CHAPTER 6. DEMAND AND SUPPLY BALANCE

6-1 Basic Considerations for Demand and Supply Balance

The balance between the electric power load forecast described in Chapter 4 and the existing supply capacity plus the supply capacity already determined to be developed by INECEL and electric power enterprises in the regional systems was investigated and power generation projects which should be added were studied.

The month of maximum demand during the year is December in every one of the regional systems. Therefore, in the study of demand and supply balance, December was taken as the month of maximum demand.

The balance of demand and supply in the regional system was studied based on the following conditions:

i) Until the respective regional systems are connected with the National Interconnected System, studies were made in each regional system individually;

ii) After its interconnection with the National Interconnected System, the respective regional systems were considered as a National Interconnected System in terms of the balance of demand and supply.

The supply capacities of existing power stations were handled as described below. Of the existing power generation facilities of 452.3 MW, those of small capacities less than 0.5 MW are a total of 32.2 MW (8.5% of the whole) and have already become antiquated so that they are to be succeessively retired. Consequently, the existing power generation facilities which can be utilized in the future amount to 358.38 MW (122.10 MW hydro, 236.73 MW thermal), and the installed capacities by regional systems are as indicated in Table 6-1, with the breakdowns given in Appendix -A-2-(9)~(17).

The demand and supply balance of the National Interconnected System, was studied considering the following sequence of interconnections of the regional systems to the National System:

End 1976:

The three systems consisting of the Norte System, the Pichincha System in the Quito District, and the Centro-Norte System are to be interconnected.

August 1978:

Guayas-Los Rios System in the Guayaquil-Duran District, Milagro District, Babahoyo District and Quevedo District, and the Pichincha System in the Santo Domingo District are to be tied with the National Interconnected System.

December 1978:

The Manabi System and the Guayas-Los Rios System in the Santa-Elena District are to be connected to the National Interconnected System.

December 1979:

The Centro-Sur System is to be connected to the National Interconnected System.

December 1980:

The Esmeraldas System, El Oro System and Sur System are to be tied to complete the entire National Interconnected System.

Table 6 - 1 Existing Generating Facilities in Ecuador except for Facilities to be Retired

(Unit ; kW)

System	Hydro	Steam	Diesel	Gas Turbine	Total
Norte	12,354	-	1,409	-	13,763
Pichincha	83,160	-	35,630	-	118,790
Centro-Norte	15,516	-	8,989	-	24,505
Centro-Sur	6,432	-	10,820	-	17,252
Sur	2,400	-	2,406	-	4,806
Esmeraldas	-	-	4,860	-	4,860
Manabi	-	-	23,160	-	23,160
Guayas-Los Rios	-	63,000	24,526	55,500	143,026
El Oro	2,234	-	6,432	-	8,666
Total:	122,096	63,000	118,232	55,500	358,828

6-2 Supply Capabilities of Existing Power Generation Facilities

The power generation facilities installed in Ecuador at present total 452.3 MW in capacity, of which the monthly supply capability of the public electric power companies, municipalities, and electrification cooperatives amounting to 376.2 MW (83.2% of the national total) not including the facilities for private use was studied and their monthly available capacity were investigated.

In general, hydroelectric power plants are influenced by hydrological conditions, and decreases in output are produced in dry months. Especially, all of the existing hydroelectric power plants are run-of-river types, except for those capable of daily regulation numbering only five sites with total output of mere 93.8 MW.

There are no reservoir types among the existing hydroelectric power plants, and without exception, these plants cannot be utilized totally during dry months. The influences of such a situation were studied and the results are indicated in Table 6-2.

Table 6 - 2 Supply Capability by Regional Systems

Regional System	Installed capacity (kW)			Supply capability in dry season (MW)			Supply capability in December (MW)		
	Hydro	Thermal	Total	Hydro	Thermal	Total	Hydro	Thermal	Total
(1) Norte	12,354	1,409	13,763	9.30	1.37	10.67	9.83	1.37	11.20
(2) Pichincha	83,160	35,630	118,790	66.54	34.57	101.11	82.20	34.57	116.77
Quito	83,160	31,475	114,635	66.54	30.54	97.08	82.20	30.54	112.74
Sto. Domingo	-	4,155	4,155	-	4.03	4.03	-	4.03	4.03
(3) Centro-Norte	15,516	8,989	24,505	8.77	8.73	17.50	12.21	8.73	20.94
Latacunga	4,200	1,138	5,338	2.15	1.11	3.26	3.28	1.11	4.39
Ambato	4,128	3,000	7,128	2.09	2.91	5.00	2.09	2.91	5.00
Riobamba	6,438	3,720	10,158	3.95	3.61	7.56	6.16	3.61	9.77
Guaranda	650	775	1,425	0.50	0.75	1.25	0.60	0.75	1.35
Puyo	100	356	456	0.08	0.35	0.43	0.08	0.35	0.43
(4) Centro-Sur	6,432	10,820	17,252	4.91	10.50	15.41	4.91	10.50	15.41
(5) Sur	2,400	2,406	4,806	1.40	2.33	3.73	2.39	2.33	4.72
(6) Esmeraldas	-	4,860	4,860	-	4.71	4.71	-	4.71	4.71
(7) Manabi	-	20,600	20,600	-	19.98	19.98	-	19.98	19.98
(8) Guayas-Los Rios	-	143,026	143,026	-	138.74	138.74	-	138.74	138.74
Guayaquil, Duran	-	126,140	126,140	-	122.36	122.36	-	122.36	122.36
Babahoyo	-	2,240	2,240	-	2.17	2.17	-	2.17	2.17
Quevedo	-	2,766	2,766	-	2.68	2.68	-	2.68	2.68
Milagro	-	6,640	6,640	-	6.44	6.44	-	6.44	6.44
Santa Elena	-	5,240	5,240	-	5.09	5.09	-	5.09	5.09
(9) El Oro	2,234	6,432	8,666	0.81	6.24	7.05	0.81	6.24	7.05
Total:	122,096	236,732	358,828	91.73	227.17	318.90	112.35	227.17	339.52

6-3 Kilowatt and Kilowatt-hour Balances

Studies were made on the demand situations from 1975 to 1984 for the individual regional systems and National Interconnected System. The results of the studies are described below.

(1) Norte System

A shortage in supply capacity of 6.0 MW will be produced in 1977 only with the existing dependable supply capacity of 10.67 MW and the 2.5 MW of diesel which have already been decided to be developed. However, at the above time, interconnection with the Quito District by the Ibarra-Quito 138 kV transmission line should have been completed to make it possible for power to be received from the National Interconnected System so that problems of supply capability shortage will not be produced.

Since reserve supply capacity can be secured at the same time, antiquated small hydro and thermal plants can be repaired, while a part of them can be retired.

(2) Pichincha System

i) Quito District

The Quito District will have the existing supply capacity of 112.74 MW and supply capacity presently under construction of 35.13 MW, totaling 147.87 MW. This supply capacity is sufficient to cope with demand up to 1978, while in and after 1979, there will be no problem since power can be received from the National Interconnected System.

ii) Santo Domingo District

The Santo Domingo District will have a total supply capacity of 7.77 MW within its system consisting of 4.03 MW existing and 3.74 MW new diesel generating facilities and can satisfy demand until 1978. Meanwhile, the district will be incorporated in the National Interconnected System in 1978 so that thereafter there will be no problem about shortages of supply capacity.

(3) Centro Norte System

i) Latacunga District

The Latacunga District presently depends on the First and Second Stages of Illuchi Hydroelectric Power Plant and is greatly affected by river discharge during the dry season with supply capacity dropping from 5.32 MW of installed capacity to 4.39 MW. Therefore, there is already a shortage of supply capacity at present, and even when an additional thermal plant of 0.97 MW already determined is added, the total supply capacity will be 5.36 MW, and a supply capacity deficit of 2.17 MW is expected. On the other hand, in and after 1977, the District will be incorporated in the National Interconnected System so that there will be no shortage in supply capacity but necessary measures have to be taken against the shortage in 1976.

There would be no problem in supply shortage if, as such a measure, the 2.5 MW diesel plant scheduled to be completed in December 1976 already determined could be hastened by one year for completion at the end of 1975, but this will be impossible from the standpoint of the construction period. Meanwhile, the Quito District will have ample surplus capacity in 1976 and it is necessary for one of its compact-type 2.15 MW diesel units to be transferred to Latacunga at an early date.

ii) Ambato District

The Ambato District presently has 7.13 MW of power generating facilities, but supply capability drops to 5.0 MW due to lowering of river discharge during the dry season. Furthermore, even if new diesel facilities of 5.82 MW to be completed in 1975 are added, the toatl supply capacity is 10.82 MW and supply shortages of 0.64 MW and 1.73 MW will be produced in 1975 and 1976 respectively. From the viewpoint of construction period, it is already too late to make installation of a new diesel facility, and here again, it is necessary for one 2.15 MW diesel unit to be transferred from the Quito District, where there is a surplus, in order to meet the demand up to December 1976. On entering 1977, the interconnecting line to Quito and Norte Thermal Power Plant will be completed and the problem of shortage in supply capacity will be eliminated, while in 1978, Pisayambo Hydroelectric Power Plant will come into operation and electric power supply will become stable.

iii) Riobamba District

The existing supply capacity of the Riobamba District is 9.77 MW. However, in 1975 and 1976 there will be shortages in supply capacity of 1.17 MW and 2.86 MW produced respectively, and the most economical measure to cope with this problem will be to transfer two compact-type 2.15 MW diesel units from the Quito District.

There will be no problem in and after 1977 since tie-up with the National Interconnected System will have been made.

iv) Guaranda District

The Guaranda District can cope with electric power demand up to 1977 with its existing facilities and one 1.00 MW diesel scheduled to be completed in 1976. From 1978, Guaranda District will be incorporated in the Regional System of Centro-Norte System through interconnection of 69 kV transmission line so that there will be no problem.

v) Puyo District

In the Puyo District, with a supply capacity of 0.43 MW existing and 0.5 MW of diesel already determined, there will be shortage in supply capacity of 0.1 MW in 1975 and 0.19 MW in 1976, and these shortages are to be coped with by an 0.5 MW diesel thermal plant. From 1977, power will be received from the National Interconnected System through 69 kV line to be connected with Ambato Substation.

(4) Centro-Sur System

This system will not be tied to the National Interconnected System until the end of 1979. Therefore, it will be necessary for power sources to be secured within the system for the next five years. Besides existing facilities of 17.62 MW, there are 2.28 MW of diesel under construction, 8.52 MW of diesel scheduled to be completed in the middle of 1976, and still further, 8.0 MW of Saucay Hydro Power Plant scheduled to be completed in August 1977, and demand up to the end of 1979 can be met.

In and after 1980, power will be received from the National Interconnected System.

(5) Sur System

It will be December 1980 when this system is tied to the National Interconnected System and it will be necessary for power sources to be developed within the system for the next six years.

There is a total of 3.67 MW in diesel thermal plants decided to be added to the existing generating facilities of 4.72 MW, but shortages in supply capacity will be produced over a two-year period in 1979 and 1980. The shortages in those years will be 2.21 MW and 4.39 MW respectively, and it will be necessary to additionaly commission 5.0 MW of diesel with the target time for start-up being December 1978.

(6) Esmeraldas System

The Esmeraldas System can cope with demand up to 1980 with existing power generation facilities of 4.86 MW and 11.46 MW of diesel already determined. Consequently, tie-up with the National Interconnected System may be in December 1980. Until this interconnection the system will have ample reserve capacity.

(7) Manabi System

It will be at the end of 1978 when the Manabi System is tied to the National Interconnected System. Therefore, it will be necessary to meet demand with power plants in the system for the next four years. At present, there is existing capacity of 19.98 MW, while there are 10.0 MW of diesel thermal scheduled to be completed in the middle of 1977 so that demand up to the end of 1979 can be met with these facilities. From 1979, power will be received from the National Interconnected System.

(8) Guayas-Los Rios System

i) Guayaquil, Duran District

The problem in the Guayaquil, Duran District is the balance of supply and demand up to April 1978, when the First Stage, 73 MW, of Guayaquil Thermal Power Plant will be put into service.

The results of studies show that a shortage of approxmiately 3.27 MW will be produced in 1977, one year before the First Stage of Guayaquil Thermal Power Plant is to be commissioned. The reason for this is the delay in start of construction of the First Stage of the Guayaquil Thermal Power Plant and necessary measure should be taken. As the measure, a gas turbine of the same type and the same capacity, 21.5 MW, as the one now being constructed is to be added, by the end of 1976, taking into consideration the short period of construction required for installation of the gas turbine and in order to secure reserve capacity.

The Duran area will be suitable for the site in which this additional gas turbine generator is to be installed. The reason for this is that the shortage of supply to be produced in 1977 will be almost all in the Duran area, and also there will be a shortage in the Milagro District described below, and the Duran area is the most suitable for the site from the aspect also of power interchange between Milagro and Duran Districts by a 69 kV intrasystem interconnecting transmission line.

ii) Milagro District

Since this dirstrict presently has 6.5 MW of diesel facilities, this system does not have shortage in supply capacity. But, shortage of 3.94 MW and 11.79 MW will be produced in 1976 and 1977. The shortage in 1976 can be resolved by power interchange through a 69 kV intrasystem interconnecting transmission line scheduled to be completed in December 1975 since there will be surplus capacity in the Babahoyo District. Regarding the shortage in 1977, the Babahoyo District will no longer have surplus capacity and power is to be received from the previously mentioned 21.5 MW gas turbine to be added in the Duran area.

The reason why such great shortages in supply capacity will be proauced in the two years of 1976 and 1977 is that power demand of drainage pumps will arise from the irrigation and drainage project to be carried out in the District.

iii) Babahoyo District

The Babahoyo District is presently faced with an abnormal shortage of electric power, and as a measure to cope with this situation, construction work is proceeding on 12.5 MW of diesel thermal power plant aiming at start-up in April 1976. Power demand up to the end of 1977 can be met when this is completed. The First Stage of the Project of Guayaquil Thermal will be completed in April 1978 and thereafter power can be received from the National System. At this time Guayaquil-Milagro-Babahoyo-Quevedo will be tied by 69 kV intrasystem interconnecting transmission lines and Guayaquil-Quevedo-Quito by a 230 kV nation-wide interconnecting transmission line so that the District will be quite posssible to receive power from the National Interconnected System.

iv) Quevedo District

The Quevedo District is scheduled to have 0.8 MW and 5.6 MW of diesel plant to be put into service in 1975 and 1976 respectively and shortage in electric power will not be produced up to December 1978. This District will be tied to the National Interconnected System by a 230 kV line between Quito and Pascuales in December 1978 and demand can be met by receiving power from the National System from 1979.

v) Santa Elena District

The Santa Elena District can cope with demand until 1977 with diesel plant in the District, but a shortage in supply capacity of 0.64 MW will be produced in 1978. To improve this situation it is necessary to transfer a 2.18 MW diesel generator from the Quito District, whiel in and after 1979, a 138 kV interconnecting transmission line between Pascuales and Santa Elena is to be completed by December 1978 to receive power from Guayaquil Thermal Power Plant.

(9) El Oro System

This system will be capable of meeting power demand with power plants in the system until 1980. Since this system will become tied to the National Interconnected System in December 1980, in 1981 and thereafter, power can be received from the National System.

The National Interconnecting Power Transmission and Transforming Program will begin to be carried out in December 1976 and will be completed in December 1980. The condition of demand and supply balance by year of the National Interconnected System will be explained below.

1) 1977 The three regional systems of Norte, Pichincha and Centro-Norte among systems in the north will become interconnected during this year. Against power demand of 175.20 MW in 1977 in these interconnected systems there will be a supply capacity of 219.96 MW and the demand can be adequately met. Meanwhile, as a new power source, Norte Thermal Power Plant, 30 MW, will be commissioned in 1977 and will be in a position to transmit power mainly to the two systems of Norte and Centro-Norte. As a result, it appears that the interconnected systems will have a reserve capacity of 44.76 MW, or approximately 25%, but since small-scale hydroelectric power plants and antiquated thermal power plants requiring repairs at an early date are included, the actual reserve capacity which can be secured will be 15%.

2) 1978 The Guayas-Los Rios System will be tied to the National System during the year and the power demand of the interconnected systems will be increased to 442.63 MW. As for the supply capacity to meet this demand, Pisayambo Hydroelectric Power Plant, 69.2 MW, and Guayaquil Thermal Power Plant in the First Stage, 73 MW, will start operation and the supply capacity of the National Interconnected System at this time will become a total of 580.35 MW. As a result, the reserve capacity will become 137.72 MW (31.1 %) corresponding to the first year of operation of a total of 142.2 MW in power generation projects developed destined for the National System and so reserve capacity will be successively decreased in the following years.

The structure of the supply capability of this year shows that there will be 101.1 MW of gas turbine facilities, all of which can be considered as reserve capacity.

3) 1979 The Manabi System and the Santa Elena District of the Guayas-Los Rios System will become tied to the National Interconnected System in this year and power demand will reach 535.41 MW. On the other hand, Guayaquil Thermal Power Plant in the Second Stage, 73 MW, will be put into service resulting that the total installed capacity will be 692.33 MW.

4) 1980 The Centro-Sur System will be incorporated in the National Interconnected System in this year. As a result, the maximum demand will reach 638.06 MW. On the other hand, the effective supply capacity will be 726.21 MW, and the reserve capacity will be an 88.15 MW (13.8%). Paute Hydro, First Stage, 200 MW, will be commissioned in January of 1981, therefore, there will be no problem in reserve capacity.

5) 1981 The three systems, consisting of the Sur System, the Esmeraldas System and the El Oro System, will incorporated in the National Interconnected System in this year and the entire National Interconnected System will have been completed. With this completion the maximum demand will reach 755.14 MW whereas Paute Hydroelectric Power Plant in the First Stage, 200 MW (No. 1 and 2 units) will be started up as new supply capacity and the reserve capacity will become 218.50 MW (28.9%). In case only the No.1 unit of the Paute First Stage were to be commissioned this year, the reserve capacity would be 118.50 MW (15.7%) and it may be said that start-up of the No.2 unit could be delayed about one year. However, it will be necessary for the No.2 unit to be put into service by January 1982.

6) 1982 The power demand of the National Interconnected System will become 834.45 MW in this year. On the other hand, the No.3 unit, 100 MW, of the Paute First Stage will come into service in August of the same year and supply capacity will become 1,073.64 MW. The reserve capacity will thus become 239.19 MW (28.7 %).

7) 1983 The power demand in this year will reach 922.12 MW whereas the supply capacity will become 1,173.64 MW through commissioning of the No.4 unit of the Paute First Stage in August of the same year. Consequently, the reserve capacity will be 251.52 MW (27.3%).

8) 1984 The power demand in this year will reach 1,018.69 MW while the supply capacity will become 1,273.64 MW through commissioning of the No.5 unit of the Paute First Stage in August of the same year. Therefore, the reserve capacity will be 254.95 MW (25.0%). The power demand in August of the same year will be 986.5 MW while the supply capacity will be 1,173.64 MW, the same as in the previous year, so that the reserve capacity at the end of July will be 187.14 MW (19.0%).

The demand and supply balances in the respective years described above are indicated in Tables 6-3 to 6-5.

