(2) In this projection, the nation's total demand in 1994 is predicted to be 3,458.0 GWh in terms of energy and 654 MW in terms of maximum demand, and the energy demand of the Metropolitan Area to be 2,224.8 GWh, with the maximum demand of 419 MW. The average annual growth rate of electricity demand for the period from 1989 to 1994 will be about 11% for the whole system and about 10% in the Metropolitan system. The demand in the Project Area under this study corresponds to approximately 90% of the total demand in the Metropolitan Area.

4.3 Power Demand Projection for the Project Area

4.3.1 Items of Consideration for Power Demand Projection

As a power demand projection forms the very basis of power facility planning and financing plan, the projected values must be established with high accuracy as much as possible. The following considerations were taken into account in formulating this demand projection.

(a) The transmission and distribution facilities must have sufficient capacity in reference to the maximum power demand projected. For this purpose, it is necessary to accurately predict the maximum demand of each year in establishing the facility plan, and the projected values must be compatible with the projections of energy demands and load factors of future years.

(b) As the suitableness of capital investment directly affect the business performance of the corporation, an excessive investment on fixed capitals must be excluded. Care must be taken to avoid over-estimation of demands through careful analysis of past load growth and prediction of economic and social changes in future.

(c) It is required to understand the general trend of power demand growth in the whole Project Area and at the same time identify the demand trend in each local area, so that an efficient plan is established for each power system facility. This is particularly important in planning construction, expansion of substations and distribution facilities.

4.3.2 Methodology of Power Demand Projection

As discussed above, the projection of maximum demands is important in planning transmission and distribution systems. The macroscopic method, in which the demand is projected by the consumer end energy consumption and annual load factor, has been selected in projecting the maximum demand for the whole area under study. The consumer end energy consumption was projected by the following two methods, and the higher projection value was adopted for the study.

(a) The future population of the Project Area and the future energy consumption per capita were projected, and the total energy consumption at the consumer end was calculated by these two factors.

(b) The consumer end energy consumption was projected based on the past trend.

4.3.3 Projection of Population in the Project Area

(1) According to the "Statistical Yearbook" published by the Statistics Bureau of the United Nations, the total population of Paraguay was 2,357,995 in 1972 and 3,029,830 in 1982. The average population growth rate was 3.7% per annum for the period from 1975 to 1980, and 3.2% from 1980 to 1986. (Table 4-9)

(2) It is estimated by "Direccion General de Estadistica y Censo" that the population in the years after 1986 is 3,807 thousands in 1986, 4,642.6 thousands in 1993, and 5,537.6 thousands in 2000. The corresponding average population growth rate per annum is 2.9% from 1986 to 1993, and 2.6% from 1993 to 2000. (Table 4-10)

(3) According to the national census conducted in 1982, the population in the Project Area was 807.3 thousands. As this value

Table 4-9 Population in Paraguay

References	Latest Census (in units)				Mid-year Estimates (in thousands)		Annual Rate of Increase (%)
	Date	Both Sexes	Male	Female			
1981 Statistical Yearbook	9-VII-'72	2,357,955	1,169,111	1,188,844	2,647 (as of 1975)	3,168 (as of 1980)	(1975 - 80) 3.7
1985/86 Statistical Yearbook	11-VII-'82	3,029,830	1,521,409	1,508,421	3,147 (as of 1980)	3,807 (as of 1986)	(1980 - 86) 3.2

Issued by Department of International Economic and Social Affairs, Statistical Offices United Nations.

Table 4-10 Estimation and Prediction of Population of Paraguay

Year	Total	Male	Female
1986	3,807,030	1,927,052	1,879,977
1987	3,922,374	1,985,776	1,936,597
1988	4,039,161	2,045,117	1,994,043
1989	4,157,287	2,105,054	2,052,231
1990	4,276,649	2,165,568	2,111,080
1991	4,397,306	2,226,676	2,170,630
1992	4,519,328	2,288,392	2,230,935
1993	4,642,624	2,350,688	2,291,936
1994	4,767,107	2,413,538	2,353,569
1995	4,892,687	2,476,914	2,415,773
1996	5,019,312	2,540,783	2,478,529
1997	5,147,042	2,605,165	2,541,877
1998	5,275,953	2,670,106	2,605,847
1999	5,406,126	2,735,657	2,670,468
2000	5,537,636	2,801,867	2,735,769

Source: Direccion General de Estadistica y Censo was 581.8 thousands in the census of 1972, the annual average population growth rate from 1972 to 1982 can be estimated as 3.33%.

(4) Although there is no official data of recent date concerning the current and future population in each local area of the Metropolitan Area, these data can be estimated by the population of the Project Area of 807.3 thousands in 1982, and the predicted average population growth rates for the whole Paraguay, which are 3.2% from 1981 to 1986, 2.9% from 1986 to 1993, and 2.6% from 1993 to 2000. Based on this estimate, the population in the Project Area will be 1,118.6 thousands in 1993, and 1,338.7 thousands in 2000. (Table 4-11, Fig. 4-9)

4.3.4 Estimation of Consumer End Energy Consumption by Population Projection

The time history trend of energy demand per capita (consumer end) was inferred from the records of energy consumption and the estimated population in the Project Area from 1981 to 1988, and the future energy consumption per capita (consumer end) was predicted by this trend. This projection was combined with the future population projection to estimate the consumer end energy consumption in future.

This estimation is presented in Table 4-11 and Fig. 4-10. The projected consumer end energy consumption in 2000 thereby obtained was 2,141.4 GWh.

4.3.5 Estimation of Consumer End Energy Consumption by Time History Trend

When it can be assumed that the economic and social development patterns in the past several years will be maintained in future, the demand projection by time history trend is a very effective tool of demand projection. In the Project, this methodology is applicable. The trend line was estimated by a real linear equation and a real quadratic equation using the least square method.

Table 4-11 Forecast of Energy Demand at Ultimate Consumer's Level and Estimates and Forecast of Population in the Project Area

(X)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy Demand (GWH)	485.9	545.8	591.9	631.4	705.7	784.3	882.3	960.6	1,022.7	1,106.1	1,193.3	1,284.6	1,380.4	1,476.2	1,576.1	1,680.1	1,788.6	1,901.4	2,019.0	2,141.4
Population (in thousands)	782.3	807.3	833.1	859.8	887.3	915.7	942.3	969.6	997.7	1,026.6	1,056.4	1,087.0	1,118.6	1,147.6	1,177.5	1,208.1	1,239.5	1,271.7	1,304.8	1,338.7
Energy Demand per Capita (y) (kWH)	621.1	676.1	710.5	734.4	795.3	856.5	936.3	990.7	1,025.1	1,077.4	1,129.6	1,181.8	1,234.0	1,286.3	1,338.5	1,390.7	1,443.0	1,495.2	1,547.4	1,599.6

Note:
1. Annual rates of increase used for estimate and forecast of the population are as follows:
   3.2% (1981 - 86), 2.9% (1986 - 93), 2.6% (1993 - 2000)
2. Energy demand per capita (kWH) = Energy demand (GWH) x 10^3/ Population (in thousands) for 1981 - 1988, but the equation as follows is used for 1989 - 2000.
   $y = 555.09 + 52,274X \qquad r = 0.98934$
3. Energy demand (GWH) for 1981 - 88 is actual,
   Energy demand (GWH) for 1989 - 2000 = Population (in thousand) x Energy demand per capita (kWH) x 10^{-3}

Fig. 4-9 Transition of Population in the Project Area, Estimated and Predicted

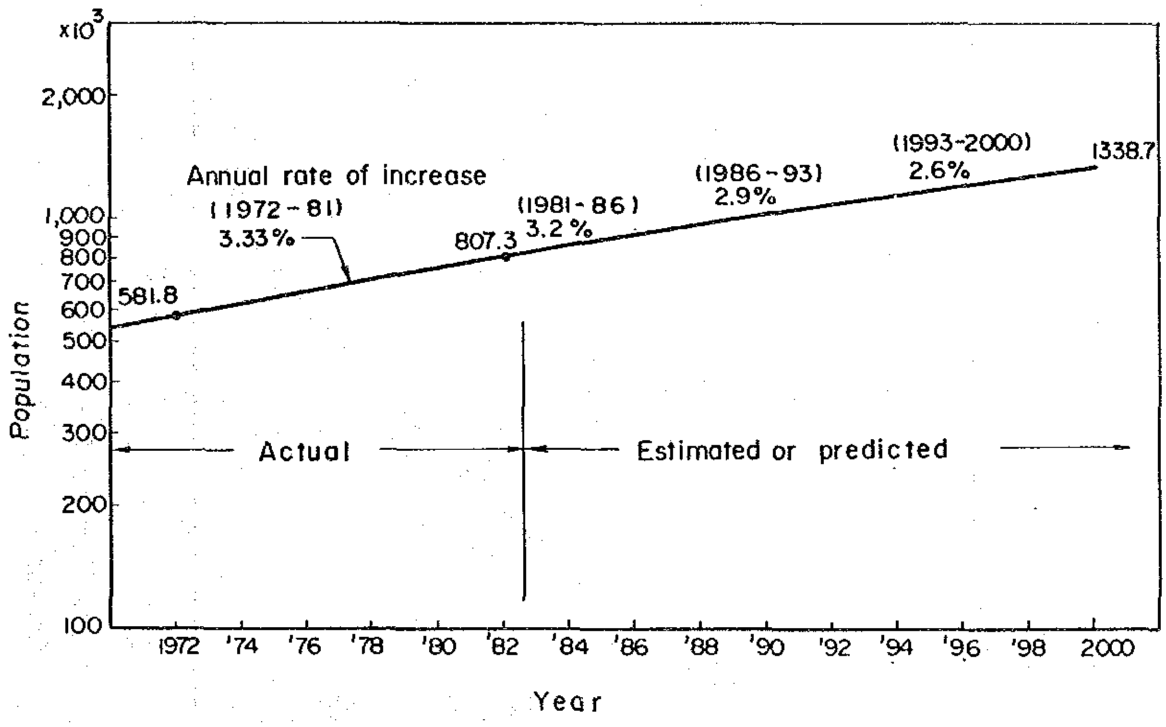
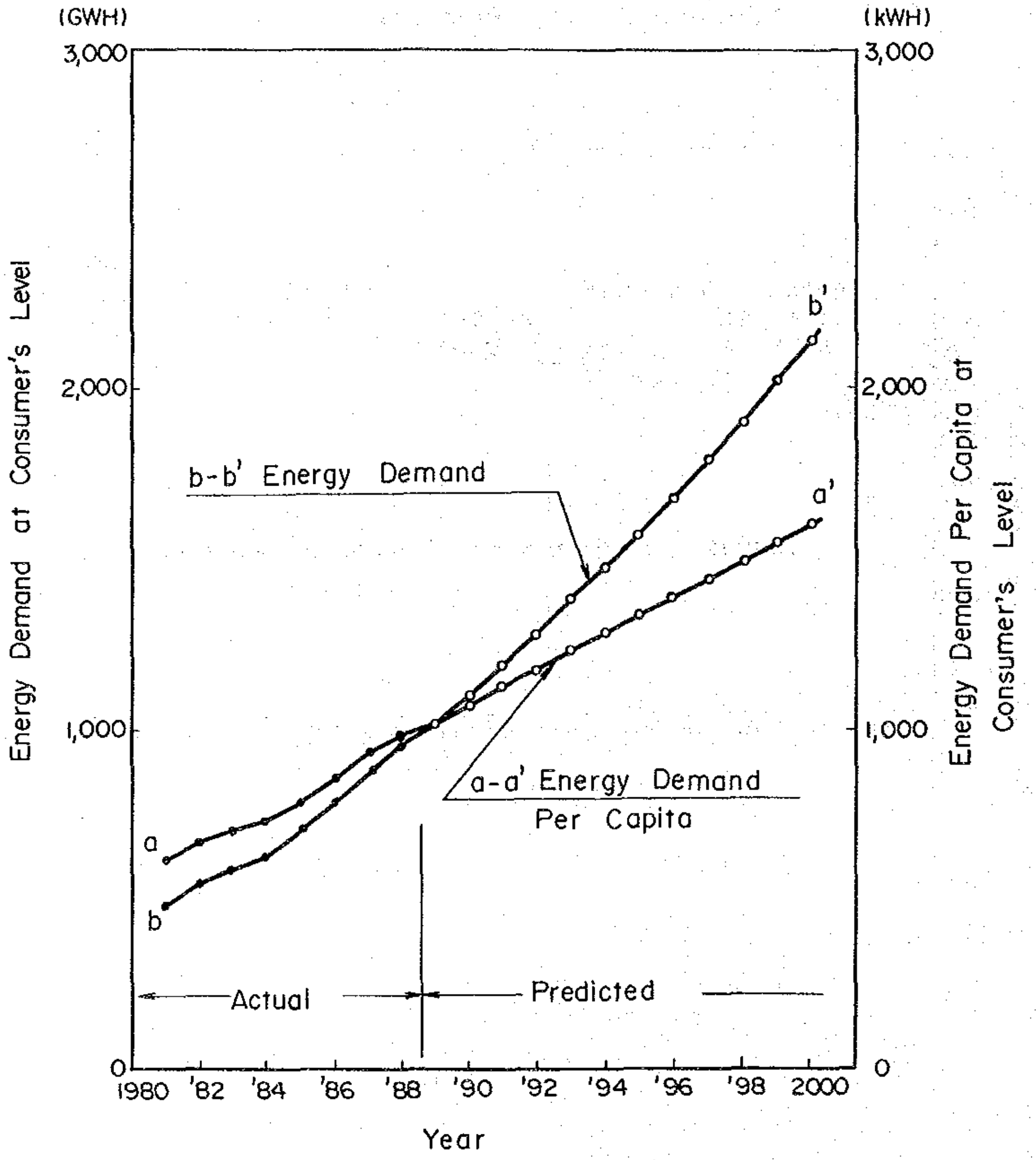


Fig. 4-10 Predicted Energy Demand (GWH) and Energy Demand Per Capita (kWH) at Consumer's Level



The estimated results are given in Table 4-12 and Fig. 4-11.

4.3.6 Projection of Consumer End Energy Consumption

(1) The following values were obtained as the projected consumer end energy consumption for year 2000 by the two projection methods discussed above.

Consumer End Energy Consumption in 2000
(Projected Values)

Quadratic Approximation	2,776.3 (GWh)
Projection by Population	2,141.4 (GWh)
Linear Approximation	1,742.3 (GWh)

(2) The linear approximation method gives the lowest value, and the quadratic approximation the highest.

The projection based on the population prediction gives a value between the above two. The quadratic approximation is said to fit most exactly to the past data of energy consumption. In this calculation, the deviation from data is very small, and this method seems to be most effective for projection of demand in near future.

The quadratic approximation tends to give a higher projection for a long future when projection is made for a long term exceeding 10 years. Therefore, it can be inferred that the actual energy demand in the year 2000 may be lower than the value given by this quadratic approximation, and the actual value may approach the one given by population prediction or the linear approximation.

(3) When energy demand is projected for a long term, the errors created by structural changes of economic and social trend can not be avoided. Also, unpredictable factors in the supply side, such as the failure of electric facility, may introduce changes in supply capability.

Table 4-12 Predicted Energy Demand at Consumer's Level in the Project Area

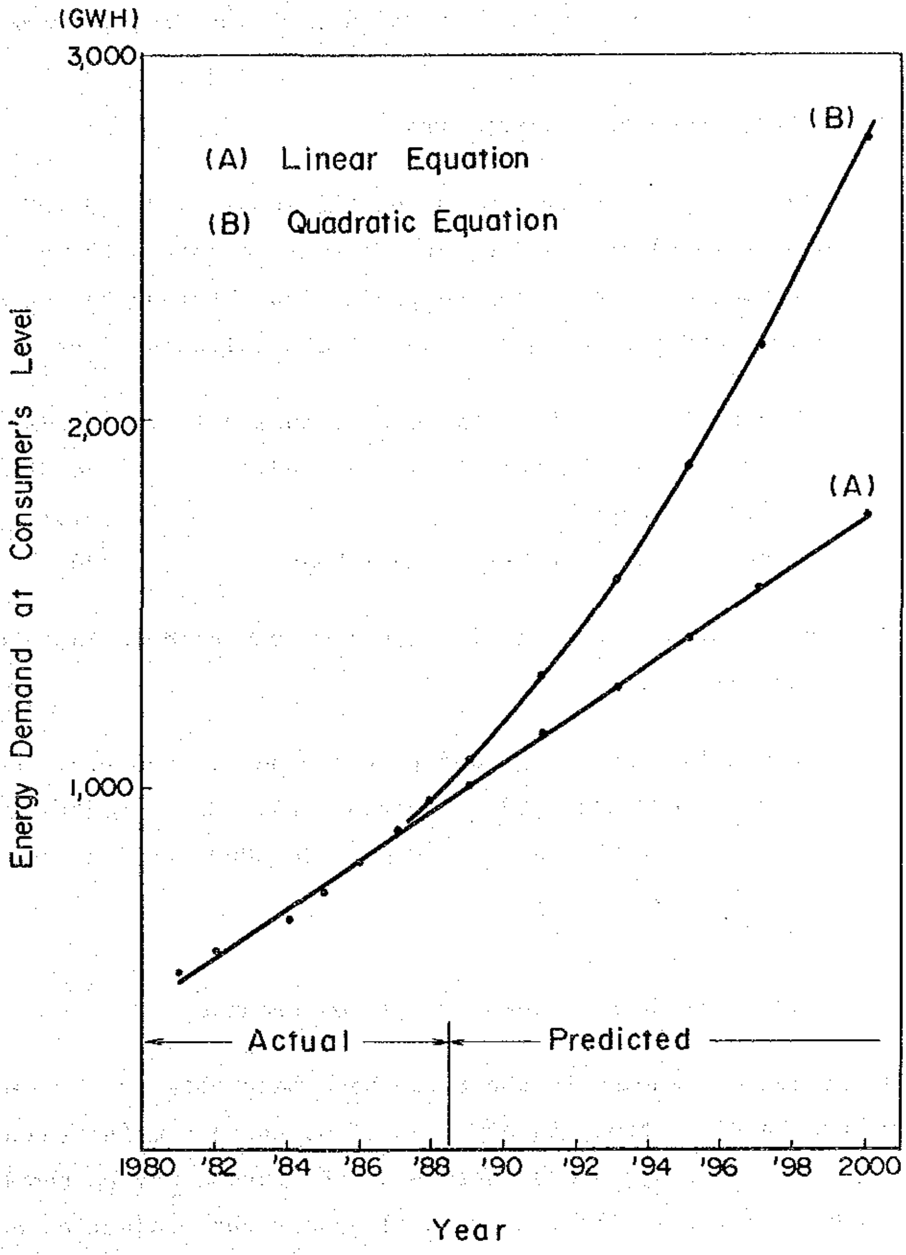
(GWH)

(X)	-7	-5	-3	-1	1	3	5	7	9	11
Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(A) Linear Equation (y)	485.9	545.8	591.9	631.4	705.7	784.3	882.3	960.6	1,001.5	1,068.9
(B) Quadratic Equation (y)									1,067.5	1,178.9

13	15	17	19	21	23	25	27	31	33	35	37
1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1,136.2	1,203.6	1,270.9	1,338.3	1,405.6	1,472.9	1,540.3	1,607.6	1,675.0	1,742.3	1,809.7	1,877.0
1,299.0	1,428.0	1,565.7	1,712.2	1,867.6	2,031.7	2,204.7	2,386.4	2,576.9	2,776.3	2,984.4	3,201.4

Note: Linear Equation $y = 698.5 + 33.67x$ $r = 0.9902$
Quadratic Equation $y = 675.4 + 33.67x + 1.10x^2$ $r = 0.9986$

Fig. 4-11 Predicted Energy Demand (GWH) at Consumer's Level in the Project Area



Although an excessive investment on the power supply facilities must be avoided, it is inevitable that the projection on a higher side is adopted, within a reasonable range, if one wish to develop a power facility plan that will provide high supply reliability despite various uncertainties of future. Based on the above reasoning, the load end energy demand projection established by the quadratic approximation method was adopted in estimating the future energy and peak demands on the supply side (23 kV busses in substations) of the Project Area.

4.3.7 Demand Projection of Project Area

(1) The energy and peak demands on the supply side (23 kV busses in substations) of the Project Area were obtained based on the consumer end energy demand projection obtained by the quadratic method and the assumed values of the following factors.

Annual Energy Loss by Power Transmission:	14.2%
Annual Load Factor at Sending End:	54.8%
Loss Factor:	0.375
Rate of Loss at System Peak Load:	20.8%

(2) The results of this estimation are presented in Table 4-13 and Fig. 4-12.

The sending end energy and peak demands of the Project Area in the year 2000 are 3,235.8 GWh and 674.1 MW respectively, and the annual growth rates from 1988 to 2000 are 9.2% and 9.5% respectively.

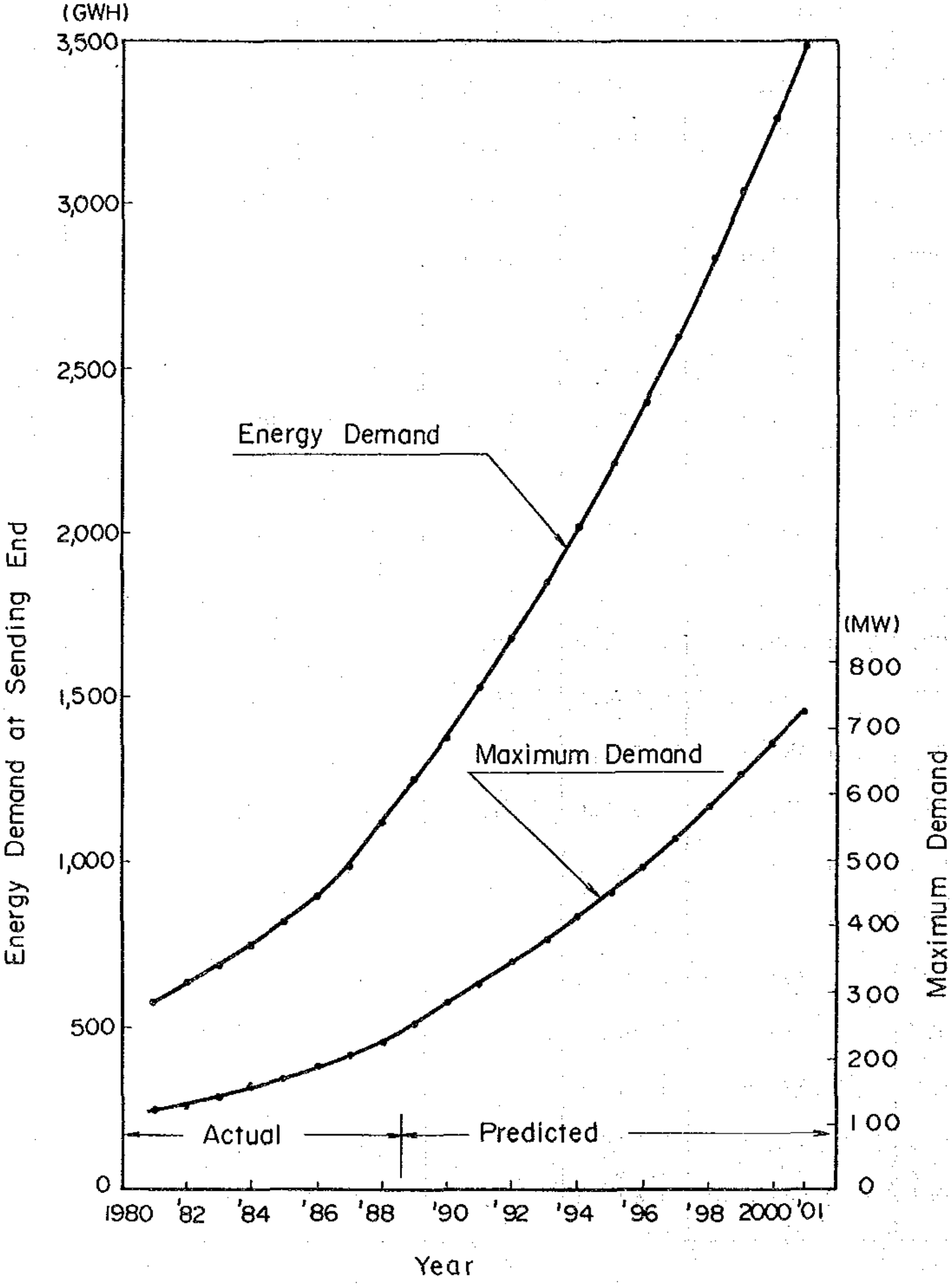
4.3.8 Necessity of Re-Evaluation of Projected Demands

The projected demands in the Study have been obtained by macroscopic methods based on time history trend, and there remains the possibility that the projected values in a long future may be too high, as discussed before. Also, there will appear the projection errors which are caused by changes in economic activities and social structures.

Table 4-13 Power Demand Projection for the Project Area

Year	Energy Demand at Consumer's Level (GWH)	Energy Demand at Sending End		Trans-mission Losses (%)	Maximum Demand		Annual Load Factor (%)
		(GWH)	% Increase		(MW)	% Increase	
1981	485.9	576.7	16.3	15.7	124.8	-	52.8
1982	545.8	639.8	10.9	14.7	133.7	7.1	54.6
1983	591.9	695.1	8.6	14.9	145.5	8.8	54.5
1984	631.4	754.5	8.6	16.3	157.7	8.4	54.6
1985	705.7	826.7	9.6	14.6	171.1	8.5	55.2
1986	784.3	893.9	8.1	12.3	185.7	8.5	55.0
1987	882.3	994.0	10.1	11.2	207.2	11.6	54.8
1988	960.6	1,118.5	12.5	14.1	225.9	9.0	56.5
1989	1,067.5	1,244.2	11.2	14.2	259.2	14.7	54.8
1990	1,178.9	1,374.0	10.4	14.2	286.2	10.4	54.8
1991	1,299.0	1,514.0	10.2	14.2	315.4	10.2	54.8
1992	1,428.0	1,664.3	9.9	14.2	346.6	9.9	54.8
1993	1,565.7	1,824.8	9.6	14.2	380.1	9.7	54.8
1994	1,712.2	1,995.6	9.4	14.2	415.7	9.4	54.8
1995	1,867.6	2,176.7	9.1	14.2	453.4	9.1	54.8
1996	2,031.7	2,367.9	8.8	14.2	493.3	8.8	54.8
1997	2,204.7	2,569.6	8.5	14.2	535.3	8.5	54.8
1998	2,386.4	2,781.4	8.2	14.2	579.4	8.2	54.8
1999	2,576.9	3,003.4	8.0	14.2	625.6	8.0	54.8
2000	2,776.3	3,235.8	7.7	14.2	674.1	7.8	54.8
2001	2,984.4	3,478.3	7.5	14.2	724.6	7.5	54.8

Fig. 4 - 12 Load Forecast of Project Area



The power demands in the Project Area are mostly for residential and commercial use, and the proportion of industrial loads is not so high. Also, the growth of power demand is not very high. After the main frames of the transmission/distribution systems for the Metropolitan Area are completed in 1994, the remaining expansion programs after this year can be completed in relatively short time. Therefore, the demand projection should be reviewed from time to time at this period to adjust the expansion programs in an economical manner.

4.3.9 Demand Projection of Each Mesh of 1 km^2

(1) The projection of peak demand of each mesh of 1 km^2 in the Project Area is the key factor in determining the plans for construction of new substations and expansion of distribution facilities.

ANDE had prepared the demand projection for each mesh of 1 km^2, in the year 2000. The maximum peak demand of each mesh was calculated by multiplying the total capacity of pole transformers in the mesh by the estimated capacity factor, by estimating the peak loads of 23 kV customers from their receiving capacities in the same manner, and by taking into account the diversity factors between these customers.

Then the projected demands of each mesh in the year 2000 were estimated by considering the overall demand growth and population growth, and by taking into account the known construction plans of buildings, industrial parks, etc.

(2) The JICA Study Team checked the projected demand of each mesh in the year 2000, which has been prepared by ANDE, by comparing the total projected peak demand developed in the preceding section and the sum of the mesh demands by using the following values of diversity factor which seem to be appropriate according to similar data in Japan and Paraguay, and verified that these projected demand of each mesh was generally valid.

