4.4 Results of Load Forecast

The following conclusions were drawn on analyzing the present state of power demand, and considering population trends, the present state of the electrification program, and the trends of new industrial demand.

Table 4-10 Comparison of Power Demand Projection

Unit : GWh

	Panay		Negros		Cebu		Leyte		Samar	
	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990
(1) Customers end										
JICA estimate	230	359	766	1,172	723	1,158	194	317	47	75
NPC estimate	260	337	1,171	1,507	1,033	1,531	519	964	55	84
JICA/NPC	0.88	1.06	0.65	0.77	0.70	0.76	0.37	0.33	0.85	0.89
(2) Generating end										
JICA estimate	307	422	1,021	1,563	904	1,448	259	422	59	94
NPC estimate	283	366	1,301	1,674	1,123	1,664	561	1,041	60	91
JICA/NPC	1.08	1.15	0.78	0.93	0.81	0.87	0.43	0.41	0.98	1.03

As shown in the table above, there are differences between the forecast values of the Survey Team and NAPOCOR. The differences at the customer ends are due to the different points for measurement of power demand. That is, whereas the power demand forecast by the Survey Team was based on the locations of installation of integrating watt-hour meters of individual customers, the power demand forecast by NAPOCOR is that at the 69 kV sides at primary substations as a wholesaler of electric power. Consequently, the transmission and distribution losses from primary substations to customers are not included while the losses from generating ends are calculated to be 9 to 10%. On the other hand, since the forecast values of the Survey Team are for demands at customer ends, in estimating the differences between customer ends and generating ends, present performances were taken into account and transmission and distribution losses of 25 to 20% were considered. As a result, the forecast figures of NAPOCOR and the Survey Team at generating ends are close together except for the case of Leyte, and it may be judged that the load forecasts of NAPOCOR are more or less reasonable. Accordingly, regarding power demands at the cross sections of 1985 and 1990 necessary for formulating the power transmission and transformation project, it was considered that the forecast values of NAPOCOR which are on the conservative side for such formulation should be adopted.

The above are results of energy forecasts. Regarding maximum demands, in consideration of past annual load factors and trends in new industrial demands, it is judged that the forecast figures of NAPOCOR are reasonable. The maximum demands used in Chapter 5, "Interconnected Power Transmission and Transformation Project," and Chapter 7, "Power System Analysis" are those given in Table 4-11, and the power demands at primary and secondary substations are determined by deducting transmission losses and station service losses at thermal power plants from the above-mentioned maximum demands.

The main reason the load forecasts for Leyte Island differ greatly between the Survey Team and NAPOCOR is the difference in the timing of completion of the Pasar Industrial Estate.

The power demands by island and by year forecast by NAPOCOR are indicated in Table 4-11.

Table 4-11-(1) Load Pick-up Forecast of Panay-Negros-Cebu Grid

Year	Panay Grid				Negros Grid				Cebu Grid				Total				
	Customer level	Generation level			Customer level	Generation level			Customer level	Generation level			Customer level	Generation level			
	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	
1974	58.5	9.5	63.6	76	98.0	19.6	105.7	62	168.5	37.8	208.9	63	325.0	66.9	378.2	65	Actual record
1975	66.2	10.6	71.9	77	107.6	20.9	115.9	63	181.9	40.5	220.8	51	355.7	72.0	408.6	65	
1976	73.8	13.9	80.2	66	109.3	20.8	117.8	65	191.4	43.6	238.5	62	374.5	78.3	436.5	64	
1977	83.5	18.7	90.7	55	90.0	16.8	97.5	66	249.0	64.0	301.6	54	422.5	99.5	489.8	56	
1978	97.1	20.5	105.5	59	125.8	26.1	139.6	61	389.0	72.0	452.6	72	611.9	118.6	697.7	67	
1979	105.0	23.0	114.0	57	134.0	27.0	145.0	61	389.6	73.0	453.0	71	628.6	121.0	712.0	67	
1980	183.0	41.0	199.0	55	146.0	28.0	160.0	65	438.0	80.0	509.0	73	767.0	146.0	868.0	68	
1981	199.0	43.0	216.0	57	196.0	42.0	214.0	58	571.0	105.0	621.0	68	966.0	186.0	1,051.0	65	
1982	215.0	46.0	234.0	58	410.0	83.0	445.0	61	757.0	137.0	823.0	69	1,382.0	261.0	1,502.0	66	
1983	232.0	49.0	252.0	59	745.0	141.0	827.0	67	873.8	152.0	950.0	71	1,850.8	335.0	2,029.0	69	
* 1984	245.0	51.0	266.0	60	958.0	177.0	1,064.0	69	948.9	164.0	1,031.0	72	2,151.9	384.0	2,361.0	70	
1985	260.0	54.0	283.0	60	1,171.0	215.0	1,301.0	69	1,032.7	180.0	1,123.0	71	2,463.7	440.0	2,707.0	70	
1986	275.0	57.0	299.0	60	1,238.0	226.0	1,375.0	69	1,123.0	192.0	1,221.0	73	2,636.0	466.0	2,895.0	71	
1987	290.0	59.0	315.0	61	1,305.0	238.0	1,450.0	70	1,215.9	208.0	1,322.0	73	2,810.9	495.0	3,087.0	71	
1988	305.0	61.0	332.0	62	1,370.0	249.0	1,521.0	70	1,316.8	225.0	1,431.0	73	2,991.8	525.0	3,284.0	71	
* 1989	322.0	64.0	350.0	62	1,439.0	261.0	1,598.0	70	1,419.6	240.0	1,543.0	73	3,180.6	554.0	3,491.0	72	
1990	337.0	67.0	366.0	62	1,507.0	276.0	1,674.0	69	1,530.6	255.0	1,664.0	74	3,374.6	586.0	3,704.0	72	
1991	350.0	70.0	381.0	62	1,567.0	287.0	1,741.0	69	1,622.4	270.0	1,763.0	74	3,539.4	614.0	3,885.0	72	
1992	364.0	74.0	396.0	61	1,630.0	299.0	1,811.0	69	1,719.8	287.0	1,870.0	74	3,713.8	647.0	4,077.0	72	
1993	379.0	78.0	412.0	60	1,695.0	310.0	1,883.0	69	1,823.0	304.0	1,982.0	74	3,897.0	678.0	4,277.0	72	
1994	394.0	81.0	428.0	60	1,763.0	323.0	1,958.0	69	1,932.3	322.0	2,101.0	74	4,089.3	712.0	4,487.0	72	
1995	410.0	86.0	445.0	59	1,833.0	336.0	2,037.0	69	2,048.3	341.0	2,227.0	74	4,291.3	748.0	4,709.0	72	
Annual increase (%)																	
'74 to '78	13.5	21.2	13.5	-	7.2	7.4	7.2	-	23.3	17.5	21.3	-	17.1	15.4	16.5	-	
'78 to '95	8.8	8.8	8.8	-	17.1	16.2	17.1	-	10.3	9.6	9.8	-	12.1	11.4	11.9	-	

Note : Source : SPD-CORPLAN 9-7-79/tgi of NPC Report

Integration of Negros, Panay, Cebu by 1984

Diversity factor = 1.02

* Power demand and energy for 1985 and 1990 were crossly checked by JICA Survey Team (Refer to Table A-1).