Table 6 - 3 Demand and Supply Balance before Interconnection with National Interconnected System (Firm kW) (1-3)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(1) Norte										
Supply capacity	11.20	11.20	–	–	–	–	–	–	–	–
Demand	8.16	9.13	–	–	–	–	–	–	–	–
kW-balance	3.04	2.07	–	–	–	–	–	–	–	–
(2) Pichincha										
Quito										
Supply capacity										
Existing	104.30	104.30	–	–	–	–	–	–	–	–
"	2.11 1/	2.11	–	–	–	–	–	–	–	–
"	2.11 2/	2.11	–	–	–	–	–	–	–	–
"	2.11 3/	2.11	–	–	–	–	–	–	–	–
"	2.11 3/	2.11	–	–	–	–	–	–	–	–
New facilities	35.13	35.13	–	–	–	–	–	–	–	–
Total	147.87	139.43	–	–	–	–	–	–	–	–
Demand	94.94	105.05	–	–	–	–	–	–	–	–
kW-balance	52.93	34.38	–	–	–	–	–	–	–	–
Santo Domingo										
Supply capacity	4.03	7.77	7.77	–	–	–	–	–	–	–
Demand	2.92	3.73	4.64	–	–	–	–	–	–	–
kW-balance	1.11	4.04	3.13							
(3) Centro-Norte										
Latacunga										
Supply capacity										
Existing	4.39	4.39	–	–	–	–	–	–	–	–
New facility	0.97	0.97	–	–	–	–	–	–	–	–
Transfer (from Quito)	–	2.11	–	–	–	–	–	–	–	–
Total	5.36	7.47	–	–	–	–	–	–	–	–
Demand	6.85	7.53	–	–	–	–	–	–	–	–
kW-balance	-1.49	-0.06	–	–	–	–	–	–	–	–
Ambato										
Supply capacity										
Existing	5.00	5.00	–	–	–	–	–	–	–	–
New facility	5.82	5.82	–	–	–	–	–	–	–	–
Transfer (from Quito)	–	2.11	–	–	–	–	–	–	–	–
Total	10.82	12.93	–	–	–	–	–	–	–	–
Demand	11.46	12.55	–	–	–	–	–	–	–	–
kW-balance	-0.64	0.38	–	–	–	–	–	–	–	–
Riobamba										
Supply capacity										
Existing	9.77	9.77	–	–	–	–	–	–	–	–
Transfer (from Quito)	–	4.22	–	–	–	–	–	–	–	–

Note : 1/ Transfer to Latacunga
2/ " Ambato
3/ " Riobamba

Table 6 - 3 Demand and Supply Balance before Interconnection with National Interconnected System (Firm kW) (2-3)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Total	9.77	13.99	—	—	—	—	—	—	—	—
Demand	10.94	12.63	—	—	—	—	—	—	—	—
kW-balance	-1.17	1.36	—	—	—	—	—	—	—	—
Guaranda										
Supply capacity	1.35	2.32	—	—	—	—	—	—	—	—
Demand	1.38	1.66	—	—	—	—	—	—	—	—
kW-balance	-0.03	0.66	—	—	—	—	—	—	—	—
Puyo										
Supply capacity										
Existing	0.43	0.43	0.43	—	—	—	—	—	—	—
New facility	—	0.49	0.49	—	—	—	—	—	—	—
Transfer	—	0.29 1/	0.29	—	—	—	—	—	—	—
Total	0.43	1.21	1.21	—	—	—	—	—	—	—
Demand	0.53	1.11	1.21	—	—	—	—	—	—	—
kW-balance	-0.10	0.10	0	—	—	—	—	—	—	—
(4) Centro-Sur										
Supply capacity	17.62	25.88	33.88	33.88	33.88	—	—	—	—	—
Demand	14.11	16.01	24.01	27.57	31.21	—	—	—	—	—
kW-balance	3.51	9.87	9.87	6.31	2.67	—	—	—	—	—
(5) Sur										
Supply capacity										
Existing	4.72	4.72	4.72	4.72	4.72	4.72	—	—	—	—
New facility	1.24	1.24	1.24	1.24	1.24	1.24	—	—	—	—
"	—	2.43	2.43	2.43	2.43	2.43	—	—	—	—
" (Proposed facility)	—	—	—	—	4.85	4.85	—	—	—	—
Total	5.96	8.39	8.39	8.39	13.24	13.24	—	—	—	—
Demand	5.50	6.42	7.23	8.33	10.60	12.78	—	—	—	—
KW-balance	0.46	1.97	1.16	0.06	2.64	0.46	—	—	—	—
(6) Esmeraldas										
Supply capacity	10.01	15.83	15.83	15.83	15.83	15.83	—	—	—	—
Demand	5.56	6.49	7.59	9.06	10.64	14.27	—	—	—	—
kW-balance	4.45	9.34	8.24	6.77	5.19	1.56	—	—	—	—
(7) Manabi										
Supply capacity	19.98	19.98	29.68	29.68	—	—	—	—	—	—
Demand	13.74	17.33	20.96	23.72	—	—	—	—	—	—
kW-balance	6.24	2.65	8.72	5.96	—	—	—	—	—	—

Note : 1/ Transfer from other system

Table 6 - 3 Demand and Supply Balance before Interconnection with National Interconnected System (Firm kW) (3-3)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(8) Guayas-Los Rios										
Guayaqui, Duran										
Supply capacity										
Existing	122.36	122.36	122.36	–	–	–	–	–	–	–
New facility	20.86	20.86	20.86	–	–	–	–	–	–	–
"	–	20.86	20.86	–	–	–	–	–	–	–
" (Proposed facility)	–	–	20.86	–	–	–	–	–	–	–
	–	–	1/-7.85	–	–	–	–	–	–	–
Total	143.22	164.08	177.09	–	–	–	–	–	–	–
Demand	135.87	150.70	167.35	–	–	–	–	–	–	–
kW-balance	7.35	13.38	9.74	–						
Babahoyo										
Supply capacity										
Existing	2.17	2.17	2.17	–	–	–	–	–	–	–
New facility	–	12.13	12.13	–	–	–	–	–	–	–
"	–	–	0.97	–	–	–	–	–	–	–
	–	2/ -3.94	2/ -3.94	–	–	–	–	–	–	–
Total	2.17	10.36	11.33	–	–	–	–	–	–	–
Demand	5.97	8.72	10.06	–	–	–	–	–	–	–
kW-balance	-3.80	1.64	1.27	–						
*Milagro										
Supply capacity										
Existing	6.44	6.44	6.44	–	–	–	–	–	–	–
	–	3/ 3.94	4/ 11.79	–	–	–	–	–	–	–
Total	6.44	10.38	18.23	–	–	–	–	–	–	–
Demand	5.52	10.38	18.23	–	–	–	–	–	–	–
kW-balance	0.92	0	0	–	–	–	–	–	–	–
Quevedo										
Supply capacity	3.46	8.95	8.94	–	–	–	–	–	–	–
Demand	3.88	5.87	7.07	–	–	–	–	–	–	–
kW-balance	-0.42	3.08	1.88	–	–	–	–	–	–	–
Santa Elena										
Supply capacity										
Existing	5.09	5.09	5.09	5.09	–	–	–	–	–	–
New facility	5.51	5.51	5.51	5.51	–	–	–	–	–	–
Transfer (from Quito)	–	–	2.11	2.11	–	–	–	–	–	–
Total	10.60	10.60	12.71	12.71	–	–	–	–	–	–
Demand	7.02	9.24	9.82	11.24	–	–	–	–	–	–
kW-balance	3.58	1.36	2.89	1.47	–					
(9) El Oro										
Supply capacity	12.54	12.54	18.36	18.36	18.36	18.36	–	–	–	–
Demand	8.43	10.56	12.71	14.56	16.10	17.80	–	–	–	–
kW-balance	4.11	1.98	5.65	3.80	2.26	0.56	–	–	–	–

Note: 1/, 2/ Supply to Milagro
3/ Received from Babahoya
4/ Received from Babahoya and Guayaquil
* Included to National Interconnected System

Table 6 - 4 Demand and Supply Balance after Interconnection with National Interconnected System

Unit : MW

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
A. Demand											
(1) Norte	7.34	–	–	19.68	21.38	23.00	24.84	26.58	28.51	30.65	33.01
(2) Pichincha	89.24	–	–	117.08	135.60	151.41	169.35	189.27	211.32	235.71	262.67
Quito	86.92	–	–	117.08	129.77	144.27	160.55	178.60	198.28	220.49	245.46
Santo Domingo	2.32	–	–	–	5.83	7.14	8.80	10.67	13.04	15.22	17.21
(3) Centro-Norte	26.95	–	–	38.44	49.92	55.31	62.15	68.25	75.47	83.09	91.69
Latacunga & other cities	26.47	–	–	38.44	48.60	53.87	60.58	66.53	73.59	81.02	89.42
Puyo	0.48	–	–	–	1.32	1.44	1.57	1.72	1.88	2.07	2.27
(4) Centro-Sur	12.57	–	–	–	–	–	38.56	42.04	45.96	50.45	55.54
(5) Sur	4.41	–	–	–	–	–	–	14.92	17.51	19.97	22.55
(6) Esmeraldas	4.64	–	–	–	–	–	–	16.81	19.54	22.19	26.23
(7) Manabi	11.66	–	–	–	–	26.80	30.74	34.79	38.14	42.22	46.59
(8) Guayas-Los Rios	135.97	–	–	–	235.73	278.89	312.42	342.64	375.88	413.22	453.01
Guayaquil & other cities	130.45	–	–	–	235.73	263.14	294.19	323.21	355.32	390.50	429.04
Santa Elena	5.52	–	–	–	–	15.75	18.23	19.43	20.56	22.72	23.97
(9) El Oro	6.98	–	–	–	–	–	–	19.84	22.12	24.62	27.40
Total	299.76	–	–	175.20	442.63	535.41	638.06	755.14	834.45	922.12	1,018.69
B. Supply capability	539.52	–	–	219.96	580.35	692.33	726.21	973.64	1,073.64	1,173.64	1,273.64
C. Supply reserve (B - A)	–	–	–	44.76	137.72	156.92	88.15	218.50	239.19	251.52	254.95
D. Reserve ratio (C/A) (%)	–	–	–	25.5	31.1	29.3	13.8	28.9	28.7	27.3	25.0

Table 6 - 5 Demand and Supply Balance in kWh

Unit : GWh

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
A. Demand											
(1) Norte	23.65	–	–	101.68	107.51	112.48	118.13	123.67	129.77	136.63	144.31
(2) Pichincha	402.51	–	–	532.17	614.79	684.14	762.32	849.92	946.24	1,052.66	1,168.71
Quito	392.15	–	–	532.17	590.80	655.38	727.62	808.79	897.14	996.73	1,106.89
Santo Domingo	10.36	–	–	–	23.99	28.76	34.70	41.13	49.10	55.93	61.82
(3) Centro-Norte	98.73	–	–	147.54	202.34	222.26	248.77	271.89	299.68	327.96	359.61
Latacunga & other cities	97.16	–	–	147.54	198.03	217.55	243.62	266.25	293.51	321.19	352.18
Puyo	1.57	–	–	–	4.31	4.71	5.15	5.64	6.17	6.77	7.43
(4) Centro-Sur	47.87	–	–	–	–	–	143.83	157.07	172.13	189.20	208.37
(5) Sur	14.04	–	–	–	–	–	–	52.30	62.12	72.10	82.71
(6) Esmeraldas	15.28	–	–	–	–	–	–	76.41	87.27	98.99	118.09
(7) Manabi	43.69	–	–	–	–	110.00	128.75	143.47	158.89	175.27	192.84
(8) Guayas-Los Rios	579.48	–	–	–	1,030.61	1,213.97	1,358.06	1,491.68	1,640.09	1,806.24	1,988.39
Guayaquil & other cities	563.15	–	–	–	1,030.61	1,146.06	1,278.18	1,406.55	1,549.73	1,706.24	1,882.18
Santa Elena	16.33	–	–	–	–	67.91	79.88	85.13	90.36	100.00	106.21
(9) El Oro	22.39	–	–	–	–	–	–	71.32	80.76	91.37	103.34
Total	1,247.64	–	–	781.39	1,955.25	2,342.85	2,759.86	3,237.73	3,576.95	3,950.42	4,366.37
B. Supply capability	–	–	–	1,551.26	4,317.96	5,298.84	5,579.97	7,738.21	7,738.21	8,470.21	8,836.21
Hydro	–	–	–	572.69	766.00	766.00	863.42	2,634.21	3,000.21	3,366.21	3,732.21
Thermal	–	–	–	978.57	3,551.96	4,532.84	4,716.55	5,104.00	5,104.00	5,104.00	5,104.00

CHAPTER 7

EVALUATION OF LONG-RANGE ELECTRIC POWER DEVELOPMENT PROGRAM

CHAPTER 7. EVALUATION OF LONG-RANGE ELECTRIC POWER DEVELOPMENT PROGRAM

7-1 Evaluations of Paute Hydro and National Interconnecting Power Transmission and Transforming Program

In formulation of a long-range electric power development program, an evaluation or a study must be made of whether or not the scheme planned is advantageous in comparison with other alternatives. It is considered that the present Long-Range Electric Power Development Program should be evaluated from the first point of view, but as stated previously, since the Long-Range Electric Power Development Program is going ahead based on the existing long-range program, the present long-range program was compared with the alternative described below.

7-1-1 The Alternative Considered

The composition of the alternative for comparison with Paute Hydro and the National Interconnecting Power Transmission and Transforming Program would be as follows:

i) National interconnecting power transmission and transforming facilities will not be constructed.

ii) Paute Hydro Power Plant will not be constructed.

iii) Norte Thermal, Pisayambo Hydro and Guayaquil Thermal Power Plant will be started up at the times stated in Chapter 5.

iv) A 50 MW unit heavy oil-burning thermal power plant is to be newly built at Santo Domingo as the power source for the Pinchincha System centered around Quito, the Norte System, and the Centro-Norte System with units of the same capacity additionally installed as demand increases.

v) A 75 MW unit heavy oil-burning thermal power plant is to be newly built at Guayaquil as the power source of the Guayas-Los Rios System centered around Guayaquil (excluding the Santa Elena District) with unit of the same capacity of 75 MW additionally installed in accordance with increases in demand.

7-1-2 Method of Comparison

As the method of comparison, the case of constructing Paute Hydroelectric Power Station and national interconnection power transmission and transforming facilities for supply of power and the case of constructing heavy oil-burning thermal power plants as alternative facilities at Santo Domingo and Guayaquil as stated above were taken up for the comparison of annual costs.

The conditions for comparison were the following:

i) The installed capacity of the heavy oil-burning thermal stations is to be 625 MW to be comparable with the 500 MW output of Paute Hydro taking into consideration reserve capacity.

ii) The construction cost and annual cost of Paute Hydro are to be given in Chapter 8.

iii) The construction costs and annual costs of the heavy oil-burning thermal plants as alternative facilities are to be as indicated in Tables 7-1 and 7-2.

iv) The construction cost and annual cost of national interconnecting power transmission and transforming facilities are to be given in Chapter 8.

v) The annual costs are to be calculated for a 25 year period from 1980 when the heavy oil-burning thermal plant at Guayaquil starts operation, and in order to make comparisons considering the time-lags in construction between the original plans and the alternative, they are to be converted to 1980 values.

7-1-3 Results of Comparison

The annual costs of the original plan and the alternative are as follows:

Original plan:

Supply of electric power by Paute Hydro and national interconnecting power transmission and transforming facilities

US $ 439.5 x 10^6

Alternative:

Supply of electric power by alternative heavy oil-burning thermal facilities

US $ 585.7 x 10^6

As a result of comparison of the above, the plan to supply electric power constructing Paute Hydro and national interconnecting power transmission and transforming facilities, in effect, the plan proposed in this Report, is economically superior to the alternative in which national interconnecting power transmission and transforming facilities are not built, with the difference of US $ 146.2 x 10^6 in the costs over a 25 year period.

The energy production and other calculation data are as indicated in Tables 7-1 to 7-5.

Table 7 - 1 Construction Cost and Annual Cost of Oil-burning Thermal Plants in Sistema Norte, Pichincha and Centro-Norte

N	Year	Requirement Power (MW)	Requirement Energy (GWh)	Installed Capacity (MW)	Annual Cost Fixed (10^3US$)	Annual Cost Variable (10^3US$)	Present Factor (i=10%)	Present Value in 1980 (10^3US$)
1	1980	-	-	-	-	-	0.909	-
2	1981	-	-	-	-	-	0.826	-
3	1982	18.0	21.3	50	7.445	266	0.751	5,791
4	1983	52.1	162.9	100	12,470	2,036	0.683	9,906
5	1984	90.7	318.2	100	12,470	3,978	0.620	10,198
6	1985	128.8	485.5	150	17.495	6,069	0.564	13,290
7	1986	171.5	669.4	200	22,520	8,368	0.513	15,846
8	1987	218.3	871.8	250	27,545	10,898	0.466	17,914
9	1988	218.3	871.8	250	27,545	10,898	0.424	16,300
10	1989	218.3	871.8	250	27,545	10,898	0.385	14,800
:	:	ditto	ditto	ditto	ditto	ditto	38,443 x 7.606 x 0.385	
24	2003	218.3	871.8	250	27,545]	10,898		= 112,573
25	2004	218.3	871.8	250	27,545	10,898		
Total		-	-	-				216,618

Unit construction cost per kw : US$670/kW
Fuel consumption per kWh : 263 gr/kWh
Fuel price of heavy oil C : US$47.4/ton
Variable cost per kWh : 12.5 mills/kWh
Fixed cost ratio : 15%
Transmission line and transforming facilities
Annual cost ratio : 13.3%
Construction cost (Sto. Domingo - Sta. Rosa) : 18,200 x 10^3US$
Annual cost : 2,420 x 10^3US$

Table 7 - 2 Construction Cost and Annual Cost of Oil-burning Thermal Plants in Sistemas de Guayas - Los Rios without Santa Elena

N	Year	Requirement Power (MW)	Requirement Energy (GWh)	Installed Capacity (MW)	Annual Cost Fixed (10^3US$)	Annual Cost Variable (10^3US$)	Present Factor (i=10%)	Present Value in 1980 (10^3US$)
1	1980	18.0	68.4	75	5,963	807	0.909	5,509
2	1981	47.0	196.8	75	5,963	2,322	0.826	6,843
3	1982	79.1	339.9	150	11,926	4,010	0.751	11,968
4	1983	114.3	496.4	150	11,926	5,856	0.683	12,145
5	1984	152.8	672.4	225	17,889	7,934	0.620	16,010
6	1985	195.7	860.6	225	17,889	10,155	0.564	15,817
7	1986	242.9	1,067.7	300	23,852	12,599	0.513	18,699
8	1987	294.8	1,295.4	375	29,815	15,286	0.466	21,017
9	1988	294.8	1,295.4	375	29,815	15,286	0.424	19,123
10	1989	294.8	1,295.4	375	29,815	15,286	0.385	17,364
		ditto	ditto	ditto	ditto	ditto	45,101 x 7.606 x 0.385	
24	2003	294.8	1,295.4	375	29,815	15,286		= 132,070
25	2004	294.8	1,295.4	375	29,815	15,286		
Total								329,040

Unit construction cost per kW: US$530/kW
Fuel consumption per kWh : 248 gr/kWh
Fuel price of heavy oil C : US$47.4/ton
Variable cost per kWh : 11.8 mills/kWh
Fixed cost ratio : 15%

Table 7 - 3 Interconnected Power System with Paute Power Plant

N	Year	Requirement Power (MW)	Requirement Energy (GWh)	Installed Capacity (MW)	Annual Cost Paute P.P. (10^3US$)	Annual Cost Trans. line (10^3US$)	Present Factor (i=10%)	Present Value in 1980 (10^3US$)
1	1980	-	-	-	-	-	0.909	-
2	1981	33.8	87.9	100	30,528	15,335	0.826	37,883
3	1982	97.1	361.2	100	30,528	15,335	0.751	34,443
4	1983	166.4	659.3	200	33,432	15,335	0.683	33,308
5	1984	242.9	990.6	300	36,336	15,335	0.620	32,036
6	1985	324.5	1,346.1	400	39,240	15,335	0.564	30,780
7	1986	414.4	1,737.1	500	42,144	15,335	0.513	29,487
8	1987	513.1	2,167.2	500	42,144	15,335	0.466	26,785
9	1988	513.1	2,167.2	500	42,144	15,335	0.424	24,371
10	1989	513.1	2,167.2	500	42,144	15,335	0.385	22,129
⋮	⋮	ditto	ditto	ditto	ditto	ditto	57,449 x 7,606 x 0.385	
24	2003	513.1	2,167.2	500	42,144	15,335		= 168,228
25	2004	513.1	2,167.2	500	42,144	15,335		
	⋮	ditto	ditto	ditto	ditto	ditto		
49	2028	513.1	2,167.2	500	42,144	15,335	-	-
50	2029	513.1	2,167.2	500	42,144	15,335	-	-
Total		–	–	–	–	–		439,450

