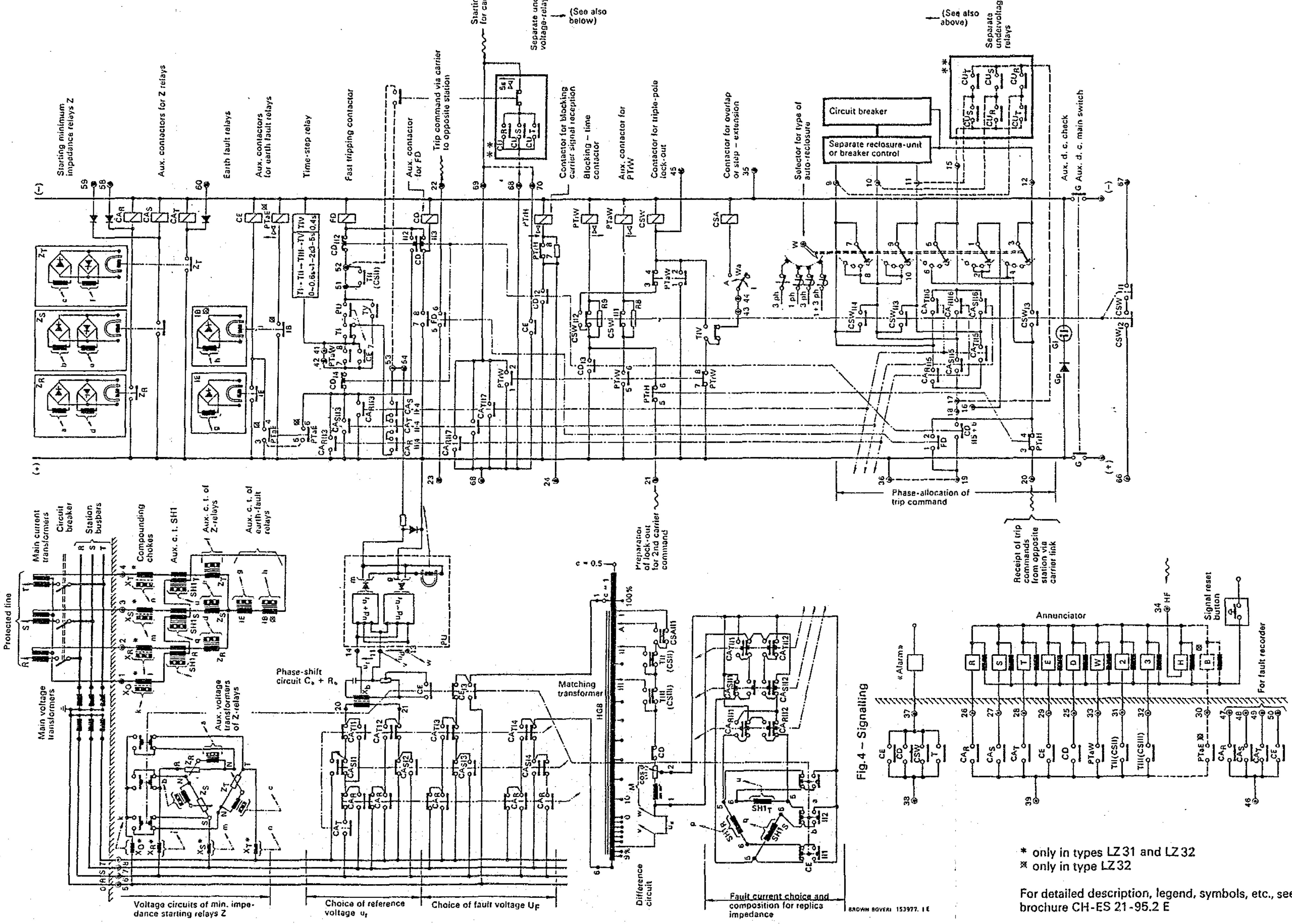
Distance relay LZ 32
General schematic diagram

Fig. 6-2 Sequence of BBC LZ Type Distance Relay

– DC-Control-Circuits

– AC-Circuits



* only in types LZ 31 and LZ 32
⊠ only in type LZ 32

For detailed description, legend, symbols, etc., see brochure CH-ES 21-95.2 E

trip system which gives a command for output control of Magat power plant for the system north of Mexico, which is more subjected to over power flow of unaffected lines when there is a fault in the system. System separation in case of power swing should also be considered.

Existing relay system is shown in appendix 3.

g. Replacement of Obsolete Equipment

The circuit breakers at Mexico substation, which occupies an important position in northern Luzon power system, are old as they have been in use since 1960 and may become a source of extended system failure as in the case of Balintawak substation in March 1984. Early replacement of these breakers should be considered.

h. Measures for Stability of Northern Luzon Power System

(1) Construction of one-circuit 230 kV transmission line extending from Baung substation to Labrador, St. Cruze and Olongapo substations is now under planning for western Luzon. Efforts should be made to materialize this plan as early as possible to stabilize and expand the northern Luzon power system.

(2) When there is a tripping of the Ambukulao-Binga-San Manuel line or the Pantabangan-Mexico line, in the northern Luzon power system, power generation at Magat power plant must be controlled to prevent overloads of unaffected lines. For this purpose, adoption of the transfer tripping relaying system should be considered.

(3) As the distance between Santiago and Ambukulao is approximately 100 km, two-circuit PI branching should be intro-

duced to Bayombong substation located in the middle of the transmission line also for the stable operation of Magat power plant.

i. Reinforcement of Transmission Lines for Sections of Large Power Flows

The San Jose-Balintawak line will become a heavy load section with the commissioning of PNPP nuclear power plant. In order to prevent the fault in the section from developing into a total system failure like the one which occurred in March 1984, it is mandatory to construct a new double-conductor two-circuit 230 kV line in the section.

j. Expansion of Microware Communication System

The present north microwave communication system covers up to La Trinidad (Baguio) substation. This system should be extended to Magat power plant (360 MW), which is situated in the important location for system operation including frequency control of power system, for enhancement of control circuit.

The existing south microwave link covers up to Kalayaan power plant. The system should be extended further south to Tiwi geothermal power plant (330 MW) which occupies an important position in system operation and in restoration of power system in case of a system failure.

CHAPTER 7

ANALYSIS OF POWER SYSTEM AND PROBLEMS TO BE CONSIDERED

CHAPTER 7

Chapter 7. Analysis of Power System and Problems to be Considered

7-1. Power Flow and Voltage

a. Preconditions for Calculation

(1) Effective Power (Load)

The system capacity for the years of calculation is as follows.

1983	2,478 MW
1985	2,395 MW (96.7% of the previous year)
1986	2,410 MW (100.6% of the previous year)
1987	2,510 MW (104.1% of the previous year)
1990	2,985 MW (118.9% of 1987: annual growth rate of 4.9%)

Peak hours:

Metro Manila	11:00 AM or 2:00 PM
Other areas	Mainly 7:00 to 8:00 PM
All Luzon	11:00 AM

Accordingly, calculation for system analysis was made for the peak hour zone of 11:00 AM.

(2) Reactive Power (Load)

For Metro Manila, the reactive power (load) of each 115 kV substation was estimated from reactive power flow at peak hours, the record of which was provided by MERALCO during the field survey.

Refer to: (Appendix-2)

Table 1. Demand Forecast for NAPOCOR substations and All Luzon Grid

Table 2. Demand Forecast and Reactive Power for MERALCO substations

(3) Distribution of Generator Output

1) 1983

As calculation was made for wet season, the following was assumed.

Hydro power plant..........All generating units in parallel operation

Base steam power plants....Geothermal power plant (Tiwi, Mak-Ban)

As some of the oil-based power plants have generating units which cannot give a rated output, the available output of each power plant was assumed as follows.

Available Output of Power Plants

Power Plant	Rated Output (MW)	Available Output (MW)
Calaca	300	300
Malaya 1	300	260
Malaya 2	350	320
Bataan 1	75	75
Bataan 2	150	150
Sucat 1	150	150
Sucat 2	200	160
Sucat 3	200	160
Sucat 4	300	260
Manila 1	100	100
Manila 1	100	100
Rockwell 6--8 (Retired in October 1984)		

Nos. 1 and 2 unit of Malaya power plant and Nos. 2, 3 and 4 unit of Sucat power plant are now under rehabilitation and the following was assumed.

Malaya power plant.........Rated output from 1986

Sucat power plant..........Rated output from 1990

2) 1985

Power plants to be commissioned newly in 1985 are as follows.

PNPP......................620 MW (Nuclear)

Calaca....................300 MW (Coal-based)

Mak-Ban (No. 5 & 6 units)..110 MW (Geothermal)

Operating conditions of hydro and steam power plants were assumed as follows upon consultation with NAPOCOR.

i. Operation of hydro power plants in dry season (April--June)

(i) Magat......Two units are to be operated (Total of 4 units)

(ii) Kalayaan...Two units are to be operated (Total of 2 units)

(iii) Botocan....One unit is to be operated (Total of 3 units)

(iv) Caliraya...All units are to be stopped (Total of 4 units)

ii. PNPP and north hydro power plants are not to be in full operation simultaneously until the completion of north EHV transmission lines (calculation was made at a capacity

iii. One unit of Bataan is to be operated constantly as offsite power for the event of emergency of PNPP. For calculation, operation of No. 2 unit (150 MW) was assumed.

iv. Five units are to be operated at Tiwi, for one unit is always in shut-down maintenance.

v. Six units are to be operated at Mak-Ban, for shut-down maintenance of one unit requires 35 days.

vi. Operating priority of oil-based power plants

(i)	Malaya No. 2 unit	(vi)	Bataan No. 2 unit
(ii)	Malaya No. 1 unit	(vii)	Sucat No. 1 unit
(iii)	Sucat No. 4 unit	(viii)	Sucat No. 2 unit
(iv)	Manila No. 2 unit	(ix)	Sucat No. 3 unit
(v)	Manila No. 1 unit	(x)	Bataan No. 1 unit

(No. 2 unit of Bataan is to be operated constantly as a measure against emergency.)

Table 7-1 (Reference)

Records of Faults at Sucat and Malaya Power Plants

vii. Operating priority of steam power plants

(i) Geothermal power plants

(ii) Coal-based power plants

(iii) Oil-based power plants

Table 7-2 (Reference)

Generating Cost by Region and Generator Type

Table 7-1 Present Condition of Sucat & Malaya Generators (Unit: hour)

item	C.Y	Sucat 1	Sucat 2	Sucat 3	Sucat 4	Malaya 1	Malaya 2
Stopping hours by Trouble (a)	1983	496.3	1063.9	746.0	846.6	3137.5	426.0
	1982	1979.5	3826.9	1798.2	685.8	1838.0	1209.4
	1981	651.6	1455.8	2900.4	2405.9	960.0	350.2
	1980	611.7	1842.0	2088.8	2172.8	740.0	841.2
	1979	685.3	832.0	2011.9	1382.2	991.6	1240.0
Stopping hours by Ballance (b)	1983	117.7	49.5	0.0	0.0	0.0	0.0
	1982	0.0	0.0	0.0	0.0	0.0	0.0
	1981	0.0	125.5	38.1	0.0	0.0	17.4
	1980	54.1	4.7	16.3	303.2	0.0	54.2
	1979	54.3	95.7	176.5	0.0	0.0	0.0
Overhaul hours (c)	1983	0.0	0.0	3241.3	241.0	0.0	1140.4
	1982	1213.3	0.0	0.0	2382.5	0.0	1032.0
	1981	0.0	0.0	0.0	4183.6	0.0	946.7
	1980	431.0	1860.3	0.0	0.0	3294.5	2208.0
	1979	1648.1	0.0	2228.8	1938.4	0.0	0.0
Operation hours (d)	1983	7226.4	7549.5	4761.9	7287.3	5440.4	7139.4
	1982	5558.7	4933.1	6930.2	5649.3	6876.8	6503.7
	1981	8108.4	7162.4	5817.8	2170.5	7696.3	7309.8
	1980	7667.1	5056.8	6667.7	6279.5	4545.0	5659.4
	1979	6359.7	7485.2	4277.3	5439.4	7751.1	5859.7
Stopping factor by own trouble (a)/(a)+(b)+(c)+(d)	1983	6.33	12.28	8.53	10.11	36.58	4.89
	1982	22.62	43.69	20.60	7.87	21.09	13.83
	1981	7.44	16.65	33.12	27.46	11.09	4.06
	1980	6.98	21.02	23.81	24.82	8.63	9.60
	1979	7.83	9.89	23.14	15.78	11.34	17.47

Table 7-2 NAPOCOR

Production Cost by Region by Type of Plant

(Jan. to Sept., 1984 & 1983)

(Unit: Pesos)

Gen. type	1984 Production cost	1984 Fuel cost	1983 Production cost	1983 Fuel cost
Total PHILIPPINES	0.7005	0.4539	0.4738	0.3448
Hydro	0.2640	-	0.2806	-
Oil-Based	1.0150	0.8004	0.5761	0.4878
Geo	0.5074	0.2195	0.2868	0.1365
Coal	0.7949	0.3811	0.5265	0.2393
Luzon	0.7444	0.5169	0.4865	0.3655
Hydro	0.4523	-	0.5295	-
Oil-Based	0.9654	0.7931	0.5596	0.4870
Geo	0.4293	0.2069	0.2810	0.1353
Visayas	1.3135	0.6088	0.7022	0.4287
Hydro	0.3726	-	0.5070	-
Oil-Based	1.5329	0.8871	0.7483	0.4943
Geo	1.2862	0.3449	0.6264	0.2073
Coal	0.7949	0.3811	0.5265	0.2393
Mindanao	0.2239	0.0663	0.2860	0.1620
Hydro	0.1074	-	0.1080	-
Oil-Based	1.6165	0.8589	0.6492	0.4926

For the operation of hydro power plants, there are many restrictions in the use of reservoir operating rule curve because of such limitations as irrigation water by the National Irrigation Administration (NIA) and water supply to Metro Manila by the National Water Resources Council (NWRC) but there is sufficient water, including inflow, for continuous operation of all generating units of hydro power plants for two weeks during the wet season. Accordingly, operation of hydro power plants was assumed as follows except for the case of the preceding item i.

Wet season......All units are to be operated as the most stringent power condition

Dry season......One unit is to be operated at each power plant for the required voltage

Table 7-3-A.-B (Reference)

Trial Calculation of Water Volume of Each Reservoir

Nuclear, geothermal and coal-based power plants were assumed to be in continuous operation as base power plants and AFC was assumed as follows.

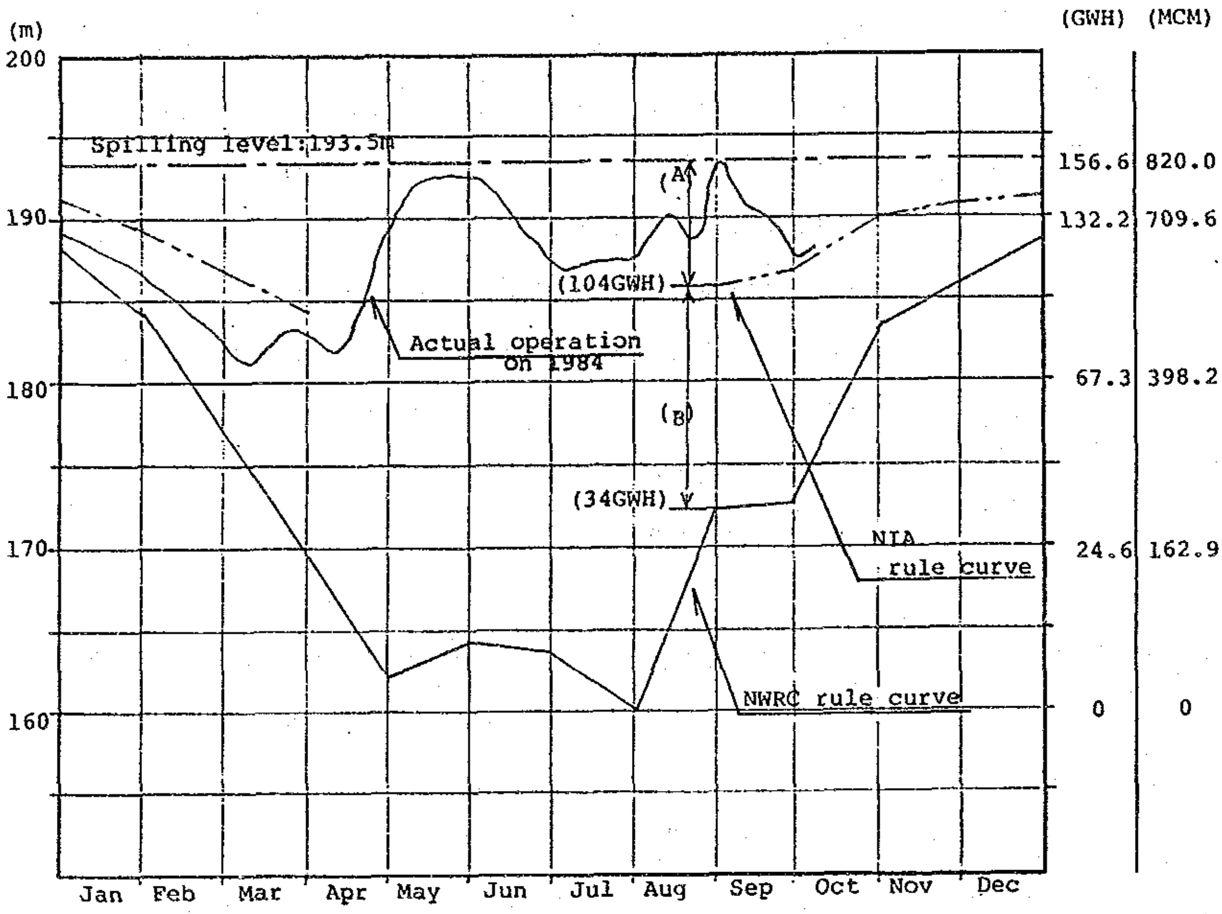
Daytime.........One unit of Kalayaan (Pumping-up at night)

Nighttime.......One to two units of Angat

3) 1986

Same as for 1985

Table 7-3-A Operation of Storage Water in Magat Dam



Note: NIA...NATIONAL IRRIGATION ADMINISTRATION

NWRC..NATIONAL WATER RESOURCES COUNCIL

Available capacity of the storaged water on Sep. (unit:Day)

Condition:Gen.90MW X 4units operation....360MW

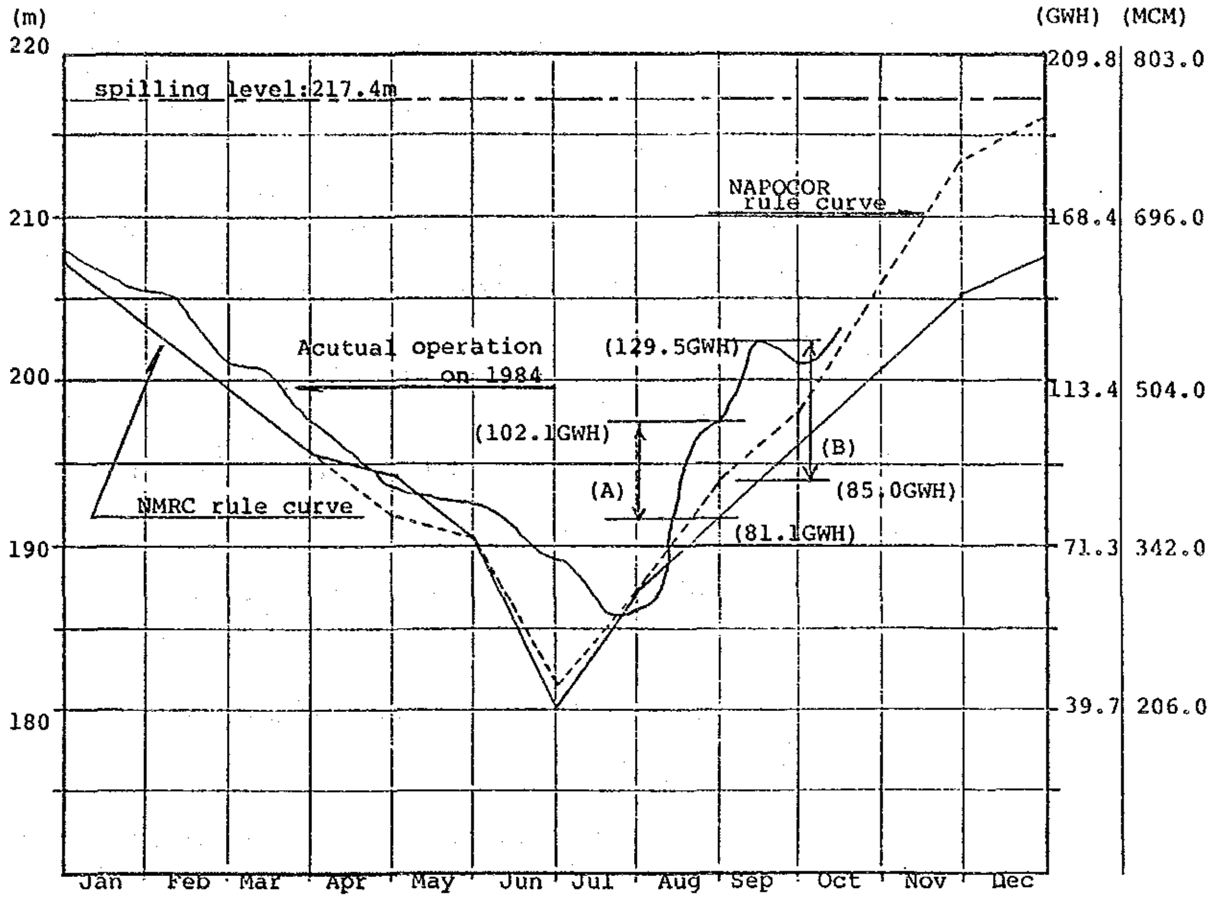
Operation hours/day.............10H

(A)=156.6GWH-104.0GWH/0.36GW X 10H=14.4days

(B)=104.0GWH-34GWH/o.36GW X 10H=19.4days

Average inflow on Sep. (1954--1971)=860GWH-660GWH/o.36GW X 10H=55.6days

Table 7-3-B Operation of Storage Water in Angat Dam



Available capacity of the storaged water on Sep. (unit:Day)

Condition:Gen.50MW X 4units operation....200MW

Operation hours/day............10H

(A)=102.1GWH-81.1GWH/0.2GW X 10H=10.5days

(B)=129.5GWH-85.0GWH/0.2GW X 10H=22.3days

Average inflow on Sep.(1969--1972)=1000GWH-820GWH/0.2GW X 10H=22.0days

4) 1987

Same as for 1985

5) 1990

New generating units to be commissioned in 1990 are:

Manito Nos. 1 and 2 unit.....110 MW (Geothermal)

Output distribution is the same as for 1985 except the addition of Nos. 1 and 2 unit of Manito to base power plants.

Refer to: (Appendix-2)

Table 3 Distribution of Generator output in 1984

Table 4 Distribution of Generator Output in 1985

Table 5 Distribution of Generator Output in 1986

Table 6 Distribution of Generator Output in 1987

Table 7 Distribution of Generator Output in 1990

(4) Transmission Line and Transformer Constants

A table of constants provided by NAPOCOR was used.

