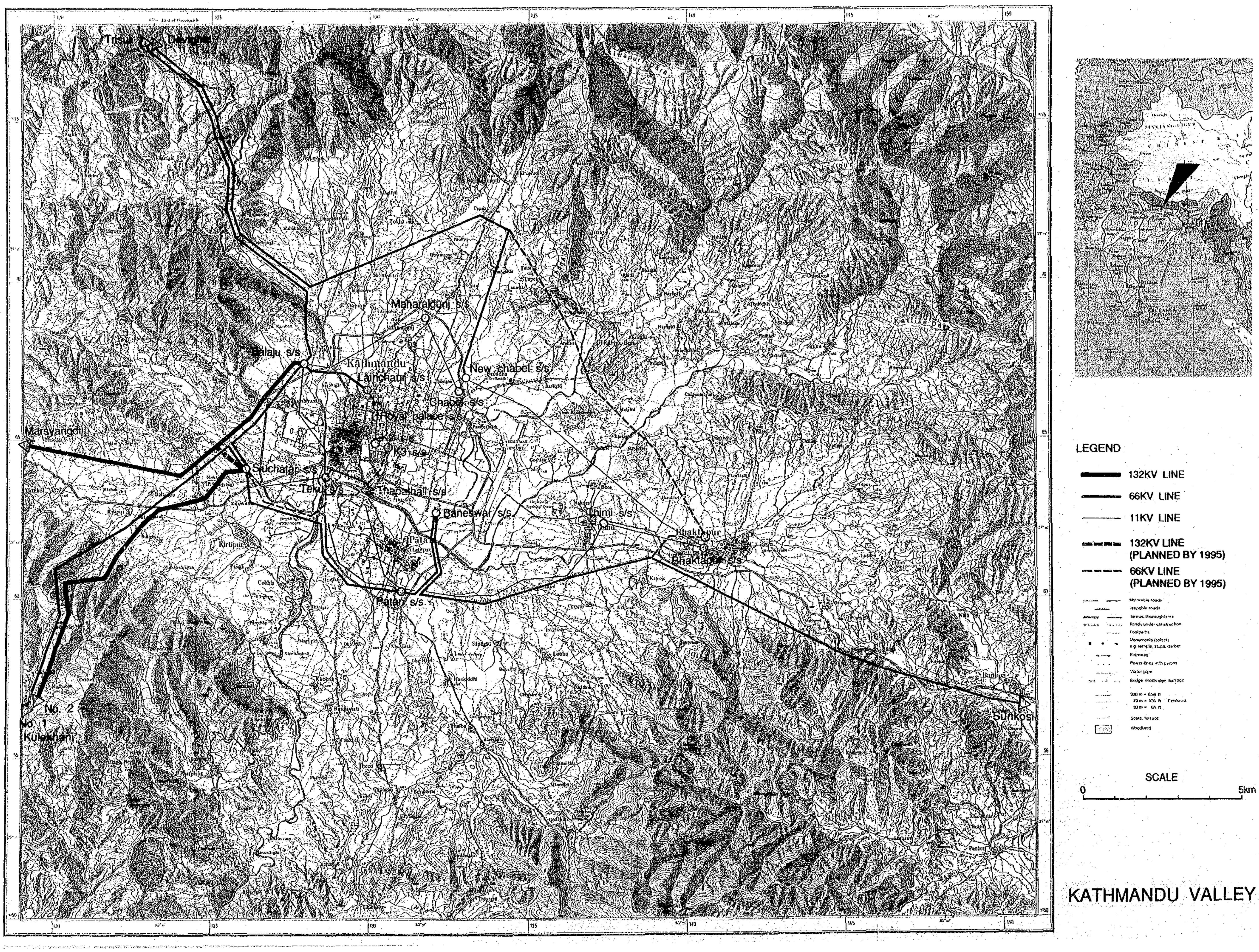
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

