capacity and the increase of energization ratio, with the growth through the 12-year period being 7.2 percent and 9.9 percent, respectively, which are much higher than the growth rate of Luzon.

2-4. Present Generating Capacity

Because of scarcity of oil resources in the Philippines, expansion of generating capacity is centered on the development of hydro and geothermal resources, which are being developed steadily. Development of nuclear power is also in progress and the first nuclear power plant in Bataan is expected to be commissioned in 1985.

Generating capacity up to 1983 (up to 1984 for Luzon) by area is shown in Tables 2-4 and 2-5. In Luzon, the total generating capacity is 3,801 MW, comprising 916 MW (24.1%) of hydro power plant, 300 MW (7.9%) of pumping-up power plant, 1,925 MW (50.6%) of oil-fired thermal power plant and 660 MW (17.4%) of geothermal power plant.

However, the Sucat and Malaya thermal plants have problems with generating facilities and their combined capability is now reduced to 1,125 MW (75% of installed capacity). These two power plants are being rehabilitated under the Rehabilitation Program.

Of the geothermal plants, Tiwi power plant is experiencing a decrease of output by 30 MW due to insufficient steam supply. On the other hand, Ambukulao and Binga hydro power plants are operating by increasing their outputs by 6 MW and 16 MW, respectively, for a total of 22 MW. The generating capability in Luzon in October, 1984, including the period of shut-down maintenance, was 2,796 MW or 73.5 percent of installed capacity.

Table 2-4 Generating Capacity in Luzon

Unit : MW

Type	Plant	1977	1978	1979	1980	1981	1982	1983	1984
Hydro	Ambukulao	75	75	75	75	75	75	75	75
	Angat	212	218	218	218	218	218	218	218
	Binga	100	100	100	100	100	100	100	100
	Caliraya	32	32	32	32	32	32	32	32
	Botocan	17	17	17	17	17	17	17	17
	Barit	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Cawayan	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Pantabangan	100	100	100	100	100	100	100	100
	Masiway				12	12	12	12	12
	Kalayaan						300	300	300
	Magat							270	360
	Subtotal	538.2	544.2	544.2	556.2	556.2	856.2	1126.2	1216.2
Oil—Thermal	Sucat	850	850	850	850	850	850	850	850
	Manila	200	200	200	200	200	200	200	200
	Rockwell	305	305	305	305	180	180	305	0
	Bataan	225	225	225	225	225	225	225	225
	Malaya	300	300	650	650	650	650	650	650
	Subtotal	1880	1880	2230	2230	2105	2105	2230	1925
Diesel	Diesel	6	0	0	0	0	0	0	0
Geo—Thermal	Tiwi			110	220	275	330	330	330
	Mak-Ban			110	220	220	220	220	330
	Subtotal			220	440	495	550	550	660
Total		2424.2	2424.2	2994.2	3226.2	3156.2	3511.2	3906.2	3801.2

Table 2-5 Generating Capacity in Mindanao

Unit : MW

Type	Plant	1977	1978	1979	1980	1981	1982	1983
Hydro	Agusan	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Agus 4	200	200	200	200	200	200	200
	Agus 2			180	180	180	180	180
	Agus 7						27	54
	Subtotal	201.6	201.6	381.6	381.6	381.6	408.6	435.6
Thermal & Diesel	Aplaya 1	11	11	11	11	11	11	11
	Aplaya 2			36	72	108	108	115.7
	General Santos				21.9	21.9	21.9	22.3
	Barge							32
	Subtotal	11	11	47	104.9	140.9	140.9	181
Total		212.6	212.6	428.6	486.5	522.5	549.5	616.6

Generating Capacity in Visayas

Unit : MW

Type	Plant	1977	1978	1979	1980	1981	1982	1983
Hydro	Loboc (Bohol)	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Amlan (Negros)	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Sub total	2	2	2	2	2	2	2
Diesel & Thermal	Cebu 1 (Cebu)	36.5	51.1	51.1	51.1	51.1	51.1	51.1
	Cebu 2 (Cebu)						36	57.9
	Naga 1 (Cebu)					50	50	50
	Amlan (Negros)		11	11	11	11	11	11
	Barge 2 (Negros)					32	32	32
	Bohol (Bohol)		5.5	11	11	11	11	11
	Panay (Panay)			14.6	21.9	29.2	29.2	29.2
	Barge 1 (leyte)					32	32	
	Subtotal	36.5	67.6	87.7	95.0	216.3	252.3	242.2
Geo-Thermal	Palinpinon 1				3	3	3	115.5
	Palinpinon 2						3	3
	(Negros)							
	Tongonan (Leyte)	3	3	3	3	3	3	115.5
	Subtotal	3	3	3	6	6	9	234
Total		41.5	72.6	92.7	103.0	224.3	263.3	478.2

Note : Barge 1 was Transfered to Mindanao.

In Visayas, the total generating capacity is 478 MW, comprising 2.0 MW of hydro, 242.2 MW of diesel and thermal (including barge power plant) and 234.0 MW of geothermal.

In Mindanao, the total generating capacity is 617 MW, comprising 435.6 MW of hydro and 181 MW of diesel and thermal (including barge power plant).

The Philippines experienced an extraordinary dry weather in succession in 1982 and 1983. Table 2-6 shows a record of rainfalls in Manila (1965, 1970 - 1983). In 1983, power generation by hydro power plants decreased drastically because of lack of rain in the wet season (May to December) of the previous year and a very small annual rainfalls of 110 mm in 1983.

Table 2-6 Rainfalls MANILA

Year	Rainfall (mm)	Year	Rainfall (mm)
1965	1,865	1977	2,694
1970	2,293	1978	2,557
1971	2,937	1979	2,034
1972	3,336	1980	2,107
1973	1,520	1981	1,681
1974	2,008	1982	104
1975	1,486	1983	110
1976	1,332		

For this reason, hydro power plants in Luzon and Mindanao were constantly operating under difficult conditions. Mindanao had to call one of the two barge power plants located in Visayas to secure the required power supply. In Luzon, on the other hand, the share of oil-based thermal plants, which had been decreasing year by year, increased from 57.5 percent in 1982 to 61.6 percent in 1983.

2-5. Power Expansion Program

The growth of power demand and peak load is expected to level off in the next several years in Luzon but an average growth of about 5 percent is forecast for the Philippines in the 12-year period up to 1995. To meet the growth of power demand in each area as mentioned previously, expansion of generating capacity is contemplated as shown in Table 2-7. Under the Power Expansion Program, effort is directed mainly to the development of nuclear, hydro, geothermal and coal-based thermal power plants, with additional construction of barge power plants, to attain the goal of reducing the share of oil-based thermal power plants to less than 16.2 percent of total generating capacity by 1995. (See Table 2-8)

Main power plants to be constructed under the Power Expansion Program are as follows.

For hydro power plants, Pantay power plant (23 MW), San Roqse power plant (390 MW) in Luzon are to be completed in 1993, power plants in the Agus river system in Mindanao with a combined capacity of 510 MW is to be completed by 1991 and Pulangi power plant (255 MW) also in Mindanao is to be completed in 1985, for a combined capacity of 1,178 MW.

For coal-based thermal power plants, Calaca power plant (600 MW) and Isabela power plant (300 MW) in Luzon, a power plant (55 MW) in Visayas and power plants (400 MW) in Mindanao a combined capacity of 1,355 MW are under planning.

Table 2-7 Power Expansion Program (1)

Unit : MW

Grid	Type	Plant	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Luzon	Hydro	Magat 4	90											
		Pantay							23					
		San Roque										390		
	Coalthermal	Calaca I		300										
		Isabela 1,2								200				
		Iaabela 3									100			
		Calaca II											300	
	Geothermal	Mak-Ban 5,6	110											
		Manito 1,2					110							
	Nuclear	PNPP		620										
	Oilthermal	Rockwell	△305											
		Additional	△105	920			110		23	200	100	390	300	
		Existing	3906											
		Total	3801	4721	4721	4721	4831	4831	4854	5054	5154	5544	5844	5844
Visayas	Diesel	Diesel	7.3	6.8		5.7	△ 6.0							
		Barge		64.0	32.0		△32.0	32.0			△32.0			
	Coalthermal	Naga II			55.0									
	Geothermal	Tongonan II						37.5					37.5	
		Palinpinon II								37.5	37.5	37.5		
		Additional	7.3	70.8	87.0	5.7	△38.0	69.5		37.5	5.5	37.5	37.5	
		Existing	478.2											
		Total	485.5	556.3	643.3	649.0	611.0	680.5	680.5	718.0	723.5	761.0	798.5	798.5

Table 2-7 Power Expansion Program (2)

Unit : MW

Grid	Type	Plant	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Mindanao	Hydro	Agus V	55											
		Agus IV		150										
		Pulangi IV		255										
		Agus I			80									
		Agus III								225				
	Diesel	Diesel	21.9			36.0		△36.9						
		Barge		△32.0			32.0	△32.0						
	Coalthermal	Bislig 1,2						100	100					
		Sur 1,2										100	100	
		Additional	76.9	373	80	36	32	31.1	100	225		100	100	
		Existing	616.6											
		Total	693.5	1066.5	1146.5	1182.5	1214.5	1245.6	1345.6	1570.6	1570.6	1670.6	1770.6	1770.6

Table 2-8 Generation by Energy Source (Actual & Forecast)

		Hydro	Geo	Nuclear	Coal	Oil	Total
1983	(GWh)	2965	4093	0	110	11514	18682
	(%)	(15.92)	(21.9)	(0)	(6)	(61.6)	
1984	(GWh)	5502	4540	0	271	7456	17769
	(%)	(31.0)	(25.5)	(0)	(1.52)	(42.02)	
1985	(GWh)	6518	4686	1900	2217	3783	19104
	(%)	(34.1)	(24.5)	(10.0)	(11.6)	(19.8)	
1986	(GWh)	7074	4697	2715	2513	3658	20657
	(%)	(34.3)	(22.7)	(13.1)	(12.2)	(17.7)	
1987	(GWh)	7681	4858	3258	2513	3788	22098
	(%)	(34.8)	(22.0)	(14.7)	(11.4)	(17.1)	
1988	(GWh)	7855	5682	3531	2513	3734	23315
	(%)	(33.7)	(24.4)	(15.1)	(10.8)	(16.0)	
1989	(GWh)	7912	6131	3803	2918	4224	24988
	(%)	(31.7)	(24.5)	(15.2)	(11.7)	(16.9)	
1990	(GWh)	8067	6535	3803	3458	4808	26671
	(%)	(30.2)	(24.5)	(14.3)	(13.0)	(18.0)	
1991	(GWh)	9158	6634	3803	4239	4548	28382
	(%)	(32.3)	(23.4)	(13.4)	(14.9)	(16.0)	
1992	(GWh)	9158	6940	3803	5203	4828	29932
	(%)	(30.8)	(23.2)	(12.7)	(17.4)	(16.1)	
1993	(GWh)	10058	7184	3803	5608	4976	31629
	(%)	(31.8)	(22.7)	(12.0)	(17.7)	(15.8)	
1994	(GWh)	10058	6997	3803	7939	4556	33353
	(%)	(30.2)	(21.0)	(11.4)	(23.8)	(13.6)	
1995	(GWh)	10058	7366	3803	8284	5706	35217
	(%)	(28.6)	(20.9)	(11.8)	(23.5)	(16.2)	

Geothermal power plants to be constructed are Manito (110 MW) in Luzon and Palinpinon (112.5 MW) and Tongonan (75 MW) in Visayas, for a total capacity of 297.5 MW.

For nuclear power, the first nuclear power plant (620 MW) in Bataan is expected to be commissioned in 1985.

As a result, the total generating capacity to be developed by 1995 amounts to 3,587 MW, increasing the total generating capacity of the Philippines, including the existing generating capacity, to 8,413 MW, with hydro accounting for 33.7 percent, oil-based thermal 28.9 percent, coal-based thermal 16.7 percent, geothermal 14.2 percent and nuclear 7.4 percent.

2-6. Power System

In the Philippines, an independent power system is maintained by each main island. Power systems of main islands are shown in Figures 2-3, 2-4 and 2-5.

In Luzon, the power system is formed mainly by 230 kV trunk lines running through the island from north to south, with hydro power plants located mainly in the north, thermal, geothermal and pumping up power plants located in and around Metro Manila, and Tiwi geothermal plant located in the south. The greatest portion of the load is accounted for by Metro Manila and its vicinity, while a major portion of the load in local area is accounted for by general consumers.

In Visayas, an independent system of 138 kV trunk lines is provided for each of Leyte, Samar, Bohol, Cebu, Negros and Panay islands. Construction of submarine cables interconnecting Negros and Panay islands is expected to complete in 1988.