Table 4-11-(2) Load Pick-up Forecast of Leyte-Samar Grid

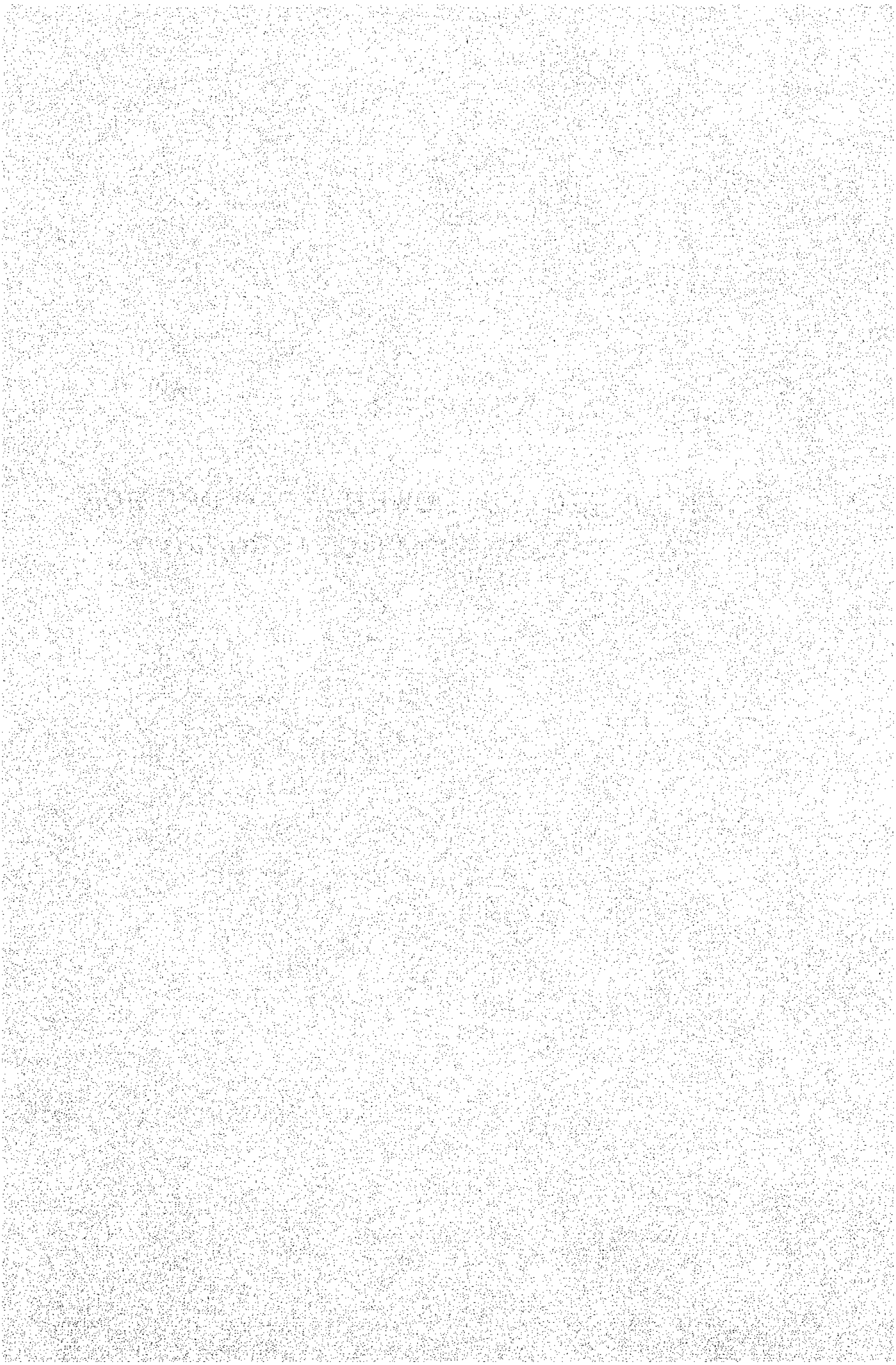
Year	Leyte Grid				Samar Grid				Total				
	Customer level	Generation level			Customer level	Generation level			Customer level	Generation level			
	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	Energy (GWh)	Demand (MW)	Energy (GWh)	L. F. (%)	
1974													
1975													
1976													
1977	3.1	0.6	3.3	60					3.1	0.6	3.3	60	} Actual record
1978	3.2	0.6	3.3	60					3.2	0.6	3.3	60	
1979	5.1	1.1	6.0	60					5.1	1.1	6.0	60	
1980	7.1	1.5	7.7	59					7.1	1.5	7.7	59	
1981	109.8	20.8	118.6	65					109.8	20.8	118.6	65	
1982	119.1	24.6	128.6	60					119.1	24.6	128.6	60	
1983	265.2	63.5	286.4	51					265.2	63.5	286.4	51	
1984	404.2	66.1	436.5	75	33.1	6.2	35.8	66	437.3	72.3	472.3	75	
* 1985	519.2	77.9	560.7	82	55.3	12.3	59.8	55	574.5	90.2	620.5	79	
1986	536.5	80.8	579.4	82	59.4	13.4	64.2	55	595.9	94.2	643.6	78	
1987	624.5	93.1	674.5	83	65.8	14.1	71.0	57	690.3	107.2	745.5	80	
1988	714.2	105.7	771.3	83	71.5	15.8	77.3	56	785.7	121.5	848.6	80	
1989	803.1	118.1	867.3	84	77.6	17.1	83.9	56	880.7	135.2	951.2	80	
* 1990	963.5	139.8	1,040.6	85	84.2	18.5	90.9	56	1,047.7	158.3	1,131.5	81	
1991	1,053.6	152.8	1,137.9	85	91.3	20.0	98.6	56	1,144.9	172.8	1,236.5	82	
1992	1,147.7	166.1	1,239.5	85	99.2	21.6	107.2	57	1,246.9	187.7	1,346.7	82	
1993	1,173.8	170.6	1,267.7	85	107.4	23.4	116.0	57	1,281.2	194.0	1,383.7	81	
1994	1,196.0	174.5	1,291.7	84	116.8	25.2	126.1	57	1,312.8	199.7	1,417.8	81	
1995	1,220.3	178.5	1,317.9	84	126.7	27.1	136.9	57	1,347.0	205.6	1,454.8	81	
Annual increase (%)													
'78 to '95	41.8	40.2	42.2	-	-	-	-	-	42.7	41.0	43.1	-	
'84 to '95	10.6	9.5	10.6	-	13.0	14.3	13.0	-	10.8	10.0	10.8	-	

Note : Source : Revised SPD-CORPLAN 9-1-79/eah of NPC Report

* Power demand and energy for 1985 and 1990 were crossly checked by JICA Survey Team (Refer to Table A-1).

CHAPTER 5

INTERCONNECTED POWER TRANSMISSION AND TRANSFORMATION PROJECT



CHAPTER 5 INTERCONNECTED POWER TRANSMISSION AND TRANSFORMATION PROJECT

5.1 Present State of Power System and Fundamental Considerations

The electric power system of the Visayas Region consists of small-scale independent systems on each of the islands. In general, these systems consist of small-capacity diesel generators from which power supply to neighboring cities, towns and village is carried out employing 69kV or 13.8kV transmission lines. Most of these power transmission and distribution systems on any one island are not interconnected. Consequently, it is inevitable for electric power costs to be comparatively high, and this is naturally the reason that large-scale industries are not located, while also, much cannot be expected of growth in residential power demand.

Fortunately, however, the Visayas Region is favored with geothermal energy, and if stable and cheap electric power can be obtained through development of this energy, a tremendous development of this region can be looked forward to. Development plans for hydro (including Bohol Island) up to 1993 amount to 145 MW, while regarding coal, there are indicated reserves of 510 million tons, but the economic feasibility of development of this coal has not yet been fully established. In development of a power source, it is fundamentally important for economy of scale to be pursued by making the facility as large as possible, while for the Visayas Region as a whole, consumption of petroleum must be reduced effectively utilizing indigenous energy (geothermal energy, hydro power, coal). For this purpose, the sizes of power systems must be made large, and it must be made possible for transportation of electric power between systems to be freely carried out. In other words, strong interconnections should be made within each island and between islands.

When interconnections are made, besides the effects mentioned above, there will be such effects as savings in reserve supply capacity, rational selection of periodic inspection periods, savings in spinning reserves, and narrowing of frequency and voltage variation range. Furthermore, to electrically connect the various islands will not have only economic effects, but also the effect of bringing a feeling of togetherness between the inhabitants of the islands. In fact, NAPOCOR is aiming for early realization of interconnections of Panay-Negros-Cebu and Leyte-Samar along with pushing forward with construction of large-capacity geothermal and coal-fired thermal power plants.

5.2 Panay-Negros-Cebu Power System

5.2.1 Power Demand and Supply

The outlines of the demand and supply situations on the three islands in 1985 and 1990 are as described below.

(1) Panay Power System

The demand on Panay will be 54 MW in 1985 and 67 MW in 1990, comparatively small, and only a little more than 10% of the total of the three islands. Except for sugar refining plants, there are no conspicuous industrial demands, and lighting loads of Iloilo City and communities scattered along the coastline are main.

Meanwhile, the power sources will be only the diesel power plants, of Dingle and Panitan until 1985, but this will not be sufficient to meet the demand, and it is scheduled for power to be received from the Negros Grid.

That is, already taking into account interconnection with Negros, a 138 kV transmission line (wooden poles, 1 cct) was constructed between Panitan, Dingle and Sta. Barbara, of which, the section between Panitan and Sta. Barbara is being operated at 69 kV.

When the interconnection of the three islands is completed, it will be possible for electric power to be transmitted to the other islands in the latter 1980s upon development of coal-fired thermal and hydro on Panay Island.

(2) Negros Power System

The demand on Negros will be 215 MW in 1985 and 276 MW in 1990, roughly equal to the scale of power demand on Cebu. Of this demand, that for mining of Marinduque Mining and Industrial Corporation (MMIC) at Sipalay, Lepanto Consolidated Mines (LCM) and Construction & Development Corporation of the Philippine Mining Co. (CDCP) makes up approximately 100 MW. The demand of Bacolod City is the next largest. In contrast with demand being concentrated in Negros Occidental, Negros Oriental has loads only at communities scattered along the seacoast, less than 10% of the demand of Negros as a whole.

Meanwhile, Palimpinon Geothermal Power Plant to be developed in the first half of the 1980s is to be located in Negros Oriental. There are also plans for geothermal, hydro and coal-fired thermal plants in Negros Occidental, but the development works are scheduled for the latter half of the 1980s. Seen from the demand and power source distributions of Negros Island, and the sequence of power source development, it is necessary for the interconnection of Occidental and Oriental to be hurried, while at the same time, it is important for surplus non-petroleium energy to be sent to other islands, especially Cebu.

(3) Cebu Power System

The demand of Cebu in 1985 is estimated to be 180 MW, and 255 MW in 1990, a scale about the same as on Negros. The major demands are those of the Cebu City area and Atlas Consolidated Mining & Development Corporation (ACMDC) of Sigpit, which make up about 70% of the whole.

Cebu was the first to be developed in the Visayas Region, and the power system voltage already uses 138 kV. However, the power supply sources were developed mainly through increases of small-capacity diesels in step with increases in demand. Neither is Cebu favored with geothermal energy as on

Negros. As a result, even in 1990, the proportion to be covered with diesel will exceed 50%. If, by interconnection with other islands non-petroleum-based energy is brought in, it will be possible for diesel to be made reserve capacity, thus enabling conservation of petroleum.

(4) Three-Island Interconnected Power System

The interconnections of the three islands of Panay, Negros and Cebu are to be done with 138 kV submarine cables and 138 kV overhead transmission lines, and the electric power systems of the three islands are to be operated as a sole power system. The power demands aggregating Panay, Negros and Cebu are estimated to reach approximately 450 MW in 1985 and approximately 600 MW in 1990.

The power supplies according to rating plates will be approximately 600 MW in 1985 and approximately 840 MW in 1990. Of these capacities, non-petroleum energy sources (geothermal, coal, hydro) will be approximately 290 MW in 1985 and approximately 550 MW in 1990, and in the latter half of the 1980s it will become possible to reduce operation of the diesel power plants, and diesel units can be diverted to reserve capacity. The two power generating barges will be moored at any two of three mooring points, Bacolod (Negros), Naga (Cebu) and Isabel (Leyte), and connected as suited with the power system, will demonstrate their effects as supply capabilities common to the Visayas Region.