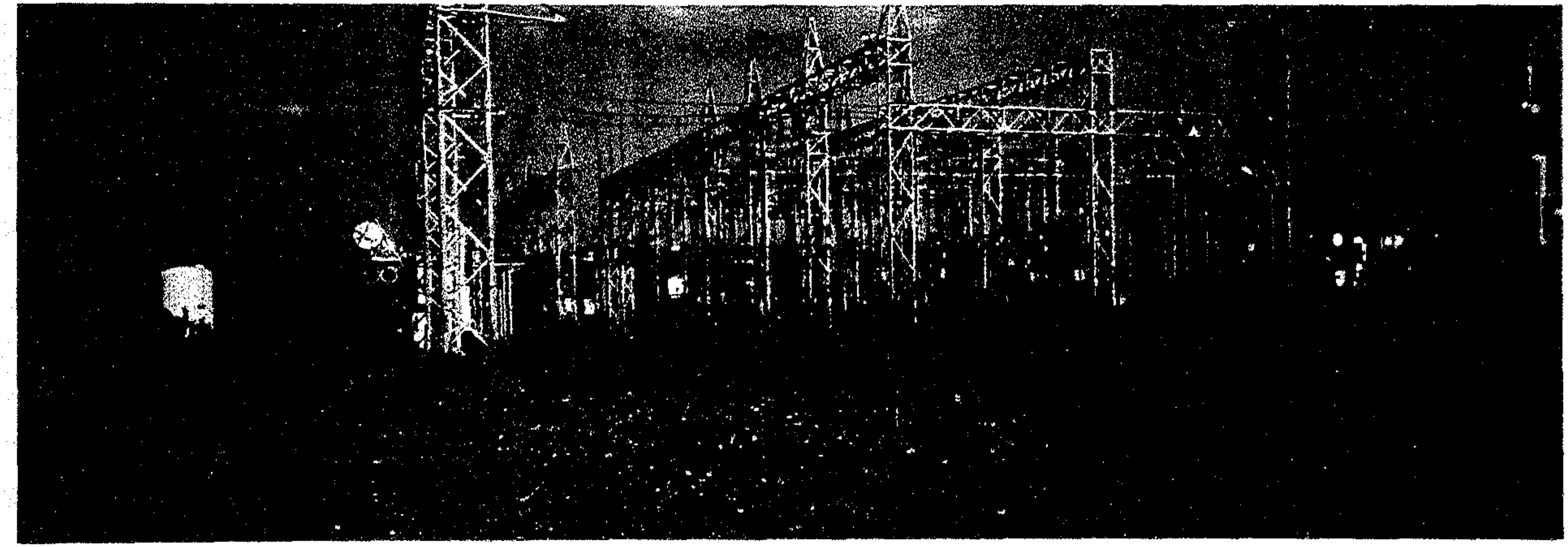
December 1991

Kensuke Yanagiya

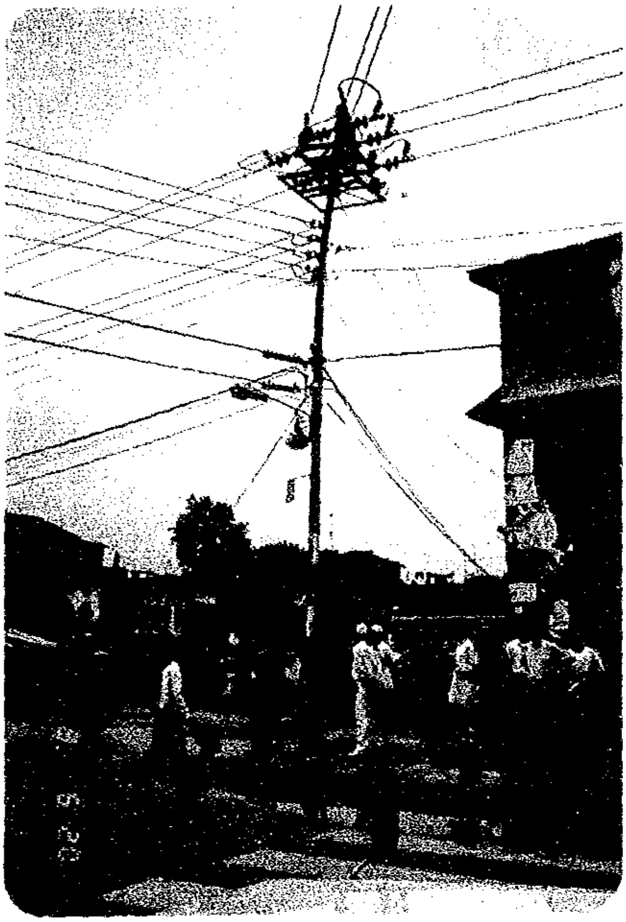
Kensuke Yanagiya
President
Japan International Cooperation Agency



KATHMANDU VALLEY



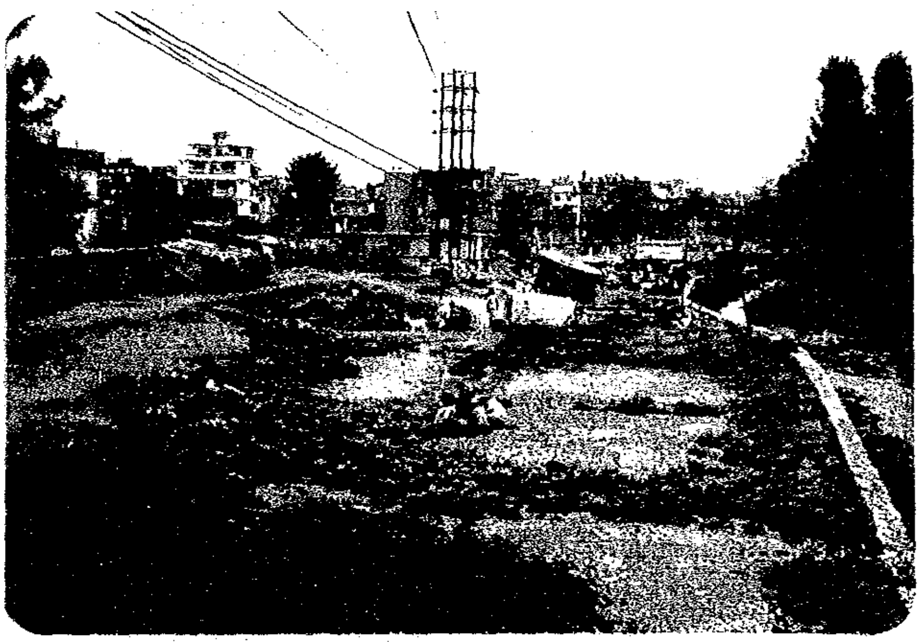
General view of outdoor switch yard, Siuchatar S/S



Deteriorated Pole on
Baneswar Feeder

Low Tension Lines on Wall of Houses
In Kathmandu Center

Patan - K2 11kV Ring Main Line
(Proposed Route for TEKU - K3 66kV Line)



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CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 Background and Objective of the Project

The Kathmandu Valley is the center of Nepal in all respects of its life, be it in politics, administration, economics, finance, culture, etc. encompassing the capital of the country, Kathmandu. However, the power supply in the Kathmandu Valley in the late 1970's to the early 1980's was in a miserable state. People's daily life was considerably hindered by frequent power black-outs and large voltage drops due to insufficiency in power generating capacity and inadequacy in transmission and distribution network.

In order to improve such situations, the Government of Japan (GOJ) conducted, upon the request of the His Majesty's Government of Nepal (HMG/N), a feasibility study in 1978 on the reinforcement of the transmission and distribution system in the Kathmandu Valley to meet the demand growth up to the year 1990/91 and the establishment of a load dispatching center. On the basis of the study, the reinforcement projects of the transmission and distribution system were implemented under three grant aids from the GOJ in 1980, 1982 and 1986.

After completion of the system reinforcement projects and commissioning of the generating facilities such as Kulekhani I, Kulekhani II, Devighat and Marsyangdi power stations, power supply in the Kathmandu Valley has remarkably improved with reliable and quality power supply.

Though the power supply system has been improved under the reinforcement projects, this system will face over-loading soon. Besides, the system demand is growing at a higher rate than that forecasted in the feasibility study of 1978.

Under such circumstance, HMG/N requested GOJ to conduct the Master Plan Study on extension and reinforcement of the power transmission and distribution system in the Kathmandu Valley and the Feasibility Study for urgently required transmission and distribution facilities identified in the Master Plan.

1.2 Scope of Study

The Scope of Work for the Study was mutually agreed in March 1990 between the Nepal Electricity Authority (NEA) and the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation program of the GOJ. It was also agreed that the Study would be undertaken by the study team appointed by JICA in collaboration with the officials of NEA.

Annex-1 of this report indicates the agreed Scope of the Work and the minutes of discussion held between both parties concerning to the Scope of Work.

The objectives of the Study are;

(a) to establish a master plan for the ten years from 1991 to 2000 for the extension and reinforcement of the power transmission and distribution system to meet demand growth in the Kathmandu Valley, and

(b) to perform feasibility study on the power transmission and distribution facilities which will be selected in the master plan as an urgent and important reinforcement countermeasure to be implemented within the coming five years.

The Study consists of two parts; Master Plan Study and Feasibility Study, and their agreed scopes are given below:

Phase-I : Master Plan Study

(1) Collection and review of existing data, study reports and relevant information for the Study.
(2) Field survey.
(3) Power demand forecast.
(4) Planning of power transmission and substation facilities.
(5) Planning of distribution line facilities.
(6) Preparation of implementation schedule.
(7) Cost estimation for the project.

Phase-II : <u>Feasibility Study</u>

(1) Detailed field survey for likely construction sites.
(2) Feasibility design of the project.
(3) Preparation of implementation schedule.
(4) Cost estimation.
(5) Economic evaluation and financial analysis of the project.

The above two studies were conducted in two stages as follows:

- Master Plan Study : from September of 1990 to March of 1991.
- Feasibility Study : from June to December of 1991.

CHAPTER 2

GENERAL DESCRIPTION OF THE STUDY AREA

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2.1 The Study Area

The Kingdom of Nepal is a land-locked country being surrounded by Tibet on its north and by India on its east, west and south. The area of the country is about 147,200 sq.km. The population in 1990 is estimated at about 18.90 million from the figure of 15.02 million in the 1981 census, and its annual growth rate was about 2.6% in the last decade.