Fig. 2-3 LUZON GRID

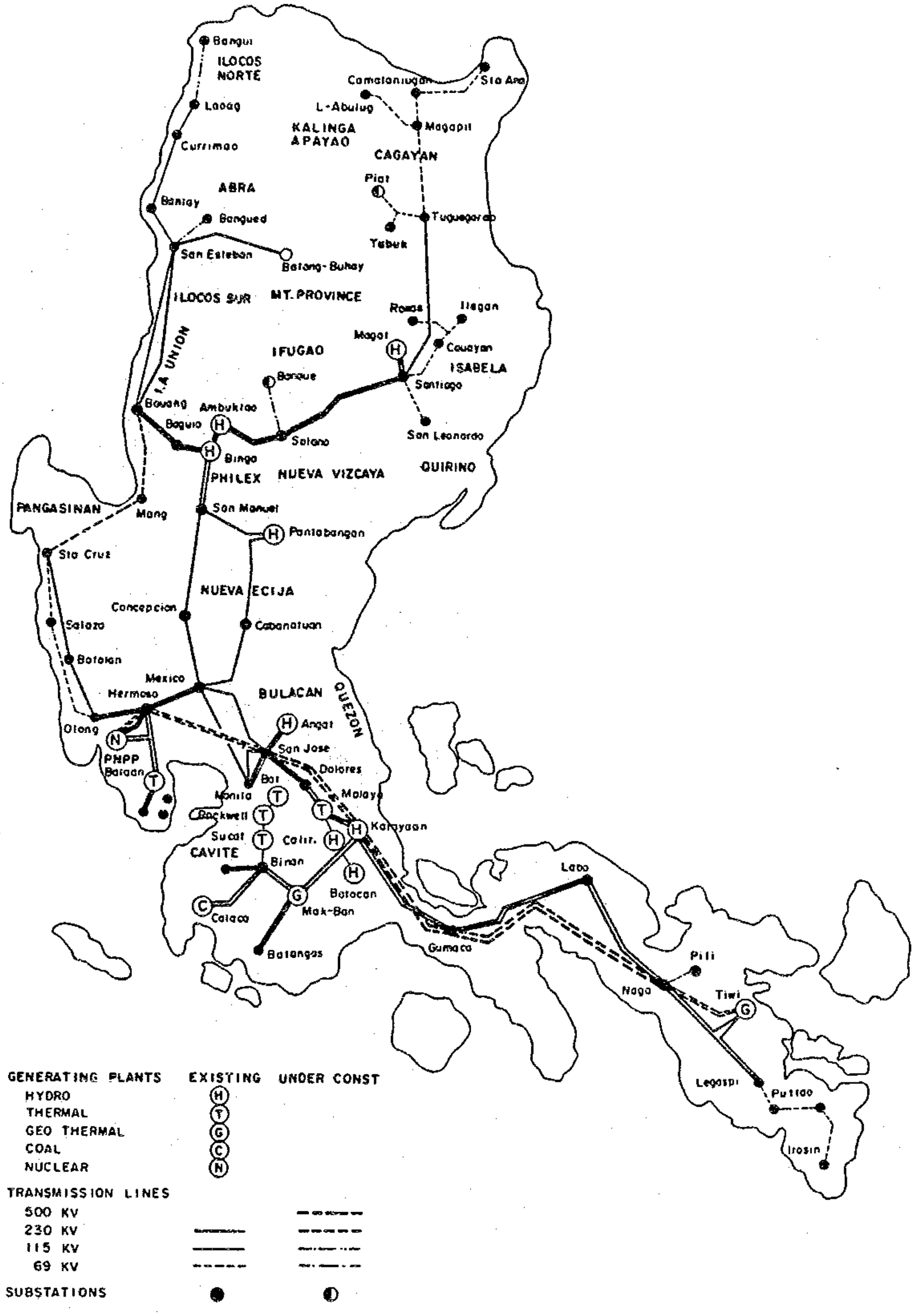


Fig. 2-4 VISAYAS GRID

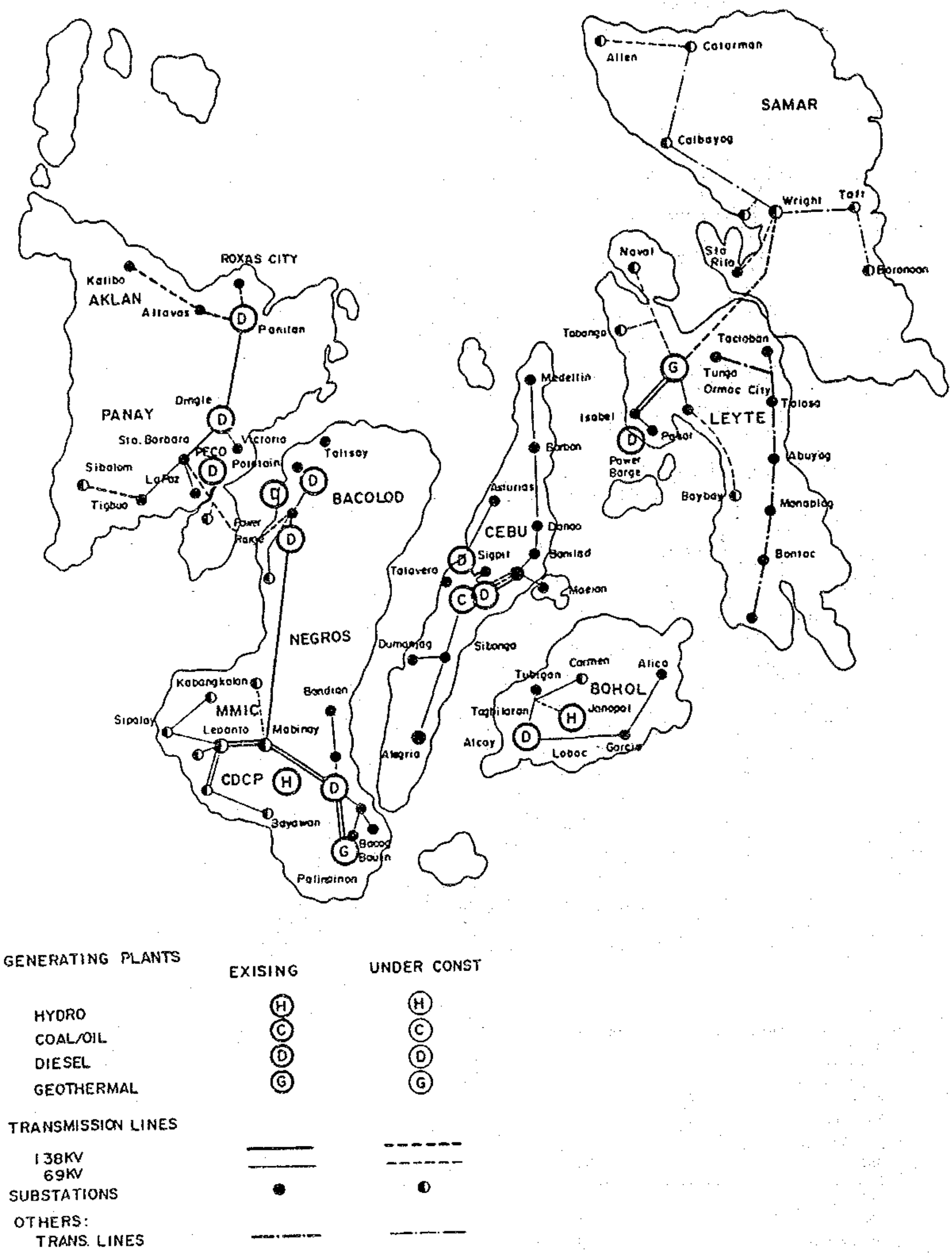
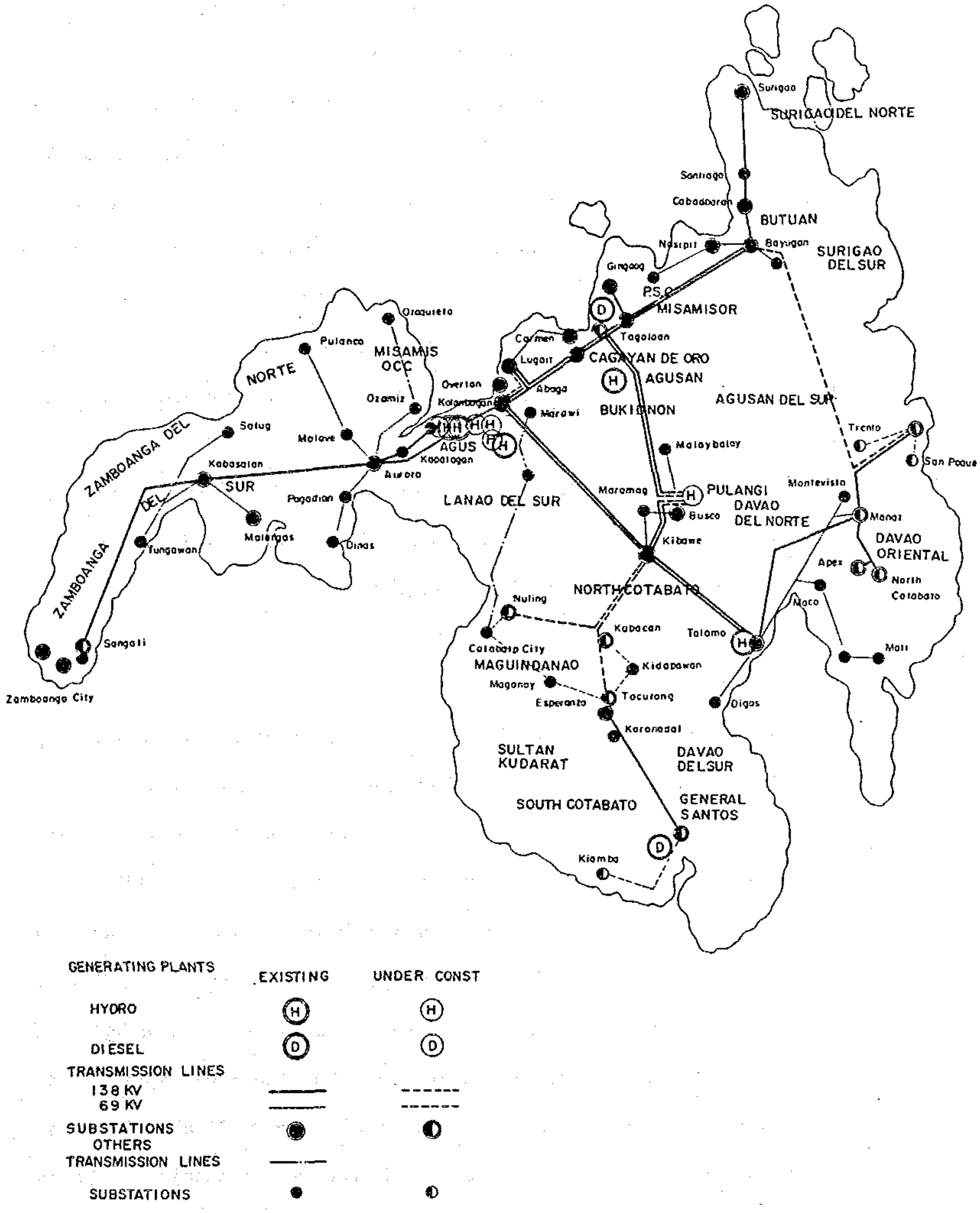


Fig. 2-5 MINDANAO GRID



In Mindanao, the present power system with 138 kV trunk lines is supported mainly by hydro power plants, most of them are located along the Agus river, but construction of coal-based power plants is also planned to cope with the increasing demand.

Changes in the total length of transmission lines and the capacity of substations are shown in Fig. 2-6. The length of 69 kV, 115 kV, 138 kV and 230 kV transmission lines has increased annually, with the total length reaching 4,396 km, 484 km, 2,067 km and 3,164 km, respectively, by the end of 1983.

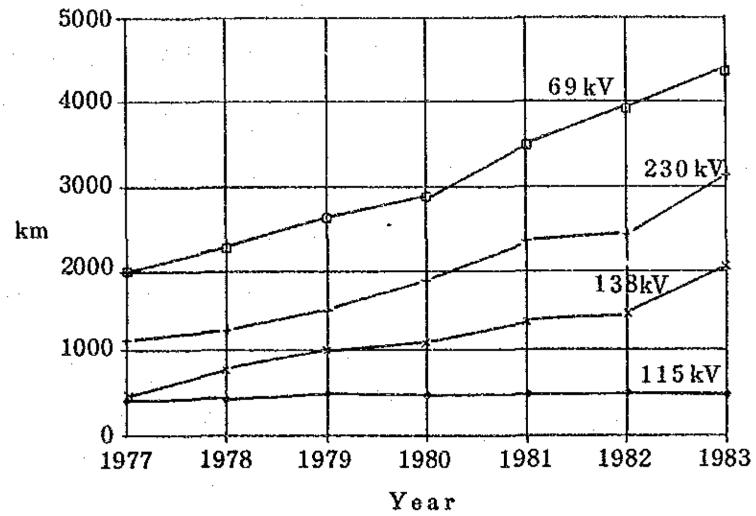
The length of 69 kV, 115 kV and 230 kV transmission lines in the Luzon Grid in October, 1984 is 2,539 km, 662 km and 3,461 km, respectively.

The expansion of the capacity of 230 kV substations is remarkable and it reached 5,700 MVA at the end of 1983. This was caused by the expansion of 230 kV transmission lines.

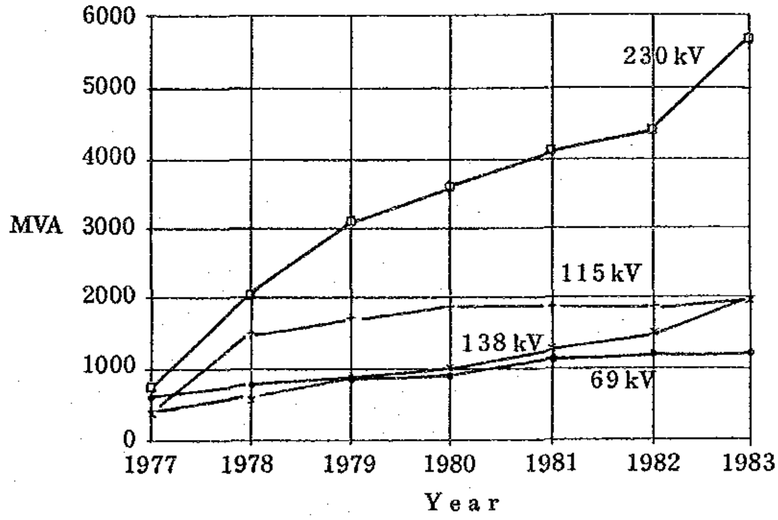
2-7. Luzon Grid Transmission Network

The 230 kV transmission lines in the Luzon Grid extends 965 km, comprising approximately 510 km from Tuguegarao in the north to San Jose in the east of Metro Manila, approx. 340 km from Kalayaan pumping-up power plant in southeast of Metro manila to Tiwi geothermal power plant in the south and 115 km between San Jose and kalayaan in the outer link of Metro Manila. Power supply to Manila is from the east by 230 kV transmission lines extending from Kalayaan to Mak-Ban geothermal power plant and to Binan substation. The 230 kV transmission lines constructed between Binan substation and Sucat power plant in the west of Manila are scheduled to be in operation in the near future.

Fig. 2-6 Length of Transmission Line



Substation Capacity



San Jose substation is interconnected with Balintawak substation in the north of Metro Manila by 230 kV transmission lines. Between San Jose substation and Kalayaan power plant, Dolores substation is located as an eastern supply base for Manila.

Power is supplied to Metro Manila by Dolores, Balintawak and Binan (or Sucat) substations but within Metro Manila two power plants, Sucat (850 MW) and Manila (200 MW).

For secondary transmission system in Metro Manila, 115 kV transmission lines of MERALCO are drawn out from the above mentioned power stations and substations thereby providing a mesh interconnection.

CHAPTER 3

NATIONAL POWER CORPORATION

CHAPTER 3

Chapter 3. National Power Corporation

3-1. History of National Power Corporation

The National Power Corporation (NAPOCOR) was founded in 1936 upon passage by the Parliament according to the Republic Act No. 6395 aimed for efficient and comprehensive development of water resources and effective utilization of all available energy resources to facilitate energization of the whole country. The main objectives of NAPOCOR are to secure a stable supply of low cost energy, which is indispensable to industrial and economic development of the Philippines, and to establish a power generation and supply system for energization of households to stabilize the people's livelihood.

At the time of its foundation, NAPOCOR was a public corporation which was not authorized to issue stocks but the reorganization in 1960 enabled it to issue stocks.

Since then, the demand for power increased sharply with the rapid growth of the Philippine economy and there was an increasing need for the expansion of generating capacity. For this reason, NAPOCOR decided to expand the scope of its operation in 1972 and purchased four thermal power plants, having a total capacity of 1,700,000 kW, from Philippines' largest private power company in 1978. NAPOCOR is continuing its effort to provide a stable power supply through expansion of generating capacity and improvement and enhancement of transmission system by dividing its service area into three grids of Luzon, Visayas and Mindanao.

NAPOCOR is capitalized at 22,928 million Pesos as of December, 1983 and sells energy to MERALCO, local industries, cooperatives and government agencies.

3-2. Organization of NAPOCOR

The scope of activities of NAPOCOR is determined by the Board of National Power Committee, the highest decision-making organ. All members of the Committee are appointed by the President of the Philippines, and the Minister of Energy takes the chair.

The business of NAPOCOR is carried out by five departments of Finance & Administration, Engineering, Utility Operation of Luzon, Utility Operation of Visaya & Mindanao and PNPP (Nuclear Power Plant Construction) under president of NAPOCOR. (See Fig. 3-1)

At present, the power system in the Philippines is separated into the Luzon, Visayas and Mindanao grids, which are operated independent from each other.

The lower organizations of NAPOCOR responsible for the system operation will be described in the following, taking Luzon, the largest of the three, as an example.

a. The organization responsible for the operation of power system in Luzon is the System Operation Department under the Utility Operation of Luzon, which is composed of divisions charged with planning and analysis, operation control and communication. The responsibility for the operation and maintenance of power facilities is shared by North Luzon Regional Center, South Luzon Regional Center and Metro Manila Regional Center.

b. The organization of South Luzon Regional Center is shown in Fig. 3-2 as an example.

   Bicol and South Tagalog area offices are charged with the operation of substations and inspection and maintenance of transmission lines. Bicol and South Tagalog Technical Services are charged with inspection and maintenance of relays and other heavy equipment of substations within their respective areas.