The programs for introduction of power generating facilities by year are indicated in Table 5-1, while Table 5-2 shows the types of power plants in 1985 and 1990.

5.2.2 Interconnection Capacity

The following items were paid attention in determining the necessary interconnection capacities.

i) The demand distributions of the various islands explained in 5.2.1, and the sizes of power flows from the power supply to the 138 kV trunk overhead transmission line and the submarine lines connecting the various islands.

ii) The relation between an interconnection capacity at a certain reliability level and extent of interconnection capacity. (In view of the system capacities of the power systems of the various islands, there will be a certain interconnected capacity which will be economical.)

iii) Submarine cables possessing ample capacities for short-time overloading in case of forced outage of the unit of maximum capacity on the islands occurs at normal power flow.

iv) As other matters to be considered, it is important for interconnection capacities on the large scale to be considered in the sense of providing flexibility to unknown factors of the future.

Table 5-1 Generation Expansion Program (Panay-Negros-Cebu Grid)

(MW)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Panay	Dingle Diesel 4 x 7.3 MW Panitan Diesel 2 x 5.5 MW						Panay Thermal 1 x 55 MW				Aklan Hydro 2 x 10 MW
Negros	Amlan Hydro 2 x 0.8 MW Amlan Diesel 2 x 5.5 MW Talisay Diesel 2 x 5.5 MW 1 x 3.6 MW CENECO pick up 22.45 MW	Palimpinon Geothermal 2 x 1.5 MW Power Barge 4 x 8 MW	Sipalay Diesel 2 x 18 MW	Palimpinon Geothermal 3 x 3.75 MW	CENECO Retire (-) 9 MW	Negros Thermal I 1 x 55 MW		Bago Hydro 1 x 10 MW 1 x 50 MW	Negros Thermal II 1 x 55 MW	Mambucal Geothermal 1 x 37.5 MW	Mambucal Geothermal 1 x 37.5 MW CENECO Retire (-) 8 MW
Cebu	Cebu Diesel I 7 x 7.3 MW VECO Pick up 59.3 MW	Cebu Diesel II 3 x 18 MW Power Barge 4 x 8 MW Naga Thermal I 1 x 55 MW VECO Retire (-) 9 MW		VECO Retire (-) 13.5 MW	Naga Thermal Thermal II 1 x 55 MW				VECO Retire (-) 15 MW		
Total Installed Capacity (MW)	199.45	366.45	402.45	501.45	547.45	602.45	657.45	717.45	757.45	794.95	844.45

Table 5-3 Generation Expansion Program (Leyte-Samar Grid)

(MW)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Leyte	Tongonan Geothermal 1 x 3 MW	Power Barge 4 x 8 MW	Tongonan Geothermal 3 x 37.5 MW		Tongonan Geothermal 1 x 37.5 MW		Tongonan Geothermal 1 x 37.5 MW			Tongonan Geothermal 1 x 37.5 MW	
Samar								Catubig Hydro 2 x 15 MW			
Total Installed Capacity (MW)	3	35	147.5	147.5	185	185	222.5	252.5	252.5	290	290

Table 5-2 Installed Capacity devided into Type of Power Plants in 1985 and 1990 in Panay-Negros-Cebu Grid

Unit: MW & ( ) in %

Year	Grid	Hydro	Geothermal	Coal-fired thermal	Diesel	Total
	Panay	-	-	-	40.2	40.2 (6.7)
1985	Negros	0.8	115.5	55.0	107.05	278.35(46.2)
	Cebu	-	-	120.0	163.9	283.9 (47.1)
	Total	0.8(0.1)	115.5(19.2)	175.0(29.0)	311.15(51.7)	602.45(100.0)
	Panay	20.0	-	55.0	40.2	115.2 (13.6)
1990	Negros	60.8	190.5	110.0	99.05	460.35(54.5)
	Cebu	-	-	120.0	148.9	268.9 (31.8)
	Total	80.8(9.6)	190.5(22.6)	285.0(33.7)	288.15(34.1)	844.45(100.0)

(1) Power Flow

The sizes and directions of power flows in 138 kV trunk overhead transmission lines and 138 kV submarine cables will vary considerably even without taking into account equipment faulting, and there will be fairly great amounts of change according to fluctuations in demand by season and by time of day. There would also be scheduled outage of generator units while delays in power development would also contribute to variations, but in order to determine the power transmitting capacity of the interconnected lines, power flows were calculated based on the demand forecasts for 1985 and 1990 and on power development projects.

Power demand was considered in the three categories of peak load, average load, and off-peak load. It was considered that loading of supply capability would be done in order from the cheapest in terms of fuel cost. In effect, for peak loads, loading would be done in the order of hydro, geothermal and coal-fired, and in case there were to be a shortage in supply capability even then, then diesel generators or power generating barges would be operated. For off-peak load, since peaking hydro, restricted in kWh capacity, cannot be utilized, loading would be done in the order of geothermal, coal-fired thermal, and diesel or power barge. The power flows calculated based on the above criteria are shown in Fig. 5-1. It may be seen that the sizes and directions of power flows indicate considerable changes.

The power flow between Panay and Negros in 1985 will be approximately 30 MW from Negros to Panay, whereas in 1990 it will be in the reverse direction and similarly about 30 MW. The power flows between Negros and Cebu will both be from Negros to Cebu with approximately 10 MW in 1985 and approximately 80 MW in 1990.

The above-mentioned power flows will be through submarine cables. The 138 kV overhead transmission line crossing Negros, the Pulupandan-Kabankalan-Amlan transmission line, will show the maximum pwer flow which is estimated to be 90 MW.

(2) Interconnected Capacity and Necessary Reserve Capacity

The necessary reserve capacity of a power system can be determined based on the concept of supply reliability if the power supply source composition were to be known. The standard of NAPOCOR is for possession as necessary reserve capacity, that equivalent to the largest unit in the system or 15 to 20% of the size of power demand in the system, whichever is larger.

Calculations will be made here of the degrees of savings in the necessary reserve capacities made possible by sizes of interconnected capacities compared with independent systems. For this purpose, loss of load probability was adopted as supply reliability. According to the results of calculations, 1.0 day/mo (number of days of loss of load in the month indicating maximum demand) is close to the standard of NAPOCOR and this was made the target reliability. Chapter 7, "Power System Analysis," should be referred to for details.

As can be comprehended from the results given in Chapter 7, when the interconnected capacity becomes 50 MW or more (20% of system capacity on small-system side) there is a trend for savings in reserve capacity to reach a saturation point. Therefore, when limited to this viewpoint, and considering capital investment required for interconnection, about 50 MW may be said to be the economical interconnected capacity.

(3) Interconnected Capacities between Islands

Based on (1) and (2) above, it will suffice to consider up to about 50 MW between Panay and Negros and up to about 100 MW between Negros and Cebu. The capacities of the 138kV submarine cables must be those which can secure these interconnected capacities.

5.2.3 Power Transmission System of Interconnecting Lines

(1) Transmitting Voltage

The maximum voltage presently used in the Visayas Region is AC 138 kV, and in view of the sizes of power demands of the various islands, the sizes of power plants presently being constructed or planned, and unit capacities, 138 kV will be suitable as the transmitting voltage for this region. It will also be possible with this voltage to amply secure power transmission capability suited to the interconnection objective. Furthermore, since the maximum length of submarine cables is 16.5 km (the total cable length between Panay and Negros), the size of charging current due to electrostatic capacitance which can be a problem with an AC transmission system will not be of consequence, and therefore an expensive DC transmission system need not be applied.

(2) Number of Circuits

The sections between Sta. Barbara and Pulupandan and between Amlan and Naga are to be single-circuit and that from Pulupandan to Kabangkalan to Amlan double-circuit. Since this interconnecting transmission line will be the backbone (both electrically and symbolically) of the power system of the Visayas Region, it was decided to adopt steel towers, which are high in reliability, for all sections of the Project.

Since this interconnected system will be a typical long-distance series grid (431 km from Panitan Substation to Banilad Substation), calculations of stability will be necessary. As a result of stability analysis described in Chapter 7, there will not be very much allowance in stability with single-circuit for the entire length, and by making the middle portion of the series grid double-circuit, improvement in stability of the three-island grid will be aimed for.

(3) Types and Sizes of Conductors

ACSR 240 mm^2, is to be adopted for overhead transmission lines. Regarding submarine cables, XLPE single-core, 300 mm^2, will be adopted for both Panay-Negros and Negros-Cebu.

5.2.4 Interconnection Route

(1) Principle of Interconnection Route Selection

The 138-kV transmission line which is to be the backbone of the interconnected system is a long-distance transmission line from Panitan Substation on Pany Island to Banilad Substation on Cebu Island going via Negros Island. Of this line, the portion on Panay Island going from Panitan Substation through Dingle Power Plant to reach Sta. Barbara Substation has been completed. Panitan Substation and Dingle Power Plant have been completed, while Sta. Barbara is under construction. On Cebu Island, a transmission line from Naga Power Plant to Banilad Substation and the transforming facilities of the two are in operation.

Consequently, in selection of the interconnection route, the objects of study will be the middle portion excluding the already-completed two end terminals, in effect, the transmission line route from Sta. Barbara Substation to Naga Power Plant and substations to be provided in between.

The following points were given consideration in selection of the transmission line route.

i) The route is to be as short as possible in view of stability since the transmission line is to be the backbone of a long-distance series grid.

ii) The route is to be such that in relation to selection of substation locations, connections between demand and power supply can be readily accomplished.

iii) For overhead lines, routes along roads with easy access are to be selected as much as possible for convenience of construction and maintenance.

iv) With regard to submarine cables, the following were paid attention:

(a) The construction cost of a submarine cable will be about 10 times that of an overhead line and thus the route must be made as short as possible.