The Gross Domestic Products (GDP) of the country in 1989/90 was approximately 84.9 billion Nepalese Rupees (NRs) at current price (refer to Table 2.1). It was NRs. 37.9 billion at 1974/75 constant price and its annual growth rate was about 5.9% in the last decade.

Nepal is an agricultural country. The GDP share of agriculture including forestry and fishery is about 57.6% of the country GDP, while that of industry is only 2.6%. About 90% of the total population is engaged in the sector of agriculture, forestry and fishery.

Although no resources of oil, gas and coal have been confirmed in its territory, Nepal is one of the richest countries in the world in respect of hydro potential. However, development of the hydro resource is hindered due to lack of access roads in the severe topographical condition, large variation of river water flow, heavy silt contamination and limited local power demand against the large scale development.

The total hydro potential in the country is presently estimated at 83,000MW, out of which about 25,000MW are technically and economically exploitable in accordance with the estimate of the Ministry of Water Resources of the country. However, only 229MW including mini-hydro power plants have been developed till now.

Less development of indigenous commercialized-energy in the country and high transportation cost of imported fuel to hilly regions constrain production in the non-agricultural sector. Per capita energy consumption of the country is about

7kg in oil equivalent per annum. Present commercial energy required by people is supplied by coal, coke and petroleum imported as well as by indigenous hydro-power and imported electric power. It is mentioned, however, that those energy sources meet only 5% of total requirement and the remaining is supplied by biomass energy such as firewood, agricultural waste and animal dung. Although the country is rich in forest resources, huge consumption of firewoods is degrading the land and environment.

2.2 Geography

The country is ecologically divided into 3 zones, i.e., mountainous, plateau and Terai plain zones.

Mountainous Zone

The zone lies at an altitude of 4,877m to 8,848m (Mt. Everest) above sea level, and covers about 35% of the whole land area of the country. But, only 2% of its area is arable. As of 1990, about 7.2% of the total population was living in the zone, mainly engaged in sheep and yak pasturing.

Plateau Zone

The zone is located in the middle of the country, at an altitude of 610m to 4,877m above sea level covering mountains, valleys and ravines where such large towns as Pokhara, Kathmandu, Hetauda, etc. lie. The zone occupies about 42% of the country's territory but only 10% of it is arable. About 45.9% of the total population of the country inhabits this zone.

People living on higher land are mainly engaged in pasturage, cottage industry and agriculture of highland cereals, while those at lower altitude in cultivation of cereals and cash crops.

Terai Plain Zone

The zone extends from east to west on the southern region of the country covering about 23% of the whole land. The Terai zone is generally on the low and plain land covered by alluvial fertile soil and dense forest. About 40% of the zone is arable. Population of 46.9% as of 1990 live in the zone and it is growing with a high rate compared with that of the plateau zone.

2.3 Climate

The climate of the country varies from region to region. Summer and late spring temperature range from more than 40°C in the Terai to about 28°C in the mid-section of the country. In winter, average maximum and minimum temperature in the Terai vary from 23°C to 7°C while the central valleys experience average maximum temperature 12°C and minimum temperature below the freezing point. At higher elevations, much colder temperature prevails.

The Kathmandu Valley situated at an altitude of 1300 m has very pleasant and equable climate. Air temperature in the Valley varied between -3.5 and 34 degrees C in the recent 11 years (1976-1986), and annual mean air temperature is stable at 17.4 to 18.5 degrees C during the said period. The minimum air temperature is usually recorded during January, while the maximum temperature during June.

Temperature recorded at the observatory station at the Kathmandu airport in the period of 1976 to 1986 is summarized as below:

Maximum air temperature		34.0 deg. C
Minimum air temperature		-3.5 deg. C
Mean monthly air temperature:	highest	24.4 deg. C
	average	18.0 deg. C
	lowest	11.7 deg. C

Humidity in the Valley is not so high and relative humidity varies from about 40% in April to about 85% in August.

The annual average rainfall in the Valley during the period of 1976 to 1986 recorded at the same observatory station was 1,420mm, of which 80% to 90% was recorded during the wet 5 months from May to September.

Tables 2.2, 2.3, 2.4 and 2.5 show the details of the highest and lowest air temperature, rainfall and humidity in the Valley.

2.4 Population

In 1971 and 1981, censuses were conducted in the country. Population grew from 11,555,983 in 1971 to 15,022,839 in 1981 at an average annual growth rate of 2.66% in the period.

Population of the country in 1990 is estimated to reach 18,900,289 and that in the Kathmandu area including Lalitpur and Bhaktapur would be 956,273 in the year 1990 as detailed in Table 2.6. Population density in the year 1990 is estimated at 128/sq.km for the whole country. The population densities in the Kathmandu Valley are given below:

	Kathmandu	Lalitpur	Bhaktapur	Total
Land area (sq. km)	395	385	119	899
Population				
- 1981 census	422,237	184,341	159,767	766,345
- 1990 (estimated)	514,547	224,292	217,434	956,273
Population density				
- 1981 census	1,069	479	1,343	852
- 1990 (estimated)	1,303	583	1,827	1,064

See: Table 2.6

The annual population growth rate in the Terai zone was higher than that of whole Nepal as mentioned in the previous Section 2.2. Population and its growth rate in each zone in 1971, 1981 and 1990 are shown in Table 2.7.

The Central Bureau of Statistics of Nepal conducted projection of population under four (4) scenarios (high, low, medium and appropriate) based on the results of 1981 census.

The average annual growth rates thus projected for the respective scenarios are summarized below:

Projected Average Annual Growth Rate of Population (%/year)

Scenario	1981-86	1986-91	1991-96	1996-2000
Scenario-1 (high)	2.71	2.76	2.76	2.85
Scenario-2 (low)	2.53	1.92	1.28	1.00
Scenario-3 (medium)	2.62	2.46	2.12	1.82
Scenario-4 (appropriate)	2.64	2.57	2.39	2.25

(Source: Statistic Year Book of Nepal-Central Bureau of Statistics)

CHAPTER 3

ECONOMIC PERSPECTIVES AND ENERGY SECTOR

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3.1 Current Economic Activities

It is reported that about 8,585,370 (45%) persons out of the total population of 18,900,300 were engaged in the economic activities as of 1990. Since the number of persons engaged in these activities in 1981 was registered at 6,850,886, the increase rate was 25% during the period.

Table 3.1 shows the breakdown of population by industrial groups as of 1981. This reveals that approximately 91% (6,244,289) of the economically active population was engaged in the agricultural sector of the country.
The same tendency was also recorded in the Kathmandu area with the rate of the agricultural sector to total economic sector in the area to be 72%.

Although Nepal is an agriculture-based country as indicated from the above fact, the land has never been effectively utilized. Table 3.2 summarizing land use of the country in the year 1981/82 discloses that 83% of the whole land is still non-arable. There are also such non-arable lands in Kathmandu, Bhaktapur and Lalitpur areas with non-arable rates of 36%, 22% and 60%, respectively.