Fig. 3-1 Organization Chart of NAPOCOR

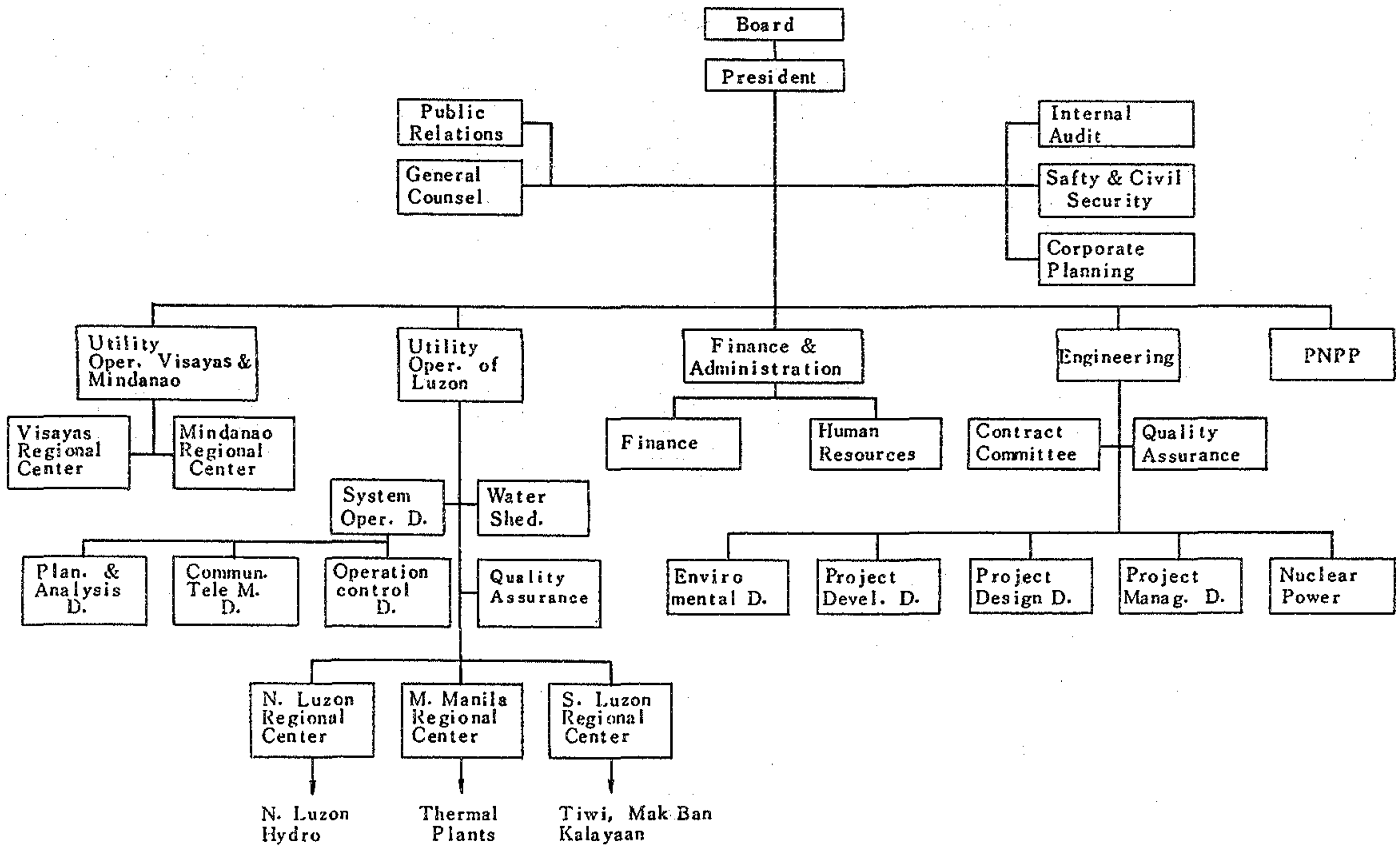
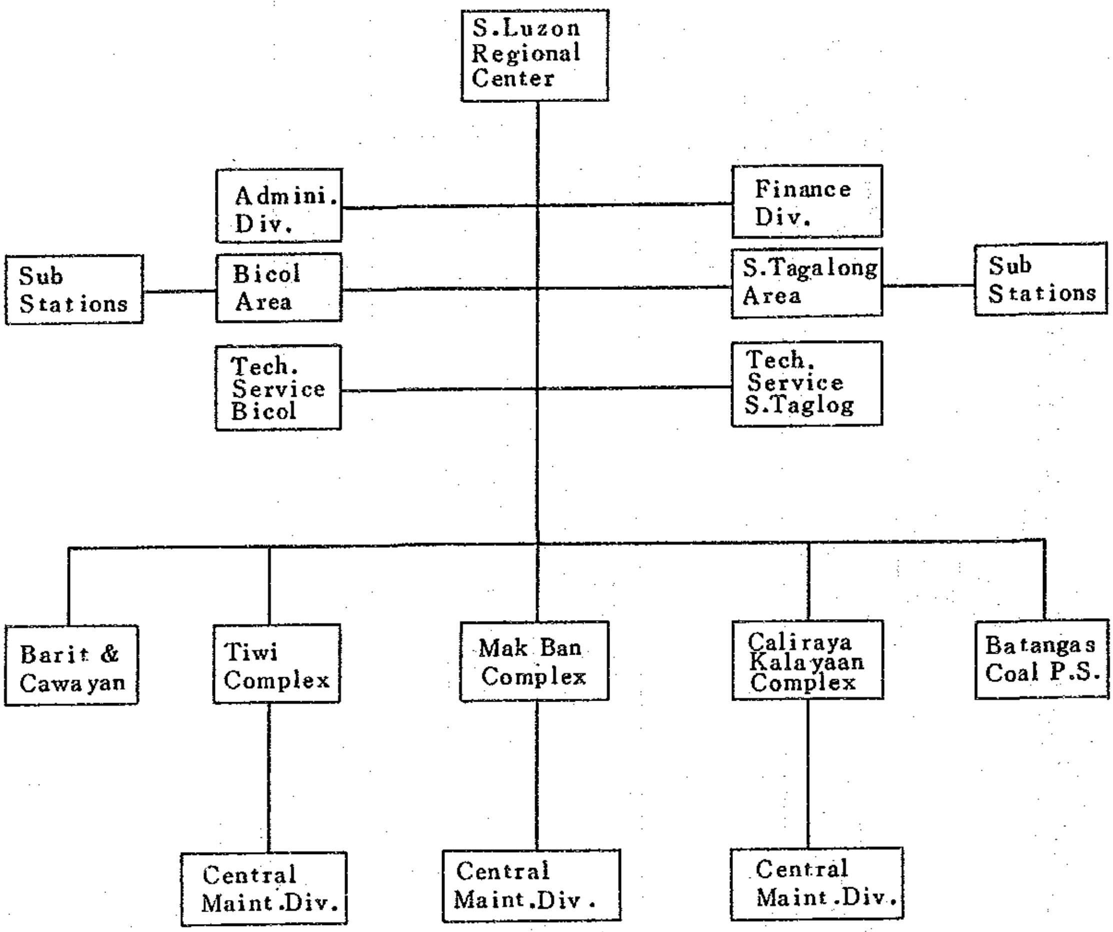


Fig. 3-2 Organization Chart of Regional Center



As shown in Fig. 3-3, the Technical Service has protective relays, meter test (including supply of meters), substation equipment test and communication (power line carrier communication and lower level communication) sections.

An example of organizations of area offices is shown in Table 3-1. The area office has a branch office in each province, which is composed of administration, substation operation, maintenance and line gang sections.

At present, maintenance of microwave communication system is the responsibility of the Communication and Telemetering Division of the head office, but the creation of a microwave maintenance section is being planned for each of the North and South Luzon Regional Centers.

c. NAPOCOR has introduced a performance appraisal system and a merit rating program into its pilot organizations for the purpose of revitalizing the organization and raising the morale of employees and plans to expand the scope of application.

In the pilot substation, for example, tables showing changes in actual and predicted expenditures and maintenance cost, as well as monthly records of electric energy flowing through transformers, are posted for employees' information as a means to uplift cost consciousness of the employees.

At present, SyCip, Corres and Velayo is hired as a consultant for improvement of organization efficiency.

Fig. 3-3 1984 Table of Organization Bicol Technical Services

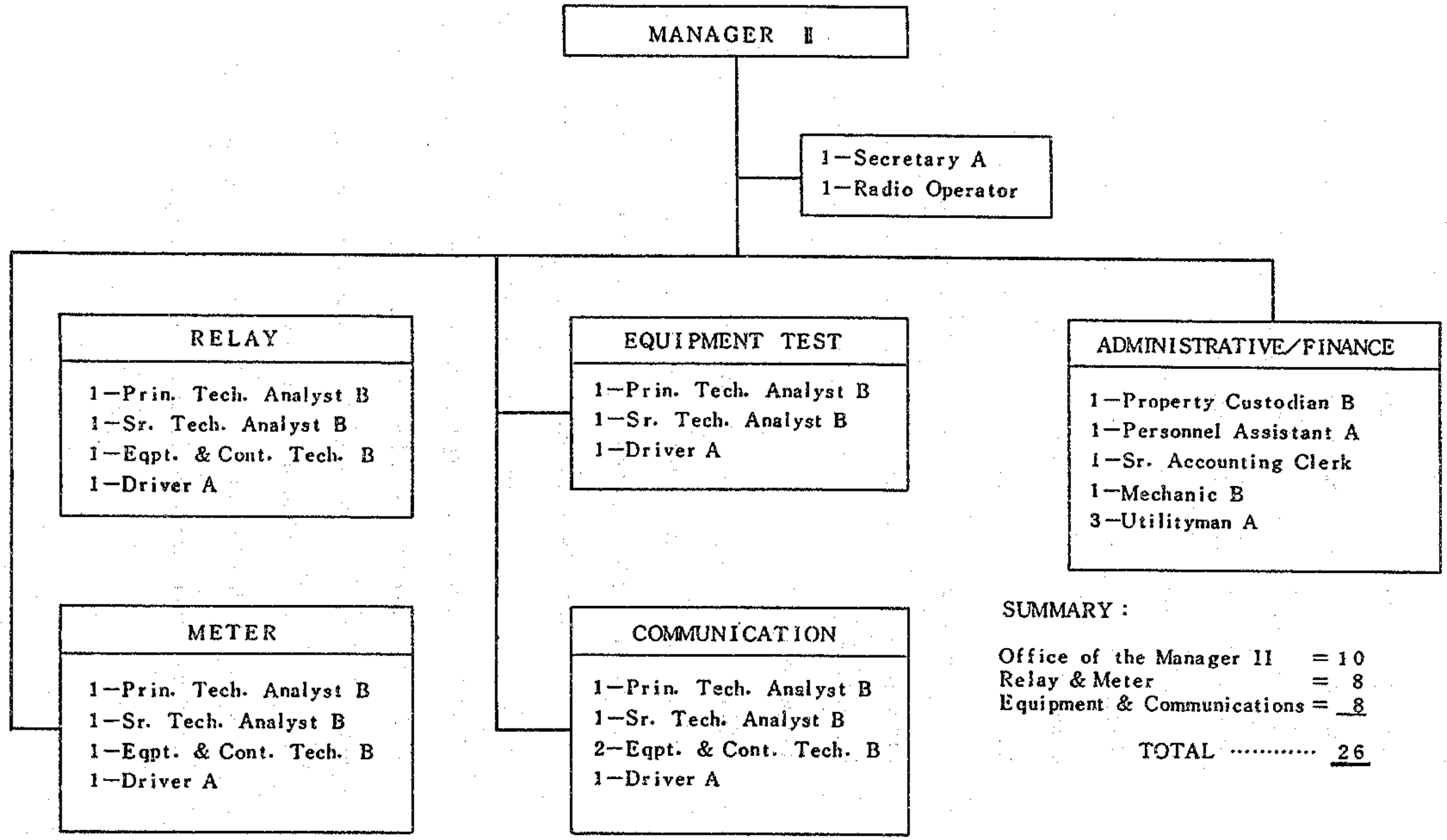


Table 3-1 Example of the Organization of Area Office

Manager

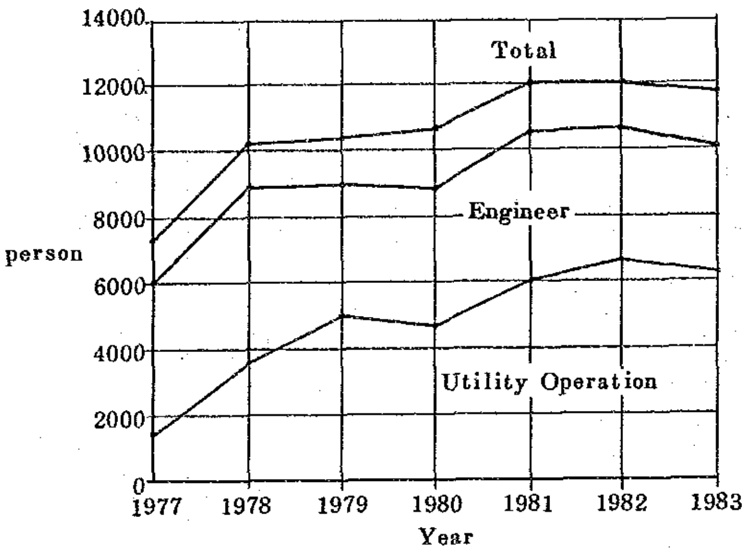
Laguna (Province)	Cavite (Province)	Branch office	Batangas (Province)	Quezon (Province)
1, SS	1, SS	14	1, SS	1, SS
Chief 1	Chief 1		Chief	Chief 1
shift 2×5	shift 2×5		shift 2×5	shift 2×5
others 2	others 2		others 2	others 2
guard 6	guard 6		guard 6	guard 6
2, line gang	2, line gang		2, line gang	2, line gang
8×3 24	8×2 16		8×2 16	8×4 32
others 1	others 1		others 1	others 1
3, maintenance	3, maintenance		3, maintenance	3, maintenance
3	3		3	4
4, Admi.	4, Admi.		4, Admi.	4, Admi.
3	3		3	6
guard 4	guard 1		guard 8	others 2

Note : Numeral is number of employee.

3-3. Employees and Training Program

Changes in the number of NAPOCOR employees are shown in Fig. 3-4. The number of employees, which was 7,132 in 1977, increased sharply to 12,062 in 1981 and decreased to 11,628 in 1983. Of 11,628 employees, about 52 percent are utility personnel and operators, 34 percent are engineers and the rest are head office staff and employees of administration, labor, finance and material sections of lower organizations.

Fig. 3-4 Number of employee



NAPOCOR is endeavoring to educate and train its employees to level up their skills and provide them an opportunity to acquire new techniques. In 1983, a total of 4,066 training courses were provided, of which 36 percent were for operators and 34 percent for engineers. For acquisition of new techniques, 87 personnel participated in short-term and long-term overseas training programs. Of all the overseas training programs, 55 percent were for the operation and maintenance of nuclear power plants and the rest were attended by the personnel related to operation and maintenance in other technical fields.

3-4. Highlights of Account Settlement

Highlights of account settlement for NAPOCOR in 1983 as compared with those in 1982 are shown in Table 3-2.

Table 3-2 Highlights of Account Settlement for NAPOCOR in 1983

ITEM	1983	1982	Increase/ (Decrease), %
I Utility Operations			
Generating Capacity (MW)	5,001	4,324	15.6
Luzon	3,906	3,511	11.2
Visayas	478	263	81.7
Mindanao	617	550	12.2
Energy Generation, (GWh)	18,682	17,413	7.3
Generation Mix, (%)			
Oil-Based	61.6	57.6	4.0
Geothermal	21.9	20.6	1.3
Hydro	15.9	21.5	(5.6)
Coal	0.6	0.3	0.3
Fnergy Sales, (GWh)	17,089	16,000	6.8
Net Operating Revenue, (m₱)	9,629	6,665	44.5
Average Power Rate, (P/kWh)	0.5790	0.4299	34.7
Operating Expenses, (m₱)	8,143	6,059	34.4
Net Operating Income*, (m₱)	1,486	606	145.2
Return on Rate Base, (%)	8.2	4.5	3.7
Gross Internal Cash Generation, (m₱)	2,771	1,448	91.4
Number of Personnel	11,628	11,978	(2.9)
MWh Produced Per Employee	1,607	1,454	10.5
Number of Customers	287	281	2.1
Substation Capacity, (MVA)	10,842	9,010	20.3
Transmission Lines, (km)	10,298	8,535	20.6
II Investment Activities			
Generation Projects Completed (MW)	541	421	28.5
Generation Projects Under Construction year-end (WM)	1,715	2,210	(22.4)
Capital Expenditures, (m₱)	8,005	6,304	27.0
Foreign Loans	4,746	3,403	39.5
Net Intemal Cash Generation	721	542	33.0
Govt. Equity Contribution	1,145	2,131	(46.3)
Others	1,393	228	511.0
III Balance Sheet Items, Year-End			
Total Assets	71,250	44,263	61.0
Utility Plant	56,495	37,001	52.7
Under constion	35,110	22,196	58.2
Operating	21,385	14,805	44.4
Proprietary Capital	22,928	17,676	29.7
Long-Term Debt	36,716	19,797	85.5

* Before financing charges & net other income

a. Utility Operations

(1) Generating Capacity

Generating capacity in 1983 reached 5,001 MW, an increase of 15.6 percent over the previous year. Power plants constructed in 1983 are Kalayaan pumping-up plant (150 MW x 2) in Luzon, Tongonan geothermal plant (37.5 MW x 3) in Leyte and Palinpinon geothermal plant (37.5 MW x 3) in Negros. Substation and transmission facilities were expanded by 20 percent over the previous year with the expansion of generating capacity as a result of the growth of power demand.

The number of employees in 1983 was 11,628, a decrease of 2.9 percent from the previous year.

(2) Energy Generation

Energy generation in 1983 amounted to 18,682 GWh, an increase of 7.3 percent over the previous year. However, energy generation by hydro power plants decreased drastically due to extraordinary drought ever experienced in ten years and the operation of oil based power plants had to be increased. As a result, the share of oil-based power plants increased to 61.6 percent of total energy generation, an increase of 4 percent from 57.6 percent in the previous year.

(3) Energy Sales

Energy sales in 1983 amounted to 17,089 GWh, an increase of 6.8 percent over the previous year. However, the raise of power rate contributed to the increase of net operating revenue by 44.5 percent to 9,629 million Pesos.

Because of the increase of price index, operating expenses increased by 34.7 percent to 8,143 million Pesos but the net operating income remained at 1,486 million Pesos, with the return on rate base increasing by 3.7 percent to 8.2 percent from 4.5 percent in the previous year. Due to the decrease of the number of employees, MWh produced per employee increased by 10.0 percent to 1,470 MWh/person from 1,336 MWh/person in the previous year.

b. Fund Position

Capital expenditures for construction amounted to 8,005 million Pesos, an increase of 27 percent from 6,304 million Pesos in the previous year, of which foreign loans amounted to 4,746 million Pesos accounting for 59.3 percent of the total, an increase of 1,700 million Pesos or 5.3 percent from 54 percent in the previous year.

However, the government equity contribution decreased by 990 million Pesos to 1,145 million Pesos from the previous year due to fiscal retrenchment, and the procurement of funds from other domestic sources increased by 1,165 million Pesos to 1,393 million Pesos.

c. Balance Sheet at End of 1983

Utility assets amounted to 56,495 million Pesos, an increase of 12,200 million Pesos from 44,263 million Pesos in the previous year. Proprietary capital increased by approximately 5,300 million Pesos to 22,928 million Pesos.

The long-term debts, in the meantime, increased by 17,000 million Pesos to 36,716 million Pesos.

3-5. Financial Analysis of NAPOCOR

Financial analysis of NAPOCOR was made on the basis of financial statements for five years from 1979 to 1983, with respect to labor productivity, earnings of corporate, security of capital and liquidity of finance as shown in Table 3-3.