(b) The conditions of the sea bottom (topography, geology, current flow velocity, existence of obstacles) and depth of water must be suitable for cable laying.

(c) There must be sites suitable for landing of submarine cables with hinterland areas where facilities for connection between the cables and overhead lines can be provided.

v) With regard to substations to be newly provided, attention was given to the items below.

(a) The location must be one where connections between demand and supply source will be easy.

(b) The location must be about 1 km distant from the coastline to avoid salt contamination.

(c) In case an existing substation can be utilized, it is to be expanded and used.

(d) The site must be as flat as possible and where an area of about 9 ha. can be secured.

(2) Substations

Related substations are to be constructed at the three sites of Pulupandan, Kabangkalan and Amlan on Negros Island.

i) Pulupandan Substation

The features of the site of the substation are that it is close to the large load center of Bacolod City, that it is close to Bago Hydro Power Plant and Mambucal Geothermal Power Plant, and further, that it is close to the landing site of the submarine cable coming from Guimaras Island.

ii) Kabangkalan Substation

The location of this substation is at roughly the middle between Pulupandan Substation and Amlan Diesel Power Plant, and the feature of this substation is that it will be convenient for interconnecting large mining demands in the Sipalay area with Negros Thermal I (coal-fired thermal).

iii) Amlan Diesel Power Plant

The existing Amlan Diesel Power Plant is to be expanded and the site is close to Palimpinon Geothermal Power Plant and the landing point for a submarine cable.

(3) Submarine Cable Routes

Submarine cable routes were selected considering the sea-bottom geologies and topographes and the conditions of location for terminal facilities for connections with overhead transmission lines on land. Details are described in Chapter 6, "Preliminary Design."

It is suitable for the distance between Panay and Negros to be traversed by routes crossing the Iloilo Strait and Guimaras Strait, while the distance between Negros and Cebu is to be by a route across the Tañon Strait. The recommended cable landing points and distances are as indicated below.

i) Iloilo Strait

Panay side	:	Jaro site near Point Jaro
Guimaras side	:	Point Salag
Distance	:	3.7 km

ii) Guimaras Strait

Guimaras side	:	Barcelona site near Point Tumanda
Negros side	:	Pagayan site near Point Pandan
Distance	:	12.8 km

iii) Tañon Strait

Negros side : Jilacon site
Cebu side : Liloan site near Point Liloan
Distance : 7.1 km

(4) Overhead Line Route

For overhead lines, the routes connecting substation locations selected up to this time and submarine cable landing points by roughly the shortest distances respectively are recommended.

(5) Interconnected Route Map and Distances

The interconnected route map and the distances of the various sections are indicated in Fig. 5-2. The distance between Sta. Barbara Substation and Naga Power Plant is a total of 326 km. Of this, overhead lines account for 302 km and submarine cables 23.6 km.

(6) Examinations of Alternative Interconnection Routes

Examinations were made for the three alternatives indicated below, all of which were found to be inferior in economics to the interconnection proposals previously cited.

i) Calatrava-Talavera Interconnection Proposal (Alternative A)

This is a route in lieu of the Amalan-Naga Transmission Line, which would run from Pulupandan Substation, through Bago Hydro Power Plant to Calatrava, where Negros Coal-Fired Thermal II is to be provided, to Talavera by submarine cable, and on to Naga Power Plant. This alternative calls for a submarine cable distance of approximately 25 km between Calatrava and Talavera which is long, and is clearly inferior to the original plan with respect to economy.

ii) Two-Route Proposal Between Pulupandan and Amlan (Alternative B)

One single-circuit line would have the same route as the original plan with another single-circuit line running along the coastline from Calatrava, through Bago, to reach Pulupandan. This alternative would result in a looped system and will have slightly better supply reliability compared with the original plan, but the construction cost will be high and the economics will be poorer than with the original plan.

iii) Kabangkalan-Sipalay-Amlan Interconnection Proposal (Alternative C)

This alternative would have the route pass through Sipalay where large loads in mining are concentrated. However, it will require a higher construction cost compared with the original plan, while stability will be poorer because the length of the interconnected line would be longer.

Comparisons of the above alternatives are given in Table 5-3. Next, although not directly related to the interconnection route, the method of supplying power to Sipalay will be touched upon. In the original plan it is contemplated for the power of Palimpinon Geothermal Power Plant to be transmitted over the Amlan-Kabangkalan Line to be supplied from Kabangkalan to Sipalay by 138 kV, 2 cct. Consequently, unless the interconnected line is completed about the same time as start-up of Palimpinon Geothermal Power Plant, power supply to Sipalay will be hampered. In such case, it is conceivable for Sipalay to be supplied from Amlan by 138 kV, 1 cct, ahead of construction of the interconnected line, with 138 kV, 1 cct, constructed from Kabangkalan to Sipalay after completion of the interconnected line. See Fig. 5-3.

5.2.5 Timing of Interconnection

It is desirable for the interconnections of all three islands to be completed as soon as possible, and moreover, at the same time as much as possible for the reasons given below.

(1) It has been confirmed that the economic effect of interconnection will be good based on calculations for the 1985 cross section. See Chapter 9, "Economic Analysis."

(2) Start-up of Palimpinon Geothermal Power Plant (37.5 MW x 3) is scheduled for 1983. It would be advantageous to supply the power generated here to Sipalay from Kabangkalan through the interconnected line and at the same time reduce diesel generator operation on Cebu.

(3) There will be a shortage of electric power on Panay unless interconnection is hurried.

(4) The 55 MW unit of Naga Coal-Fired Thermal Power Plant will start operation in 1981. With only the independent grid of Cebu, there will be a great frequency drop if tripping of this large-capacity unit were to occur. By enlargement of system capacity through early interconnection the adverse effects when the large-capacity unit trips will be alleviated.

5.3 Leyte-Samar Power System

NAPOCOR is proceeding with a plan to construct an AC 138 kV, wooden pole, 1 cct transmission line between Tongonan Geothermal Power Plant and Wright Substation (distance 115 km) to interconnect the islands of Leyte and Samar. Start of operation of this transmission line is scheduled to be about the same time as start-up of Tongonan Geothermal Power Plant. This transmission line will be constructed with wooden poles and in view of the size of power demand on Samar Island and the transmitting distance between Tongonan Geothermal Power Plant and Wright Substation, there will be no problems in particular regarding the transmitting voltage and conductor size adopted. However, the crossing of San Juanico Strait will be of long span, and large-sized, tall steel towers will be required.

5.3.1 Power Demand and Supply and Power Flow

The feature of this interconnection is that with the large-scale development of Tongonan Geothermal Power Plant as the impetus, a power grid including power interconnection of Leyte and Samar is to be completed aiming for power supply to the large-scale copper refinery at Pasar and to electric cooperatives.

At present, with the exception of Ormoc City being supplied from the pilot plant of Tongonan Geothermal Power Plant, all the remainder of Leyte and Samar are being supplied by diesel generating facilities, and the loads are all small. It is forecast that the loads of Leyte-Samar will be 90 MW in 1985 and 158 MW in 1990. Of these loads, the demand at Pasar will make up about 60%, while the demand on Samar will make up about 12% of the whole. On the other hand, with regard to power sources, it is planned for a total of six 37.5 MW units to be developed at Tongonan Geothermal Power Plant by 1990. This plan, at first glance, would appear to be excessive in view of the demand forecast, but this is in consideration of supply reliability based on operating experience with the previously-mentioned pilot generating facilities, and is thought to be reasonable. With this development, all existing diesel generating facilities will become reserve capacity.

There is a possibility for construction of a hydro power plant on Samar, and start-up of Catubig Hydro Power Plant is scheduled for the latter half of the 1980s. The power expansion plans of NAPOCOR are shown in Table 5-4.

Next, on forecasting the power flows in 1985 and 1990, the results are as indicated in Fig. 5-4, and the power flow between Tongonan Geothermal Power Plant and Wright Substation will be about 15 MW.

5.3.2 Power Transmission System and Interconnection Route

The 138 kV, 1 cct line planned by NAPOCOR is reasonable. A voltage of 69 kV would not be appropriate since the interconnecting line is comparatively long at 115 km so that there would be little allowance in steady-state stability and transmitting capacity.

Regarding conductor size, although mountainous areas of elevation higher than 1,000 m will be crossed, it will be possible to adopt 336.4 MCM even when considering corona noise. With respect to the transmission line route from Tongonan Geothermal Power Plant to Wright Substation, there will be no special problem except for crossing of San Juanico Strait. As a method of crossing this strait, it is conceivable to additionally string a power cable on San Juanico Bridge (2.7 km), but the construction cost will be high to impair the economics, and the method of crossing the strait by aerial line will be adopted.

The recommended plan is to take the Uban route, and the maximum span of the transmission line will be approximately 1,200 m.

5.3.3 Adoption of Steel Tower Transmission Line

Considering reliability as a trunk transmission line, difficulty anticipated in obtaining large wooden poles in the future and increase in construction cost accompanying replacement, the next time, construction should be with steel towers as supports.

5.4 Cebu-Leyte Interconnection

NAPOCOR has an idea to interconnect the islands of Cebu and Leyte. If the power systems of these two islands were to be interconnected, effects similar to those of interconnection of the three islands of Panay, Negros and Cebu will be obtained such as that the cheap, and moreover, non-petroleum energy-source produced at Tongonan Geothermal Power Plant can be transmitted to Cebu City, the load center of the Visayas Region, and that power development can be reduced through savings in reserve capacity.