However, the land is gradually being developed. Table 3.3 shows the cultivated area, production and unit yield per hectare of the principal food crops such as paddy, maize, wheat, barley and millet during the last 15 years from 1974/75 to 1989/90. According to the table, the cultivated land has increased at an annual growth rate of 2.5%.

Major manufacturing industrial products with weight of 5% or more of the gross output in Nepal are indicated in Table 3.4. Production of jute goods, which accounted for over 20% of the gross output every year, was 17.2 thousand tons in 1987/88 showing a decreasing trend since 1984/85. On the other hand, productions of sugar, cement and cigarettes were increasing in the period 1981/82 - 1987/88, especially the cement production in 1987/88 amounted to about 6 times that in 1981/82.

The gross output and value added of the manufacturing industry of Nepal amounted to NRs.13,500 million and NRs.4,490 million respectively in

1986/87. In the Kathmandu Valley, those were NRs.2,810 million (21%) and NRs.1,130 million (25%) respectively in the same year, and the gross output and value added in the Kathmandu District accounted for two/third of those in the entire valley (see Table 3.5)

On the other hand, the number of employees of enterprises countrywide rapidly increased 8.2 times during the last 22 years or 3 times during the last 11 years. Especially, increase of employees in the Kathmandu area was remarkably higher than that in other areas, i.e., from 2,250 in 1964/65 to 4,500 in 1976/77 and 30,750 in 1986/87 showing respective growths of 13.7 times and 6.8 times, as seen in Table 3.6.

Increase of number of enterprises was 7.4 times in the period from 1964/65 to 1976/77 and 2.7 times in the period from 1976/77 to 1986/87. The number of enterprises in the Kathmandu area increased 4.2 times and 2.2 times respectively during the same periods, which is understood that the scale of newer enterprises has turned larger. The central development region including Kathmandu and other large towns shares 47% of the number of enterprises and 57% of the number of employees.

Nepal is one of the most attractive countries in the world because of having beautiful natural resources such as snow peaks like Mt. Everest called "the roof of the world", green forests, lakes and rivers. In addition to the natural, landscapes, historical monuments and variety of religions and cultures of ethnic groups also are the important tourism resources of Nepal.

Table 3.7 shows statistics of tourism industry. Number of tourist arrivals amounted to 248,000 in 1987 representing an average increase rate of 6.5% per annum since 1980, especially 10% or more during the period of 1985 - 1987. In 1987, approximately 75% of arriving tourists were for pleasure and 15% for trecking.

According to information from the Department of Tourism, the gross foreign exchange earnings from the tourism sector amounted to US$60 million in 1987, at an average annual increase rate of 3.8% for the period of 1980 - 1987. The increase of tourist arrivals links to hotel business. Numbers of rooms and beds of hotels in Nepal were 23,194 and 45,385 respectively in 1987, of which approximately 82% were located in the Kathmandu Valley. These numbers showed little growth in recent years, but the proportion of bed occupancy in 1987 was 46% in the Kathmandu Valley and 40% in other areas, an increase at a rate of almost 10% since 1981. Of tourists to Nepal in 1987, Indian tourists accounted for 24%, followed by tourists from U.S.A. (11%), U.K. (8%) and Japan (7%). More than 80% of the visitors arrived by air.

3.2 Finance of Government

The finance of HMG/N has increased from the amount of NRs.3,471 million in 1979/80 to NRs.18,005 million in 1988/89 in its expenditures, an increase of 5.2 times during those 10 years, and from 2,686 million in 1979/80 to NRs.9,457 million in 1988/89 in its revenues, an increase 3.5 times, as seen in Table 3.8. The expenditures have exceeded the revenues every year, and deficit of the finance has inevitably increased 10.9 times from NRs.785 million in 1979/80 to NRs.8,548 million in 1988/89. The greater part of financial deficits has been covered by foreign loans. The loan amount which stood at NRs.5,666 million in 1988/89 has increased 10.6 times from NRs.535 million in 1979/80.

Most of the expenditures were used for the national development program, which accounted for almost 70% of the total expenditures in 1988/89 or NRs.12,329 million. This was 5.3 times the amount of NRs.2,309 million in 1979/80. The regular expenditure has increased from NRs.1,162 million in 1979/80 to NRs.5,676 million in 1988/89 (4.9 times).

On the other hand, most of the revenues were from taxes which reached NRs.6,287 million in 1988/89 from NRs.1,529 million in 1979/80 (4.1 times). It is understood from this fact that tax-paying ability of people is increasing year by year. Non-tax revenue was simultaneously increased from NRs.351 million in 1979/80 to NRs.1,490 million in 1988/89 (4.2 times).

3.3 Development Plan

3.3.1 Present Development Plan

The year 1990 was the final year of the Seventh Five-Year Development Plan of Nepal which started in 1985/86. A draft of the Eighth Five-Year Development Plan is now under preparation. HMG/N abolished the Panca-Yat System (the Village Assembly system) in April 1990, and adopted a thought of symbolical monarchy based on the new constitution declared on November 9, 1990. Furthermore, a free election was held after an interval of 32 years with plural parties system and the new government organization was set up since then. So the new Development Plan is being prepared taking into consideration such conditions of social upheaval.

3.3.2 Seventh Five-Year Development Plan

HMG/N established the Seventh Five-Year Development Plan (Seventh Plan) for the period of 1985 to 1990, which indicated various terms for amount of money, growth rate, compositions, etc. of the development targets.

Following is an outline of the Seventh Plan: (refer to Table 3.9)

(1) GDP was set separately for agricultural and non-agricultural sectors.

(2) The GDP target of the agricultural sector was set at NRs.22,080 million for the first year (1985) and NRs.26,220 million (at 1984/85 price level) for the final year (1990) with an average annual growth rate of 3.5%.

(3) The GDP target of the non-agricultural sector was set at NRs.20,060 million for the first year (1985) and NRs.26,290 million (at 1984/85 price level) for the final year (1990) with an average annual growth rate of 5.6%.

Thus, GDP of both agricultural and non-agricultural sectors at the final year (1990) of the Seventh Plan was targeted at 50% each.

However, since the firm amount of GDP was not clarified in the first year (1985), the actual amount of GDP in the starting year was higher than the planned GDP, i.e, NRs.24,170 million for the agricultural sector against the planned NRs.22,080 million and NRs.20,250 million for the non-agricultural sector against the planned NRs.20,060 million. Accordingly, it is estimated that the final GDP of the agricultural sector would reach NRs.30,340 million in 1990 from its initial NRs.24,170 million and the final GDP of the non-agricultural sector would reach NRs.23,670 million in 1990 from its initial NRs.20,250 million. Average annual growth rates will be 4.7% for the agricultural and 3.2% for non-agricultural sectors, and those rates will be higher than the planned target. As seen in Table 3.10, GDP shares of agricultural and non-agricultural sectors will be finally 56% and 44%.

It is noted that since the amounts were converted into the 1984/85 price level, there are some small differences between amounts in Table 3.10 and Table 2.1 due to the difference of estimated deflators.