Table 3-3 Financial Analysis of NAPOCOR

		Unit	1979	1980	1981	1982	1983
Productivity	Per employee net income	₱	14,862	37,932	35,933	13,514	53,250
	Per employee net operating revenue	₱	270,892	443,672	508,319	556,461	828,071
	Per employee energy sales	MWh	1,225	1,296	1,237	1,336	1,470
Earnings	Ratio of net profit to total liabilities and net work	%	0.6	1.4	1.2	0.4	0.9
	Profit ratio of sales	%	5.5	8.5	7.1	2.4	6.4
	Net profit per stock	₱	0.31	0.80	0.87	0.32	1.24
Security	Turnover ratio of total liabilities and net worth	No.	0.11	0.16	0.17	0.15	0.14
	Ratio of net worth	%	34.0	39.2	40.2	39.9	32.2
	Net assets per stock	₱	16.7	22.8	29.0	35.4	45.9
Liquidity	Ratio of fixed assets to long-term capital	%	89.0	92.3	100.9	98.7	94.7
	Current ratio	%	139.2	151.0	87.5	90.7	67.9
	Working capital	(M₱)	919	1,488	-594	-520	-3,388
Return on rate base		%	5.5	6.8	6.2	4.5	8.2

a. Analysis of Productivity Indicators

In the analysis of productivity indicators, per employee net operating revenue and per employee net income were taken up as the objects of study. The per employee net operating revenue increased steadily from 271,000 Pesos in 1979 to 444,000 Pesos in 1980, 508,000 Pesos in 1981, 556,000 Pesos in 1982 and 828,000 Pesos in 1983. However, the classification of per employee net operating revenue into energy sales and power rate shows the following result.

Secular Changes of Energy Sales and Power Rate

Year		1979	1980	1981	1982	1983	Average Annual Increase
Energy Sales	GWh	12,640	13,697	14,918	16,000	17,089	7.8%
	Annual Growth (%)	-	8.4	8.9	7.3	6.8	
Power Rate	₱	0.2212	0.3422	0.4166	0.4299	0.5790	27.2%
	Annual Increase (%)	-	54.7	21.7	3.2	34.7	

Against the average annual growth of 7.8 percent of energy sales, the average annual growth of power rate is 27.2 percent, indicating that the growth of per employee operating revenue is supported solely by the increase of power rate.

On the other hand, the decrease of per employee net income in 1979 and 1982 is due to annual fluctuations of appraisal profit due to adjustment of exchange rates for fuel costs.

Note: Fluctuation of Appraisal Profit due to Adjustment of Exchange Rates for Fuel Costs (in thousand Pesos)

1977	1980	1981	1982	1983
12,941	400,867	1,275,354	143,113	805,393

b. Analysis of Earnings

While no definite trend of recurring profit for the current term can be obtained from the analysis of earnings for the past five years because of annual fluctuations of appraisal profit due to adjustment of exchange rates for fuel costs, the earning rate is definitely showing a downward trend in general.

c. Analysis of Security of Capital

There is no specific problem as to the security of capital, but the ratio of net worth was 32.2 percent in 1983 falling below the generally accepted limit of 1/3 of total liabilities and net worth of an enterprise. This situation needs to be rectified in the future.

d. Analysis of Liquidity of Finance

Analysis of liquidity of finance with respect to working capital, generally expressed by "Floating assets minus floating liabilities", indicates definitely the deterioration of liquidity position in 1983. This is believed to have been caused by inbalance between capital expenditures and investment funds including foreign loans as shown in Table 3-4.

Table 3-4 Relations Between Capital Expenditures and Investment Funds including Foreign Loans

(in millions of Peso)

Year	1979	1980	1981	1982	1983
Investment Funds (A)	6,637	3,566	3,831	7,960	4,419
Foreign Loans	4,720	1,650	2,053	5,829	3,274
Gov. Subsidies	815	1,461	1,085	1,357	140
Gov. Advance	1,102	455	693	774	1,005
Capital Expenditures (B)	4,529	4,464	6,161	6,587	7,337
Balance (A-B)	2,108	- 898	- 2,330	- 1,373	- 2,918
Outstanding Account	821	502	1,039	- 410	2,929

Note: On capital base

To be more specific, NAPOCOR, in the face of decreasing foreign borrowings, coupled with curtailment of government subsidies, in the environment of worsening economic conditions following the outflow of foreign exchange reserve in 1983, held down repayment of foreign loans and appropriated the portion thus saved to capital expenditures. As a result, outstanding account increased by 2,919 million Pesos over the previous year, thereby contributing to the deterioration of liquidity position of NAPOCOR.

As to fixed assets, the ratio of fixed assets to long-term capital presents no problem as shown in the previous table.

As seen so far, the analysis of financial statements of NAPOCOR indicates a generally smooth and favorable progress of financing. Only exception is the previously mentioned deterioration of liquidity position in 1983, which is considered to be a direct reflection of the influence of depressed Philippine economy on the financial status of NAPOCOR and which is caused by so-called external factors.

Accordingly, the inbalance between capital expenditures and investment funds of NAPOCOR is expected to be rectified and brought to the state prior to 1972 if the economy recovers from the present state with financial aids such as IMF relief loans and others.

3-6. Power Rates of NAPOCOR

a. Changes in Power Rates

Power rates of NAPOCOR are determined by the National Power Committee. All electric energy is sold at wholesale prices of two main categories, the price for Cooperatives and the price for direct purchasers.

Since the management of NAPOCOR is based on non-profit making principle in accordance with the Presidential Decree No. 938, its power rates are determined to be close to generating costs, with the rates applied to cooperatives set lower than those applied to direct purchasers. The power rate also varies considerably according to regions, with the rate being highest in the Visayas Grid where power is generated mainly by diesel power plants, followed by the Luzon Grid, and the Mindanao Grid where power is generated mainly by hydro power plants and where power rate is less than half of that applied to the Visayas Grid.

Changes in power rates (kWh) by grid in recent years are shown in Table 3-5.

Table 3-5 Changes in Power Rates

(in Peso)

	Luzon	Visayas	Mindanao	Philippines
1975	0.1265	0.1348	0.0248	0.1024
1976	0.1403	0.1420	0.0198	0.1125
1977	0.1810	0.2921	0.0426	0.1441
1978	0.1816	0.2949	0.1000	0.1723
1979	0.2278	0.3080	0.1366	0.2212
1980	0.3640	0.4062	0.1651	0.3422
1981	0.4480	0.4982	0.1800	0.4166
1982	0.4670	0.5444	0.1859	0.4299
1983	0.6152	0.7235	0.2996	0.5790
Average annual increase rate for 1975-1983 period (%)	21.9	23.4	36.5	24.2
Average increase rate for 1982-1983 (%)	31.7	32.9	61.2	34.7

b. Long-Term Forecast of Power Rates

The long-term forecast of power rates under the 1984-1995 Power Expansion Program formulated by NAPOCOR in June, 1984 is as shown in Table 3-6.

Table 3-6 Long-Term Forecast of Power Rates

(in Peso)

	Philippine Average Rate		Philippine Average Rate
1984	0.8288	1990	1.7706
1985	1.2251	1991	2.0506
1986	1.3347	1992	2.2755
1987	1.3638	1993	2.5859
1988	1.4132	1994	2.9543
1989	1.5829	1995	3.2308
	Annual Increase Rate		13.2%

In the review of changes in power rates and long-term forecast, the high annual increase rate for the period 1982-1985 is especially noteworthy. More specifically, the annual increase rates are particularly high at 34.7 percent for 1982-1983, 43.1 percent for 1983-1984 and 47.8 percent for 1984-1985. These high increase rates are maintained to comply with the strong request of money lending institutions, including World Bank, to secure the return on rate base higher than 8 percent, whose lending conditions are becoming more and more stringent for the Philippines in the midst of depression following the fast drain out of foreign currencies in the last few years.

For this reason, it may be inevitable for NAPOCOR to resort to the hike of power rates in order to secure the required return on rate base until such time when the Philippines is able to overcome economic difficulties.

CHAPTER 4

OUTLINE OF TOTAL BLACK-OUT FAULTS

CHAPTER 4

Chapter 4. Outline of Total Black-out Faults

4-1. General

The Philippines experienced an extraordinary dry weather in 1982 and 1983 in succession, forcing the hydro power plants to decrease their output and the newly constructed Kalayaan pumping-up power plant to operate at a very high operating rate. This also resulted in the compulsory operation of Malaya and Sucat power plants for full capability.

Such being the case, the total output of a group of Tiwi (330 MW), Mak-Ban (220 MW), Kalayaan (300 MW) and Malaya (650 MW) power plants often reached 1,230 MW. On the other hand, inadequacy of the capacity of the Binan-Sucat line (170 MW) was a bottleneck often causing the system to operate with the Mak-Ban-Kalayaan 230 kV line being open. As a result, a greater portion (over 500 MW) of the output of Tiwi and Kalayaan power plants was fed to the Kalayaan-Malaya line forcing it to operate at the very limit of the capacity in many cases. Besides, the Malaya-Dolores line often experienced a power flow of about 600 MW since Dolores substation was supplying a greater portion of power destined to Metro Manila.

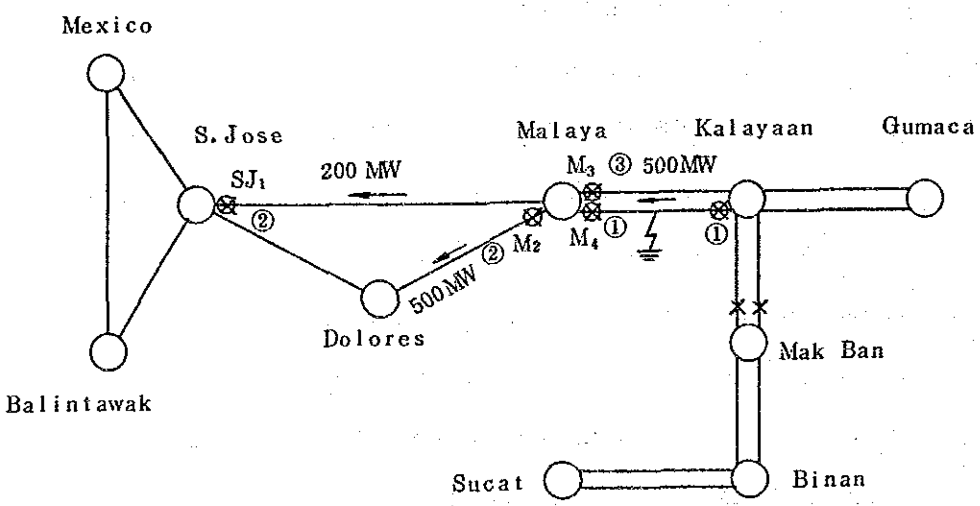
Under such a circumstance, a failure of the 230 kV line in the outer link of Metro Manila would often result in the step-out condition of the system and other major disturbances, leading to a total system blackout.

With this background, a series of major power system failures occurred in Luzon, three times in 1983 and two times in 1984.

4-2. Total System Black-out of August 22, 1983

As shown in Fig. 4-1, the initial fault occurred in the Malaya-Kalayaan line, and immediately out-of-step condition developed, causing the protective devices at San Jose substation and Malaya power plant to trip all unaffected transmission lines, resulting in the total system blackout.

Fig. 4-1 System Black-out of August 22, 1983



Notes: 1. Figures in circle indicate the sequence of operation

2. MW of transmission lines indicates estimates.

As shown in the figure, protective devices M2 and M3 at Malaya and SJI at San Jose tripped because of out-of-step condition, cutting off the supply of about 1,000 MW (40%) in the area north of Metro Manila which shares a greater portion of the load in Luzon (about 2,150 MW) and resulting in total system failure due to lack of power supply.

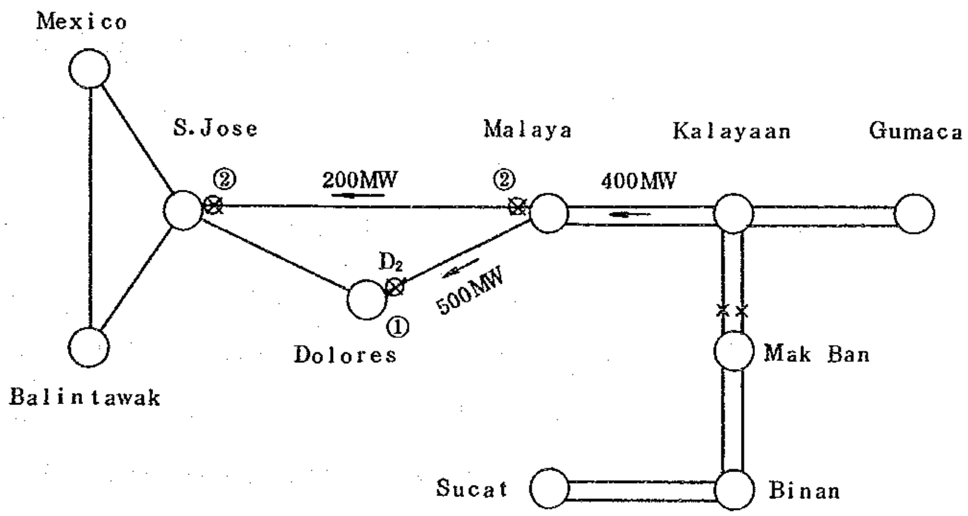
On the basis of the findings of the Technical Committee of NAPOCOR for the total black-out, the following emergency measures were recommended for immediate implementation.

1. To install a step-out relay on the distance relay.
2. To expand the load limit shedding system by frequency relay from the existing 900 MW to 1,200 MW as a measure against the separation of power source of 1,000 MW or over.
3. To provide sequence event recorders.

4-3. Total System Failure of August 24, 1983

The condition of the system prior to the failure is shown in Fig. 4-2.

Fig. 4-2 System Black-out of August 24, 1983



Notes: 1. 1 indicates manual tripping for maintenance and

2 indicates tripping by relay

2. MW of transmission lines indicates estimates.

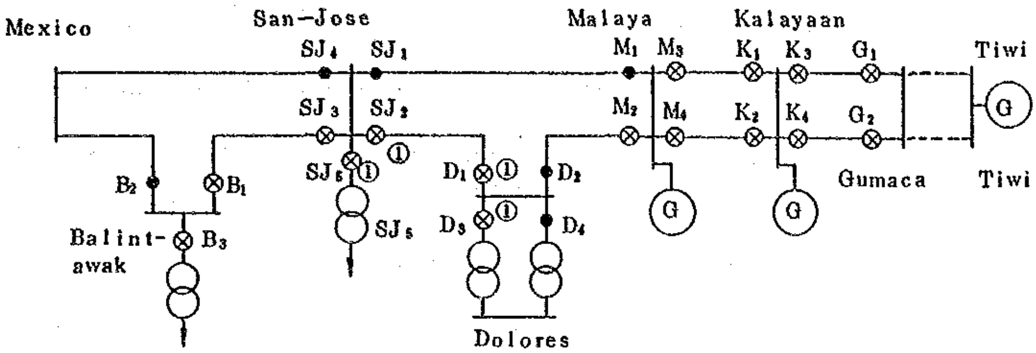
The fault occurred at 13:45 hours when the breaker D2 at Dolores substation was manually opened for maintenance of the Malaya-Dolores 230 kV line, which resulted in the operation of protective devices at Malaya and San Jose substations and tripping of the Malaya-San Jose line. As a result, supply of 750 MW generated by Tiwi, Kalayaan and Malaya power plants to the load in Metro Manila was suspended, resulting in the total system black-out.

Investigation into the cause of the failure showed that the manual tripping of breaker at Dolores substation was hardly the cause of the system failure. It was assumed, therefore, that a high resistance ground fault had occurred in the Malaya-San Jose line simultaneously by chance. As a remedial measure, it was decided to study the installation of high sensitivity of ground relays.

4-4. Total System Black-out of September 15, 1983

The condition of the system prior to the failure is shown in Fig. 4-3. The weather was bad with thunderstorms and a total of 950 MW generated by Tiwi, Kalayaan and Malaya power plants was being fed to the load in Metro Manila through Dolores substations and others. Then some lightnings occurred between San Jose and Dolores, putting the line out of system and tripping one transformer banks at Dolores substation and San Jose substation.

Fig. 4-3 System Black-out of September 9, 1983



● - Breaker not tripped

⊗ - Breaker tripped

Note: 1 indicates the relay that operated first

At about the same time, the protective device of the Dolores line at the Malaya power plant tripped by carrier command signal. As a result, power source to the load in Metro Manila had to be supplied through transformers at Balintawak substation, resulting in voltage drop and out-of-step of the system and causing breaker B1 at Balintawak to trip and breaker SJ3 at San Jose substation to trip by carrier command signal.

Also, the transformer at Balintawak was tripped by over current relay because of overloading. As a result, a greater portion of the load of transformer was shut down resulting in the collapse of the 230 kV system.

In the system south of San Jose, the malfunctions of protective devices due to out-of-step condition did not occur because step-out relays had been provided following the previous major power failures. In other words, the 230 kV line was operating normally until the tripping of transformers of Balintawak substation due to over-loading resulting in the total system black-out in Metro Manila.