There are the three alternatives below conceivable for the Cebu-Leyte interconnection route.

i) Northern Camotes Sea route
ii) Camotes Islands route
iii) Bohol Island route

On the above, the Camotes Islands route of ii) would have the merit that transmitting capacity can be increased by installing charging current compensating facilities on the islands, but there will be large numbers of appurtenant facilities such as cable terminals and this alternative will not necessarily be economically advantageous. As for iii), the Bohol Island route, since the sea-bottom topography is complex, it is thought it will be difficult to find a suitable cable route, while the landing point on the Leyte side will be a low power demand area at the southern part of the island and a long-distance overland overhead transmission line would be required, so that there are numerous disadvantageous points to this route.

The most promising at the present stage is the Northern Camotes Sea route of i) where several cable routes are conceivable. One alternative, that of interconnecting a point north of Tobogan close to the northern tip of Cebu and a point close to Canaguayan at the western shore on the Leyte side would have a submarine cable length of approximately 40 km, and approximately 120 km of overland overhead transmission lines (Cebu City - Tongonan Geothermal Power Plant).

The maximum depth in the case of this submarine cable will be as much as about 800 m which would make this the deepest submarine cable route in the world, and the cable-laying conditions are extremely severe. The tension acting during cable laying will be about 40 tons so that a cable of extremely high mechanical strength will be required, while research and development will be needed regarding various problems concerning the cable-laying method, and much expense and time will be required in resolving these problems.

The types of cables to be considered would be OF, GF and XLPE cables. As for cable size, the minimum cross-sectional size would be restricted from the aspect of mechanical characteristics. Based on these factors, the minimum transmitting capacity will be about 150 MW, and any smaller interconnected capacity would be extremely disadvantageous economically.

Further, regarding voltage and whether to adopt alternating or direct current, the scale of this submarine cable route is close to the economic dividing line between AC and DC and a decision should be made based on detailed comparison studies. If the cable length were to be increased more, or the costs of AC/DC converters can be brought down, there would be an advantage in adopting DC power transmission.

It is imagined that the construction cost required for this Cebu-Leyte interconnection would be roughly around 50 million dollars, but since the generating cost at Tongonan Geothermal Power Plant is low, economic merit can be looked forward to if there were to be a suitable power flow in the interconnecting cable. In the future, when there is an outlook for solutions to the previously-mentioned engineering problems, and power demands on the Cebu and Leyte sides are increased so that the capacity of the two systems reach about 500 MW, it may be assumed reasonable for Cebu-Leyte interconnected power transmission to be realized.

Fig. 5-1 Power Flow (Panay - Negros - Cebu Grid)

(MW)