Diversity Factors Used in Verification

Between Transformers: 1.18 - 1.36

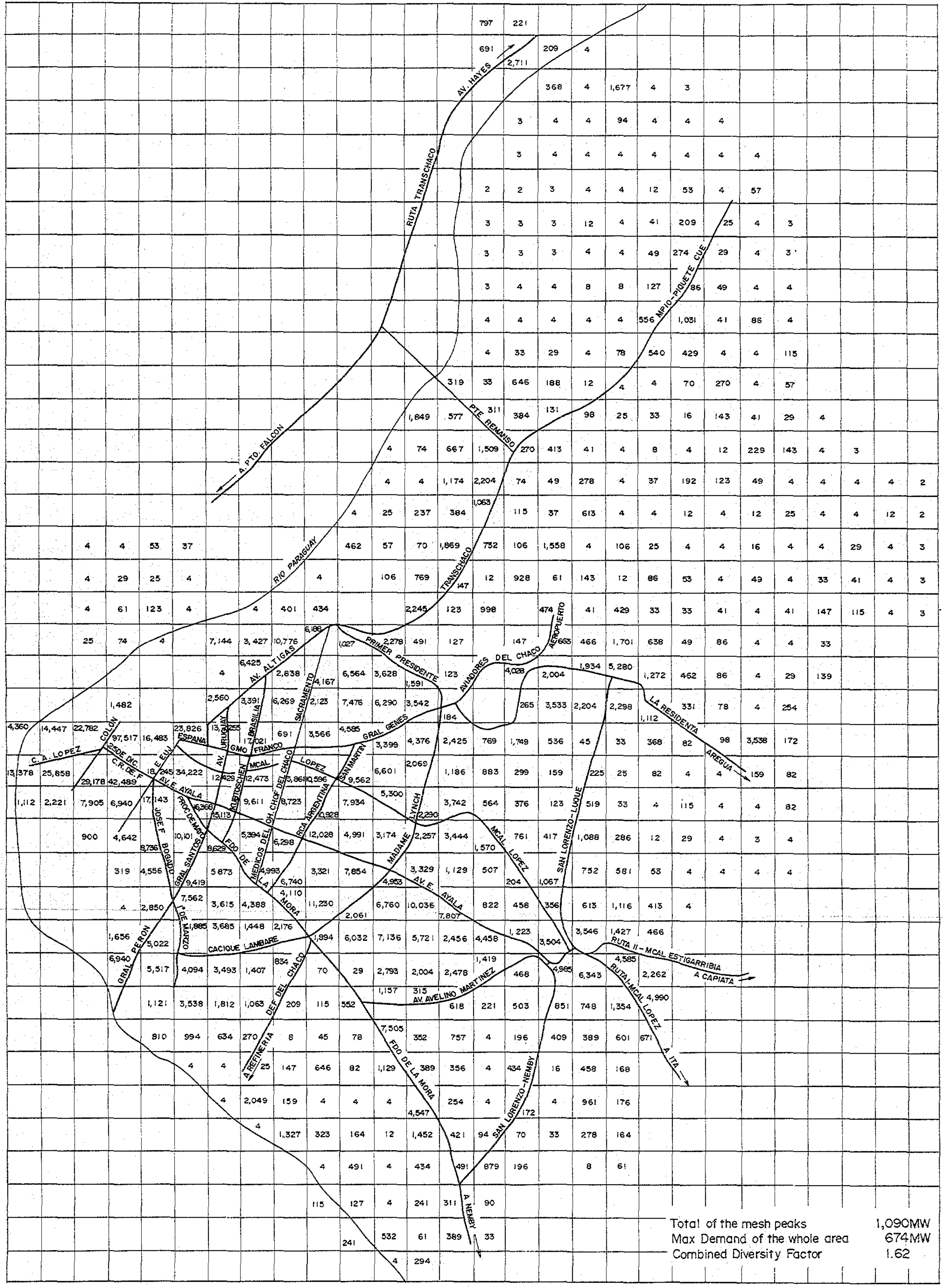
Between Feeders : 1.09 - 1.15

Between Substations : 1.13 (Estimated value from recent diversity in the Metropolitan Area)

The projected peak demand of each 1 km^2 mesh in the Project Area is presented in Fig. 4-13.

Fig.4-13 Predicted Load Density in the Project Area in 2000

Unit : kW/km²



Total of the mesh peaks 1,090MW
Max Demand of the whole area 674MW
Combined Diversity Factor 1.62

CHAPTER 5

POWER SYSTEM PLAN

CHAPTER 5 POWER SYSTEM PLAN

CONTENTS

List of Tables and Figures

CHAPTER 5 POWER SYSTEM PLAN

5.1 Current Status of Power System in Paraguay

5.1.1 Power Supply to the Metropolitan Area

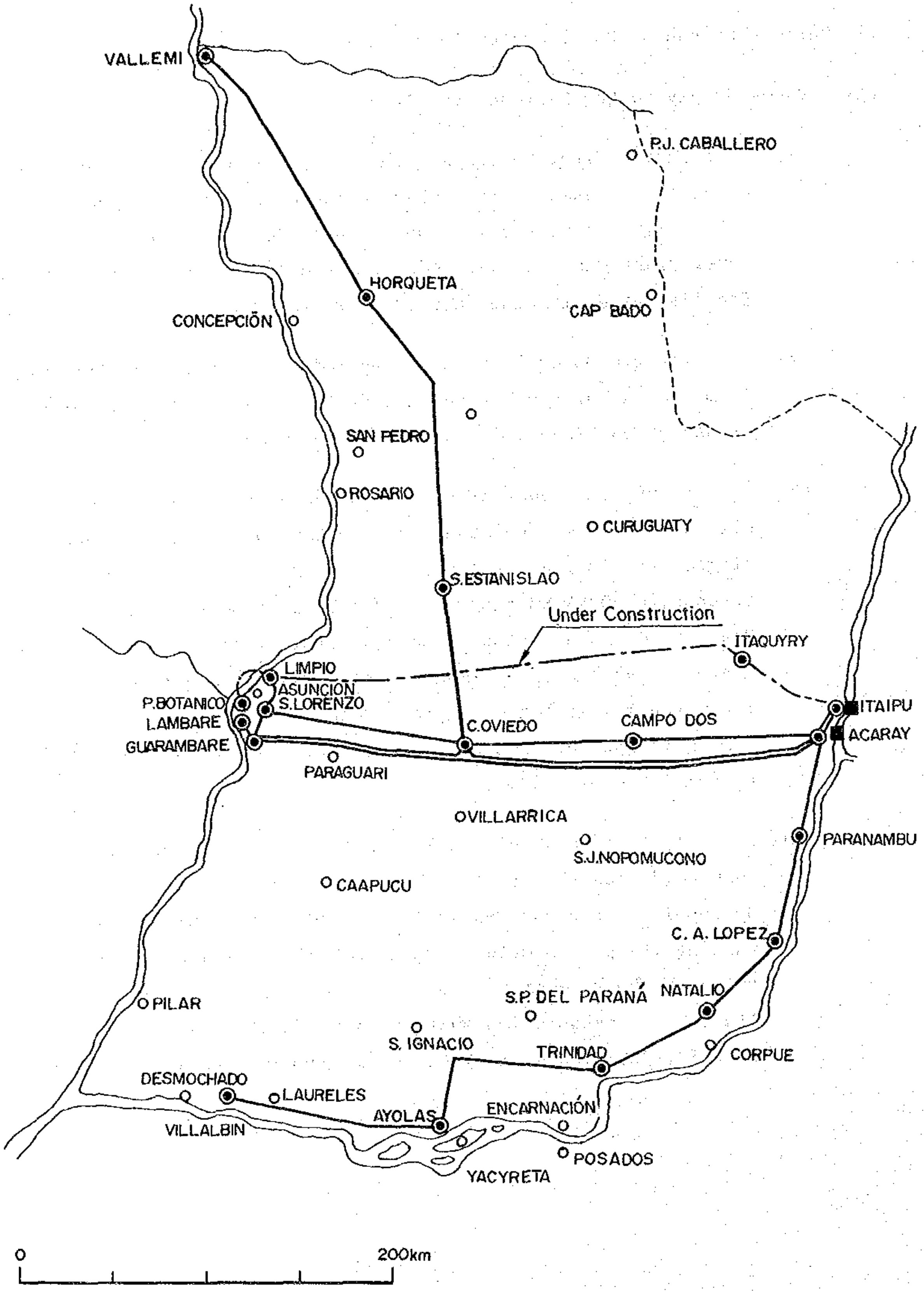
(1) In Asuncion City, there is a thermal power generation facility of 33.15 MW capacity in a place adjacent to Puerto Sajonia Substation. This facility has been seldom used since Itaipu Power Plant was commissioned, and it has remained as a reserve facility after it generated 1940 kWh in 1987.

(2) The electric power is mainly supplied to the Metropolitan Area from Itaipu Power Plant and Acaray Power Plant through 220 kV transmission lines which are from 300 to 320 km in length.

(3) At present, the power transmission system from these power plants to the Metropolitan Area consists of a 302.2 km long single circuit line of Acaray - Campo Dos - C. Oviedo - San Lorenzo, a 309.4 km single circuit line of Acaray - C. Oviedo - Guarambare - San Lorenzo, and a 314.7 km single circuit line of Acaray - Guarambare - Lambare. Also another single circuit line, running Itaipu - Limpio - Puerto Botanico, approximately 348 km in length, is under construction, which is scheduled to be completed by 1990. (Fig. 5-1)

(4) That is, 4 circuits of 220 kV transmission lines will be completed from the eastern power source area to the Metropolitan Area by 1990. As the 220 kV transmission line running Itaipu - Limpio - Puerto Botanico has support structures which are designed for a double circuit transmission line, this transmission system can be easily converted to a 5 circuit, 220 kV system by stringing another circuit in future.

Fig. 5-1 220kV Trunk Line in Paraguay (1989)



5.1.2 Power Systems of the Metropolitan Area

(1) The power system in the Metropolitan Area (system having 66 kV or higher voltage) is illustrated in Fig. 5-2.

The 66 kV system in the Project Area consists of a single circuit loop connecting two 220 kV substations, San Lorenzo and Lambare. The transmission capacity of the 66 kV transmission line constituting the loop is currently 30 MVA in certain sections. However, the cables are being replaced, and most sections will have capacity of 50 to 60 MVA by 1990.

(2) When the transmission and substation facilities being constructed between Limpio and Puerto Botanico are completed, the power will be supplied to the Project Area from the 220 kV outer loop, connecting San Lorenzo - Limpio - Puerto Botanico by stepping down the voltage to 66 kV and 23 kV at substations. (Fig. 5-3)

(3) The central part of the Metropolitan Area will be supplied by the three key substations of Lambare, San Lorenzo and Puerto Botanico, and the supply reliability will be improved substantially. However, most of secondary substations at city center have capacity of 40 MVA, and these substations will be heavily loaded by 1990. If substations having relatively large 23 kV capacity, such as Lambare and Puerto Botanico, are not effectively utilized, the loading of secondary substations at the center of Capital City will become critical, and load control will have to be enforced under emergency conditions such as failure of a transformer bank.

It is planned to decommission the existing Jardin Botanico Substation when Puerto Botanico Substation is completed.

5.1.3 Power Transmission Capability of 220 kV Power System to Send Power to the Metropolitan Area

The power transmission capability of the 220 kV power system, which supply power from the power sources in the eastern area to the

Fig. 5-2 Power System in and Around Asuncion

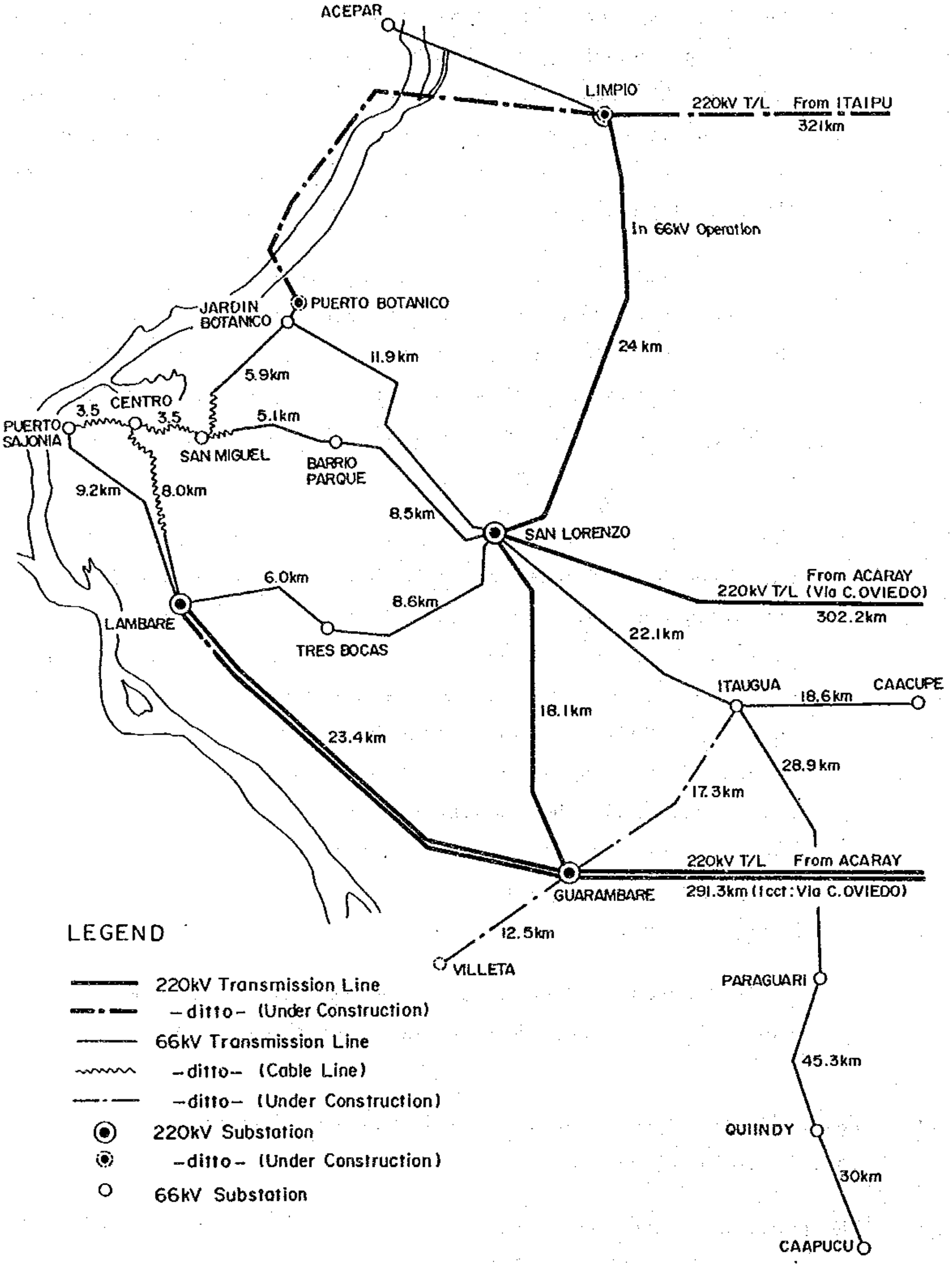
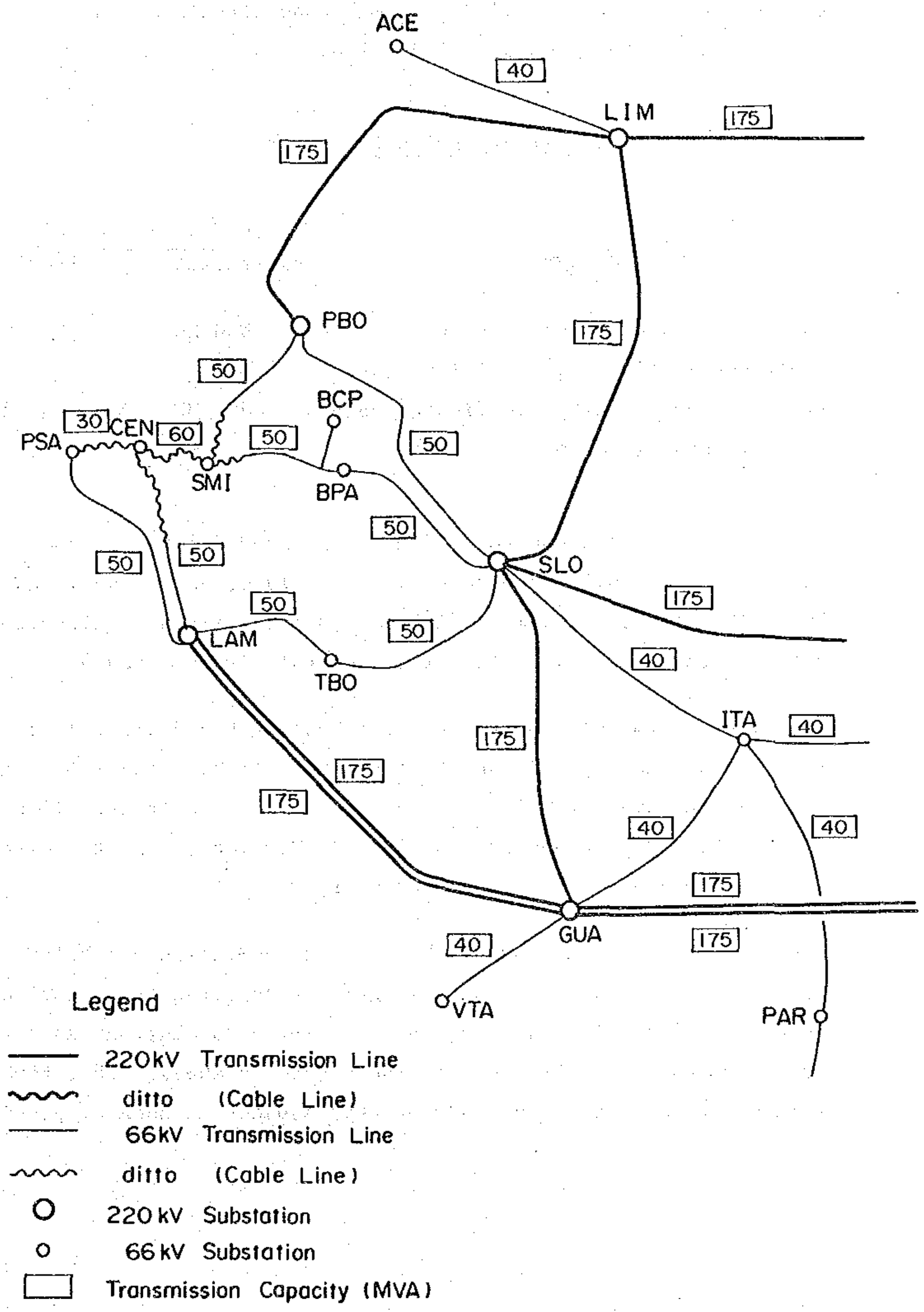


Fig. 5-3 Power System Diagram in and around Asuncion in 1990



Metropolitan Area, is not within the scope of the Study. Therefore, we have not conducted a detailed study, but the power transmission capability can be roughly estimated by simple methodologies. In this case, the term "power transmission capability" means the amount of power that can be supplied even when one circuit of the transmission system goes out of service.

Power Transmission Capability

Methodology	Number of 220 kV Lines 4 circuits	 5 circuits
Measuring phase angle difference between sending and receiving ends.	500 MW	660 MW
Transmission capacity coefficient method.	500 MW	660 MW
Surge impedance method.	420 MW	560 MW

It is estimated that the power demand in the Project Area comprising the capital city will grow to 415.7 MW by 1994, and to 453.4 MW by 1995. Therefore, the demand will exceed the limit of 4-circuit system as early as 1994. (The fifth circuit is required.)

It is also estimated that the power demand of the Project Area will grow to 535.3 MW by 1997, and to 579.4 MW by 1998. The limit of transmission capacity will be reached by 1997 even if the fifth circuit of the 220 kV transmission lines is completed, and the next power system expansion will be necessary.

Concerning the computation of the power transmission capability limit and the measures of increasing it, a detailed study including computer analysis is required, and a definite conclusion can not be drawn from the simplified estimation discussed above. Therefore, it is recommended to start a study on this subject as soon as possible.

5.2 Power System Expansion Plan for the Project Area

5.2.1 Basic Conditions in Formulation of Power System Expansion Plan

(1) As discussed in Chapter 4, "Power Demand Projection", the power demand in the Project Area is estimated to grow at a rate of approximately 9% per annum, and the total energy consumption at consumer end will reach approximately 2,776 GWh, and the peak demand 674 MW, in the year of 2000. However, the power systems of the Project Area do not have sufficient supply capability, as shown in Table 5-1, for such a growing demand and there may be a shortage of supply capability in two or three years, so they must be reinforced and expanded as quickly as possible.

Specifically, construction of new 220 kV and 66 kV transmission lines, construction of 220 kV or 66 kV key substations, construction of new secondary substations, and other measures will be required.

(2) The following items were basically considered in formulating the reinforcement and expansion of power systems.

(a) Supply Reliability

(i) For key substations or important power systems that supply power to an area having dense power demand, there must not be a stoppage of power supply in case of a single installation's fault such as a fault of one circuit line or one transformer bank.

(ii) For systems besides above-mentioned, a temporary stoppage of power supply may be tolerated when a single installation's fault occurs on condition that a power supply is resumed in a short time.

(b) Transmission Voltage

The voltage of new transmission lines will be limited to the 220 kV and 66 kV class which are now being operated in Paraguay, and not new voltage class will be introduced.

Table 5-1 Installed Transformers and Supply Capability of the Substations in the Project Area in 1989

Substation	Transformer		Supply Capability (MVA)	
	Voltage (kV)	Capacity (MVA) x No. of Banks	66 kV	23 kV
San Lorenzo	220/66 220/23	60 x 2 40 x 1	120 -	- 40
Lambare	220/66/23	120/60/60 x 2	120	120
Guarambare	220/66 66/23	37.5 x 1 20 x 1	37.5 -	- 20
Puerto Sajonia	66/23	20 x 2	-	40
San Miguel	66/23	20 x 2	-	40
Barrio Parque	66/23	20 x 2	-	40
Jardin Botanico	66/23	12 x 2	-	24
Tres Bocas	66/23	10 x 2	-	20
Centro	66/23	20 x 2	-	40
Total			277.5	384

Note: Exclusive of Acepar 66 kV/13.8 kV, 15 MVA x 2

(c) System Configuration

(i) The 220 kV transmission line or 66 kV transmission line supplying power to a key substation must have two circuits or more.

(ii) After the voltage of the 220 kV designed transmission line connecting San Lorenzo-Limpio-Puerto Botanico is raised to 220 kV, the system configuration of the 66 kV lines in the Project Area must be converted to form locally double circuit radial systems or radial-loop systems (loop systems operated as radial lines).

(d) Standard Unit Capacity of Substation and Final Number of Banks

(i) 220 kV Substations

When a new substation is to be constructed, the final installed capacity shall be designed as given below, considering the land area of site, transmission capacity of related 220 kV lines, the number of secondary (66 kV) and tertiary (23 kV) feeders, possible to be installed, and supply reliability.

220 kV/66 kV/23 kV, 120 MVA/99 MVA/21 MVA x 3 banks, or
220 kV/66 kV, 120 MVA x 3 banks

For existing substations, the newly installed equipment shall be the same as the existing one, within the limit allowed by the site area.

(ii) 66 kV Substations

Considering the rated current of the secondary (23 kV) equipment, number of feeders, and supply reliability, the final installed capacity of 66 kV substations should be planned for 66 kV/23 kV, 20 MVA x 3 banks. For existing substations, however, the newly installed equipment shall be the same as the existing one, within the limit allowed by the site area.

(e) Operating Limits of Facilities

(i) Transmission Lines

The power at which the sound line is allowed to be overloaded for a short time (approximately 30 minutes) when a single line goes out of service due to a fault.

(ii) Substations

Where there are 2 transformer banks:

The power at which the overload on the remaining bank becomes 130% full load when one bank goes out of service due to a fault.

Where there are 3 transformer banks:

The power at which the overload on the remaining bank becomes 120% full load respectively when one bank goes out of service due to a fault.

(f) Timing of Expansion of Transmission Lines and Substations

The transmission lines and substations must be expanded when the operating limits defined above may be exceeded due to a single fault of a facility.

5.2.2 Power System Expansion Plans

(1) The following two alternatives have been developed for the expansion of the power systems in the Project Area, based on the site surveys and discussions held with ANDE staff.

(a) Alternative 1

The 220 kV systems will be introduced into the center of the Capital City with two primary substations (220 kV/66 kV substations) to be newly constructed in the city center area. The 66 kV lines and the secondary substations (66 kV/23 kV substations) will be expanded properly to strengthen the 66 kV systems.

(b) Alternative 2

The power supply to the center of Capital City will be done by expansion and reinforcement of 66 kV systems. For this purpose, primary substations will be newly constructed around the Capital City, thereby increasing the supply capability for the urban center, and the 66 kV lines and secondary substations will be expanded properly to strengthen the 66 kV systems.

(2) The expansion of transmission and distribution networks is planned to be implemented with the target year of 2000. The whole plan is formulated in two stages. The first stage is to be completed by the time of the maximum demand in 1994, and the second stage by the end of 1997.

5.2.3 Alternative 1

(1) The Alternative 1, in which it is intended to introduce the 220 kV lines to the center of Capital City, is illustrated by the power system diagram of the year2000 in Fig. 5-4. The facility expansion program is given in Table 5-2 to Table 5-5.

The power supply-demand balance of the transmission and substation facilities (secondary substations and above) in the Project Area is given in Fig. 5-5.

(2) The outline of the Alternative 1 is described below.

(a) Construction of 220 kV Transmission Lines

(i) Two circuits of 220 kV lines will be constructed from Lambare to Site A (Obrero).

One of the double circuit transmission line running from Guarambare to Lambare will be pi-branched into Lambare Substation, and will be extended to Site A at

Fig. 5-4 Power System Diagram in the Project Area in 2000
Alternative 1

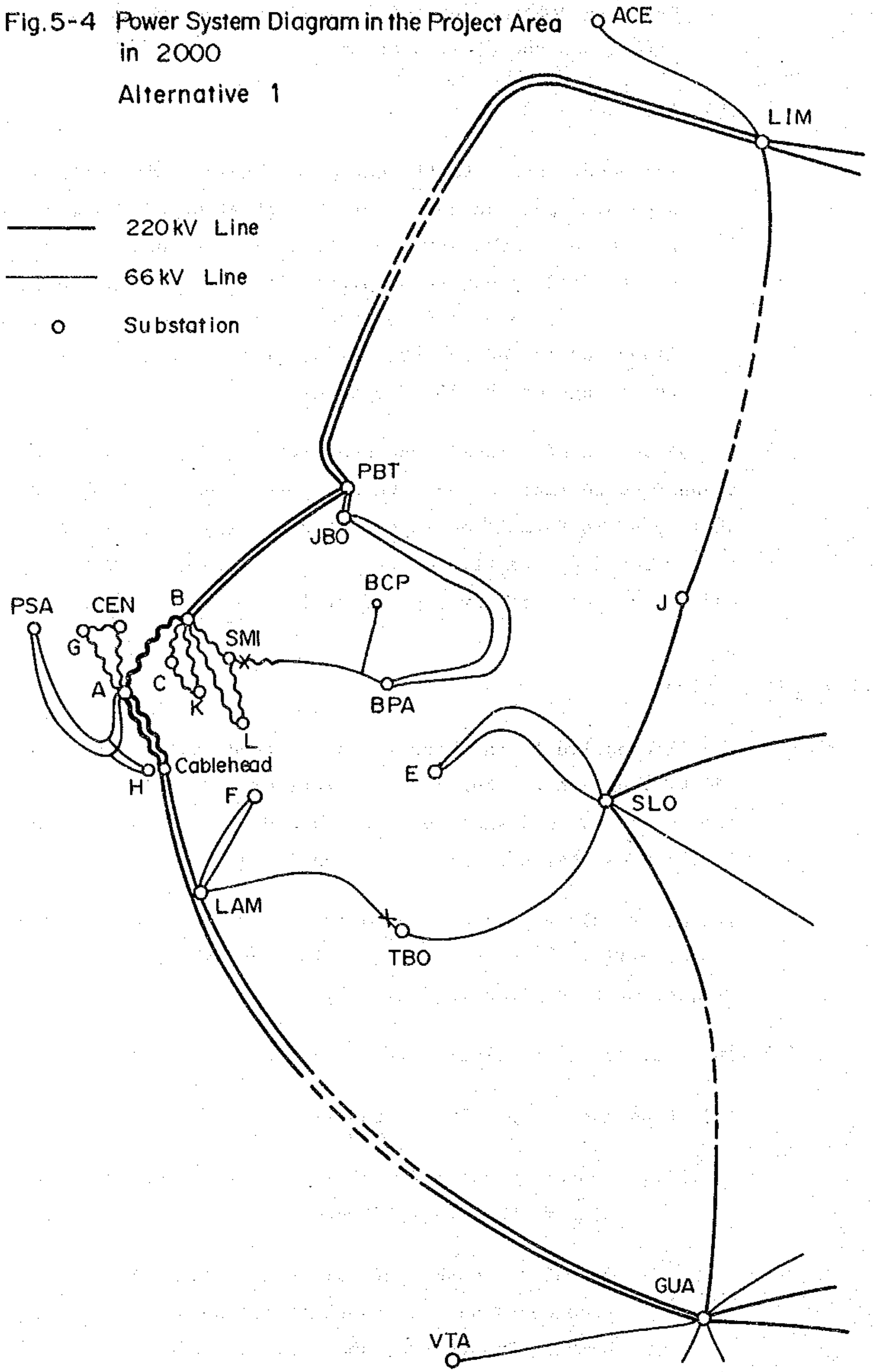


Table 5-2 Outline of the Installation Plan at 1st Stage of Alternative 1

Transmission Lines

Voltage (kV)	Equipment to be installed		From - To	Transmission Capacity (MVA)
220	1 double cct.	OL	Lambare - Cable head	250/cct.
"	2 single cct.	UC	Cable head - A	250/cct.
"	1/2 double cct.	OL	Limpio - Puerto Botanico	250/cct.
"	1 double cct.	OL	Puerto Botanico - B	250/cct.
66	2 single cct.	OL	A - Puerto Sajonia	50/cct, partly 70/cct
"	1 single cct	UC	A - Centro	90
"	"	"	Centro - G	90
"	"	"	G - A	90
"	"	"	B - San Miguel	100
"	"	"	B - C	100
"	2 single cct.	OL	Jardin Botanico - Barrio Parque	70/cct.
"	"	"	Puerto Botanico - Jardin Botanico	70/cct.
"	"	"	Lambare - F	100/cct.
"	"	"	San Lorenzo - E	70/cct.