As a result of investigation into the cause of the failure, the chief cause of system failure was determined to be an erroneous operation of protective devices in the Dolores line at Malaya power plant by carrier command signal.

The following remedial measures were recommended.

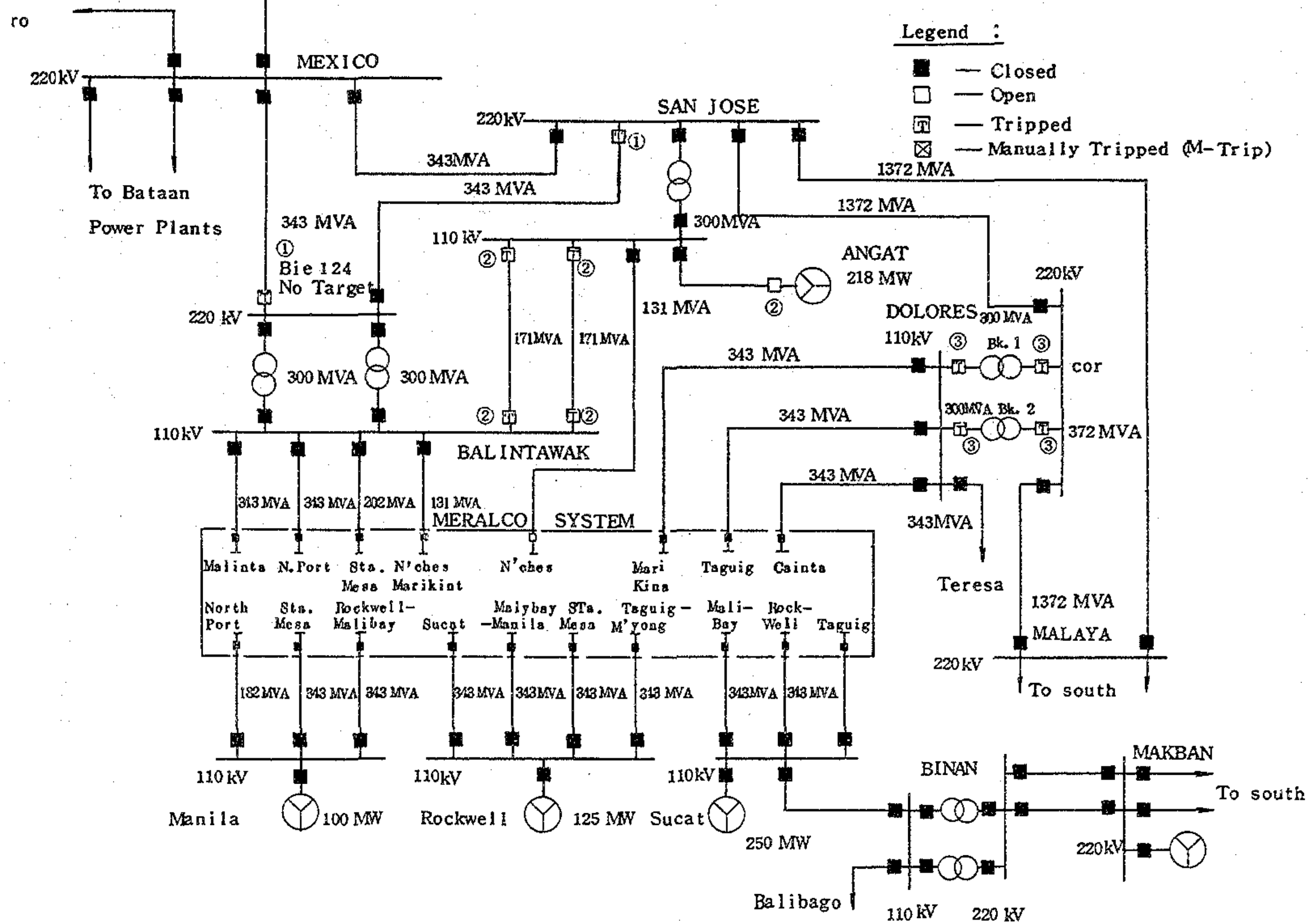
1. Carrier command signal circuit is to be duplicated to prevent erroneous operation of protective devices.
2. Dolores substation is to be modified from the present one circuit PI branching between San Jose and Malaya to two circuits PI branching as shown in the original design.
3. Coordination relay settings between system line protections and transformer protections.

4-5. Total System Black-out of March 13, 1984

The condition of the system prior to the failure is shown in Fig. 4-4.

The fault started with a tripping of the Mexico-Balintawak line at Balintawak substation, followed by a tripping of 230 kV Balintawak line at San Jose substation and the succeeding tripping of two 115 kV San Jose-Balintawak line due to overloads. While the restoration effort was being made, two transformers at Dolores substation tripped because of overloading, developing to a failure of the entire power system in Metro Manila. In the midst of subsequent system restoration effort, there was a series of total power failure because of unbalance between the load and power generation. The system was finally restored only toward the evening of the following day.

Fig. 4-4 System Black-out of March 13, 1984



As a result of detailed review of the failure by the Technical Committee, the remedial measures were recommended as first priority measure, second priority measure and third priority measure.

a. First Priority Measure

(1) Inspection and improvement of jumper clamps of transmission lines.

(2) Improvement of 230 kV facilities at Balintawak substation.

(3) Enhancement of communication links between NAPOCOR and MERALCO load dispatching offices.

(4) Improvement or replacement of protective devices (ground relays in particular).

(5) Provision for sequence event recorders.

b. Second Priority Measure

(1) Installation of an additional transformer bank at Dolores substation.

(2) Boosting of the San Jose - Balintawak 115 kV line.

(3) Calibration of meters for all substations.

(4) Assignment of NAPOCOR operators to Balintawak substation (owned by MERALCO) for operation of 230 kV system.

c. Third Priority Measure

(1) Load dispatching offices of NAPOCOR and MERALCO should have adequate facilities to monitor the position of breakers at power plants and substations in their respective areas.

(2) A joint task force should be organized to ensure good coordination of protective devices of both utilities.

4-6. Total System Failure of September 24, 1984

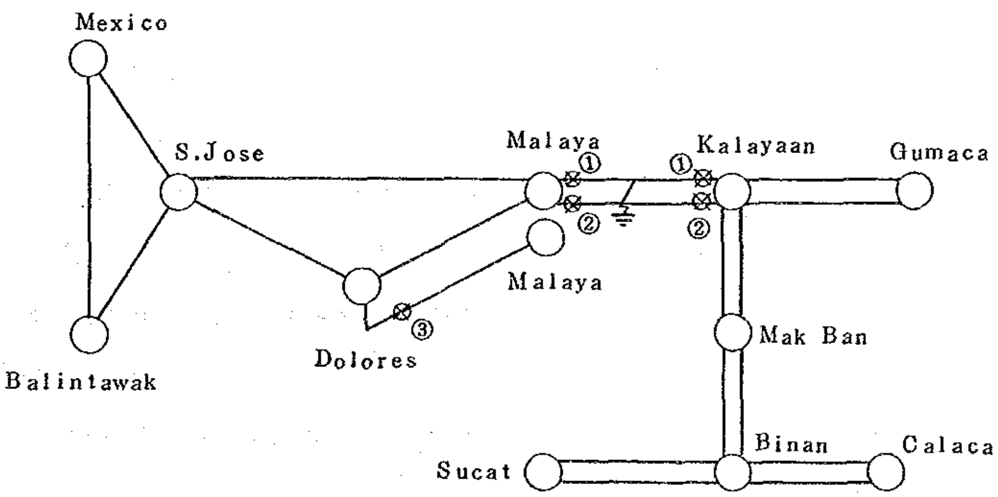
The condition of the system prior to the failure is shown in Fig. 4-5. The 230 kV system and power plants were operating in the following special operating pattern because of trial operation of Calaca coal-based power plant.

a. Malaya power plant was separated from the 230 kV system and was transmitting power to Dolores substation with the 115 kV line.

b. The 230 kV lines of Kalayaan, Mak-Ban and Calaca power plants were interconnected and a total output of more than 400 MW generated by Mak-Ban, Calaca, Tiwi and Kalayaan power plants was being fed to the Malaya-Kalayan line.

(Malaya plant sent power to Dolores Substation through 115 kV Teresa line.)

Fig. 4-5 System Failure of September 24, 1984



Note: Figure in circle indicates operating sequence.

The first fault occurred in Malaya-Kalayaan No. 2 line, tripping the line at both Malaya and Kalayaan power plants, followed immediately by the tripping of No. 1 line. This resulted in the out-of-step condition which was however, restored a few second later. However, the Dolores-Malaya 115 kV line tripped soon after due to overloading causing the Malaya power plant out of system, leading to eventual total system Blackout.

The root of this failure is the delay in the completion of the Binan-Sucat 230 kV lines and the 4-conductors Malaya-Kalayaan line because of the problem of land acquisition and other reasons, which should have been completed prior to the completion of Calaca power plant. This was a kind of fault which would not have occurred if both lines had been completed on schedule before the trial operation of Calaca power plant.

4-7. Implementation of Measures Taken Based on the Study of Each Case of Failures

Taken measures have been recommended by NAPOCOR Investigation (Technical) Committee for each case of the Black-outs. The status of main items of the recommended measures as of October, 1984 is as follows.

a. Installation of Step-Out Relays on Protective Relays for the 230 kV Line

Installation of step-out relays at the power plants and substations in the system south of San Jose was completed following the fault of September, 1983 using relays on hand. For the system north of San Jose, installation of step-out relays is expected to start upon arrival of equipment.

After September, 1983, there has been no case of extended system failure caused by malfunctions of relay when the system is in the out-of-step condition.

b. Improvement of Transmission Line Protective Relays

For improvement of transmission line protective relays, (replacement) of existing switching type distance relays with static distance relays had already been planned prior to the occurrence of a series of power failures and some of the orders have already been ordered. However, the change of distance relay from the type with circular characteristics to the type with squareness characteristics has been proposed based on the findings of studies of the past system failures and an application for import of distance relays having such characteristics has been submitted.

a study was also made on the coordination between transmission line ground relays and transformer ground relays following the occurrence of series of disturbances and a step has been taken for installation of timers on the transformer side.

Immediately after the system failure of September, 1984, an investigation was made into the cause of erroneous operation of protective relays at Malaya substation by carrier command signal and necessary measures were implemented.

c. Relay Coordination Between NAPOCOR and MERALCO

Following the disturbance of August, 1983, a series of relay coordination meetings have been held between the two utilities in an attempt to maintain the required relay setting coordination.

At present a study is being made jointly on the measure of isolated operation of thermal power plants (island system) in the event of system failure proposed following the disturbances.

d. Energization of Two-Circuits PI Line and Installation of Additional Transformers at Dolores Substation

Construction work is under way in the adjacent lot for energization of two-circuits PI line and installation of one transformer bank (300 MW) and is expected to complete in March, 1985.

e. Modification of 230 kV Switch Yard of Balintawak Substation

Installation work of new 230 kV equipment at Balintawak substation is being carried out by MERALCO in the adjacent lot and is expected to complete in December, 1984. Since there was a delay in the arrival of breakers for this work, the spare breakers of NAPOCOR are being installed to be replaced later.

f. Installation of Fault Recorders

At present, fault recorders (sequence event recorders) are provided at Dolores, Malaya and San Jose substations for recording the operation of 230 kV protective relays and circuit breakers. A study was made on the use of automatic oscillograph fault recorders and an application has been made for import of four units of the recorder.

g. Communication link between NAPOCOR and MERALCO Load Dispatching Offices

As of October, 1984, exclusive telephone lines and VHF circuits are provided between the two load dispatching offices.

Under the agreement, a liaison personnel from MERALCO load dispatching office is dispatched to NAPOCOR load dispatching office for closer liaison and coordination of restoration efforts in the event of a major system failure.

h. Improvement of Communication System of NAPOCOR

As of October, 1984, a microwave communication circuit extends from the head office and direct communication from related substations to all power systems is possible through PLC circuits as shown in Fig. 4-6.

The microwave communication circuit is now in commission extending from the head office to PNPP, manila power plant and to Sucat, Mak-Ban, Kalayaan and Malaya power plants via Mt. Maunong relay station in the south and then to San Manuel and Baguio substations via San Jose substation in the north.

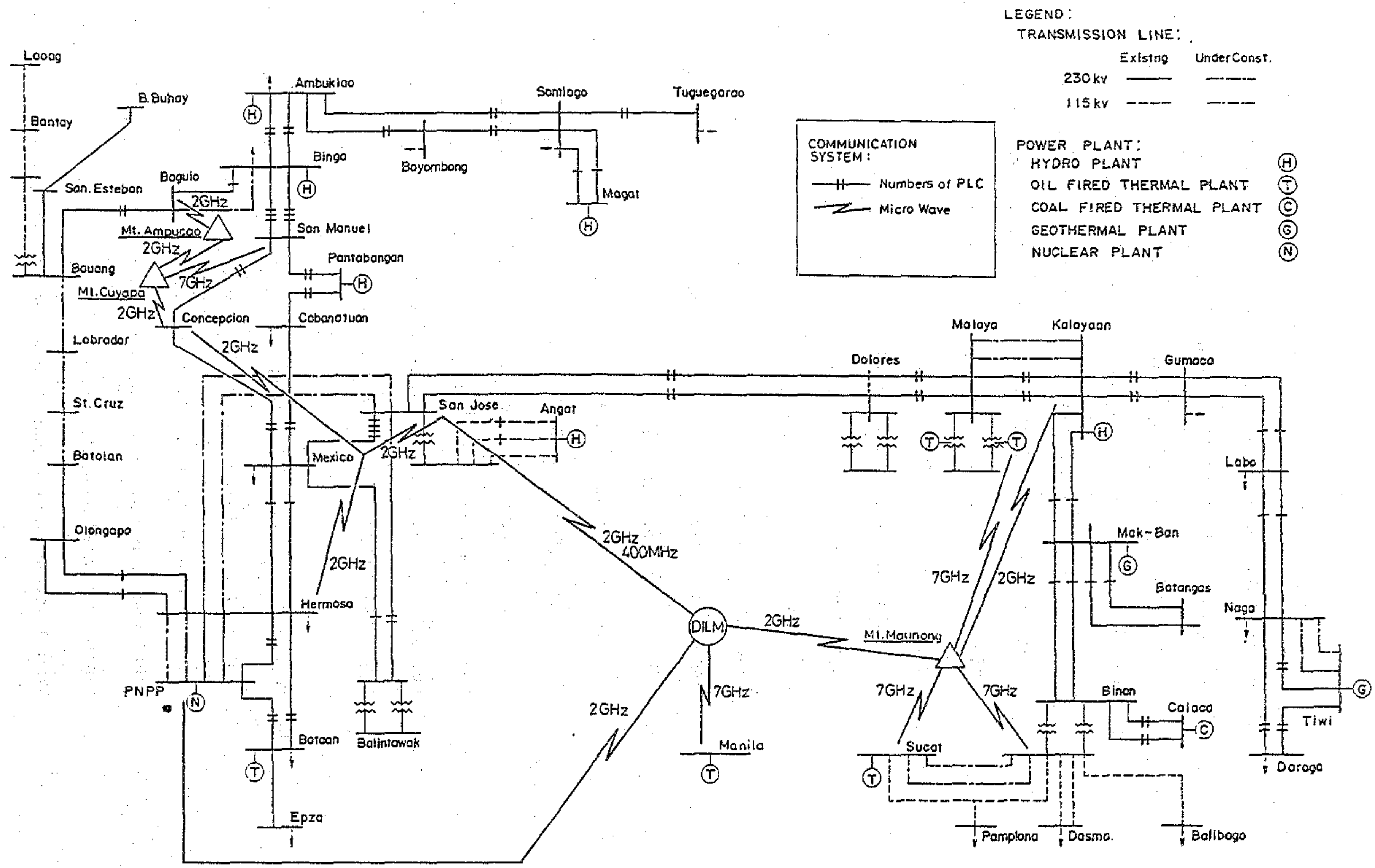
i. SCADA System of NAPOCOR

As of September, 1984, the computer aided system monitoring device (SCADA system) of NAPOCOR is in commission and is now being adjusted. With this system, it becomes easier for NAPOCOR to monitor the operating condition of circuit breakers, current, generation and load conditions of main power plants and substations in its service area.

j. Future Improvements Required on the Basis of the Experience in Restoration of September 24, 1984 System Failure

The system fault of September 24 occurred while the aforementioned improvement measures were being implemented. In this sense, the early completion of improvement works and construction of transmission and substation facilities now under way is

Fig. 4-6 Communication System Diagram



an important requirement. Besides, the adequate policy and procedures of in emergency must be established in parallel to the progress of physical improvement of facilities in view of remarkable progress of development of generating capacity of the 230 kV system in and around Metro Manila since 1983.