Refer to: (Appendix-2)

Table 8 Transmission Line and Transformer Constants

b. Calculation Cases

Calculation was made for 16 cases shown in Table 7-4 upon consultation with NAPOCOR (calculation was made for additional

Table 7-4 Calculation cases
for
Power flow & Voltage regulation

Year	Case No.	Nuclear	Season	System configulation	Time	Remark
1985	5-1	in	wet	loop	day	
	5-2	in	wet	loop	night	
	5-3	in	wet	seperate	day	
	5-4	in	dry	seperate	day	
	5-5	in	dry	loop	day	
	5-6	out	dry	loop	day	
	5-7	out	dry	seperate	day	
	Add-1	out	wet	loop	day	additional
1986	6-1	in	dry	seperate	day	
	6-2	out	wet	seperate	day	
1987	7-1	in	wet	loop	day	
	7-2	in	wet	seperate	day	
	7-3	in	dry	seperate	day	
	7-4	out	wet	seperate	day	delete
	7-5	out	dry	seperate	day	delete
	Add-2	in	dry	loop	day	additional
	Add-3	out	dry	loop	day	additional
1990	0-1	in	wet	seperate	day	
	0-2	out	dry	seperate	day	
	Add-4	in	wet	loop	day	additional

cases for reference purpose).

c. Results of Calculation

(1) 1984

Power flow and voltage were calculated with computer on the basis of actual data and constants of power demand, reactive power flow and voltage distribution provided by NAPOCOR and MERALCO during the field survey to study the following.

- Reliability of data used for calculation and appropriateness of calculation through comparison of calculation results and recorded actual values
- Extraction of problems of existing system as revealed by calculation

1) Comparison of Recorded Actual Values and Calculation Results

A comparison of bus voltage between main substations of 230 kV system is as follows.

	Record of Sept. 5, 1984 (kV)	Calculation Results (kV)
Magat	231	231
Tiwi	241	241
San Jose	210	207
Malaya	216	213
Dolores	213	205
Balintawak	214	207
Mexico	206	206
Hermosa	209	210

For details, refer to (Appendix-2) Fig. 1

Distribution of Actual and Calculated Voltage

Calculation was made on condition that the above-mentioned values can be maintained.

. However, the result showed a very large difference in bus voltage of 230 kV system between Dolores and Balintawak substations. This difference is considered to be due to the assumption that all units of Magat (hydro) and Tiwi (geothermal) power plants are in operation and that all oil-based power plants in Metro Manila are not in operation as the most stringent condition for calculation and also due to the calibration problem of measuring instruments.

. For this reason, calculation was made again by assuming the bus voltage of 230 kV system at Balintawak to be around 207 kV. The result is as shown above.

2) A Comparison of Calculation Results and Actual Operation Values

i. Assuming the voltage of 230 kV busbars at main 230 kV substations to be around 240 kV, the result of calculation for the most stringent condition (all units of Tiwi geothermal power plant and north hydro power plants are in operation) is as follows.

. The gradient of 230 kV voltage between sending end and the system around Metro Manila becomes about 25 kV presenting a problem for the operation of 115 kV system in Metro Manila (detailed calculation was made for the case of 1985).

ii. In the calculation made at a bus voltage of 207 kV for the 230 kV system at Balintawak, there was a shortage of reactive power at Balintawak substation and the surrounding 115 kV substations.

iii. While the recorded 230 kV bus voltage at Magat on Sept. 5, 1984 is 231 kV, the voltage schedule PMC instruction) of NAPOCOR power plants was as indicated below.

(Generator voltage at Magat)

(Note) 230/13.8 main transformer, Tap used 230,050/13,800 V (From NAPOCOR Generator Transformer list)

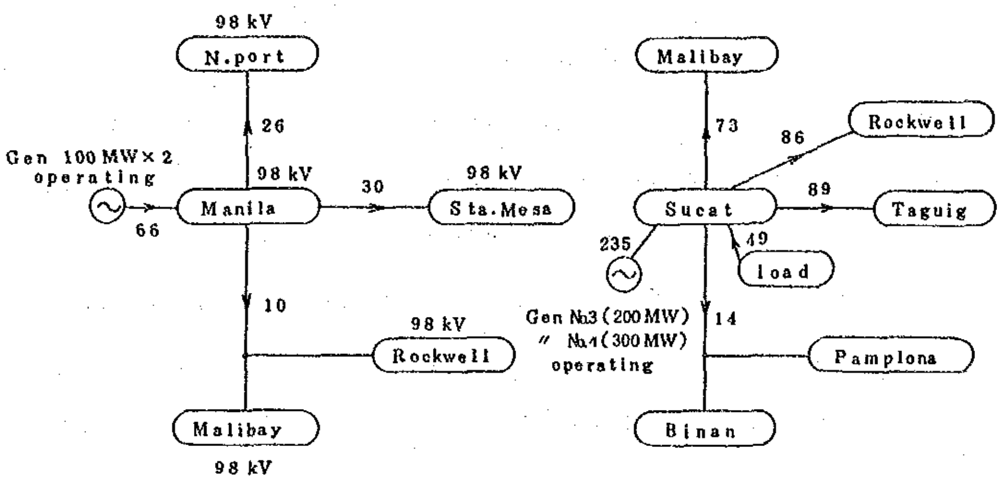
	Generator voltage	Converted to 230 kV bus voltage
. Recorded value, Sept. 5, 1984 231 kV x 13,800/230,050 =	(13,860 V)	(231 kV)
. Instructed value, Nov. 28, 1983	13,800 V	230 kV
. Instructed value between Dec. 30, 1983 and Jan. 2, 1984	14,300 V	238 kV
. instructed value, Dec. 18, 1984	14,000 V	233 kV

This is an indication that 230 kV bus voltage at Magat is operated at 230-233 kV in normal case.

The daily voltage operation of all Luzon Grid system (including MERALCO's 115 kV system) is controlled mainly by the voltage schedule instructions given to all power plants by PMC (NAPOCOR) and also by the operation of static condenser by LDC (MERALCO). However, the present voltage within Metro Manila is already operated at a low level as a whole.

As evident from the example of voltage operation at Magat, the voltage of north hydro power plants should be operated at a little higher level, and use of automatic voltage regulator (LTC) of main 230/115 kV transformers at 230 kV substations...not all of existing regulators are being used at present...should be considered in the voltage operation of total power system. Since the Luzon Power Grid has a number of problems including the one mentioned above, now is *the opportune time for a thorough review of the* voltage operation system (Details were studied with the case of 1985).

iv. The *calculated voltage and reactive power of the* 115 kV system in Metro Manila at the main points (115 kV busbars of Manila and Sucat power plants) are as follows.



(Since the voltage of the 115 kV system may be compensated by about 3 kV by tap operation of the 230/115 kV main transformers, the actual voltage is estimated at around 101--103 kV.)

The above-mentioned condition represents a case where the generators of Manila and Sucat power plants are in operation, with Var generated from both sides to provide voltage compensation. However, there will be a problem when large capacity power plants (PNPP, Calaca, etc.) are commissioned in the future (A detailed study was made for each stage after 1985).

v. The problem of power flow is that there is a very heavy power flow in the following three 115 kV transmission lines. It will be necessary to take some measures in the near future.

	Rated capacity (A) (MVA)	Power flow (B) (MVA)	B/A (%)
San Jose-Novaliches	137	128	93.4
Balintawak-N. Port	211	171	81.0
Sta.Mesa-Balintawak	211	159	75.0

vi. The constants and data used for calculation such as power demand were considered reasonable and the calculation results were considered to have simulated the actual state of the system.

From the above results, calculation was made for the years after 1985 on the basis of precondition used for 1984, and analysis was made with the aforementioned various factors taken into consideration.

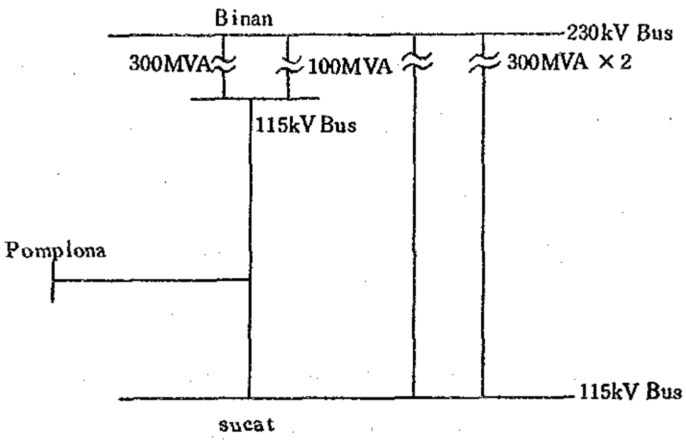
(2) 1985

Reinforcement of main transmission lines in 1985 is as follows.

- Construction of two-circuit 230 kV Malaya-Kalayaan line (795 x 2)
- Construction of two-circuit 230 kV Hermosa-San Jose line (795 x 2)
- Construction of two-circuit 230 kV Naga-Tiwi line (795 x 2)
- PI connection of 230 kV Malaya-San Jose line at Dolores substation
- construction of two-circuit 115 kV (230 kV design) Binan-Sucat line (795 x 2)

. Installation of an additional 230/115 kV main transformer (300 MVA) at Dolores substation

. The system composition of Binan-Sucat line is as follows.



Simultaneously with the above reinforcement of transmission lines, large power plants (PNPP and Calaca), having a combined capacity of 1,030 MW, are scheduled to be commissioned in 1985 as mentioned previously. The power demand is forecast at a low 2,395 MW with the influence of economic condition taken into consideration.

The following are the results of analysis made for each case.

1) Wet season, PNPP in operation

(Cases 5-1, 5-2, 5-3)

i. System configuration.....Loop
Time....................Daytime (Case 5-1)

If all generating units of hydro power plants are to be operated because of wet season, operation of steam power plants will be as follows to maintain demand and supply balance.

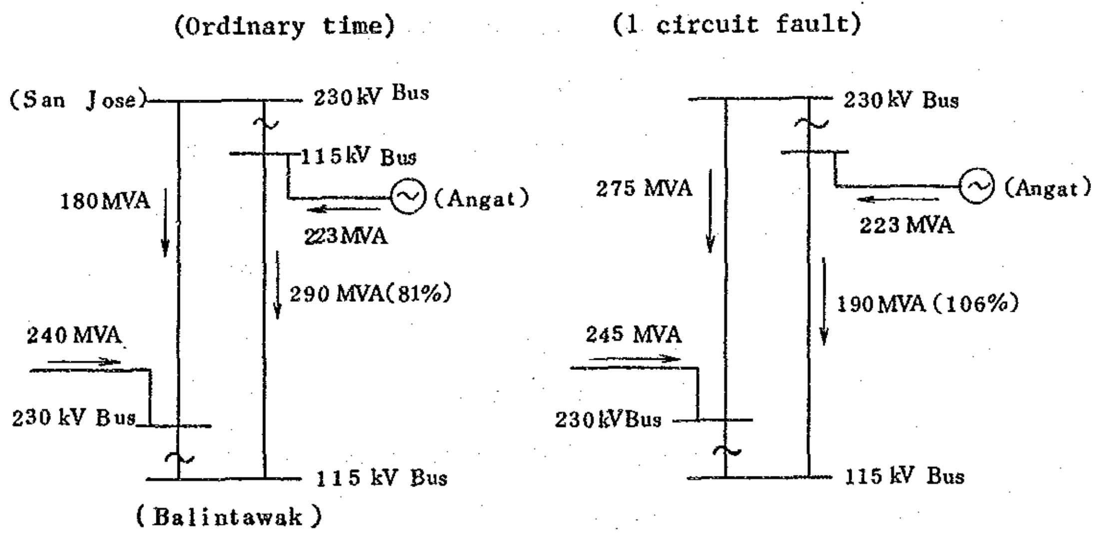
PNPP	500 MW
Tiwi	275 MW
Mak-Ban	330 MW
Calaca	260 MW
Malaya No. 2	80 MW
Bataan No. 2	70 MW

Analysis of power flow and voltage under this condition gives the following result.

1) Power flow

Power generation by north hydro power plants and nuclear power plant feeding into 230 kV San Jose and Balintawak substations will amount to 1,380 MW, and the increase of the share of power plants in Northwestern Luzon will cause a heavy power flow in the 115 kV San Jose-Balintawak line (calculated value is 290 MVA or 81% of a capacity of 358 MVA of two-circuit line).

Accordingly, a fault in one circuit of the 115 kV San Jose-Balintawak line will result in a heavy power flow in the line as shown in the following chart, which exceeds the capacity of one circuit. Since the 115 kV San Jose-Novaliches line is always open as power flow exceeds the line capacity, change of system configuration using other circuit will also be difficult (refer to the result for 1990).



ii) Voltage

The voltage in Metro Manila in 1984 calculated by actual load (MW, MVar) is 96-99 kV as shown in Va of Table 7-5. Trial calculation by assuming S.C. 260 MVar for 230 kV busbar at Balintawak gives 97-100 kV as shown in Vb indicating an increase of about 1 kV as a whole. The voltage in Metro Manila, therefore, is 97-100 kV when Manila and Sucat power plants are in operation and can be maintained at 100 kV or over with the selection of tap of main transformers at 230/115 kV substations.

In 1985, however, the operation of such existing oil-based power plants as Malaya, Sucat, Bataan and Manila power plants will be limited during wet season following the commissioning of large power plants as mentioned previously for economic demand and supply balance, and there will be a requirement for a reactive power totaling 290 MVA at the location shown in Table 7-5.

For actual operation, however, the requirement for reactive power should be considered in conjunction with the adjustment by tap operation of 230/115 kV main transformers, and the requirement for reactive power sources will be on the order shown below.

Mexico (or Hermosa)	120 MVar
Dolores	40 MVar
Sucat (or Manila)	40 MVar
Total	200 MVar

Since the investment program for new facilities will not be in time for the requirement in 1985, the shortage of reactive power will be made up by the operation of thermal power plants in Metro Manila.

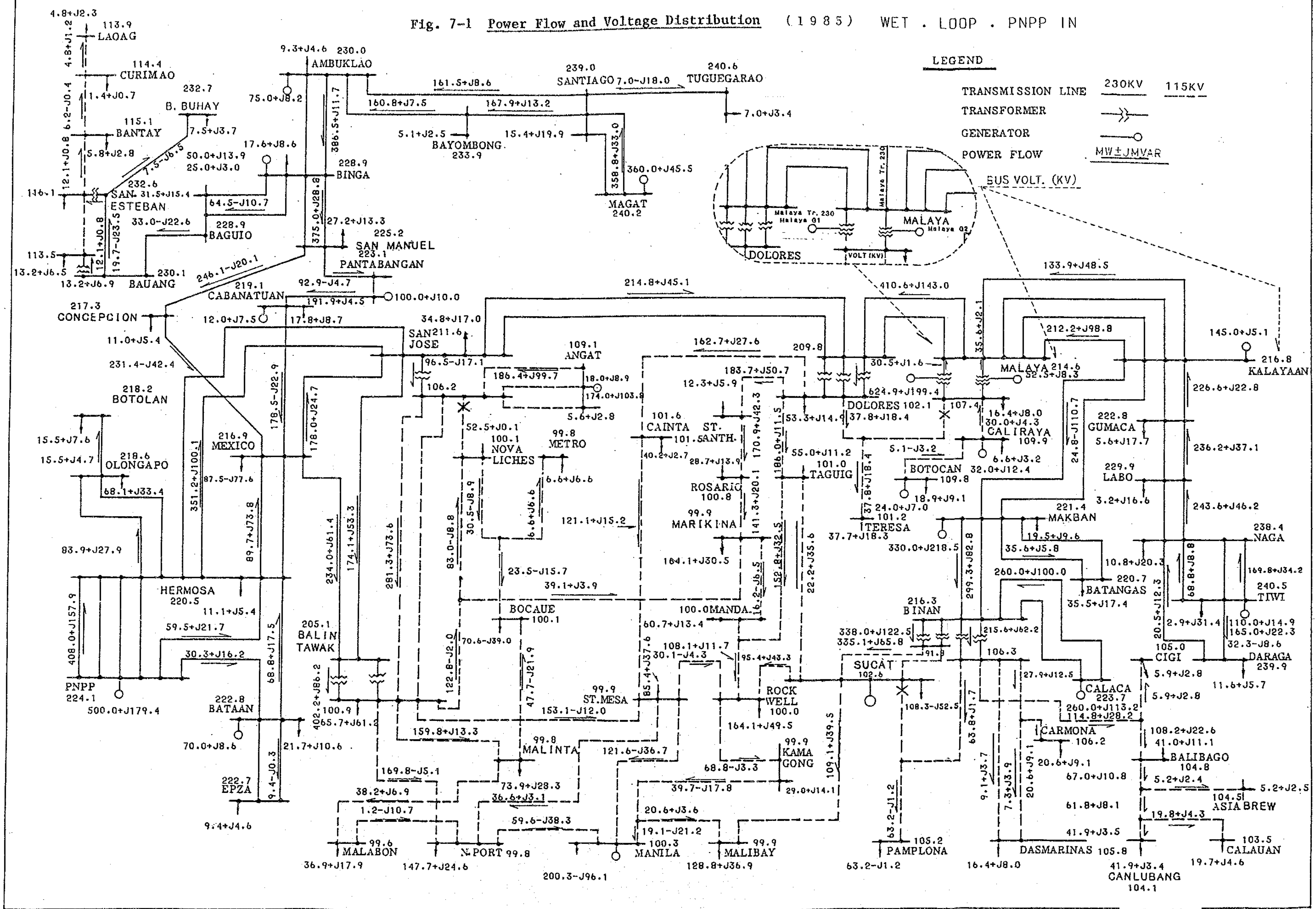
Refer to: Fig. 7-1

Power Flow and Voltage Distribution in Wet Season of 1985 (PNPP in, loop, daytime)

Table 7-5 Study of Voltage Regulation (Case...1984 Wet PNPP in)

S/S(P/S)	Bus (kV)	calculation P(MW)	calculation Q(MVar)	calculation Va(kV)	add Var	230kV Amend Vb(kV)	(b-a)	remarks	(reference) '85 Wet PNPPin P(MW)	(reference) '85 Wet PNPPin Q(MVar)	(reference) '85 Wet PNPPin Vc(kV)	remarks Add Var source
Magat	230	-	-	231.0		231.0	0.0		-	-	239.9	to Mexico 50MVA
Tiwi	230	-	-	241.0		241.0	0.0		-	-	241.1	Dolores 60MVA
Kalayaan	230	-	-	216.3		217.6	1.3				218.6	Binan 60MVA
Mexico	230	-	-	207.0		216.0	9.0		-	-	216.0	Taguig 30MVA
Balintawak	230	-	-	197.4	260MVar	207.0	9.6		-	-	207.1	Malinta 30MVA
-do-	115	65.7	61.2	97.7		99.6	1.9		65.7	61.2	101.9	Rockwell 40MVA
Novaliches	115	61.5	0.1	98.9		100.0	1.1		52.5	0.1	101.2	Total 270MVA
N.Port	115	181.2	30.2	96.4		97.8	1.4		147.7	24.6	101.1	
Bocaue	115	79.2	-46.8	97.7		99.0	1.3		70.6	-39.1	101.3	
Marikina	115	168.7	31.2	96.7		97.8	1.1		164.1	31.5	101.2	
Taguig	115	70.0	52.5	98.0		98.5	0.5		55.0	11.2	102.6	
Manila	115	112.9	-66.1	97.1		98.2	1.1	(gen.in)	200.3	-96.1	101.8	
Malinta	115	96.1	75.8	96.1		97.8	1.7		73.9	28.3	101.0	
Rockwell	115	199.8	96.8	97.1		97.7	0.6		164.1	49.5	101.6	
Sucat	115	102.0	-49.4	103.2		102.4	-0.8	(gen.in)	108.3	-52.5	105.4	
Dolores	115	67.4	18.8	98.5		99.6	1.1		53.3	14.9	103.8	
Total					260MVar							

Fig. 7-1 Power Flow and Voltage Distribution (1985) WET . LOOP . PNPP IN



ii. System configuration.....Loop

Case 5-2

Time....................Night time

The night load was assumed as follows.

(Night load of each substation)

= (Day peak load of each substation) x M

$$M = \frac{\text{Luzon Grid total night load}}{\text{Luzon Grid total peak load}} = 60\%$$

Note:

M = 60% is from Luzon Grid Total Load (except the load of Kalayaan pumping-up power plant).

Under this condition, there is no problem of power flow.

As for voltage, the bus voltage of the 115 kV line at each 230/115 kV substation increases to about 110 kV from the daytime voltage. If the tap position of substation transformers and pole transformers of 34.5 kV and 13.8 kV distribution lines should not be changed, the voltage to the consumers at midnight may abnormally be increased.

For this reason, it will be necessary to consider integrated total system voltage operation in the future.

When there is a large river flow, many hydro power plants will be operated 24 hours a day and shut down of steam power plants at midnight will present a problem. Frequent start/stop operation of steam power plants affects the life of generating facilities and involves extra cost for starting and stopping.

Japan had the same experience in the past, but in recent years, the operation of relatively large thermal power plants is stopped at midnight as routine. This may be the opportune time to consider the operating mode like this for the Luzon Grid.

This can also be said with the present analysis by which the operating conditions of Bataan thermal power plant as a voltage operation measure (especially in the event PNPP is out of system). For effective voltage operation, it is necessary to make a comparative study between the installation of phase modifiers and constant operation of thermal power plants.

Refer to: (Appendix-2) Fig. 2

Power Flow and voltage Distribution in Wet Season of 1985 (PNPP in, loop, night time)

iii. System configuration.....Separate
Time....................Daytime
Case 5-3

As for the point of system separation, studies were made with various transmission lines in the course of calculation, and the conclusion was to cut off the following four transmission lines with relatively small kW power flows as one of selections.

i) Marikina-Novaliches Tapping Point

ii) St. Mesa-Rockwell

iii) St. Mesa-Cainta

iv) Manila-Malibay

With these four transmission lines cut off, the 115 kV system can be separated into the following two groups.

. San Jose and Balintawak substations group

. Dolores, Malaya and Binan substations group

Other system conditions are the same as those of case 5-1.

What is different from the loop system under these conditions is that there is unbalance of terminal voltage of both groups resulting from a cut off of kV or power flow for voltage adjustment because of selection of transmission lines with a small kW power flow. However, the difference from the loop system is only 1 to 1.5 kV and this should not be a problem.

The power flow of the 115 kV San Jose-Balintawak line increased by 35 MVA as compared with the loop system to 315 MVA (88%). Anyway this line requires reinforcement in the near future to meet the growth of power demand in Metro Manila.

Other power flow and voltage conditions are not much different from those of loop system.

Refer to: (Appendix-2) Fig. 3.

Power Flow and Voltage Distribution in Wet Season of 1985 (PNPP in separate, day time)

2) Dry Season, PNPP in (Cases 5-4, 5-5)

i. System configuration.....Loop
Time....................Daytime
Case 5-5

In dry season, it was assumed that one generating unit at each hydro power plant would be operated except for the precondition mentioned previously.

As a result, power generation by north hydro power plants, PNPP and steam power plants connected to 230 kV San Jose and Balintawak substations will amount to about 880 MW, and the operation of the following power plants was considered instead.

Malaya	No. 1 unit	(300 MW)
Sucat	No. 4 unit	(300 MW)

This operating condition presents the following problem.