Table 7 - 4

Discount rate (i) :	10.0%
Paute Hydro Power Station	
Annual cost ratio :	12.1%
Transmission line and transforming facilities	
Annual cost ratio :	13.3%

(1) Annual cost of Paute Hydro Power Station

Installed capacity	Annual cost
100 MW	30,528 x 10^3US$
200 MW	33,432 x 10^3US$
300 MW	36,336 x 10^3US$
400 MW	39,240 x 10^3US$
500 MW	42,144 x 10^3US$

(2) Transmission line and transforming facilities

Section	Construction cost (10^3US$)	Annual cost (10^3US$)
Paute - Pasucuales	60,600	8,060
Pasucuales - Quito	54,700	7,275
Total	115,300	15,335

Table 7 - 5 KW and KWh Balance for Alternative Thermal Power Plants

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	
Peak demand														
Sistema Norte (MW)	8.2	9.1	19.7	21.4	23.0	24.8	26.6	28.5	30.6	33.0	36.3	39.9	43.9	
" Pichincha (MW)	97.9	108.8	121.7	135.6	151.4	169.4	189.3	211.3	235.7	262.7	288.9	317.8	349.6	
" Centro-Norte (MW)	31.2	35.5	39.7	49.9	55.3	62.2	68.2	75.5	83.1	91.7	100.9	111.1	122.1	
Sub-total	137.3	153.4	181.1	206.9	229.7	256.4	284.1	315.3	349.4	387.4	426.1	468.8	515.6	Growth rate from 1985 = 10%/year
Energy demand														
Sistema Norte (GWh)	26.4	29.6	101.7	107.5	112.5	118.1	123.7	129.8	136.6	144.3	158.7	174.6	192.1	
" Pichincha (GWh)	442.0	492.8	551.7	614.8	684.1	762.3	849.9	946.2	1,052.7	1,168.7	1,285.6	1,414.1	1,555.5	
" Centro-Norte (GWh)	115.8	134.4	151.5	202.3	222.3	248.8	271.9	299.7	328.0	359.6	395.6	435.1	478.6	
Sub-total	584.2	656.8	804.9	924.6	1,018.9	1,129.2	1,245.5	1,375.7	1,517.3	1,672.6	1,839.9	2,023.8	2,226.2	ditto
Available supply capability by existing and new power plant														
Dependable power (MW)	-	-	230.8	297.3	297.3	297.3	297.3	297.3	297.3	297.3	297.3	297.3	297.3	
" energy (GWh)			1,279.2	1,335.9	1,354.4	1,354.4	1,354.4	1,354.4	1,354.4	1,354.4	1,354.4	1,354.4	1,354.4	
Difference (MW)	-	-	49.7	90.4	67.6	40.9	13.2	-18.0	-52.1	-90.1	-128.8	-171.5	-218.3	
" (GWh)			474.3	411.3	335.5	225.2	108.9	-21.3	-162.9	-318.2	-485.5	-669.4	-871.8	
Peak demand without Santa Elena														
Sistema Guayas-Los Rios (MW)	158.3	184.9	212.5	247.0	278.9	312.4	342.6	375.9	413.2	453.0	498.3	548.1	602.9	
" Santa Elena (MW)	7.0	9.2	9.8	11.2	15.8	18.2	19.4	20.6	22.7	24.0	26.4	29.0	31.9	
Sub-total	151.3	175.7	202.7	235.8	263.1	294.2	323.2	355.3	390.5	429.0	471.9	519.1	571.0	ditto
Energy demand without Santa Elena														
Sistema Guayas-Los Rios (GWh)	679.4	793.7	917.7	1,071.9	1,214.0	1,358.1	1,491.7	1,640.1	1,806.2	1,988.4	2,187.2	2,405.9	2,646.5	
" Santa Elena (GWh)	22.4	32.7	35.3	41.3	67.9	79.9	85.1	90.4	100.0	106.2	116.8	128.4	141.3	
Sub-total	657.0	761.0	882.4	1,030.6	1,146.1	1,278.2	1,406.6	1,549.7	1,706.2	1,882.2	2,070.4	2,277.5	2,505.2	ditto
Available supply capability by existing and new power plants														
Dependable power (MW)			276.2	276.2	276.2	276.2	276.2	276.2	276.2	276.2	276.2	276.2	276.2	
" energy (GWh)			1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	1,209.8	
Difference (MW)	-	-	73.5	40.4	13.1	-18.0	-47.0	-79.1	-114.3	-152.8	-195.7	-242.9	-294.8	
" (GWh)	-	-	327.4	179.2	63.7	-68.4	-196.8	-339.9	-496.4	-672.4	-860.6	-1,067.7	-1,295.4	
Interconnected power system with Paute Hydro Power Plant														
Difference (MW)	-	-	123.2	130.8	80.7	22.9	-33.8	-97.1	-166.4	-242.9	-324.5	-414.4	-513.1	
" (GWh)	-	-	801.7	590.5	399.2	156.8	-87.9	-361.2	-659.3	-990.6	-1,346.1	-1,737.1	-2,167.2	

7-2 Power Generation Projects in and after 1985

7-2-1 Load Forecast for 1985 - 1990

From 1985, it is expected that both electric power and energy would grow at an annual rate of 10.5%, and the loads forecast up to 1990 with 1984 as the basis would be as indicated in Table 7-6.

Table 7 - 6 Load Forecast from 1985 to 1990

Year	Max. demand (MW)	Energy demand (GWh)
1984	1,018.7	4,366.4
1985	1,125.7	4,831.8
1986	1,243.9	5,339.1
1987	1,374.5	5,899.7
1988	1,518.8	6,519.2
1989	1,618.3	7,203.7
1990	1,857.6	7,954.9

7-2-2 Considerations on Additions of New Projects

Power generation projects to be put into service in the National System up to 1984 will amount to 99.2 MW in the northern region and 646.0 MW in the southern region, showing one-sided concentration in the south. In and after 1985, considering appropriate location of power sources, it was decided to seek power sources in the north. In other words, the distribution of demand will be 40% in the northern region and 60% in the southern region, but in the present plan including Paute Hydro, power sources would be concentrated in the south in contrast to the demand so that power transmitted to the north would be increased while there would be a limit to transmission capacity and it would become necessary to extend interconnecting transmission lines. Furthermore, power sources to be concentrated in only one region would bring about a risk of complete outage at demand ends having no power sources if a fault should occur in a nation-wide interconnecting transmission line. Consequently, it is judged that it would be economical and advantageous in system operation to seek the power generation project to be selected to follow the Paute Hydro First Stage in the northern area, and moreover, in the vicinity of nation-wide interconnecting transmission line presently planned.

7-2-3 Power Generation Projects

The hydroelectric projects in the northern region investigated by INECEL up to the present, the hydroelectric projects contemplated by the Survey Mission in the present study, and the thermal projects which would compose alternative facilities are as indicated in Table 7-7.

Table 7 - 7 Generation Project under Investigation

Project	Installed Capacity (MW)	Energy Production (GWh)	Performance
Toachi 1st stage	225 (300)	752	Under investigation for definit study
Guayllabamba No.1	210 (420)	1,435	Proposed by the Mission
Montufar	150	438	Feasibility study was completed in 1974
Guayllabamba No.2	100	432	Proposed by the Mission
Guayllabamba No.3	220	889	Proposed by the Mission
Sto, Domingo thermal (Steam)	300 (100 x 3)	1,738	Proposed by the Mission as alternative

Note: Figurs in parenthesis indicate final output of power stations

The particulars of the plans and the economic comparisons of the projects are as indicated in Table 7-8.

Other than these projects, the Coca Hydroelectric Project is being carried out by INECEL, but since there are many important matters concerning this project which needs further investigations in future, this was not included in the candidate sites in the present study.

7-2-4 Examination of Development Sequence

Regarding the power generation projects which should be developed from 1985, the six cases indicated in Table 7-9 were considered in examining the optimum standings of development.

Table 7 - 8 Economic Comparison of the Projects to be installed after Completion of Paute Project

Project	Toachi 1st stage	Guayllabamba No. 1	Montufar	Sto. Domingo thermal	Guayllabamba No. 2	Guayllabamba No. 3
Type of power plant	Dam	Dam	Dam		Dam	Dam
Installed capacity (MW)	225 75 x 3 units	420 105 x 4 units	150 50 x 3 units	300 100 x 3 units	100	220
Annual energy production (GWh)	1, 358 F 752 S 606	1, 883. 5 F 1, 435. 0 S 448. 5	562 F 438 S 124	1, 738. 4	431. 6 F 340. 9 S 90. 7	889. 4 F 606. 2 S 183. 2
Construction cost (X10³US$)						
Generation	228, 000	338, 000	126, 000	117. 800	60, 000	164, 000
Transmission and transforming	25Km 230KV 2cct 2, 250	50Km 230KV 2cct 4, 500	50Km 138 KV 2cct 3, 250	20Km 230KV 2cct 1, 800	4. 5Km 230KV 2cct 410	13Km 230KV 2cct 1, 170
Total	230, 250	342, 500	129, 250	119, 600	60, 410	185, 170
Unit construction cost generating end						
per kW (US$)	1, 013. 3	804. 8	840	392. 7	600	836. 7
per kWh (US$)	0. 168	0. 179	0. 224	0. 068	0. 139	0. 207
Annual cost (10³US$)	29, 344	43, 500	16, 216	34, 790	7, 722	23, 681
per kWh (US$)	0. 0216 (0. 0390)	0. 0231 (0. 0303)	0. 0289 (0. 0370)	0. 0200	0. 0179 (0. 0227)	0. 0266 (0. 0391)
Unit construction cost at receiving end						
per kW (US$)	1, 023. 3	815. 5	861. 7	398. 7	604. 1	841. 7
per kWh (US$)	0. 170	0. 182	0. 230	0. 069	0. 140	0. 208
Annual cost (10³US$)	29, 671	44, 155	16, 689	35, 052	7, 780	23, 851
per kWh (US$)	0. 0218 (0. 0395)	0. 0234 (0. 0308)	0. 030 (0. 0381)	0. 0202	0. 0180 (0. 0228)	0. 0268 (0. 0393)

Note: Figures in parenthesis indicate unit energy cost evaluated only by firm energy

Table 7 - 9 Combination of the Projecto to be Developed in and after 1985

Project	Stage	Installed capacity (MW)	Year of compleation
(Case 1)			
Thermal Sto. Domingo	No. 1 Unit	100	Dec. 1985
" "	No. 2,3 Units	200	Dec. 1986
Hydro Toachi	1st No. 1,2 Units	150	Dec. 1987
" "	1st No. 3 Unit	75	Dec. 1988
Hydro Guayllabamba No.1	No. 1,2 Units	210	Dec. 1989
Total		735	
(Case 2)			
Hydro Toachi	1st No. 1,2 Units	150	Dec. 1985
" "	1st No. 3 Unit	75	Dec. 1986
Thermal Sto. Domingo	No. 1 Unit	100	Dec. 1986
" "	No. 2 Unit	100	Dec. 1987
" "	No. 3 Unit	100	Dec. 1988
Hydro Guayllabamba No.1	No. 1,2 Units	210	Dec. 1989
Total		735	
(Case 3)			
Hydro Guayllabamba No.1	No. 1 Unit	105	Dec. 1985
" "	No. 2,3 Units	210	Dec. 1986
" "	No. 4 Unit	105	Dec. 1987
Hydro Toachi	1st No.1,2,3 Units	225	Dec. 1988
Thermal Sto. Domingo	No. 1,2 Units	200	Dec. 1989
Total		845	
(Case 4)			
Hydro Guayllabamba No.1	No. 1 Unit	105	Dec. 1985
" "	No. 2,3 Units	210	Dec. 1986
" "	No. 4 Unit	105	Dec. 1987
Thermal Sto. Domingo	No. 1,2 Units	200	Dec. 1988
" "	No. 3 Unit	100	Dec. 1989
Hydro Toachi	1st No. 1 Unit	75	Dec. 1989
Total		795	
(Case 5)			
Thermal Sto. Domingo	No. 1 Unit	100	Dec. 1985
" "	No. 2,3 Units	200	Dec. 1986
Thermal Guayaquil	No. 1 Unit	125	Dec. 1987
"	No. 2 Unit	125	Dec. 1988
"	No. 3,4 Units	250	Dec. 1989
Total		800	
(Case 6)			
Thermal Sto. Domingo	No. 1 Unit	100	Dec. 1985
" "	No. 2,3 Units	200	Dec. 1986
Hydro Guayllabamba No.1	No. 1 Unit	105	Dec. 1987
" "	No. 2,3 Units	210	Dec. 1988
" "	No. 4 Unit	105	Dec. 1989
Hydro Toachi	1st No. 1 Unit	75	Dec. 1989
Total		795	

7-2-5 Comparisons of Sequences of Development

Times of development were estimated for the above six cases and the economy was compared converting the annual costs of all of the systems including the existing systems to values as of 1980. The results are as shown in Table 7-10.

Table 7 - 10 Order of Development

	Order of Development	Accumulated present annual cost in 1985 10^3US$	Order
1	Thermal – Toachi – Guayllabamba No. 1 (300MW) (225MW) (210MW)	665,586	2
2	Toachi – Thermal – Guayllabamba No. 1 (225MW) (300MW) (210 MW)	679,720	6
3	Guayllabamba No. 1 – Thermal – Toachi (420MW) (300MW) (75MW)	671,663	5
4	Guayllabamba No. 1 – Thermal – Toachi (420MW) (300MW) (75MW)	669,315	4
5	Thermal – Thermal (300MW) (500MW)	635,414	1
6	Thermal – Guayllabamba No. 1 – Toachi (300MW) (420MW) (75MW)	667,460	3

According to the above, it is indicated that Case 5 in which 300 MW plus 500 MW of thermal plants are brought into service is economically the best. On the other hand, the inferior case is Case 2 and the difference between Case 5 and Case 2 is 6.5%.

If power sources from 1985 and after were all to be made up of thermal power generators as proposed in Case 5, it would be necessary to examine the refining capacity in petroleum production planned in Ecuador. That is, the situation must be considered from the standpoint of bunker C heavy oil. There will be a daily amount of 50,000 barrels of petroleum refined at the Esmeraldas Oil Refining Plant now under construction of which 20%, or 10,000 barrels, will be bunker C heavy oil corresponding to an annual production of 3 million barrels. Assuming that all of this would be used at thermal power stations, the quantity remaining after use at Norte Thermal (30 MW) and Guayaquil Thermal (146 MW) will be only enough to fill the requirements of thermal power stations amounting to around 300 MW. Consequently, in case more than 300 MW of thermal power stations are to be added, a new fuel policy will be necessitated.

From the aspects of the effective utilization of fuel and water resources, it was decided to adopt Case 1. Although Case 1 is inferior to Case 5 in economy, it is the best among the cases that include hydro power, so that the new projects needed to be considered in the latter half of the long-range program studied herein, in effect, a scheme for putting into service in the order of thermal (300 MW), Toachi First Stage (225 MW), and Guayllabamba No. 1 First Stage (210 MW), are included in the funding plan.

The scheme for addition of power generation projects in and after 1985 is illustrated in Fig. 7-1, Tables 7-11 and 7-12.

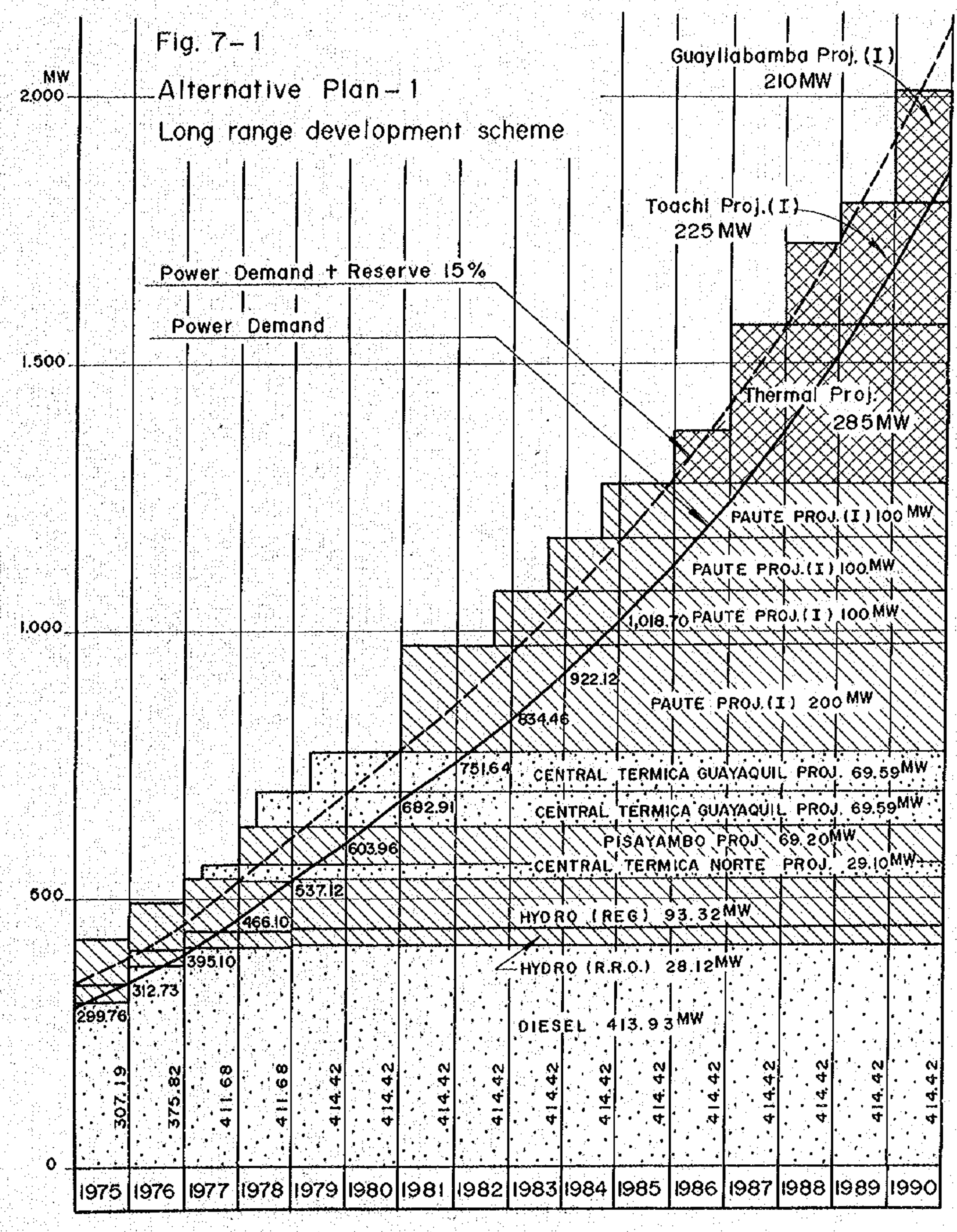
Fig. 7-1
Alternative Plan-1
Long range development scheme
MW
2,000
1,500
1,000
500
0
Guayllabamba Proj.(I) 210MW
Toachi Proj.(I) 225MW
Power Demand + Reserve 15%
Power Demand
Thermal Proj. 285MW
PAUTE PROJ.(I) 100MW
PAUTE PROJ.(I) 100MW
PAUTE PROJ.(I) 100MW
PAUTE PROJ.(I) 200MW
CENTRAL TERMICA GUAYAQUIL PROJ. 69.59MW
CENTRAL TERMICA GUAYAQUIL PROJ. 69.59MW
PISAYAMBO PROJ. 69.20MW
CENTRAL TERMICA NORTE PROJ. 29.10MW
HYDRO (REG) 93.32MW
HYDRO (R.R.O.) 28.12MW
DIESEL 413.93MW
299.76
312.73
395.10
466.10
537.12
603.96
682.91
751.64
834.46
922.12
1,018.70
307.19
375.82
411.68
411.68
414.42
414.42
414.42
414.42
414.42
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414.42
414.42
414.42
414.42
414.42
414.42
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