CHAPTER 5

LUZON GRID SYSTEM

Chapter 5. Luzon Grid System

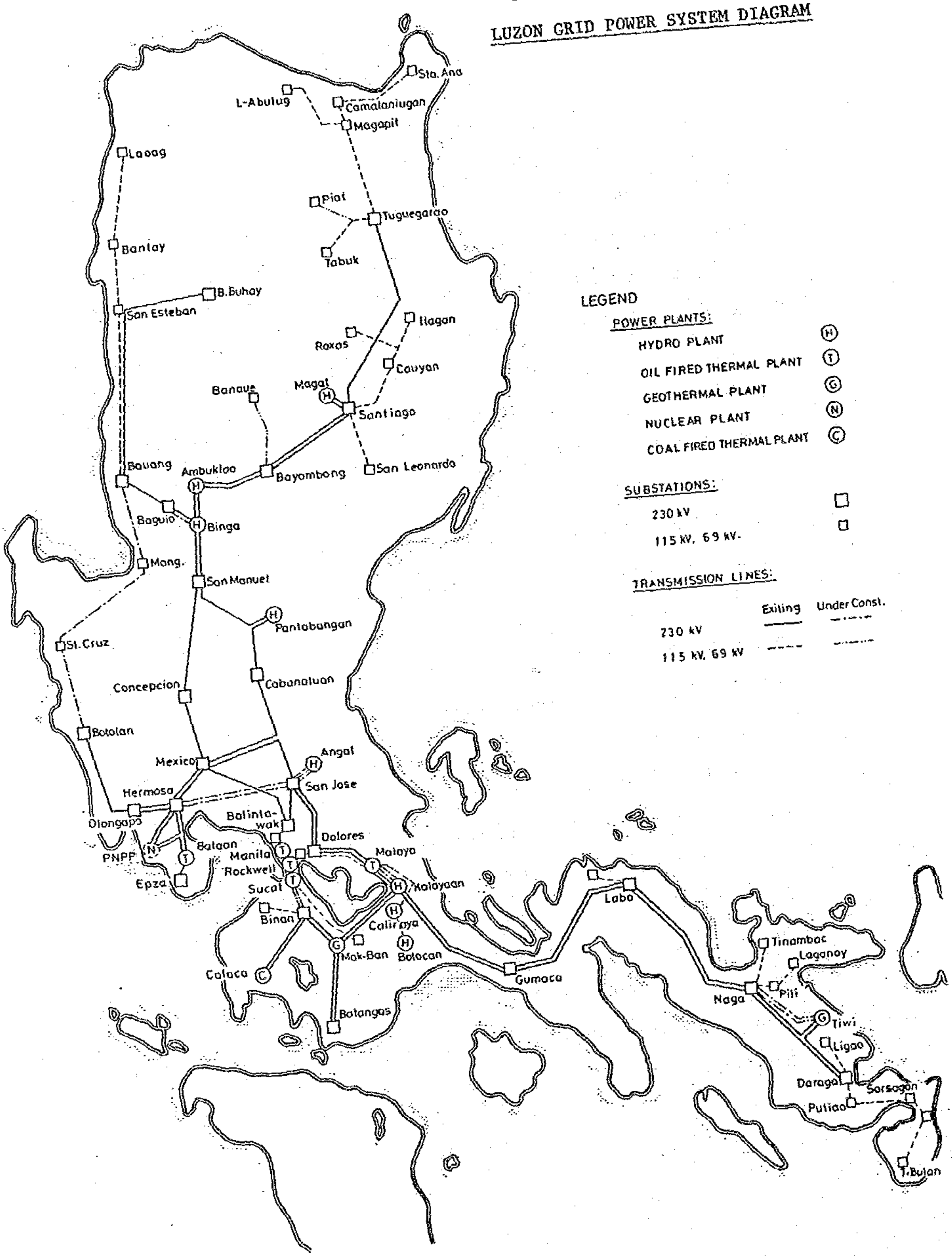
5-1. Development Process of Luzon Grid

The Luzon Grid system of NAPOCOR covers from northern Luzon to southern Luzon, with 230 kV transmission lines forming the Back bone of the system. Geographical routes of transmission lines are shown in Fig. 5-1. NAPOCOR supplies power to local cooperatives and power distribution companies mainly by 69 kV transmission lines. To the Metro Manila area which accounts for more than 60 percent of the load in Luzon, power is supplied by Binan substation and Sucat power plant from the south, by Dolores substation from the east. From the north, San Jose substation feeds Balintawak substation of MERALCO. From these substations, voltage is stepped down to 115 kV for sale to MERALCO.

Historically, two separate 230 kV systems, one extending from Ambukulao power plant to Mexico substation in the north and the other which was newly constructed with the development of Tiwi and Mak-Ban geothermal power plants in the south, were interconnected to the 115 kV system of Metro Manila independent of each other. With the completion of Kalayaan pumping-up power plant in 1982 as a turning point, San Jose substation and Malaya power plant were linked together by one circuit to establish a unified north-south 230 kV system. In 1983, Dolores substation was completed as a supply base to Metro Manila from the east. A series of system failures occurred soon after the completion of this Dolores substation.

Fig. 5-1

LUZON GRID POWER SYSTEM DIAGRAM



5-2. Outline of the Facilities of Transmission Lines

The first 230 kV Ambukulao-Mexico line was constructed with 759 MCM (about 400 mm^2) ACSR single conductors.

Moreover, the connection between San Manuel and Mexico is two lines each one-circuit transmission line of the different route.

The 230 kV transmission lines constructed thereafter were of the two-circuit steel tower design but single conductor of the same size were used. However, the San Jose-Malaya line constructed in 1982 adopted the design of 759 mcm ACSR four conductors in anticipation of the flow of a large load current with the expansion of generating capacity in the future. Construction of the same four-conductor transmission line between Malaya and Kalayaan is near completion.

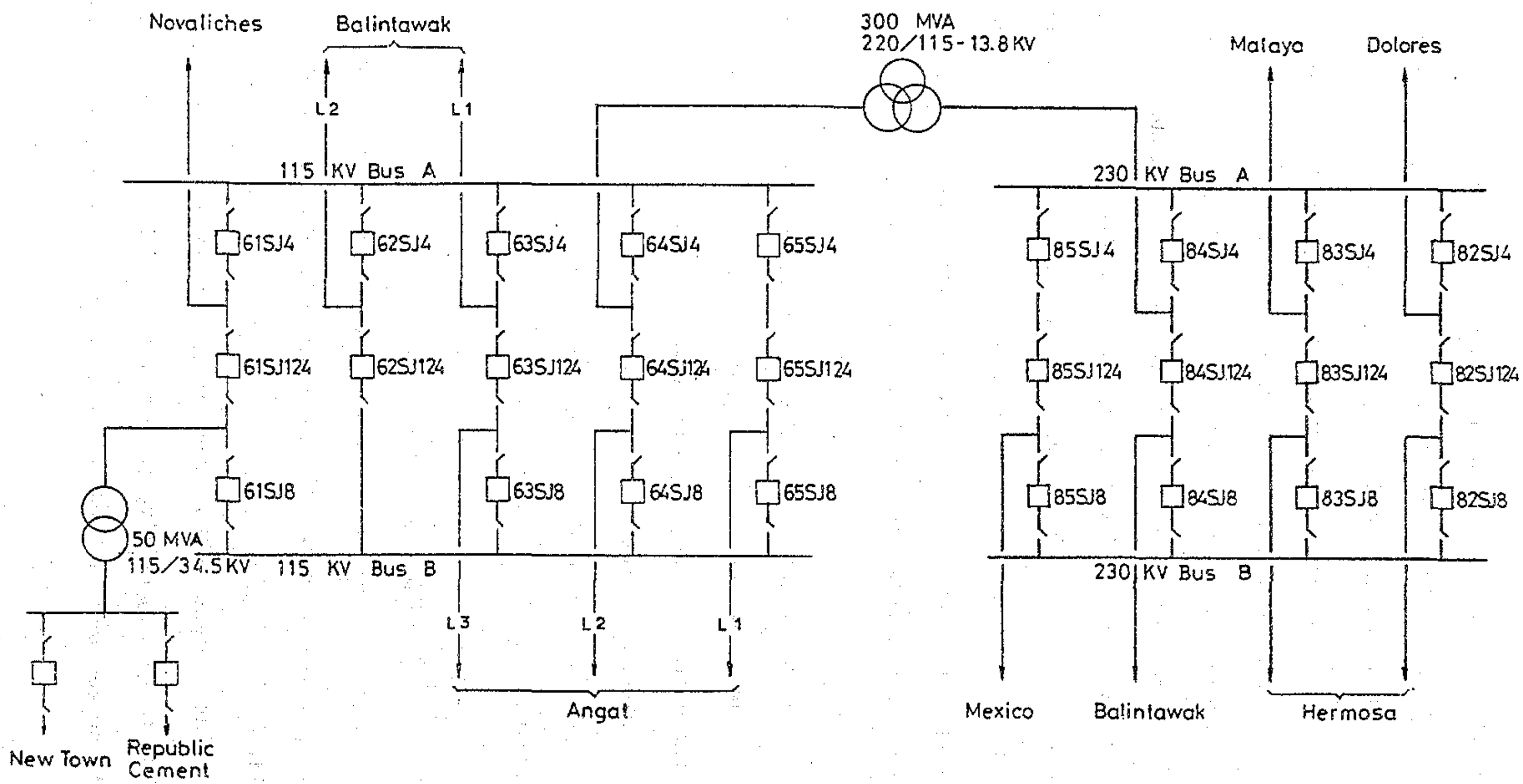
For the transmission lines from Calaca coal-fired power plant, PNPP and those between Binan and Sucat, a design of 759 CMC double-conductors two-circuit steel tower transmission lines is adopted. For PNPP, in particular, a design of six circuits of four routes, comprising two routes of two circuits and the existing Hermosa transmission line, is adopted.

5-3. Outline of Substation Facilities

For the design of substation bus bars, 1-1/2 CB system is adopted as a rule. A typical example of the design is shown in Fig. 5-2.

At present, 230 kV substations are attended stations with operators working on five shifts of two persons in many cases. The 69 kV substations of NAPOCOR are unattended stations as a rule.

Fig. 5-2 Single Line Diagram of SUN JOSE Substation



Except Balintawak substation, all substations of MERALCO are unattended stations which are remotely supervised and controled from the load dispatching office.

Dolores, Binan and San Jose substations of NAPOCOR and Balintawak substation of MERALCO are large substations, each having a capacity of 300 MW to 900 MW. Others are small substations, each having a capacity of 50 MW to 100 MW.

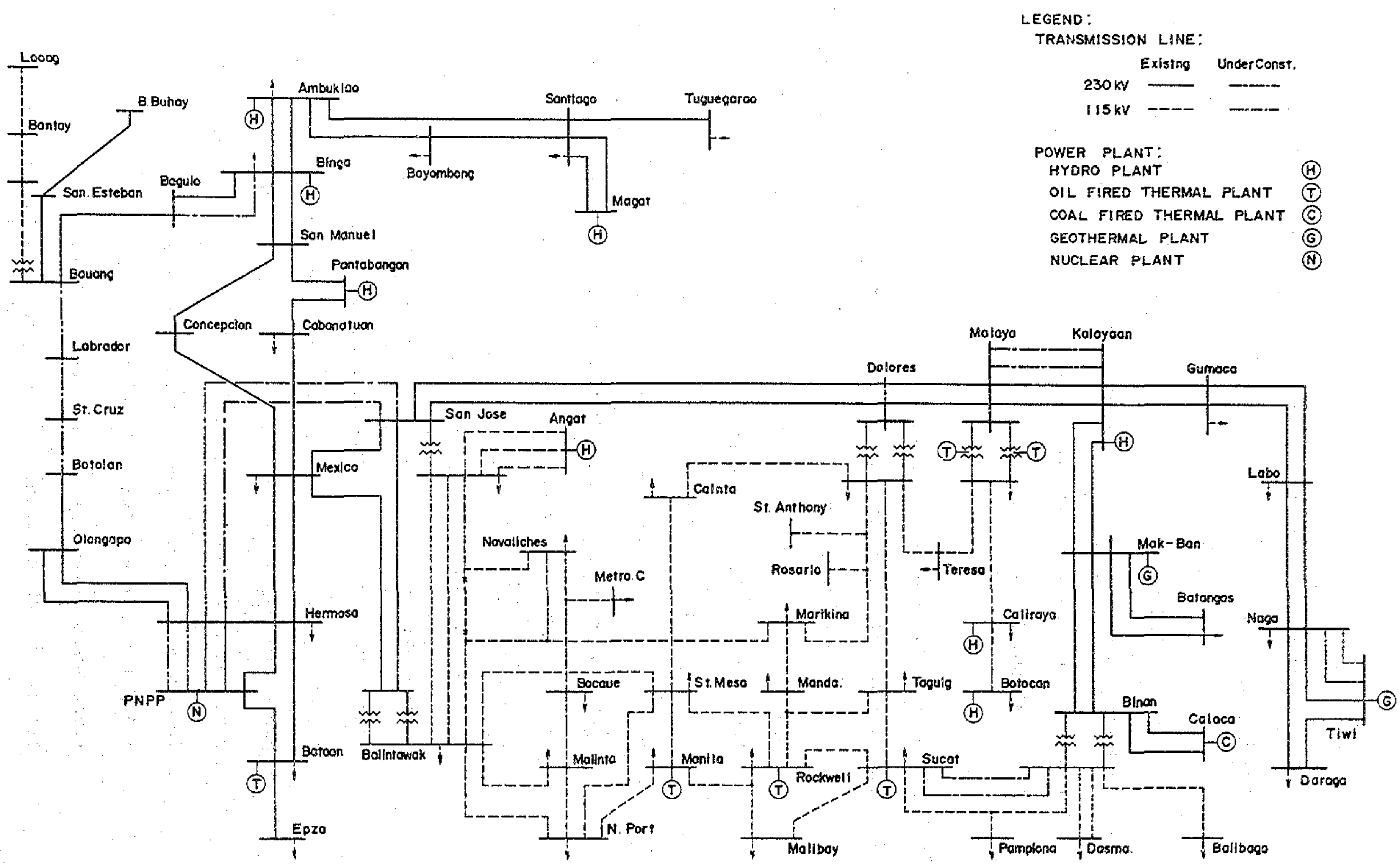
5-4. Composition of Transmission System

a. System Composition in 1984 (See Fig. 5-3)

In northern Luzon, four reservoir type power plants, namely, Magat (360 MW), Ambukulao (75 MW), Binga (100 MW) and Pantabangan (100 MW), generate a total of 635 MW. The present load in northern Luzon is less than 150 MW even at the evening peak time. For transmission of the energy generated by these hydro power plants to Metro Manila, only two circuits of transmission line are available and the transmission distance is nearly 300 km.

The energy generated by Bataan thermal power plant is transmitted to Mexico substation by two circuits of transmission lines, while the transmission of power generated by a number of power plants in northern and central Luzon from Mexico substation to San Jose and Balintawak substations, supply bases for Metro Manila, is only by two circuits 230 kV transmission lines. The transmission lines between San Jose and Malaya are two four-conductor lines and one circuit has a transmission capacity of more than 1,200 MW. The scheduled two-circuit PI branching from these transmission lines at

Fig. 5-3 LUZON GRID SINGLE LINE DIAGRAM



Dolores substation at March, 1985 is expected increase the transmission reliability considerably.

Also, the capacity of the Malaya-Kalayaan lines will be enhanced considerably with the scheduled commissioning of two circuits of four-conductors at the end of the year and the existing two circuits of single-conductor.

There is a transmission line which originates in Kalayaan power plant, passes through Mak-Ban power plant and extends to Binan substation is the west of Metro Manila. Calaca coal-based power plant is interconnected with Binan substation. From Binan substation to Sucat power plant, two-circuits double-conductor transmission lines designed for 230 kV are under construction but is scheduled to be used for 115 kV in the initial stage.

There are two 230 kV transmission lines over a distance of approx. 360 km from Kalayaan power plant to Tiwi geothermal power plant and Daraga substation in the south. Substation load in these districts is less than 80 MW even at the evening peak time.

b. Transmission Lines to be completed by 1987

The two-circuit double-conductor 230 kV transmission line now under construction between Hermosa and San Jose and two-circuit double-conductor 230 kV transmission line being constructed between Tiwi power plant and Naga are expected to be commissioned in 1985. In 1987, transmission lines design for four-conductor 500 kV are scheduled to be completed between Kalayaan and Naga (270 km) and between San Jose and Kalayaan (70 km).

c. Future System Composition

For transmission of energy to be generated by coal-based and hydro power plants planned for northern Luzon after 1990, construction of 500 kV design transmission lines is planned between San Jose and Santiago. DC interconnection of the Luzon Grid and the Leyte Grid is also planned depending on the expansion of generating capacity of geothermal power plant in Leyte.