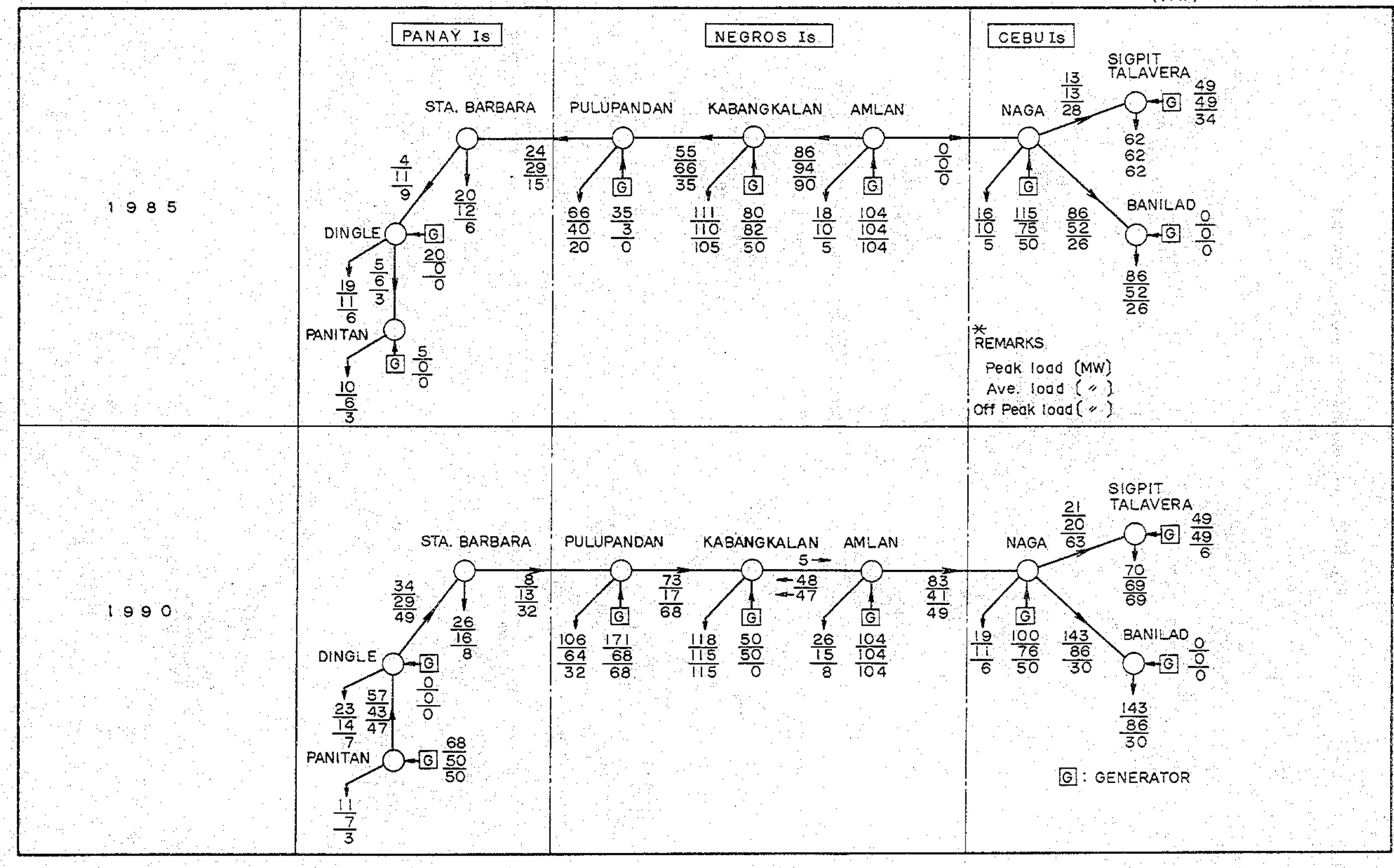


Fig. 5-2 Interconnection Route Diagram

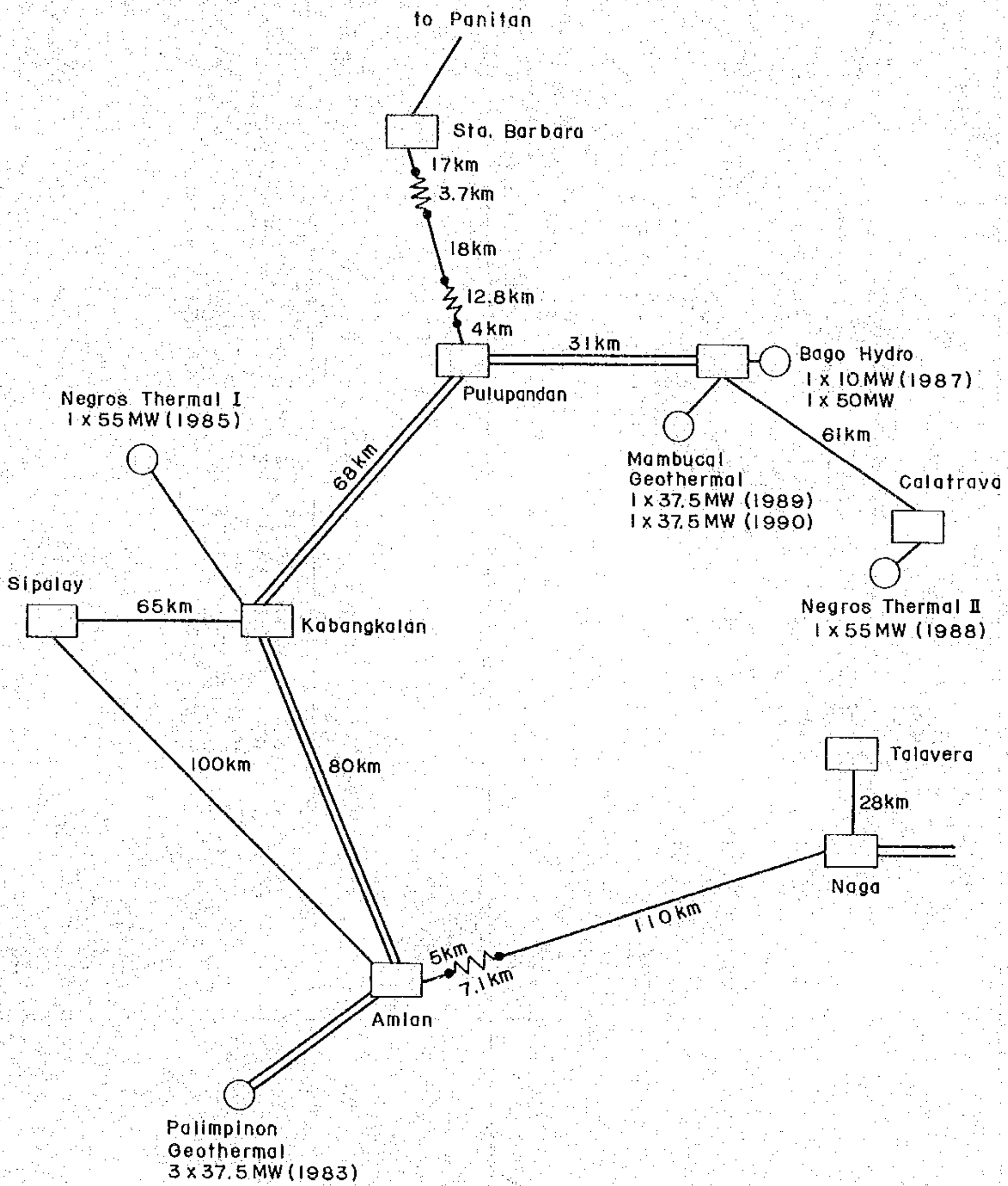
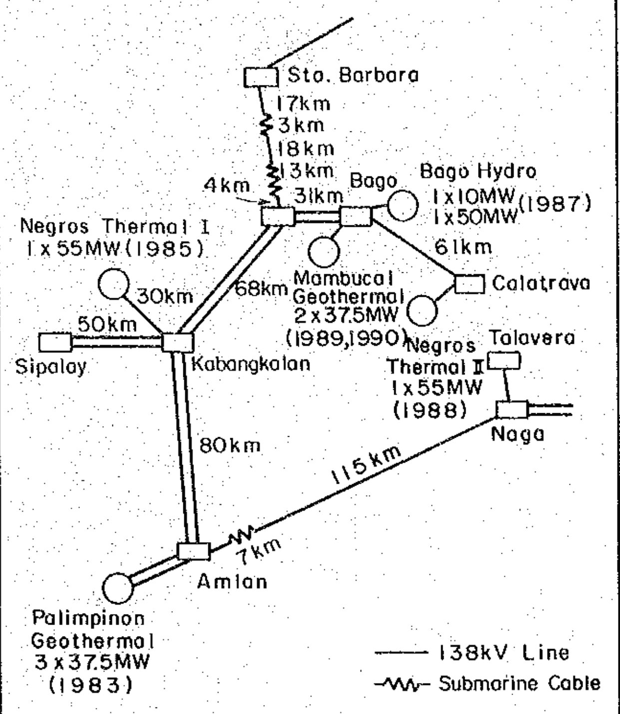
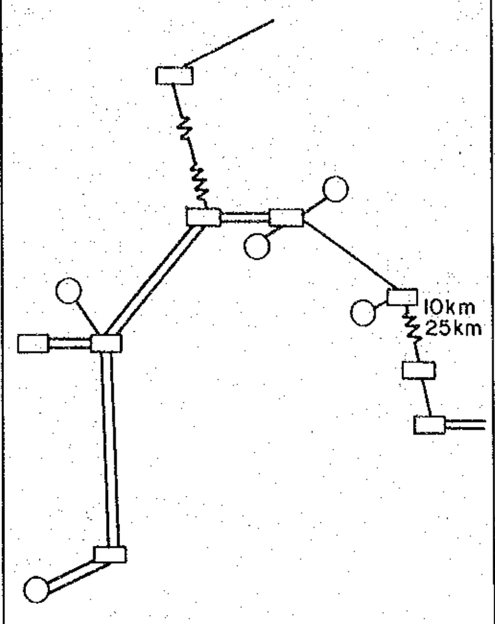
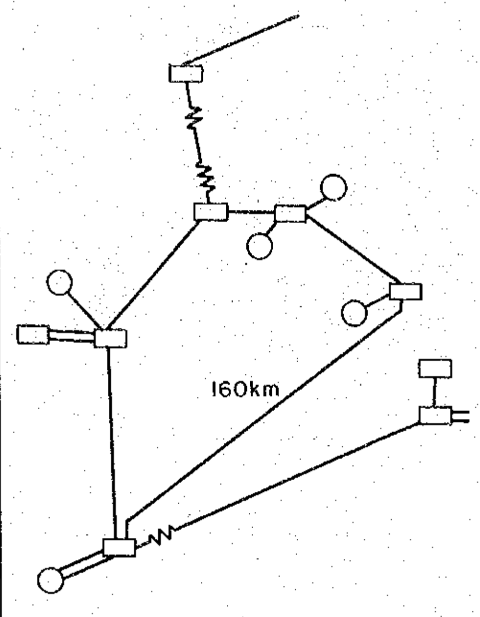
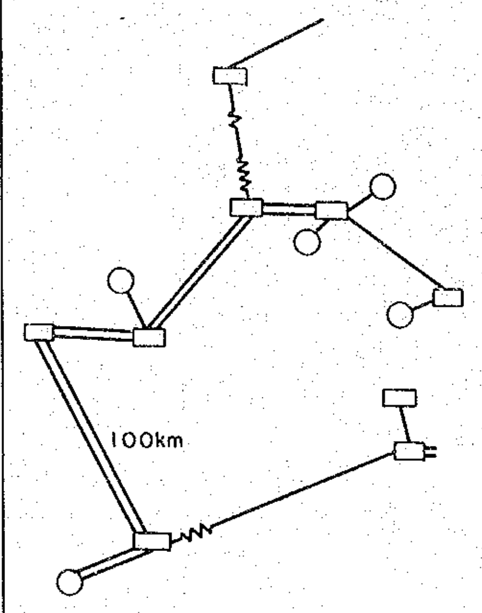
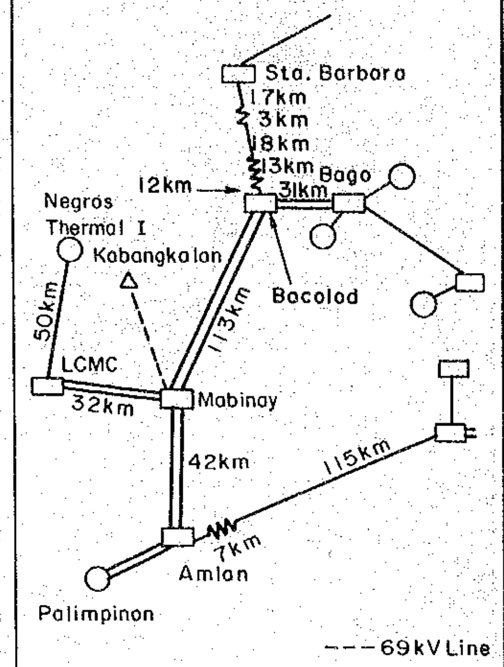


Fig. 5-3 Comparison of Construction Cost and System Characteristic

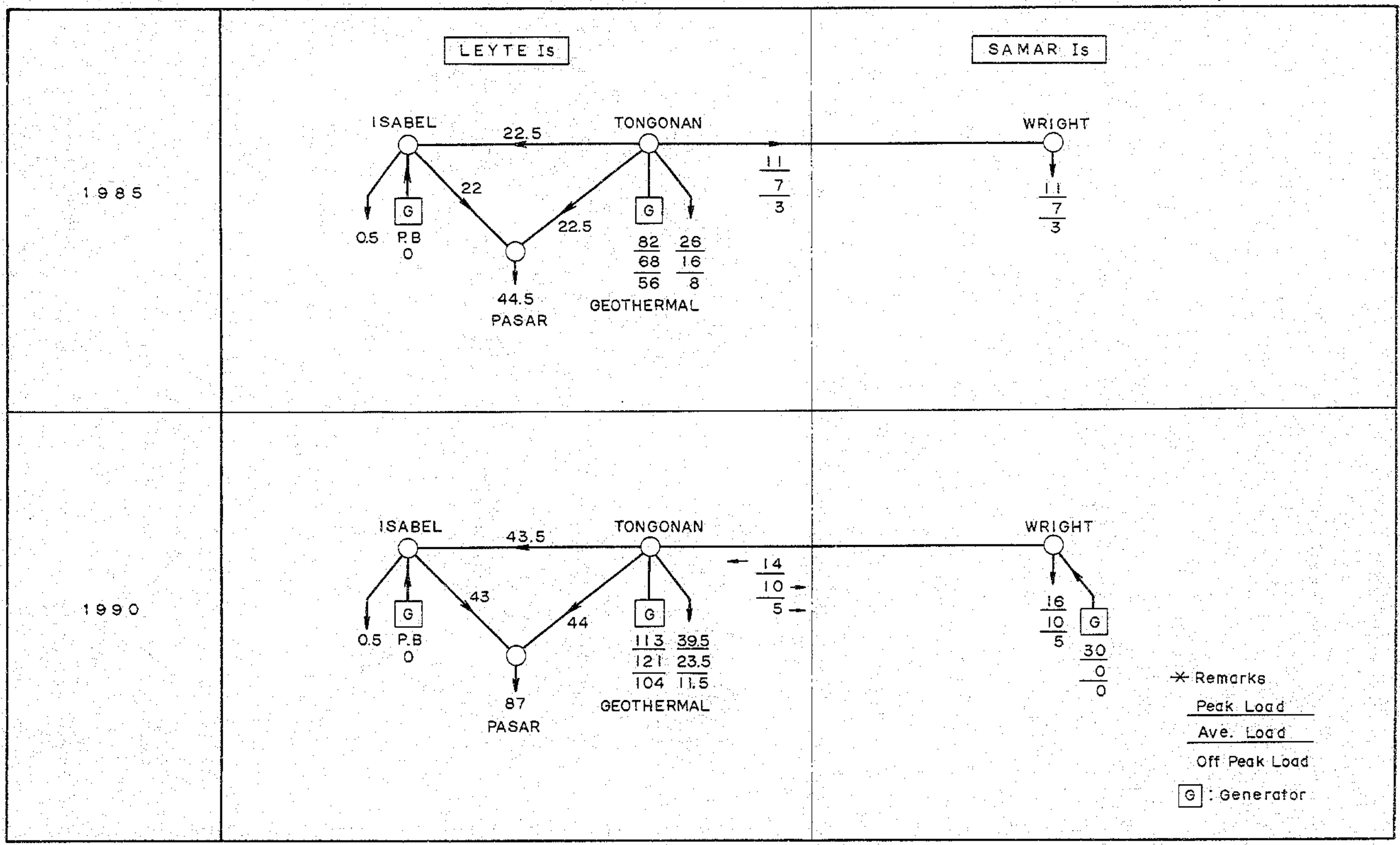
	JICA Original Plan	Alternative Plan-A	Alternative Plan-B	Alternative Plan-C	※Napocor Revised Plan
					