Table 7 - 11 Energy to be Generated by Electric Utilities from 1984 to 1990 Unit: GWH

	1984	1985	1986	1987	1988	1989	1990
Demand in MW	1,018.70	1,125.66	1,243.86	1,374.46	1,518.78	1,678.25	1,857.55
Demand in GWh	4,366.36	4,831.78	5,339.14	5,899.73	6,519.21	7,203.72	7,954.95
Hydro							
Private utilities	688.29						
Pisayambo (76.2 MW)	212.00	3,750.29	3,750.29	3,750.29	3,750.29	3,750.29	3,750.29
Paute (500 MW)	2,850.00						
Toachi (225 MW)	-	-	-	-	752.00 (150.00)	752.00 (225.00)	752.00 (225.00)
Guayllabamba (420 MW)	-	-	-	-	-	-	941.70 (210.00)
Total	3,750.29 (692.70)	3,750.29 (692.70)	3,750.29 (692.70)	3,750.29 (692.70)	4,502.29 (842.70)	4,502.29 (917.70)	5,443.99 (1,127.70)
Thermal							
Private utilities	123.00	395.41	421.14	186.67	237.24	405.08	293.45
Norte thermal / Guayaquil thermal	493.36 (176.00)	686.08 (176.00)	655.25 (176.00)	477.95 (176.00)	439.40 (176.00)	601.29 (176.00)	601.29 (176.00)
Proposed projects	-	-	512.46 (100.00)	1,484.82 (300.00)	1,340.28 (300.00)	1,695.06 (300.00)	1,616.22 (300.00)
Total	616.36 (326.00)	1,081.49 (432.96)	1,588.85 (551.16)	2,149.44 (681.76)	2,016.92 (676.08)	2,701.43 (760.55)	2,510.96 (729.85)

Note: Figures in parenthesis indicate installed capacity

Table 7 - 12 Annual Cost of Power Facilities of National Interconnected System

Unit: 10^3US$

Item \ Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(1) Hydro																
Private utilities INECEL	8,394	8,394	9,023	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829	8,829
Pisayambo (76.2MW)	–	–	–	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009	9,009
Paute (200-500MW)	–	–	–	–	–	–	42,124	43,024	43,925	44,826	44,826	44,826	44,826	44,826	44,826	44,827
Toachi (225MW)	–	–	–	–	–	–	–	–	–	–	–	–	–	28,803	29,344	29,344
Guayllabamba (420MW)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	41,699
Sub-total	8,394	8,394	9,023	17,838	17,838	17,838	59,962	60,862	61,763	62,664	62,664	62,664	62,664	91,467	92,008	133,707
(2) Thermal																
Private utilities INECEL	15,463 (22,255)	18,884 (27,491)	20,688 (32,680)	20,688 (26,253)	20,821 (29,742)	20,821 (30,550)	20,821 (4,758)	20,821 (3,415)	20,821 (3,201)	20,821 (3,309)	20,821 (10,637)	20,821 (11,329)	20,821 (5,021)	20,821 (6,382)	20,821 (10,897)	20,821 (7,894)
Norte-thermal	–	–	3,344 (1,959)	3,344 (1,866)	3,344 (1,866)	3,344 (1,866)										
Guayaquil thermal	–	–	–	4,893 (3,593)	9,110 (5,390)	9,110 (8,983)	12,454 (4,960)	12,454 (5,241)	12,454 (5,428)	12,454 (5,989)	12,454 (8,329)	12,454 (7,955)	12,454 (5,802)	12,454 (5,334)	12,454 (7,300)	12,454 (7,300)
Proposed projects	–	–	–	–	–	–	–	–	–	–	–	5,615 (6,006)	16,845 (17,402)	16,845 (15,708)	16,845 (19,866)	16,845 (18,942)
Sub-total	15,463 (22,255)	18,884 (27,491)	24,032 (34,639)	28,925 (31,712)	33,275 (36,998)	33,275 (41,399)	33,275 (9,718)	33,275 (8,656)	33,275 (8,629)	33,275 (9,298)	33,275 (18,966)	38,890 (25,290)	50,120 (28,225)	50,120 (27,424)	50,120 (38,063)	50,120 (34,136)
Total (1 + 2)	23,857 (22,255)	27,278 (27,491)	33,055 (34,639)	46,763 (31,712)	51,113 (36,998)	51,113 (41,399)	93,237 (9,718)	94,137 (8,656)	95,038 (8,629)	95,939 (9,298)	95,939 (18,966)	101,554 (25,290)	112,784 (28,225)	141,587 (27,424)	142,128 (38,063)	183,827 (34,136)
	46,112	54,769	67,694	78,475	88,111	92,512	102,955	102,793	103,667	105,237	114,905	126,844	141,009	169,011	180,191	217,963
Present value in 1985	–	–	–	–	–	–	–	–	–	–	104,460	104,830	105,942	115,436	111,884	123,034
Total present value from 1985 to 1990											665,586					

From 1981 to 1990 the figures shown in the Guayaquil thermal row are printed once for Norte-thermal and Guayaquil thermal together, joined by a brace.

Note: Figures in parenthesis indicate fuel cost of the thermal power plants

7-3 Timing of Interconnections between National Interconnected System and Regional Systems.

The installed capacity of the First Stage of Paute Hydroelectric Power Project is 500 MW and the construction work is scheduled to be completed by 1984. This capacity will comprise 40% of installed capacity of all of Ecuador in that year. Consequently, the electric power of Paute Hydro is enough to be supplied to the nine regional systems by the 230 kV national interconnection transmission line to be constructed from Paute to Quito via Guayaquil and by 138 kV branch transmission lines. Therefore, taking into account the existing facilities and size of demand in each regional system, a study was made of the timing of interconnections between the National Interconnected System and regional systems.

7-3-1 Preconditions

In the 230 kV nation-wide Interconnecting transmission line, the section between Quito and Guayaquil has already been put out for bidding and is scheduled to be completed in June 1978. Meanwhile, 138 kV branch lines to the Norte, Pichincha and Centro-Norte Systems are presently under construction. Except for the abovementioned lines and the Guayaquil District which would be the major load center for Paute Hydro, the times at which interconnections would be made with five systems and two districts were studied.

The method of study was to compare the energy costs at the outlets of secondary substations (138/69 kV) to be provided at the ends of the branch transmission lines in case of supply of the electric power from Paute Hydro Power Plant to load areas by the nation-wide interconnecting transmission line and the generating cost at a diesel power station as alternative power generating facilities based on the electric power demand in each year, and the time for interconnection of a load area was taken to be when it becomes cheaper to receive power from the branch transmission lines.

The energy cost at a secondary substation was calculated by adding 6.3 mills/kWh, the transmitting and transforming cost of the 230 kV interconnected transmission and transforming facilities, to 15.8 mill/kWh, the average generating cost of Paute Hydroelectric Power Station during its service life, to arrive at 22.1 mills/kWh, the cost at the 230/138 kV substation site for interconnection with the regional system. To this 22.1 mills/kWh, the power transmission cost of 138 kV transmission lines to 138/69 kV substations to be constructed at load centers within each regional system was added to arrive at the energy cost of power received.

The particulars and data employed in calculation of generating cost are as described in 7-3-3.

7-3-2 Results of Study

The results of comparisons of costs of power received by transmission lines and generating costs of diesel generators for five systems (Centro-Sur, Sur, Esmeraldas, Manabi, El Oro) and two districts (Santa Elena, Babahoyo) are as shown in Table 7-13 and Fig. 7-2. As can be seen in the table, it will be economical for the three regional systems of Centro-Sur, Manabi and El Oro, and the two districts of Santa Elena and Babahoyo to receive power from Paute Hydro making interconnections at early dates as much as possible, while in view of the scales of power demands and existing generating facilities, it will be economical for the Esmeraldas System to be interconnected in 1984, and the Sur System in 1985.

7-3-3 Particulars and Data for Economic Comparisons

(1) Generating Cost of Paute Hydroelectric Power Station

1) Dependable Energy

	Dry Year (GWh)	Average Year (GWh)
Primary energy	2, 750	2, 850
Secondary energy	780	1, 180
Total	3, 530	4, 030

2) Construction Cost and Generating Cost

a) Construction Cost

US $ 348. 3 x 10^6 (including interest during construction)

b) Annual Cost

The annual cost for the service life taking into consideration lags in times of investment is US$ 43.2 x 10^6 as indicated in Table 7-14.

c) Dependable Energy

The dependable energy production for the service life taking into consideration the period of latency is, adopting an average year, 2, 730 GWh annually as shown in Table 7-14.

d) Generating Cost

	Annual Cost (US $ 10^6)	Dependable Energy (GWh)	Unit Energy Cost (mill/kWh)
For Service Life	43. 2	2, 730	15. 8

Table 7 - 13 Generating Cost of Paute Project Converted to 138/69kV Substation and Alternative Diesel Plants at Each Regional System

Unit: mills/kWh

Sistema	1978	1979	1980	1981	1982	1983	1984
Centro-Sur (Cuenca s. s.)							
Generating Cost by Diesel	39.4	42.7	42.4	40.1	41.9	39.1	40.5
" " "Paute"	29.6	28.8	27.6	27.1	26.7	26.3	25.9
Sur (Loja s. s.)							
Generating Cost by Diesel	61.5	53.5	48.7	48.6	42.4	42.4	42.3
" " "Paute"	83.5	70.8	62.2	56.3	51.1	47.1	44.1
Manabi (Portoviejo s.s.)							
Generating Cost by Diesel	32.6	32.9	34.6	32.3	34.1	32.1	33.5
" " "Paute"	32.0	30.8	29.6	28.7	28.1	27.6	27.1
Esmeraldas (Esmeraldas s.s.)							
Generating Cost by Diesel	43.1	36.6	34.9	35.7	32.5	32.8	32.8
" " "Paute"	54.6	49.5	40.7	38.3	36.3	34.6	32.6
Santa Elena (Santa Elena s.s.)							
Generating Cost by Diesel	46.5	37.9	37.6	34.9	34.4	34.7	34.2
" " "Paute"	44.4	35.6	33.6	32.9	32.3	31.3	30.8
Babahoyo (Babahoyo s.s.)							
Generating Cost by Diesel	35.7	36.7	37.4	35.0	35.9	36.4	34.2
" " "Paute"	28.9	27.9	27.2	26.6	26.2	25.8	25.4
El Oro (Machala s.s.)							
Generating Cost by Diesel	45.8	40.4	38.9	39.0	37.5	37.5	37.5
" " "Paute"	37.8	35.4	33.5	32.0	30.6	29.6	28.7

Fig. 7-2 Generating Cost of Paute Hydro P.S at 138kv/66kv Substation and Diesel Project at each Regional System

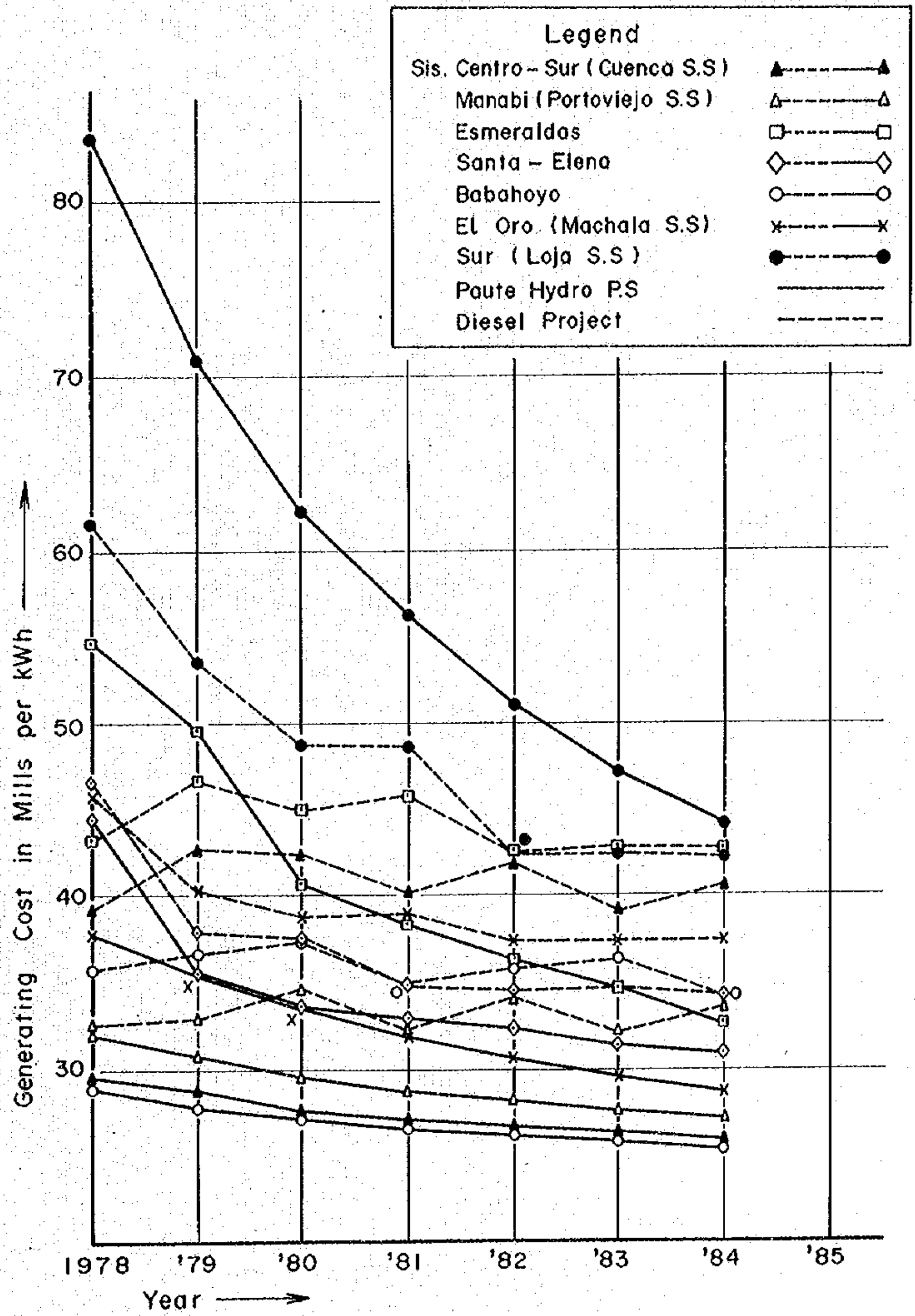


Table 7 - 14 Generating Cost of Paute P.S.

Year	Annual Cost (10^3US$)	Dependable energy (GWh)	Unit energy Cost (mills/kWh)
1	35,560	1,752	20.3
2	38,650	2,628	14.7
3	41,740	2,850	14.6
4	44,830	2,850	15.7
5	44,830	2,850	15.7
⋮			
50	44,830	2,850	15.7
Mean	43,200	2,730	15.8

(2) Construction Cost and Annual Cost of 230kV National Interconnecting Power Transmission and Transforming Facilities.

1) Construction Cost

Pascuales - Quito	US $ 54,700 x 10^3
Paute - Pascuales	US $ 60,600 x 10^3
Total	US $ 115,300 x 10^3

2) Annual Cost

(construction cost) x (annual cost ratio)

= US $ 115,300 x 10^3 x 0.145 = US $ 16,780 x 10^3

3) Transmission Cost from Paute Power Station to 230kV Primary Substation Outlet.

$$\frac{\text{Annual cost of 230kV transmission and transforming facilities}}{\text{(Dependable energy of Paute P.S.) - (Energy loss of 230kV primary transmission and transforming facilities)}}$$

$$= \frac{16,780 \times 10^3}{(2,730 - 48) \times 10^6} = 6.3 \text{ mills/kWh}$$

(3) Construction Costs and Annual Costs of 138kV Power Transmission and Transforming Facilities

The construction costs and annual costs of 138kV transmission and transforming facilities connecting 230 kV national interconnecting power transmission and transforming facilities with regional systems are indicated in Table 7-15.

Table 7 - 15 Annual Cost of 138kV Transmission and Transforming Facilities

sector	Voltage (kV)	Length (km)	No. of circuit	Kind of conductor	Transformer (MVA)	Construction cost (10^3US$)	Annual cost (10^3US$)
Paute - Cuenca	138	40	1/2	ACSR 477MCM	40	5, 400	790
Quevedo - Portoviejo	138	120	1/2	"	40	6, 600	960
Sto. Domingo-Esmeraldas	138	170	1/2	"	20	8, 500	1, 240
Milagro-Machala	138	125	1/2	"	40	8, 400	1, 220
Milagro- Babahoyo	138	40	1/1	"	20	2, 800	410
Pascuales-Sta.Elena	138	120	1/1	"	20	6, 300	920
Machala-Loja	138	150	1/1	"	20	8, 700	1, 270

(4) Energy Cost in Case of Power Supply from Paute Hydroelectric Power Station to 138/69kV Substation

Adding to the generating cost of 15. 8 mills/kWh of Paute Hydroelectric Power Station during its service life, the transmission cost of 6. 3 mills/kWh via the 230 kV national interconnecting transmission line to 230/138 kV substations, the energy cost at the 138 kV sides of these substations will be 22. 1 mills/kWh.

Further, excluding the Pichincha System and the Guayas-Los Rios System which will receive power supply by 138kV transmission lines, the energy costs for the seven other systems at 138/69kV substations will be as shown in Table 7-16.

(5) Service Lives and Cost Ratios of Various Electric Power Facilities

1) Service Life and Cost Ratio of Transmission Lines and Substations

Average service life 30 years, interest per annum 10. 5%

Capital recovery factor	11. 05 %
Operation and maintenance cost	3. 30 %
General administrative cost	0. 20 %
Total	14. 55 %

Table 7 - 16 Energy Cost at 138kV Substations

Substations(138kV/66kV)	1978	1979	1980	1981	1982	1983	1984
Cuenca							
Energy requirement(GWh)	105.3	117.3	143.8	157.1	172.1	189.2	208.4
Trans. cost(mills/kWh)	7.5	6.7	5.5	5.0	4.6	4.2	3.8
Gen. cost at 66kV Bus(")	29.6	28.8	27.6	27.1	26.7	26.3	25.9
Portoviejo							
Energy requirement(GWh)	96.6	110.0	128.8	143.5	158.9	175.3	192.8
Trans. cost(mills/kWh)	9.9	8.7	7.5	6.6	6.0	5.5	5.0
Gen. cost at 66kV Bus(")	32.0	30.8	29.6	28.7	28.1	27.6	27.1
Esmeraldas							
Energy requirement(GWh)	38.2	45.2	66.7	76.4	87.3	99.0	118.1
Trans. cost(mills/kWh)	32.5	27.4	18.6	16.2	14.2	12.5	10.5
Gen. cost at 66kV Bus(")	54.6	49.5	40.7	38.3	36.3	34.6	32.6
Machara							
Energy requirement(GWh)	77.5	92.0	107.2	123.6	142.9	163.5	186.0
Trans. cost(mills/kWh)	15.7	13.3	11.4	9.9	8.5	7.5	6.6
Gen. cost at 66kV Bus(")	37.8	35.4	33.5	32.0	30.6	29.6	28.7
Babahoyo							
Energy requirement(GWh)	60.5	70.1	80.9	90.4	100.7	111.8	123.9
Trans. cost(mills/kWh)	6.8	5.8	5.1	4.5	4.1	3.7	3.3
Gen. cost at 66kV Bus(")	28.9	27.9	27.2	26.6	26.2	25.8	25.4
Sta. Elena							
Energy requirement(GWh)	41.3	67.9	79.9	85.1	90.4	100.0	106.2
Trans. cost(mills/kWh)	22.3	13.5	11.5	10.8	10.2	9.2	8.7
Gen. cost at 66kV Bus(")	44.4	35.6	33.6	32.9	32.3	31.3	30.8
Loja							
Energy requirement (GWh)	27.8	35.9	44.2	52.3	62.1	72.1	82.7
Trans. cost (mills/kWh)	61.4	48.7	40.1	34.2	29.0	25.1	22.0
Gen. cost at 66kV/Bus (GWh)	83.5	70.8	62.2	56.3	51.1	47.1	44.1

Transportation cost

Cuenca	1.01 s/./gallon,	10.3 US$/ton
Loja	0.7 "	7.1 "
Babahoyo	0.5 "	5.0 "

Fuel Oil and Lubricating Oil cost

	Bunker C Oil	Diesel Oil	Lubricating Oil
Cuenca	57.7 US$/ton	115.6 US$/ton	336 US$/ton
Loja	54.5 "	112.4 "	336 "
Babahoyo	52.4 "	110,3 "	336 "

2) Service Life and Cost Ratio of Hydroelectric Power Station

Average service life 50 years, interest per annum 10.5%

Capital recovery factor	10.57 %
Operation and maintenance cost	2.10 %
General administrative cost	0.20 %
Total	12.87 %

3) Service Life and Cost Ratios of Steam Thermal Power Station

Average service life 25 years, interest per annum 10.5 %

Capital recovery factor	11.44 %
Repair cost	2.35 %
Personnel cost and administrative cost	US $4,000/man
Fuel cost	US $47.4/ton 1/

1/ International prices should ordinarily be used for fuel costs, but the above price used as basis by INECEL was adopted here.