Note: Abbreviations

cct.	circuit
OL	Overhead Line
UC	Underground Cable

Table 5-3 Outline of The Installation Plan at 1st Stage of Alternative 1

Substations

Substation		Equipment to be installed		Equipment as of the End of 1993	
		Transformer	Line Equipment	Transformer	Line Equipment
A	New	220/66/23kV 120/99/21MVA x 2	220kV, 2 cct 66kV, 4 cct	220/66/23kV 120/99/21MVA x 2	220kV, 2 cct 66kV, 4 cct
B	New	220/66/23kV 120/99/21MVA x 2	220kV, 2 cct 66kV, 2 cct	220/66/23kV 120/99/21MVA x 2	220kV, 2 cct 66kV, 2 cct
Limpio	Existing	-	220kV, 2 cct	220/66/13.8kV 37.5/37.5/ 12.5MVA x 1 66/23kV 20MVA x 1	220kV, 5 cct 66kV, 1 cct
Puerto Botanico	Existing	220/66/23kV 120/60/60MVA x 1	220kV, 3 cct 66kV, 2 cct	220/66/23kV 120/60/60MVA x 2	220kV, 4 cct 66kV, 2 cct
Jardin Botanico	Existing	66/23kV 12MVA x 1	66kV, 2 cct	66/23kV 12MVA x 3	66kV, 4 cct
Puerto Sajonia	Existing	66/23kV 20MVA x 1	-	66/23kV 20MVA x 3	66kV, 2 cct
San Miguel	Existing	66/23kV 20MVA x 1	-	66/23kV 20MVA x 3	66kV, 3 cct
Barrio Parque	Existing	66/23kV 20MVA x 1	66kV, 1 cct	66/23kV 20MVA x 3	66kV, 3 cct
C	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
E	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
F	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
G	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct

Table 5-4 Outline of the Installation Plan at 2nd Stage of Alternative 1

Transmission Lines

Voltage (kV)	Equipment to be installed		From - To	Transmission Capacity (MVA)
220	1 single cct.	UC	A - B	250/cct.
"	1 double cct.	OL	J - 220 kV line	175/cct.
66	2 single cct.	OL	H - 66 kV line	50/cct
"	1 single cct.	UC	C - K	100
"	"	"	B - K	100
"	"	"	B - L	100
"	"	"	San Miguel - L	100

Note: Abbreviations

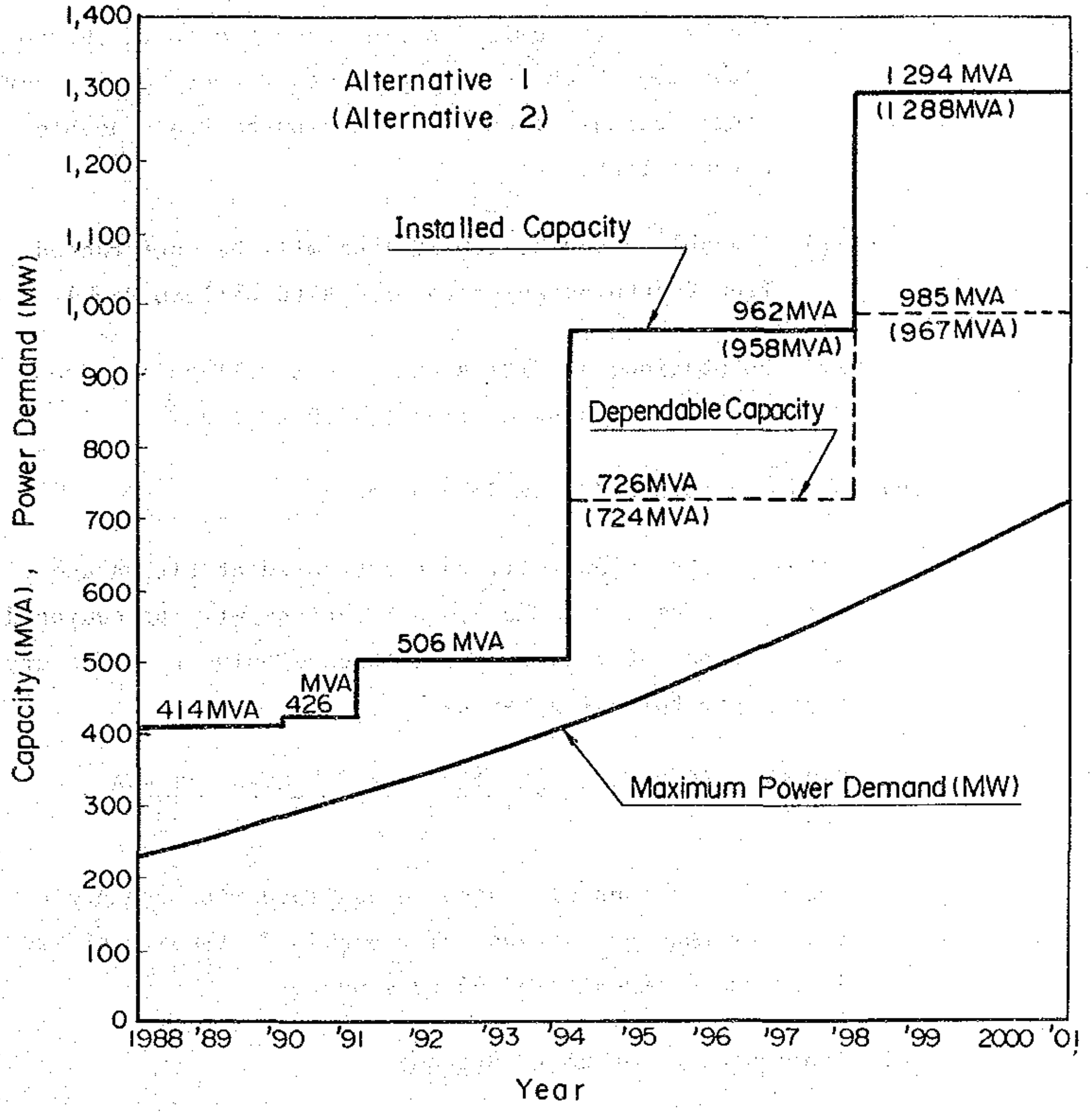
cct.	circuit
OL	Overhead Line
UC	Underground Cable

Table 5-5 Outline of The Installation Plan at 2nd Stage of Alternative 1

Substations

Substation		Equipment to be installed		Equipment as of the End of 1997	
		Transformer	Line Equipment	Transformer	Line Equipment
A	New	220/66/23kV 120/99/21MVA x 1	220kV, 1 cct	220/66/23kV 120/99/21MVA x 3	220kV, 3 cct 66kV, 4 cct
B	New	220/66/23kV 120/99/21MVA x 1	220kV, 1 cct 66kV, 2 cct	220/66/23kV 120/99/21MVA x 3	220kV, 3 cct 66kV, 4 cct
San Lorenzo	Existing	220/66kV 60MVA x 1 220/23kV 40MVA x 1	-	220/66kV 60MVA x 3 220/23kV 40MVA x 2	220kV, 3 cct 66kV, 4 cct
J	New	220/23kV 40MVA x 1	220kV, 2 cct	220/23kV 40MVA x 1	220kV, 2 cct
Guarambare	Existing	220/66kV 37.5MVA x 1 66/23kV 20MVA x 1	-	220/66kV 37.5MVA x 2 66/23kV 20MVA x 2	220kV, 5 cct 60kV, 4 cct
Tres Bocas	Existing	66/23kV 10MVA x 1	-	66/23kV 10MVA x 3	66kV, 2 cct
H	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
K	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
L	New	66/23kV 20MVA x 2	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct

Fig.5-5 Supply-Demand Balance in the Project Area by Alternative 1 and 2



the center of city. As this 220 kV transmission line will run through densely populated area, it would be practically impossible to build an overhead line for the whole length. Therefore, cable heads will be installed somewhere on the route, and underground cables will be used for the remaining portion of the line and be taken into the new 220 kV substation (Site A).

(ii) The 220 kV transmission line from Limpio to Puerto Botanico, which is currently under construction for a single circuit line, will be expanded to a double circuit line.

(iii) A double circuit, 220 kV line will be constructed from Puerto Botanico to Site B (Caballero Park).

(iv) Substations at Site A and Site B will be interconnected by a single circuit, 220 kV line.

(b) Construction of 220 kV Substations

Primary substations will be constructed at Site A and Site B in urban center. The new substations will be equipped with 3 banks of single phase, three-winding transformers having the following rating.

$$\frac{220 \text{ kV}}{\sqrt{3}} \;/\; \frac{66 \text{ kV}}{\sqrt{3}} \;/\; 23 \text{ kV}, \; \frac{120 \text{ MVA}}{3} \;/\; \frac{99 \text{ MVA}}{3} \;/\; \frac{21 \text{ MVA}}{3} \times 3$$

These substations will also be equipped with connection bays for the three transformer banks, 3 circuits of 220 kV lines and 4 circuits of 66 kV lines.

(c) Configuration of 66 kV Systems

As 220 kV transmission lines are introduced into urban center and a 220 kV loop is formed, the existing loop of 66 kV system will be modified to form radial systems by two routes of a single circuit line or to form local radial-loop systems to supply power from the primary substations. (See Fig. 5-3 and Fig. 5-4.)

The transmission capacity of some of the existing 66 kV lines will become insufficient, and their conductors will have to be changed or the lines will be needed to be replaced. The capacity of the lines should be such that there is no stoppage of power supply even when a single circuit goes out of service due to a fault.

(d) Secondary Substations

In principle, the new secondary substations will be equipped with 3 banks of 66/23 kV, 20 MVA transformers (at the final stage), and the existing substations will be expanded to have 3 banks of transformers with the same rating as the existing ones.

However, in order to prevent a stoppage of power supply during a 1-bank fault, the operating load of each bank will be limited to 80% rated capacity for substations where 3 banks are available, and to 65% rated capacity for substations where 2 banks are available.

5.2.4 Alternative 2

(1) For the Alternative 2, in which it is proposed to reinforce the power supply to the Center of the Capital City by expansion of 66 kV systems, the power system diagram of the year 2000 is presented in Fig.5-6. The facility expansion program is given in Table 5-6 to Table 5-9.

The power supply-demand balance of the transmission and substation facilities (secondary substations and above) in the Project Area is given in Fig. 5-5.

Fig.5-6 Power System Diagram in the Project Area in 2000

Alternative 2

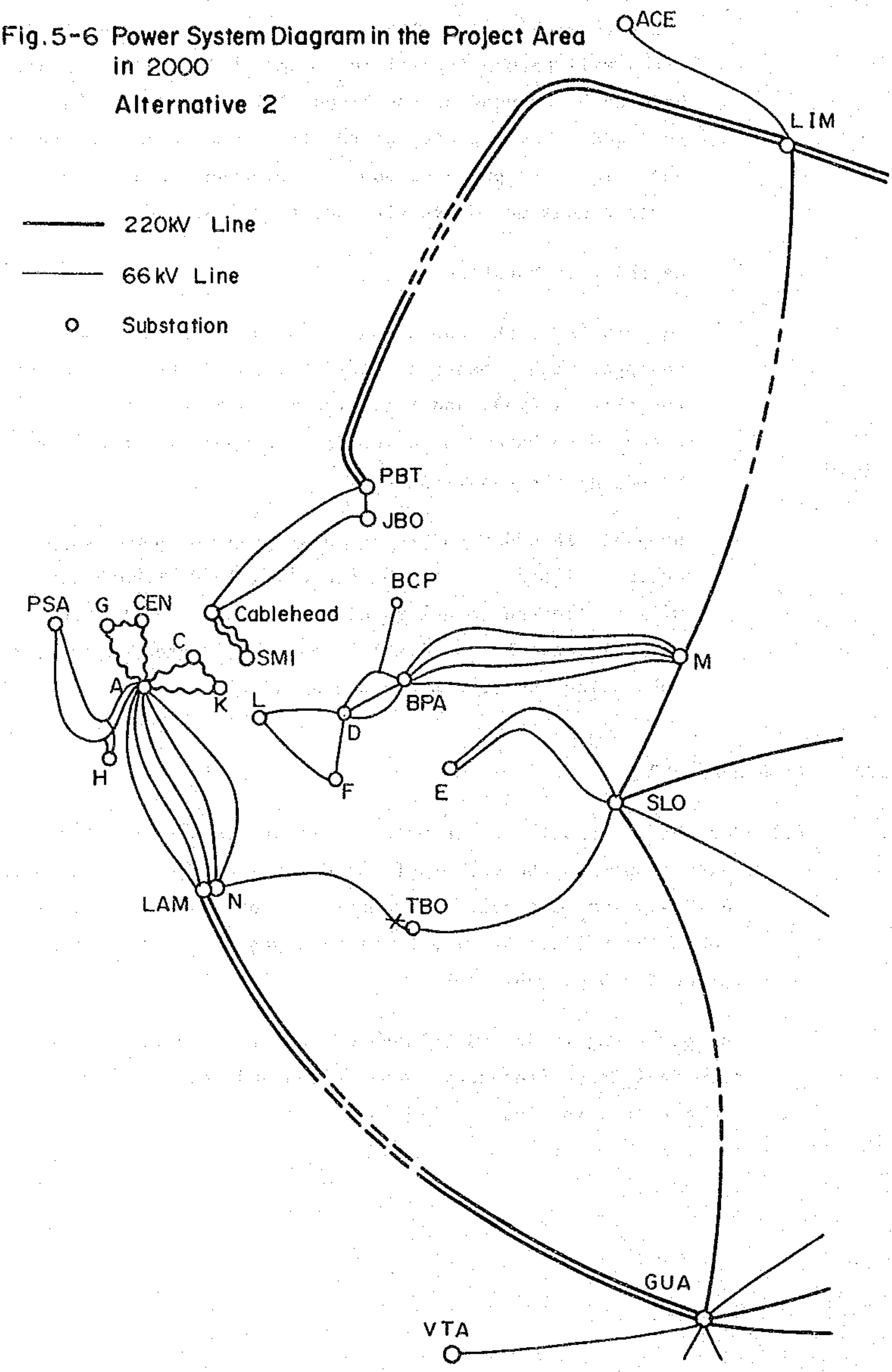


Table 5-6 Outline of the Installation Plan at 1st Stage of Alternative 2

Transmission Lines

Voltage (kV)	Equipment to be installed		From - To	Transmission Capacity (MVA)
220	1 double cct.	OL	M - 220 kV line	175/cct
"	1/2 double cct.	OL	Limpio - Puerto Botanico	250/cct.
66	2 single cct.	OL	Lambare - A	100/cct.
"	1 single cct.	"	N - A	100
"	2 single cct.	"	A - Puerto Sajonia	50/cct, partly 70/cct
"	1 single cct.	UC	A - G	90
"	"	"	G - Centro	90
"	"	"	Centro - A	90
"	"	"	A - C	100
"	"	OL	Puerto Botanico - Cable head	90
"	"	"	Puerto Botanico - Jardin Botanico	90
"	2 single cct.	UC	Cable head - San Miguel	90/cct.
"	3 single cct.	OL	M - Barrio Parque	90/cct.
"	2 single cct.	"	Barrio Parque - D	90/cct.
"	2 single cct.	"	D - L	100/cct.
"	2 single cct.	"	San Lorenzo - E	60/cct.

Note: Abbreviations

cct.	circuit
OL	Overhead Line
UC	Underground Cable

Table 5-7 Outline of The Installation Plan at 1st Stage of Alternative 2

Substations

Substation		Equipment to be installed		Equipment as of the End of 1993	
		Transformer	Line Equipment	Transformer	Line Equipment
N	New	220/66kV 120MVA x 2	* 220kV, 2 cct 66kV, 3 cct	220/66kV 120MVA x 2	* 220kV, 2 cct 66kV, 3 cct
A	New	66/23kV 20MVA x 2	66kV, 8 cct	66/23kV 20MVA x 2	66kV, 8 cct
G	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
C	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
Puerto Sajonia	Existing	66/23kV 20MVA x 1	-	66/23kV 20MVA x 3	66kV, 2 cct
Puerto Botanico	Existing	220/66/23kV 120/60/60MVA x 1	220kV, 1 cct 66kV, 2 cct	220/66/23kV 120/60/60MVA x 2	220kV, 2 cct 66kV, 2 cct
Jardin Botanico	Existing	66/23kV 12MVA x 1	-	66/23kV 12MVA x 3	66kV, 2 cct
San Miguel	Existing	66/23kV 20MVA x 1	-	66/23kV 20MVA x 3	66kV, 3 cct
M	New	220/66kV 120MVA x 2	220kV, 2 cct 60kV, 3 cct	220/66kV 120MVA x 2	220kV, 2 cct 66kV, 3 cct
Barrio Parque	Exsiting	66/23kV 20MVA x 1	66kV, 3 cct	66/23kV 20MVA x 3	66kV, 5 cct
D	New	66/23kV 20MVA x 3	66kV, 4 cct	66/23kV 20MVA x 3	66kV, 4 cct
L	New	66/23kV 20MVA x 2	66kV, 2 cct	66/23kV 20MVA x 2	66kV, 2 cct
E	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
Limpio	Existing	-	220kV, 3 cct	220/66/13.8kV 37.5/37.5/12.5MVA x 1 66/23kV 20MVA x 1	220kV, 5 cct 66kV, 1 cct

Note: 220kV, 2 cct and 66kV 2 cct are for interconnection between busses of N and Lambare Substation.

Table 5-8 Outline of the Installation Plan at 2nd Stage of Alternative 2

Transmission Lines

Voltage (kV)	Equipment to be installed		From - To	Transmission Capacity (MVA)
66	1 single cct.	UC	C - K	100
"	"	"	A - K	100
"	2 single cct	OL	H - 66 kV line	50/cct
"	"	"	F - 66 kV line	100/cct
"	"	"	N - A	100/cct
"	1 single cct	"	Barrio Parque - D	90
"	"	"	M - Barrio Parque	90
"	"	"	M - J	60

Note: Abbreviations

cct.	circuit
OL	Overhead Line
UC	Underground Cable

Table 5-9 Outline of The Installation Plan at 2nd Stage of Alternative 2

Substations

Substation		Equipment to be installed		Equipment as of the End of 1997	
		Transformer	Line Equipment	Transformer	Line Equipment
N	New	220/66kV 120MVA x 1	66kV, 2 cct	220/66kV 120MVA x 3	* 220kV, 2 cct 66kV, 5 cct
A	New	66/23kV 20MVA x 1	66kV, 3 cct	66/23kV 20MVA x 3	66kV, 11 cct
H	New	220/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
K	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
M	New	220/66kV 120MVA x 1 66/23kV 20MVA x 2	66kV, 2 cct	220/23kV 120MVA x 3 66/23kV 20MVA x 2	220kV, 2 cct 66kV, 5 cct
L	New	66/23kV 20MVA x 1	-	66/23kV 20MVA x 3	66kV, 2 cct
F	New	66/23kV 20MVA x 3	66kV, 2 cct	66/23kV 20MVA x 3	66kV, 2 cct
Tres Bocas	Existing	66/23kV 10MVA x 1	-	66/23kV 10MVA x 3	66kV, 2 cct
Guarambare	Existing	220/66kV 37.5MVA x 1 66/23kV 20MVA x 1	-	220/66kV 37.5MVA x 2 66/23kV 20MVA x 2	220kV, 5 cct 66kV, 4 cct

Note: 220kV, 2 cct and 66kV, 2 cct are for interconnection between busses of N and Lambare Substation.

(2) The outline of the Alternative 2 is described below.

(a) Construction of 220 kV Substations

The site areas of the 220 kV substations around Asuncion City, that is, Lambare, San Lorenzo and Puerto Botanico substation, are limited, and they can not be effectively used for enhancement of power supply capability to the Metropolitan Area.

Therefore, it is proposed to construct new 220 kV substations at the site neighboring Lambare Substation (Site N), and a site near San Lorenzo Substation (Site M), to increase the supply capability of 66 kV systems into the Project Area.

(b) Configuration of 66 kV Systems

The power supply to the center of Capital City will be implemented by the 66 kV transmission lines going from Lambare, Site N, San Lorenzo, Site M, and Puerto Botanico Substations. The 66 kV lines will run from the above primary substations in radial configurations, consisting of radial 2-routes of a single circuit line or radial multiple circuit lines. Site A Substation at urban center and Barrio Parque Substation will be the key stations for power supply. From these key stations, 66 kV power will be transmitted by radial, 2 route of a single circuit line, or by radial-loop systems.

The transmission capacity of some of the existing 66 kV lines will become insufficient and their conductors will have to be changed or the lines will be needed to be replaced. The capacity of the lines should be such that there is no stoppage of power supply even when a single circuit goes out of service due to a fault.

(c) Secondary Substations

In principle, the new secondary substations will be equipped with 3 banks of 66 kv/23 kV, 20 MVA transformers (at the final stage), and the existing substations will be expanded to have 3 banks of transformers with the same rating as the existing ones. However, in order to prevent a stoppage of power supply during a 1-bank fault, the operating load of each bank will be limited to 80% rated capacity for the substations where 3 banks are available, and to 65% rated capacity for the substations where 2 banks are available.

5.2.5 Comparison of Alternative 1 and Alternative 2

(1) The relative advantage and disadvantage of Alternative 1 and Alternative 2 are as described below.

(a) Alternative 1

(i) ANDE has a concept in which 220 kV systems are introduced to the urban areas of Asuncion, connecting Lambare and Puerto Botanico by a 220 kV transmission line to form a ring system. Alternative 1 is based on this concept.

(ii) There are constraints on the right of way for the 220 kV transmission lines and the land required for the 220 kV substaitons as well to introduce 220 kV systems into Asuncion City.

(iii) Although the construction cost of transmission lines is higher in Alternative 1 than in Alternative 2 because 220 kV lines are constructed, the substation facility cost is lower than in Alternative 2 because the number of 66 kV/23 kV transformer banks and 66 kV line bays are smaller. The total construction cost of Alternative 1 is a little lower than that of Alternative 2.

(iv) As the future increase of power demand can be met by the supply from Substation-A and Substation-B, the transmission line construction cost will be reduced in future.

(v) Alternative 1 is more advantageous in terms of transmission loss and voltage drop because 220 kV systems are introduced to the city center.

(b) Alternative 2

(i) The 220 kV transmission line from Limpio to Puerto Botanico can not be effectively utilized.

(ii) There are less constraints on construction of transmission lines and substations because 220 kV systems are not introduced into Asuncion city.

(iii) Although the transmission line construction cost is lower than that of Alternative 1, the substation construction cost is higher because there are more transformer banks and 66 kV line bays, and the total construction cost is higher than in Alternative 1.

(iv) In future, it will be required to gradually increase the supply capacity from 220 kV substations "M" and "N". For this purpose, it will be required to expand the 66 kV transmission lines between "N" and "A", and "M" and "BPA".

(v) Alternative 2 is disadvantageous in terms of transmission loss and voltage drop as compared to Alternative 1 because power is transmitted by 66 kV lines.

(2) The JICA Study Team compared Alternative 1 and Alternative 2 in a comprehensive manner, and has reached the conclusion that Alternative 1 is more advantageous. The Team explained this point of view to ANDE in presenting the Interim Report.

Upon consultation with ANDE, it has been decided to formulate Alternative 3, in which more stringent rule are adopted for operation of facilities to reduce the total construction cost.

5.2.6 Alternative 3

(1) This alternative is a modification of Alternative 1, and the plan has been formulated by incorporating the following revisions upon consultation with ANDE.

- (a) The number of new substations to be constructed at Micro Centro District is to be reduced.
- (b) In relation to "1" above, the facilities of Substation-A and Substation-B are to be restudied.
- (c) The existing 66 kV transmission lines are utilized more effectively.
- (d) The new substations will be constructed and existing substations expanded on step-by-step basis; dividing the construction schedule into several stages.
- (e) The construction of 220 kV underground cable between "A" and "B" is eliminated.
- (f) The maximum utilization factor of two-bank transformers is 80%.

The power system diagrams describing Alternative 3 are presented in Fig. 5-7 through Fig. 5-10. The facility construction plan is presented in Table 5-10 and Table 5-11.

The power supply-demand balance of the Project Area is presented in Fig. 5-11.

(2) The relevant items of this Alternative 3 are presented below.

- (a) Construction of 220 kV Transmission Line
  - (i) A double circuit, 220 kV transmission line (with 250 MVA transmission capacity per circuit) will be constructed between Lambare and A (Obrero).