(i) While the problem of a heavy power flow in the 115 kV San Jose-Balintawak line, which was the problem with the case in wet season, is lessened somewhat, the actual power flow will amount to 245 MVA (138%) against the capacity of 178 MVA of one circuit when the voltage (about 207 kV) of the 230 kV system around Balintawak substation is taken into account.

(ii) The actual power flow of 115 kV (230 kV design) Binan-Sucat line (358 MVA x 2 circuits) would be about 410 MVA with the increase of generating capacity in southeast, exceeding the capacity (358 MVA) of one circuit by 16%.

(iii) While the situation is improved somewhat as compared with wet season because of operation of thermal power plants (calculation considers the operation of No. 4 unit of Sucat) in Metro Manila, there is still a shortage of reactive power source in Metro Manila. A comparison of calculated impact of reactive power sources between main locations is shown in Table 7-6.

For this comparison, the voltage of 230 kV system was calculated to be about 240 kV for both Tiwi and Magat power plants, and the voltage at Magat is higher than actual operating voltage by about 10 kV.

Table 7-6 Effect of S/C in Metro Manila (case...'85 Dry PNPP in)

S/S(P/S)	Bus	P(MW)	Q(MVar)	Var source in (a) V(kV)	Var source none (b) V(kV)	(a-b) V(kV)	Var source (temporary)
Balintawak	230	-	-	207.1	210.0	-2.9	+100MVar
-do-	115	65.7	61.2	101.9	100.7	1.2	
Novaliches	115	52.5	0.1	101.2	98.4	2.8	
N.Port	115	147.7	24.6	101.1	99.6	1.5	
Bocaue	115	70.6	-39.1	101.3	95.8	5.5	+90MVar
Marikina	115	164.1	31.5	101.2	100.1	1.1	
Taguig	115	55.0	11.2	102.6	101.6	1.0	
Manila	115	200.3	-96.1	101.8	100.3	1.5	
Malinta	115	73.9	28.3	101.0	98.8	2.2	
Rockwell	115	164.1	49.5	101.6	100.2	1.4	
Sucat	115	108.3	-52.5	105.4	98.9	6.5	
Dolores	115	53.3	14.9	103.8	100.6	3.2	

Refer to: (Appendix-2) Fig. 4.

Power Flow and Voltage Distribution in Dry Season of 1985 (PNPP in, loop, daytime)

ii. System configuration.....Separate
Time....................Daytime
Case 5-4

The basic problem is the same as that for loop system.

While the calculated voltage of San Jose and Balintawak system is lower by about 3 kV, improvement can be made by selecting more appropriate system separation points (Separation of 115 kV bus at St. Mesa substation, for example).

The problem of powerflow is that there is a heavy power flow (356 MVA) in the 115 kV San Jose-Balintawak line, exceeding the capacity (179 MVA) of one circuit by 99%. However, nearly same condition as that of loop system can be expected through better selection of separation points as in the case of voltage. In any event, a heavy power flow of 115 kV Binan-Sucat line cannot be avoided, however.

Refer to: (Appendix-2) Fig. 5.

Power flow and voltage Distribution in Dry Season of 1985 (PNPP in, separate, daytime)

3) Dry season, PNPP out (Cases 5-6, 5-7)

	Case 5-6	Case 5-7
System configuration	...Loop	...Separate
Time	...............Daytime	...Daytime

(Additional Case 1)

Wet season, PNPP out

System configuration.......Loop

Time......................Daytime

As the case of wet season, PNPP out condition was not included in the agreement with NAPOCOR at the time of field survey and the case was added to calculation upon return to Japan.

Since the steam power plants will be operated in Metro Manila in both wet and dry seasons, the power flow of the 115 kV system will be relatively stabilized.

The difference in power flow between the case where PNPP is operated and the case where PNPP is not operated is that in the latter case, the increase of power generation by power plants in southeast (increase of output at malaya and operation of Sucat), which operate a substitute of

PNPP, will increase the power flow from power plants in southeast to Metro manila in such lines as the 230 kV Malaya-Dolores line and 230 kV Mak-Ban--Binan line as indicated in Fig. 7-2.

In particular, the 230 kV Mak-Ban--Binan line will be influenced greatly by the operation of Sucat power plant, with the power flow in the case shown in Charts A and B of Fig. 7-2 amounting to 335 MVA (94%) against the capacity (358 MVA) of one circuit (this point will be reviewed again in the analysis for 1987 and 1990).

The case of separation of 115 kV system is not much different from the case of loop system except a voltage drop of the San Jose-Balintawak line by about 1 kV.

Refer to: (Appendix-2)

Fig. 6.

Power Flow and Voltage Distribution in Dry Season of 1985 (PNPP out, loop, daytime)

Fig. 7.

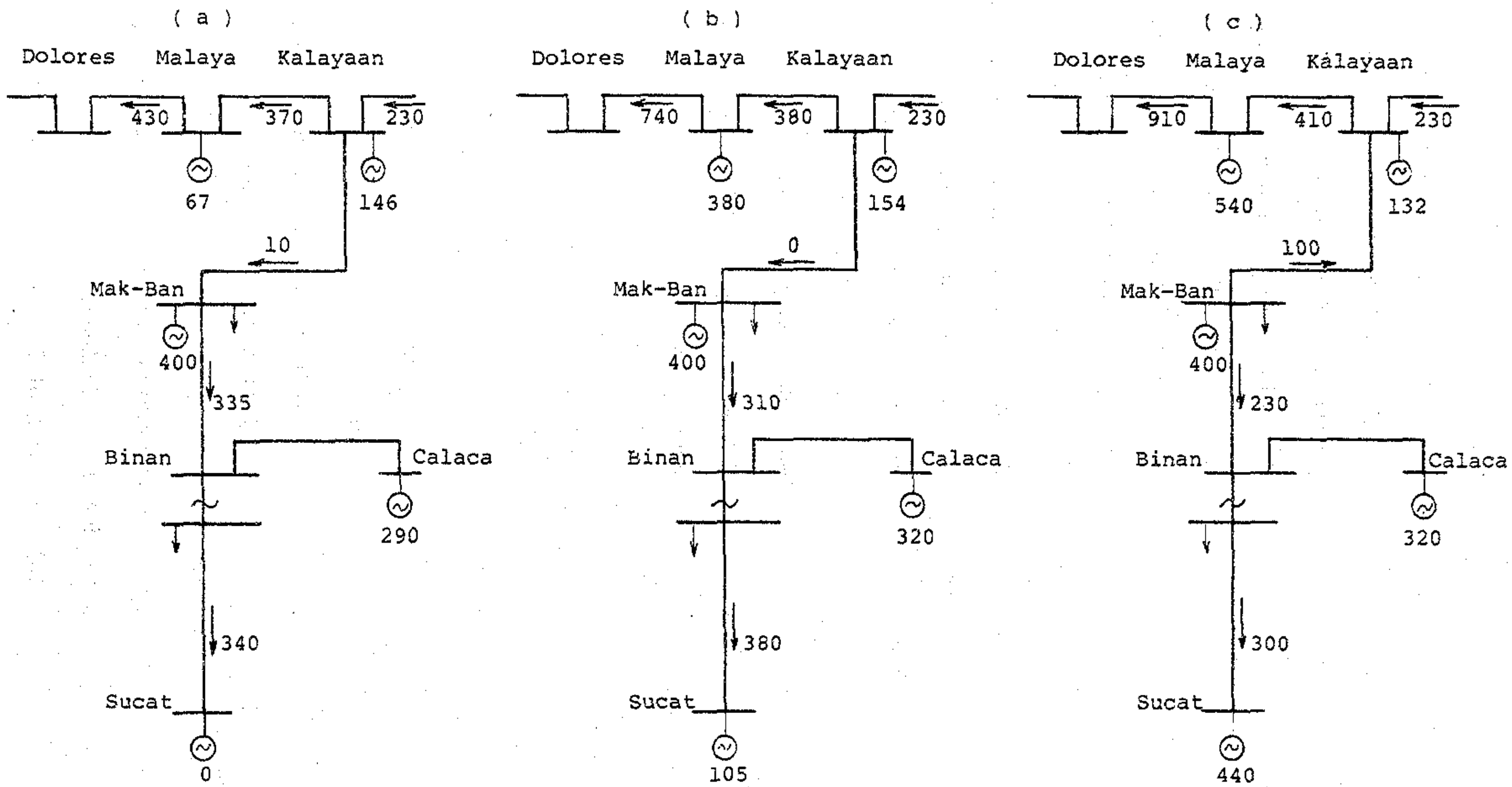
Power Flow and Voltage Distribution in Wet Season of 1985 (PNPP out, loop, daytime)

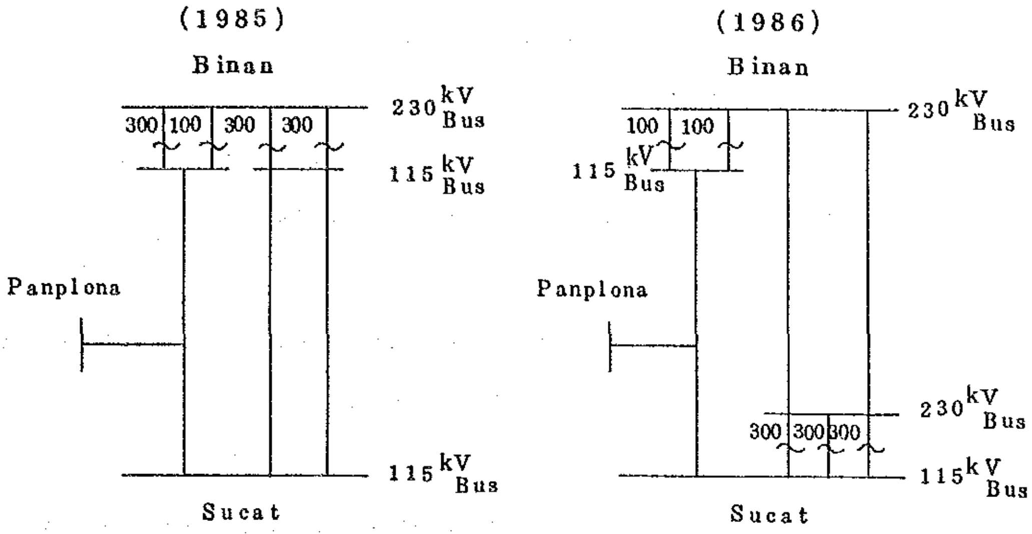
(3) 1986

Reinforcement of main transmission system scheduled in 1986 is as follows.

(i) Boosting of 115 kV Binan-Sucat line and Sucat substation to 230 kV

Fig. 7-2 230 kV Mak-Ban--Binan Line Power Flow (Unit: MVA)





(Unit of transformer capacity: MVA)

(ii) Construction of two-circuit 230 kV Kalayaan-San - Esteban line (795 MCM x 2)

(iii) Construction of one-circuit 230 kV Bauang-San Esteban line (795 MCM x 1) and grade up of San Esteban substation to 230 kV

(iv) Construction of two-circuit 230 kV Bauang-Labrador line (795 MCM x 2) and one-circuit 230 kV Labrador-Botolan line (795 MCM x 1)

Since the power demand in 1986 is expected to level off as compared to 1985 and the transmission system will be reinforced by the above-mentioned grade up of Sucat substation to 230 kV and others, no specific problems are anticipated except that the condition of the 230 kV Mak-Ban--Binan line will become more stringent in Case 6-2 PNPP out, wet season.

Refer to: (Appendix-2)

Fig. 8.

Power Flow and Voltage Distribution, in Dry Season of 1986 (PNPP in, Separate, Daytime)

Fig. 9

Power Flow and Voltage Distribution, in Wet Season of 1986 IPNPP out, Separate, Daytime)

(4) 1987

In 1987, there is no specific plan for reinforcement of the 230 kV system.

(a) Wet season, PNPP in (Case 7-1, Case 7-2)

System configuration.......Loop (Case 7-1),
Separate (Case 7-2)

Time.......................Daytime

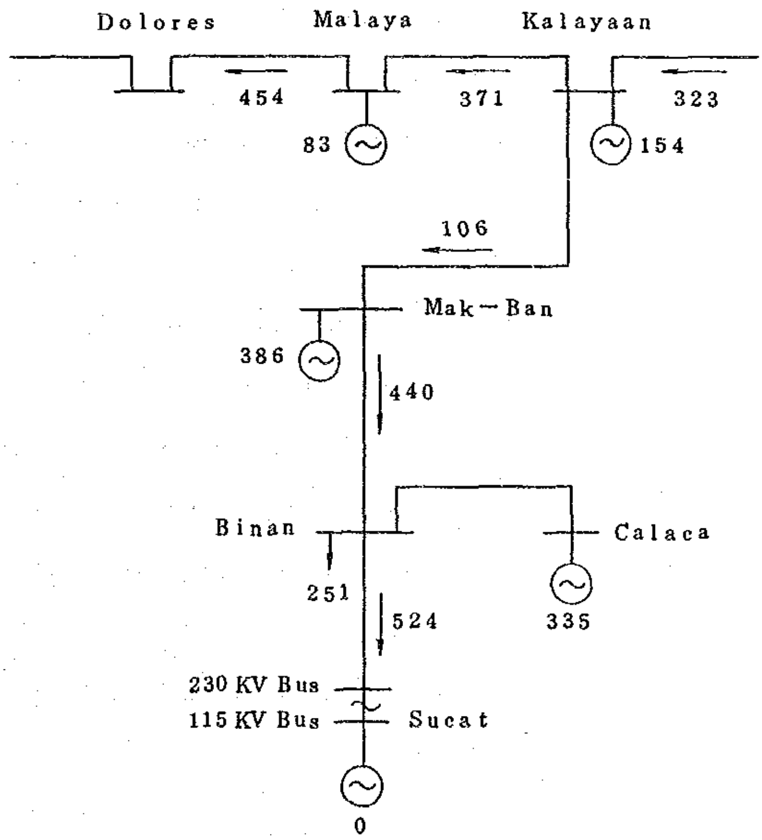
(Additional Case 2)	(Additional Case 3)
Dry season, PNPP in	Dry season, PNPP out
System configuration ....Loop	System configuration ....Loop
Time.........Daytime	Time.........Daytime

1) Power flow

The power flow of the 230 kV Kalayaan--Mak-Ban--Binan line discussed in the study for 1985 was analyzed on the assumption that the demand in 1987 will increase by about 110 kW. During wet season, therefore, absorption of the increased portion of power demand by the increase of output mainly of Kalayaan, malaya and Calaca power plants and the decrease of reactance due to the introduction of 230 kV Binan-Sucat line and installation of three 300 MVA transformers at Sucat power plant, will result in a heavier power flow in the 230 kV Mak-Ban--Binan line. The outline of the analysis is shown in Fig. 7-3. The actual power flow of 440 MVA is about 123% of the capacity (358 MVA) of one circuit of the line (795 x 1, 2).

Fig. 7-3 Power Flow of 230 kV Kalayaan--Binan Line

(Wet Season, PNPP in) (Unit: MVA)



2) Voltage

A detailed study was made for installation of static condensers on the assumption that the equipment to be procured under the investment plan will be available in 1987.

At first, the system voltage in Metro Manila was calculated for the case where only the existing phase modifiers are provided and there is no output of thermal power plants located in the center of Metro Manila. The result was that the calculated voltage was below 90 kV in a number of main points as shown in Table 7-7.

As mentioned previously, the calculation for 1985 sought the Var source in generating units of Manila and Sucat power plants assuming that the static condenser would not be available. This analysis, therefore, assumed non-operation of these power plants. The total capacity of static condensers required is calculated to be approximately 290 MVAR as shown in the table for 1987.

On the other hand, the Var loss of Balintawak, Dolores and Binan 230 kV substations and the surrounding 230 kV and 115 kV transmission line, shown in Table 7-8, may be summarized as follows.

Table 7-7 Calculation Result for Voltage Drop Improvement

		(1987 Wet) Before S.C install.	Load		+S.C	After S.C install.	Load	(1990 Wet)	Load
S/S(orP/S)	Bus (kV)	Volt (kV)	P (kW)	Q (MVar)	Cap (kVA)	Volt (kV)	Q (MVar)	Volt (kV)	Q (MVar)
Magat	230	240.6	-	-		240.6	-	240.6	-
Tiwi	230	240.5	-	-		240.5	-	240.4	-
Mexico	230	216.9	-	-		216.9	-	216.9	-
Balint'wk	230	193.2	-	-		204.8	-	205.0	-
Balint'wk	115	90.9	59.2	55.2		100.0	55.2	100.0	64.3
Sta.Mesa	115	88.1	87.6	38.5		99.0	38.5	99.1	46.9
Rockwell	115	88.6	168.9	81.8	30	99.2	51.8	99.4	69.4
Sucat	115	94.0	82.1	39.8		101.9	39.8	102.5	44.1
Pamplona	115	97.9	64.7	-1.3		102.4	-1.3	99.6	-1.5
Balibago	115	97.5	41.8	11.9		102.0	11.9	99.3	13.8
Canlubang	115	96.7	42.6	3.4		101.2	3.4	98.4	4.1
Malibay	115	88.2	131.8	37.8		99.0	37.8	99.5	45.8
Manila	115	86.5	208.4	13.9	100	99.2	-78.0	99.9	-51.7
N.Port	115	87.4	151.5	25.3		98.6	25.3	98.7	28.0
Malinta	115	85.4	63.1	49.9	50	97.8	-0.1	97.5	4.4
Bocaue	115	83.8	70.2	38.3	30	96.9	8.3	96.4	10.7
Novaliches	115	88.0	39.5	0.1		98.6	0.1	98.7	0.1
Marikina	115	90.3	142.1	26.4		99.4	26.4	99.3	29.7
Dolores	115	94.6	55.3	15.4		102.3	15.4	102.2	18.7
Cainta	115	92.9	41	2.7		101.5	2.7	101.4	3.3
Taguig	115	90.8	56.8	93.2	80	100.6	13.2	100.5	33.2
Mandal'yng	115	89.5	63.1	13.9		99.5	13.9	99.5	12.8
calauan	115	96.1	20.5	4.7		100.6	4.7	97.6	5.5
Total					290				

Table 7-8 Line & Transformer Var Loss

(Case...1987 Wet PNPP in)

	Line & Tr	Q.loss (MVar)	S.C (MVar)
230kV	San Jose-Balintawak	10.2	
230kV	Mexico-Balintawak	23.5	
230/115kV	Balintawak Tr	41.4	
	Total	75.1	70
115kV	San Jose-Balintawak	39.3	
115kV	Balintawak-POB	6.1	
115kV	POB-Malinta	0.6	
115kV	Balintawak-N.Port	9.4	
115kV	Balintawak-Sta Mesa	6.0	
115kV	Balintawak-Marikina T	1.5	
115kV	Malinta-Bocaue	0.1	
115kV	Malinta-Malabon	0.2	
	Total	63.2	60
230kV	San Jose-Dolores	11.6	
230kV	Malaya-Dolores	7.9	
230/115kV	Dolores Tr	64.4	
	Total	83.9	80
115kV	Dolores-Cainta	4.1	
115kV	Dolores-Rosario	5.9	
115kV	Dolores-Taguig	7.0	
115kV	Dolores-Teresa	0.1	
	Total	17.1	15
230kV	Binan-Sucat	8.9	
230/115kV	Sucat Tr	35.3	
	Total	44.2	40
115kV	Sucat-Sun Valley	5.3	
115kV	Sun Valley-Malibay	6.0	
115kV	Sucat-Rockwell	8.3	
115kV	Sucat-Taguig	1.1	
	Total	20.7	20
Total	230kV(NAPOCOR)	203.2	190
	115kV(MERALCO)	101.0	95
G.Total		304.2	285

230 kV Transmission lines and Transformers	190 MVAR
115 kV Transmission lines	95 MVAR
Total	285 MVAR

From the above the reasonable requirement for static condensers is considered as follows.

230 kV system (NAPOCOR)	
Mexico (or, Hermosa)	50
Dolores	60
Binan (or Sucat)	60
Total	170 MVA
115 kV system (MERALCO)	100 MVA
Grand Total	270 MVA

A comparison of bus voltages of main 230 kV and 115 kV power plants and substations between the following three cases gives a result shown in Table 7-9, which indicates that the decrease of output of power plants in west and north of Metro Manila causes the decrease of bus voltage of 230 kV system at Mexico substation, with the difference amounting to about 5 kV (2.5%).

Wet season, PNPP in (Case 7-1)

Dry season, PNPP in (Additional case 2)

Dry season, PNPP out (Additional case 3)

Table 7-9 Comparison of Voltage Regulation

(Case...Wet PNPP in)

(Dry PNPP in)

(Dry PNPP out)

S/S(P/S)	Bus	Wet(a) PNPPin V(kV)	Gen.	Dry(b) PNPPin V(kV)	Gen.	Dry(c) PNPPout V(kV)	Gen.	(b-a) V(kV)	(c-a) V(kV)
Magat	230	240.7	4 nuits	240.9	2 units	239.9	2 units	0.2	-0.8
Tiwi	230	240.4	5 units	240.4	5 units	240.4	5 units	0.0	0.0
Kalayaan	230	222.7	2 units	222.6	2 units	222.4	2 units	-0.1	-0.3
Mexico	230	216.9		213.9		211.6		-3.0	-5.3
Dolores	230	212.1		211.6		212.1		-0.5	0.0
Binan	230	213.3		214.7		217.0		1.4	3.7
Balintawak	230	204.8		204.8		207.0		0.0	2.2
-do-	115	100.0		100.2		101.7		0.2	1.7
Novaliches	115	98.6		98.8		100.6		0.2	2.0
N.Port	115	98.6		99.1		101.4		0.5	2.8
Bocaue	115	96.9		97.2		99.2		0.3	2.3
Marikina	115	99.4		99.8		101.3		0.4	1.9
Taguig	115	100.6		101.3		102.9		0.7	2.3
Manila	115	99.2	G none	99.9	G none	103.2	G1.2 in	0.7	4.0
Malinta	115	97.8		99.2		100.2		1.4	2.4
Rockwell	115	99.2		100.0		102.0		0.8	2.8
Sucat	115	101.9	G none	103.5	G4 in	105.2	G1-4 in	1.6	3.3
Dolores	115	102.3		102.6		103.6		0.3	1.3

In this respect also, installation of static condensers at Mexico substation (or Hermasa substation) is desirable. In Metro Manila where bus voltage of the 115 kV system fluctuates by 2-4 kV when the operation of Sucat and Manila power plants is stopped, the following locations are considered appropriate for installation of static condensers.

230 kV power plant and S/S.....Dolores, Binan

115 kV power plant and S/s.....Sucat, Manila

Refer to: (Appendix-2) Fig. 10.

Power Flow and Voltage Distribution, in Wet Season of 1987 (PNPP in, Loop, Daytime)

(5) 1990

The reinforcement of main transmission lines scheduled for 1990 is as follows.