5-5. System Operation

The objective of system operation is to ensure a stable supply of power of good quality and small frequency and voltage fluctuations by minimizing the occurrence of system failures. At present, the Luzon Grid system has only a limited number of large customers who can be the source of voltage and frequency fluctuations. Maintenance of frequency can easily be accomplished as long as generating capability is stabilized. Details of present system operation are described in the following.

a. Management of Demand and Supply

Daily load forecast and hourly forecast of the capability of generating units are calculated with computer and transmitted to the operator on duty at the Power Management Center (PMC) for management of demand and supply. The seasonal forecasts are also made with use of computer. Such data as the present output of each power plant and system frequency are indicated in digital on the system panel. Deviations of bus voltage from the reference voltage in each substation are also indicated. Commands are given to each power plant by telephone. However, there are some data transmission devices which are not yet completed or which are still in the stage of adjustment.

b. Frequency Control

Frequency is controlled mainly at hydro power plants. Frequency control during daytime is provided mainly by Kalayaan and Angat power plants, while frequency control at night is provided by Magat power plant. Fine adjustment of frequency control is with an electric clock installed on the system panel.

c. Voltage Control

Each power plant is operated in accordance with reference voltage of generating unit for daytime, evening hours and midnight hours specified by PMC of NAPOCOR. However, the voltage control by phase modifiers or on-load voltage regulators of transformers at substations on load side is not being considered.

Only Santiago substation in the north is provided with a 15 MVA shunt reactor, which off sets the charging capacity of transmission lines when there is a small power flow on the long distance transmission lines, and each of Gumaca, Labo, Naga and Daraga substations in the south is provided with one 15 MVA shunt reactor, while Tiwi is provided with two 15 MVA shunt reactors. These shunt reactors are constantly in operation for voltage control.

MERALCO provides voltage control for consumers with on-load voltage regulators provided at 115 kV/33 kV substations, and by installing time duty phase modifiers on distribution lines and continuous duty phase modifiers at different points.

However, the voltage level at consumer side tends to become low during day time and evening by heavy load flow on lines, and high midnight with the charging var from the 230 kV line.

d. System Operation for Normal Time

Circuit breakers of NAPOCOR power plants and substations are controlled according to the system operation procedures (SOP) on command from MPC.

MERALCO's 115 kV system is remotely controlled directly from its load dispatching office. (However, the Balintawak substation is an attended station and is therefore controlled on command from the load dispatching).

An example of SOP is given in attached reference No. 1.

e. Restoration Procedure in Emergency

(1) Each substation opens all circuit breakers and stands by upon declaration of Total Black-out by PMC.

(2) Tiwi, Mak-Ban, Caliraya, Kalayaan, Angat, Ambukulao and Magat power plants start their operation according to Emergency SOP.

(3) Each power station starts trial charging of specified transmission lines according to its own SOP in emergency.

(4) Each substation energizes transmission lines sequentially according to the procedure set forth in SOP.

(5) Restoration of the 115 kV system in Metro Manila should be in accordance with the restoration procedure agreed on between NAPOCOR and MERALCO.

5-6. Outline of System Protective Devices

a. Locations of protective devices in the 230 kV system of NAPOCOR are shown in Fig. 5-4. Protective devices used are mainly LZ32 or LZ3 made by Brown Boverry. Westinghouse KD4 type is used in some sections around Kalayaan. For system protection, these distance relays of under reach type signal system and PLC are combined to transmit trip signals.

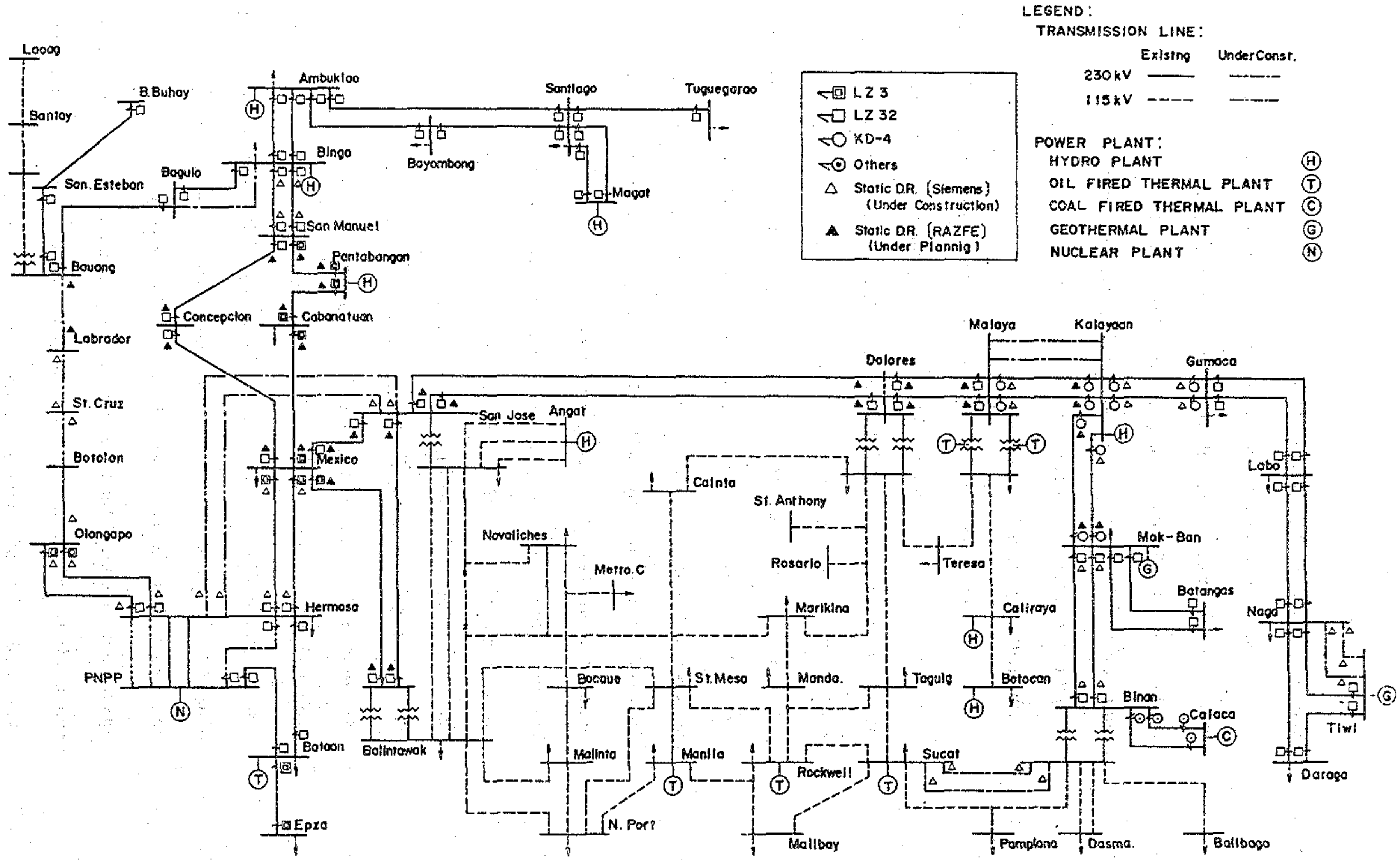
   Since only the distance relay is used for protection of transmission lines from short circuits and ground faults, the range of third stage of these distance relays has been increased to protect the lines from overloading.

   For bus bars at substations, the bus protective relay is used. For transformers, ratio differential relay and the ground protection overcurrent relay are used. At present, the time relay is used in combination with these relays following the occurrence of a series of system failures.

   Three-phase or single-phase reclosing relay is not used. This is because the use of three-phase reclosing relays resulted in the expansion of the fault some years ago.

b. For the 115 kV system of MERALCO, General Electric's GCY type distance relay and Westinghouse's KD4 type distance relay are used for protection from short-circuits. These relays are over reach type and generate trip signals by third zone. The tripping of the circuit breaker is composed of a tripping signal and operation on the second zone. Of course, the first zone operation unconditionally opens the breaker. For grounding protection, directional overcurrent relays of instantaneous type and that of inverse time type are used in combination. For reclosing, three-phase reclosing system is used.

Fig. 5-4 Relay System in Luzon Grid



c. Coordination between NAPOCOR and MERALCO

To materialize relay coordination between the two utilities, the requirement for which was pointed out following the investigation of the system failure of September, 1983, a task force, composed of related engineers, was started immediately after the disturbance to conduct necessary studies. On the basis of the findings of the task force, what should be done was done. At present, a study is being made on the system separation and division into individual systems (Island system) to be applied in the event of a major system following the review of the system failure of March, 1984.

5-7. Outline of Communication System

a. Communication System of NAPOCOR (See Fig. 5-5)

(1) Power Line Carrier Communication (PLC) System

PLC of one channel to four channels is provided for each section of the 230 kV transmission lines.

The frequency band of one channel is divided into the following use.

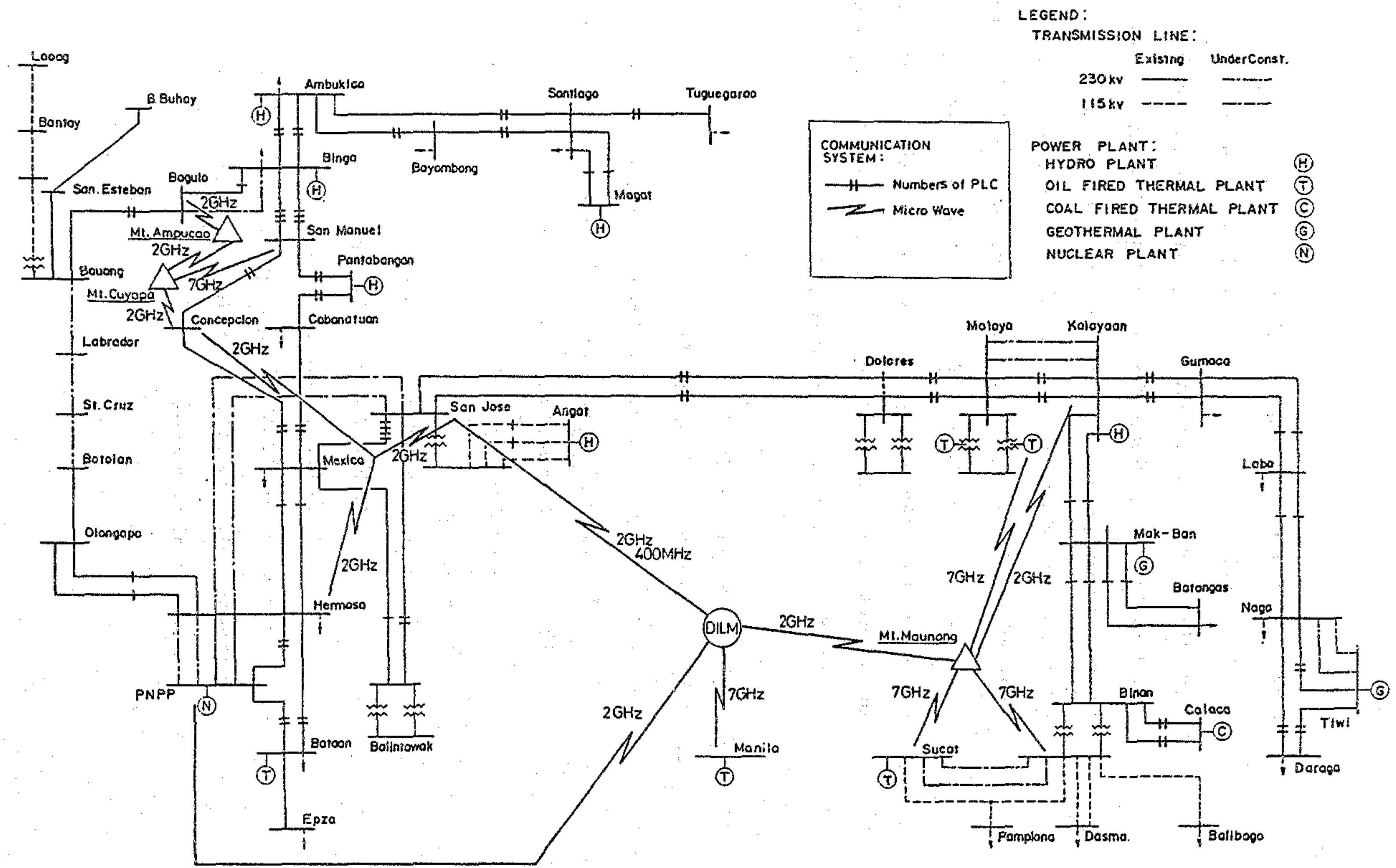
300 - 2,000 Hz.......Voice channel

2,760 Hz, 600 Bd.....Protection & meter signal

3,450 Hz, 50 Bd......TELEX channel

For transmission of command signals at time of a system fault, the relay is designed to stop the transmission of (voice) signals.

Fig. 5.5 Communication System Diagram



(2) Microwave Communication System

For microwave communication (using digital system), trunk circuits use a frequency of 2GHz, while branch circuits use a frequency of 7GHz. One trunk circuit originates at the head office in Dilman (to be referred to DILM hereafter) and extends to south to Kalayaan power plant via Mt. Maunong relay station and to north to Baguio through San Jose, Mexico, Conception and Mt. Ampucao relay station. Another trunk circuit is provided between DILM and PNPP. Branch circuits of 7GHz extend from DILM to Tegen, from Mt. Maunong to Sucat, Biñan and Malaya and from Mt. Cuyapo to San Manuel.

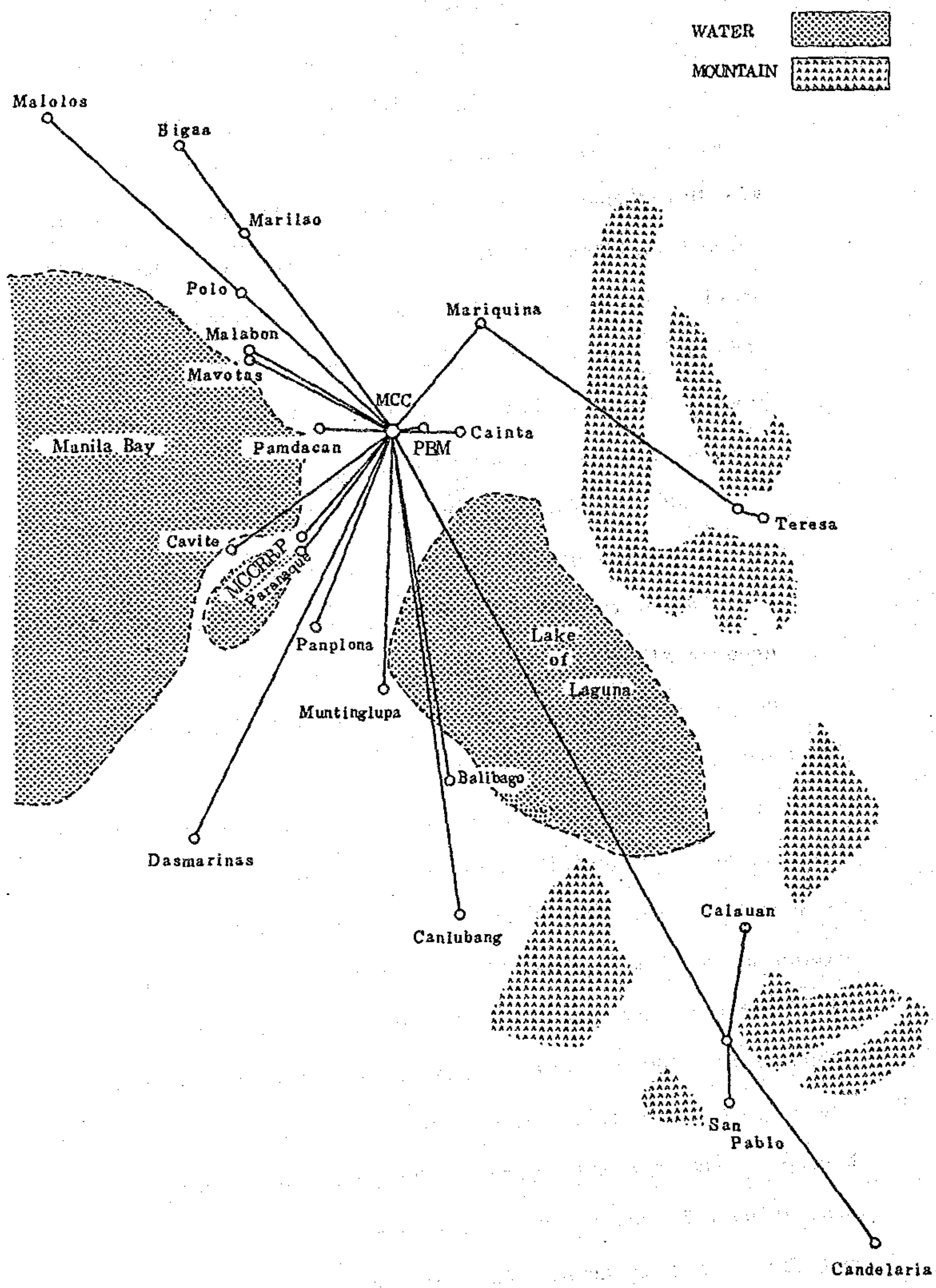
Under the future plan, expansion of coverage to Magat in the north and Naga in the south is considered.

One of the features of microwave communication system used by NAPOCOR is that two parabolic antennas are provided for each trunk circuit to cope with fading problems.

b. Communication System of MERALCO

The communication system of MERALCO is composed of UHF multi-radio, multi-micro wave system, VHF system and Cable telephone system. UHF multi radio system is used for communication between main substations. Micro wave multi communication system is used communication between head office and main substations. VHF is used for the communication between maintenance office and work trucks. Cable system is used for the backup system for UHF system. Supervise and telecontrol of substations, Telemeter, relay signal and voice channel use UHF and Micro wave systems. Fig. 5-6 shows micro communication system of MERALCO.