As seen in Tables 3.11 and 3.12, consumption of GDP in 1990 was set at NRs.48,168 million or 92% of the planned total GDP, but actual amount in the year 1988/89 had already reached NRs.49,287 million or 93% of the planned total GDP. Investment planned at NRs.9,350 million (18%) has actually reached NRs.10,343 million (20%), while amount of savings planned at NRs.4,398 million (8%) remained at only NRs.3,839 million (7%) in 1989. It is noted that the actual amounts of consumption and investment were more than the targets, but the actual amount of savings was less than the target. It should be considered from those facts that the figures in the first year of the plan were higher than the figures assumed in the Seventh Plan, since no final figures were clarified at the time of establishment of the plan.

Both the national revenues and expenditures grew greatly by the year 1988/89. In 1988/89, one year before the final year of the Seventh Plan, the expenditures and revenues have reached NRs.12,356 million and 6,490 million against the planned NRs.10,300 million and 7,370 million, respectively, with average annual growth rates of 10.1% against the planned 3.7% and 7.6% against the planned 6.7%.

On the other hand, the total amount of planned expenditures of NRs.47,970 million has been spent by NRs.41,565 million or 87% of the planned amount by 1988/89, while the total amount of actual revenues was only NRs.24,869 million against the planned NRs.32,460 million or at 77% of the target.

Therefore, deficit of the national finance turned to be larger than the planned amount. The high increase in expenditures was mainly due to the high investment for development. The planned expenditures for development were NRs.29,000 million over 5 years, but the actual investment by 1988/89 over 4 years was NRs.27,503 million or already 95% of the 5-year plan.

3.4 Balance of International Payments

Balance of International Payments

As shown in Table 3.12, the total amount of imports including services by 1988/89 was NRs.13,283 million, and that of exports was NRs.6,779 million resulting in a deficit amount of NRs.6,504 million, corresponding to a deficit rate of 13.3% per annum during 4 years.

The similar tendency is also observed on the trade of goods since 1974/75. Total amount of exports was NRs.4,1985 million in 1988/89 increasing at an average annual rate of 11.7% for the last 14 years, while that of imports was NRs.16,264 million in 1988/89 with an average annual growth rate of 17%. Total deficit of exports and imports was NRs.12,069 million as seen in Table 3.13.

Influence of Cargo Transit through India

Nepal is a typical land-locked country, and all international trade of the country should be done through the territory of India, for which the Treaty for Trade and Transit had been concluded between Nepal and India. Since 1977, both countries have renewed the treaty without any modification on it. But the treaty was made to expire on March 28, 1989.

In order to examine influence of the treaty expiry to the trade of Nepal, monthly fluctuations of exports and imports for the period of August 1987 - April 1990 is shown in Table 3.14 and illustrated in Figure 3.1.

Amount of imports has decreased in April 1989, but recovered in the next month immediately. Such fluctuation pattern was frequently experienced in the past.

The country's exports continuously stagnated for over 6 months after the treaty expires. However, exports have recovered after October 1989 and the amount of exports has been increasing after that. Consequently, there seemed to be no remarkable influence of treaty expiry to the international trade of Nepal.

It is expected that the treaty will be resumed as before with few modifications after establishment of the elected Government in Nepal.

3.5 Energy Consumption in Nepal

Total energy consumption in Nepal was 5,930,000 tons oil equivalent (TOE) as of 1987/88, of which 94.8% (5,620,000 TOE) was consumed by domestic use, 2.0% (120,000 TOE) by industry, 0.9% (50,000 TOE) by commerce, 2.2% (130,000 TOE) by transport, 0.2% (10,000 TOE) by agriculture and others as seen in Table 3.15. Average annual growth rates in the period 1980/81 to 1987/88 were 8.3% in domestic consumption, 12.0% in industry, 16.3% in commerce, 9.2% in transport, 6.8% in agriculture and 20.7% in others.

Electric energy shared only 0.4% of total energy requirement in 1980/81 and 0.6% in 1987/88. Shares of energy sources in the year 1987/88 were recorded as fuelwood at 75.5%, agricultural residue at 10.9%, animal dung and other biomass at 8.3%, coal at 0.9%, petroleum products at 3.9%, electricity at 0.6%. Table 3.16 shows further details of energy consumption.

Table 3.17 details consumption of electric energy in 8 years from 1980/81 to 1987/88 in Nepal by consumer's category. It is known from the Table that average annual growth rates during the period were 14.2% nationwide, 13.0% in domestic use, 18.7% in industry, 1.1% in commerce, 6.2% in transport, 14.5% in agriculture and 21.5% in others. In terms of electric energy consumption, 185GWh (44.8%) were shared by domestic sector, 166GWh (40.2%) by industry, 25GWh (6.1%) by commerce, 2GWh (0.4%) by transport, 9GWh (2.1%) by agriculture and 26GWh (6.4%) by others.

of electricity consumption was shared by both domestic and industry, while share by agriculture was less.

CHAPTER 4

POWER SYSTEM IN NEPAL

CHAPTER 4
POWER SYSTEM IN NEPAL

4.1 Present Power System

4.1.1 Electric Industry in Nepal

Electric industry in Nepal is managed by the Nepal Electricity Authority (NEA), administratively organized under the Ministry of Water Resources (MWR). NEA was established on August 15, 1985 by the merger of the Nepal Electricity Corporation(NEC) , the Electricity Department (ED) under MWR and the Small Hydro Development Board (SHDB) .

NEA has responsibility for the planning, construction, operation and maintenance of all generation, transmission and distribution facilities in Nepal's interconnected power system and principal isolated systems. However, the Marsyangdi hydroelectric project (69 MW) put into operation in 1990 was constructed by the specially organized Marsyangdi Hydro-power Development Board.

NEA's board presently consists of 10 members, with the Minister of Water Resources as the chairman. As seen in Figure 4.1, NEA has six (6) directorates of Finance and Personnel Administration, Planning, Engineering, Construction, Operation/Maintenance and Distribution/Consumer Service.

4.1.2 Power Generating Facilities

Total installed capacity of power generating facilities in Nepal was 257 MW, but their possible output was 228 MW in total as of 1990. Most of those facilities (98%) are interconnected to the Central Nepal Power System (CNPS) by 132kV and 66kV transmission lines. During 10 years from 1981 to 1990, hydro-power stations of 176MW in total have been developed in the country, by which share of hydro and thermal power facilities was largely altered. Such main hydro-power stations as Kulekhani I (60 MW), Kulekhani II (32 MW), Devighat (14 MW) and Marsyangdi (69 MW) were commissioned in 1982, 1984, 1986 and 1990, respectively. Due to the commissioning of these hydropower stations, the share of hydropower to total installed capacity in the country has increased from 67% in the year 1980 to 89% in 1990.

Details of the generating facilities are shown in Table 4.1and 4.2. Following is a summary of these Tables.

Existing Generating Facilities

Facility	CNPS	Others	Total
Hydro	227.2 MW	1.9 MW	229.1 MW
Diesel	25.0 MW	3.1 MW	28.1 MW
Total	252.2MW	5.0 MW	257.2 MW

In addition to the above existing generating facilities, the following power plants are under construction:

(a) A diesel power plant having total installed capacity of 26MW (4 units) in Biratnagar in the eastern region (completion in 1992), under financial assistance of FINNIDA.