Construction of two-circuit 230 kV Kalayaan-San Jose line (795 MCM x 4)

a) Wet season, PNPP in (Case 0-1, Additional case)

System configuration.....Loop (Additional case),

Separate (case 0-1)

Time....................Daytime

i. Power flow

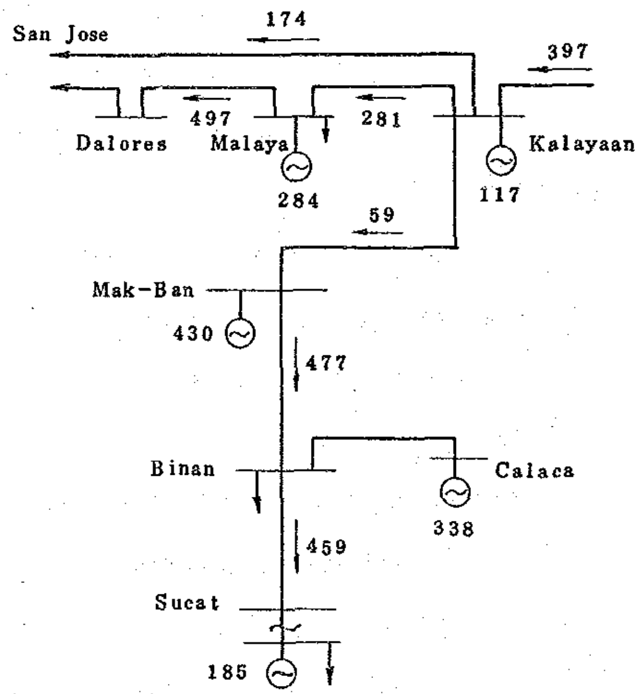
The load flow on Mak-Ban--Binan line is liable to over its capacity in 1985 and 1987. However, even after the completion of new San Jose--Kalayaan line, the load flow on Mak-Ban--Binan line reaches 440 MVA.

The reason is that the output of Kalayaan and Mak-Ban increases by the growth of load in 1990. The load flow, 477 MVA, is about 133% of a line capacity (358 MVA).

So, if there happens to occur a fault tripping one of the line, the over load on the remained line will become a problem in load dispatching operation. (See: Fig. 7-4)

Fig. 7-4 Power Flow of 230 kV Kalayaan--Binan Line

(Wet Season, PNPP in) (Unit: MVA)



ii. System Voltage

The load demand of the system in 1990 increases about 475 MW from that in 1987. But only Manito power station (110 MW) will be completed for the growth of load.

So, the power stations in Metro Manila 115 kV system should be in operation from the balance of production and demand.

115 kV system voltage may be same condition of 1987 because of the above mentioned reason and the S.C. installed by the implementation of the immediate corrective measures.

See: Appendix-2

Fig. 11 Load flow Map, Wet, PNPP in, Loop, Day, in 1990

Fig. 12 Load flow Map, Wet, PNPP in, Separate, Day, in 1990

b) Dry Season, PNPP Out (0-2)

System configuration.....Separate

Time....................Day time peak

The output of hydro power plants decreases to 550 MW and PNPP (620 MW) is out for its maintenance. So, 3 units of Sucat and 2 units of Manila become necessarily to operate from the balance of production and demand. So, the 115 kV system voltage becomes higher and has no problem in operation.

NAPOCOR is studying to decrease the output of PNPP from 620 MW to 500 MW in the case that the full output of northern hydro plants including Magat is expected.

But, it is recommendable that the full capacity operation of PNPP should be studied on overall checking the balance of production and demand.

7-2. System Stability

a. Assumptions used for Calculation

In the study of system stability, calculation was made on the following assumptions according to the agreement made with NAPOCOR during site survey.

(1) Cases

	Case	Season	PNPP	System Configuration	Time
1985	5-1	Wet	in	Loop	Day(time)
	5-3	Wet	in	Separate	Day
	5-6	Dry	out	Loop	Day
1987	7-1	Wet	in	Loop	Day
1990	0-1	Wet	in	Separate	Day

(2) Locations and Nature of Faults Simulated

For the simulation of a fault, simultaneous 3 LG of two circuits was assumed for (each of) the following five transmission lines.

	1985, 1987	1990
Kalayaan--Gumaca	o	-
San Manual--Conception	o	o
Hermosa--San Jose	o	o
San Jose--Dolores	o	o
Dolores--Malaya	o	-
Kalayaan--San Jose	-	o
Binan--Sucat (230 kV)	-	o

(3) Constants of Generators

Constants of generators assumed are shown in Table 9 (Appendix-2).

b. Calculation Results and Discussion

(1) 1985

1) Case 5-1 (Wet, PNPP in, Loop, Day)

System stability can be secured for all lines except the Kalayaan-Gumaca line and the San Manuel-Conception line.

With the Kalayaan-Gumaca line, the section between Gumaca S/S and Daraga S/S becomes an independence and the generators of Tiwi are stepped out, but there is no problem for transient stability in the main system west of Kalayaan power plant.

With the San Manuel-Conception line, there is a large difference in phase angle between the two groups of north hydro system of Magat, Ambukulao and Pantabagan and the main system south of Cabanatuan, resulting in trippings of the two groups.

Calculation results are shown in Figures 13-17, Appendix-2.

2) Case 5-3 (Wet, PNPP in, Separate, Day)

In this case, the 115 kV system is separated into the San Jose and Balinkawak system and the Dolores and Binan system and there is a difference in phase angle between the two groups of west and north power plants and east and south power plants by calculation, but system stability is considered possible, and, in case of impossible to keep it, system separation can be provided by transfer tripping of separation points (4 to 5 points) according to frequency fluctuation immediately after the fault instead of constant separation.

Others are similar to case 5-1.

Calculation results are shown in Figures 18-22 (Appendix-2).

3) Case 5-6 (Dry, PNPP out, Separate, Day)

In this case, the system is relatively stable as thermal power plants in Metro Manila are in operation because of the operation of only one to two generators in each of north hydro power plants (However, generators of Ambukulao and Pantabangan hydro power plants will step out in early stage). Also, because of a large power flow (approx. 900 MW) in the 230 kV Dolores-Malaya line as compared with wet season, there is a large power swing of each generator.

Calculation results are shown in Figures 23-27 (Appendix-7).

(2) 1987 (Wet, PNPP in, Loop, Day)

In 1987, there is no problem for system stability if the 230 kV Kalayaan-San Jose line, scheduled to be completed in 1987, is commissioned. Analysis was also made on the assumption that the line was not in operation but there was no specific problem for system stability since the condition of 1985 is much improved by the expansion of the 230 kV system with the addition of new 230 kV

Kalayaan-Malaya line and new 230 kV Olongapo-Bauang line. Calculation results are shown in Figures 28-32 (Appendix-2).

(3) 1990 (Wet, PNPP in, Separate, Day)

With the addition of new 230 kV San Jose-Kalayaan line after 1987, the system will be more stabilized except the tendency that the phase angle of generators at Magat differs from that of the main system as compared with 1987 (refer to Fig. 24, Appendix-2).

Since the stability of north hydro power system is dependent on the increase of load in the entire luzon Grid, expansion of interconnection with north power system by constructing a new 500 kV San Jose-North Luzon line in conjunction with the construction of coal-fired power plant in Cagayan Valley will be required in the future.

Prior to the calculation of each case in the above analysis, calculations were made for one case with consideration of controlling devices such as AVR, governor and without consideration of controlling devices. As a result of a comparison of the two results, it was determined that there was no problem in the evaluation of system stability by calculation without consideration of controlling devices.

Since the calculation made in this analysis for evaluation of system stability did not consider any controlling device, the result is more or less conservative.

Calculation results are shown in Figures 33-37 in Appendix-2.

7-3. Problems in Restoration Efforts

a. Voltage Rise in the 230 kV Transmission Systems under the Self-Exciting Effect of Generators

As in the case of the damage of lightning arresters due to voltage rise on Gumaca side under the effect of generator(s) at Tiwi power plant when there was a tripping of the 230 kV Kalayaan-Gumaca line and the case of a voltage rise (about 280 kV) in the 230 kV Malaya-San Jose line and the Malaya-Dolores line under the effect of generators at Kalayaan power plant at the time of total system failure on September 24, 1984, and also in the case of a similar problem in providing a station power to PNPP by way of the 230 kV San-Jose-Hermosa line and the Hermosa-PNPP line, the abnormal voltage rise considered to be due to the system restoration procedure following the total system failure has occurred and will occur in the future. Needless to say, the analysis of these abnormal phenomena should be made at the earliest opportunity in the future. However, the system operation procedure (SOP) of NAPOCOR:

(1) Fails to indicate a concrete method of charging the 230 kV transmission lines sequentially by Kalayaan and Angat hydro power plants while feeding to the load compatible to the generator output.

(2) Seems to be inadequate in the means of communication between PMC of NAPOCOR and LDC of MERALCO in the joint system restoration effort to cope adequately with such emergencies as total system failure.

It is essential in the future to make comprehensive studies including phenomenal analysis, shunt reactor installation plan and improvement of system operation procedures.

b. Transient Current of Transmission Lines Following the Fault in Main 230 kV Systems

Immediately after the restoration of main 230 kV transmission lines which have a large power flow, the large current flow transfers to other unaffected lines thereby causing a large power swing.

It will be necessary in the future to study measures in advance for such an event, including system separation, by considering the allowable short time current of each 230 kV and 115 kV transmission line.

7-4. Measures Required for System Stability

As discussed in chapter 4, the system fault of the Luzon Grid occurring on five occasions since August 1983 resulting in the *system collapse and the delay in the subsequent restoration efforts* are considered to be due to the combination of the following factors from a system operation viewpoint.

a. Step Out Phenomenon

b. Load Shut Down at the Time of Frequency Drop

c. System Separation

d. Overload of Transmission Lines and Transformers

e. Abnormal System Configuration

f. Voltage Rise of Transmission Lines

g. Inadequate PMC-LDC Communication

h. Inadequate System Operation Procedures for Emergency

For the solution of these problems, the following may be considered from the result of system analysis with computer.

a. With respect to the transient stability, step out condition or instability is observed when there is a fault in the following transmission lines.

System in 1985: Kalayaan-Gumaca line
(Step out of generators at Tiwi)
San Manuel-Conception line
(Step out of generators at north hydro power plants)
Dolores-Malaya line
(Unstable to some extent)

System in 1987: San Manuel-Conception line
(Unstable to some extent)
Dolores-Malaya line
(Unstable to some extent)

System in 1990: San Manuel-Conception line
(Unstable to some extent)

As seen from the above progress, the transmission system is expanding year by year with gradual improvement of stability of generators. However, the problem of system instability still remains in part (in north hydro power plants), and the state of system instability may develop at the time of maintenance work or when a special system configuration is used. For further improvement of system stability in the future, a study should be made promptly on the following measures.

(1) High Speed Reclosing System

As already mentioned in Chapter 5 and Section 6, the reclosing system is not being used by NAPOCOR at present. While the failure of reclosing generally results in the decrease of system stability to some degrees, the probability of success of reclosing is considerably high (85% in Japan), and adoption of this system should be reviewed promptly in the light of annual increase of the capacity of the Luzon Grid.

(2) Transfer Tripping of Generators

While the interconnection of main transmission lines of the Luzon Grid and north hydro power system will be strengthened to some extent with the construciton of the 230 kV Olongapo-Bauang line, there is a tendency that the Luzon Grid system will become unstable in the event of a fault in the 230 kV San manual-conception line in the future when viewed from the calculation of transient stability. In addition, there is a problem of a heavy power flow in the event of a fault in the 230 kV San Manuel-Pantabagan-Mexico line, a study should be made promptly on the requirement for transfer trippings of generators at Magat power plant.

(3) System Separation

The 115 kV system in Metro Manila is fed by four 230/115 kV substations of Balintawak, San Jose, Dolores and Binan, each of which being operated in loop. This operating pattern is most efficient for normal operation. However, a failure of any 230 kV or 115 kV trunk line or transformer may result in a shift of power flow causing over power flow in the unaffected transmission lines with the eventual system collapse. (Example: Total system failure on September 25, 1983). To avoid the worst case like this, separation of the 115 kV system in Metro Manila from the Luzon Grid may be considered. The case study for system separation conducted in the analysis is for this purpose).

As to the method of system separation, permanent separation and separation immediately after the system fault may be considered. The permanent separation is easy for operation but is disadvantageous to some extent with respect to efficient operation of facilities and voltage operation. The separation immediately after the system fault, in the meantime, is advantageous for normal operation but requires transfer trippings of circuit breakers at several points (4 to 5 locations) depending on such conditions as overload and frequency fluctuations at main locations following the occurrence of a fault, necessitating system analysis and installation of additional relays and communication equipment. In this sense, each method may be said to have its merits and demerits.

However, the survival of even a part of the system is basically more desirable than the total system collapse in consideration of social impact or system restoration following the occurrence of a fault, a thorough study should be made toward the adoption of system separation.

(4) Intermediate Switching Station

The concept of intermediate switching station is for lessening the increase of reactance following the removal of the source of a fault but involves a large amount of construction cost. Since the Pi connection is being realized at Dolores substation as a measure for the time being, Pi connection should also be introduced to Bayombong substation.

CHAPTER 8

RENOVATION PLAN

Chapter 8. Renovation Plan

8-1. Basic Idea for Renovation Plan

A power system is composed of generating power plants, thermal power plants, geo-thermal plants, hydro power plants, pumping up plants and nuclear power plants, and extra high voltage transmission lines and substations which link consumers and power plants, and organically operated as an union. As the load demand grows, the power system adopts a bigger unit size of generator, extra high voltage for transmission lines and substations, and long distance transmission lines year by year. Because the power system expands more complicated one, the establishment of higher control technics and a suitable protecting system becomes the urgent task for the system operation.

Not only the facilities in the power system, generators, transmission lines and substations, should be operated in the best condition each, but in addition, the power system should be operated as a whole system to serve consumers with a reasonable service level on voltage, frequency and reliability. The power system which should be met with the ever growing demand should be expanded with a suitable coordination between each facility and should be a flexible arrangement for its operation.

To eliminate a total blackout fault in the Luzon Grid system, it is necessary to execute the immediate corrective measures which are designed to renovate the existing system considering its future expansion plan. However, without the survey and study on the basic planning methods for long and medium term plan and on the organization for the maintenance system, the works of immediate corrective measures could not fully be useful for the improvement of the stability of the system.

Therefore, the engineering services which support the study and survey for the planning methods on the operation and maintenance of system as the basic data for Phase 2, - medium term plan -, and for Phase 3, - long term plan 1 -, are one of the main works as well as the execution of the construction works during Phase 1, - immediate corrective measures -.

The plans for the expansion, renovation, operation and maintenance of the power system should be designed with the coordination of all sections plan taking a long sighted view of the system (from 10 to 15 years).

The plans are divided in following sections, for example.

Long term load and demand forecast

Development plan for generating plants

Standards for the power system operation

Expansion and renovation plan for power system

Plan for maintenance on the facilities in the power system

Maintenance and operation schedule for the power system

Plan for human resources (including training plan)

Financial plan

The utility's business is duly managed with the coordination between each plan and with the effective execution of each plan.

In the survey on the plant renovation (Luzon Grid), the report recommends not only the immediate corrective measures for the elimination of a total blackout fault considering above mentioned view point, but the policy of NAPOCOR to keep the reliable system operation in the long term.

The renovation plan is divided in the following three Phases up to 2000, each plan should be executed to maintain the system in a reliable condition.

Phase 1. Immediate corrective measure (1985...1987)

The immediate corrective measures include the corrective measures to eliminate a total blackout fault in the power system up to 1987. In the plan, the study and survey for the renovation plan on the basis of medium and long term forecast also should be included.

Phase 2. Medium term plan (1988...1990)

The ;additional renovation plan for the improvement of reliability of the system should be executed in medium term plan from 1988 to 1990. and also, the study and survey for long term plan should be done in the plan.

Phase 3. Long term plan (1990...2000)

The plan should include the plan for construction and operation in order to fulfill the criteria for the power system operation which are shown in the following section and to maintain the high service level.

Specially, during Phase 1, the basic study for planning should be prepared with the assistance of a consultant and immediate corrective measures should be systematically designed considering future expansion vision for the establishment of stabilized system operation.

The details for the immediate corrective measures are shown in Chapter 9.

8-2. Service Criteria of Power System Operation

The service criteria of electric power system should be determined for each item listed below, and utility makes efforts to attain these criteria through the long term plan and day to day operation.

a. Criterion of Frequency

The criterion is the indicator for power demand-supply balance and for the responding capability of power system to the load fluctuation.

(60 Hz ± 0.1 Hz) should be determined.

To attain the criterion, when a big factory (steel mill) and the like will be constructed, NAPOCOR should take a close cooperation with users.

b. Criteria of Voltage

- Ordinary users	±6%
- Industrial users	±10%
- 230 kV substations around Manila	±1%
- Around the hydro power plants in the north	±5%

(On load voltage regulator is necessary for transformer)

The criterion for ordinary users shown above is determined based on the characteristics of electric lights and appliances. To keep the voltage within these ranges, the voltage regulation must be shared by each voltage rank of 230 kV, 115 kV, 66 kV and 13 kV systems.

c. Criteria of Reliability

The reliability contains the supply reliability and service reliability. The supply reliability is the indicator for power demand and supply balance and the service reliability is the indicator for aiming at the reduction of power interruption.

Supply Reliability

1 Day/10 Year.....Probability of power supply shortage

Service Reliability

The criteria is usually expressed by the frequency of occurrence of interruption and duration, but, as for NAPOCOR which operates the 230 kV trunk system, the following criteria should be determined.

- One circuit transmission line fault for ordinary line and one route fault for especially important line should not cause the supply interruption and system instability.
- One bank fault of substation transformer should not cause the supply interruption.

d. Measures to Attain the Criteria

The measure to attain the above criteria should be studied dividing into three stages. 1st stage is the study from a long term sighted viewpoint, 2nd stage the study from a mediun term sighted viewpoint and 3rd stage immediate corrective measure. The immediate corrective measure will be described in Chapter 9.

8-3. Basic Study for Long Term Plan

a. Power Plant Unit Size

At present, NAPOCOR appears to place stress on the pursuance of scale merit in the power plant development. That is, the power plants with a unit capacity of more than 10% of forecast system peak demand have been constructed. Therefore, the power system, its operation and system reliability, has been in a severe condition. It will be necessary to review and study the policy on this matter which has a great impact on the basis of the power system planning. However, on the contrary, the coal fired power plant with a unit size of 100 MW is projected after 1990. Regarding to the unit size, long term sighted study should be made.

b. Long Term Demand and Supply Plan

Considering the prolongation of construction period of power plants and transmission lines, due consideration must be given to the formulation of the firm long term plans on supply capacity, reserve capacity and demand forecast. The capacity of hydro plants accounts for relatively a high portion in Luzon Grid. As for the planning of supply capacity, the study on the improvement of basic data base should be done for the water flow duration curves, maintenance period of power plants and estimation of fault frequency.

c. Power System Plan

1) Plan for EHV Backbone Line in the North

In 1987, the transmission lines designed for 500 kV are scheduled to be completed from Naga substation to San Jose substation through Kalayaan power plant as 1st and 2nd stage of EHV project. Thereby, the transmission system in the central and southern area will be greatly reinforced. However, as for the transmission line north of San Jose substation, the problem of over power flow in emergency remains to be studied. In relation to the power plant development in the north, the reinforcement plan for the transmission line in the north should be studied.

2) Supply Plan in Metro Manila

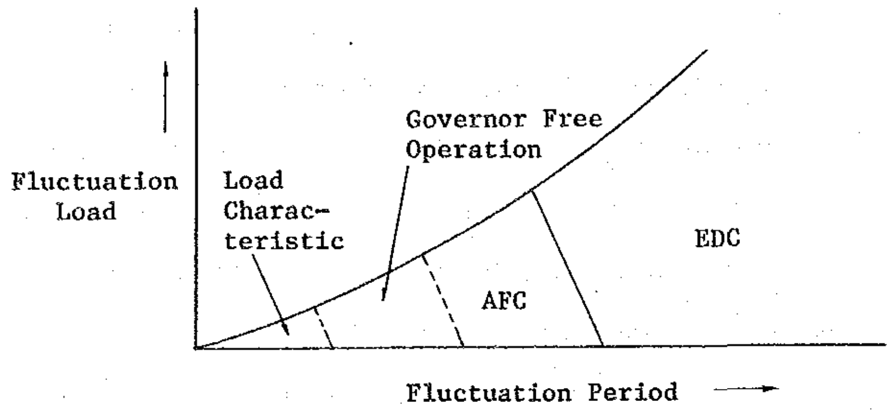
Based on the long term demand forecast in Metro Manila, the revision of the present three supply base system consisting of Sucat power plant, Dolores and Balintawak substations, should be studied with the cooperation of NAPOCOR and MERALCO.

Furthermore, it is important for the training and maintenance system to keep the system which is proposed in Phase 2 and to develop it.

8-4. Basic Study for the Medium Term Plan

a. Preservation of the Reasonable Capacity of Spinning Reserve Units

Preservation of the reasonable capacity of spinning reserve units is necessary for the stable operation of power system, especially in an independent one like the Luzon Grid. In order to keep the frequency within the criteria against the random fluctuation of load, an appropriate allocation of the spinning reserve units should be considered. The improvement of the data base for the allocation and determination of the quantity of reserve capacity should be studied.



Generally, the frequency regulation against the load fluctuation is conducted as shown in above figure. That is, the relatively long periodic fluctuations of more than 10 minutes are foreseeable and can be regulated by economic dispatching control (EDC). Short periodic ones of less than a few minutes must be regulated by governor free operation. For intermediate periodic ones, the power plant in charge of AFC operation must be responsible for the regulation. In order to study these allocation and quantity for power plants, the analysis of load fluctuation also is required. At present, there are no big loads with short periodic fluctuation in Luzon Grid. However, because of the Luzon Grid being the independent system, in the case that a large capacity strip mill and such would be installed with the progress of industrialization, the thorough study will have to be made in advance.

b. Keeping the Rated Capacity of Power Plants

The rehabilitation of thermal power plants are projected to recover the available capacity up to the rated capacity. To shorten the maintenance period adding to the recovery of output of plants becomes necessary for the planning and preserving a reasonable reserve capacity which are necessary for the stable dispatching operation. For this purpose, to keep the skill in maintenance work is the most important matter. With the progress of automation in power plants, training of workers becomes more and more urgent one. Therefore, instead of depending only on in-house workforce, the study on bringing up the compaies specialized in power plant maintenance, control and protective relay system should be considered.

c. Study on the Reinforcement of Transmission System

In Luzon Grid, the capacity of power plants directly connected to 230 kV system reaches approximately 80% of total plants. Therefore, 230 kV transmission system around Metro Manila should have reasonable abundancy in the capacity so that the system can be stably operated regardless of the operating condition of power plants connected to 230 kV system. After the completion of the reinforcement of San Jose-Balintawak lines which is proposed as the immediate corrective measure, the section between Binan substation and Kalayaan power plant remains as a problem. The reinforcement of the section also should be studied.

d. Study on Abnormal Voltage Rise when a Long Distance Transmission Line is Charged by a Small Unit

When 2 circuits of Kalayaan-Gumaca section were tripped by a fault, abnormal voltage occurred in the system south of Gumaca, and lightning arresters were damaged by high system voltage. During the restorating operation of a total blackout fault, the bus voltage at Dolores and Balintawak substations rose up to more than 280 kV, causing the difficulties in the operation. Adding to the Ferranti Phenomenon, a self-excitation phenomenon of a small unit charging a long distance transmission line might be the causes.