4) Service Life and Cost Ratio of Diesel Power Station

Average service life 20 years, interest per annum 10.5%

Capital recovery factor	12.15 %
Repair cost	2.35 %
Personnel cost	US $4,000/man
Fuel cost (under 3,000kW)	US $105.3/ton (diesel oil)
Fuel cost (over 5,000kW)	US $47.4/ton (bunker C heavy oil)
General administrative cost	0.2 %
Calorific value of bunker C heavy oil	10,200 kcal/kg 240 g/kWh
Calorific value of diesel oil	10,400 kcal/kg 236 g/kWh
Lubricating oil	4 g/kWh

7-4 System Analysis on the National Interconnecting System

7-4-1 Summary

The electric power system in Ecuador is presently divided into nine regional systems, each constituting an independent power group, with no interconnecting transmission lines.

INECEL has a plan for establishment of a system of 230 kV transmission lines for the purpose of interconnecting the regional power systems throughout the country.

In this plan, a two-circuit, 230 kV interconnecting line will be erected in the Quito-Guayaquil Section (route length 330 km) in 1978, and in the Guayaquil-Paute Section (route length 200 km) in 1980.

The Paute Hydraulic Power Plant, scheduled for start-up in 1981 will commence operations at 200 MW, followed by an additional output of 100 MW each year until 1984, when an ultimate capacity of 500 MW——a large source of electricity——will be reached.

Hereunder, an investigation will be carried out on the problems of voltage regulation, transient stability, and short-circuit capacity, in the event of realization of the network linkage throughout the country. The present analysis, however, is conducted on the basis of the INECEL's original plan, with some partial modifications on the following three points deemed desirable in the course of our examinations.

(1) Outgoing Facilities at Paute Hydraulic Power Plant

As shown in Fig. 7-3, the original plan stipulated an outgoing system at the Paute Hydraulic Power Plant, in which the generator voltage was being stepped up in two stages of 138 kV - 230 kV. Since the bulk of the power generated at the Paute Plant is being supplied to the 230 kV side, a two-stage transformation such as this will entail an additional impedance due to the duplication of transformers, as seen from the generator side——a value equivalent to about a 40 km, two-circuit, 230 kV transmission line. This is evidently an undesirable situation from the viewpoint of transient stability. Therefore, a modification, as shown in Fig. 7-4, is made so that the generator voltage will be stepped up directly to 230 kV.

(2) Extension of One-circuit in the Paute-Milagro Section

In the original plan, the Paute-Milagro Section consisted of a two-circuit, 230 kV line. If the direct 230 kV transformation is adopted at Paute, the two-circuit line cannot carry power of more than 300 MW due to the transient stability limitations, and the line will be incapable of carrying the output of the Paute Plant in excess of 400 MW. Therefore, it becomes necessary to add one additional 230 kV circuit to the Paute-Milagro Section when the power plant reaches an output of 400 MW.

Fig. 7-3 Paute P.S Pull Out Method (Origininal)

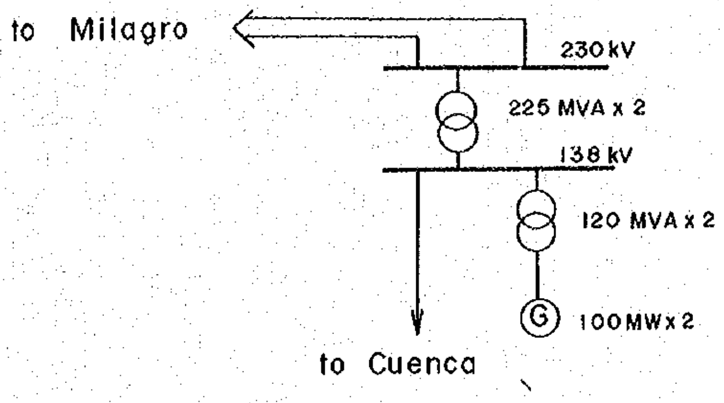
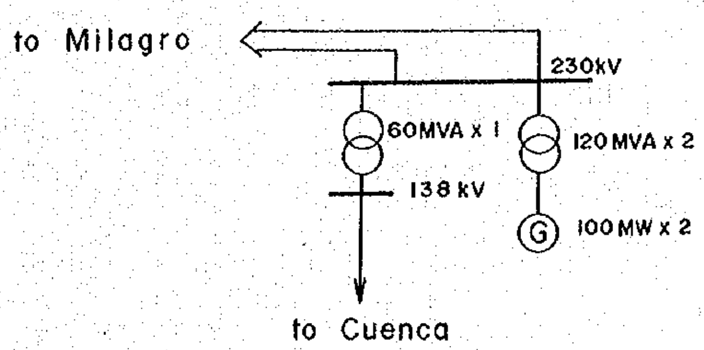


Fig. 7-4 Paute P.S Pull Out Method (Alternative)



(3) Saving a Transformer Bank at the Pascuales Linking Substation

The original plan stipulated installation of two transformer banks, each bank consisting of three single-phase, 75 MVA units (225 MVA). The peak electric power passing through this linking transformer bank in 1985 is estimated to be 120 MW, and considering the shut-down of one 73 MW unit at the Guayaquil Steam Power Plant, installation of one transformer bank (225 MVA) will be quite adequate. Therefore, our calculations will be made on the basis of a 225 MVA transformer capacity at Pascuales.

7-4-2 Voltage Regulation

(1) Standard for Voltage Regulation

The key to voltage regulation is how to adjust the balance of reactive power of the system, and voltage regulation is carried out by means of generators, phase modifiers, and transformer taps.

The standard for voltage regulation is set up as described hereunder.

1) As the object of the investigation, consideration was given to the three operating conditions of the system, namely, at peak load and off-peak load arising in 1980 when the nation-wide interconnecting transmission line is completed, and at peak-load arising in 1985 when the Paute Hydraulic Power Plant reaches an output of 500 MW.

2) Voltage regulation at the busbar of both the 230 kV and 138 kV systems is set at 95-105% and that of the generator terminal voltage at 95-105%, for operation within the rated power factor.

3) The loads on each transforming substation are as shown in Table 7-17, and the corresponding power factors are assumed as 85% in 1980 and 90% in 1985. The off-peak load is taken as 40% of the peak load.

4) In light of the large voltage variations arising between the hours of peak load and off-peak load, all the transformers will be provided with load-ratio adjustors.

(2) Results of Investigation on Voltage Regulation

An impedance map of the entire interconnected system is shown in Fig. 7-5, and its power flow diagrams in Figs. 7-6 through 7-8.

At off-peak in 1980, when the load is light and the pwer flow in the transmission lines is accordingly small, the voltage rise due to ground capacity will be so large as to raise the 230 kV system voltage to 110% or more, if a shunt reactor is not provided. An 80 MVA capacity shunt reactor will be required in the system. At peak load in 1985, the heavy power flow in the transmission lines supplying power from the Paute Hydraulic Power Plant to the Guayaquil and Quito areas will bring about a big loss of reactive power, thus causing a voltage drop in the 230 kV system. For compensation of this voltage drop, capacitors of 100 MVA capacity will be required in the entire system. The phase modifier installations for each transforming station are given in Table 7-18.

1) Shunt Reactor

The year 1980, when the 230 kV interconnected transmission line system (Quito-Paute, 530 km) is completed, will be the most critical period in terms of voltage rise. Especially, at off-peak load, the 230 kV system voltage will rise to over 110% because of the light load. To keep the 230 kV busbar voltage below 105%, the power system will require an 80 MVA reactor capacity. The longest transmission route is the 155 km section between Paute and Milagro and the voltage rise due to Ferranti effect is not so big, being only 102%. Therefore, the shunt reactors may be installed on the tertiary side of the 230/138 kV linking transformers.

Table 7 - 17 Demand at Each Substation

Unit : MW, MVar

Substation	1980 Peak	1980 Off-Peak	1985 Peak	1985 Off-Peak
1. Norte Ibarra	24.8+j18.6	9.9+j7.4	35.6+j17.2	14.2+j6.9
2. Pichincha Quito	160.6+j120.5	64.2+j48.2	273.3+j132.4	109.3+j52.9
Sto. Domingo	8.8+j6.6	3.5+j2.6	19.5+j9.4	7.8+j3.8
3. Centro-Norte Ambato	62.2+j46.7	24.9+j18.7	101.4+49.1	40.6+j19.7
4. Centro-Sur Cuenca	38.6+j29.0	15.4+j11.6	61.2+j29.6	24.5+j11.9
5. Sur Loja	–	–	24.8+j12.0	9.9+j4.8
6. Esmeraldas Esmeraldas	14.3+j10.7	5.7+j4.3	29.3+j14.2	11.7+j5.7
7. Manabi Portoviejo	30.7+j23.0	12.3+j8.2	51.3+j24.8	20.5+j9.9
8. Guayas-Los Rios Guayaquil	231.6+j173.3	92.6+j69.5	379.5+j183.8	151.8+j73.5
Sta. Elena	18.2+j13.7	7.3+j5.5	25.3+j12.3	10.1+j4.9
Milagro	28.0+j21.0	11.2+j8.4	37.2+j18.0	14.9+j7.2
Babahoyo	20.6+j15.5	8.2+j6.2	34.1+j16.5	13.6+j5.9
Quevedo	14.0+j10.5	5.6+j4.2	21.1+j10.2	8.4+j4.1
9. El Oro Machala	–	–	30.6+j14.8	12.2+j5.9
Total	652.4+j489.5	260.8+j194.8	1124.2+544.3	449.5+j217.1

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Fig. 7-5 Impedance Map in 1985 1000MVA 230kV 138kV Base

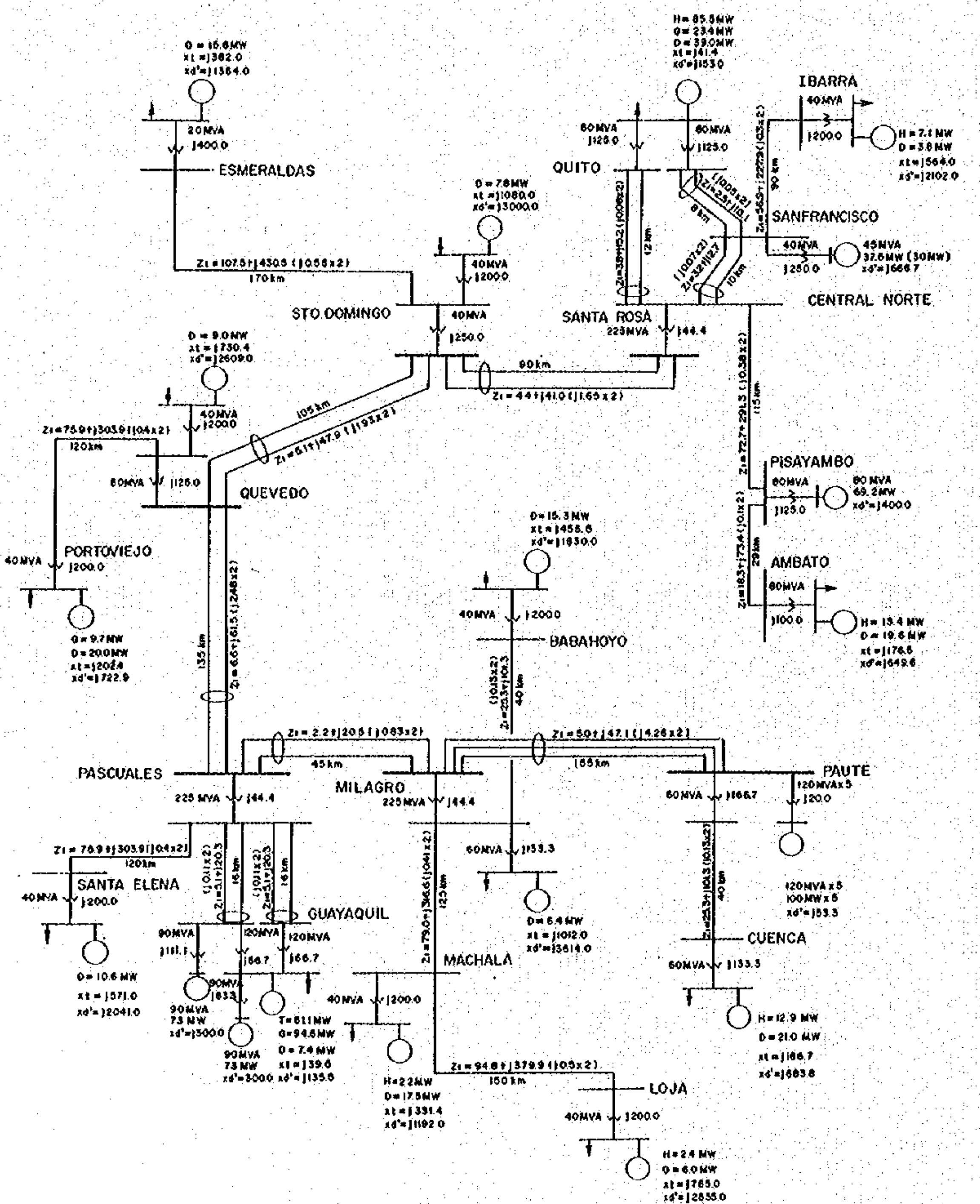

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Fig. 7-6 Power Flow and Voltage Regulation at Peak Time in 1980

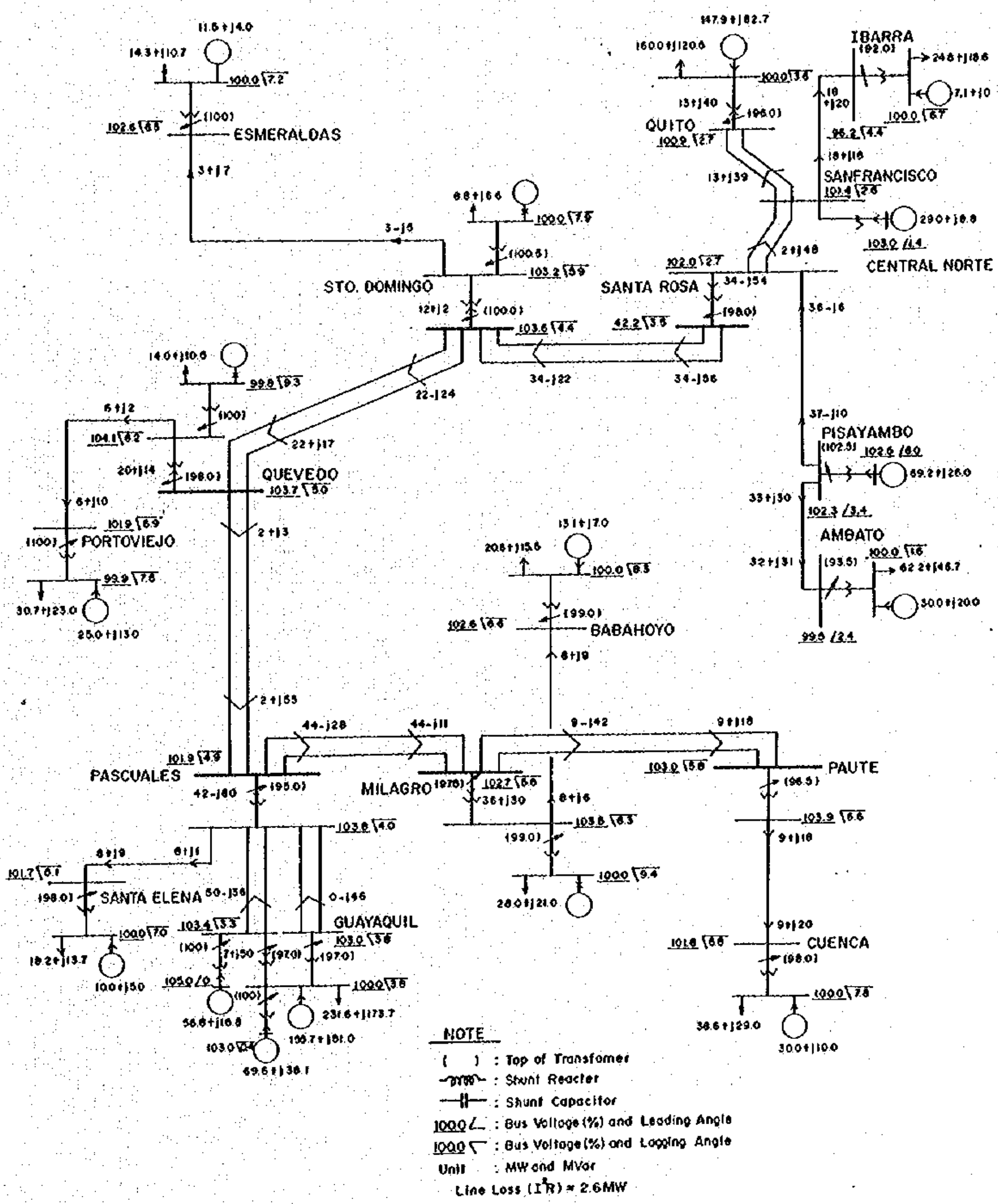

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Fig. 7-7 Power Flow and Voltage Regulation at off Peak Time in 1980