Interconnection	Amlan – Naga	Calatrava – Talavera	Amlan – Naga	Amlan – Naga	Amlan – Naga
Construction Cost of Transmission Line	138kV 2cct 229km 138kV 1cct 245km Cable 1cct 23km 100 % 47.25x10⁶ US$ ①	138kV 2cct 229km 138kV 1cct 140km Cable 1cct 41km 113% 53.2x10⁶ US$ ⑤	138kV 2cct 50km 138kV 1cct 584km Cable 1cct 23km 112% 53.1x10⁶ US$ ④	138kV 2cct 249km 138kV 1cct 245km Cable 1cct 23km 103% 48.8x10⁶ US$ ③	138kV 2cct 218km 138kV 1cct 273km Cable 1cct 23km 102% 48x10⁶ US$ ②
Stability	Electrically Equivalent Distance Sta. Barbara to Naga 251km ②	Electrically Equivalent Distance Sta. Barbara to Naga 166.5km ①	Electrically Equivalent Distance Sta. Barbara to Naga 325km ⑤	Electrically Equivalent Distance Sta. Barbara to Naga 286km ④	Electrically Equivalent Distance Sta. Barbara to Naga 262.5km ③
Reliability	Two feeders are enough for power supply to main loads in terms of reliability each plan has sufficient reliability level.				
Order of Priority	①	⑤	④	③	②

Note (1) Cost estimate per Kilo-meter of 138kV Transmission Line and Submarine Cable (138kV 2cct : 77×10^3 US$/km, 138kV 1cct : 58×10^3 US$/km, Cable 670×10^3 US$/km)

(2) ※ As a result of comparison Study between JICA's original plan and NAPOCOR's revised plan, the incremental construction cost including 69kV Transmission Lines, compared with the JICA's original plan is 1.3 million US dollers.

Fig. 5-4 Power Flow (Leyte - Samar Grid)

(MW)



CHAPTER 6

PRELIMINARY DESIGN

CHAPTER 6 PRELIMINARY DESIGN

6.1 Principles of Preliminary Design

The power transmission facilities to be described herein comprise a most important trunk transmission line interconnecting the power grids of the three islands of Panay, Negros and Cebu, and one of the principal aims, as described in the preceding chapter, is to transmit cheap power generated with non-petroleum-based fuel to the various demand centers of the abovementioned three islands. If a fault were to occur on the transmission lines making it impossible for power to be transmitted, not only will power supply to Panay, Negros and Cebu be hampered, the energy producted at Palimpinon Geothermal Power Plant will be wasted. Consequently, an extremely high reliability will be required of the power transmission facilities, while in the event there should happen to be faulting, normal conditions must be rapidly restored. It is from this viewpoint that in preliminary design of the power transmission facilities, it was decided to place emphasis on securing high reliability as much as possible. Needlesss to say, attention will be paid to the economics, but considering future development of the power transmission system, it was decided to adopt a design with some allowance so that there will not be any bottlenecks.

In regard to the relation between this preliminary design for the Project and the existing 138 kV transmission lines in the Visayas Region, harmony between the two will be considered with respect to the basic design, but the overall reliability of the power transmission facilities is to be better.

6.2 Panay-Negros-Cebu Power System

6.2.1 Overhead Transmission Lines

(1) Routes of Overhead Transmission Lines

NAPOCOR has routes planned for the 138 kV transmission lines to be newly constructed on the 3 islands of Panay, Negros and Cebu, and has already carried out topographic surveying of the transmission line route on Negros Island. Therefore, the investigations for this project were made along these routes planned by NAPOCOR.

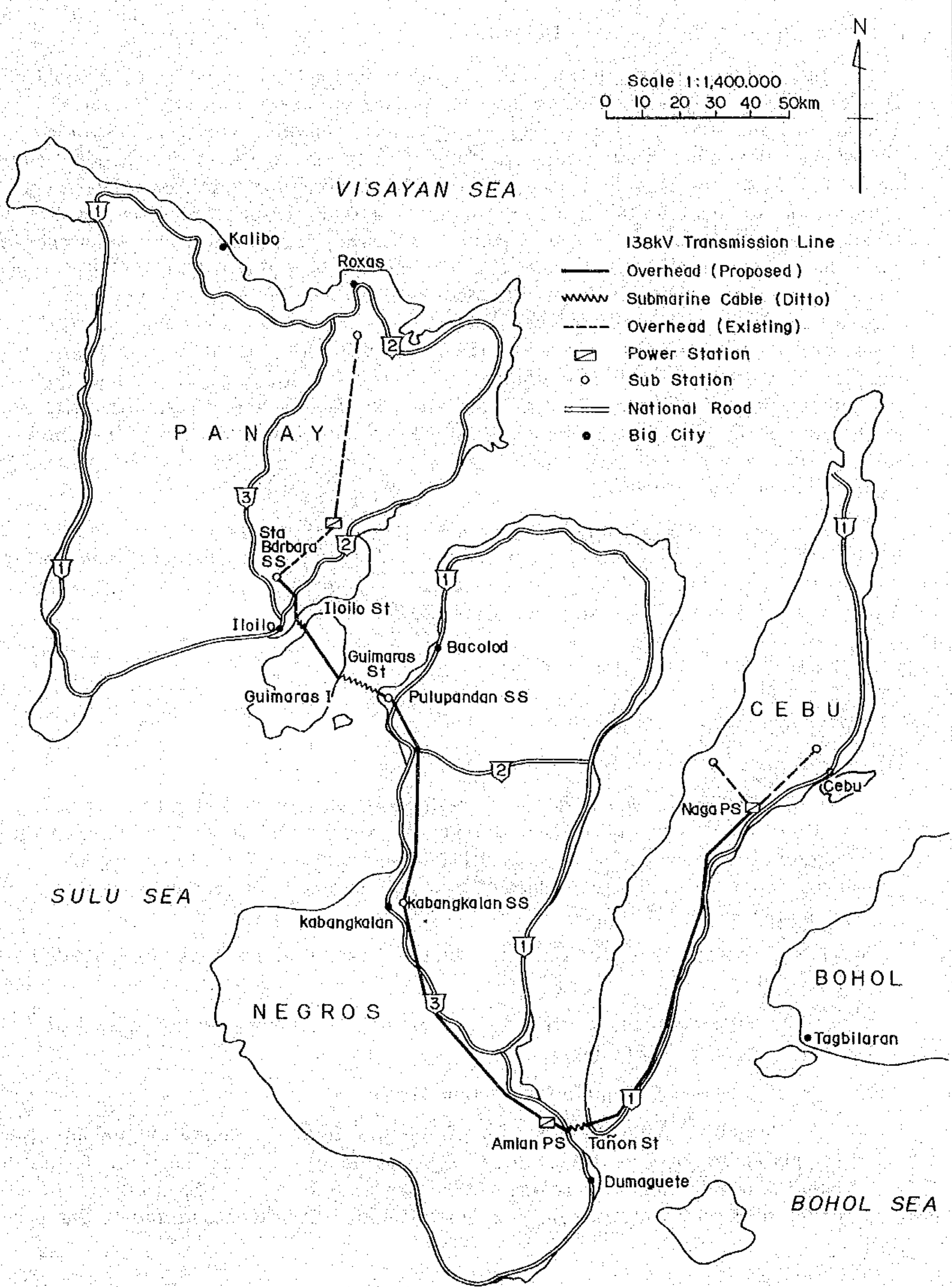
The routes investigated for the various transmission lines are indicated in Fig. 6-1.

The outlines of the overhead transmission line routes on the individual islands are described below.

i) Intra-Panay Transmission Line Route

Roughly the entire section between Sta. Barbara Substation and Jaro, the projected site for the terminal of the submarine cable, consists of rice paddies which cannot be avoided no matter what kind of route is taken. In order to supply power to La Paz Substation of PECO located close to the

Fig. 6-1 138 kV Transmission Line Route (Panay - Negros - Cebu Line)



Jaro site, there has already been a 69 kV transmission line owned by NAPOCOR constructed from Sta. Barbara Substation, and the route of this 69 kV transmission line, instead of taking the shortest straight line, makes a slight detour to the east for reasons of the right of way. NAPOCOR is planning to construct the new 138 kV transmission line parallel to the existing 69 kV transmission line. This route has a length of approximately 17 km. The soft ground layer at the rice paddy area is considered to be a maximum of about 2 m seen from the experience in construction of the existing transmission line, while conditions for hauling of construction materials are not particularly adverse, so that it is more or less appropriate as a transmission line route.

However, it is considered important for investigations to be made of geological conditions such as bearing capacity of ground to the respective necessary depths at representative steel tower construction sites on the projected route. Designing of foundations for transmission line supports should be done based on these data.

Regarding the transmission line on Guimaras Island, a route passing in a roughly straight line from the two cable terminals of Salag at the northern part of the island to Barcelona near Tumanda Point at the southern part is conceivable. This route has a length of approximately 18 km, and the topography of the entire section is that of a hill area. For transportation of construction materials to be used on Guimaras Island, it is possible to utilize the small wharf at the landing site of Santo Rosario at the northern side of the island, but there are no cargo landing facilities at all, and it will be necessary either for materials to be landed manually or by temporarily installing simple landing facilities.

ii) Intra-Negros Transmission Line Route

The transmission line route from Pagayon, the projected site for the terminal of the submarine cable crossing Guimaras Strait, through Pulupandan Substation to reach Kabangkalan Substation, will go along National Highway No. 1 at the west coast of Negros Island, running by while avoiding watery areas such as fishponds scattered along the way. The length of this section is approximately 68 km.

The greater part of the section between Kabangkalan Substation and Amlan Power Plant is mountainous, and the watershed running down Negros Island from north to south will be crossed. The elevation of the point of maximum height is approximately 500 m above sea level, and is the highest of the entire 3 island power transmission interconnection line. The length is approximately 80 km, of which about one fourth is topographically rugged, while National Highway No. 3 runs along more or less the entire length.