At present, four shunt reactors of 15 MVar each are distributed on 69 kV side at Gumaca, Labo, Naga and Daraga substations, and two shunt reactors of the same capacity at Tiwi power plant. Total capacity is 90 MVar in the south system. Since the charging capacity of 230 kV transmission lines south of Kalayaan power plant is approximately 120 MVar, when this section is separated from main system, the exceeding charging capacity, 30 MVar, will be supplied by one unit of Tiwi power plant (55 MVA). To prevent the high voltage in the south system, there are two measures. One is to cut off Naga-Labo-Gumaca line at Naga substation (1st measure), and another is the relocation of shunt reactors (2nd measure). The 2nd measure contains the relocation of shunt reactors from Tiwi power plant to Gumaca and Naga substation, the study on the additional shunt reactors and the resonance voltage of line. Consequently, it will be better to take the 1st measure as a temporary step and then to study the 2nd measure. Regarding to other areas, the study of allocation of shunt reactors including the resonance phenomena should be put forward.

e. Study on the Reinforcement of Communication System

Microwave communication trunk circuits extending from north to south of Luzon island are scheduled in the immediate corrective measures. However, for the main power plants and substations, there are only two system available, the microwave of one circuit and PLC of one circuit. With the expansion of power system, from the viewpoint of system operation, the following microwave loop system for main power plants and substations should be studied.

. Head Office-San Jose-Mexico-Hermosa-PNPP-Head Office

. Head Office-Dolores-Kalayaan-Mt. Maunong-Head Office

f. Establishment of the Maintenance Organization

According to the results of survey for maintenance organization and the training for the operators and maintenance crew which will be executed in immediate corrective measures, the organization for maintenance, allocation of crew, standard for maintenance works and finance schedule for maintenance should be proposed.

g. Study and Planning for the Long Term Plan

The power system might become a reliable one with the execution of the immediate and medium term renovation plans until 1990. It is necessary to refrain from total blackout faults in future system expansion.

The methods of study and analysis for the establishment of stable power system and generating sources should be systematized and the renovation plans in Phase 2 should be designed.

CHAPTER 9

MEASURES TO BE TAKEN FOR SOLUTION OF PROBLEMS

Chapter 9. Measures to be Taken for Solution of Problems

9-1. Education and Training of NAPOCOR Employees

a. Organization of Education and Training

NAPOCOR values human resources as one of the most important assets and is concentrating its effort on human resources development. The organization responsible for education and training is the Human Resources Department, which includes the following four divisions for implementation of programs according to their requirements.

Management Development Division	(MDD)
Technical Development Division	(TDD)
Organization Development Service Division	(ODSD)
Learning Resource Service Division	(LRSD)

MDD provides training on management, TDD is charged with technical training, ODSD is responsible for education and training on organization and human relations and LRSD is responsible for administration of scholarship, planning of overseas training and study of literatures and training materials.

b. Status of Education and Training

In 1983, NAPOCOR implemented 20 MDD courses, 26 TDD courses and 13 ODSD courses, for a total of 59 training courses, with substantial achievements.

For technical training, 12 engineering training courses and 14 operations training courses were provided as shown in Table 9-1-1.

The technical development program of NAPOCOR shown in the table provides training on power plant operation, substation operation, mechanical maintenance and line maintenance.

A breakdown of NAPOCOR training program by nature is as follows.

Engineering Training

Training of newly hired personnel	- 3 courses
Training of supervisors and candidates for supervisors	- 3 courses
Training of Nuclear power related personnel	- 3 courses
Training on hydro power projects	- 2 courses
Training on civil works	- 1 course
Total:	12 courses

Operations Training

Training of newly hired personnel	- 3 courses
Special training on thermal power	- 5 courses
Training of substation operators	- 1 course
Training on maintenance	- 1 course
Training on line maintenance	- 1 course
Training on special subjects	- 3 courses
Total:	14 courses

These training courses are summarized in Appendix-3.

c. Problems of NAPOCOR Training Program

For technical training on power system related to the present renovation project, two courses are provided in the program.

One is basic training of personnel engaged in the work related to power system and the other is practical training on operation and maintenance of equipment and facilities of power

Table 9-1-1 Technical Development Programs

Item		No.	Course
Engineering Training	Newly Hired Personnel	1	Junior Engineers Program
	Power System	2	Advanced Power Systems Analysis
	Project	3	Basic Planning and Scheduling with CPM
		4	Project and Construction Management Course
		5	Abra River Basin Hydroelectric Development Project Training Program
		6	Echo-Seminar in Hydro Power Development
		7	Short Courses on Power Projects (Mechanical Design)
	Civil	8	Seminar-Workshop for the Civil Design Division Staff
	Nuclear Power Plant	9	Orientation on Nuclear Power
		10	Self-Study Technical Training Series on Nuclear Power Plant Operation
		11	Instrumentation and Control Engineers/Technicians Course
		12	Health Physics Course
Operations Training	Newly Hired Personnel	1	Basic Course on Thermal Power Plant Operation
		2	Hydroelectric Power Plant Operation
	Power Plant	3	On-Shift Refresher Course on Thermal Power Plant Operation
		4	Geothermal Power Plant Operation & Maintenance Course
		5	Diesel Power Plant Operation & Maintenance Course
		6	Instramentation & Control Training Course
	Substation	7	Substation Operation and Maintenance
	Power System	8	Electrical Maintenance Course
	Mechanical	9	Mechanical Maintenance Course
	Lineman	10	Basic Lineman's Course
		11	Hotline Maintenance Course
	Chemical	12	Chemical Technician's Course
		13	Corrosion and Pollution Course
	Welding	14	Basic Welding Course

system as shown in Table 9-1-1.

A review of the contents of these training courses shows that emphasis of training is placed mainly on the acquisition of basic knowledge of power system (including power system analysis) and knowledge of operation and maintenance of individual equipment and facilities.

As a training program, it seems to lack training courses on system operation for both normal time and emergency.

Training courses for practical aspects of system operation, including case study of switchgear operation simulating a wide-area system fault or training on protective devices are considered essential.

More specifically, the following are considered essential.

(1) Training on system fault handling restoration procedures using simulators for operators of load dispatching office and substations.

(2) Practical training on maintenance of protective devices and fault analysis.

Provision for fault recorders and sequence recorders required for training and fault analysis.

(3) Self-study on mechanical maintenance and line maintenance by line patrolling and other means.

(4) Intensive technical training on the operation of control circuits.

(5) Training of senior technical personnel.

9-2. Maintenance

a. Organizations and Responsibilities for Maintenance

The outline of maintenance related organizations of NAPOCOR is shown in Fig. 3-1. The structure of local organizations differ from place to place. The maintenance related organizations for the Luzon Grid are:

Head office : Quality Assurance Group located in the Utility Operation

Local offices: Metro Manila Regional Center (MMRC)
(For maintenance of thermal power plants)
Northern Luzon Regional Center (NLRC)
(For maintenance of north hydro power plant)
(For maintenance of transmission lines and substations in northern Luzon and western Metro Manila)
Southern Luzon Regional Center (SLRC)
(For maintenance of south hydro power plants)
(For maintenance of geothermal power plants)
(For maintenance of transmission lines and substations in southern Luzon and eastern Metro Manila)

As seen from the above, maintenance of hydro power plants, transmission lines and substations of the Luzon Grid is shared by NLRC and SLRC with luzon divided into two parts, north and south.

b. Maintenance of Thermal Power Plants

The present JICA study team conducted a study of the "Luzon Transmission Grid" as part of its effort in working out a plant renovation program for the Philippines.

For thermal power plants, which account for a major portion of maintenance-related investment of NAPOCOR, the first survey for the plant renovation program has already been conducted and subsequent studies have also been made for a more detailed rehabilitation program.

The efficient management and maintenance of facilities of an enterprise can be realized only upon long-term and organic function of such elements as the policy, organization, manpower resources and financial resources of the enterprise.

The main points, which are said to show the actual state of maintenance of thermal power plants in the Philippine (Luzon Grid), may be summarized as follows.

(1) In many cases, there is a considerable delay in the progress of shut down maintenance. One of the reasons for this delay is said to be the fact that the chief operator on duty, who is not involved in maintenance work normally, takes full charge of supervision of several hundred workers including sub-contractors.

(2) There is a shortage of experienced technical personnel in the case of thermal power plants, in particular, the drain of experienced technicians to overseas is said to be frequent in the past.

(3) While there are a sufficient number of field workers such as machinists, welders and painters who have been working

in the power plants for a long time, there is a shortage of experienced skilled technicians for overall supervision of these workers, and the result is poor coordination of the work as a whole.

(4) Technical level of the workers for the work requiring a high technical level such as welding of high voltage parts is not adequate.

(5) In the management of material procurement, there are frequent cases of long delivery date, incorrect specifications and ambiguity in ledger control.

(6) Custody of drawings and data used for construction work is not adequate.

(7) Investment in maintenance is extremely small.

	NAPOCOR				"K" company in Japan
	Fund for maint.	Energy generated by thermal power plant (GWh)	Unit cost of maint. ₱/kWh	¥kWh	¥/kWh
1980	40.8	7,798	0.0052	0.156	0.78
1981	60.8	7,768	0.0078	0.234	1.31
1982	151.3	-	-	-	1.50

(8) In relation to the above, improvement of technical level of maintenance contractors should be considered as a future question. For maintenance of thermal power plants, two firms and one public organization (MIRDC) rate under contract with NAPOCOR for providing laborers and for materials test, respectively.

c. Maintenance of Hydro Power Plants, Transmission Lines and Substations

The operating expense (including maintenance cost, depreciation expense and personnel expense) of transmission lines and substations of NAPOCOR's entire power system in 1982 amounts to approx. 215.2 million Pesos (3,400 million Yen) as shown in Table 9-2-1, accounting for about 2.5% of the operating revenue. In the case of "K" utility company in Japan, the operating expense for transmission lines and substations in the same year amounts to 74.8 billion Yen, accounting for about 7.2% of the operating revenue as shown in the same table. The operating expense of NAPOCOR, therefore, is about 4.5% and 35% of that of "K" utility company in Japan in terms of absolute value and in the ratio to operating revenue, respectively.

Since the personnel expense has a major share in the operating expense, a calculation was made to determine the ratio of operating expense of NAPOCOR to that of "K" company with the percentage of personnel expense of NAPOCOR (1/8 to 1/10 of that of "K" company) taken into consideration. The result shows that the operating expense of NAPOCOR is about 26% of that of "K" utility company as detailed below.

	Percentage of Personnel expense (%)	Percentage of Maintenance cost and dep. expense (%)	Total (%)
"K" company	85	15	100
NAPOCOR (Assumed to be 1/8 of "K" company in personnel expense)	11	15	26

Table 9-2-1 Comparison of Operating Expenses

Between NAPOCOR & "K" Co. (Japan)

Item	NAPOCOR(A) (M*P)	Equi.Yen (B*Y)	(incl.Depreciation) (M*P)	Equi.Yen (B*Y)	K Co.(B) (B*Y)	Remark
Net operating revenue	9628.8	134.8	9628.8	134.8	1044.2	Ex.Rate;P1=Y14
Operating expenses						
Generation	6879.7	96.3	7757.0	108.6	555.6	
Transmissilon & Distribution	215.5	3.0	243.0	3.4	74.8	T/L & S/S
Distribution line(K Co. only)	0.0	0.0	0.0	0.0	98.9	D/L
Selling expenses	0.0	0.0	0.0	0.0	33.6	
General & Administration	111.3	1.6	125.5	1.8	59.6	
Sub-Total(a)	7206.5	100.9	8125.5	113.8	822.5	
Special tax	0.0	0.0	0.0	0.0	30.0	
Depreciation	795.3	11.1	0.0	0.0	0.0	
Depletion	123.7	1.7	0.0	0.0	0.0	
Provision for Doubtful acc't	4.4	0.1	4.4	0.1	0.0	
Lease cost	12.8	0.2	12.8	0.2	0.0	
Total(b)	8142.7	114.0	8142.7	114.0	852.5	
Trans. & Dist./Sub-Total(a) (%)	2.99			2.99	9.09	
Trans. & Dist./Total(b) (%)	2.65			2.98	8.77	
Trans. & Dist./Ope. revenue	2.24			2.52	7.16	
Transmission line length	(km)A	A/B(%)			(km)B	
500kv	0				269	
230kv	3164				3510	incl.220Kv
138kv	2067				2441	incl.115KV,110KV
69kv	4396				6473	
Total	9627	75.8			12693	
Substation capacity (MVA)	10842	30.9			35070	

While it is not appropriate to generalize that the maintenance cost of NAPOCOR is inadequate in view of the above result, it can safely be said that the amount is very small. For reference, the transmission line length and total substation capacity of NAPOCOR are 75.8% and 30.9%, respectively, of those of "K" company and there is not so big a difference in the scale of operating facilities between the two utilities.

In the course of field study, the following opinions were heard frequently from the heads of field offices (Technical Service Station and Provincial Offices, for example).

(1) Extremely long delivery date.

(2) There is a shortage of materials, measuring instruments and tools for replacement and maintenance work.

(3) Vehicles used for maintenance work are becoming obsolete and are not appropriate in specification (Especially vehicles for maintenance of transmission lines).

(4) There is a shortage of engineers for overall supervision, planning and management of specialty field in regional (local) offices (no engineers assigned to transmission lines at present).

These opinions are almost similar to those from personnel at thermal power plants mentioned in the proceeding paragraph and can be said to indicate a chronic shortage of technical personnel, equipment and materials for maintenance work and the fund. In the case of Japanese utility companies, maintenance of turbines and generators of hydro power plants is all done by outside contractors and maintenance of circuit breakers and protective relays for the transmission system is also done by outside contractor (GCB is by the manufacturer).

Hence, the development and fostering of supporting technical firms so that they can provide efficient maintenance work is an important question for the future, as in the case of maintenance contractors for thermal power plants, with the progress and sophistication of technology.

d. Summary

Since the question of maintenance involves the entire organization of an enterprise as mentioned previously, it is important that the problem is tackled by the concerted effort of the organization with the attitude toward constant improvement through the following.

(1) Review of the organizational structure for efficient operation and management.

(2) Establishment of maintenance standards, policies, etc.

(3) Improvement of material procurement method through standardization of design and specifications and quality control.

(4) Securing constantly sufficient funds for maintenance.

(5) Development of personnel

(6) Fostering supporting technical firms.

While the current renovation program is expected to eliminate most of the sources of major system failures, the success or failure of long-term reliability and improvement of power supply are largely dependent on the effort of NAPOCOR in achieving various measures recommended.

9-3. Load Dispatching Operations

a. Problems Revealed by Analysis of Power System

The problem of load dispatching operations which have become evident as a result of system analysis with computer are as follows.

(1) System Operation of the San Jose-Balintawak Line

As mentioned previously, there is a heavy power flow in the San Jose-Balintawak line especially in wet season. Moreover, a fault in this transmission line (a fault even in one circuit) makes the restoration effort by system switching more difficult because of relative weakness of the 115 kV transmission lines around San Jose and Balintawak substations.

For this reason, it is essential to make a thorough study of the measures for system operation including both 230 kV and 115 kV systems in the event of a fault in the 115 kV San Jose-Balintawak line as a provisional step until the planned expansion of the system is materialized.

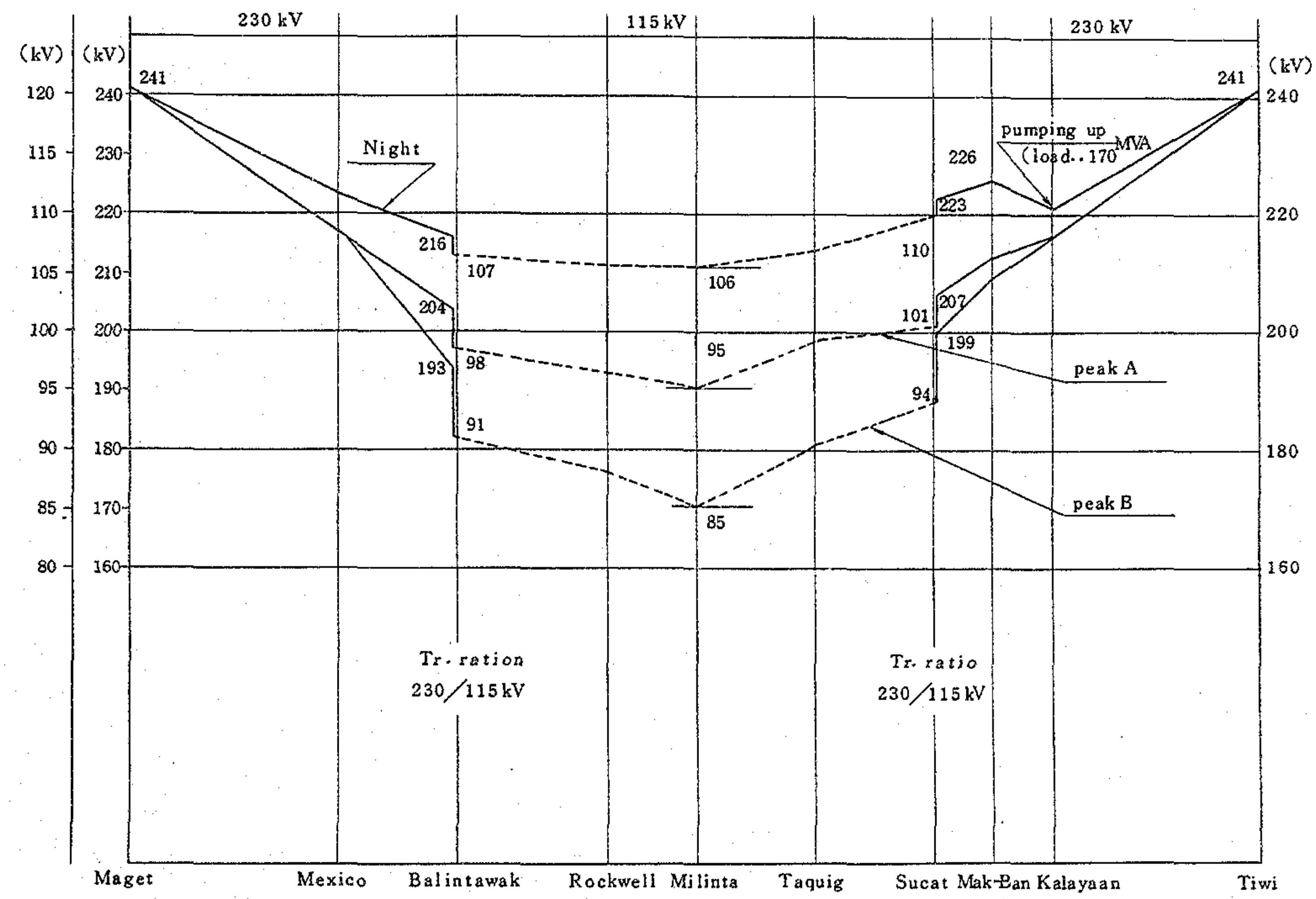
(2) Systematic Voltage Operation

At present, the voltage operation of the Luzon Grid is effected through Var adjustment by generators and the operation of static condensers of transmission lines and substations of less than 34.5 kV through remote control from LDC. Accordingly, the difference of bus voltage on 115 kV side of 115/34.5 kV substations between day and night in 1987 will amount to about 11 kV (10%) as shown in Fig. 9-3-1. While the voltage gradient shown in Fig. 9-3-1 is the result of calculation made on the condition

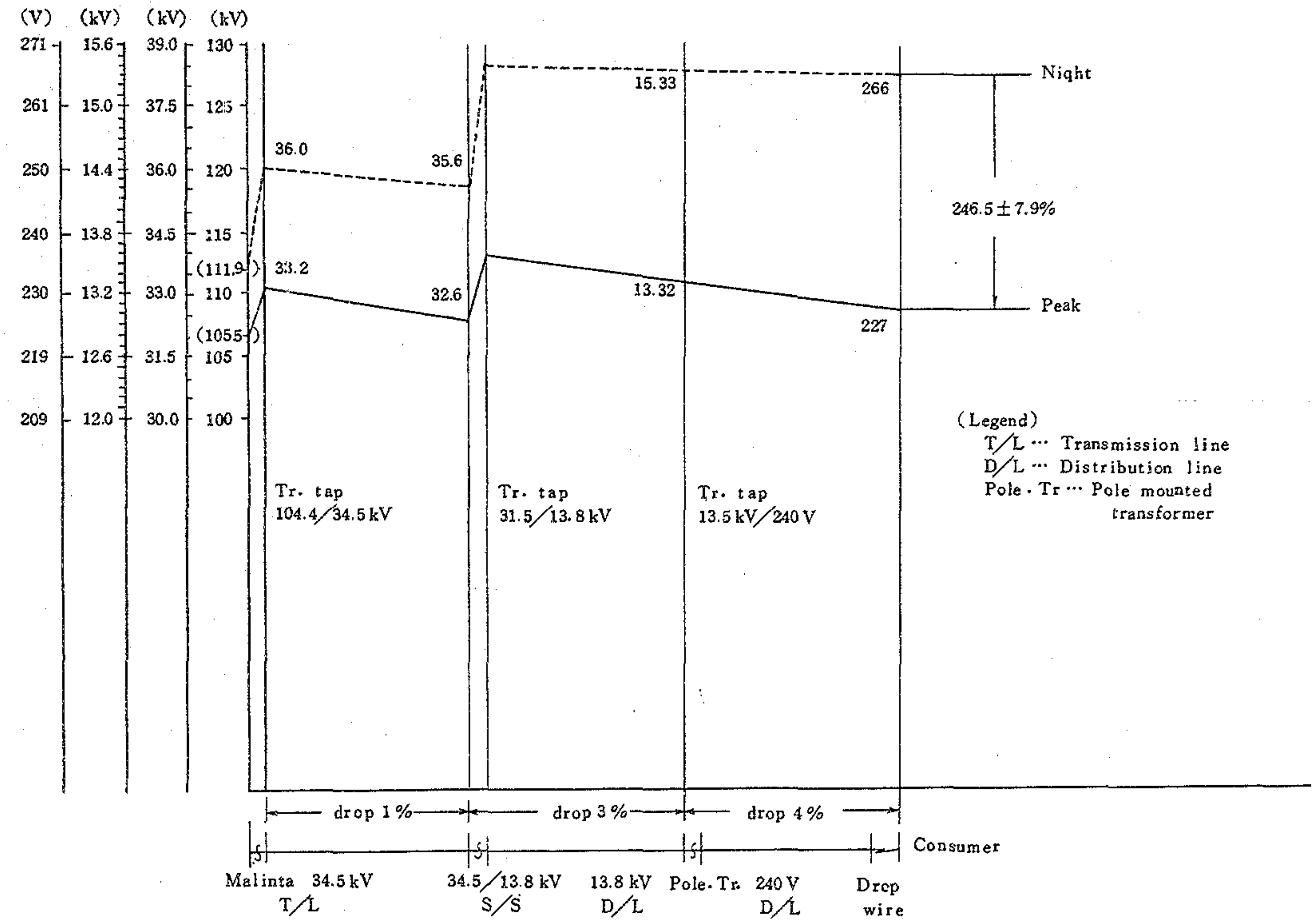
1987

Fig 9-3-1 (A) 230 & 115kV Power system Voltage requlation (Calculation result)

(Legend) Case···wet, PNPP in
Peak A ··· VAR source(temporary) to Malinta, Rockwell, Taguig (30MVA)(40MVA)(30MVA)
Peak B ··· VAR source none



(B) 34.5kV T/L, 13.8kV D/L, 240V D/L Voltage regulation



that the bus voltage of 230 kV system at Magat and Kalayaan power plant is adjusted to the same value between day and night and that the static condensers in Metro Manila are maintained in the present state, the voltage fluctuation at consumers between day and night is considered to be very great.