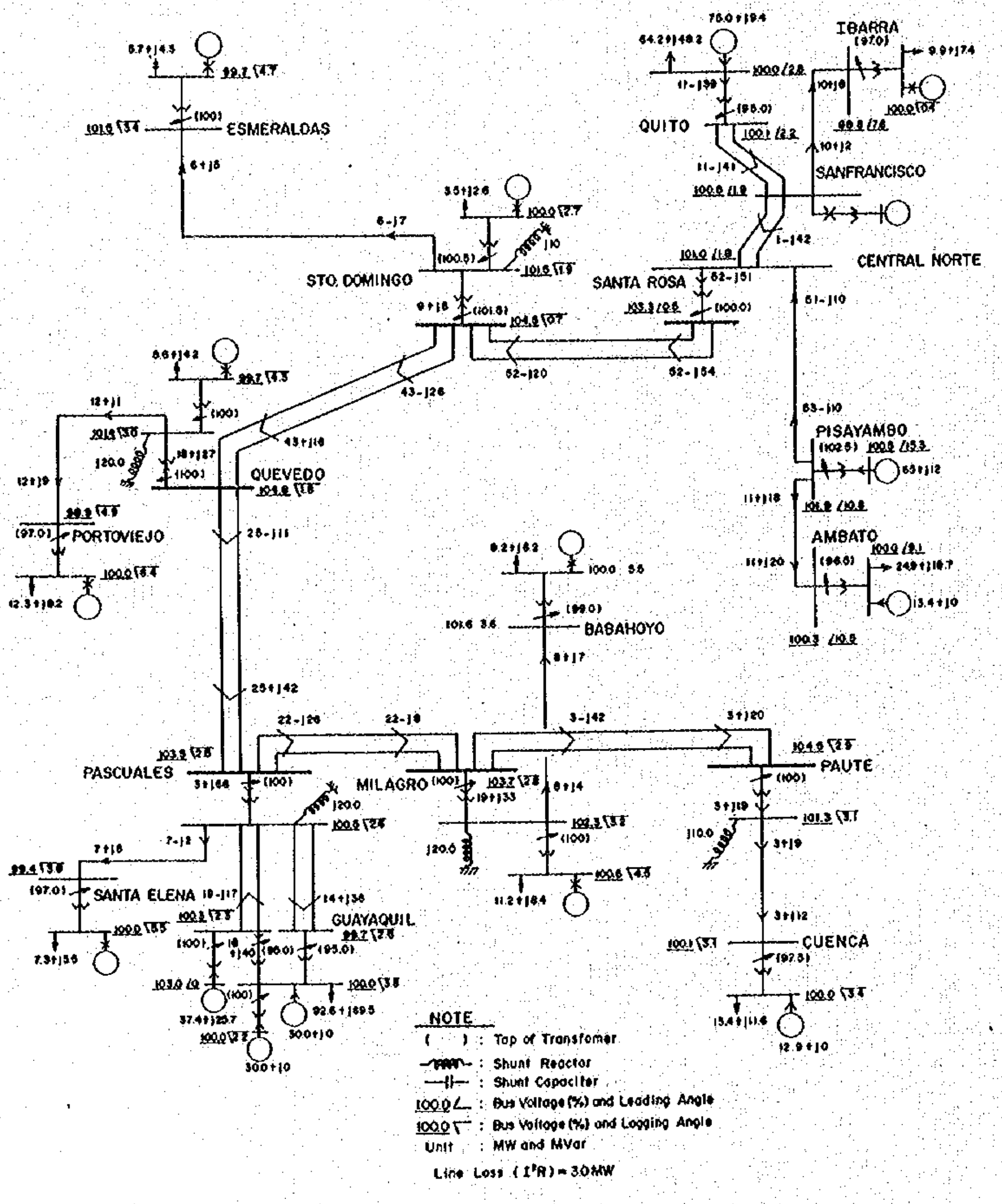

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Fig. 7-8 Power Flow and Voltage Regulation at Peak Time in 1985

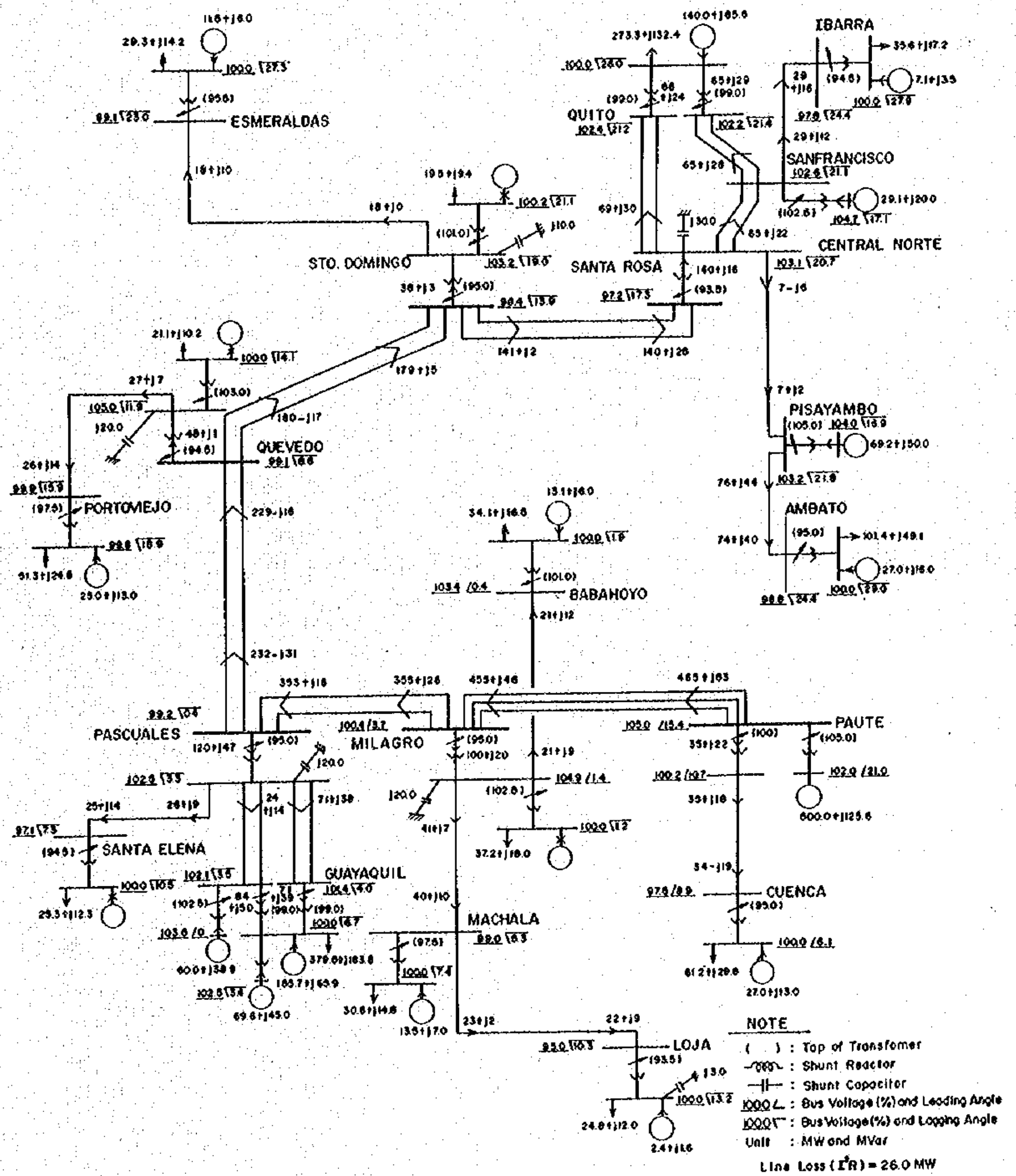


Table 7 - 18 Required Reactor Power Generating Facilities

Unit: MVA

Substation	Shunt Reactor (1980 Off Peak)	Shunt Capacitor (1985 Peak)
Sta. Rosa (230kV/138kV)	0	30
Sto. Domingo (")	10	10
Quevedo (")	20	20
Pascuales (")	20	20
Milagro (")	20	20
Paute (")	10	0
Loja (138kV/69kV)	-	3

2) Shunt Capacitor

At peak load in 1980, the power flow in the transmission lines will be too small to cause any voltage drop, and installation of a shunt reactor will not be required. When the Paute Hydraulic Power Plant is put into service, however, the power flow in the transmission lines will become so heavy that the system capacitor requirement will amount to 100 MVA at peak load. The shunt capacitors, like the reactors, will be installed on the tertiary side of the transformers.

3) Load-Ratio Controll Transformer

Up to 1981, the power flow in the transmission lines will be light for both on-peak and off-peak loads, and the 230 kV busbar voltage will be subjected to little voltage variations. When the Paute Hydraulic Power Plant is put into service, the power flow at peak load will become heavy with the result that the voltage difference between peak and off-peak loads will become larger. Also, the 138 kV transmission system, like the 230 kV system, will be subjected to wide voltage variations, as they are mostly of long-distance lines. Therefore, transformers without under-load tap changers are considered unsatisfactory, and all transformers for system-linkage use will be equipped with under-load tap-changing devices on the primary side. The range of the load-ratio transformer taps for each transforming station is shown in Table 7-19, and results of our analysis on voltage regulation indicate that taps in the range of 230 kV $\pm$ 10% are adequate for keeping the secondary voltage at the target voltage, with a fair margin.

Table 7 - 19 Voltage of Substation Bus Converted to Tap Voltage of On-loard Tap Changer

Substation		1980		1985
		Peak	Off Peak	Peak
Sta. Rosa	(230kV/138kV)	98.0	100.0	93.5
Sto. Domingo	(")	100.0	101.5	95.0
"	(138kV/69kV)	100.5	100.5	101.0
Quevedo	(230kV/138kV)	98.0	100.0	94.5
"	(138kV/69kV)	100.0	100.0	103.0
Pascuales	(230kV/138kV)	95.0	100.0	95.0
Milagro	(")	97.5	100.0	95.0
"	(138kV/69kV)	97.0	100.0	102.5
Paute	(230kV/138kV)	96.5	100.0	100.0
Ibarra	(138kV/69kV)	92.0	97.0	94.5
Ambato	(")	93.5	96.5	95.0
Quito	(138kV/46kV)	96.0	95.0	99.0
Esmeraldas	(138kV/69kV)	100.0	100.0	95.5
Portoviejo	(")	100.0	97.0	97.5
Santa Elena	(")	98.0	97.0	94.5
Babahoyo	(")	99.0	99.0	101.0
Cuenca	(")	98.0	97.5	95.0
Guayaquil	(")	97.0	95.0	99.0
Machala	(")	-	-	97.5
Loja	(")	-	-	93.5

Note: (1) L.T.C to be installed in Substations will be equipped with transformers.

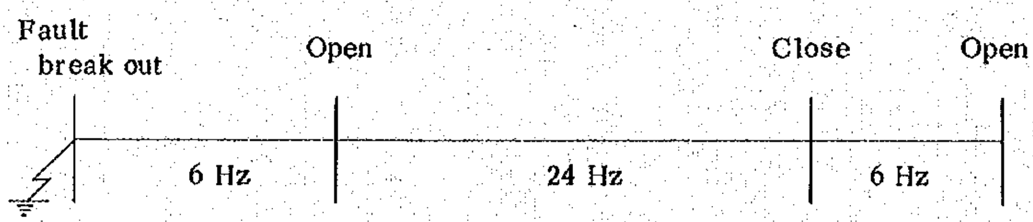
(2) Figures indicate percent voltage based on 230kV and 138kV

(3) Supply Particulars of Power Plants

The total supply capability in the interconnected system will be 742 MW in 1980 and 1,274 MW in 1985, and the corresponding peak loads will be 652 MW and 1,124 MW, respectively. Thus, the respective supply reserve capacities are 90 MW (14%) and 150 MW (13%). The load of each power plant will be distributed in such a way that hydraulic-power and steam-power plants will take the base load, while gas and diesel-power plants will partially carry the peak load. A break-down of power supply capability of each plant is shown in Table 7-20.

7-4-3 Range of Transient Stability

The results of system transient stability calculations are shown in Table 7-21. An analysis is made of a case of re-closing a single-circuit line, assuming that a 3-phase, ground short-circuit has occurred at peak load time in 1985. The circuit-breakers on both ends of the faulty transmission line are to operate in a sequence of O-CO, at the following intervals.



The power flow just before occurrence of the faults is shown in Fig. 7-8. The results of analysis on the two-circuit Paute-Milagro Section indicate, as shown in the swing curves of Figs. 7-9 to 7-12, that in the event of a 3-phase, ground short-circuit in a single-circuit of a two-circuit line, the system will remain stable, provided that not more than three generator units (Output 300 MW) are in service at the Paute Hydraulic Power Plant. In this case, if four or more units (Output 400 MW) are put into commission at the plant (Fig. 7-11), system stability will be lost and the generator units will lose synchronism in about 0.6 sec. If the Paute Hydraulic Power Plant is operated at 500 MW and the Paute-Milagro line is extended to three circuits, system stability will be assured in any of the previously mentioned transmission line faults. Therefore, the Paute-Milagro transmission line will be expanded to three-circuits at the same time the Paute Hydraulic Power Plant output is increased to 400 MW in 1983.

7-4-4 Short-Circuit Capacity

The distribution of short-circuit capacities at peak load in 1985 is shown in Fig. 7-13.

The short-circuit capacities of the principal power plants and transforming stations are shown in Table 7-22, which indicates that the breaking capacities of the circuit breakers may be safely chosen as 5,300 MVA on the 230 kV side, 3,100 MVA on the 138 kV side, and 1,600 MVA on the 69 kV side.

Incidentally, in this calculation, xd' is used as generator constant.

Table 7 - 20 Break Down of Supply Capability

Unit : MW

Station	Dependable firm power	1980 Peak	1980 Off Peak	1985 Peak
Ibarra	H - 7.1	H - 7.1	0	H - 7.1
	D - 3.8	D - 0	0	0
Sub total	10.9	7.1	0	7.1
Quito	H - 85.5	H - 85.5	H - 75.0	H - 85.5
	G - 23.4	G - 23.4	0	G - 23.4
	D - 39.0	D - 39.0	0	D - 31.1
Sub total	147.9	147.9	75.0	140.0
Santo Domingo	D - 7.8	0	0	0
Ambato	H - 13.4	H - 13.4	H - 13.4	H - 13.4
	D - 19.6	D - 16.6	0	D - 13.6
Sub Total	33.0	30.0	13.4	27.0
Cuenca	H - 12.9	H - 12.9	H - 12.9	H - 12.9
	D - 21.0	D - 17.1	0	D - 14.1
Sub total	33.9	30.0	12.9	27.0
Loja	H - 2.4	-	-	H - 2.4
	D - 6.0	-	-	0
Sub total	8.4	-	-	2.4

Station	Dependable firm power	1980		1985
		Peak	Off Peak	Peak
Esmeraldas	D - 15.8	D - 11.5	0	D - 11.5
Portoviejo	G - 9.7	G - 9.7	0	G - 9.7
	D - 20.0	D - 15.3	0	D - 15.3
Sub total	29.7	25.0	0	25.0
Guayaquil	S - 61.1	S - 61.1	S - 30.0	S - 61.1
	G - 94.6	G - 94.6	0	G - 94.6
	D - 7.4	D - 0	0	D - 0
Sub total	163.1	155.7	30.0	155.7
Sta. Elena	D - 10.6	D - 10.0	0	0
Milagro	D - 6.4	0	0	0
Babahoyo	D - 15.3	D - 13.1	0	D - 13.1
Quevedo	D - 9.0	0	0	0
Machala	H - 2.2	-	-	H - 2.2
	D - 17.5	-	-	D - 11.3
Sub total	19.7	-	-	13.5

Station	Dependable firm power	1980 Peak	1980 Off Peak	1985 Peak
Centro Norte	D - 29.1	D - 29.1	0	D - 29.1
Pisayambo	H - 69.2	H - 69.2	H - 65.0	H - 69.2
Guayaquil	S - 69.6 S - 69.6	S - 69.6 S - 56.8 (Swing G)	S - 30.0 S - 37.4 (Swing G)	S - 69.6 S - 60.6 (Swing G)
Paute (Service in 1981)	H - 100 x 5	-	-	H - 100 x 5
Total	H - 692.7 S - 200.3 G - 127.7 D - 228.2	H - 188.1 S - 187.5 G - 127.7 D - 151.7	H - 166.3 S - 97.4 G - 0 D - 0	H - 692.7 S - 190.7 G - 127.7 D - 139.1
	1,248.9	655.0	263.7	1,150.2
Total Demand (Except Loss)		652.4	260.8	1,124.2

Note: H : Hidro Power Plant G : Gas Power Plant
S : Steam Power Plant D : Diesel Power Plant

Table 7 - 21

Year	Output of Paute P.S.	Fault Points	Judgement	Reference
	500 MW	Paute - Milagro	Steady	Paute-Milagro 3 cct
	"	"	Unsteady	"
				2 cct
1985	400 MW	"	"	"
	300 MW	"	Steady	"
	500 MW	Pascuales-Quevedo	"	"

Table 7 - 22 Short Circuit Capacity

Station		Breaking Capacity (MVA)	Remarks
Santa Rosa	230kV	950	Xd' is used as generator constant
"	138kV	1,022	
Santo Domingo	230kV	978	
"	138kV	333	
"	69kV	216	
Quevedo	230kV	1,117	
"	138kV	543	
"	69kV	284	
Pascuales	230kV	1,646	
"	138kV	1,547	
Milagro	230kV	1,649	
"	138kV	1,028	
"	69kV	452	
Paute	230kV	1,982	
"	138kV	544	
"	Generator Terminal	2,426	
Quito	138kV	939	
"	46kV	963	
Guayaquil	138kV	1,352	
"	69kV	1,535	