Fig. 5-7 Power System Diagram in and around Asuncion by Alternative 3 (1994-95)

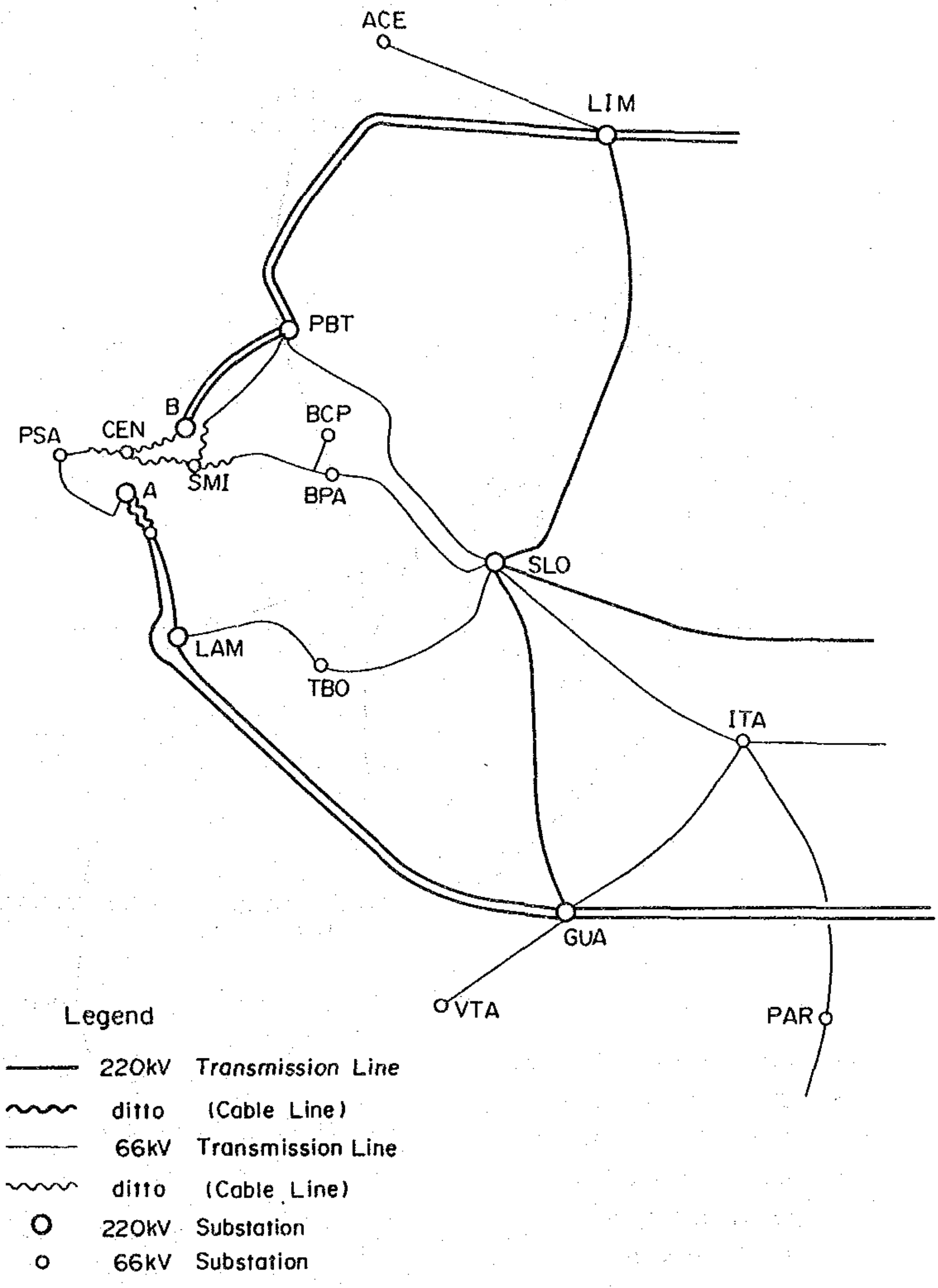


Fig.5-8 Power System Diagram in and around Asuncion by Alternative 3 (1996-97)

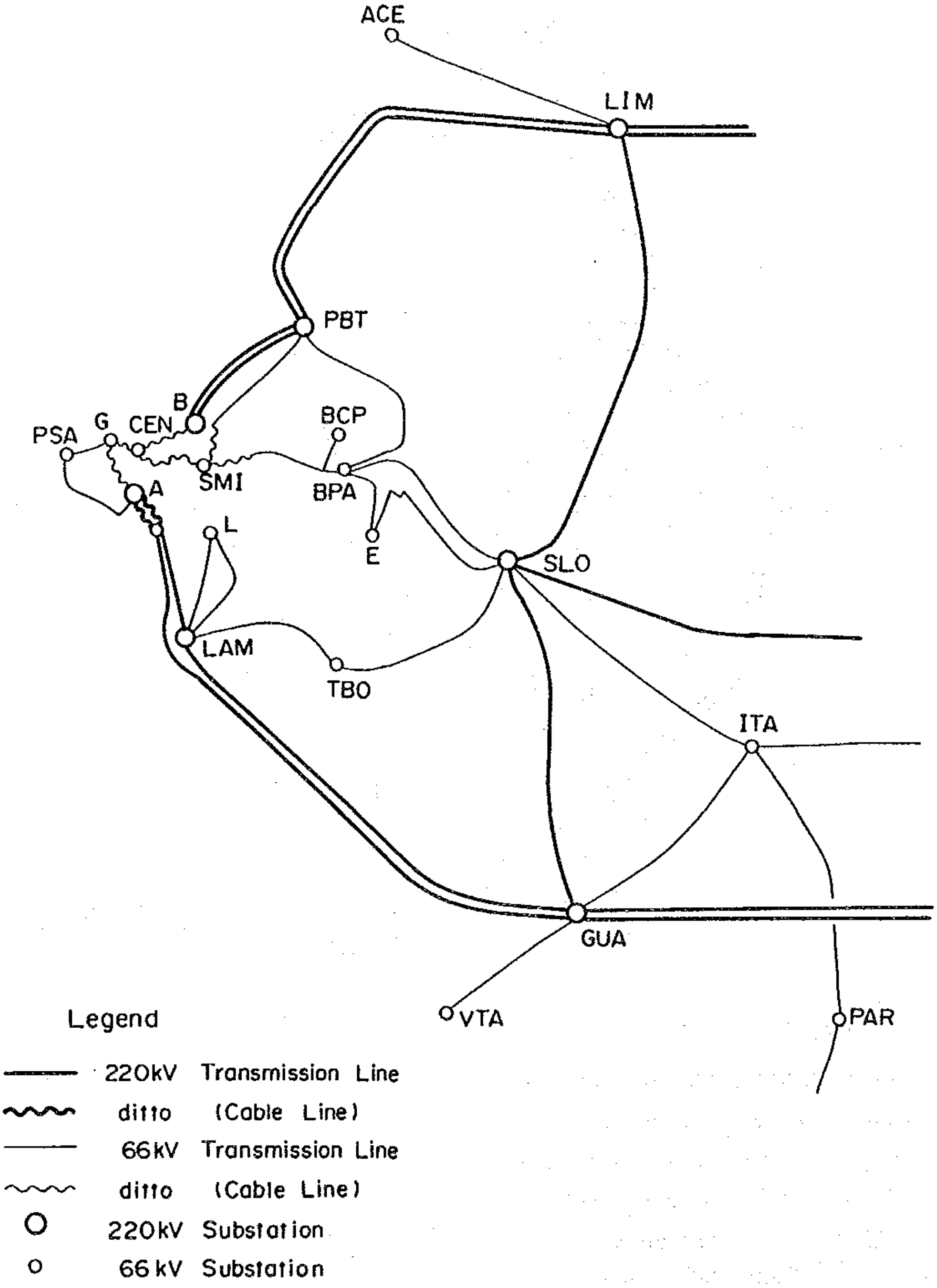


Fig.5-9 Power System Diagram in and around Asuncion by Alternative 3 (1998-99)

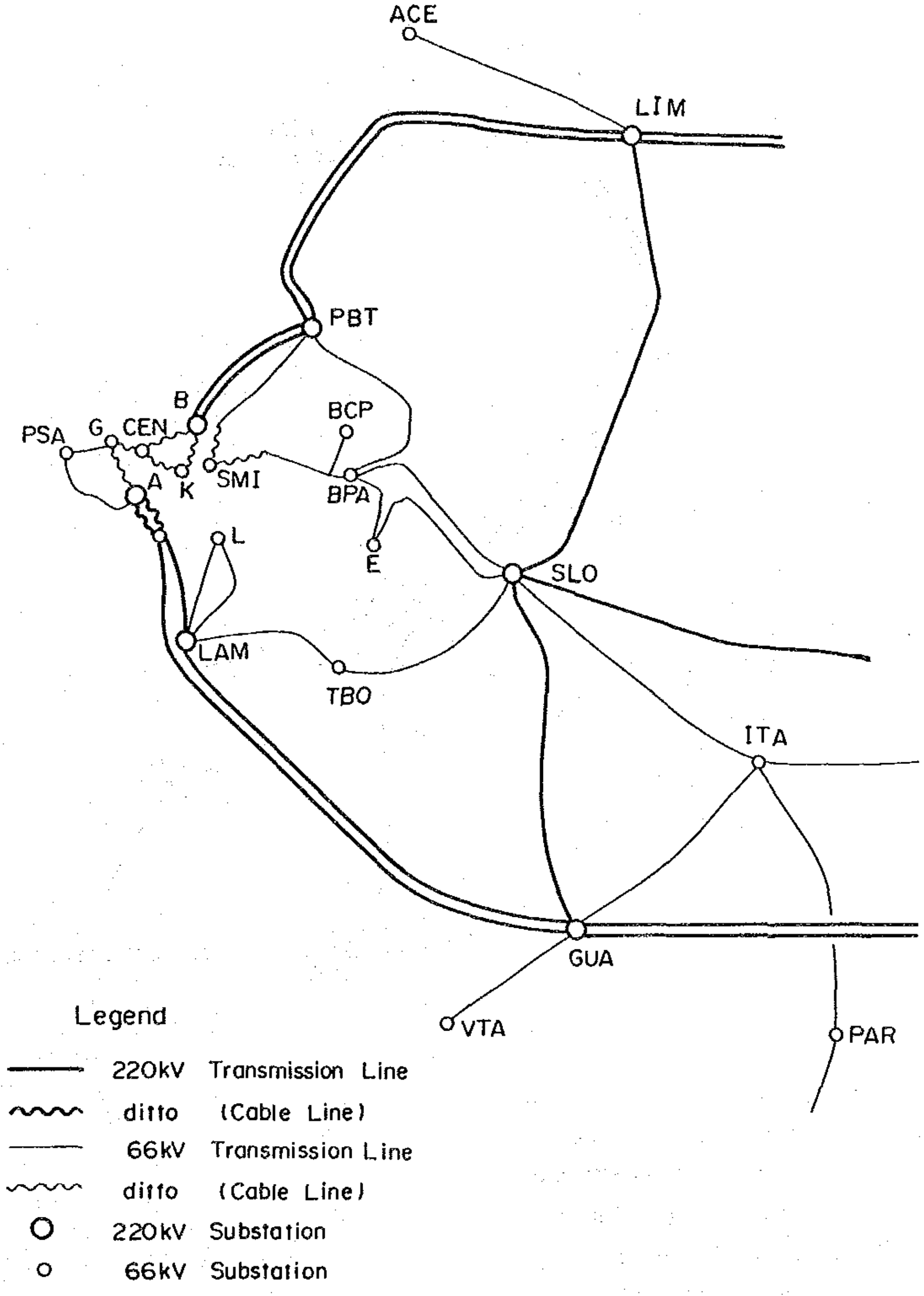


Fig. 5-10 Power System Diagram in and around Asuncion by Alternative 3 (2000)

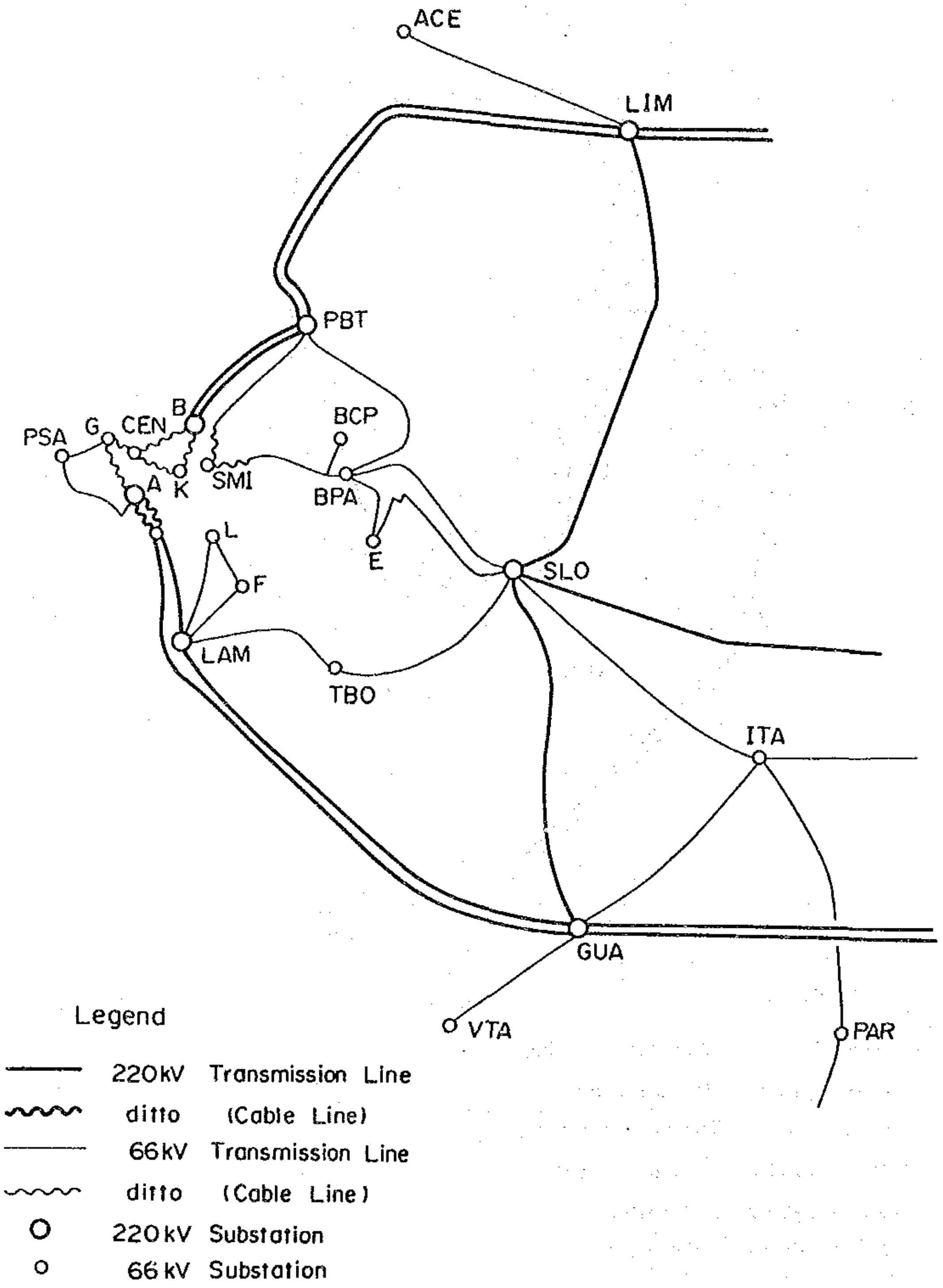


Table 5-10 Outline of the Installation Plan of Alternative 3

Transmission Lines

Voltage (kV)	Transmission Lines		From - To	Transmission Capacity (MVA)	Commissioning
220	1 double cct.	OL	Lambare - Cable head	250/cct.	1994
220	2 single cct.	UC	Cable head - A	250/cct.	1994
220	1/2 double cct.	OL	Limpio - Puerto Botanico	250/cct.	1994
220	1 double cct.	OL	Puerto Botanico - B	250/cct.	1994
66	1 single cct.	OL	Puerto Sajonia - A	50	1994
66	1 single cct.	UC	B - Centro	100	1994
66	1 single cct.	OL	Puerto Botanico - Barrio Parque	50	1994
66	1 single cct.	UC	A - G	100	1996
66	1 single cct.	UC	G - CEN	100	1996
66	1 single cct.	OL	Puerto Sajonia - G	50	1996
66	1 single cct.	OL	San Lorenzo - Barrio Parque	50	1996
66	1 single cct.	OL	Barrio Parque - E	50	1996
66	1 single cct.	OL	San Lorenzo - E	50/cct.	1996
66	2 single cct.	OL	Lambara - L	100/cct.	1996
66	1 single cct.	UC	B - K	100	1998
66	1 single cct.	UC	K - Centro	60	1998
66	1 double cct.	OL	F - 66kV line	100/cct.	2000

Note: Abbreviations

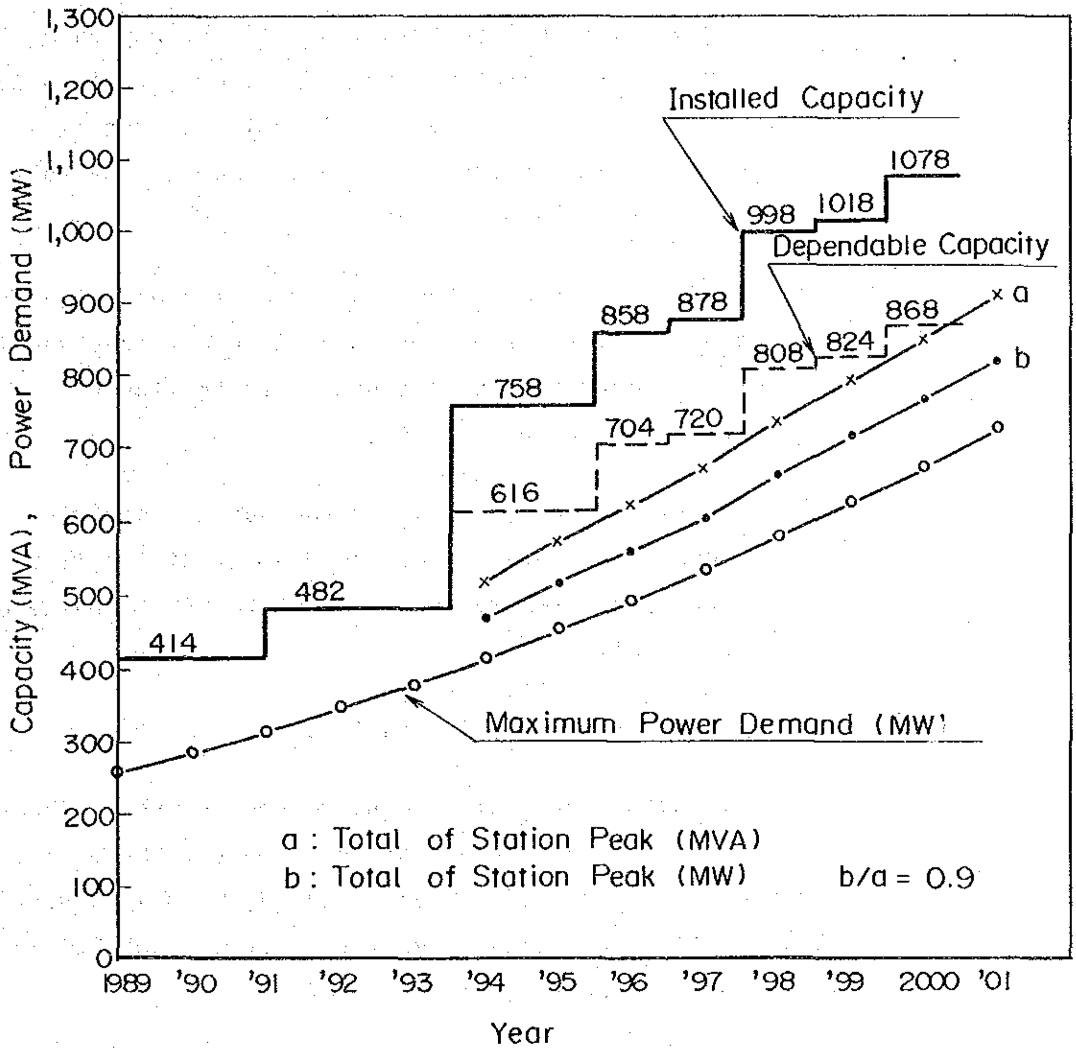
cct.	circuit
OL	Overhead Line
UC	Underground Cable

Table 5-11 Outline of the Installation Plan of Alternative 3

Substations

Substation	Installation Plan			Equipment as of the End of the Commissioning Year	
	Transformer	Line Equipment	Commissioning		
A	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,1cct	1994	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,1cct
B	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,1cct	1994	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,1cct
Limpio	-	220kV,1cct	1994	220/66/13.8kV 37.5/37.5/12.5MVAx1 66/23kV, 20MVAx1	220kV,5cct 66kV,1cct
Puerto Botanico	220/66/23kV 120/60/60MVAx1	220kV,3cct	1994	220/66/23kV 120/60/60MVAx2	220kV,4cct 66kV,2cct
San Lorenzo	220/23kV, 40MVAx1	-	1994	220/66kV, 60MVAx2 220/23kV, 40MVAx2	220kV,3cct 66kV,4cct
Puerto Sajonia	66/23kV,20MVAx1	-	1994	66/23kV, 20MVAx3	66kV,2cct
L	66/23kV,20MVAx1	66kV,2cct	1996	66/23kV, 20MVAx1	66kV,2cct
E	66/23kV,20MVAx1	66kV,2cct	1996	66/23kV, 20MVAx1	66kV,2cct
G	66/23kV,20MVAx3	66kV,3cct	1996	66/23kV, 20MVAx3	66kV,3cct
A	-	66kV,1cct	1996	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,2cct
Barrio Parque	-	66kV,2cct	1996	66/23kV, 20MVAx2	66kV,4cct
San Miguel	66/23kV,20MVAx1	-	1997	66/23kV, 20MVAx3	66kV,3cct
K	66/23kV,20MVAx3	66kV,2cct	1998	66/23kV, 20MVAx3	66kV,2cct
B	-	66kV,1cct	1998	220/66/23kV 99/60/39MVAx2	220kV,2cct 66kV,2cct
L	66/23kV,20MVAx1	-	1998	66/23kV, 20MVAx2	66kV,2cct
Barrio Parque	66/23kV,20MVAx1	-	1998	66/23kV, 20MVAx3	66kV,4cct
E	66/23kV,20MVAx1	-	1998	66/23kV, 20MVAx2	66kV,2cct
Guarambare	220/66kV, 37.5MVAx1	-	1998	220/66kV, 37.5MVAx2 66/23kV, 20MVAx1	220kV,5cct 66kV,4cct
L	66/23kV,20MVAx1	-	1999	66/23kV, 20MVAx3	66kV,2cct
F	66/23kV,20MVAx2	66kV,2cct	2000	66/23kV, 20MVAx2	66kV,2cct
Guarambare	66/23kV,20MVAx1	-	2000	220/66kV, 37.5MVAx2 66/23kV, 20MVAx2	220kV,5cct 66kV,4cct

Fig.5-11 Supply Capability and Maximum Power Demand of the Project Area



One circuit of the double circuit, 220 kV transmission line from Guarambare to Lambare is "pi"-branched and connected to Lambare Substation, and the line is extended to site "A" at the city center. As the 220 kV line passes through the densely populated areas in urban center, it would be impossible to extend this line all the way as an overhead transmission line. Therefore, cable heads will be installed at a certain point on the line, and the line will be connected to the new 220 kV substation (site "A") by cables.

(ii) The 220 kV transmission line from Limpio to Puerto Botanico (one circuit of which is under construction) will be converted to a double circuit line by stringing another circuit.

(iii) A double circuit, 220 kV transmission line (with transmission capacity of 250 MVA/circuit) will be constructed from Puerto Botanico to "B" (Caballero Park Site).

(b) Construction of Primary Substations

Primary substations will be constructed at urban center sites "A" and "B". 2 banks of three phase, three winding transformers (rated 220 kV/66 kV/23 kV, 99 MVA/60 MVA/39 MVA) and line connection bays for 2 circuits of 220 kV lines and 2 circuits of 66 kV lines.

The substation capacities have been changed from Alternative 1. In order to decrease the number of secondary substations to be constructed at Micro Centro Area, the 23 kV side capacity of the transformers installed in Substations "A" and "B" will be larger and the 66 kV side capacity smaller than those in Alternative 1.

(c) 66 System Configuration

The two primary substations, "A" and "B" will be interconnected by a 66 kV system, and 66 kV ring system will be formulated around the Project Area in addition to the existing 220 kV system. An existing 66 kV transmission line will be "pi"-branched into Barrio Pargue Substation, and the interconnection between the primary San Lorenzo Substation and Puerto Botanico Substation will be strengthened.

New transmission lines will be designed in such a manner that no supply failure is caused even when a single circuit is shut down.

(d) Secondary Substation

3 transformer banks, each 66 kV/23 kV, and 20 MVA in capacity, will be installed (in the final stage) in new secondary substations as a rule, and the existing substations will be expanded to 3 transformer banks of the same rating. The bank utilization factor will be selected at 80% so that there is no supply failure even when 1 bank goes out of service due to a failure. When only two banks are used and a failure occurs, a prompt load control operation will be performed or a part of the load on the substation will be switched on to other substations.

(e) Shunt Capacitors

Shunt capacitor banks will be required in most substations in order to keep appropriate voltage levels. The capacities of capacitor banks required have been calculated based on a power flow calculation. The capacities of capacitor banks required to keep the sending end voltage of 23 kV lines at substations in the range from 100 to 104%, with the power factor of load assumed at 0.9, are presented in Table 5-12.

The capacitor banks will be installed in units of 6 MVAR in the secondary substations, and in units of 12 MVAR in

Table 5-12 Installation Plan of Shunt Capacitors

Year Substation	Installation Plan			
	1994	1997	2000	Total as of 2000
A	12 MVAR x 2	12 MVAR x 1	-	12 MVAR x 3
B	12 MVAR x 2	12 MVAR x 1	12 MVAR x 1	12 MVAR x 4
G	6 MVAR x 1	6 MVAR x 1	-	6 MVAR x 2
L	-	6 MVAR x 1	-	6 MVAR x 1
F	-	-	6 MVAR x 1	6 MVAR x 1
K	-	-	6 MVAR x 2	6 MVAR x 2
PBT	12 MVAR x 1	12 MVAR x 2	12 MVAR x 2	12 MVAR x 5
LAM	-	12 MVAR x 1	12 MVAR x 1	12 MVAR x 2

Note: Shunt Capacitors required to be available (MVAR)

	Year	1994	1997	2000
LIM		-	3	3
SLO	23 kV	12	60	60
	66 kV	12	48	48
GUA	23 kV	6	6	18
	66 kV	-	30	42

primary substations, and capacitor banks will be connected to the 23 kV busses in principle.

The capacitor bank capacities required at the primary substations that serve as entrance to the Project Area, Limpio, San Lorenzo, and Guarambare, are also given in Table 5-12, but these values are given for the purpose of reference. The shunt capacitors at these substations must be selected appropriately based on power system analysis studies when the plan for expansion of 220 kV trunk systems is to be studied.

(f) Operating Conditions and Supply Reliability

The operating conditions of power system facilities in Alternative 3 is more stringent than those assumed in Alternative 1, and in some cases, prompt power system switching and/or load control measures will be required when a transformer failure occurs. For this reason, the overall supply reliability is expected to be reduced a little as compared to Alternative 1.

Also, as a large loop systems will be formed, this will make the power flow control of the systems a little more difficult.

CHAPTER 6

POWER SYSTEM ANALYSIS

CHAPTER 6 POWER SYSTEM ANALYSIS

CONTENTS

List of Table and Figures

CHAPTER 6 POWER SYSTEM ANALYSIS

6.1 Conditions for Power System Analysis

6.1.1 Power Systems Subjected to Power System Analysis

The power flows and short circuit capacities of the future power systems have been analyzed by using the CASTLE computer code which is owned by the Electric Power Development Co., Ltd. The power flow analysis studies have been conducted on the power systems in 1990, 1994, 1997 and 2000 under the peak load condition. The short circuit capacity calculations were done on the power systems in 1990 and 2000. In the power systems of 1990, on which the calculation was done, it was assumed that the single circuit, 220 kV transmission line from Itaipu - Limpio - Puerto Botanico was completed at that time. The power systems assumed for the period from 1994 to 2000 are the systems which are planned according to Alternative 3 described in Chapter 5, "Power System Planning".

6.1.2 Configuration of 220 kV Trunk System

It has been assumed that the power systems of 1994 that the transmission line from Itaipu to Limpio has been expanded to a double circuit line, and there are 5 circuits of 220 kV transmission lines that run from the eastern power source area consisting of Itaipu and Acaray power plants.

In the power flow calculations, the transmission system from the eastern power source area to the Metropolitan Area in 1997 are the same as the system in 1994.

In the power systems of year 2000, a power source at remote area is connected to Guarambare Substation via 220 kV transmission lines. In addition, transmission lines and shunt capacitors, which are not included in ANDE's plan are added to these power systems. Such modifications have been introduced in order to enable the calculation on the planed system, and this does not mean any proposal of power system expansion by the JICA Study Team.

6.1.3 Power System Conditions for Power Flow Calculation

(1) Power System

The power flow calculations were performed on the normal power system conditions as a rule, and sometimes it was assumed that certain transmission lines are out of service, in order to provide reference information.

(2) Transmission Line Voltage

220 kV and 66 kV systems : 94% - 107%
23 kV sending end voltage : 100% - 105% as a rule

(3) Voltage Control

The transformer taps were changed and/or power capacitor banks were connected as appropriate in order to keep the 23 kV sending end voltage within the above range.

(4) Load

Projected peak loads at each year
Power factor : 0.9

(5) Supply to Itaugua Caacupe, Paraguari, Quiindy and Caapucu Areas

It has been assumed that the power supply to the above areas, which are outside the Project Area, will be secured from San Lorenzo and Guaanbare Substations.

The transformer capacities in these two substations have been prepared as below from the point of view of power system analysis studies.

		1994	1997	2000
SLO	220 kV/23 kV	40 MVA x 2	40 MVA x 2	40 MVA x 2
	220 kV/66 kV	60 MVA x 2	60 MVA x 2	60 MVA x 2
GUA	220 kV/66 kV	37.5 MVA x 1	37.5 MVA x 1	37.5 MVA x 4

The power facility expansion plan of this project, which is given in Table 5-11, includes the 220 kV/66 kV transformers at Guarambare Substation in the year 2000 whose total capacity is 37.5 MVA x 2, but it implys facilities required only for the power supply to the Project Area.