At present, on-load tap changers (OLTC) are not in use at the 230/115 kV substations of NAPOCOR (sometimes, transformers recently installed are not equipped). When the increase of load and the increase of social demand for better quality of power supply in the future is taken into account, it will be essential to plan an appropriate voltage control measure integrating the systems of NAPOCOR and MERALCO.

(3) Voltage Problems at Hermosa Substations and Surrounding Substations

Since there are many complaints about voltage from the customers around Olongapo substation system ever before the commissioning of PNPP, the following operating pattern is adopted by NAPOCOR as a measure against the trippings of large power plants such as PNPP and Magat power plant and as a voltage measure for the system around Hermosa substation following the commissioning of PNPP.

PNPP....................Constant generation of 500 MW
(Rated capacity: 620 MW)

Bataan, 150 MW unit.....Constant operation

However, the constant operation of Bataan power plant is questionable both economically and operationally from the following reason, and it would be more advantageous to install additional static condensers at Hermosa (or Mexico) substation as a voltage measure.

1) Instead of operating generator No. 2 of Bataan power plant as a spinning reserve against PNPP (500 MW) or Magat (360 MW), operation of generator No. 4 of Sucat or generators No. 1 and No. 2 of Manila is more appropriate from economical and operational points of view.

2) As a voltage measure against the suspension of tripping of PNPP, installation of static condensers directly at Hermosa substation (or Mexico substation) is more effective.

b. Problems Related to Restoration Efforts

As a reason for requiring an extremely long time for system restoration following the fault of September 24, 1984, a problem of voltage rise can be pointed out.

The restoration effort was made according to SOP, but the feeding of transmission lines in sequence by Kalayaan hydro power plant and receiving from north hydro power plants were greatly hampered by voltage rise as mentioned previously.

(1) Present System Restoration Procedure

The essence of the system operation procedure (SOP) practiced by NAPOCOR and MERALCO at present is as follows.

1) Operating Procedure in the Event of Total System Failure

i. Operating procedure for NAPOCOR system

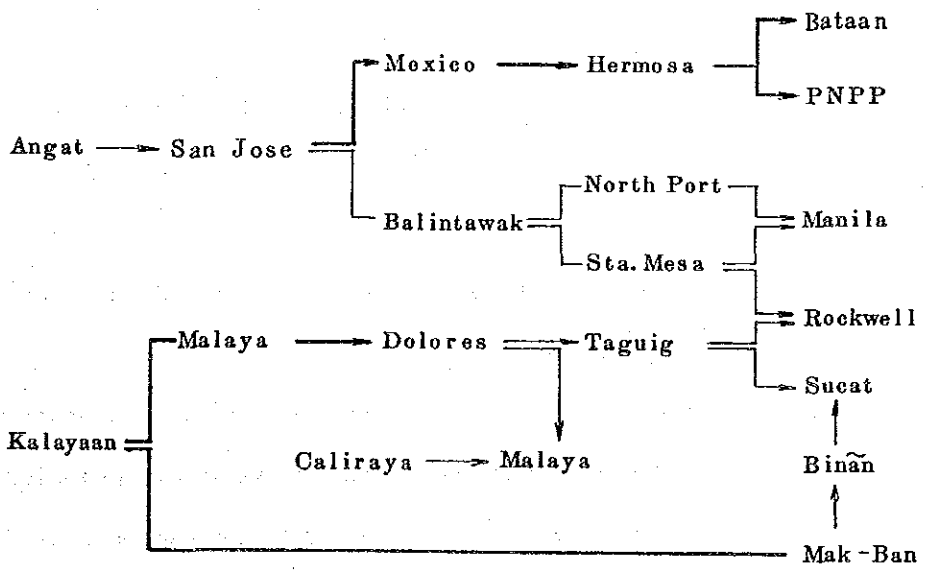
In the event of a total system failure of the Luzon Grid, NAPOCOR's operating procedure required separate restoration of the northern system and the central and southern system independent of each other and then restoration of the whole system. The outline of the procedure is as follows.

i) Northern system

Ambukulao, Magat and Binga hydro power plants (north of Binga) will be put into parallel operation one by one.

ii) Central and southern system

Power plants in Metro Manila and the surrounding area will be started with Angat and Kalayaan hydro power plants used as starting power sources. The operating sequence is as shown below.



iii) Parallel operation of northern system and central and southern system

Northern system and central and southern system will be put into parallel operation.

iv) Loop operation of 230 kV Malaya-San Jose-Dolores line

v) Restoration of MERALCO system

vi) Restoration of load

ii. Operating procedure for MERALCO system

MERALCO has a detailed operating procedure for the following six cases of system failures.

i) Case I-A.....All power plants out, starting power from north hydro power plant(s).

ii) Case II-B....All power plants out, starting power from south hydro power plant(s).

iii) Case III.....All power plants out except Rockwell P/S

iv) Case IV......All power plants out except Manila P/S

v) Case V.......All power plants out except Sucat P/S

vi) Case VI......All power plants out except Malaya P/S

(Refer to Appendix-3. NAPOCOR and MERALCO System Operating Procedures)

(2) Problems of Present System Restoration Procedure

1) With the present system restoration procedure, authority is concentrated on PMC and each substation merely carries out what is said in the SOP without knowing

what is happening to the power system. And of course, there is no single line diagram or Mimic Board provided at each substation. (Moreover, the relay station has a strong nature of a mere messenger station.) System operation of the Luzon Grid is becoming more and more complicated because of the following development.

i. System capacity has increased (Approx. 2,500 MW).

ii. Large power plants have been commissioned one after another (PNPP, Magat, Calaca).

iii. 230 kV transmission system has been expanded and reinforced and such system compositions as loop circuit and multiple-circuit parallel system are increasing in number.

iv. The 115 kV system in Metro Manila is becoming more and more a meshwork.

With the present setup of PMC with three operators on duty and existing communication lines linked to each substation, it will be extremely difficult to respond quickly to any emergency. Of course, there is an arrangement for reinforcement of staff by additional personnel from NAPOCOR and liaison personnel from MERALCO in case of emergency, but efficient load dispatching operation is questionable because of incompleteness of communication facilities and inadequate daily training of operators.

Operators should be given repeatedly daily training with such training aids as simulators so that they can quickly respond to various types of emergency.

2) The system restoration procedure (Fig. 9-3-2) specified in SOP requires "each substation to start feeding the lines (only one circuit in case of two-circuit line) one by one upon receipt of power and wait for instructions to feed the line to the load". Accordingly, when Kalayaan power plant feeds the 230 kV lines one by one to secure station power to steam power plants, it is a rule that PMC gropes the situation and gives instructions to Dolores substation, LDC and others to put a load (about one-fourth of 150 MW) compatible to the output of Kalayaan power plant. However, in case no instructions are given by PMC or contact cannot be made with Dolores substation and LDC, such a procedure as allowing Kalayaan power plant to put some load voluntarily as a first step should be considered.

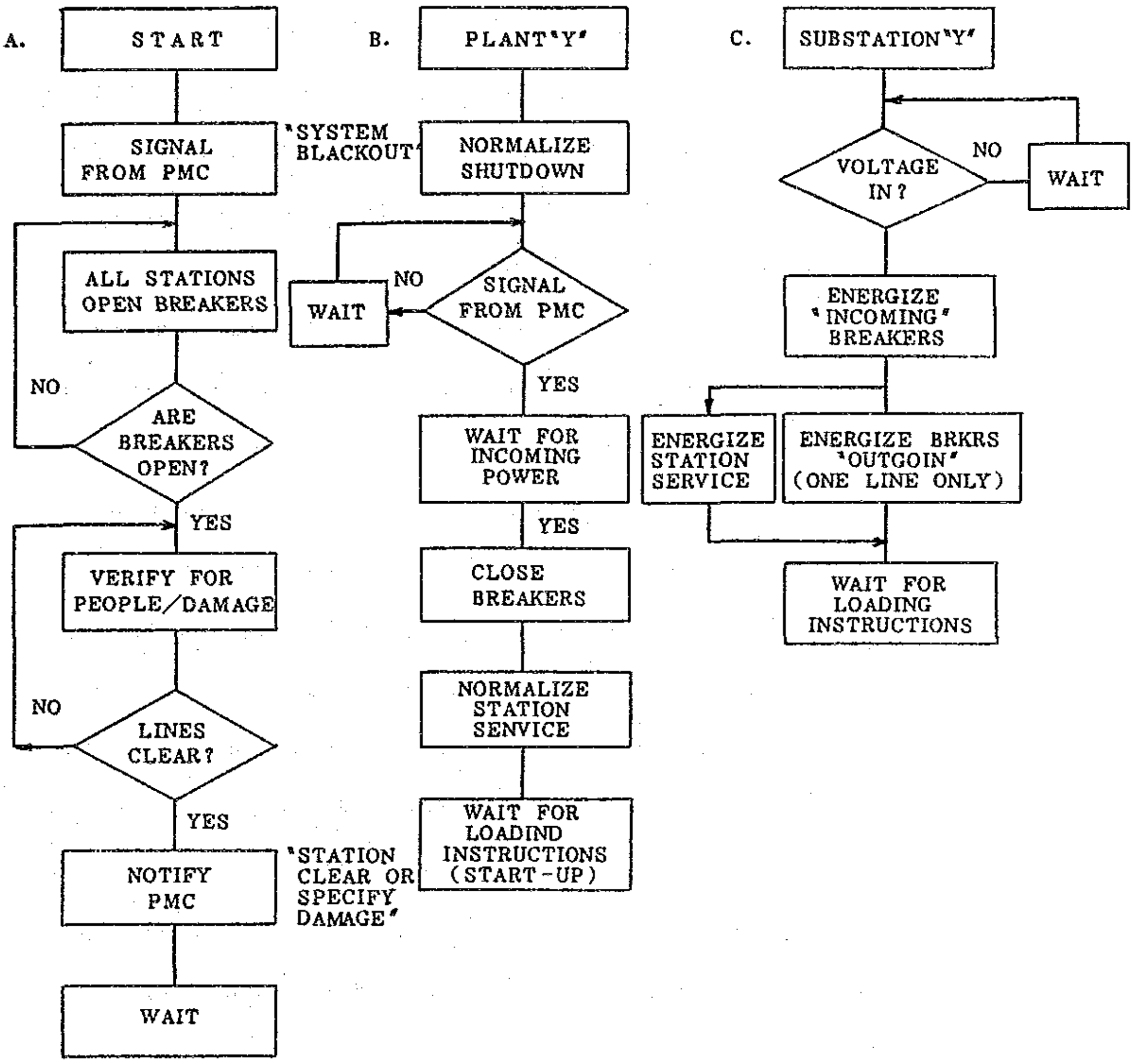
   Even though the implementation of this procedure involves reinforcement of load dispatching facilities including installation of communication lines and system boards mainly at key substations and improvement of load dispatching organization, it should be reviewed and evaluated at the earliest opportunity.

c. Problems of Load Dispatching Facilities

PMC is already equipped with Supervisory Control and Data Acquisition (SCADA) system as an automatic

Fig. 9-3-2 Blackout Operation (Flow Diagram)

(From NAPOCOR SOP)



load dispatching system, but the system is still in the stage of adjustment and is not functioning adequately. PMC is constantly staffed by three operators. Under the situation where the SCADA system is not fully functioning, it would be extremely difficult for the three operators on duty at MPC to carry out efficiently such jobs as adjustment of demand-supply balance, system operation, data collection and recording and preliminary study of restoration procedures for assumed system failures.

NAPOCOR, therefore, should make further efforts to put the SCADA system in full operation as early as possible. The proper functioning of the SCADA system will free the operators on duty at PMC from daily routine and will provide them an opportunity to study in advance the system restoration procedures for assumed system failures for themselves.

For this purpose, improvement of software for system operation and addition of such hardware as remote terminal unit (RTU) may be required but a systematic study of the problem involving the entire load dispatching organization is considered essential.

9-4. PI Connection of Two-Circuit 230 kV Line at Bayombong Substation

a. General

Bayombong substation is a 230 kV substation located between Ambuklao power plant in North Luzon and Santiago substation and is operated at present with one circuit PI of 230 kV

Ambuklao-Santiago line. Another circuit (No. 1 line) passes through the substation considering for future connection. However, connection of No. 1 line is considered essential for stability of power system in North Luzon. For this purpose, switchgears required for connection of one circuit will be installed and necessary works will be provided for PI connection of two circuits of 230 kV line.

A proposed plan of Bayombong substation with a single line diagram is shown in Fig. 9-4-1.

b. Specifications of Main Equipment

Specifications of main equipment to be installed are as follows in accordance with existing NAPOCR standards and specifications of existing equipment.

However, the Puffer-type gas circuit breaker with built-in bushing current transformer (CT) will be employed instead of existing porcelain-clad gas circuit breaker (with separate CT) in view of present state of NAPOCOR facilities and for economic reason. Specifications for insulation of 230 kV insulators and bus bars are the same as before and HAL (hard drawn aluminum stranded conductor) 850 mm^2 will be used for station bus bars for compatibility with existing facilities.

(1) 230 kV Gas Circuit Breaker, Outdoor Use, Puffer-Type with Built-In Bushing Current Transformer : 3 units

Rated Voltage	:	230 kV
Max. Design Voltage	:	242 kV
Rated Current	:	1,200 A
Rated Interrupting Capacity	:	25 kA

Rated Interrupting Time	:	3 cycles
B.C.T.	:	600-1,200/5 A

(2) 230 kV Disconnecting Switch, Outdoor Use,

Horizontal Double-Break Type	:	6 units
Rated Voltage	:	230 kV
Rated Current	:	1,200 A
Rated Short Time Current	:	25 kA

(3) Lightning Arrester, Outdoor Use,

Gapless Type	:	6 units
Rated Voltage	:	210 kV
Nominal Discharge Current	:	10 kA

(4) Capacitance Potential Device, Outdoor Use,

Single-Phase	:	6 units
Rated Voltage		
Primary	:	$230/\sqrt{3}$ kV
Secondary	:	$115/\sqrt{3}$ V
Tertiary	:	115 V
Rated Burden	:	500/100 VA

(5) Line Traps for Power Line Carrier System

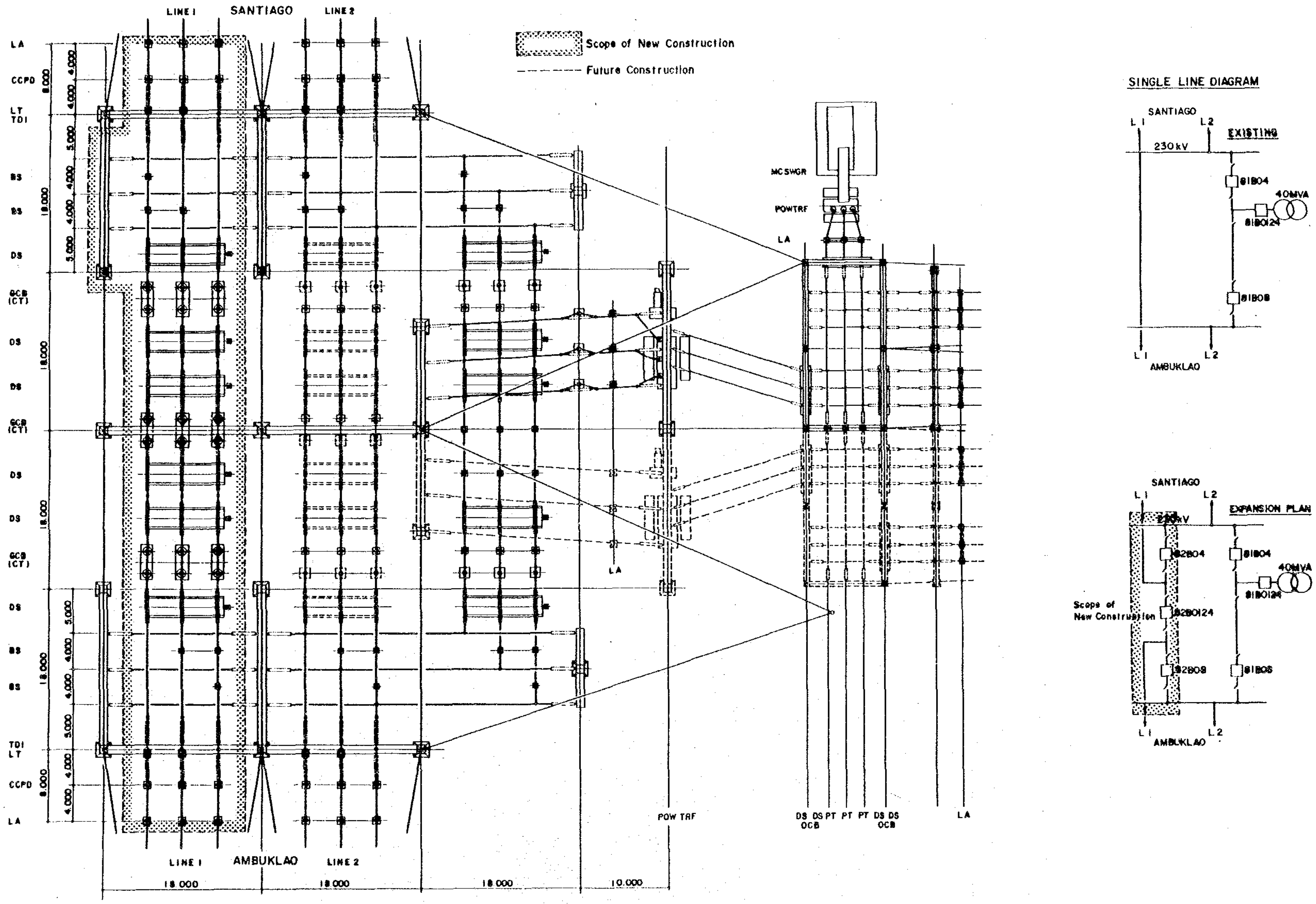
with Turning Device and Arrester	:	4 units
Rated Current	:	1,200 A
Rated Short Time Current	:	25 kA
Inductance	:	300 μH

(6) Other Equipment

1) Outdoor Steel Structure and 230 kV Bus Support.

2) 230 kV Conductor (HAL, 850 mm^2) and Control Cable (Cross-linked polyethylene insulated cable), etc.

Fig. 9-4-1 MACHINERY ARRANGEMENT PLAN OF THE BAYOMBONG SUBSTATION
(Transmission Line Two Circuits PI Connections)



3) 230 kV Insulating Device.

Suspension insulators and Station post insulators, etc.

4) Instrument for Switch Board.

Meters, Control switches and Signal lamps, etc.

9-5. Construction of outgoing Lines for Two-Circuits 230 kV Balintawak Line and Replacement of Existing 230 kV Oil Circuit Breakers at San Jose Substation

a. General

As discussed previously in Chapter-6, the San Jose-Balintawak section is expected to become a heavy load line following the commissioning of PNPP nuclear power plant. For this reason, it is essential to construct two circuits of 230 kV transmission lines in this section and provide associated 230 kV outgoing lines at San Jose substation.

At San Jose substation, which occupies an important position as a power supply base for Metro Manila, there are four oil circuit breakers in addition to eight 230 kV gas circuit breakers.

To ensure the reliability of power supply and further improve the stability of transmission system with the employment of high speed reclosing system for circuit breakers in the future, these four oil circuit breakers must be replaced with more efficient gas circuit breakers.

The scope of work required and single line diagram of San Jose substation are shown in Fig. 9-5-1.

b. Specifications of Main Equipment

Specifications of main equipment are as follows in accordance with NAPOCOR standards and specifications of existing equipment.

(1) 230 kV Gas Circuit Breaker, Outdoor Use, Puffer-Type with Built-In Bushing Current Transformer : 7 units

Rated Voltage	: 230 kV
Max. Design Voltage	: 242 kV
Rated Current	: 2,000 A
Rated Interrupting Capacity	: 25 kA
Rated Interrupting Time	: 3 cycles
B.C.T.	: 1,000-2,000/5A

(2) 230 kV Disconnecting Switch, Outdoor Use, Horizontal Double-Break Type : 6 units

Rated Voltage	: 230 kV
Rated Current	: 2,000 A
Rated Short Time Current	: 25 kA

(3) Lightning Arrester, Outdoor Use, Gapless Type : 6 units

Rated Voltage	: 210 kV
Nominal Discharge Current	: 10 kA

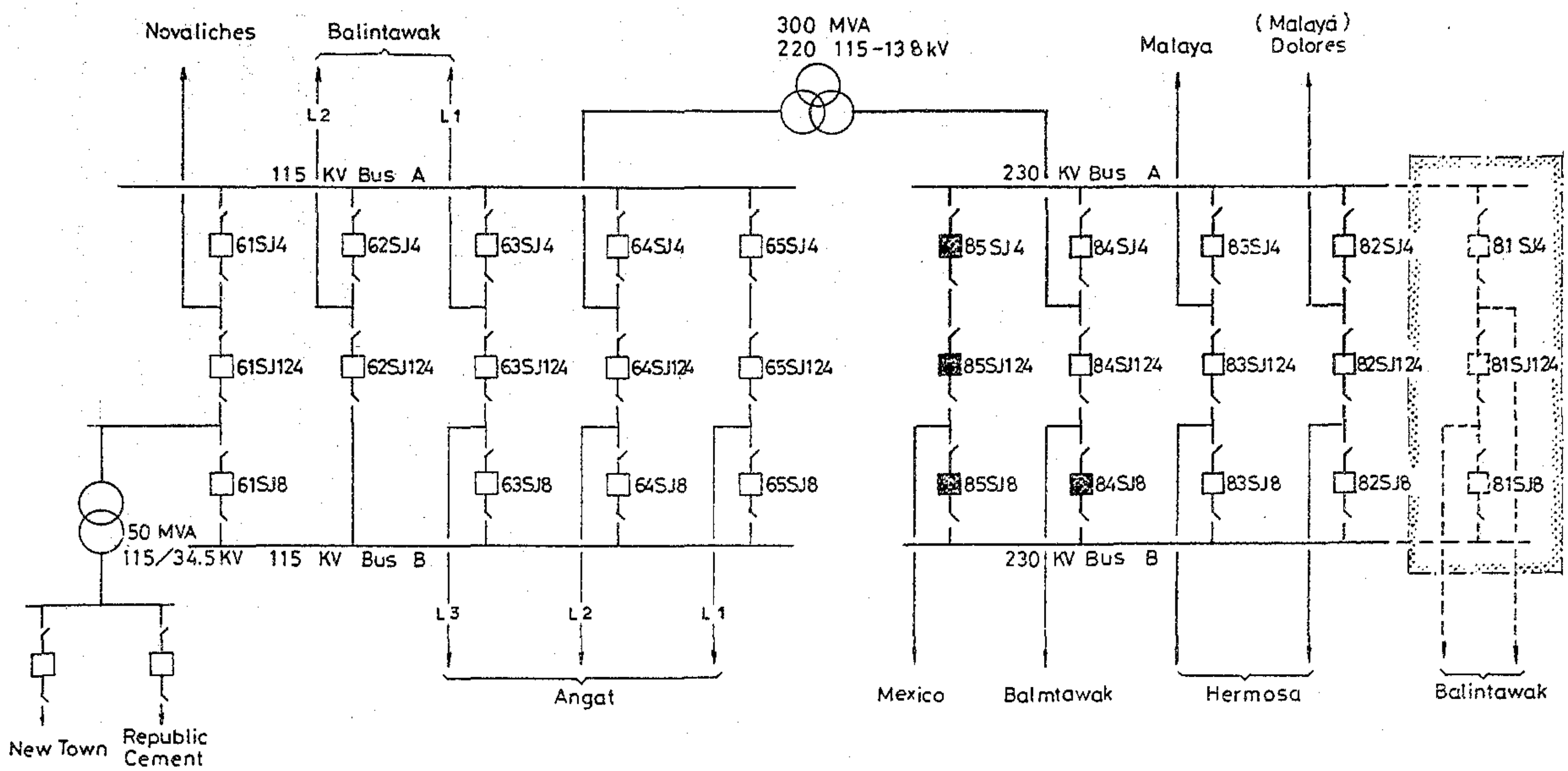
(4) Capacitance Potential Device, Outdoor Use, Single-Phase : 6 units

Rated Voltage	
Primary	: $230/\sqrt{3}$ kV
Secondary	: $115/\sqrt{3}$ V
Tertiary	: 115 V

Fig. 9-5-1 Single Line Diagram of SUN JOSE Substation

Note : ▩ Replacement of 230 kV Circuit Breakers ..... 4 Units.