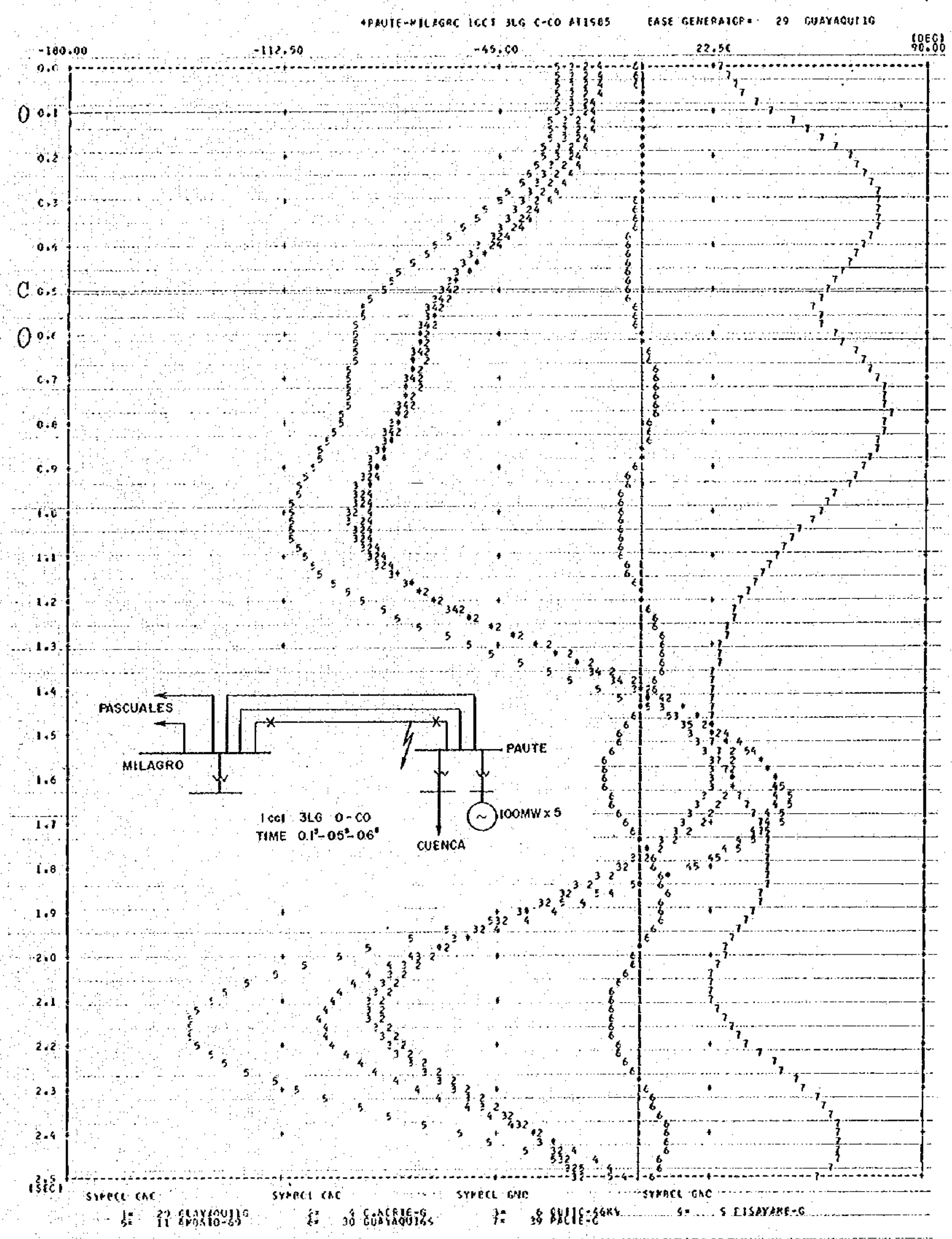


Fig. 7-9 Transient Stability at Peak Time in 1985
* PAUTE-MILAGRO 1cct 3LG O-CO

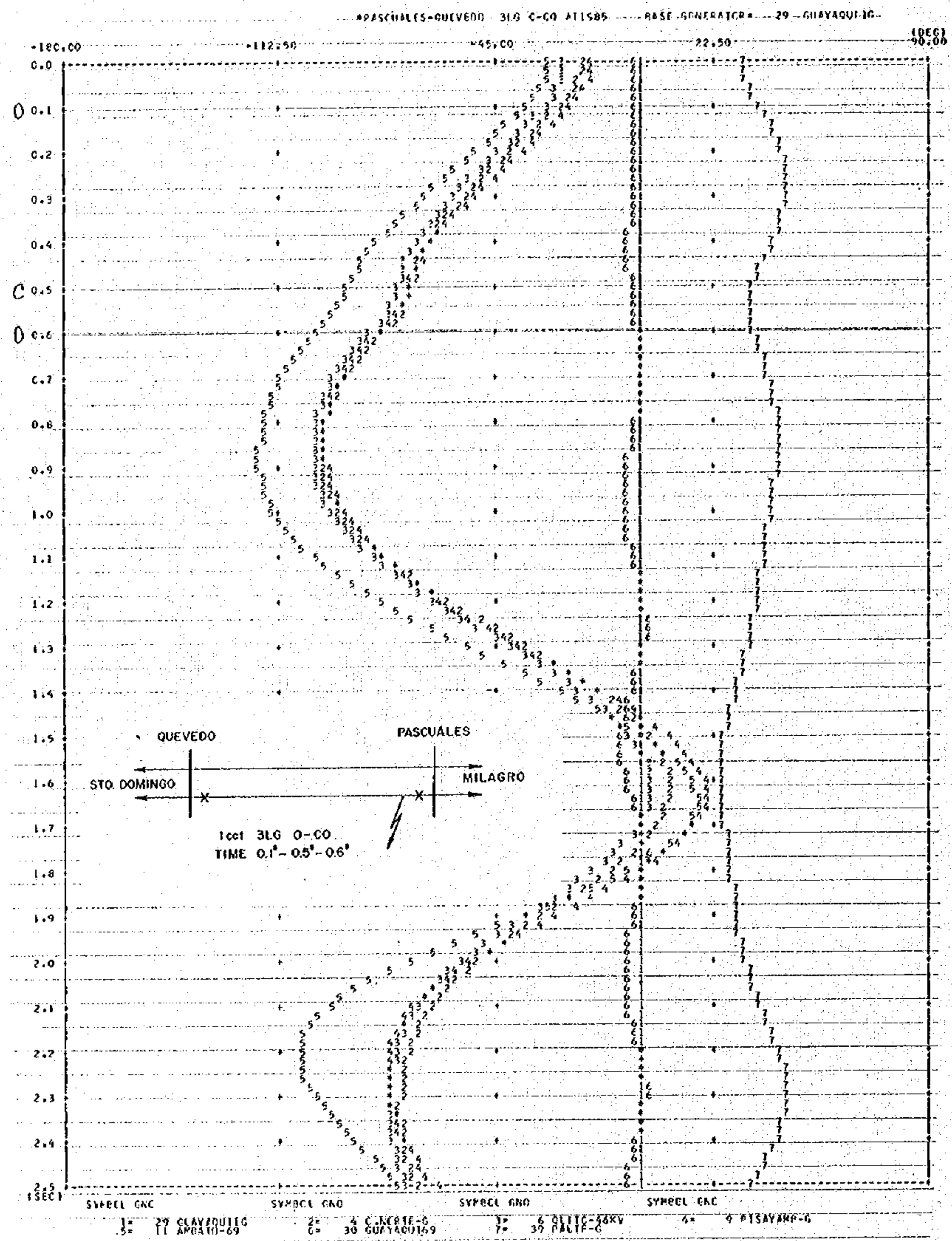


Fig. 7-10 Transient Stability at Peak Time in 1985
＊ PASCUALES – QUEVEDO 1cct 3LG O-CO

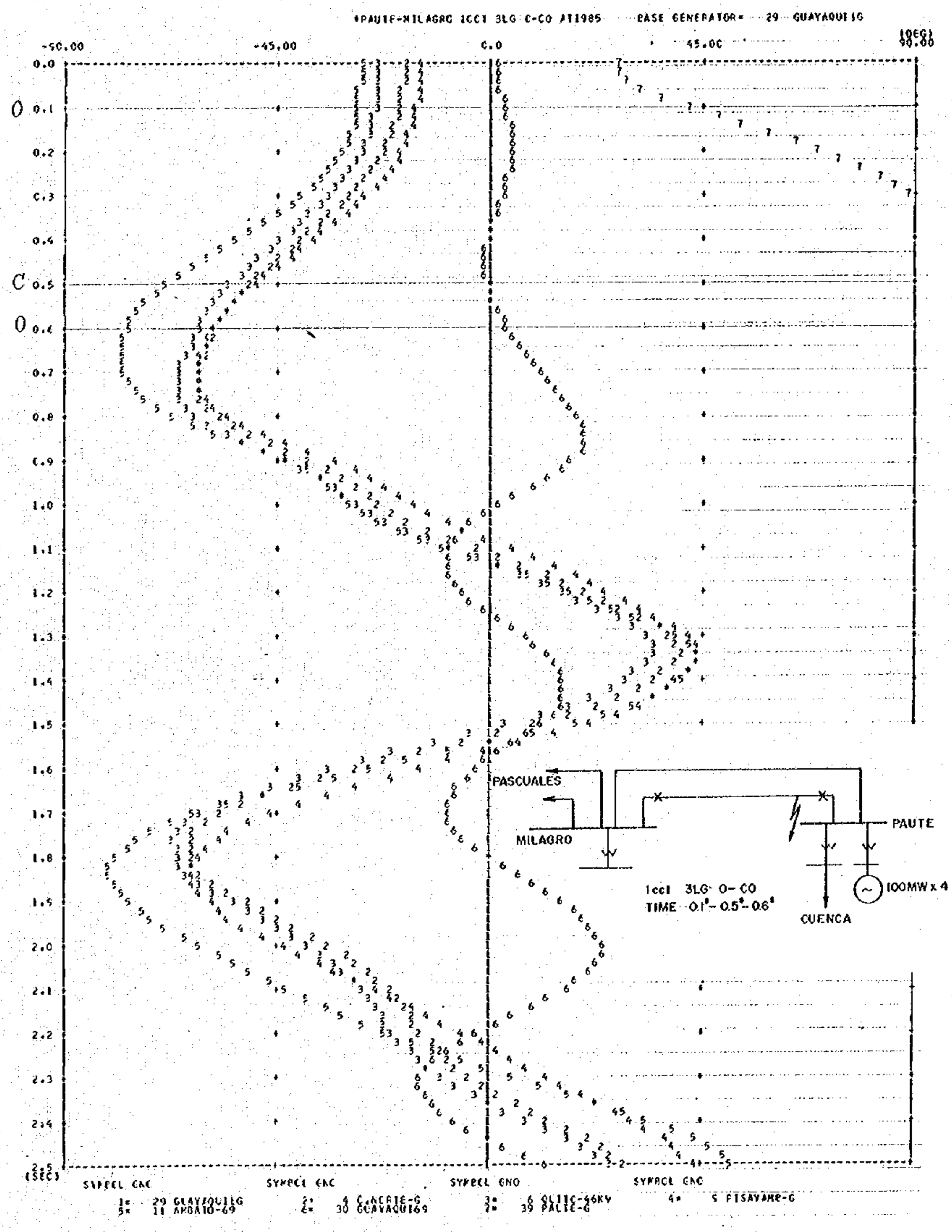


Fig. 7-11 Transient Stability at Peak Time in 1985
* PAUTE-MILAGRO 1cct 3LG O-CO.

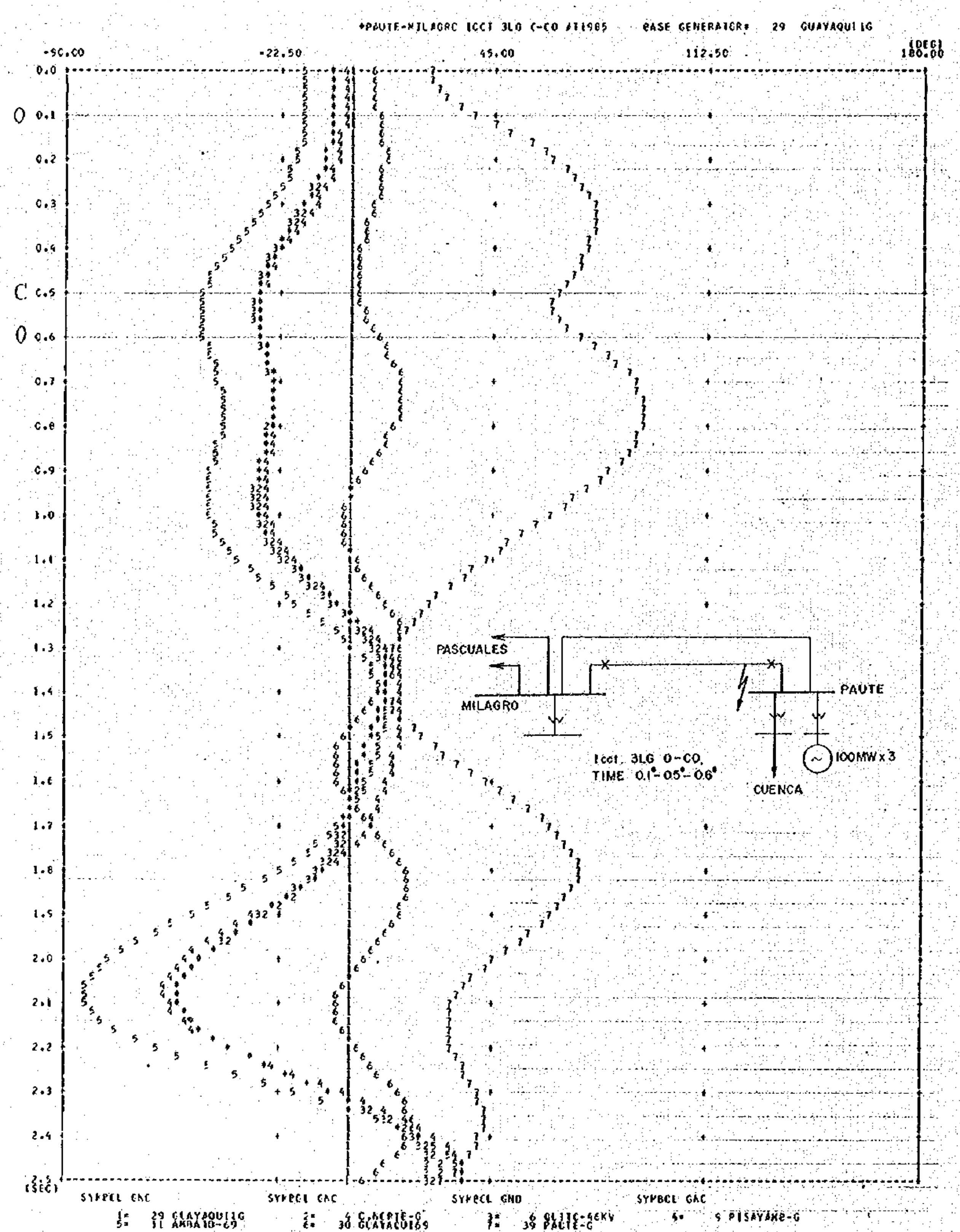


Fig. 7-12 Transient Stability at Peak Time in 1985
* PAUTE - MILAGRO 1cct 3LG O-CO

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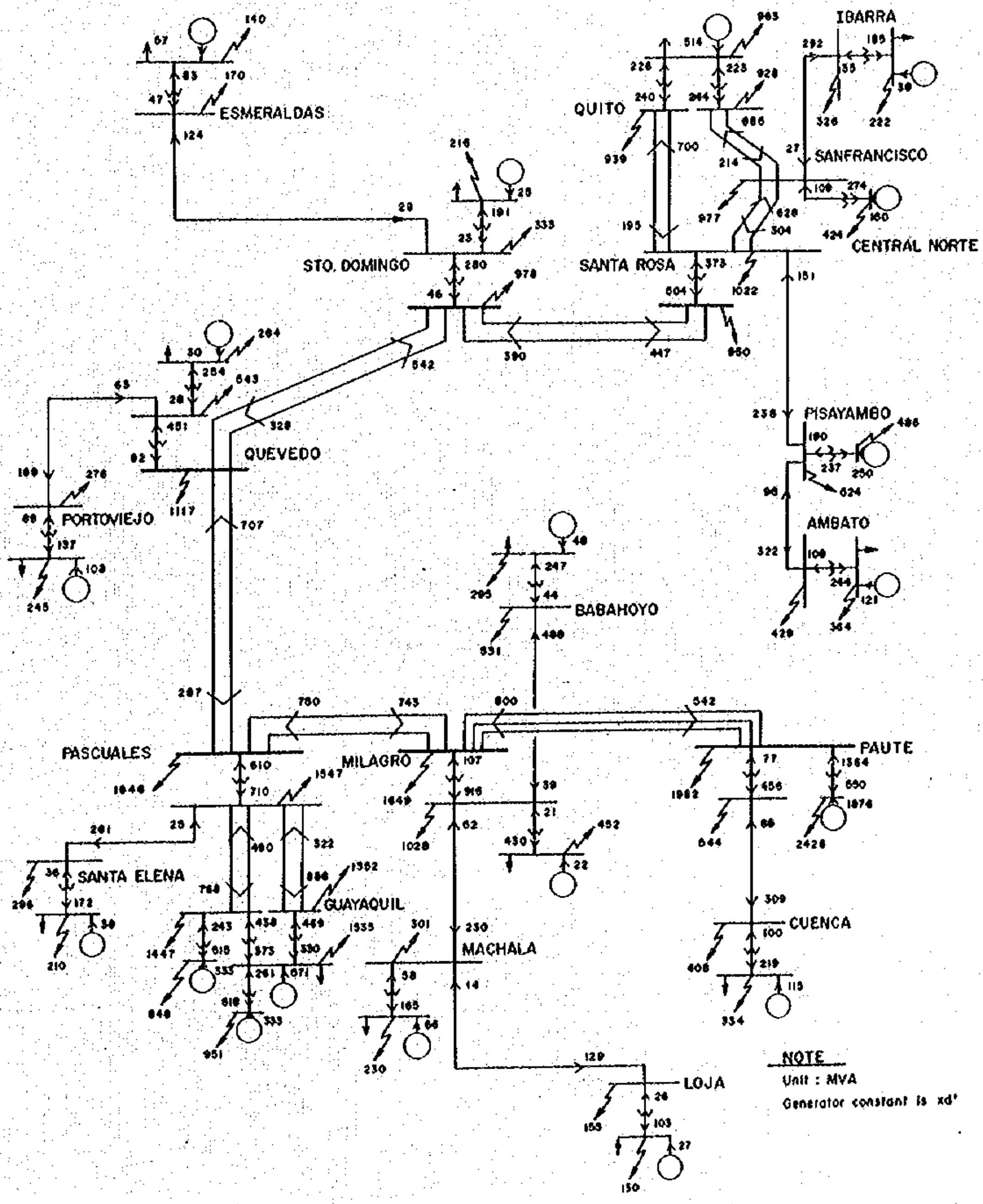
Fig. 7-13 Short Circuit Capacity at 1985 P



CHAPTER 8

INVESTMENT SCHEME

CHAPTER 8. INVESTMENT SCHEME

8-1 Required Investment Amount

8-1-1 Scope of Investment Scheme

In the scope of the investment scheme of this Report, it was decided to include the power generation projects, the National Interconnecting Power Transmission and Transforming Program, and the Regional Electrification Program described in Chapter 5 as composing the Long-Range Electric Power Development Program, survey costs, personnel training costs, and further, the funds required up to 1984 for power generation projects to be developed in and after 1985.

8-1-2 Investment Amount

The total investment amount required in the ten-year period from 1975 through 1984 will be 882.38 million US dollars, and it will be necessary to invest an annual average of 88.24 million US dollars, Of this amount, the investment amount required for power generation projects will be 576.38 million US dallars, while the amount for power transmission and substation facilities will be 175.40 million US dollars. INECEL will also bear a part of the necessary funds for the Regional Electrification Program which will amount to 73.60 million US dollars, while the amount for surveys, personnel training and others will be 57.00 million US dollars.

The investment fund requirements in domestic and foreign currencies are shown in Table 8-1 and the construction costs by year in Table 8-2.

Table 8-1 Investment Required by Year

Unit : 10^3 US $

	F.C.	L.C.	Total
(1) Generation facilities	341,150	141,950	483,100
(2) National interconnecting transmission and transforming facilities	139,230	36,170	175,400
(3) Facilities to be developed in and after 1985	38,580	54,700	93,280
(1) ~ (3) Sub total	518,960	232,820	751,780
(4) Regional electrification project	51,520	22,080	73,600
(5) Investigation cost and others	14,390	42,610	57,000
(4) ~ (5) Sub total	65,910	64,690	130,600
(1) ~ (5) Total	584,870	297,510	882,380

Note : F.C. Foreign Currency L.C. Local Currency

Table 8-2 Investment Schedule by Year

Projects		1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total
1. Hydro plant	F.C.	17,070	31,350	51,460	57,560	63,430	38,710	14,460	7,820	5,800	17,480	305,140
	L.C.	13,500	20,150	23,400	24,780	20,590	11,500	340	180	8,300	10,990	133,750
	Total	30,570	51,500	74,860	82,340	84,020	50,210	14,800	8,000	14,120	28,470	438,890
2. Thermal plant	F.C.	4,760	19,450	14,660	13,750	5,110	—	—	—	9,460	7,400	74,590
	L.C.	1,840	11,350	11,440	2,450	390	—	—	—	2,320	33,110	62,900
	Total	6,600	30,800	26,100	16,200	5,500	—	—	—	11,780	40,510	137,490
3. Transmission line	F.C.	7,880	33,040	32,930	43,470	16,340	5,570	—	—	—	—	139,230
	L.C.	3,460	6,200	5,850	7,820	8,960	3,880	—	—	—	—	36,170
	Total	11,340	39,240	38,780	51,290	25,300	9,450	—	—	—	—	175,400
National System Total (1 + 2 + 3)	F.C.	29,710	83,840	99,050	114,780	84,880	44,280	14,460	7,820	15,260	24,880	518,960
	L.C.	18,800	37,700	40,690	35,050	29,940	15,380	340	180	10,640	44,100	232,820
	Total	48,510	121,540	139,740	149,830	114,820	59,660	14,800	8,000	25,900	68,980	751,780
4. Regional system	F.C.	14,700	13,090	10,990	8,190	4,550	—	—	—	—	—	51,520
	L.C.	6,300	5,610	4,710	3,510	1,950	—	—	—	—	—	22,080
	Total	21,000	18,700	15,700	11,700	6,500	—	—	—	—	—	73,600
5. General investment	F.C.	1,000	1,060	1,490	1,460	1,800	1,580	1,500	1,500	1,500	1,500	14,390
	L.C.	1,000	940	1,010	1,040	1,200	1,420	1,500	1,500	1,500	1,500	12,610
	Total	2,000	2,000	2,500	2,500	3,000	3,000	3,000	3,000	3,000	3,000	27,000
6. Investigation and study	F.C.	—	—	—	—	—	—	—	—	—	—	—
	L.C.	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	20,000
	Total	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	20,000
7. Training and education	F.C.	—	—	—	—	—	—	—	—	—	—	—
	L.C.	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	10,000
	Total	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	10,000
Total investment	F.C.	45,410	97,990	111,530	124,430	91,230	45,860	15,960	9,320	16,760	26,380	584,870
	L.C.	29,100	47,250	49,410	42,600	36,090	19,800	4,840	4,680	15,140	48,600	297,510
	G.Total	74,510	145,240	160,940	167,030	127,320	65,660	20,800	14,000	31,900	74,980	882,380

8-2 Income and Expenditure Balance

8-2-1 Investment Amount for National Interconnected System

The income and expenditure balance of the Long-Range Electric Power Development Program was studied for the ten-year period from 1975 through 1984 which is the period of implementation of the present long-range scheme.