(b) Andhikola hydropower plant of 5.1MW (2 Pelton turbines) in Syangja district of the western region (completion in 1991), under the financial assistance of the United Mission to Nepal (UMN) and NORAD (Norway).

(c) Jhimruk hydropower plant of 12MW (3 Francis turbines) in Pyutan district of the mid-western region (completion in 1995), under the same finance for the Andhikola hydropower plant.

Both of the above hydropower plants are executed under the responsibility of the Butwal Electricity Company Ltd.

Besides, private generating facilities of about 15MW (diesel and steam) are also operated.

4.1.3 Power Transmission Facilities

The present transmission line voltages employed in the country are 132kV, 66kV and 33kV. Since the voltage of 132kV was firstly employed for the line between Gandak power station and Hetauda substation under funding by the Asian Development Bank (ADB) , the 132kV system has been extended in the country. The 132kV system has been extended to Kathmandu Valley in 1986 via Kulekhani II-Siuchatar line under the financial assistance of OECF and in the eastern region towards Biratnagar (3rd Power Project, completed in 1985) and further extended to Anarmani substation under 5th Power Project with ADB financing.

On the other hand, another 132kV system was extended towards the western region from Dumkibas to Butwal under French financing and from Butwal to Nepalganj under ADB's 4th Power Project.

Under the Marsyangdi hydropower project, 132kV single circuit line was constructed over 110km from the power station to Kathmandu (Balaju) and to Bharatpur. Another 132kV system is under construction from Nepalganj to Mahendranagar in the far west, and its completion will form a complete interconnection of the power system among main demanding centers in Nepal. Figure 4.2 indicates the transmission system in whole Nepal.

General information on transmission lines and transformers in the country is summarized below:

Transmission Lines and Substation Facilities

Voltage	Transmission Line (circuit-km)	Capacity of Transformer (MVA) *1	
		Whole system	Bagmati Area
132kV	1,000.0	213.8 *2	82.8
66kV	379.5	188.7	153.9
Total	1,379.5	402.5	236.7

Note: *1 excluding step-up transformers at power stations
*2 including 132/66kV transformers

Further details of the existing transmission lines and substation facilities are shown in Tables 4.3 and 4.4.

4.1.4 Power System Operation

The interconnected power system is operated following instructions of the Load Dispatching Center (LDC) located in the town of Kathmandu which was constructed under the grant aid of Japan.

Control of Power Supply

Hydropower stations satisfying the most of energy requirement of the interconnected power system are summarized in Table 4.1. Among these hydropower stations, only the Kulekhani I power station together with the downstream Kulekhani II are provided with substantial storage capacity and all others are of run-of-river type with a pond capable of daily and/or hourly regulation.

A detailed operation schedule for each power station has not been established. Power supply is controlled by the LDC so as to meet a variable energy demand by adjusting outputs of Kulekhani I, II and Marsynagdi power stations (daily control only), while other power stations are running under flat operation in proportion to inflow of water available to each station.

Control of System Voltage

The system voltage is managed so as to maintain the voltages of the 11kV buses of substations and switching stations in the Kathmandu Valley within a range of 10.5kV (in peak time) to 11.5kV (in off-peak time).

Actual control of the system voltage is being conducted by manual operation of tap-changers on main transformers (132/66kV and 66/11kV) at each substation under instructions from the LDC.

Switching Operation

Following are principal operation rules for switching:

(a) Operation of switches on 66kV and 132kV systems and on-off operation of static capacitors and shunt reactors are instructed by the LDC.

(b) Switches for 11kV or lower voltages are operated by substation operators on their judgement.

(c) At anytime when load shedding is required or faults occur, every operation of switches is done under instructions of the LDC.

Reporting

Following reports are periodically made:

(a) Supply data

Report in the form shown in Table 4.5 is daily prepared by the LDC and submitted to all directors of NEA.

(b) Maximum Power

Maximum demand and its time on every feeder in each substation and switching station are weekly reported to the LDC by the respective station.

(c) Tripping

All of tripping faults at substations and switching stations are reported to the LDC everyday if the case occurs, and its summary is submitted monthly by the stations.

4.2 Power Network in Kathmandu Valley

4.2.1 Power Supply to Kathmandu Valley

Power to the Kathmandu Valley is supplied from the Marsyangdi and Kulekhani II power stations through 132kV transmission lines and from the Kulekhani I, Trisuli, Devighat and Sunkosi power stations through 66kV transmission lines.

Power delivered through 132kV transmission lines is stepped down to 66kV at the Siuchatar and Balaju substations and therefrom further delivered to distribution substations in the town by 66kV transmission lines.

Following are 66/11kV distribution substations in the Kathmandu area:

(a) Balaju substation : 20.0 MVA (2x10MVA)
(b) Lainchaur substation : 20.0 MVA (2x10MVA)
(c) New Chabel substation : 18.9 MVA (3x6.3MVA)
(d) Siuchatar substation : 36.0 MVA (2x18MVA)
(e) New Patan substation : 36.6 MVA (2x18MVA)
(f) Baneswar substation : 18.0 MVA (1x18MVA)

All substations, except New Patan substation in Patan city, are located in Kathmandu city.

The Lainchaur and Balaju substations are provided with the latest GIS (Gas Insulated Switchgears) , while other substations are with conventional outdoor switchgears. The Sunkosi feeder of the New Patan substation is provided with very old-fashioned switchgear.

4.2.2 Distribution Facilities

Distribution network in the area is structured by 11kV, 3.3kV and 400/230V facilities.

Ring Main System

The so-called Ring Main is supplying highly reliable power to the Kathmandu city center area. The Ring Main system consists of 11kV double circuits of ACSR 200 sq. mm lines and several switching stations. From those switching stations on the Ring Main and distribution substations, 11kV primary distribution lines are extended for power supply to consumers on low voltage lines through 11kV/400-230V pole-mounted transformers. Power supply system in the Kathmandu area involving the Ring Main is illustrated in Figure 7.1, and details of the 11kV Ring Main lines are summarized in Table 4.6.

Reinforcement and Extension of Distribution System

Since 1980/81, facilities of transmission and distribution networks in the Kathmandu Valley have been rehabilitated and reinforced under the 3 projects (years 1980, 1982 and 1986) which utilized the grant aid from the GOJ.

Following table summarizes historical records of the facilities in the area.

Historical Records of Distribution Network in Kathmandu Valley

	1978	1980 1st Phase	1982 2nd Phase	1986 3rd Phase
(a) Distribution Line (circuit-km)				
11kV	250	342	422	450
3.3kV	64	39	20	0
Total	314	381	442	450
(b) Distribution Substation (MVA) *1				
11/0.4-0.23 kV	31.64	57.26	84.33	93.23
3.3/0.4-0.23kV	8.82	4.00	2.00	2.00
Total	40.46	61.26	86.33	95.23

Note: *1 Not including transformers installed by hospitals, factories,and others at their own expenses.

Owing to those three projects, about 84% of the population in the Kathmandu Valley is now enjoying the benefit of electricity against 42% in the Bagmati areas and 8.9% in the whole country as of 1990.