Scope of New Construction for The 230 KV Balintawak Line.



Rated Burden	:	500/100 VA

(5) Line Traps for power line Carrier System

with Tuning Device and Arrester	:	4 units
Rated Current	:	2,000 A
Rated Short Time Current	:	25 kA
Inductance	:	300 μH

(6) Other Equipment

1) Outdoor Steel Structure and 230 kV Bus Support.

2) 230 kV Conductor and Control Cable (Cross-linked polyethylene insulated cable), etc.

3) 230 kV Insulating Device.

Suspension insulators and Station post insulators, etc.

4) Instrument for Switch Board.

Meters, Control switches and Signal lamps, etc.

9-6. Construction of a New 230 kV San Jose-Balintawak Line

a. Requirement for reinforcement of 230 kV Transmission Lines in the San Jose-Balintawak section

The 230 kV Balintawak substation (MERALCO) located in the east of Metro Manila and equipped with two banks of 300 MVA transformers for a total capacity of 600 MVA is a power supply base for Eastern Metro Manila. This substation is fed by one-circuit 230 kV line (795 MCM, ACSR single conductor, transmission capacity of 300 MVA) from Mexico substation and by one-circuit 230 kV line (795 MCM single conductor, transmission capacity of 300 MVA) and two-circuits 115 kV lines (795 MCM ACSR single-conductor, transmission capacity of 175 MVA) from

San Jose substation.

Power supply to the load is by direct distribution lines and by four circuits of 115 kV transmission lines for Malinta, North port, Santa Mesa and Novoriches.

The route of inflow to Balintawak substation at the time of major system failures in March 1984 was as shown below.

Mexico-Balintawak	230 kV line,	97 MW
San Jose-Balintawak	230 kV line,	169 MW
San Jose-Balintawak	115 kV line,	208 MW
	Total	474 MW

The primary cause of the total system failure was a fault in one circuit of 230 kV line, which induced an over current and voltage drop of other circuits in cascade thereby tripping all other circuits.

Scheduled changes in power flow to Balintawak substation with the anticipated increase of load in Metro Manila following the commissioning of PNPP are shown in Table 9-6-1.

Table 9-6-1 Relation between Inflow from North and Receiving Power at Balintawak SS

No. of Case	S.J. Inflow	Mex. Inflow	Kal., Mal. Generation	Mak-Ban Generation	Sucat, Manila Generation	Balinta Tr. Inflow	S.J. -Bal. 115 kV	TOTAL
Case 1	406	391	286	279	0	410	271	681
Case 2	353	245	519	279	0	370	267	637
Case 3	303	99	717	279	0	328	262	590
Case 4	85	102	916	279	0	310	250	560

The relation between inflow from output of northern power plants and PNPP and receiving power at Balintawak substation by 230 kV and 115 kV lines is shown in Fig. 9-6-1. When the inflow from north and PNPP exceeds 500 MW, the receiving power at Balintawak substation exceeds 600 MW. This means that there is a high probability that fault in one circuit causes an over power flow in other circuits.

Fig. 9-6-1 Relation between Inflow from North and Receiving Power at Balintawak SS

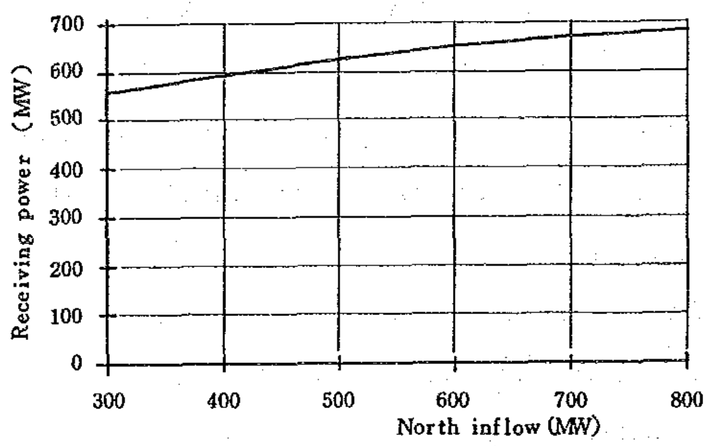
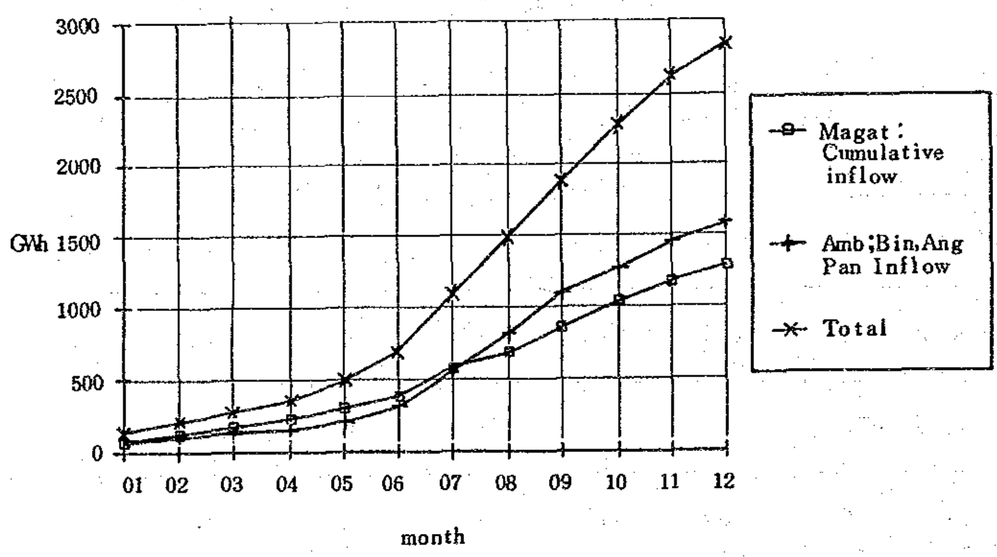


Fig. 9-6-2 Cumulative Inflow



When the operation of water stored in reservoirs is taken into account, the available output of Magat, Ambukulao and other hydro power plants is as shown in Table 9-6-2 and Table 9-6-3, and these hydro power plants can be operated at 700 MW or over out of their total capacity of 835 MW during evening peak hours even in dry season.

Assuming that the operating rate of PNPP nuclear power plant is 70%, the total inflow from north and PNPP at peak hours exceeds 600 MW in 70% of a year. In other words, the receiving power of more than 600 MW at Balintawak substation accounts for more than 70% of peak hours during the year.

To prevent a cascade tripping of transmission lines feeding into Balintawak substation by a fault in one circuit when there is a heavy load, reinforcement of transmission line in this section is considered essential.

For this purpose, two-circuits 795 MCM double-conductors 230 kV San Jose-Balintawak line should be constructed and the existing two-circuits 115 kV San Jose-Balintawak line will be removed.

Reasons: Land acquisition is difficult to provide a new transmission route up to 8 km from the lead-in point of Balintawak substation. There is no alternative but to construct a new transmission line utilizing the land occupied by existing 115 kV transmission line.

Table 9-6-2 Capability of Totalized Effective Reserve Power of Ambukulao, Binga, Pantabangan and Angat on Average Inflow Year

(Total generating capacity

Total effective reserve capacity 330 GWh)

Month	Inflow (GWh)	Save (−) Use (+) (GWh)	Total Use (A) (GWh)	Duration (B) (hour) (A)/475	(B)/230h	Max. Output in Peak time (MW)
Jan.	60	+ 40	100	210	0.91	430
Feb.	35	+ 65	100	210	0.91	430
Mar.	35	+ 70	105	221	0.96	456
Apr.	20	+ 85	105	221	0.96	456
May	55	+ 55	110	230	1.0	475
June	105	+ 15	120	252	1.09	475
Jul.	220	− 55	165	347	1.51	475
Aug.	275	−110	165	347	1.51	475
Sept.	205	− 40	165	347	1.51	475
Oct.	250	− 90	160	337	1.46	475
Nov.	195	− 35	160	337	1.46	475
Dec	115	0	115	242	1.05	475

Table 9-6-3 Capability of Effective Reserve Power of Magat on Average Inflow Year

(Generating capacity 360 MW

Effective reserve capacity 70 GWh)

Month	Inflow (GWh)	Save (−) Use (+) (GWh)	Total Use (A) (GWh)	Duration (B) (hour) (A)／36	(B)／230	Max. Output in peak time (MW)
Jan.	80	0	80	222	0.96	345
Feb.	40	+20	60	166	0.72	260
Mar.	40	+20	60	166	0.72	260
Apr.	60	+20	80	222	0.96	345
May	60	+20	80	222	0.96	345
June	90	0	90	250	1.08	360
Jul.	190	−50	140	389	1.69	360
Aug.	100	+30	130	361	1.57	360
Sept.	200	−50	150	415	1.80	360
Oct.	150	0	150	415	1.80	360
Nov.	130	0	130	361	1.57	360
Dec.	110	0	110	305	1.32	360

b. Outline of Specifications

(1) Weather Conditions of Transmission Lines:

Ambient temperature	:	Max. 45°C
Wind velocity	:	Max. 40 m/sec.
Protection from salt damage	:	Not considered

(2) Transmission Line

Section	:	San Jose S/S - Balintawak S/S
Voltage	:	230 kV
Distance	:	23 km
Standard span	:	300 m
Conductor	:	ACSR - 795 MCM x 2 (Two circuits)
Aerial ground wire	:	IACSR - 97 mmϕ - 2 stands
Buried ground wire	:	SW - 55 mmϕ, 25 m x 4 stands/tower
Insulator	:	250 mmϕ - 16/string

(3) Steel Tower

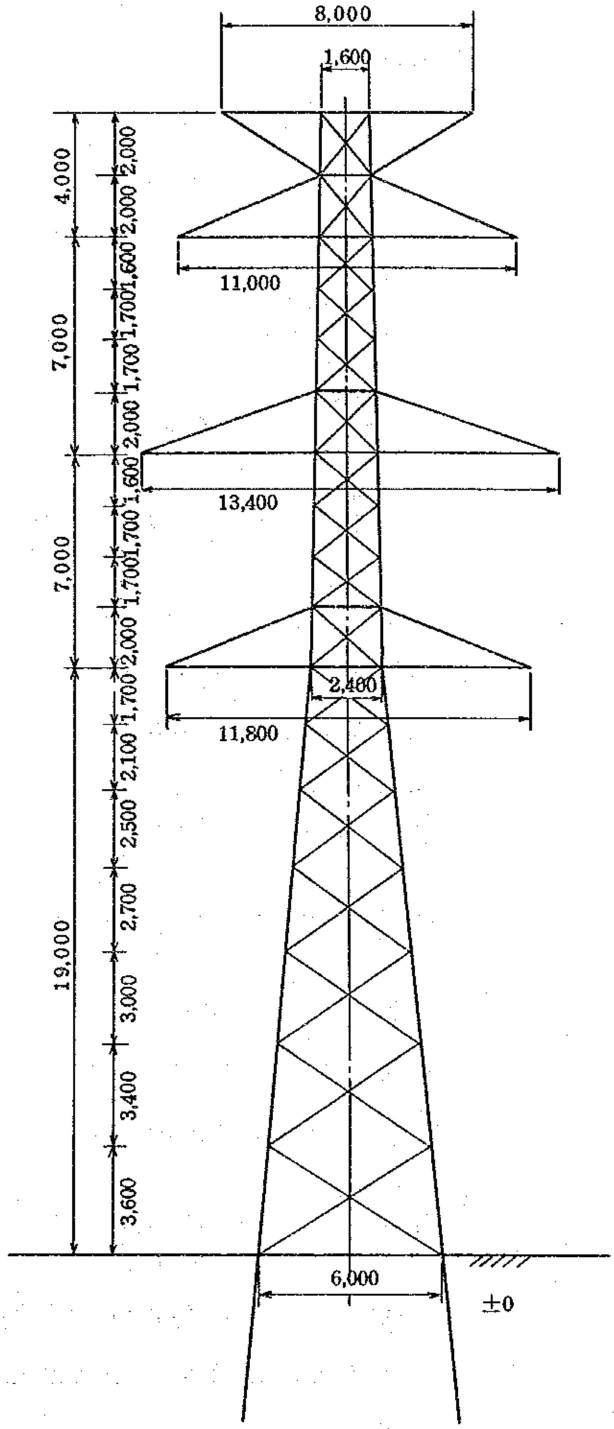
Type of steel materials - Angles

(Standard steel towers are shown in Figs. 9-6-3, 9-6-4, 9-6-5, and 9-6-6)

A.	58 towers	16 t/tower	928 t
B.	15 towers	19 t/tower	285 t
C.	3 towers	23 t/tower	69 t
D.	2 towers	37 t/tower	74 t
TOTAL	78 towers		1,356 t

Average 17.38 t/tower

Fig. 9-6-3 230 kV ACSR 795 MCM x 2, Two Circuits Tower; A Type

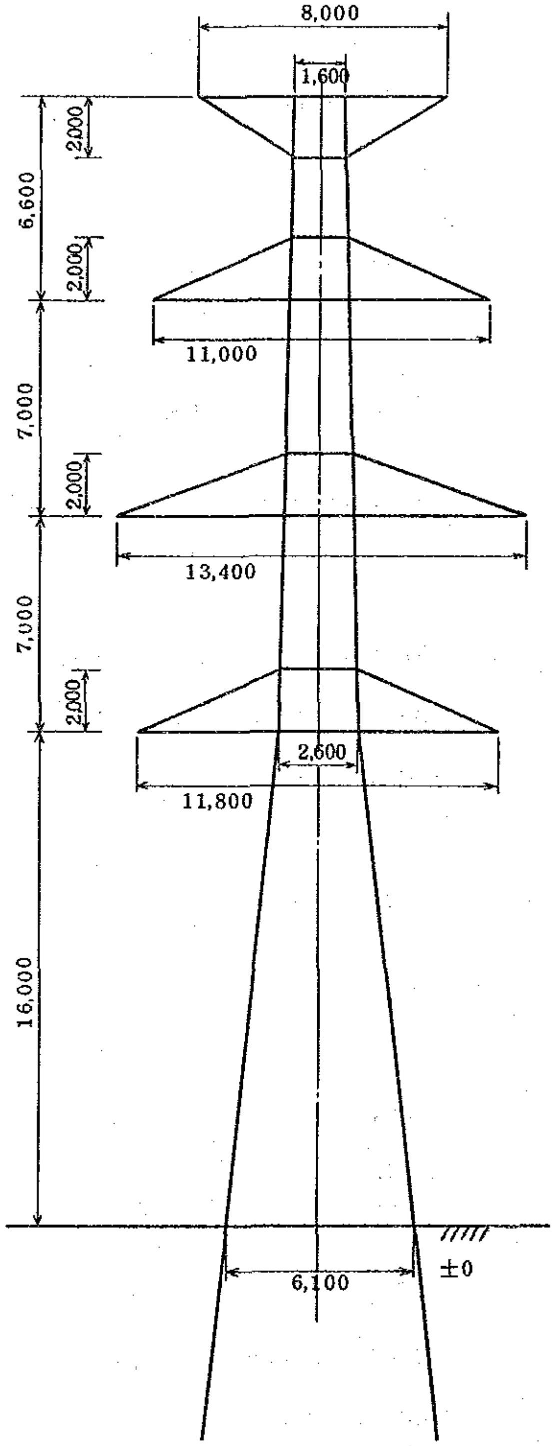


230 kV 2 cct A Type

Design Condition

Voltage	230 kV
No. of Circuit	2
Span	300 m
Horizontal Angle	3°
Vertical Angle	0.1 T
Conductor Spec.	ACSR 795 MCM x 2
Section Area	Al. 402.56 mm^2 St. 65.44 mm^2
Diameter	28.14 mm
Weight	1.526 kg/m
Max. Tension	4,700 kg
Ground Wire Spec.	IACSR 97 mm^2 x 2
Section Area	Al. 96.5 mm^2 St. 56.29 mm^2
Diameter	16.0 mm
Weight	0.708 kg/m
Max. Tension	3,000 kg
Insulator Spec.	254 mmø 16 p./st.
Weight	100 kg/st.
Wind Pressure	60 kg/st.
Wind Pressure on Conductor	90 kg/m^2
Wind pressure on Tower	255 kg/m^2

Fig. 9-6-4 230 kV ACSR 795 MCM x 2, Two Circuits Tower: B Type

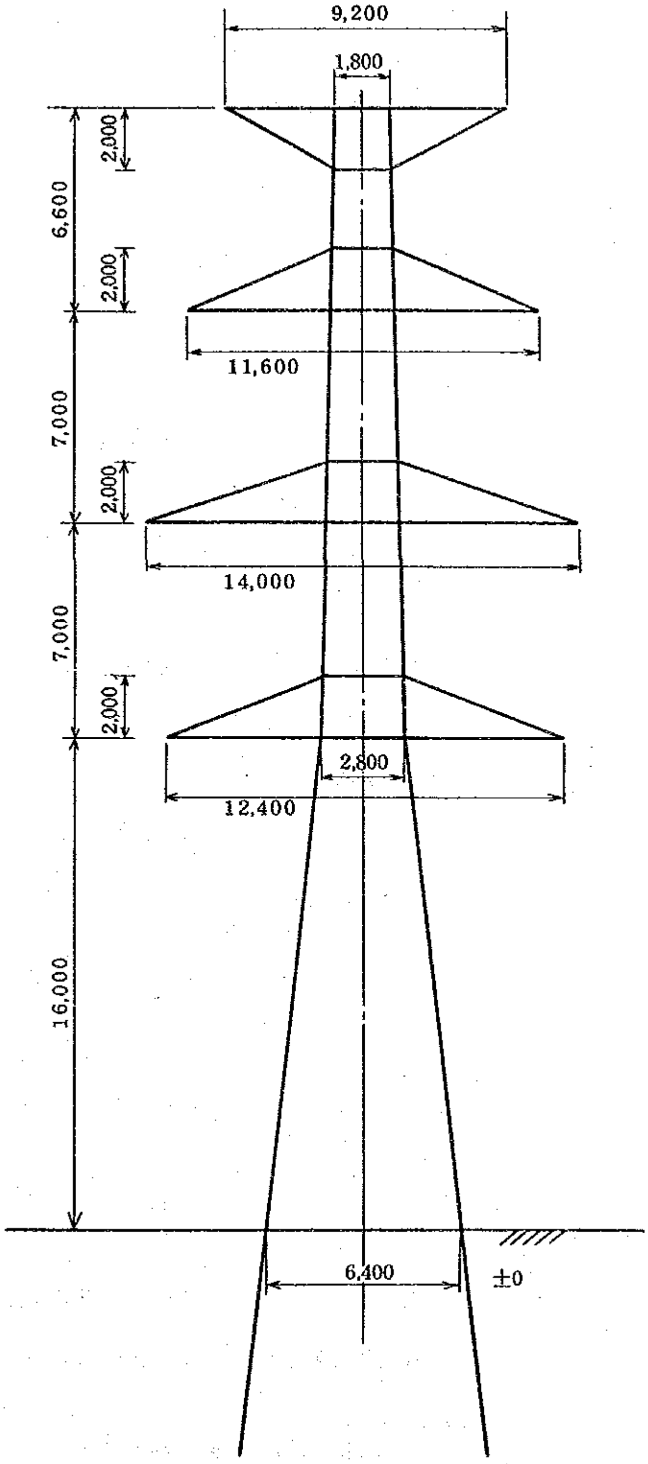


230 kV 2 cct B Type

Design Condition

Voltage	230 kV
No. of Circuit	2
Span	300 m
Horizontal Angle	15°
Vertical Angle	0.1 T
Conductor Spec.	ACSR 795 MCM x 2
Section Area	Al. 402.56 mm^2 St. 65.44 mm^2
Diameter	28.14 mm
Weight	1.526 kg/m
Max. Tension	4,700 kg
Ground Wire Spec.	IACSR 97 mm^2 x 2
Section Area	Al. 96.5 mm^2 St. 56.29 mm^2
Diameter	16.0 mm
Weight	0.708 kg/m
Max. Tension	3,000 kg
Insulator Spec.	254 mmϕ 16 p./st.
Weight	2 String 200 kg
Wind Pressure	2 String 120 kg
Wind Pressure on Conductor	90 kg/m^2
Wind pressure on Tower	255 kg/m^2