The investment amount which must be considered in examination of this income and expenditure balance is the total construction cost of the power generation projects for the National Interconnected System and the National Interconnecting Power Transmission and Transforming Program, and the toatl amount required is 751.8 thousand US dollars

8-2-2 Fund Procurement

(1) Reserves from Petroleum Concession Royalties

The Ecuadorian Government has decreed that 47 % of income from royalties accompanying petroleum exports are to be put up as reserves for electric power development funds of INECEL.

This concession income depends on petroleum production plans and those production plans are for 180 x 10^3 bbl/day from 1975 until 1979, and for 140 x 10^3 bbl/day from 1980. The ensuing reserves for INECEL from the concession royalties will be 53.20 million US dollars annually for the five-years period until 1979 and this will become 41.40 million US dollars annually from 1980 and after. Therefore, the total amount reserved for the ten-years period from 1975 through 1984 will be 473.00 million US dollars, Of this total amount of 473.00 million US dollars, the investment amount necessary for the Regional Electrification Program, survey costs and personnel training cots totals 130.60 million US dollars, and the investment amount reserved for the Interconnected National System will be 342.40 million US dollars.

The investment amounts reserved by year are given in Table 8-3.

(2) Depreciation Cost

As from 1977 and after, power generation projects for the National Interconnected System and the National Interconnecting Power Transmission and Transforming Program will be completed in succession and facilities depreciation costs of these projects will ensue and it will be possible for these to be reinvested as construction funds. The total of these facilites depreciation costs will be 90.60 million US dollars.

Depreciation costs by year are as indicated in Table 8-3.

(3) Loans from Foreign Countries

Of the construction funds required, it will be necessary for the amount exceeding the total of the reserves from the petroleum concession royalties and the facilities depreciation costs to be secured by loans from foreign countries.

Table 8-3 Investment Assigned to the National Interconnected System

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total
A. Petroleum concession (Revenue)	53,200	53,200	53,200	53,200	53,200	41,400	41,400	41,400	41,400	41,400	473,000
B. Regional system	21,000	18,700	15,700	11,700	6,500	—	—	—	—	—	73,600
C. General investment	2,000	2,000	2,500	2,500	3,000	3,000	3,000	3,000	3,000	3,000	27,000
D. Investigation and study	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	20,000
E. Training and education	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	10,000
Sub total (B ~ E)	26,000	23,700	21,200	17,200	12,500	6,000	6,000	6,000	6,000	6,000	130,600
F. Investment assigned from the petroleum concession to the national interconnected system	27,200	29,500	32,000	36,000	40,700	35,400	35,400	35,400	35,400	35,400	342,400
G. Depreciation from the national interconnected system	—	—	1,320	4,590	7,110	10,030	16,410	16,570	17,050	17,530	90,610
H. Investment assigned to the national interconnected system (F + G)	27,200	29,500	33,320	40,590	47,810	45,430	51,810	51,970	52,450	52,930	433,010
I. Construction expenditure	48,510	121,540	139,740	149,830	114,820	59,660	14,800	8,000	25,900	68,980	751,780
Exterior borrowing (H - I)	- 21,310	- 92,040	-106,420	-109,240	- 67,010	- 14,230	—	—	—	- 16,050	-426,300

The total amount of these loans, as shown in Table 8-3, will be 426.30 million US dollars. Of this amount, the foreign loans already definite are 121.20 million US dollars. Therefore, the foreign loans to be expected will be as many as 305.10 million US dollars by 1984.

(4) Interest on Foreign Loans and Repayment Conditions

The interest and repayment conditions concerning the foreign loans mentioned in (3) above are as described below.

1) Paute Hydro Power Plant

Of the funds for civil works of Paute Hydroelectric Power Plant the Inter-American Development Bank (IDB) has made a long-term, low-interest loan for the foreign currency portion, which is divided into a "special fund" and an "ordinary fund," and the conditions set are as follows:

Special Fund

Interest	: during grace period 1.0%
	: other 2.0%
Repayment Period	: 40 years (including 10-year grace)

Ordinary Fund

Interest	: 8%
Repayment Period	: 20 years (including 5-year grace)

2) Norte Thermal Power Plant

The Japanese Government and the Export-Import Bank of Japan have made loans, and the conditions set are as follows:

Primary Loan (Japanese Government Loan)

Interest	: 4.75%
Repayment Period	: 20 years (including 7-year grace)

Secondary Loan (Export-Import Bank of Japan)

Interest	: 7.5%
Repayment Period	: 7 years (including 2-year grace)

3) Guayaquil Thermal Power Plant

Contract conditions are being negotiated for the Guayaquil thermal power generating facilities, and since it may be considered probable that an interest rate of 7.5% and a repayment period of ten years after the final shipment will be concerted, these conditions will be applied.

4) New Loans

The conditions stated above were applied to the above three projects, while regarding the undecided part of the amount of loans which will be made under the conditions below being considered by INECEL the repayment conditions and the interest and principal repayment plan required for the income and expenditure balance were examined.

Interest	: 8% per annum
Repayment Period	: 9 years (including 3-year grace)

8-2-3 Energy Sales Income

The electric power produced at such power stations as Paute Hydro and Guayaquil Thermal to be developed by INECEL will be transmitted to the various regional systems through nation-wide interconnected transmitting and transforming facilities, and will be sold wholesale to the electric power companies in the various regions at the secondary sides of 138/69 kV substations (hereinafter called secondary substations).

The energy sales income of INECEL must be calculated applying the current electricity tariff based on wholesale energy amounts. However, as even INECEL has pointed out, the present electricity tariff system in Ecuador is not suitable to be adopted for calculating energy sales income for economic evaluation of this project because of such reasons as i) a proper profit is not taken into account, ii) re-evaluation of assets has not been made, and iii) the fuel costs of thermal power stations are extremely low compared with international prices. Therefore, the tariff system was disregarded here and as described in (1) below, the energy cost at the wholesale points, namely, the secondary sides of secondary substations, is adopted as the unit energy sales price for calculation of the energy sales income and examination of the income and expenditure balance.

(1) Unit Energy Sales Price

The unit energy sales price to be applied to the funding plan for the Long-Range Electric Power Development Program is to be, as shown in Table 8-4, 30.5 mills/kWh, or the unit average energy cost during service life of the generating, transmission and transforming facilities to be developed by INECEL during the ten-year period from 1975 to 1984, including Quito Diesel Plant, Guayaquil Thermal Power Plant, Pisayambo Hydroelectric Power Plant, Paute Hydroelectric Power Plant, and the national interconnecting transmission and transforming facilities.

This unit price is cheaper by 13.0 mills/kWh compared with the generating cost at diesel power plants as alternative facilities, and may be said to be reasonable.

Table 8-4 Energy Cost at 138 kV Substation End

n.	Year	Energy requirement at generating end: Hydro (GWh)	Thermal (GWh)	Total (GWh)	Annual cost: Hydro (10^3 US$)	Thermal (10^3 US$)	Transmission (10^3 US$)	Total (10^3 US$)	Unit generating cost (mills/kWh)
1.	1977	—	138	138	—	5,303	1,951	7,254	52.6
2.	1978	212	438	650	9,009	13,696	5,931	28,636	44.1
3.	1979	212	591	803	9,009	19,710	11,783	40,502	50.4
4.	1980	212	898	1,100	9,009	23,303	20,880	53,192	47.9
5.	1981	1,964	409	2,373	51,133	17,414	25,521	94,068	39.6
6.	1982	2,330	432	2,762	52,033	17,695	25,521	95,249	34.5
7.	1983	2,696	447	3,143	52,934	17,882	25,521	96,337	30.7
8.	1984	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
9.	1985	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
10.	1986	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
11.	1987	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
48.	2024	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
49.	2025	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
50.	2026	3,062	493	3,555	53,835	18,443	25,521	97,799	27.5
	Total	139,292	24,552	163,844	2,498,032	908,052	1,214,511	4,620,595	—

Unit average generating cost during service life : 30.5 mills/kWh.

(2) Energy Sales

The salable energy as shown in Table 8-5 was obtained by allotting, in terms of supply and demand balance, the demand to be met with the generating facilities owned by INECEL out of the demand to be met with all the generating facilities to be connected with the National Interconnected System and subtracting from the allotted demand of INECEL the transmission loss of 2% to the secondary sides of secondary substations.

The salable energy by year is as indicated in Table 8-6.

(3) Energy Sales Income

The energy sales income of INECEL determined from the unit energy sales price and the energy sales described in (1) and (2) above is as indicated in Table 8-6, "Statement of Income". The energy sales income is counted from 1977 when Norte Thermal will come into operation, and the income of 4.10 million US dollars in this year will be increased to 106.30 million US dollars in 1984.

8-2-4 Operation and Maintenance Costs and Depreciation Costs

In calculation of operation and maintenance costs and depreciation costs of projects for the Long-Range Electric Power Development Program, the calculation standards of INECEL were employed as indicated below.

(1) Operation and Maintenance Costs

The annual costs for operation and maintenance of power generation, transmission and transforming facilities are as follows:

Thermal power generating facilities	: 4.0 % of construction cost per year
Hydroelectric power generating facilities	: 2.1 % of construction cost per year
Power transmission and transforming facilities	: 3.3 % of construction cost per year

(2) Depreciation

Depreciation calculations of power generation, transmission and transforming facilities were made by the straight line method establishing service lives as indicated below.

Hydroelectric power generating facilities	: 50 years
Steam thermal power generating facilities	: 25 years
Diesel thermal power generating facilities	: 20 years
Power transmission and transforming facilities	: 30 years

Table 8-5 Generating Energy Share to be Borne between INECEL and Private Utilities

Unit : GWh

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Demand at generating end (MW)	342.78	395.10	466.07	537.10	604.95	682.91	754.63	834.44	922.11	1,018.70
Demand at generating end (GWh)	1,435.07	1,659.02	1,995.67	2,314.25	2,597.25	2,933.87	3,237.73	3,576.95	3,950.41	4,366.36
Hydro										
Private utilities	607.75	637.04	642.82	688.29	688.29	688.29	688.29	688.29	688.29	688.29
PISAYAMBO (76.2 MW)	—	—	—	212.00	212.00	212.00	212.00	212.00	212.00	212.00
PAUTE (200～500 MW)	—	—	—	—	—	—	1,752.00	2,118.00	2,484.00	2,850.00
Sub total	607.75	637.04	642.82	900.29	900.29	900.29	2,652.29 (392.70)	3,018.29 (492.70)	3,384.29 (592.70)	3,750.29 (692.70)
Thermal										
Private utilities	827.32	1,021.98	1,214.88	975.96	1,105.66	1,135.68	176.88	126.95	119.00	123.03
Nothern thermal (INECEL)	—	—	137.97	131.40	131.40	131.40	408.56	431.71	447.12	493.33
Guayaquil thermal	—	—	—	306.60	459.90	766.50	(176.00)	(176.00)	(176.00)	(176.00)
Sub total	827.32	1,021.98	1,352.85	1,413.96	1,696.96	2,033.58	585.44 (365.93)	558.66 (341.74)	566.12 (329.41)	616.36 (326.00)
Total	1,435.07	1,659.02	1,995.67	2,314.25	2,597.25	2,933.87	3,237.73	3,576.95	3,950.41	4,366.36
Generating energy by INECEL	-	-	137.97	650.00	803.30	1,109.90	2,372.56	2,761.71	3,143.12	3,555.33

Table 8-6 Statement of Income (Unit sales price : 30.5 mills/kWh)

Unit : x 10^3 US$

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Gross revenue	—	—	4,120	19,430	24,010	33,180	70,910	82,540	93,950	106,270
Generated energy (MWh)	—	—	137,910	650,000	803,300	1,109,900	2,372,560	2,761,710	3,143,120	3,555,330
Energy sales (MWh)	—	—	135,150	637,000	787,230	1,087,700	2,325,110	2,706,480	3,080,260	3,484,220
Unit sales price (mills/kWh)	—	—	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
(B) Total operation cost	90	330	4,860	15,620	21,190	30,090	36,760	38,530	39,420	40,630
1. Operation and maintenance	—	—	990	4,680	5,720	7,990	14,140	15,450	15,620	15,660
2. Fuel cost	—	—	1,950	5,460	7,250	10,850	4,960	5,240	5,430	5,990
3. Administration cost	90	330	600	890	1,110	1,220	1,250	1,270	1,320	1,450
4. Depreciation	—	—	1,320	4,590	7,110	10,030	16,410	16,570	17,050	17,530
(C) Operating income (A)—(B)	−90	−330	−740	3,810	2,820	3,090	34,150	44,010	54,530	65,640
(D) Financial expenditure (Interest)	170	170	2,830	5,720	10,210	17,970	22,910	20,390	17,320	12,880
(E) Net income (C)—(D)	−260	−500	−3,570	−1,910	−7,390	−14,880	11,240	23,620	37,210	52,760

(3) Fuel Cost (Bunker C Oil)

Norte Thermal (Diesel)	: US$ 50.7/ton
Guayaquil Thermal (Steam)	: US$ 47.4/ton

(4) Administrative Costs

Thermal power generating facilities	: 0.2 % of construction cost per year
Hydroelectric power generating facilities	: 0.2 % of construction cost per year
Power transmission and transforming facilities	: 0.2 % of construction cost per year

8-2-5 Income and Expenditure Balances

The income and expenditure balances in the funding plan are as indicated in Table 8-6, "Statement of Income" and Table 8-7, "Statement of Cash Flow." In effect, the cash balance until 1981 when the National Interconnection Power Transmission and Transforming Program is completed and Paute Hydro comes into operation will show a deficit. This will be due to repayments of outside loans introduced for the National Interconnection Power Transmission and Transforming Program and power generation projects to be started from 1975. The reason why the deficit will be so large is the loan conditions for the amount expected to be borrowed with interest of 8 % per annum and repayment in nine years including three years of grace, which are fairly severe for such a plant intensive industry as the electric power industry, and therefore, if the conditions were to be soft as those generally applied to electric power industry, it is thought that a surplus can be expected from 1981, when construction of Paute Hydro will be completed, and thereafter.

As shown in Table 8-7, the cumulative deficit up to 1984 will reach 80.3 million US dollars. If the unit energy sales price for bringing this cumulative deficit to roughly zero in 1984 were to be sought, it would be 36.1 mills/kWh, and the Statement of Income in case this price is applied is as shown in Table 8-8, and the Statement of Cash Flow as in Table 8-9. As indicated in Table 8-9, the cash balance will show a change to surplus in 1981 when Paute Hydroelectric Power Station will come into operation, and the surplus in 1984 will reach an amount of 18.7 million US dollars. Therefore, in order to minimize the extent of the deficit, it would be desirable to introduce construction funds which are more long-term and low-interest.

Table 8-7 Statement of Cash Flow (Unit sales price : 30.5 mills/kWh)

Unit : 10^3 US$

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Cash receipt	48,250	121,040	136,170	147,920	107,430	46,780	63,050	75,590	89,660	121,740
1. Net income	−260	−500	−3,570	−1,910	−7,390	−16,880	11,240	23,620	37,210	52,760
2. Depreciation	—	—	1,320	4,590	7,110	10,030	16,410	16,570	17,050	17,530
3. INECEL's capital (Petrolum concession)	27,200	29,500	32,000	36,000	40,700	35,400	35,400	35,400	35,400	35,400
4. Exterior borrowing	21,310	92,040	106,420	109,240	67,010	14,230	—	—	—	16,050
(B) Cash disbursement	48,510	121,540	144,030	159,280	135,150	95,130	66,520	61,450	81,790	122,540
1. Construction expenditure	48,510	121,540	139,740	149,830	114,820	59,660	14,800	8,000	25,900	68,980
2. Amortization of debit (Capital)	—	—	4,290	9,450	20,330	35,470	51,720	53,450	55,690	53,560
(C) Cash balance (A)−(B)	−260	−500	−7,860	−11,360	−27,720	−50,350	−3,470	14,140	7,870	−800
(D) Accumulated total	−260	−760	−8,620	−19,980	−47,700	−98,500	−101,520	−87,380	−79,510	−80,310

Table 8-8 Statement of Income (Unit sales price : 36.1 mills/kWh)

Unit : 10^3 US$

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Gross revenue	—	—	4,880	23,000	28,420	39,270	83,940	97,700	111,200	125,780
Generated energy (MWh)	—	—	137,910	650,000	803,300	1,109,900	2,372,560	2,761,710	3,143,120	3,555,330
Energy sales (MWh)	—	—	135,150	637,000	787,230	1,087,700	2,325,410	2,706,480	3,080,260	3,484,220
Unit sales price (mills/kWh)	—	—	36.1	36.1	36.1	36.1	36.1	36.1	36.1	36.1
(B) Total operation cost	90	330	4,860	15,620	21,190	30,090	36,760	38,530	39,420	40,630
1. Operation and maintenance	—	—	990	4,680	5,720	7,990	14,140	15,450	15,620	15,660
2. Fuel cost	—	—	1,950	5,460	7,250	10,850	4,960	5,240	5,430	5,990
3. Administration cost	90	330	600	890	1,110	1,220	1,250	1,270	1,320	1,450
4. Depreciation	—	—	1,320	4,590	7,110	10,030	16,410	16,570	17,050	17,530
(C) Operating income (A)−(B)	−90	−330	20	7,380	7,230	9,180	47,180	59,170	71,780	85,150
(D) Financial expenditure (Interest)	170	170	2,830	5,720	10,210	17,970	22,910	20,390	17,320	12,880
(E) Net income (C)−(D)	−260	−500	−2,810	1,660	−2,980	−8,790	24,270	38,780	54,460	72,270

Table 8-9 Statement of Cash Flow (Unit sales price : 36.1 mills/kWh)

Unit : 10^3 US$

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Cash receipt	48,250	121,040	136,930	151,490	111,840	50,870	76,080	90,750	106,910	141,250
1. Net income	−260	−500	−2,810	1,660	−2,980	−8,790	24,270	38,780	54,460	72,270
2. Depreciation	—	—	1,320	4,590	7,110	10,030	16,410	16,570	17,050	17,530
3. INECEL's capital (Petrolum concession)	27,200	29,500	32,000	36,000	40,700	35,400	35,400	35,400	35,400	35,400
4. Exterior borrowing	21,310	92,040	106,420	109,240	67,010	14,230	—	—	—	16,050
(B) Cash Disbursement	48,510	121,540	144,030	159,230	135,150	95,130	66,520	61,450	81,790	122,540
1. Construction expenditure	48,510	121,540	139,740	149,830	114,820	59,660	14,800	8,000	25,900	68,980
2. Amortization of debit (Capital)	—	—	4,290	9,450	20,330	35,470	51,720	53,450	55,890	53,560
(C) Cash balance (A)−(B)	−260	−500	−7,100	−7,790	−23,310	−44,260	9,560	29,300	25,120	18,710
(D) Accumulated total	−260	−760	−7,860	−15,650	−38,960	−83,220	−73,660	−44,360	−19,240	−530