As seen in the table, the 11kV distribution systems have been remarkably extended under such grant aid projects, including grading up of old 3.3kV system to 11kV one.

11kV Distribution Lines

In order to supply the electric power to the general consumers inside the Kathmandu Valley, the following facilities are provided:

- Two (2) 132/66/11kV substations (Siuchatar and Balaju)
- Four (4) 66/11kV substations (New Patan, Baneswar, Lainchaur and New Chabel)
- Nine (9) 11kV switching stations (Teku, Royal Palace, Maharajgunj, K2, Old Patan, Old Chabel, Thapathali, Thimi and Bhaktapur)
- Sixty eight (68) 11kV feeder lines of 560 km in total

The details are shown in Table 4.7.

The distribution lines are of radial feeder system, and most of them are overhead lines with three-phase, three-wire system. In the urban areas with high demand density, some distribution lines are connected to a couple of substations or switching stations, normally supplied from one station but backup is available by operation of sectionalizing switches at the section poles or by jumper connection.

Underground cables are applied and laid down at some areas of the city center, where roads are too narrow to maintain the insulation clearance between the overhead wire and the buildings.

In general, the cable is branched off at the transformer pole. However, at some underground distribution lines, oil switches are provided to supply power to several cable sections.

In general, the route length of the distribution lines is several km in city areas and then several 10 km in rural areas.

Distribution Transformers

Distribution transformers (11kV/400-230V) installed in the Kathmandu Valley as of 1989/90 fiscal year totalled 1,371 units in quantity and 182MVA in capacity, and further details are given in Table 4.8.

The unit capacity of distribution transformer ranges from 10kVA to 2,250kVA and the majority is 250kVA in urban areas, 100kVA in city areas and 50kVA in rural areas.

Principally, all distribution transformers are of three-phase type. In some rural areas, however, single-phase transformers are applied for serving lighting loads.

The electricity is generally supplied from the distribution transformers to the low-tension lines through the distribution circuit breakers. However, in some areas, the transformer is directly connected to the low-tension line without any switching device.

The transformer is generally protected by dropout switch with fuse provided on the 11kV circuit of the transformer.

Low-tension Distribution Network

The low-tension distribution network connected with the low-tension side of the distribution transformers supplies electricity to low-tension consumers through 400/230V, three-phase, four-wire system.

Low tension lines are of radial feeder system and most of them are overhead lines. In city areas, most of the distribution lines have wires for street lighting.

ACSR conductors of various sizes are used for the trunk lines. However, insulated wires and aerial cables are also applied on pole supports and/or on the wall of buildings in some areas of the city center which are densely populated and congested by houses and buildings with narrow roads.

4.3 Current Problems on Transmission and Distribution System in Kathmandu Valley

4.3.1 General

Completion of the Marsyangdi power station contributes a surplus capacity to the present power supply system so as to be sufficient even if a unit of the biggest generator in the system is out of operation, as shown below:

- Firm capacity of generating facilities including diesel plant (see Table 4.1)	225.3MW
- Maximum unit capacity of generator	30.0MW
- Peak demand (Jan. 5, 1990)	176.2MW
- Surplus capacity of the system	19.1MW

Although a considerably high voltage drop is observed at some parts of the existing Kathmandu distibution network, this does not seriously affect the current power distribution under normal supply condition. However, some hindrances to stable power supply take place on the existing transmission and distribution network as will be explained hereinafter.

4.3.2 Transmission Lines and Substations

(1) Siuchatar-Patan Line

Power fed from the New Patan substation is served from the Siuchatar substation through a 66kV single circuit line with ACSR Wolf conductors (51MVA per circuit) and from the Sunkosi power station through a 66kV single circuit line with ACSR 120 sq.mm conductors (44MVA per circuit) via the Baneswar substation.

All demand of the Baneswar substations, Old Patan and Thimi switching station and also about half of the demand of K2 and Bhaktapur switching stations are met by the New Patan substation. Maximum load of substations and switching stations in those areas as of January 5,1990 was 31.5 MW as below:

K2 switching station	6.20 MW	(12.40 MW)
Old Patan switching station	7.22 MW	
Baneswar substation	13.50 MW	
Thimi switching station	1.78 MW	
Bhaktapur switching station	2.80 MW	(5.61 MW)
Total	31.50 MW	(40.51 MW)

If a fault occurs on the Siuchatar-Patan line, Sunkosi power station (effective output of 5.8MW) or other transmission lines, power supply to the areas will be seriously affected. For stable power supply even under such a state as mentioned above, an effective measure should be taken by converting the existing single circuit Siuchatar-Patan line to double circuit construction, or by shifting the loads of the existing substations to other substation(s) to be newly constructed.

(2) Patan-Baneswar Line

As explained in (1) above, the loads of the Baneswar substation (13.5MW) are met by both the Sunkosi and Patan-Baneswar lines. If a fault occurs on the Patan-Baneswar line, a very serious load shedding in such areas should happen, since power supply source to such areas comes from the Sunkosi power station only and supply capacity of the isolated system will be limited by the possible output of the Sunkosi power station at that time.

For avoiding such serious load shedding, the following measures should be considered:

(a) Construction of another single circuit 66kV line between New Patan and Baneswar.

(b) Forming a 66kV ring system by construction of 66kV line between Baneswar and New Chabel or between Bhaktapur and New Chabel.

(3) 132kV Marsyangdi System

The Marsyangdi power station (3x23 MW) is connected with the Balaju substation in Kathmandu town and the Bharatpur substation in the Western region through 132kV single circuit transmission lines. The Balaju substation is provided with a 132/66kV, 45MVA transformer, which is connected with the existing 66kV power system. If a fault occurs on the Marsyangdi-Bharatpur transmission line under such a system structure, the output of the Marsyangdi power station must be limited mainly due to the limited transformer capacity of 45MVA at the Balaju substation. This fact results not only reduction of power supply to the entire system but also ineffective discharge of valuable water.

For improvement of such situations, the following 3 countermeasures may be conceived:

(a) Addition of 132/66kV transformer at the Balaju Substation.

(b) Construction of a new 132kV transmission line beween Siuchatar and Balaju substations.

(c) Connection of the Marsyangdi-Balaju transmission line to the Siuchatar substation

(4) 66kV Systems of Trisuli-Balaju and Devighat-New Chabel

The Devighat-New Chabel 66kV system is isolated from the Kathamandu 66kV system, but the both systems are interconnected through the 11kV system. In January 1990, however, the New Chabel and Balaju substations were connected by utilizing the 66kV Trisuli-Balaju and 66kV Devighat-New Chabel transmission lines to avoid outage of Devighat power station due to faults on the 11 kV system by a jumper line tapped from both the lines.

By this connection the 66kV systems in the Kathmandu Valley become a unified system, but one circuit each of both the 66kV lines was used for each power station and this decreased reliablity of power transmission.

The Trisuli and Devighat power stations are running in cascade operation, and any interruption of the Trisuli-Balaju transmission line results in stop of generetion of both Trisuli and Devighat power stations causing serious deficit of power supply.

In order to solve the problem, the 66kV line connection of both the power stations will be most appropriate.