The plan of power transmission to the above areas, which are outside the Project Area, must be studied together with the study of the expansion of the trunk line transmission system that connects the power source area to the Metropolitan Area.

If the power for the above areas is supplied chiefly from Guarambare Substation in the year 2000, as assumed in this power system analysis, the capacity of the 220 kV/66 kV transformers at the substation should be 37.5 MVA x 4 as above mentioned.

6.2 Results of Power System Analysis

The power flow diagrams representing the power flow calculations are given in Fig. 6-1 through Fig. 6-12. The short circuit capacity values of the power systems in the Project Area are given in Table 6-1. The impedance maps used for these calculations are presented in Fig. 6-13 through 6-16.

6.2.1 Existing Power System (Power System of 1990)

(1) No bottleneck of power flow appears on the single circuit, 66 kV loop system (under normal system configuration) in 1990 if the load distribution on the 23 kV busses is appropriate. As loads can be supplied by the remaining circuits even when a single circuit of transmission lines fails, it is expected that no supply failure occurs in this system.

(2) However, the load distribution among substaitons is currently very uneven, for example, the utilization factor in Lambare Substation is low, and those of Jardin Botanico and Tres Bocas Substation are very high. Under such conditions, certain transmission lines and transformer banks are heavily loaded,

Fig.6-1 Power Flow in 1990

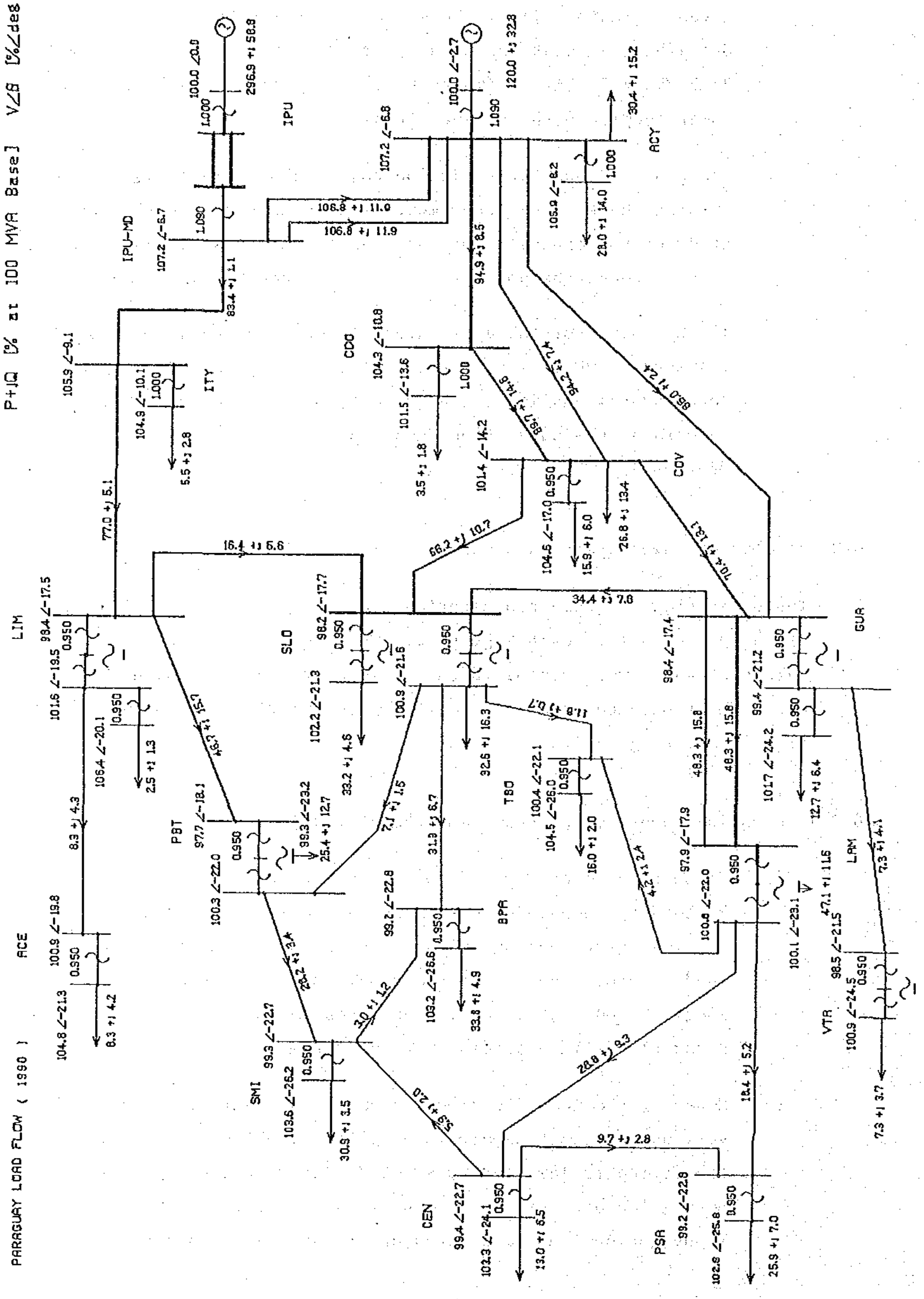


Fig.6-2 Power Flow in 1994

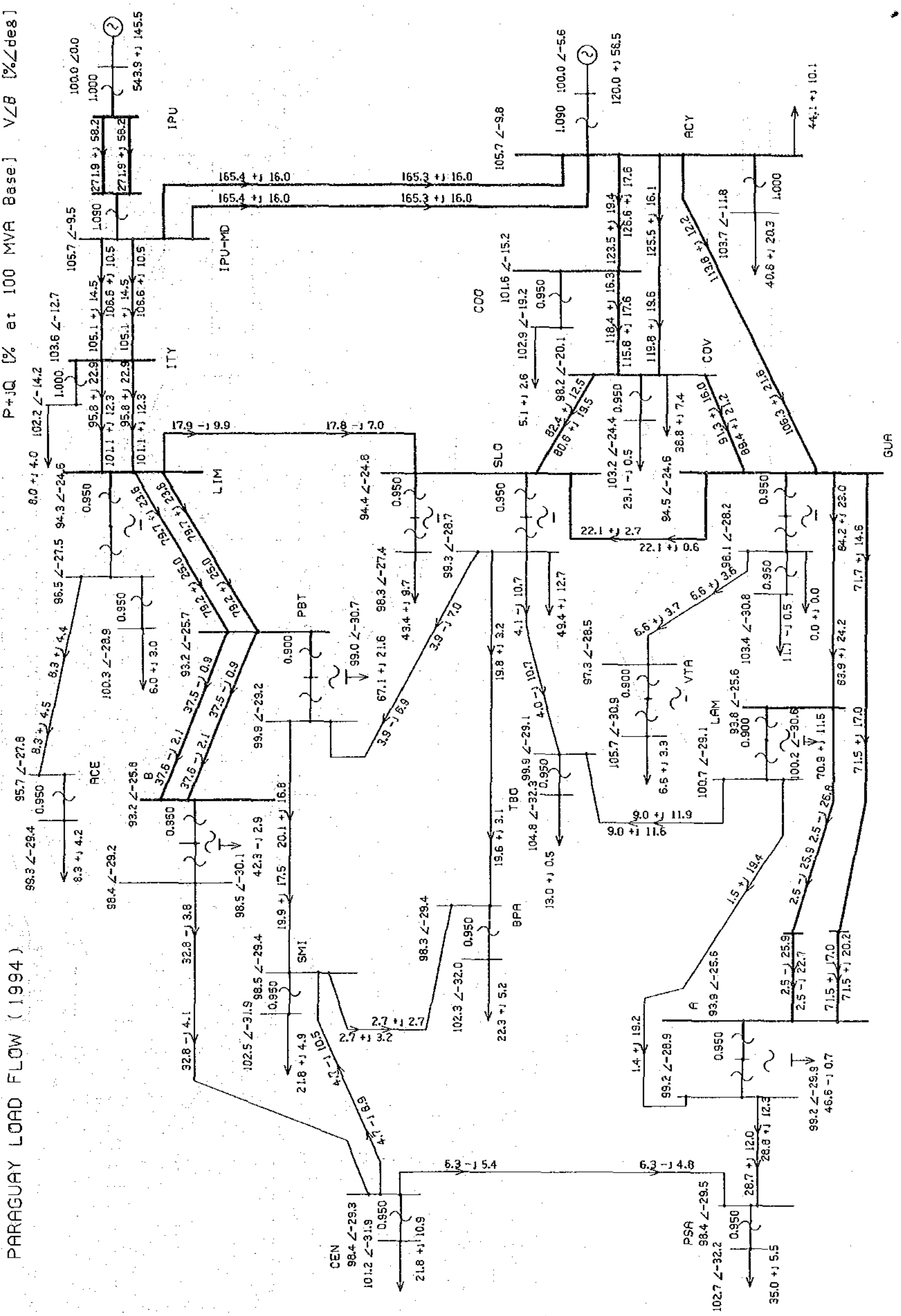


Fig.6-3 Power Flow in 1997

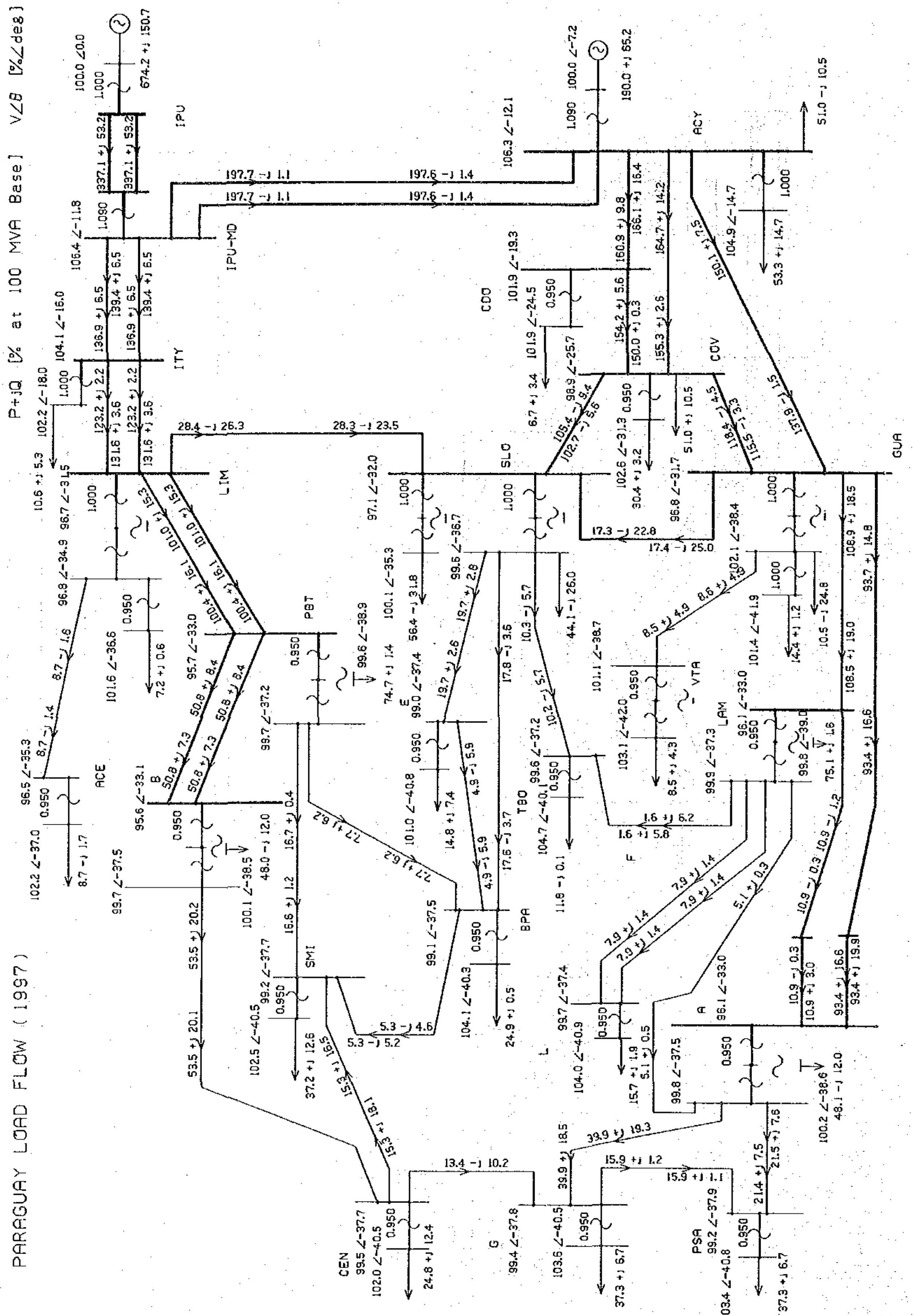


Fig.6-4 Power Flow in 2000

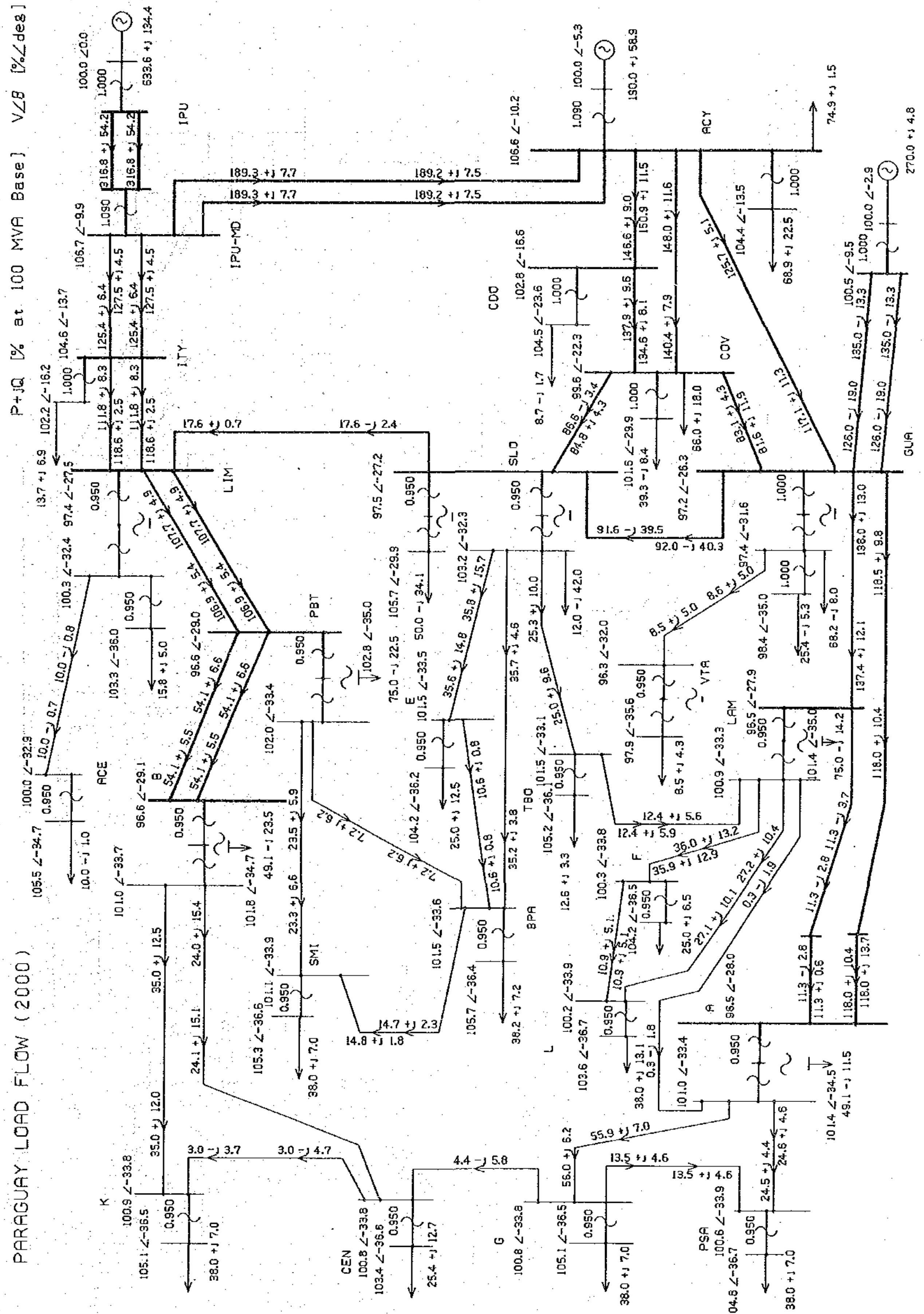


Fig.6-5 Power Flow in 1994
LAM-A 66kV Line Out of Use

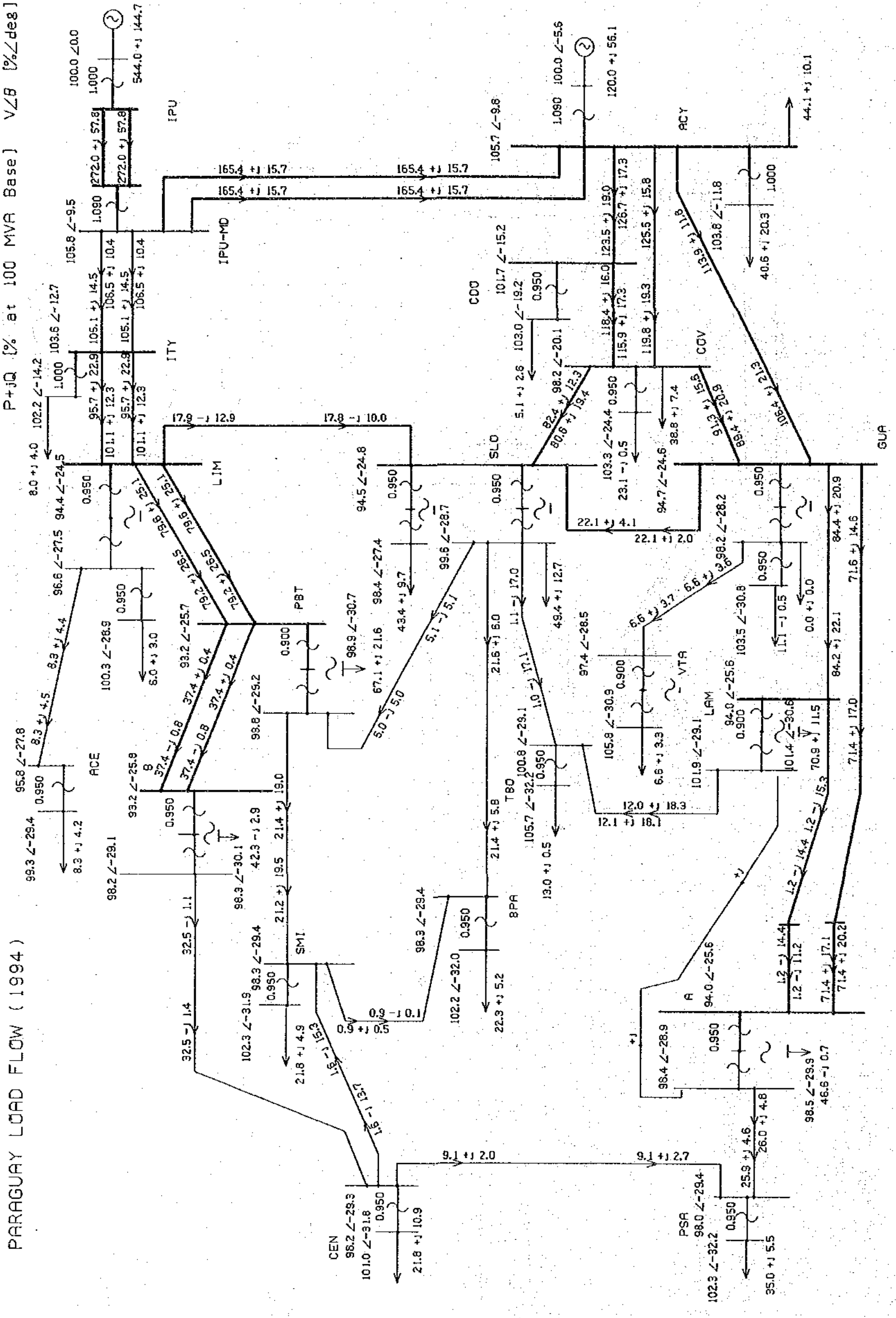


Fig.6-6 Power Flow in 1997
LAM-A 66kV Line Out of Use

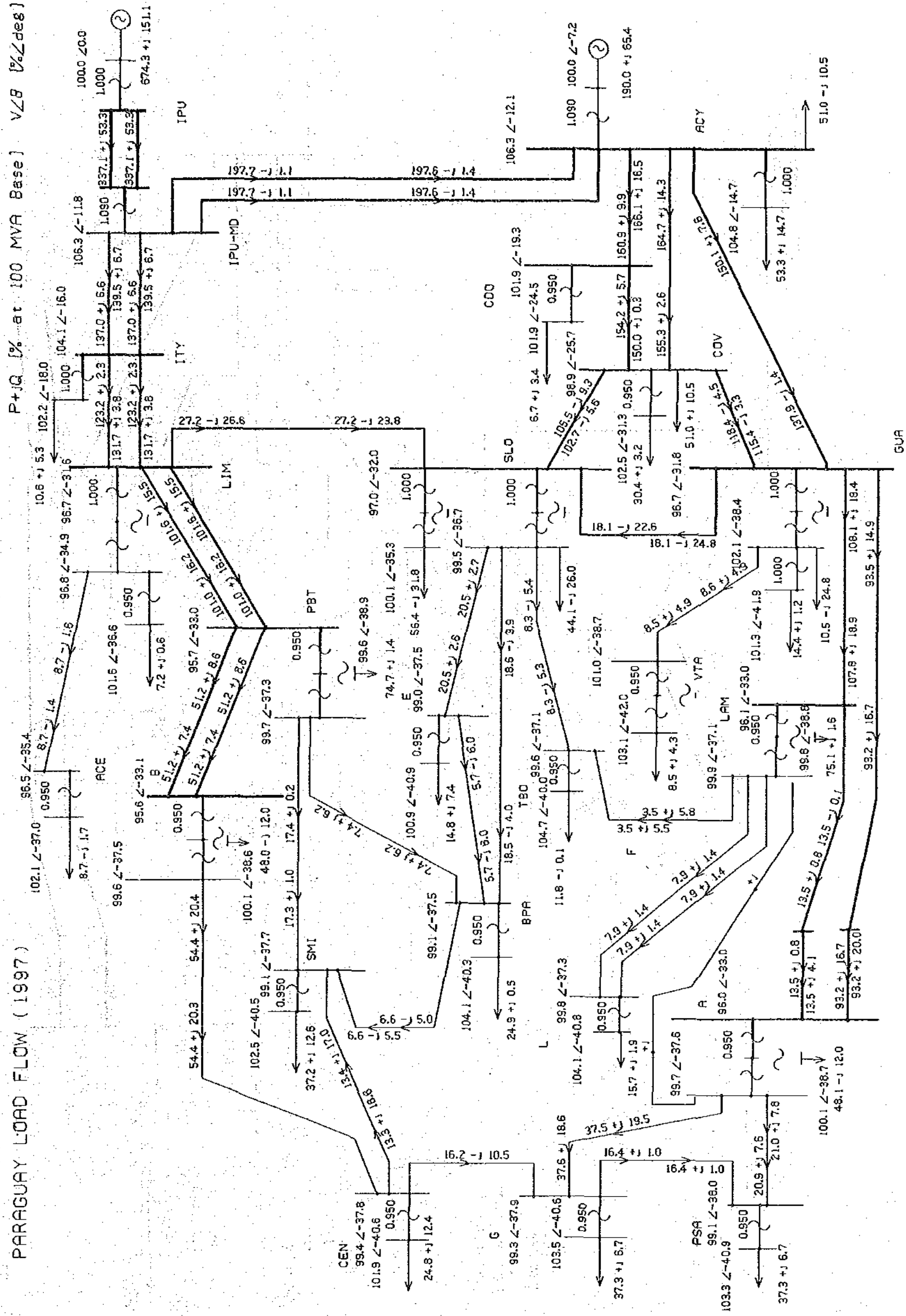


Fig.6-7 Power Flow in 2000
LAM-A 66kV Line Out of Use

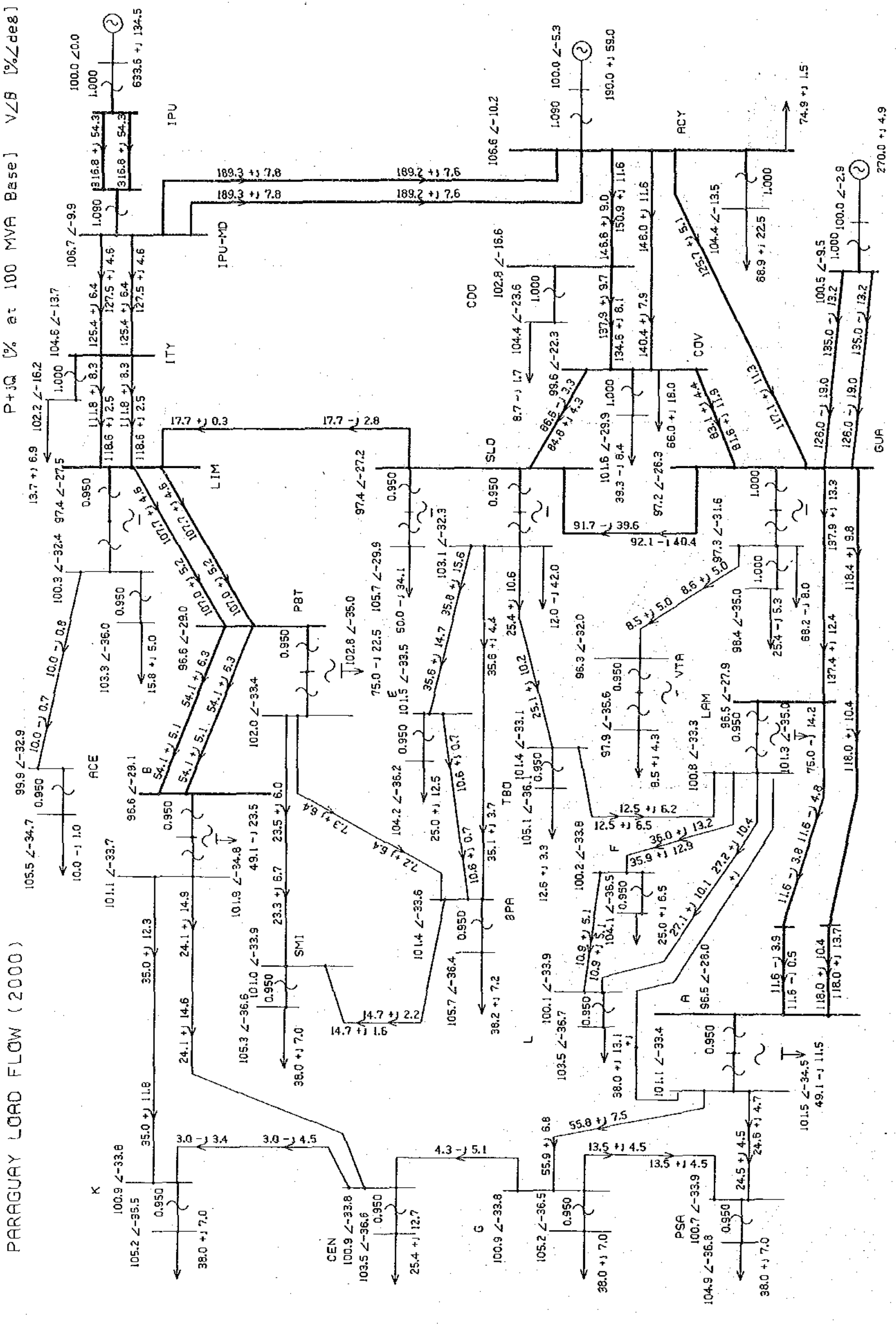


Fig.6-8 Power Flow in 1997
LAM-A 66kV Line Out of Use
ACY-GUA 220kV Line off

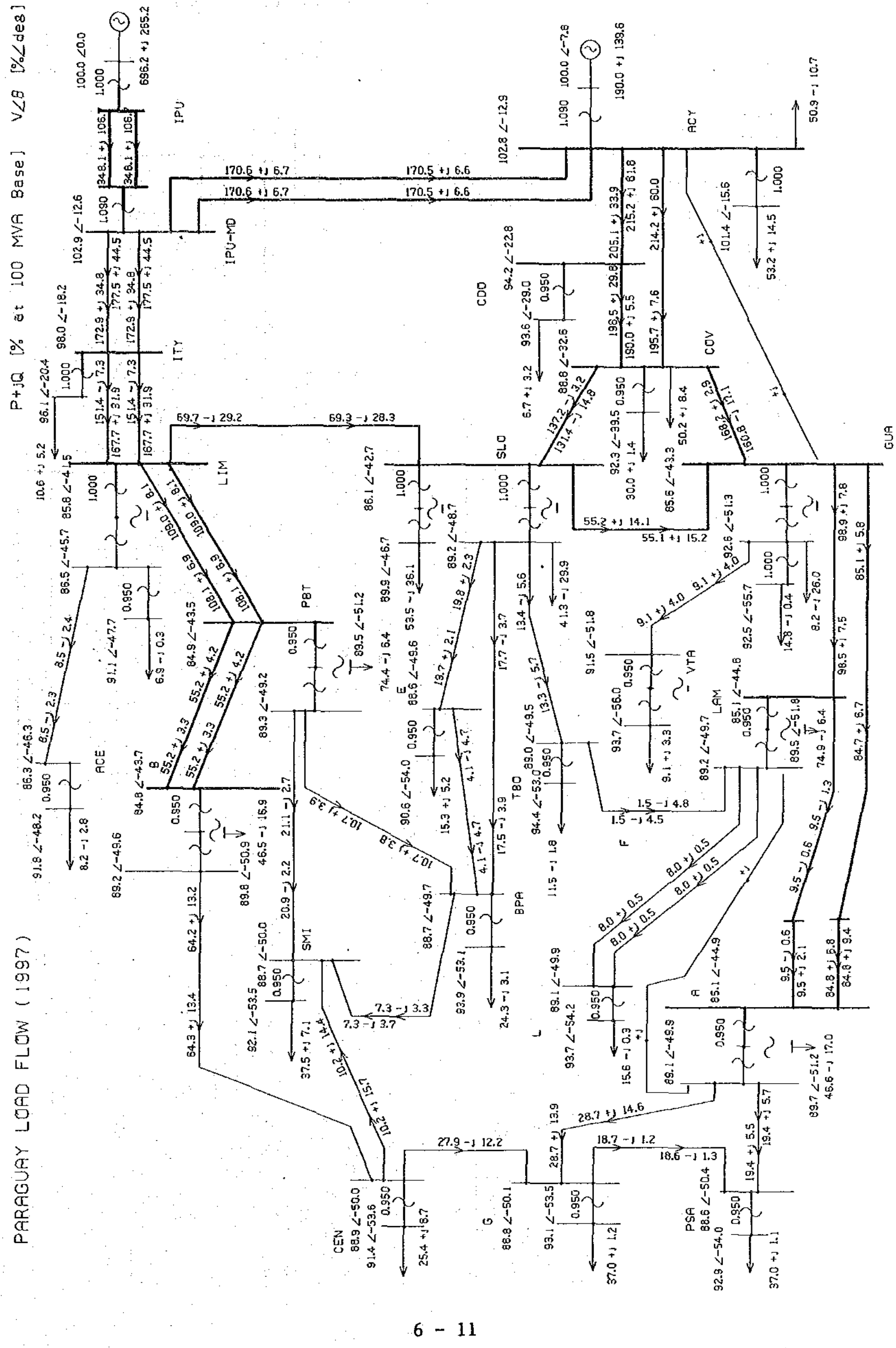
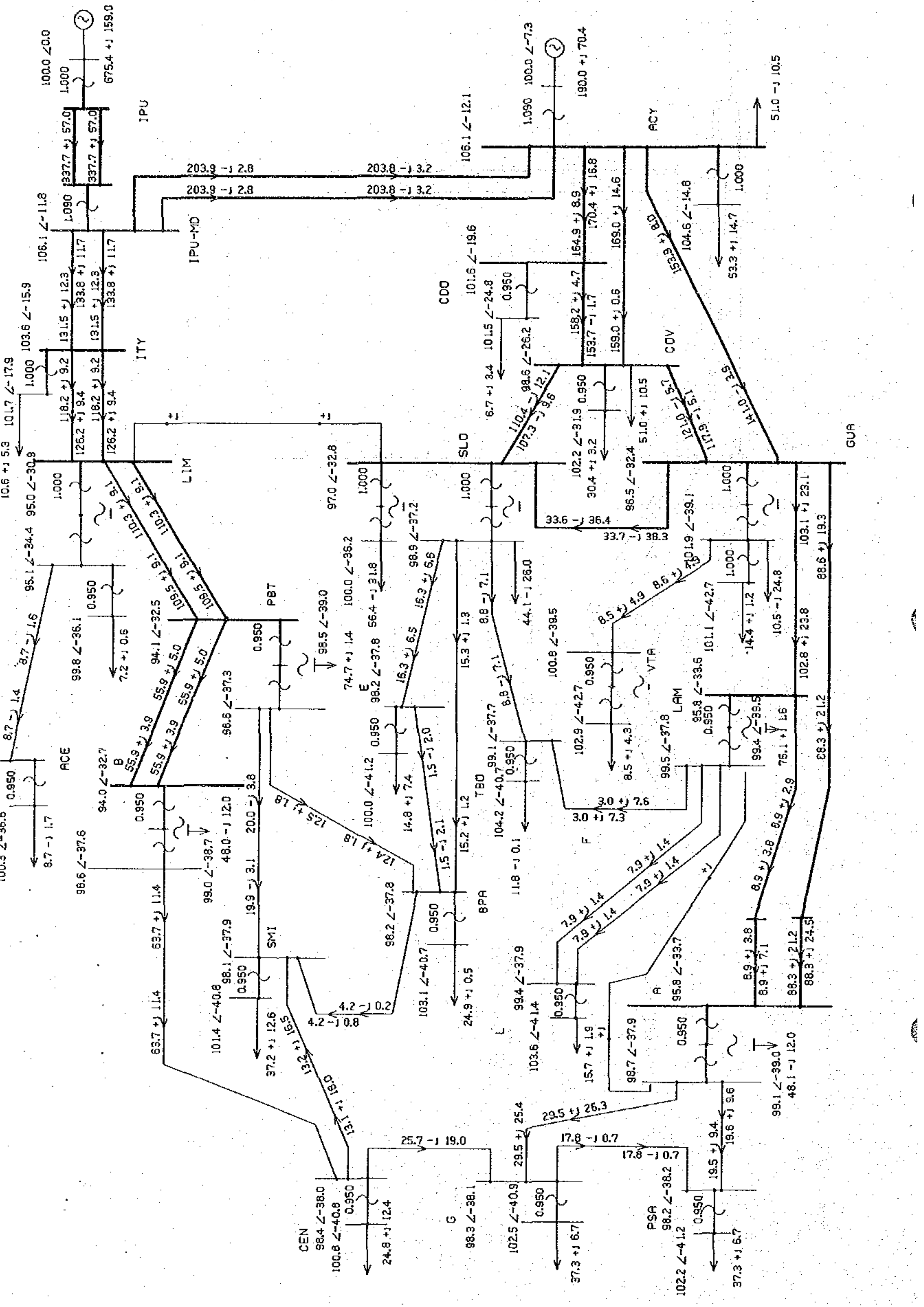


Fig.6-9 Power Flow in 1997
LAM-A 66kV Line Out of Use
LIM-SLO 220kV Line off



PARAGUAY LOAD FLOW (1997)

P+jQ [% at 100 MVA Base] V∠θ [%∠deg]

Fig.6-10 Power Flow in 1997
LAM-A 66kV Line Out of Use
B-CEN 66kV Line off

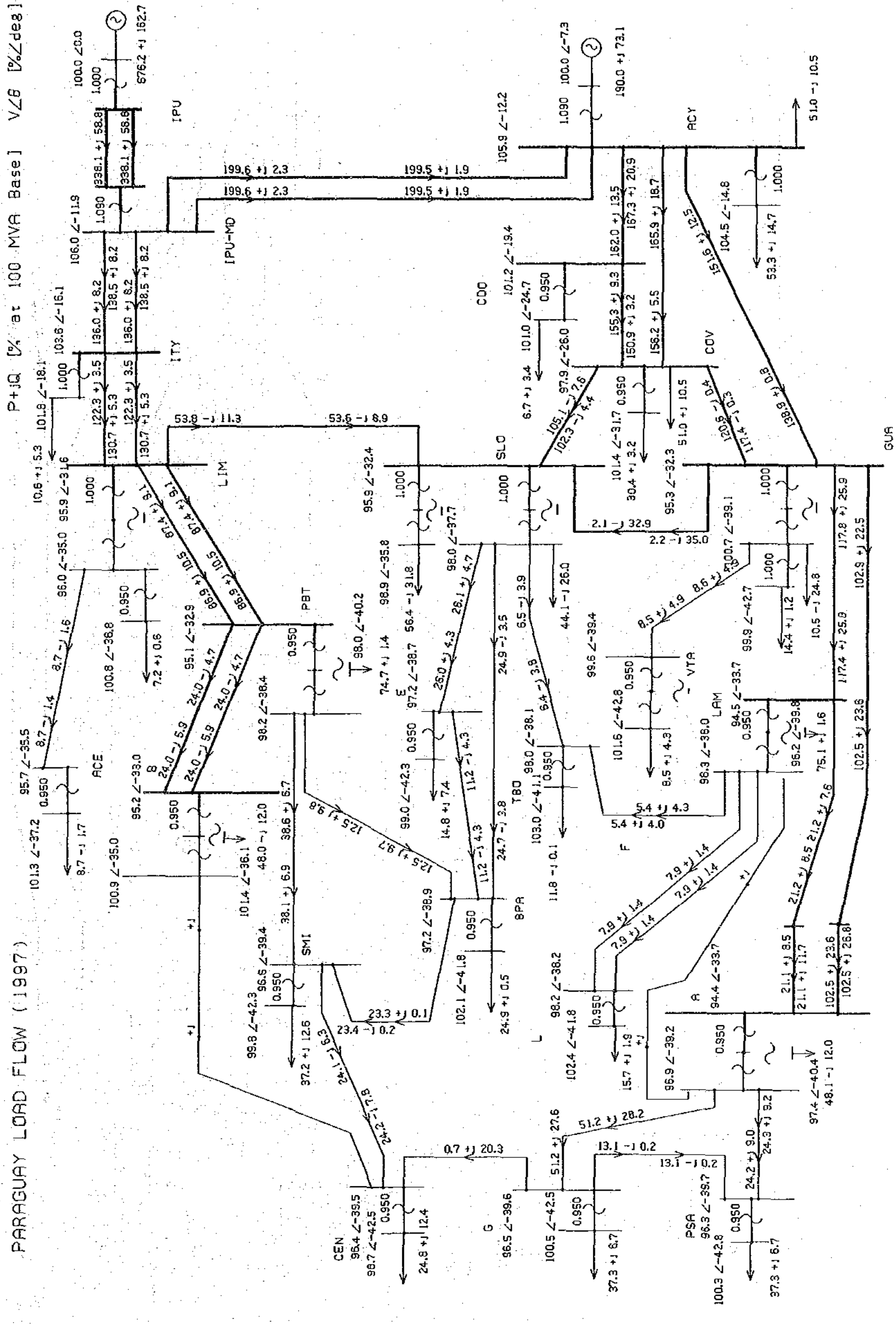


Fig.6-11 Power Flow in 2000
LAM-A 66kV Line Out of Use
LIM-SLO 220kV Line off

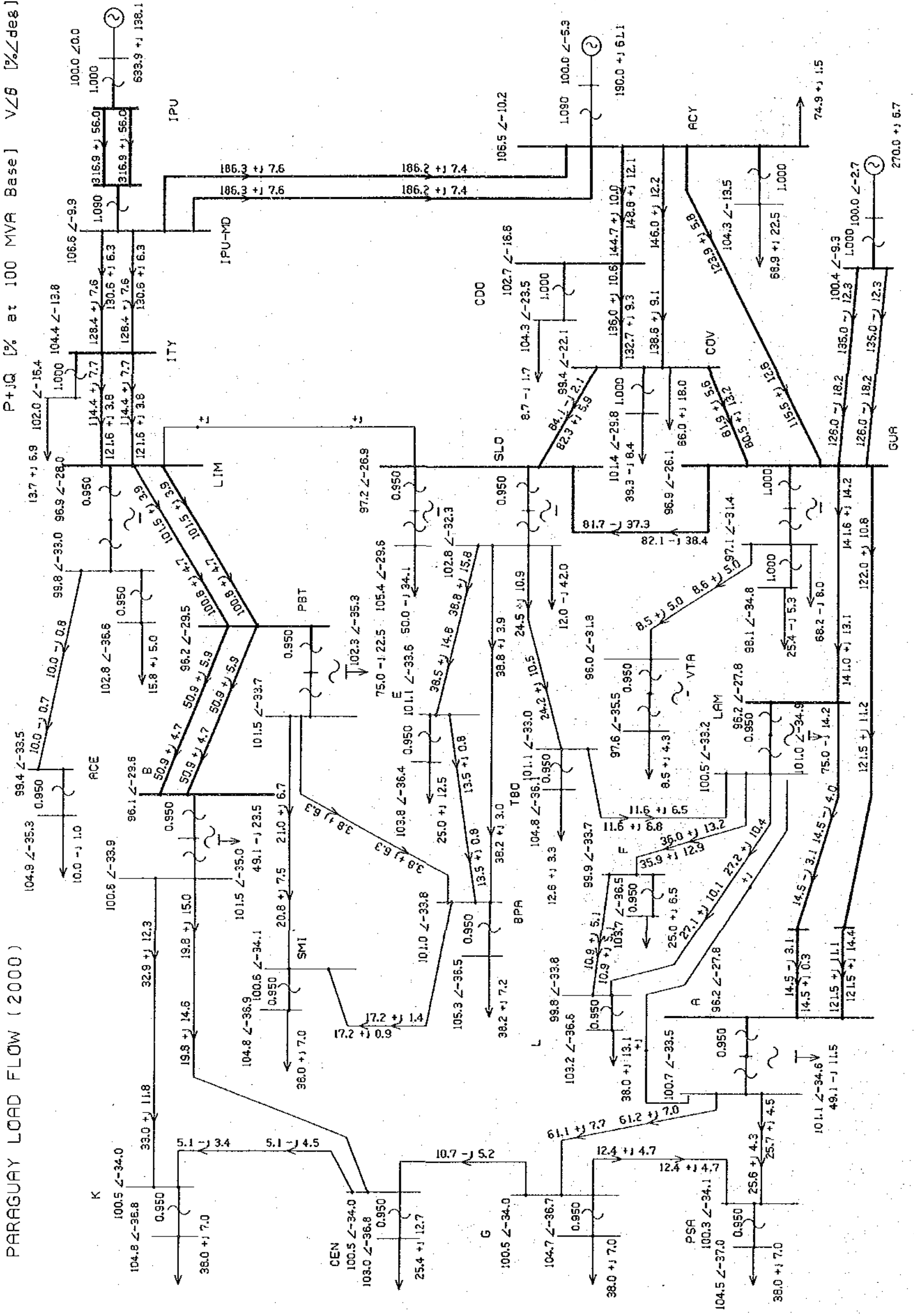


Fig.6-12 Power Flow in 2000
LAM-A 66kV Line Out of Use
A-G 66kV Line off

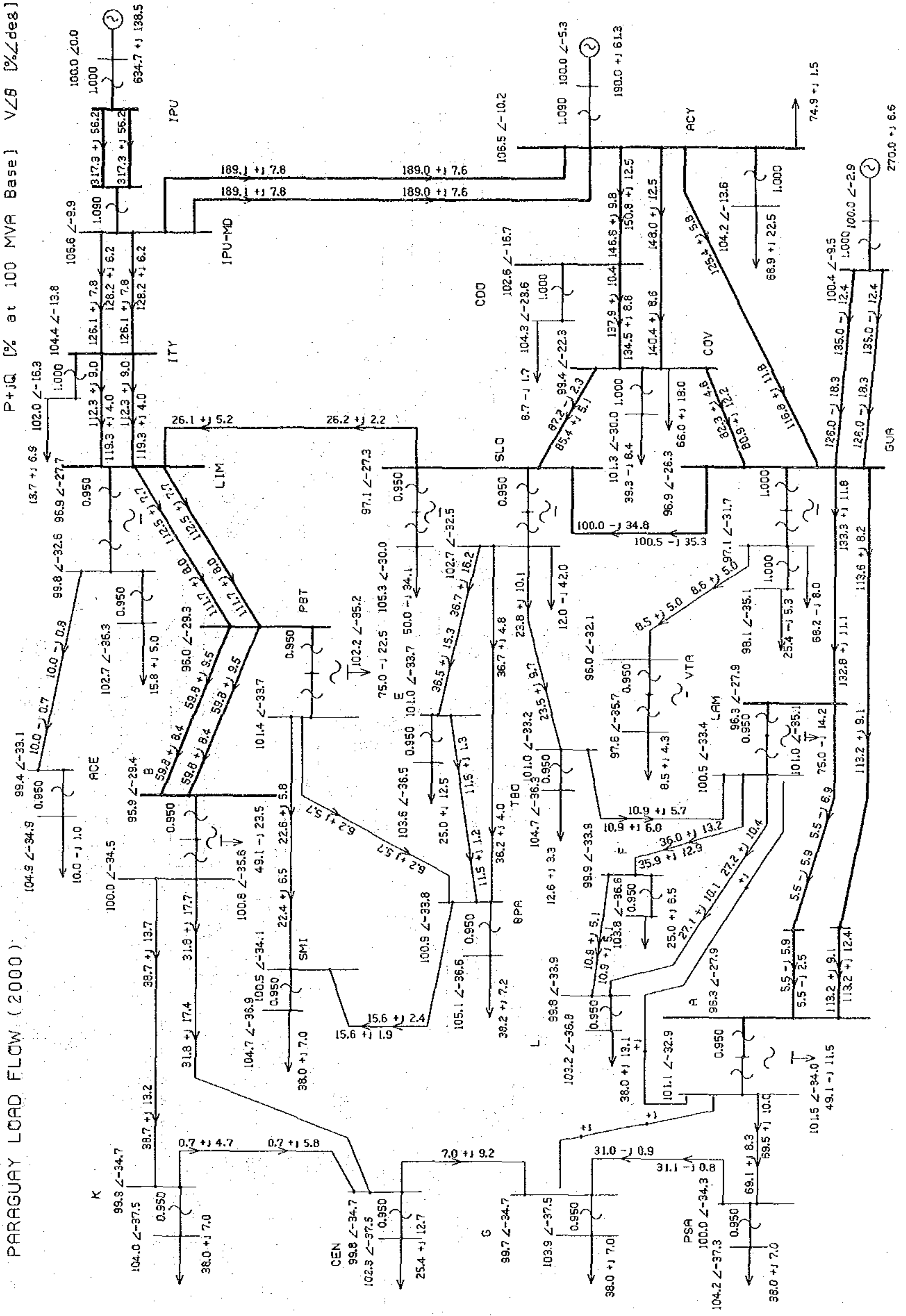
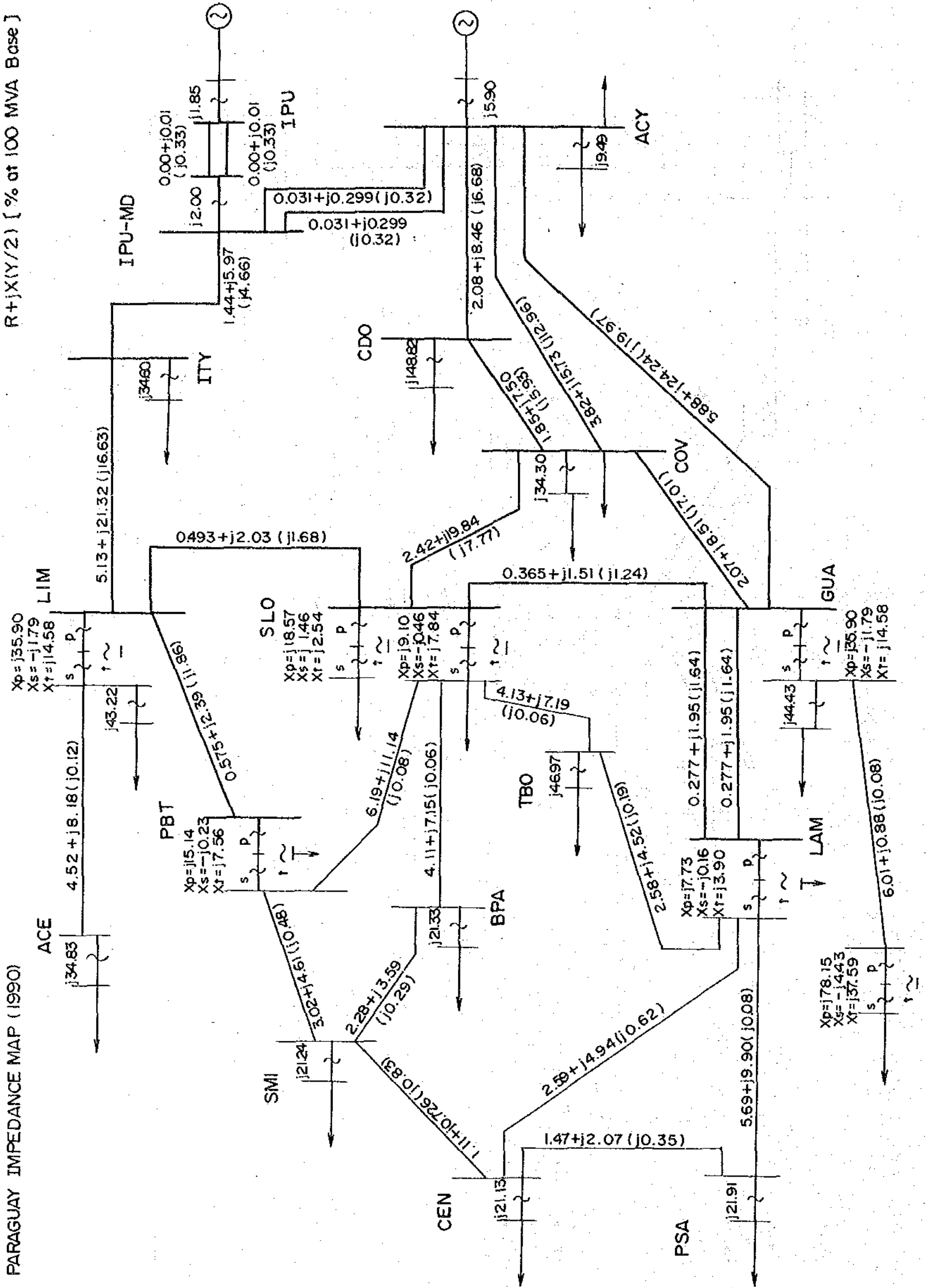


Fig.6-13 Impedance Map in 1990



PARAGUAY IMPEDANCE MAP (1990)

R+jX(Y/2) [% at 100 MVA Base]