NAPOCOR has already completed topographic surveying of these transmission line routes.

Negros Island, as may be surmised from the fact that the geothermal energy areas of Mambucal and Palimpinon exist, has a large geological fault running along the central hills between Kabangkalan Substation and Amlan Power Plant. It is judged from geological maps that there are some small-scale faults in the vicinity. In the event that a transmission line support were to be installed on a fault, there will be a risk that the supporting ground will move in the future. Although steel towers are themselves of high reliability as structures, they are surprisingly weak against displacements even though slight when changes in supporting ground are involved, and if shifting of the supporting ground were to actually occur, it will be impossible to stop such movement, and large-scale countermeasure works such as steel tower relocation will become necessary. Therefore, in selecting a steel tower location on the projected transmission line route, it will be extremely important to avoid geological faults.

iii) Intra-Cebu Transmission Line Route

The route of the transmission line from the submarine cable terminal, Liloan, at the southern tip of Cebu Island to the end of the line, Naga Power Plant, has a length of 110 km running parallel to the eastern coastline of the island. From the standpoint of materials transportation it is desirbale for the line to be constructed as close as possible to National Highway No. 1 along the coastline, but on the other hand, from the viewpoint of salt soilage of insulators of the transmission line, it is suitable for the route to be taken at least about 1 km away from the coastline or at elevations exceeding 100 m. There are also many coconut groves along the coastline and it is anticipated there will be places where it will be necessary to avoid these groves for reasons of right of way.

The entire length of this section of the transmission line route will be close to the seashore, and the matter of reduction in insulating performance due to soiling of insulators by sea salt at times of strong winds will be extremely serious from the standpoint of electrical reliability of the transmission line. Consequently, it will be necessary to carry out designing based on data obtained investigating and measuring conditions of insulator soilage in the field. It will be necessary for insulator soilage conditions to be investigated at areas having similar conditions on the other islands also.

It is estimated that topsoil is relatively thin along the southern half of the route. Especially, in the vicinity of Pt. Liloan, the geological structure is that of coral reefs heaved up to about 100 m above sea level. The locations for erecting steel towers are to be selected where the geological conditions are such that execution of foundation work will be made as easy as possible, while for sites where bedrock of high reliability has been confirmed through geological investigations, it is conceivable for rock foundations to be adopted to improve the economics.

The respective lengths of the overhead transmission lines on the three islands are as indicated in Table 6-1.

Table 6-1 Length of Overhead Transmission Lines

Island	Section	No. of circuits	Length (km)
Panay	Sta Barbara (SS) - Jaro (CT)	1	17
Guimaras	Salag (CT) - Barcelona (CT)	1	18
Negros	Pagayon (CT) - Pulupandan (SS)	1	4
	Pulupandan (SS) - Kabangkalan (SS)	2	68
	Kabangkalan (SS) - Amlan (PP)	2	80
	Amlan (PP) - Jilocon (CT)	1	5
Cebu	Liloan (CT) - Naga (PP)	1	110
	Sub-total	1	154
	Sub-total	2	148
	Total		302

Notice : SS : Substation

PP: Power Plant

CT: Cable Terminal

(2) Outline of Preliminary Design

i) Conductor

As described in 5.2.2, 100 MW is aimed for as the interconnected capacity of this interconnecting transmission line and conductor size is to be selected based on the transmitting capacity. Based on preliminary studies made by NAPOCOR, it was planned to use 336.4 MCM ACSR, but there would be some shortage in transmission capacity in such case and it was decided that 240 mm^2 ACSR should be adopted for this transmission line. The transmission capacity in this case will be 120 MW. As a result of comparison studies between the cases of use of 336.4 MCM ACSR and 240 mm^2 ACSR with regard to the economics including transmission line construction costs and transmission losses, it was judged that the latter would be economically advantageous if the average power transmission throughout the year for the entire transmission line distance is about 5,000 kW or more. Further, with regard to the section on Panay, it is expected that power flow will be comparatively small and it would be possible to adopt 336.4 MCM ACSR from the stand-point of transmitting capacity, but in view of the abovementioned transmission loss and considering increase in power flow due to future system expansion, a uniform 240 mm^2 ACSR is to be used for the entire length of the 3 island interconnection.

The conductor surface potential gradient of 240 mm^2 ACSR is a low value of 12 kV/cm, and there will be no problem of corona noise.

The stringing conditions of conductor are for conductor tension in a normal state (air temperature 15°C, no wind) not more than 22% of breaking strength, with moreover, that during typhoon (air temperature 7.22°C (corresponding to 45°F), wind speed 46 m/sec, wind-pressure drop ratio 0.6) not more than 40%, and maximum horizontal tension of about 3,600 kg will be permissible.

As a measure against conductor vibrations caused by light breezes, dampers and armor rods are to be provided at conductor support points.

ii) Insulator

The route of this transmission line has many sections passing close to coastlines as stated in the preceding section. Since insulating performance will be impaired through adherence of salt on insulator surfaces due to salty winds blowing in from the sea, the number of insulators to be strung must be decided considering the resulting effects.

With the objective of obtaining design data regarding soiled conditions of insulators, during the field investigations for the present study, measurements were made of the density of salt adherence to surfaces of NAPOCOR and VECO electric power facilities and the following data were obtained:

-Naga Power Plant of NAPOCOR

Measured Jan. 21, transformer bushing (3 month exposure)
max. 0.06 mg/cm^2

Measured Mar. 1, pilot SP insulator (40 day exposure)
0.03, 0.033 mg/cm^2

-Cebu Power Plant of VECO

Measured Jan. 23, transformer bushing (2 month exposure)
max. 0.078 mg/cm^2
av. 0.061 mg/cm^2

The salt adherence on insulators will vary greatly depending on meteorological conditions and measuring points, and for grasping the insulator soilage condition of a certain area, investigations and measurements over a long period of 2 to 3 years must be continued at many sites in that area. Hereafter, thorough investigations should be made of the projected transmission line route to grasp the insulator soilage condition, based on which the number of insulators to be strung should be determined.

According to insulator salt adherence investigations in Japan, the maximum amount on making measurements for a long period at a certain area was 4 times the average adhered quantity for that area. However, the Visayas Region has more annual rainfall than Japan, and moreover, there is periodic rainfall, and it may be expected that the above ratio will be smaller. Taking such a factor into consideration, and estimating the approximate maximum salt adherence from the previously-mentioned measurement data, it is thought to be about 0.12 mg/cm^2 near the seashore and about 0.05 mg/cm^2 at areas in general other than near the seashore. The number of insulators necessary to withstand normal voltage to ground of 80 kV ($= 138\ kV/\sqrt{3}$) for these soilage conditions are ten 250 mm suspension insulators for seashore areas and eight of the same type for areas in general. It will be assumed in this preliminary design that these numbers of insulators will be used.

According to the standard designs of NAPOCOR, 8 insulators are to be strung at suspension towers and 9 at strain towers, and this consideration may be said to be more or less reasonable if areas very close to the seashore are excepted.

iii) Clearance

With the maximum allowable voltage of the line at 145 kV, and if effective grounding is done at the electricity stations, the size of the switching surge voltage is assumed will be 2.8 Pu. Further, it is assumed there will be a possibility for insulation reduction of 25% considering minimum atmospheric pressure during typhoon of 950 mb (at sea level) and maximum elevation of 500 m.

The required clearance is standard insulation clearance of 100 cm and minimum insulation clearance of 75 cm. Further, the number of insulators required against switching surge voltage will be seven, and it will be sufficient to string the number of insulators determined based on insulator soilage.

iv) Lightning Protection Design

The isokeraunic levels according to meteorological statistics are 98.8 days at Iloilo City, 131.5 days at Cebu City and 69.5 days at Tacloban City, and it appears that occurrences are more frequent during the rainy season from May to October. The number of lightning occurrence for the Visayas Region is about 100 days as a whole, and it may be said to be an area of high frequency of lightning occurrence. Consequently, it can be expected that lightning strokes will reach as many as 200 times per 100 km annually, and lightning protection measures are to be provided.

One line of 70 mm^2 GSC is to be strung as an overhead ground line in a manner that the shielding angle to the conductor will be less than 30 deg for 95% shielding of conductors from lightning strokes.

In order to reduce faults involving back flashover to conductors as much as possible when there are lightning strokes to steel towers or overhead ground wires, the ground resistance of steel towers is to be reduced aiming for 20Ω.

Further, to prevent insulator damage at times of back flashover, insulator strings are to be provided with arcing horns, with horn gap 90 cm.

Estimating the lightning fault rate based on the above lightning protection design, it is expected there will be 17 faults per 100 km annually.

v) Supports

In consideration that this transmission line will be required to have a high reliability as a trunk interconnecting transmission line, that 60% of the transmission line route will pass over mountainland, and wooden poles will require reinstallation due to rotting, angle steel towers are to be used as supports.

Typical configurations of steel towers for single-circuit and double-circuit are shown in Fig. 6-2.

With regard to foundations for supports, concrete foundations having normal slabs will be used from the aspect of reliability. For rice paddy areas, as stated in 6.2.1(1), it is estimated that the depth of soft ground will be shallow so that reinforcements with piles are not considered in particular, but depending on data from geological investigations, it may be necessary to employ piles for reinforcement.

The design wind speeds against the supports will next be examined. NAPOCOR uses a design wind speed of 46 m/sec (= 166 kph instantaneous) as standard, and is applying this to existing transmission lines of the Visayas Region. According to storm-wind observations during typhoons in the 28 year period from 1948 to 1975, the maximum wind speed (1 minute average) in the Visayas Region was 130 kts (= 66.9 m/sec, measured on

Fig. 6-2 138 kV Transmission Line Standard Type Suspension Tower