(5) Lainchaur 66kV Substation

The substation was completed in 1989 with indoor type GIS supplied under the same specifications and by the same manufacturer as those for the Balaju substation. The substation was burnt down by a spreading fire of 11kV cubicles in July 1990. The substation has not been rehabilitated yet, but its power supply operation was resumed directly from the 66/11kV transformer and newly installed 11kV cubicles since October 17, 1990, without 66kV switchgears at Lainchaur.

(6) 132kV Switchgears

Switchgear installed in the Siuchatar substation is of conventional outdoor type and no difficulty is anticipated for its future expansion.

No consideration has been paid for the Balaju substation with indoor type GIS regarding space and facilities necessary for future expansion. Therefore, expansion plans of the substation should be prepared with utmost care.

(7) 66kV Switchgears

The Balaju and Lainchaur substations are provided with indoor type GIS and other substations with outdoor type conventional switchgear. Although there is no serious problems at present, the following should be taken into account for planning future expansion of the substations:

(a) Ratings of Equipment

As seen in Table 4.12 for the ratings of the existing circuit breakers, no standard ratings are applied to the breakers. In the future expansion or development, a standard design for the equipment should be established as far as applicable.

(b) Balaju Substation

The existing indoor type GIS are installed taking into account future expansion of the substation. Current ratios of the existing current transformers (CT) in the substation are as follows:

- 132/66kV transformer (CT on secondary)	:	400/1A
- Bus-tie CT	:	400-200/1A
- Transmission line and transformer CT	:	200-100/1A

In case of load growth or replacement of transformers at the Lainchaur substation, new CTs may be required on the transmission line circuit, since the power transmission limit of the transmission line circuit is 22MVA by the CT ratio.

(c) New Chabel Subsation

Following are current ratios of the existing CTs in the substation, and replacement of the CTs may be required in case of load growth or replacement of transformers.

- 66/11kV transformer(CT on primary side)	:	400-200/1A
- Transmission line bay	:	200-100-50/1A

(d) Patan Substation

Chinese-made switchgear is installed under the Sunkosi project. There are difficulties in maintenance of this equipment. It is nearly 20 years old and no detailed specifications or manual of the equipment exist. Since this equipment has been deteriorated, its replacement will be necessary at an appropriate occasion.

4.3.3 Capacity of Transformers

Maximum loadings of 66/11kV transformers in the Kathmandu area as of January 5 and October 10, 1990 were as follow:

Loadings of Transformers

Substation	Installed Capacity (MVA)	Loading (MW)	
		Jan. 5, '90	Oct. 10, '90
Balaju	20.0	13.0	14.0
Siuchatar	36.0	15.3	17.0
New Patan	36.0	23.2	23.4
Baneswar	18.0	13.0	11.5
New Chabel	18.9	6.9	14.6
Lainchuar	20.0	17.9	4.9(*1)
Total	148.9	89.3	84.4

Note: (*1) One unit only (10MVA) is commissioned.

Following are clarified from the above records.

(a) No over-loadings of transformers are observed at present.

(b) The transformer at the New Chabel substation is anticipated to be over-loaded soon. However, the loading to the New Chabel substation will be decreasaed after the Lainchaur substation is completely rehabilitated.

4.3.4 11kV Ring Main System

(1) Underground Cable of Lainchaur-K2

The underground cable in this section was laid 25 years ago and was not used at the time of the site investigation by the Team in 1990 because of breakage. Therefore, most of demand of the K2 switching station was met by supply through 11kV double circuit line between New Patan and K2 stations. The Patan-K2 line may be over-loaded in the near future. With the same cable breakage, the 66kV line between Siuchatar and New Patan substations is also going to be heavy-loaded as mentioned in the foregoing Section 4.3.2. The damaged underground cable however has been restored by NEA in middle of 1991.

(2) Power Supply to Bhaktapur Area

Power to the Bhaktapur area is supplied through two 11kV double circuit lines from the New Chabel and New Patan substations. However, voltage drops in both lines are considerable as the transmission distance of about 10km from both the New Patan and New Chabel substations is too long for the 11kV lines and their transmission capacities are near to their limit. Many new factories are also planned in this area. Urgent construction of new 66/11kV substation will be required for the area.

(3) Teku-Patan 11kV Line

Teku-Patan 11kV double circuit line is at present not used for the following reasons:

(a) Fault on an underground cable on the New Patan side.

(b) Shift of the cubicle for Patan lines to Thapathali lines, since a cubicle for Thapathali lines at Teku substation was damaged due to over-heating.

4.3.5 11kV Distribution Lines

The following five items were examined on each distribution line to make clear the present problems:

(a) Voltage drop
(b) Current carrying capacity of conductors
(c) Tripping frequency of circuit breaker due to line faults
(d) Utilization factor of distribution transformers
(e) Capacity of multi-circuit oil switch

Voltage Drop

The examination results are shown in Table 4.9 with a criterion that voltage drop of 7.5% is to be allowed over a 11kV distribution line.

Calculations were conducted with the condition that the load is uniformly distributed along the trunk line, on the basis of data on load current measured at each substation and switching station on January 5, 1990.

As a result of the above examination, voltage drop on the Godawari - 2 and Sundarijal (from Old Chabel) feeders exceed the allowable limit and shift of some load on these feeders is needed immediately.

Current Carrying Capacity of Conductors

The maximum current carrying capacity and load current for each section of conductor size are shown together in Table 4.9.

According to this result, the maximum load current of all the distribution lines is within the maximum current carrying capacity of each conductor and it is found that there is no problem in current carrying capacity of conductors.

Tripping Frequency of Circuit Breakers due to Line Faults

Tripping frequency of the distribution circuit breakers installed in each substation and switching station due to short-circuit fault and earth fault occurred for one year from April 1989 to March 1990 is shown in Table 4.10.

According to this table, the distribution lines with high tripping frequency of circuit breaker over 100 times in a year are the following.

(a) Thankot line (Siuchatar substation)
(b) Godawari - 1 line (Baneswar substation)
(c) Godawari - 2 line (Baneswar substation)
(d) Pharping line (Old Patan switching station)
(e) Kirtipur line (Teku switching station)
(f) Tahachal line (Teku switching station)
(g) Boudha-Jorpati line (Old Chabel switching station)

The total monthly tripping frequency of all the distribution circuit breakers installed in the Kathmandu Valley is illustrated in Figure 4.3.

From these figures, it was found that the earth fault occupies more than a half of these faults and tripping frequency per month is high during the rainy season. It is likely that touch of tree to a line occurs frequently due to improper maintenance works.

Utilization Factor of Distribution Transformers

At present, utilization factor of distribution transformers is measured as a part of the Loss Reduction Project under IDA's assistance.

The measurement results in the Lalitpur area are shown in Table 4.11, and the distribution of the utilization factor in the area is in Figure 4.4.

As a result of this study, it was found that 8 percent of transformers were operated under overloaded conditions of more than 130 percent of the transformer rated capacity.

Capacity of Multi-circuit Oil Switch

At present, a multi-circuit oil switch is installed on the Mahabauda line (K2 switching station) and the Mint line (Teku switching station).

The rated current and rated short-time current of the oil switch are 400A and 13.1kA respectively.