Fig. 5-6 MERALCO's Micro System



CHAPTER 6

STUDY OF PROBLEMS WITH THE LUZON GRID AND REMEDIAL MESURES

Chapter 6. Study of Problems with the Luzon Grid and Remedial Measures

6-1. Introduction

The Luzon Grid is an outcome of rapid development of the 230 kV transmission system with the growth of power demand and expansion of generating capacity as shown in Fig. 6-1.

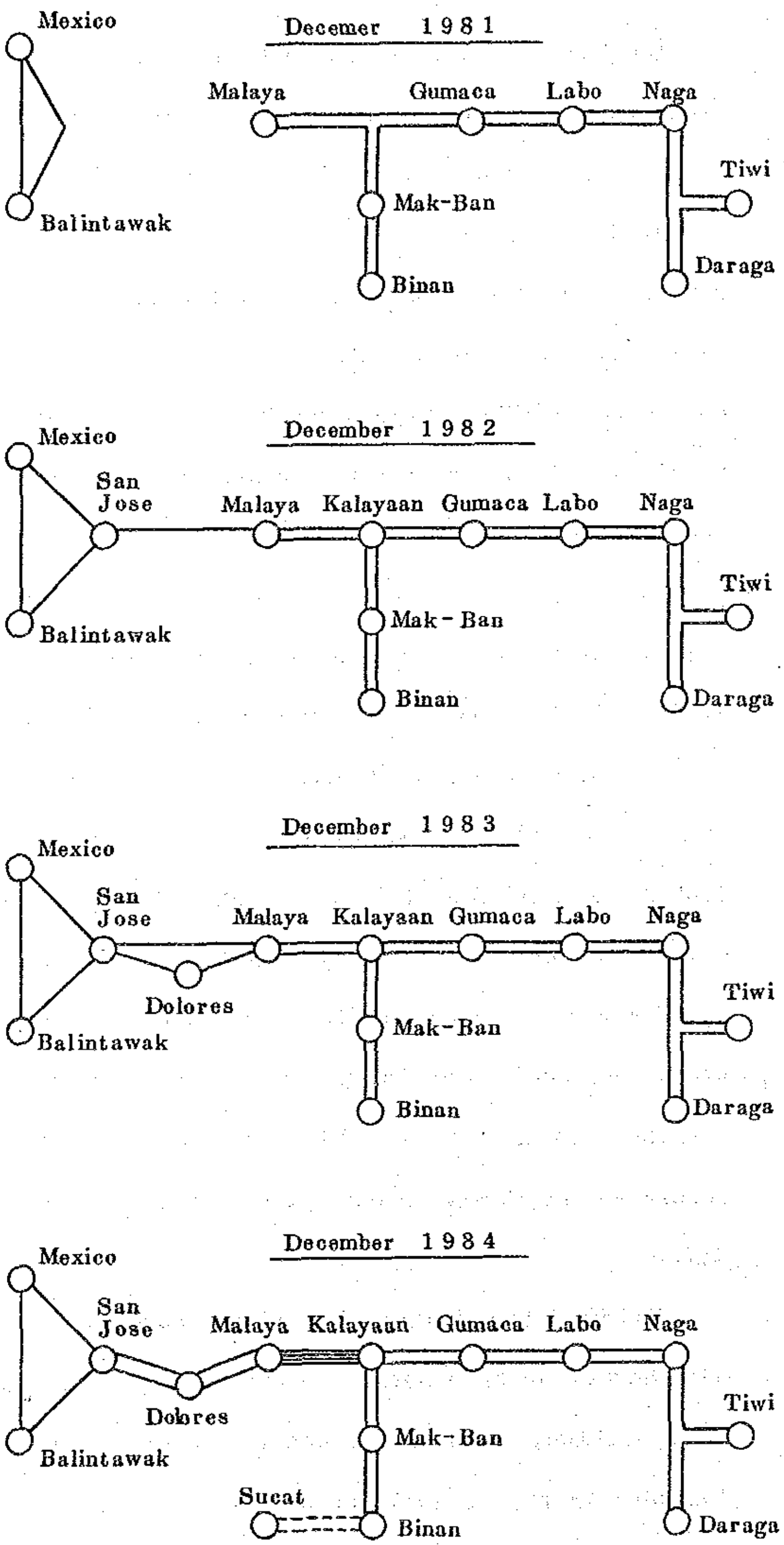
With a view to effective utilization of domestic energy resources, the emphasis of development effort has been placed especially on the development of hydro and geothermal power, and the completion of Magat hydro power plant (360 MW), Mak-Ban (330 MW) and Tiwi (330 MW) geothermal power plants is a major achievement of the development effort.

However, Magat and Tiwi power plants are located at a distance of more than 300 km from Metro Manila, a load center of the Luzon Grid, and they are interconnected by two-circuit 230 kV transmission lines of 759 mcm (approx. 400 mm^2) ACSR single conductor. In particular, the transmission lines from Magat power plant are linked to Ambukalao (75 MW), Binga (100 MW) and Pantabangan (100 MW) hydro power plants before they reach Metro Manila.

The load in northern Luzon is mainly a household load in such areas as Baguio and is very small at around 150 MW even at the evening peak hour. For this reason, a large portion of the power generated by these power plants must be transmitted to Metro Manila.

Within Metro Manila, there are Manila (200 MW) and Sucat (850 MW) thermal power plants. However, Sucat power plant is not stable in operation, with its present capability being 730 MW, and is included in the rehabilitation program.

Fig. 6-1 Progress of 230 kV System around Matro Manila and Southern Luzon



Power plants located near Manila are Malaya thermal power plant (650 MW), Bataan thermal power plant (225 MW), Mak-Ban geothermal power plant (330 MW) and Kalayaan pumping-up power plant (300 MW), all of which supply power to Metro Manila by 230 kV transmission lines. Besides, Calaca coal-fired power plant (300 MW) is under construction in the south and is scheduled to be commissioned at the end of 1984 and PNPP nuclear power plant (620 MW) is being built in the Bataan Peninsula with the target commissioning in 1985.

Since the greatest portion of power supply to Metro Manila had to be fed by the 230 kV lines of the Metro Manila outer link system, NAPOCOR had been implementing the system expansion program for the outer links such as the Hermosa-San Jose line, the San Jose-Dolures-Malaya-Kalayaan line and the Biñan-Sucat line.

However, in the course of the system expansion program, the Philippines experienced an extraordinary dry weather in 1982 and 1983 in succession, which resulted in a drastic cut in power generation by dam type power plants and high operating rate of Kalayaan pumping-up power plant. A series of major system failures occurred under these adverse conditions in and after August 1983.

Immediately after each failure, an investigation committee was created by NAPOCOR, and especially for the March 1984 system failure, a special investigation committee was created by the order of the President. These investigation committees made recommendations as to measures taken immediately and protective devices measures as already mentioned in Chapter 4.

The JICA expert team then assigned to NAPOCOR also submitted a report to NAPOCOR on three times, recommending remedial measures and stressing the importance of technical guidance by experts, especially from a long-range viewpoint. The contents of these reports were also explained to the management of NAPOCOR and the recommended measures to be implemented immediately were referred to the operation level for their review and implemented as required.

The present study team conducted its study on the basis of these reports of JICA expert team to work out measures for recommendation.

6-2. Implementation of Measures Recommended by the Committees

Of the measures recommended by the investigation committees and the JICA expert team, those which were considered to be feasible were put into practice, by making the best use of equipment and materials on hand in consideration of the adversed economic conditions of the Philippines.

The main accomplishments are as follows.

a. Installation of Step Out Relays

Installation of step out relays in the 230 kV lines south of San Jose substation was completed using relays on hand. For the 230 kV lines north of San Jose substation, application is being made for import of additional step out relays.

b. Adoption of Static Distance relay

Prior to the occurrence of a series of system failures, there was a plan to install Siemens 7SL24 distance relays (static type) and the shipment of relays for 36 terminal stations arrived in October 1984. This relay integrates a fault locator.

Of a total of 130 terminal stations of the 230 kV system, 35 terminal stations, mainly in Metro Manila outer link system, are scheduled to be equipped with high power ASEA's RAZFE static distance relays, and application is being made for import of them. A study is being made as to the type of relay to be installed in about 60 remaining terminal stations.

c. PI Branch Drawing of Two-Circuit 230 kV Lines and Installation of Additional Transformers at Dolores Substation

Since Dolores substation was commissioned in 1983 with temporary facilities, a construction work is now underway in the adjacent lot to provide PI branch of two-circuit 230 kV lines and three additional transformers (300 MW). Commissioning is scheduled for March 1985.

d. Improvement of 230 kV Equipment at Balintawak Substation

The 230 kV equipment of Balintawak substation were installed in 1962, with circuit breakers and other equipment becoming extremely obsolete. For this reason, a new 230 kV switching station is being constructed in the adjacent lot. Since there was a delay in the import of some breakers, work is being progressed with breakers on loan from NAPOCOR.

e. Coordination of Relay System between NAPOCOR and MERALCO

A task force was created by the two utilities immediately after the September 1984 system failure to study and discuss relay coordination between the two organizations.

At present, the task force is reviewing the separation of the 115 kV system of Metro Manila in case of a system failure, particularly the independent thermal system (called island system), the requirement of which was pointed out by the JICA expert team.

f. Improvement of PMC Facilities and Coordination between PMC and LDC of MERALCO

The SCADA system of NAPOCOR is in commission and is now being adjusted. At present, the system is displaying power plant output, frequency (at 3 locations) and the state of circuit breakers but is still in adjustment stage.

Communication between PMC and LDC is provided by three telephone circuits and one VHF radio circuit. At the time of total system failure on September 24, 1984, one operator form LDC was dispatched to PMC for liaison and close coordination.

g. Communication Lines between PMC and Power Plants and Substations

With a microwave link just completed and the existing power line carrier communication system, communication between PMC and power plants and substations was carried out without hindrance even during the system failure.

h. Logbook and Logsheet at Power Plants and Substations

A review of logbook and logsheet entries at each power plant and substation mainly at the time of system failure on September 24, 1984 showed that they were maintained in very good order with accurate time entries.

This is because each power plant and substation synchronized its time with the time synchronizing command from PMC every morning. (There is no time casting system in the Philippines.)

i. Assignment of NAPOCOR Operators at Balintawak Substation

One NAPOCOR operator in each shift is assigned at Balintawak substation to provide guidance on the operation of the 230 kV system as recommended by the Committee for the March

1984 system failure. This enables MERALCO operators to concentrate on the operation of their 115 kV system.

6-3. Problems of Luzon Power Grid

a. Facilitation of land Acquisition

Construction of 4-conductor two-circuit 230 kV lines between Malaya and Kalayaan, aimed for development of Calaca coal-fired power plant and expansion of transmission system for Metro manila, is now almost complete. For maintenance of system reliability, a decision was made to retain the existing transmission line. The new line cannot be put into operation yet because there are still some works to be done on the crossing point of new and existing lines.

There is also a double-conductor two-circuit 230 kV line which is under construction and is almost complete between Binan and Sucat. However, the completion of this line is delayed because of difficulties in acquiring a land space for construction of one steel tower on the halfway of the line.

In the meantime, trial operation of Calaca coal-fired power plant is being repeated since September 1984. when this power plant is put into commercial operation with a fairly large output, the existing 795 MCM ACSR (150 MW) single-circuit 115 kV line would not be adequate and a special system composition must be provided.

In the course of trial operation of the power plant since September 1984, there were several faults in the transmission line but some were possible to contain the fault to local section. However, the fault on September 24 developed into a total system failure because of an additional factor - Malaya power plant dropping out of the system succeedingly.

The responsibility of the maintenance department is to eliminate the cause of a fault promptly and take necessary measures to prevent the recurrence of a similar fault. But it was not so and the occurrence of a similar fault was repeated. This may be the main problem with the Luzon Power Grid.

It was also questionable that a special system composition had to be devised and operated with an anticipated risk simply because of a gap in the completion date between power generating facilities and transmission and substation facilities.

Acquisition of land is a very complicated and time consuming problem in any country. A system should be established for prompt solution of land acquisition problems in planning the future transmission and substation facilities.

b. Substantiation of Technical Education and Training

The requirement for additional education and training of technical personnel on power system operation techniques and protective device techniques was strongly felt following the discussion with those people engaged in system operation observed by the team.

c. Improvement of maintenance Work

Mobility of transmission line maintenance crews is so poor that it is hampering the effort to find out a trouble spot. Poor maintenance of meters and breakers of substations was also observed. Improvement of equipment and instruments must also be attempted together with the planning of technical training of personnel.

There is also room for improvement in the storage method of equipment and materials. In particular, outdoor storage of spare parts should be discontinued immediately.

d. Problems of System Planning

To expand th transmission system south of San Jose substation, 4-conductor two-circuit 500 kV designed lines are under construction for completion in 1987. However, the expansion of the system north of San Jose substation is planned for 1990 and thereafter. When a large southward power flow from Magat power plant and other hydro power plants is taken into account as mentioned at the outset of this Chapter, appropriate measures must be taken for system protection until the system expansion is materialized.

e. Problems of System Operation

(1) Coordination between MERALCO's 115 kV System and NAPOCOR's 230 kV System

The objective of power system operation is to supply reliable and good quality electric power to customers with less frequency variations and at a proper voltage. As far as frequency is concerned, load fluctuation is small in the system and it is possible to maintain the required frequency by securing generating capacity with appropriate margins. For voltage control, however, it is necessary to coordinate and adjust the voltage of the 230 kV system, sending voltage of the 115 kV system and sending voltage of distribution lines for peak time and for the time of light load. When the hydro power plants are operated at rated capacity while Manila and Sucat thermal power plants in Metro Manila are not much operated, the voltage in Metro Manila seems to be held at a low level. However, it is not possible to ascertain the voltage operation in Metro Manila because of lack of complete records at substations.

(2) There must be closer coordination in the operation of the 115 kV system in Metro Manila and the 230 kV back bone system for the better service to customers. up to date, the Luzon Power Grid is being operated on the premise of all loop operation of the 115 kV system in Metro Manila. This means an increased share of the power plants connected to the 230 kV system and presents a problem of loop operation of the 115 kV system under present condition when the expansion of the 230 kV system is not yet materialized. This is considered as one of the reasons for the spread of the fault leading to a total system failure in the past.

(3) For system restoration, a revision was made to the restoration procedure for total black out with respect to the operation of Kalayaan power plant. However, this revision was made without giving a serious consideration to the reality that the 230 kV transmission system has been expanded and the generating capacity connected to the 230 kV system has also been expanded. The revision is a mere addition of the procedure of Kalayaan power plant to the existing system restoration procedure.

This is considered to be a contributing factor to the very complicated restoration procedure at the time of the

September 1984 total system failure.

(4) Problem of Rising Up the System Voltage during Isolated System Operation or forced Charge Trial of Long Distance Transmission Lines

When the system is out of step (when the line is out of the system), a rising up the system voltage would occur in the system line south of Gumaca, and a high voltage destroyed the lightning arresters at Gumaca, Naga and Daraga substations on September 25, 1984. According to the operator on duty at Naga power plant, the voltage of the 230 kV system increased to more than 280 kV and nearly 300 kV on that day.

Also during the restoration effort of the September 24, 1984 system failure, the system voltage at San Jose and Dolores substations on receiving a test charge from Kalayaan power plant increased gradually from the initial 244 kV to 260 kV and then to 280 kV under the influence of charging current of 115 kV. As a result, there was a delay in load recovery at substations.

Since a similar voltage increase can be considered when feeding from Angat power plant to PNPP nuclear power plant for house power, a study must be made to provide measures against voltage rise of generators (self-excitation phenomenon of generator) affected by charging current of long distance transmission lines and load.

f. Problem of Protective Relays

The sequence of protective relays currently used in the 230 kV trunk system is shown in Fig. 6-2 by broken lines in the diagram.

Selection is made between current circuit and voltage circuit according to the type of fault in the troubled phase, and the operating range of first step, second step and third step is selected by time relay and inputted into current circuit and voltage circuit of the P.U.

There is a danger of erroneous operation on the operation of switching relay time in this type of relay. It is also theoretically possible to cause over reach in measuring the trouble point when earth fault occurred. There is a possibility of erroneous operation in a fault changing from 1 LG to 2 LG. The over reach compensation circuit is not appropriate for ground relay circuit as it involves many factors for erroneous operation.

in the center of the right half of the diagram is a signal transmission and receiving circuit. Theoretically, relay operation in any step transmits a trip signal to the other terminal.

The static type distance relay scheduled to be installed soon has a problem of over reach and erroneous operation as a distance relay. This problem should be studied thoroughly and completely. The protective relay should be duplicated using the phase comparison relay system which is theoretically different from the distance relay or the FM current comparison relay system. The important relay signal lines should also be duplicated and should be used in parallel with a microwave link and power line carrier communication system.

It is also essential to consider adoption of the transfer