Fig.6-14 Impedance Map in 1994

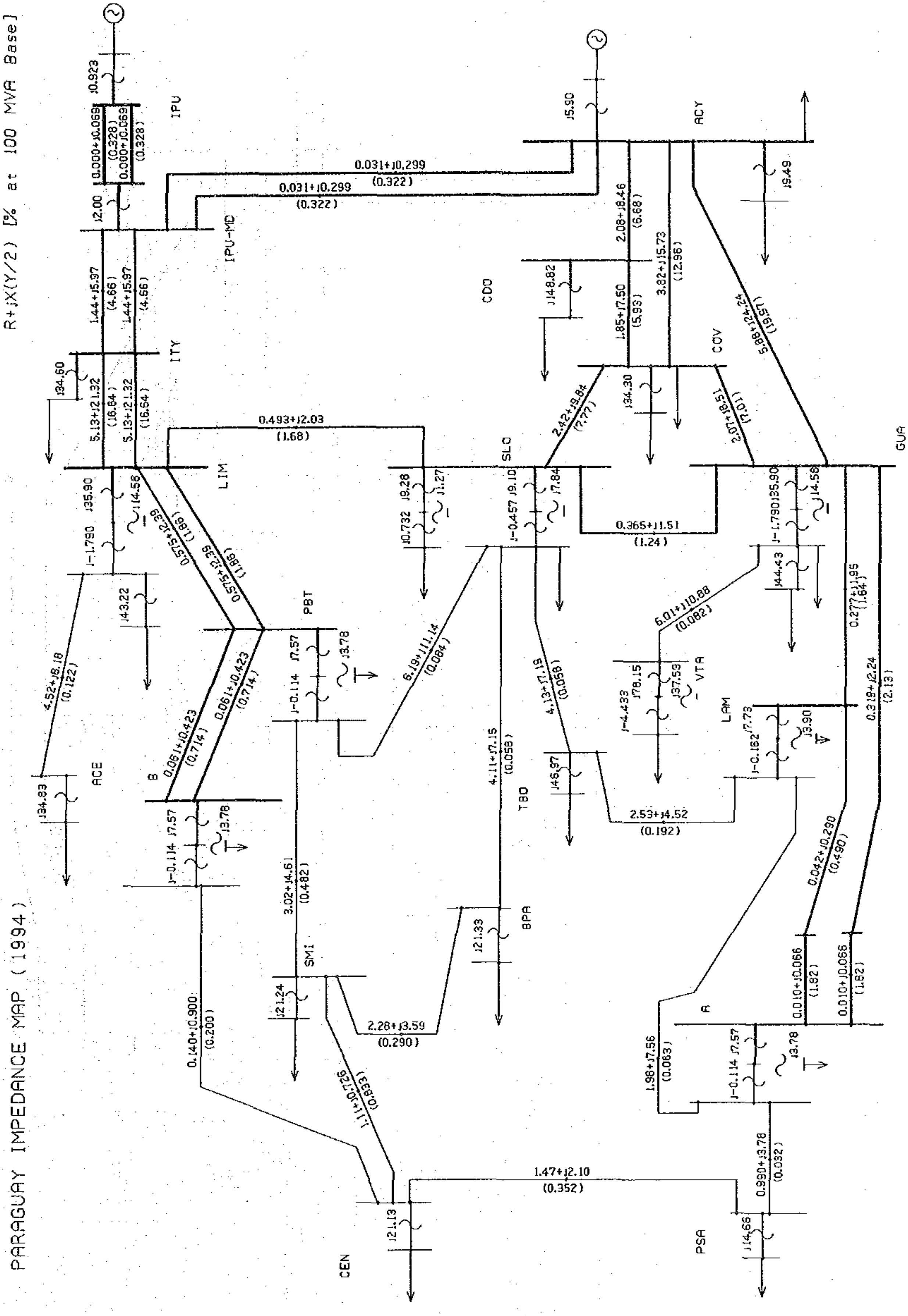


Fig.6-15 Impedance Map in 1997

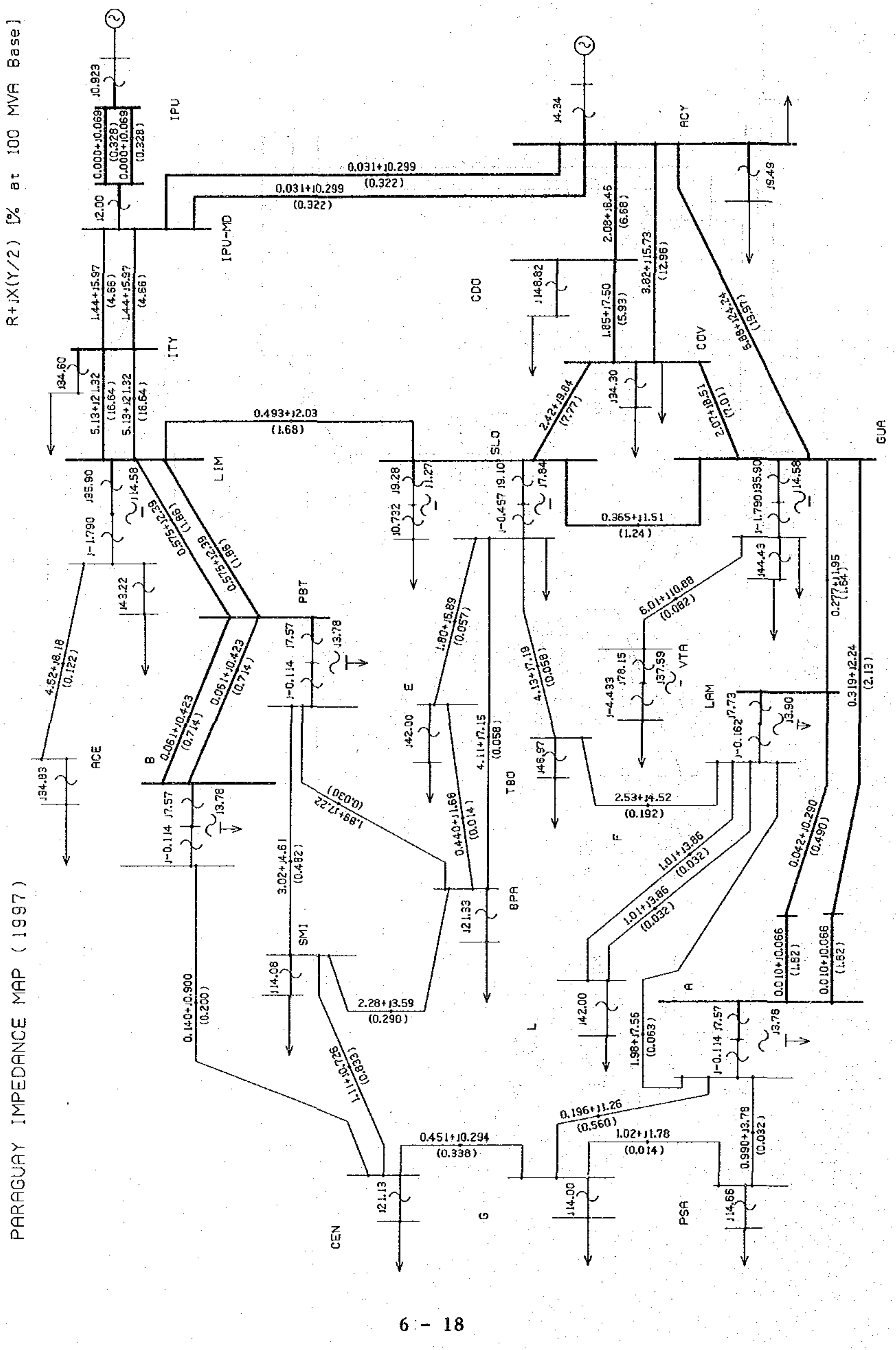
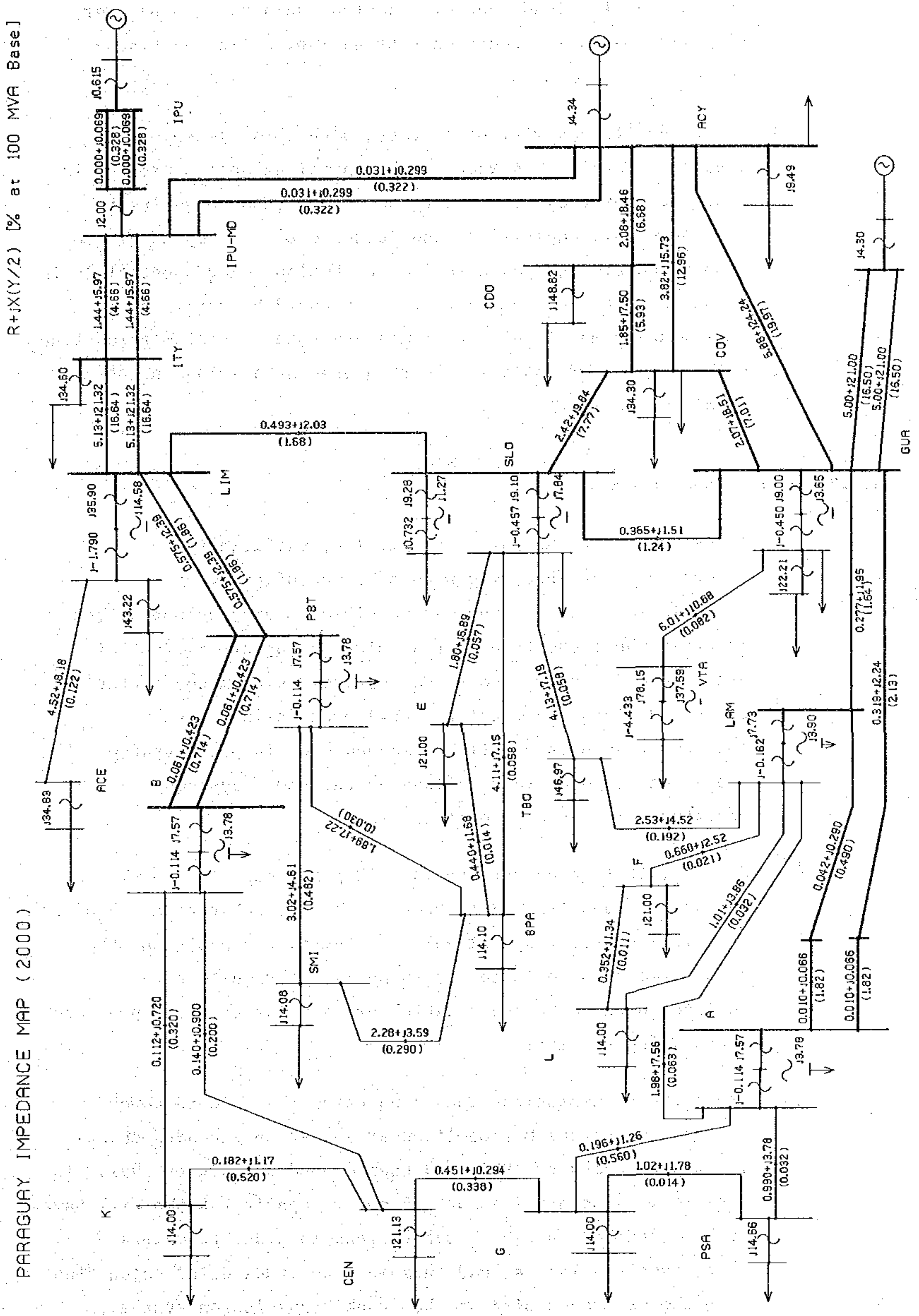


Fig.6-16 Impedance Map in 2000



and substantial load control measures would have to be exercised when a fault occurs on a transmission line or transformer.

(3) The power systems will be operated with this system configuration until 1994 when a substantial expansion program is started. Power systems under these conditions have insufficient supply capability, and it would become impossible to resolve bottlenecks even load distribution among substations is adjusted to the optimum pattern. It would be required to implement prompt load control measures when a transmission line or a transformer fails in order to prevent overloading of remaining facilities.

6.2.2 Future Power Systems

(1) In establishing the power system plan, sufficient considerations have been given to make use of existing transmission lines as much as possible to create loop systems in areas where shortage of transmission capacity is anticipated, and to apply prompt load control (system configuration switching, load restriction, etc.) when failure occurs. Therefore, no problem will be encountered in power system operations in each year as long as the power systems are operated under normal configuration.

(2) However, it is necessary to install power capacitor banks in new substations (including Puerto Botanico Substation) in order to maintain proper system voltage levels. In addition, the transformers to be installed in new substations must be equipped with tap changers which are similar to those provided on existing facilities.

(3) The trunk transmission lines connecting the eastern power source area to the Metropolitan Area must be expanded to at least 5 circuits by 1994, and then expanded again by 1997. In addition, substantial amount of power capacitor banks will have to be installed in 220 kV substations in order to maintain proper voltage levels, and this must be studied in conjunction with the expansion plan of the trunk transmission system.

(4) The usefulness of the existing 66 kV transmission line from Lambare (LAM) and Puerto Sajonia (PSA) has been examined by power flow calculations by assuming such a system configuration that the 66 kV line is connected to "A" substation through a "π" branch and for the cases that the 66 kV line from LAM to "A" is used (Fig.6-2 through Fig. 6-4) and it is not used (Fig. 6-5 through Fig. 6-7). The calculation indicated that the power flow of the section between LAM and "A" is very small, being 0.2 to 4.7% of the power flowing through "A" Substation, with most of the power flowing on the 220 kV transmission line. Therefore, this 66 kV line is practically meaningless, and it could be decommissioned.

(5) On the basis of the power system configuration that the above assumed 66 kV line from LAM to "A" is out of use, the power flows in the following abnormal conditions of the system have been calculated.

For 1997:

i) ACY - GUA 220 kV transmission line is not used (Fig. 6-8).

ii) LIM - SLO 220 kV transmission line is not used (Fig. 6-9).

iii) B - CEN 66 kV transmission line is not used (Fig. 6-10).

For 2000:

i) LIM - SLO 220 kV transmission line is not used (Fig. 6-11).

i) A - G 66 kV transmission line is not used (Fig. 6-12).

(6) When the 220 kV transmission line from Acaray (ACY) to Guarambare (GUA) is out of service (Fig. 6-8), the power system voltage is substantially reduced and it may not be possible to operate the system stably. Therefore, it is necessary to

implement the power system reinforcement which has been discussed in Clause (3).

(7) Even when the 220 kV transmission line from Limpio (LIM) to San Lorenzo (SLO) is out of service (Fig. 6-9, Fig. 6-11), no problem is encountered because there are 66 kV interconnections from Puerto Botanico to San Lorenzo and from "A" to "B".

(8) No problem in power system operation, i.e. overloading, will be encountered when the relatively heavy load 66 kV transmission lines, such as those from "B" to Centro (CEN) and from "A" to "G", are put out of service (Fig. 6-10, Fig. 6-12).

6.2.3 Power Supply Reliability

The current power systems are such that the supply capacity will fall short within a few years even with the normal system configuration.

In future power systems, it is so planned that sufficient supply margin is provided for the projected demand. Also, as most substations are supplied by two circuits of transmission lines having different route, it is anticipated that no supply failure will occur even when a single circuit of transmission line fails.

When a transformer fails, however, it may be required to switch system configuration on the 23 kV side or exercise load control. Particular attention must be given on substations having only 1 or 2 banks concerning this possibility.

In addition, it is required to maintain appropriate load distribution on substations and avoid to place heavy load on certain substations.

6.2.4 Short Circuit Capacity

(1) The results of short circuit capacity calculations are presented in Table 6-1. The calculation was performed based on the power system in 1990, and assuming that 2 units of Itaipu Power Plant and 3 units of Acaray Power Plant were connected to the power system.

The short circuit capacity calculation was also performed on the power system of the year 2000, and it was assumed in this case that 3 units of Itaipu Power Plant and 4 units of Acaray Power Plant, plus 2 more units of Itaipu Power Plant or Yacyreta Power Plant were connected to the power system.

In all cases, the values of generator impedance are based on the subtransient reactance (x_d'').

(2) In the power system of the year 1990, the 3-phase short circuit current does not exceed the interrupting current of a circuit breaker in any substation.

In the power system of the year 2000, the 3-phase circuit current on the 23 kV busses will become 14 - 15 kA in San Lorenzo Substation and Lambare Substation, exceeding the interrupting current of 12.5 kA of the existing circuit breakers. Therefore, the circuit breakers whose capacities become insufficient must be replaced, or some measures of limiting the short circuit current must be provided.

The time when this measures must be introduced depends on the expansion program of the 230 kV power systems that supply power from the eastern power source area to the Metropolitan Area, but probably it will become in around 1997.

Table 6-1 3-Phase Short Circuit Current in the Project Area in 1990 and 2000

Substation	Nominal Voltage (KV)	Short Circuit Current (A)	
		1990	2000
LIM	220 66 23	1980 1796 2584	3484 2063 2783
SLO	220 66 23	2112 4664 7450	3786 7423 14234
GUA	220 66 23	2146 1839 2585	4035 3722 5492
LAM	220 66 23	2014 4555 10878	3520 6694 14768
PBT	220 66 23	1745 4263 8995	3162 6745 14995
A	220 66 23	—	3513 7347 16002
B	220 66 23	—	3106 7272 15894
BPA	66 23	4127 5631	6700 8822
TBO	66 23	4186 3595	6320 4046
CEN	66 23	4367 5820	7272 7298
PSA	66 23	4094 5354	6703 8644
SMI	66 23	4381 5814	6081 8414
ACE	66 23	1528 2559	1718 2756
VTA	66 23	1483 1717	2493 2240
K	66 23	—	7089 9088
E	66 23	—	6413 6976
G	66 23	—	7278 9206
L	66 23	—	5810 8209
F	66 23	—	5909 6731

Note 1. No. of cnnected generators:

In 1990: Itaipu 2, Acaray 3
In 2000: Itaipu 3, Acaray 4, New 2

2. Generator Impedance: Xd′

CHAPTER 7

TRANSMISSION LINE AND SUBSTATION PLAN

CHAPTER 7 TRANSMISSION LINE AND SUBSTATION PLAN

CONTENTS

List of Tables and Figures

CHAPTER 7 TRANSMISSION LINE AND SUBSTATION PLAN

7.1 Transmission Facility Plan

7.1.1 Current Status of Power Transmission Facilities

The transmission systems in the Project Area is illustrated in Figure 7-1. The details of current transmission facilities, those being constructed, and the related future plan are presented in Table 7-1 and Table 7-2.

(1) The main 220 kV transmission systems supplying the Metropolitan Area consist of three 220 kV circuits, with two running from Acaray Power Station to San Lorenzo Substation, and one from Acaray Power Station to Lambare Substation. In addition, three 220 kV circuits are under construction with scheduled commission dates in 1990, one circuit is from Itaipu Power Station to Limpio Substation, another circuit from Limpio Substation to Puerto Botanico Substation, and another from Limpio Substation to San Lorenzo Substation.

(2) The 66 kV transmission systems in the Metropolitan Area supply power to the Project Area of this study which include Asuncion City and its surrounding areas, and the county areas which lie to the east and southeast of Asuncion City. The 66 kV system supplying the county areas is a single circuit radial system that branches off from San Lorenzo Substation. The section of this transmission line from Guarambare to Itaugua Substations is now being constructed. Guarambare Substation will be the key substation supplying these county areas in the future.

(3) The 66 kV system in the Project Area forms a loop system, with the two 220 kV substations, San Lorenzo Substation and Lambare Substation, functioning as the source of this 66 kV system. When the 220 kV Puerto Botanico Substation, which is now under construction, is completed, there will be three key substations supplying this 66 kV system. These three substations are located roughly at the three apices of a triangle that contains the Project Area.

Fig. 7-1 Transmission Line Route in the Project Area

Table 7-1 Outline of the 220 kV Transmission Lines in the Project Area

Section	Nos. of Circuit	Length (km)	Conductor		Kind of Line	Capacity (MVA)		Completion Year	Note
			Type	Size		Continuously	Temporary		
GUA-SLO	1	18.1	ACSR	636 MCM	Overhead	175	210	1980	
LIM-PBT	2	28.0	ACSR ACAR	954 MCM 950 MCM	Overhead	175	210	-	1 cct under constructing
GUA-LAM	2	23.4	ACAR	950 MCM	Overhead	175	210	1981	1 cct 1.2 km under planning
Total		69.5							

Table 7-2 Outline of the 66 kV Transmission Lines in the Project Area

Section	Nos. of Circuit	Length (km)	Conductor		Kind of Line	Capacity (MVA)		Completion Year	Note
			Type	Size		Continuously	Temporary		
SLO-JBO	1	11.9	ACSR	300 MCM	Overhead	50	55	1978	2 cct designed
JBO-SMI	1	4.0	ACSR	300 MCM	Overhead	50	55	1968	
		1.9	XLPE	300 mm^2	Underground	60	65	1989	
SMI-CEN	1	3.5	OF	150 mm^2	Underground	30	-	1968	In 1990, to be renewaled to XLPE 300 mm^2
CEN-PSA	1	1.4	OF	150 mm^2	Underground	30	-	1968	
		2.1	ACSR	300 MCM	Overhead	50	55	1968	
SLO-BPA	1	8.5	ACSR	300 MCM	Overhead	50	55	1968	
BPA-SMI	1	4.0	ACSR	300 MCM	Overhead	50	55	1968	
		1.1	OF	150 mm^2	Underground	30	-	1968	In 1990, to be renewaled to XLPE 300 mm^2
SLO-TBO	1	8.6	ACSR	300 MCM	Overhead	50	55	1968	
TBO-LAM	1	4.8	ACSR	300 MCM	Overhead	50	55	1968	
		1.2	XLPE	300 mm^2	Underground	60	65	1990	
LAM-PSA	1	6.5	ACSR	300 MCM	Overhead	50	55	1987	
		5.3	ACSR	300 MCM	Overhead	50	55	1968	
LAM-CEN	1	3.6	ACSR	300 MCM	Overhead	50	55	1968	
		4.4	XLPE	300 mm^2	Underground	60	65	1987	
LIM-SLO	1	24.4	ACSR	636 MCM	Overhead	-	-	1984	220 kV designed
		9.4	ACSR	300 MCM	Overhead	-	-	-	
GUA-VIL	1	12.5	ACSR	300 MCM	Overhead	40	45	-	Under constructing
BCE Branch Line	1	1.3	ACSR	300 MCM	Overhead	50	55	-	Under constructing
Overhead		106.9							
Underground		13.5							
Total		120.4							

The main part of the 66 kV transmission lines has been constructed in 1968, and then it has been expanded and strengthened in 1976 and 1987. Currently, a transmission line is being constructed from Guarambare Substation to Villeta Substation. All transmission lines of this system has a single circuit, and their conductors are small. Therefore, although there is sufficient supply capacity under normal conditions, the transmission capacity falls short when there is a single circuit failure, leading to supply failures.

As of the end of 1988, the aggregate circuit length of 66 kV transmission lines was 107 km, consisting of 93 km overhead lines, and 14 km underground cable lines. The conductors of overhead lines are 300 MCM and 636 MCM ACSR. Most of support structures are steel masts, but steel pipe poles are used in some parts. The underground cable lines are directly buried. The cables are 300 mm^2 X LPE copper cable and 150 mm^2 OF copper cable.

(4) It is expected that the supports of 66 kV transmission lines in the Project Area will be usable for a considerable time to come. Substantial numbers of high voltage, medium voltage and low voltage lines have been constructed along existing roads, and there are many roads along which power lines are built on both sides of roads. In urban areas, construction of new power lines is becoming more and more difficult. However, more overhead lines can be constructed in the suburban areas.

7.1.2 Transmission Line Planning Conditions

As mentioned in Chapter 5, three alternatives were considered in planning the transmission facilities in the Project Area.

Discussions were held with ANDE based on Alternative-1 and Alternative-2, and it has been agreed upon by the Study Team and ANDE that Alternative-3, which is a modification of Alternative I, was to be selected as the basis of the plan. Based on this Alternative-3, the following basic conditions were considered for the transmission line planning.

(1) Effective Utilization of Existing Facilities

Although the service life of transmission facilities are defined as 30 years according to ANDE's standard, most of 66kV transmission lines have been built in 1968, and this means the service spans of these lines will exceed 30 years by the year 2000.

However, we shall plan not to refurbish or replace the facilities which have been used beyond their service lives, but to continue to utilize these facilities. However, concerning the transmission line route of the 66 kV line between LAM and PSA (part of which support structures have been built in 1987), the section between LAM and "A" will be used for construction of a new 220 kV transmission line, and the section between "A" and PSA will be used by the existing 66 kV transmission line. Although the possibility of utilizing the existing 66 kV transmission line from LAM to "A", in parallel connection with the 220 kV transmission line, has been studied, the power that flows on the 66 kV line in this system configuration will be very small, being 0.2 to 4.7% of the total power flow of "A" Substation, as discussed in Paragraph (4) of 6-2-2 in the preceding Chapter.

Considering the cost incurred for the equipment (GIS for line connection) required for "π"-connecting one circuit of the 66 kV line, such a plan is not economical.

Concerning the existing transmission lines which will become unnecessary by this Project, it shall be our policy not to dismantle the facilities unless they present obstacles, but to preserve them as reserve transmission lines or utilize them as distribution lines.

(2) Meteorological Conditions

The meteorological conditions of the Project Area have been assumed as presented in Table 7-3 based on the data found in documents collected by the Study Team and in reference to the design conditions of the transmission line from Limpio to Puerto Botanico which is currently under construction as Phase-4 transmission line project.

Table 7-3 Meteorological Data (Metropolitan Area)

Item	Period	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.	Min.	Av.
Precipitation Av.	1956/85	mm	154	145	140	166	99	73	49	64	86	124	162	142	166	49	117
Temperature Max.	"	°C	42.0	40.8	40.0	36.7	33.5	32.9	34.0	38.7	39.1	40.3	40.2	41.9	42.0	32.9	38.3
Temperature Min.	"	°C	12.4	14.0	10.0	6.4	2.6	1.4	-0.6	0.0	3.6	7.0	8.8	10.8	14.0	-0.6	6.4
Temperature Av.	1971/80	°C	27.5	27.1	25.9	22.5	19.6	17.9	18.2	18.4	20.6	23.0	24.4	26.4	27.5	17.9	22.6
Humidity Av.	"	%	68	70	72	71	76	75	70	71	66	67	67	68	76	66	70

	Data Collected in This Study	Phase-4 Trans. Project	Adopted Value
Maximum Temperature (°C)	+42.0	+40.0	+40.0
Minimum Temperature (°C)	- 0.6	- 5.0	- 5.0
Average Temperature (°C)	+22.6	+25.0	+25.0
Maximum Wind Velocity (m/s)	33.3	34.0	34.0
IKL (occurrencies/year)	60	60	60

(3) Salt and Dust Pollution

Although there is no measured datum on salt and dust pollution, it can be assumed that there will be practically no pollution considering the distance from sea shore (around 1300 km from the Pacific shore and around 950 km from Atlantic shore), the absence of pollution sources, as well as the number of insulators used in past line designs.

(4) Transmission Line Route Plan

As the transmission routes have not been explored and surveyed by ANDE, the Study Team proposed the recommended routes based on the exploration of the Team members. These routes are presented in Figure 7-2 (in 2000), and the outline of facilities in Table 7-4.

The aggregate lengths of transmission lines which are planned in this Study for construction are 9.5 km of 220 kV double circuit overhead transmission lines, 28 km of additional 220 kV circuit strung on the existing overhead transmission line, 2.0 km of 220 kV underground cable lines, 21 km of 66 kV overhead transmission lines, and 11 km of 66 kV underground cable lines (single circuit).

The water level fluctuation of Rio de Paraguay is presented in Figure 7-3. The height of the foundation crest of transmission line support structures and the cable burial locations must be determined in reference to these data.

Fig.7-2 Planning and Existing Transmission Line Route

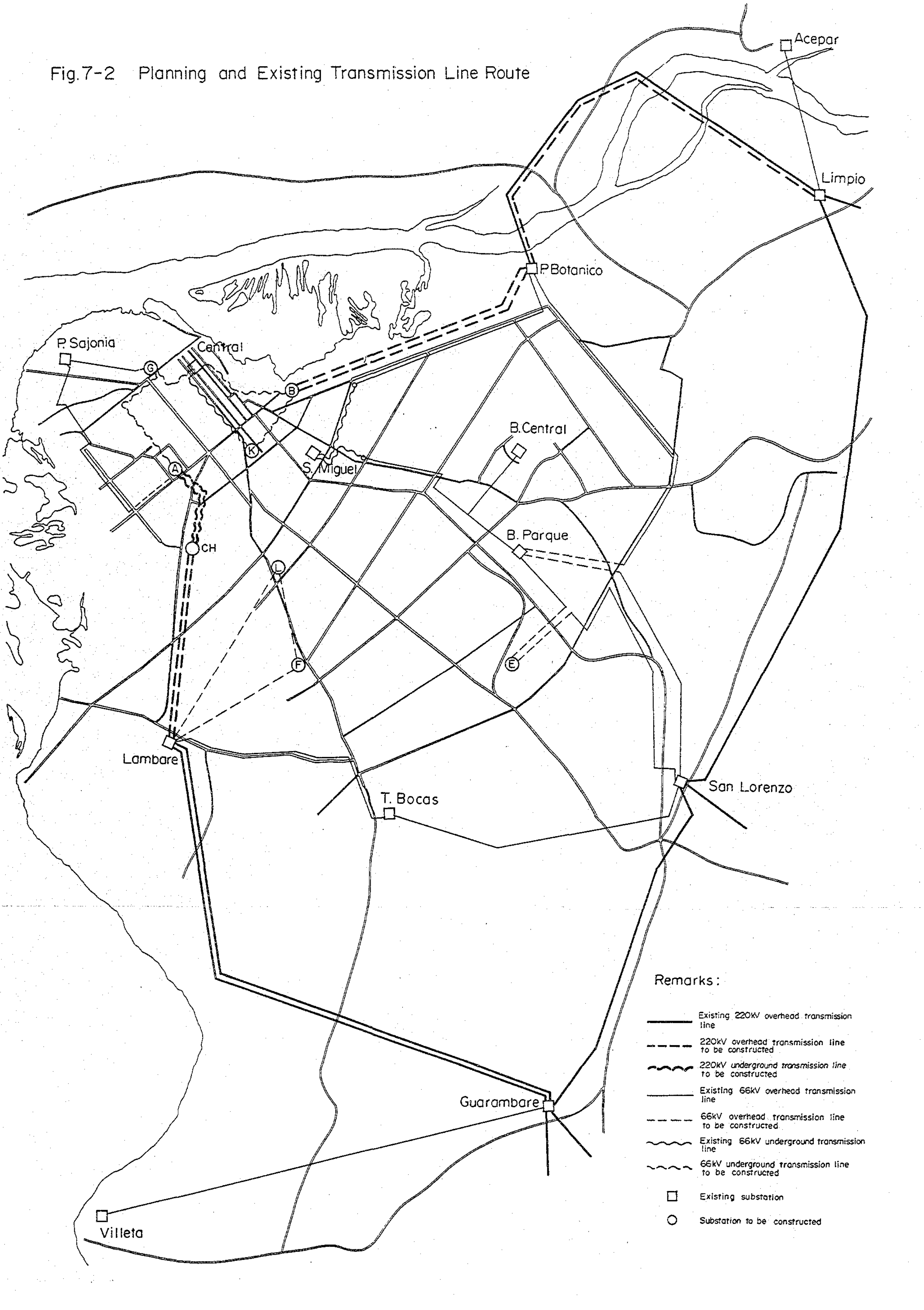


Table 7-4 Outline of the Transmission Lines (1)

Voltage (kV)	Transmission Lines		From - To	Transmission Capacity (MW)	Kind of Conductor	Line Length (km) (Approx.)	Completion
220	1 double cct	OL	Lambare - Cable head	225/cct	950 MCM, ACAR 954 MCM, ACSR	4.0	1994
220	2 single cct	UC	Cable head - A	225/cct	XLPE 800 mm^2	2.0	1994
220	1/2 double cct	OL	Limpio - Puerto Botanico	225/cct	950 MCM, ACAR 954 MCM, ACSR	28.0	1994
220	1 double cct	OL	Puerto Botanico - B	225/cct	950 MCM, ACAR 954 MCM, ACSR	5.5	1994
66	1 single cct	OL	Puerto Sajonia - A	45	300 MCM, ACSR	1.5	1994
66	1 single cct	UC	B - Centro	90	XLPE 800 mm^2	3.5	1994
66	1 single cct	OL	Puerto Botanico - Barrio Parque	45	300 MCM, ACSR	2.5	1996
66	1 single cct	UC	A - G	90	XLPE 800 mm^2	3.0	1996
66	1 single cct	UC	G - Centro	90	XLPE 800 mm^2	1.5	1996
66	1 single cct	OL	Puerto Sajonia - G	45	300 MCM, ACSR	1.0	1996
66	1 single cct	OL	San Lorenzo - Barrio Parque	45	300 MCM, ACSR	2.5	1996
66	1 single cct	OL	Barrio Parque - E	45	300 MCM, ACSR	2.0	1996
66	1 single cct	OL	San Lorenzo - E	45/cct	300 MCM, ACSR	2.0	1996
66	2 single cct	OL	Lambare - L	90/cct	954 MCM, ACSR	4.0 and 5.0	1996

Table 7-4 Outline of the Transmission Lines (2)

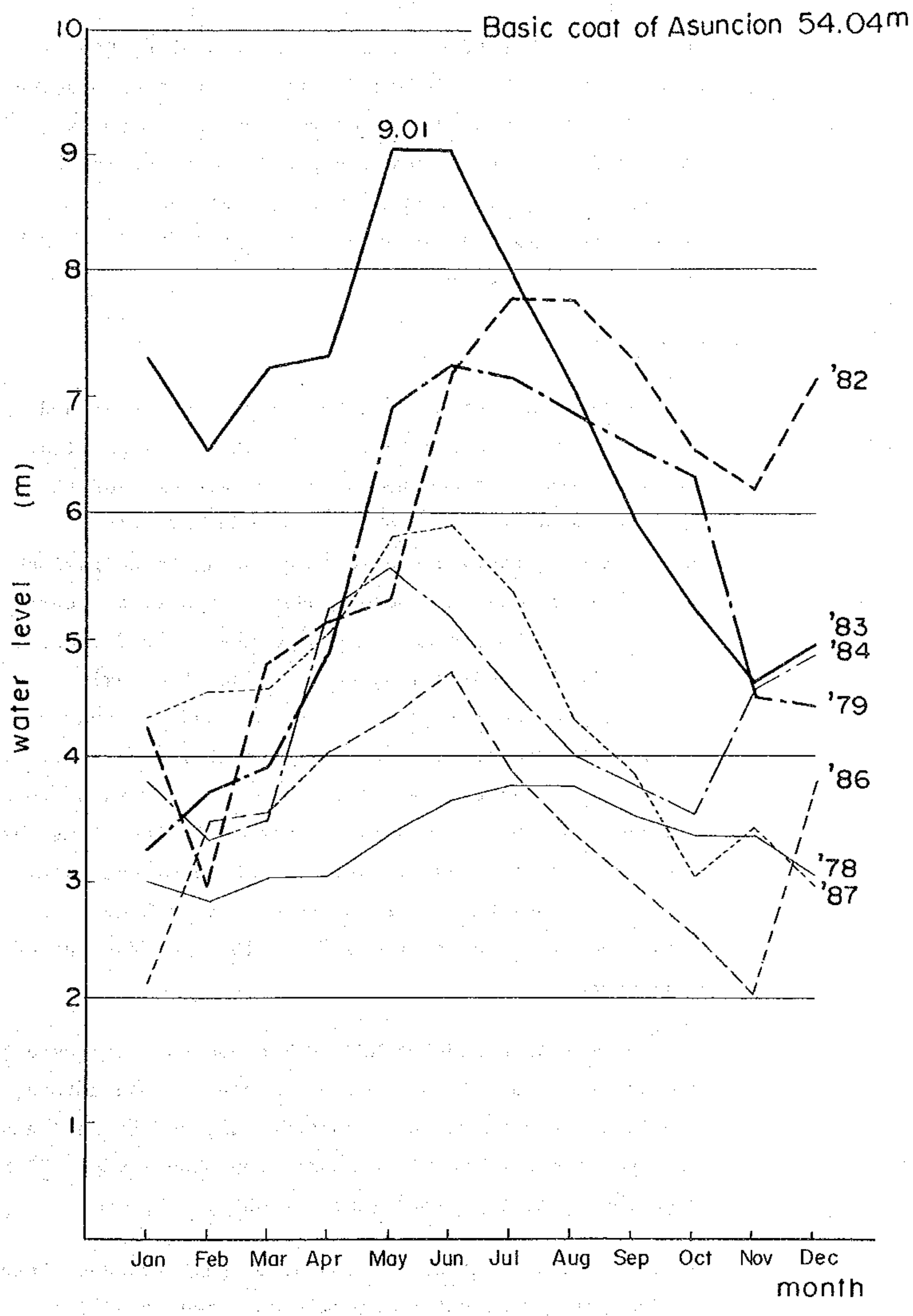
Voltage	Transmission Lines		From - To	Transmission Capacity (MW)	Kind of Conductor	Line Length (km) (Approx.)	Completion
66	1 single cct	UC	B - K	90	XLPE 800 mm^2	2.0	1998
66	1 single cct	UC	K - Centro	54	XLPE 300 mm^2	1.0	1998
66	1 double cct	OL	F - 66 kV Line	90/cct	954 MCM, ACSR	0.5	2000

Legend: UC : Underground transmission line

OL : Overhead transmission line

ACSR : Aluminum Conductor Steel Reinforced

Fig. 7-3 Max. water level - Asuncion



7.1.3 Overhead Transmission Line Plan

(1) 220 kV Overhead Transmission Line

(a) Support Structure

Considering that transmission lines run along Rio de Paraguay and urban streets, it is recommended to select three types of support structure, the steel towers, steel poles and steel pipe poles, appropriately according to the route, loading conditions, etc. The standard designs for these three types of structures are presented in Figure 7-4 through Figure 7-7.