Fig. 9-6-5 230 kV ACSR 795 MCM x 2, Two Circuits Tower; C Type

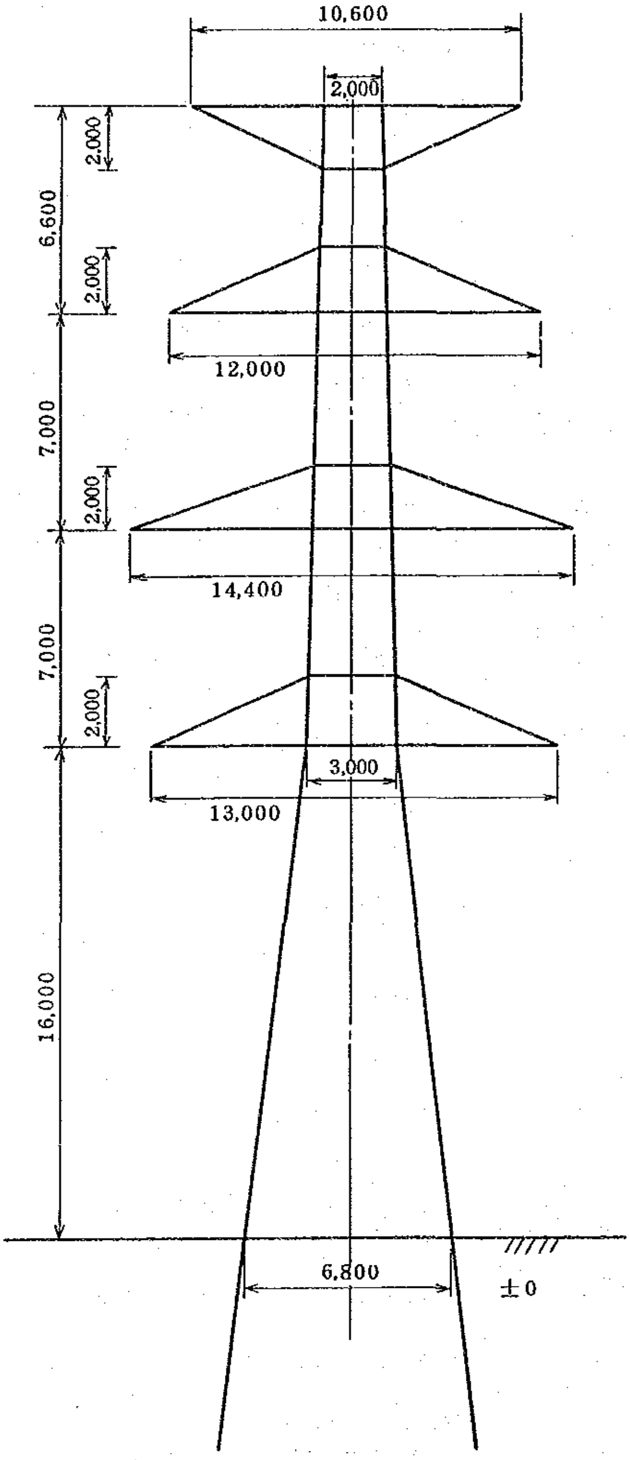


230 kV 2 cct C Type

Design Condition

Voltage	230 kV
No. of Circuit	2
Span	300 m
Horizontal Angle	30°
Vertical Angle	0.1 T
Conductor Spec.	ACSR 795 MCM x 2
Section Area	Al. 402.56 mm^2 St. 65.44 mm^2
Diameter	28.14 mm
Weight	1.526 kg/m
Max. Tension	4,700 kg
Ground Wire Spec.	IACSR 97 mm^2 x 2
Section Area	Al. 96.5 mm^2 St. 56.29 mm^2
Diameter	16.0 mm
Weight	0.708 kg/m
Max. Tension	3,000 kg
Insulator Spec.	254 mmϕ 16 p./st.
Weight	2 String 200 kg
Wind Pressure	2 String 120 kg
Wind Pressure on Conductor	90 kg/m^2
Wind pressure on Tower	255 kg/m^2

Fig. 9-6-6 230 kV ACSR 795 MCM x 2, Two Circuits Tower; D Type



230 kV 2 cct D Type

Design Condition

Voltage	230 kV
No. of Circuit	2
Span	300 m
Horizontal Angle	Dead end
Vertical Angle	0.1 T
Conductor Spec.	ACSR 795 MCM x 2
Section Area	Al. 402.56 mm^2 St. 65.44 mm^2
Diameter	28.14 mm
Weight	1.526 kg/m
Max. Tension	4,700 kg
Ground Wire Spec.	IACSR 97 mm^2 x 2
Section Area	Al. 96.5 mm^2 St. 56.29 mm^2
Diameter	16.0 mm
Weight	0.708 kg/m
Max. Tension	3,000 kg
Insulator Spec.	254 mmϕ 16 p./st.
Weight	2 String 200 kg
Wind Pressure	2 String 120 kg
Wind Pressure on Conductor	90 kg/m^2
Wind pressure on Tower	255 kg/m^2

(4) Conductor (ACSR)

Total weight of conductors:

1.526 t x 23 x 0.03 x 2 conductors x 6 strands

= 434 t

Spencer rigid type: 36/span x 78 = 2,808 = 2,800

Damper : 18/tower x 78 = 1,404 = 1,400

(5) Insulator

One-string suspension clamp: 6 strings x 58 towers

= 348 strings

No. of insulators : 16 ins. x 6 x 58

= 5,568 insulators

Two-string suspension clamp: 12 strings x 20 towers

= 240 strings

No. of insulators : 16 ins. x 2 x 12 x 20

= 7,680 insulators

Total No. of insulators : (5,568 + 7,680) x 0.01

= 13,400

(6) Ground Wire

Weight of aerial

ground wire : 0.768 t/km x 2 x 23 x 1.02

= 33.2 t

Weight of buried

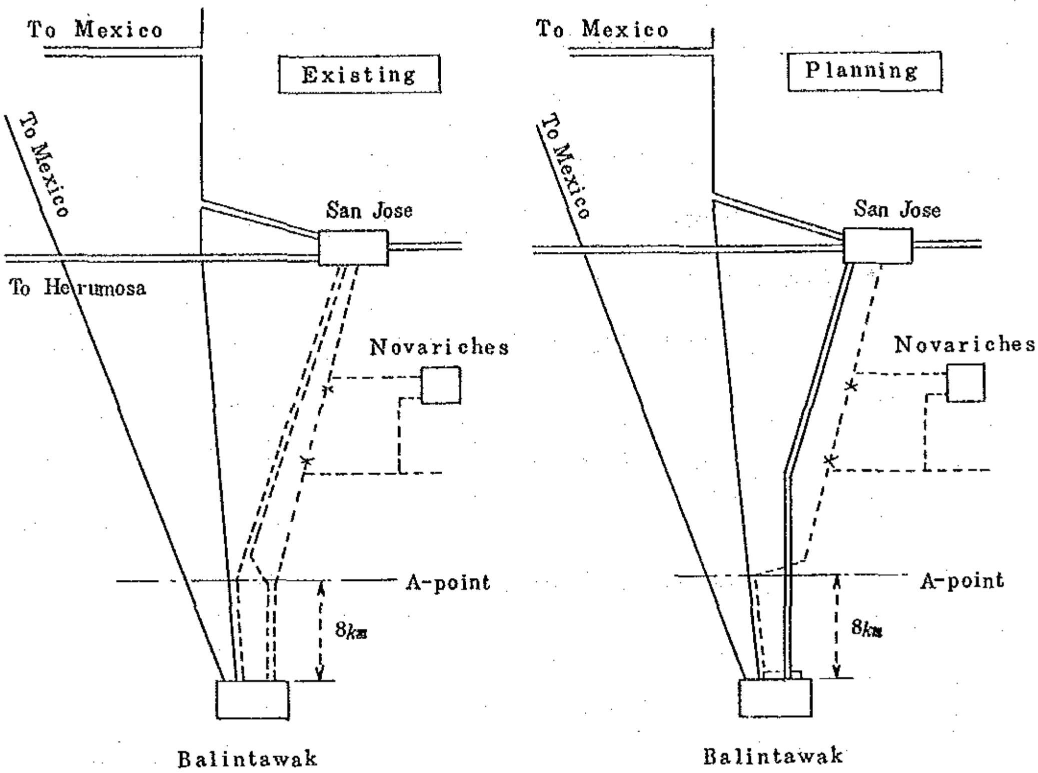
ground wire : 0.45 t/km x 0.025 x 4 x 78

= 3.5 t

(7) Construction Method

Existing and proposed transmission lines around San Jose and Balintawak substations are shown in Fig. 9-6-7.

Fig. 9-6-7 One Line Diagram of New San Jose--Balintawak T/L



As land acquisition is not possible for a distance of 8 km from Balintawak SS to a pint, the land now occupied by existing 115 kV 2 circuits must be used for construction of a new 230 kV transmission line.

To secure power supply to Balintawak SS during construction of a new transmission line, the following alternatives may be considered.

Alternative A

Right of way for New 230 kV line uses that for existing 115 kV San Jose - Balintawak line.

1st Step

. Construction of 2 Temporary 115 kV T/L from A point to San Jose (13.1 km)

. Construction of one Temporary 115 kV T/L from A point to Balintawak (8 km)

2nd Step

. Retired of existing 115 kV San Jose - Balintawak line

. Construction of New 230 kV line tower on the right of way for retired 115 kV San Jose - Balintawak line

Alternative B

In case suspension of 115 kV San Jose-Balintawak line and 115 kV Novoriches-Balintawak line is not possible:

Construct a temporary transmission line on both sides of 115 kV 2-circuits lines section between A point and Balintawak, construct 230 kV 2-circuits lines between these two temporary lines and connect it to the 230 kV 2-circuits lines of another route in the San Jose-A point section to form a new transmission line.

Remove temporary transmission lines and follow the same procedure as Alternative A.

Alternative C

In case suspension of one circuit of 115 kV San Jose-Balintawak line is possible:

Construction of only one circuit of temporary transmission line shown in Alternative B is sufficient.

With Alternative B, it is possible to maintain existing supply capacity to Balintawak SS and supply pattern to Novoriches SS, but there is an increase of construction cost.

With Alternative C, there is a decrease of supply capacity to Balintawak SS by about 100 MW. Accordingly, the operating rate of Manila power plant must be increased by 100 MW during construction. The increase of fuel cost during construction is calculated as follows assuming that the increase of output is required only during peak hours of weekdays for four months.

₱0.75 x 10 hrs x 23 days x 4 months x 100,000

= 696 m.₱

When a comparison is made between the saving of cost of temporary facilities and the increase of fuel cost, it is evident that Alternative C is inferior to Alternative B.

The construction cost for Alternative A is highest one than other Alternatives because a long temporary line should be provided for the construction.

However, the adoption of Alternative A is preferable plan for the construction because the negotiation for the acquisition of a new right of way for 230 kV line is not easy specially in the suburb of Metro Manila.

9-7. Replacement of Obsolete 230 kV Equipment at Mexico Substation

The 230 kV equipment of Mexico substation, which occupies an important position in the power system of North Luzon have been in use since 1960 and are becoming obsolete. In particular, the 230 kV oil circuit breakers are in an very unsatisfactory state because of age, with oil leaking from valves and tanks. Moreover, excess wear of contact and poor contact of auxiliary relays are observed sometime.

The 230 kV disconnecting switches are also obsolete with stiffened operating mechanism.

Since such a state of equipment may lead to a serious accident, prompt replacement of these equipment is recommended.

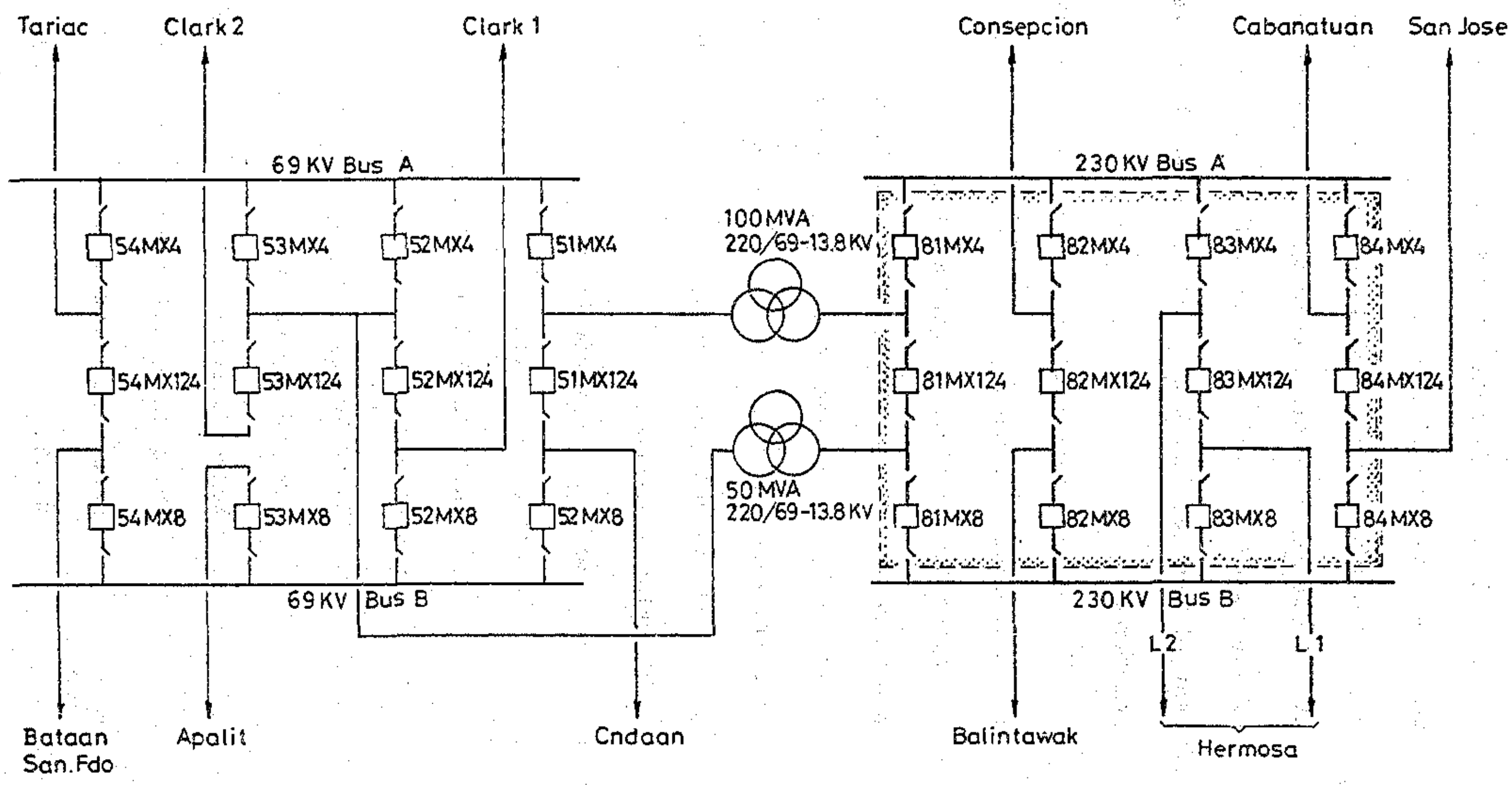
The scope of replacement and one line diagram of Mexico substation are shown in Fig. 9-7-1. Specifications of new equipment are as follows in accordance with NAPOCOR standards and specifications of existing equipment.

(1) 230 kV Gas Circuit breaker,
Outdoor use, puffer-type
with built-in bushing current

transformer	:	12 units
Rated Voltage	:	230 kV
Max. Design Voltage	:	242 kV
Rated Current	:	1,200 A
Rated Interrupting Capacity	:	25 kA
Rated Interrupting Time	:	3 cycles
B.C.T.	:	600-1,200/5A

Fig. 9-7-1 Single Line Diagram of MEXICO Substation

Note : [dotted box] Replacement of 230 kV Equipment.



(2) 230 kV Disconnecting Switch,

Outdoor use, horizontal

double-break type,	:	24 units
Rated Voltage	:	230 kV
Rated Current	:	1,200 A
Rated short Time Current	:	25 kA

(3) Other Equipment

1) Instrument for switch board.

Meters, Control switches and Signal lamps, etc.

2) Control Cable (Cross-linked polyethylene insulated cable) and Conductors.

3) Insulating Device.

Suspension insulators and Station post insulators, etc.

9-8. Installation Work of Phase Modifiers

a. Static Condenser

(1) Installation Plan

As discussed in the analysis of power system in Chapter 7-1, the operation mode of power plants located north and west of Metro Manila is expected to vary greatly during shut down maintenance of PNPP and also depending on the season, resulting in large voltage fluctuations in Metro Manila or in the area of Olongapo on the west coast of Luzon. A voltage drop is also expected with the increase of shut down cases of existing power plants in Metro Manila following the commissioning of large power plants. With this background, installation of static condensers was planned as follows for the purpose of voltage compensation.

NAPOCOR:	230 kV system	Hermosa	50 MVA
		San Jose	50 MVA
		Dolores	20 MVA
		Sucat	50 MVA
		Sub-total	170 MVA
MERALCO:	115 kV system		100 MVA
		Total	270 MVA

(2) Outline of Specifications

1) Voltage class: 230 kV

2) Unit capacity and number of transformer banks

Hermosa	25 MVA x 2 banks (230 kV)
San Jose	25 MVA x 2 banks (115 kV)
Dolores	20 MVA x 1 bank (115 kV)
Sucat	25 MVA x 2 banks (115 kV)

3) Auxiliary facilities required

i. Circuit breaker

ii. Series reactor

iii. Insulating transformer

iv. Discharge coil

v. Switch board

vi. Insulating stand

vii. Line switchgear

viii. Other accessories

For the installation of static condensers, the space indicated below will be required on the 230 kV side of a substation.

One condenser bank......50 m x 20 m

(Approx. 1,000 m^2)

Two condenser banks.....50 m x 40 m

(Approx. 2,000 m^2)

The 230 kV side switch yard of all existing substations is not sufficient in area for the installation of additional static condensers and the expansion of the yard will be required.

For MERALCO, installation of static condenser at the substations within city area involves a land acquisition problem. Besides, dispersion of static condensers to different locations rather than installation of them at one particular substation is desirable from the operational point of view.

MERALCO should work out a detailed installation plan.

b. Shunt Reactor

(1) Installation Plan

As discussed in the section for the problems of system restoration in Chapter 7-3, installation of shunt reactors at Harmosa substation was planned as a voltage measure in the event of power supply by 230 kV transmission lines from hydro power plants in San Jose area to provide station power to PNPP.

Total capacity 50 MVA

(2) Outline of Specifications

1) Voltage class 69 kV

2) Unit capacity and number of transformer banks

25 MVA x 2 banks

3) Auxiliary facilities required

i. Circuit breaker

ii. Line switchgear

iii. Other accessories

The shunt reactor is to be connected to the secondary winding (69 kV) of 50 MVA transformer as in the case of Naga and Lobo substations where the shunt reactor is already installed. Since the installation of static condensers is planned for Hermosa substation, a detailed study should be made as to which substations are to be equipped and what connection method (common use of circuit breaker, and others) is to be used in working out a detailed design.

c. SVC

This is a device which adjusts the reactive power at high speed with its thyristor for the purpose of controlling voltage fluctuations of the power system.

Since the SVC is equipped with a control device, it is more costly than the installation of a shunt reactor and a static condenser. However, it cannot be said absolutely that the installation of SVC is more expensive when the increase of line loss resulting from the permanent connection of a shunt reactor to the line is taken in consideration. It will be necessary, therefore, to make a detailed study of the installation of SVC together with its price and line loss.

9-9. System Protective Devices

a. Change of Protective Relays in Important Back Bone Lines to Dual System and Static Type

(1) Study of Relaying Systems

Each relaying system has its merits and demerits. When several relaying systems are proposed for selection in the design of system protection, every possible means should be considered to make up the disadvantage of particular system for final selection.

The advantage of the distance relay is generally known quite well but its disadvantage is often forgotten.

The distance relay has the following problems.

	Problems	Remedies
1)	Erroneous operation in heavy load transmission lines	Determine setting values by taking into account a voltage drop
2)	Over reach of leading phase relay	Protect by use of a combination with over-current relay
3)	Erroneous operation by transformer exciting rush current	Coordination with time relay

4) Erroneous operation by higher harmonics at time of a fault near SC	Installation of filters
5) Erroneous operation by voltage drop	Use of electromagnetic change ratio relay
6) Erroneous operation at time of system swing and out of step	Use of step-out relay

The phase comparison relaying system (including sample value relaying system) and the current comparison relaying system (FM) are free from erroneous operation when the system is out of step and erroneous operation by over load current and other problems normally associated with distance relays. These systems are capable of protecting the system completely and satisfactorily. However, these systems have no elements to back up the relays of corresponding terminals which are provided by the distance relay.

A combination of distance relaying system and phase comparison relaying system or FM system is more in use now for protection of important transmission lines.

Applications of the phase comparison relaying system and/or FM relaying system are as follows.

Type of System	Elements to be compared	Transmission method	Reclosing	Price
(Each) phase comparison relaying systems	Current Ia, Ib, Ic of each	Microwave 4 channels	Single-phase or three-phase	Medium
Sample volume phase comparison relaying system	(Ib-Ic) + KIa	Microwave or PLC 1 channels	Single-phase or three-phase	Medium
FM current ratio relaying system	Current Ia, Ib, Ic of each phase is used	Microwave 1 channel	Single-phase or three-phase	High

The phase comparison relaying system is a system in which a trip signal is generated by AND circuit of undervoltage relays (27S, 27G or 27GP-1) for detection of a fault and relay (78) which locates the point of fault in the system.

Fig. 9-9-1 Sequence Diagram of (Each) Phase Comparison Relaying System

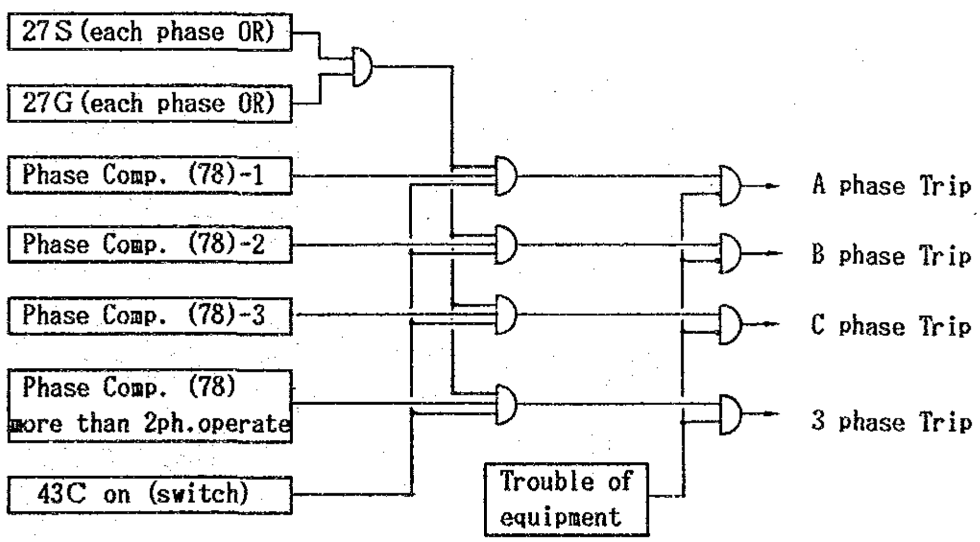
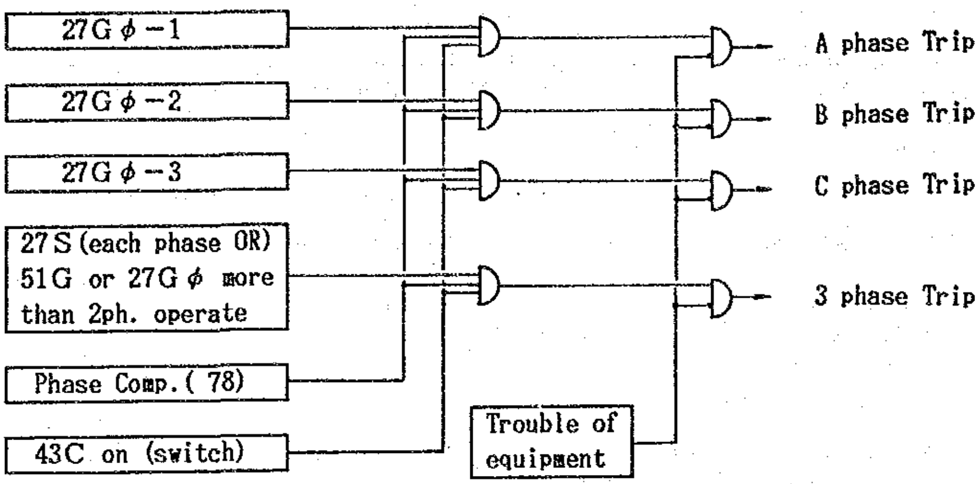


Fig. 9-9-2 Sample Volume Phase Comparison Relaying System



FM current comparison relaying system detects a fault in the system by comparing the current waveform of its own to that of the modulated current waveform received from the corresponding terminal to control trip signal.

Fig. 9-9-3 FM Current Ratio Relaying System