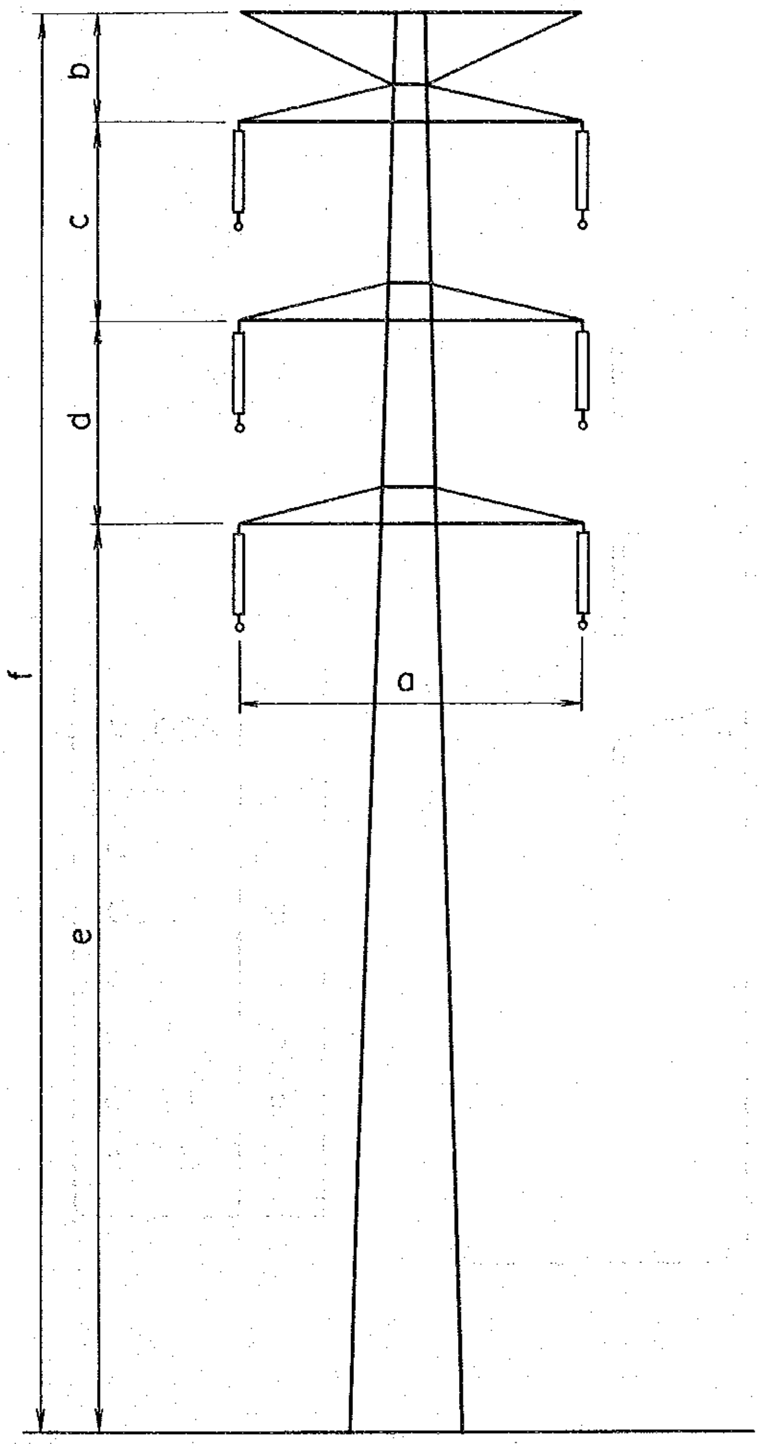
(b) Conductors

The conductors must be selected appropriately according to the transmission capacity requirement, the electrical potential gradient on the conductor surface, and the required mechanical strength. The 950 MCM ACAR and 954 MCM ACSR (Cardinal) are used in existing transmission lines. As we examine these conductor types, the current capacity at 80°C conductor temperature is sufficient for the required transmission capacity, and the maximum electrical potential gradient on the conductor surface is a value that cause no particular problem. Therefore, it is planned to generally use 950 MCM ACAR for this Project, and 954 MCM ACSR (Cardinal) conductors in locations where particularly high tensile strength is required, such as a long span crossing. It is planned to attach dampers and armor rods in order to reduce the vibration fatigue of conductors.

The 950 MCM ACAR and 954 MCM ACSR conductors are used for the transmission lines between Lambare and Guarambare, and Limpio and Puerto Botanico substations, and these lines are operated with normal transmission capacity of 175 MVA with the conductor temperature of 60°C.

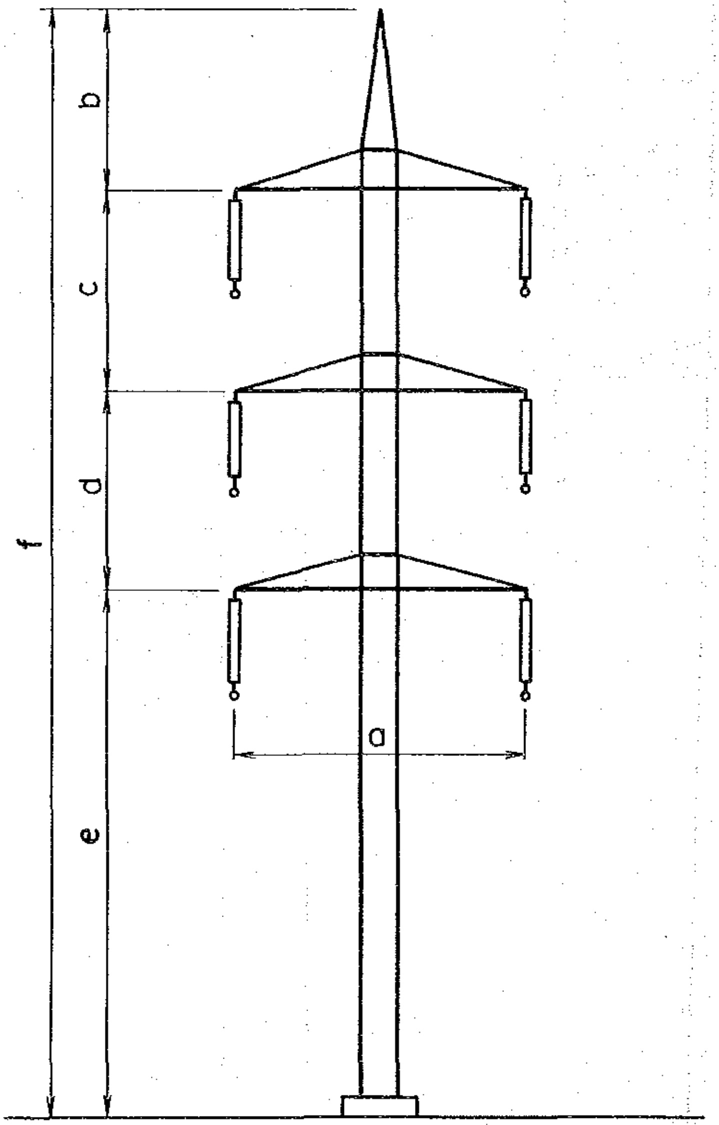
However, as we examine the conductor performance, these conductors can be satisfactorily operated at 80°C tem-

Fig. 7-4 220kV Typical type of suspension tower



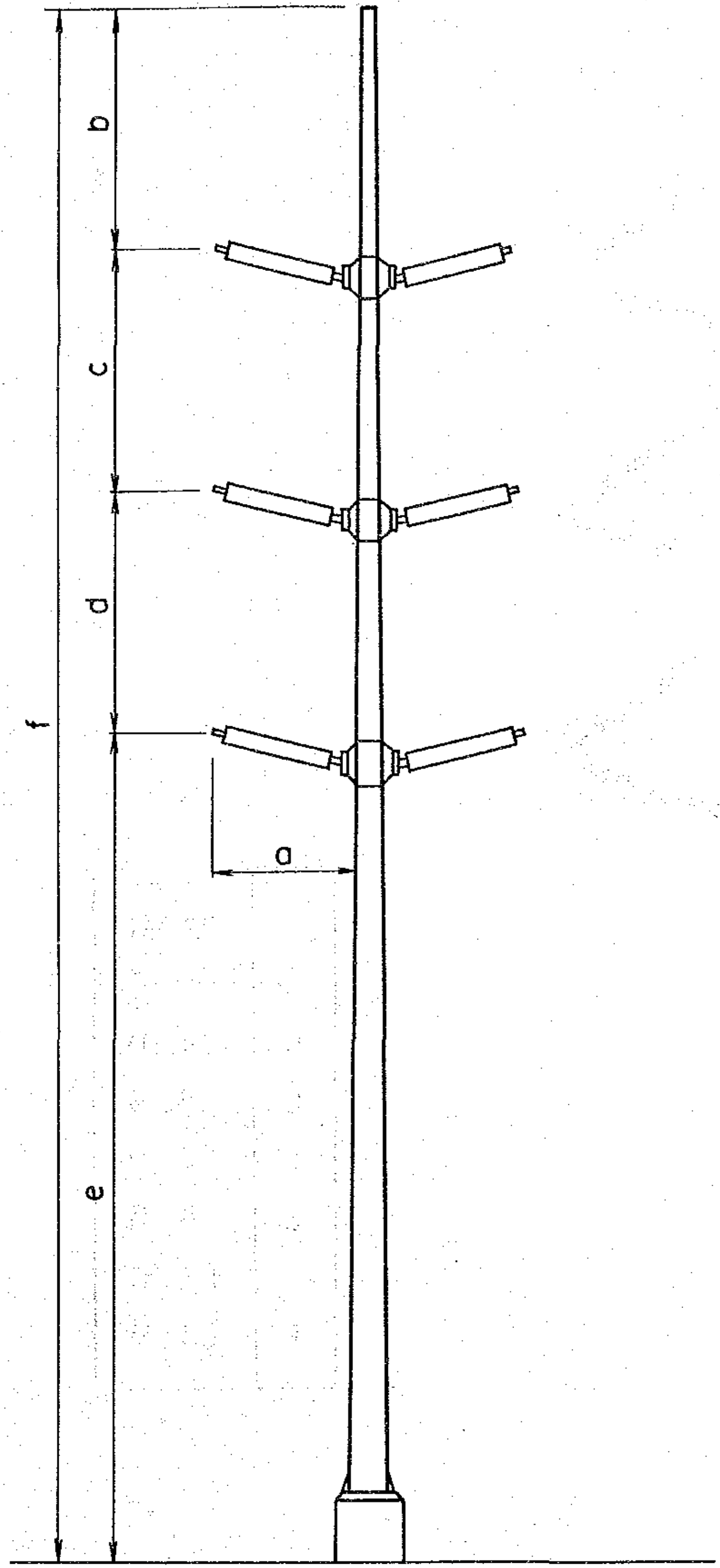
	220 kV
	(m)
a	9.5
b	3.0
c	5.5
d	5.5
e	25.0
f	39.0

Fig.7-5 220kV Typical type of suspension steel mast



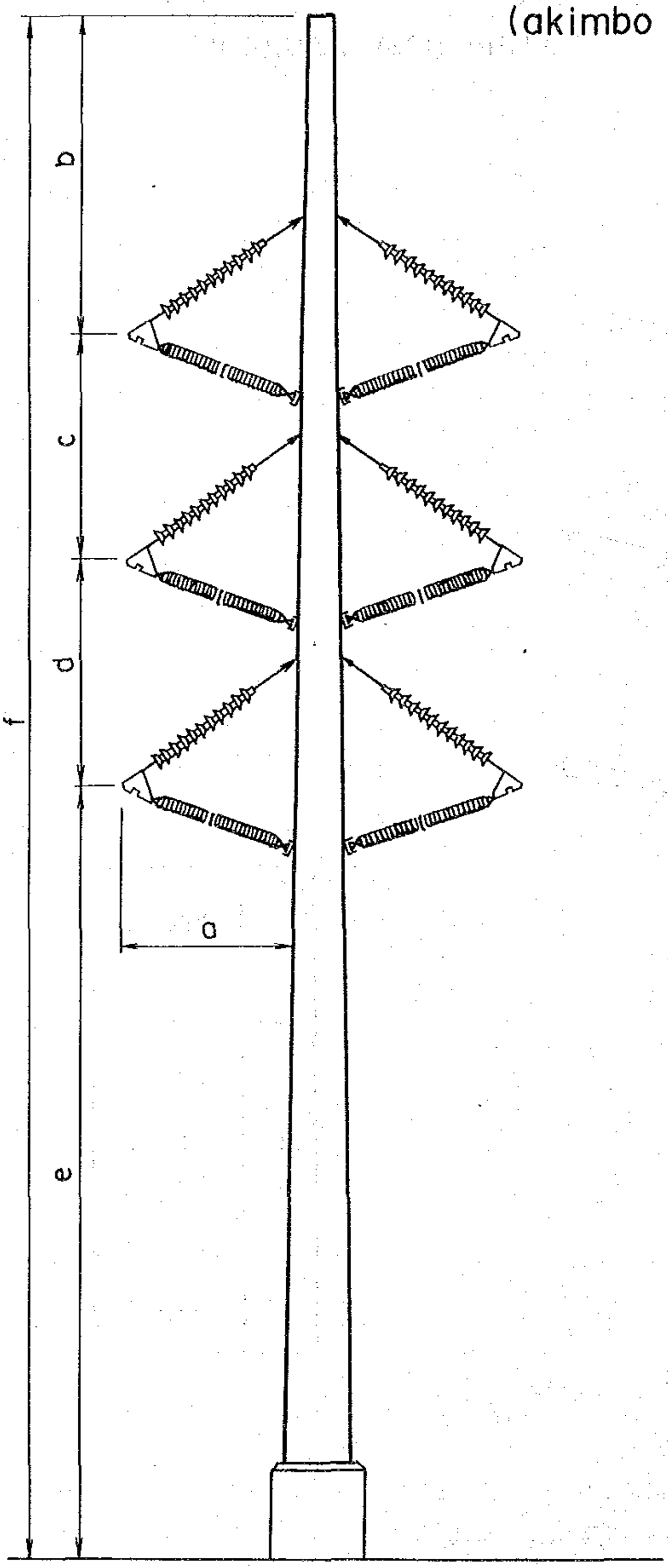
	220kV
	(m)
a	8.0
b	5.0
c	5.5
d	5.5
e	15.5
f	31.5

Fig. 7-6 220kV Typical type of steel pipe tower (line post insulator)



	220kV
	(m)
a	2.0
b	3.5
c	3.5
d	3.5
e	12.0
f	22.3

Fig.7-7 220kV Typical type of steel pipe Tower (akimbo insulator)



	220kV
	(m)
a	2.8
b	4.9
c	3.5
d	3.5
e	12.0
f	23.9

perature. Therefore, the required transmission capacity of 225 MW can be assured by raising the conductor operating temperature from 60°C to 80°C. However, the ground clearance and clearance with other objects in these sections must be checked in raising the conductor operating temperature to 80°C.

(c) Ground Wire

The same ground wire with the existing transmission lines, the 3/8" EHS, shall be used.

(d) Insulator

Suspension insulators, long rod insulators and line post insulators will be used as appropriate according to the support structure type and loading. The material of insulators shall be porcelain or glass.

(2) 66 kV Overhead Transmission Line

(a) Support Structure

The support structure shall be selected from steel pole structure and steel pipe pole structure according to the line route and mechanical loading.

The standard type of supports are presented in Figure 7-8 and Figure 7-9.

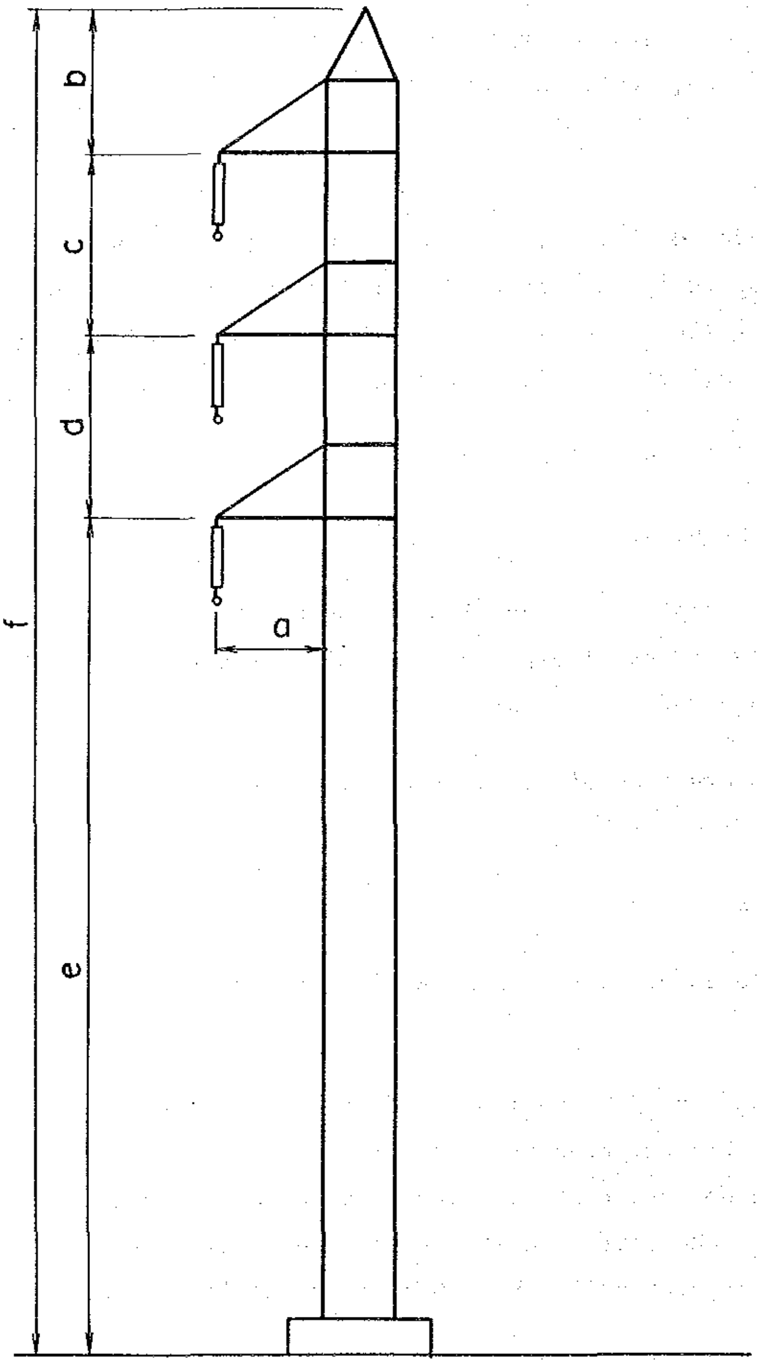
(b) Conductor

The conductors shall be ACSR conductors used in existing lines.

The conductor size shall be determined mainly by the required transmission capacity, electrical potential gradient on conductor surface and required mechanical strength. However, the last two factors will not be of particular problem in this 66 kV transmission Project.

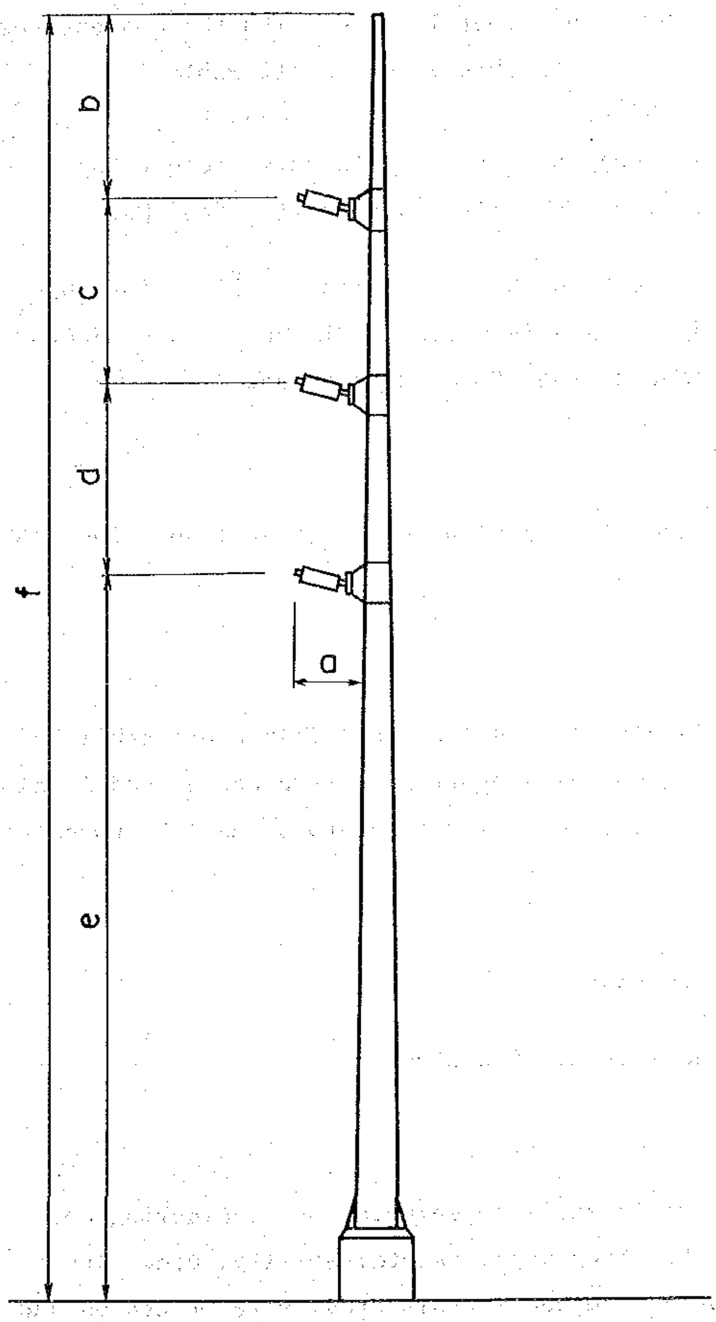
The required transmission capacity of 66 kV overhead transmission lines of this Project is classified in to

Fig. 7-8 66kV Typical type of steel mast



	66 kV
	(m)
a	2. 0
b	2 . 0
c	2 . 5
d	2. 5
e	11 . 5
f	18 . 5

Fig. 7-9 66kV Typical type of steel pipe tower



	66 kV
	(m)
a	0.9
b	2.5
c	2.5
d	2.5
e	10.0
f	17.5

45 MW and 90 MW.

The required transmission capacity of 45 MW is the same with those of existing lines, and the 300 MCM ACSR (Ostrich) is currently used in these lines.

At the transmission capacity of 45 MVA, the conductor temperature reaches approximately 90°C (with the ambient temperature of 40°C). As this value is allowable in reference to the performance of this conductor, the 300 MCM ACSR (Ostrich) shall be used in this Project for the line with required transmission capacity of 45 MW.

The conductor to be used in transmission lines for which the required transmission capacity is 90 MW, a conductor size equivalent to 954 MCM ACSR is selected.

(c) Ground Wire

The same ground wire as with the existing lines, the 3/8" EHS shall be used.

(d) Insulator

Suspension insulators and line post insulators shall be used according to the support structure design and loading conditions. The material of insulators shall be porcelain or glass.

7.1.4 Underground Transmission Line Plan

(1) 220 kV Underground Transmission Lines

(a) Cables

The type of cable shall be selected by considering cost, ease of construction work, maintainability, etc. The types of cable examined in this Study were OF cables and XLPE cables. Considering above factors for cable selection, and the state of recent cable technology in Japan, we selected XLPE cable based on an overall judgment.

The cable conductor size is determined by the required transmission capacity, and it is also affected substantially by the cable burial method to be used. In this Project, the conductor size selected is 800 mm^2 in consideration of the transmission capacity of 225 MVA.

(b) Cable Burying Method

The direct burying method has been selected, because the construction work is easy, the construction cost is low, and the construction period is short with this method.

The standard procedure of cable burying method is illustrated in Figure 7-10.

(2) 66 kV Underground Transmission Lines

(a) Cables

The cable used in this Project shall be the XLPE cable which is currently used by ANDE for 66 kV underground lines.

The conductor size is to be determined by the required transmission capacity, and there will be two classes of transmission capacity, 54 MW and 90 MW. The XLPE 300 mm^2, which is currently used by ANDE for the same transmission capacity, shall be used for the transmission capacity of 54 MW. For 90 MW transmission capacity, the XLPE 800 mm^2 shall be used.

(b) Cable Burying Method

The cables shall be buried directly for reasons which are the same with 220 kV underground lines. The standard burying method is also the same with 220 kV underground lines.

Fig. 7-10 Typical Direct Burying Method