(7) HVDC system protection (Fig. 6-16)

i) Equipment and bus protection on AC side

The standardized protection system will be adopted.

- AC bus bar (including Naga C/S - Naga S/S)

  Differential protection

- Station service transformer

  Overcurrent and differential protection

- Shunt capacitor

  Overcurrent and voltage differential protection

- 20 kV and 3.3 kV bus

  Overcurrent and differential protection

ii) HVDC system protection

a) Filter

- AC filter

  Overcurrent and differential protection

- DC filter and surge capacitor

  Overcurrent protection

b) Valve, transformer for converter and DC main circuit

- Converter transformer

  Overcurrent and differential protection

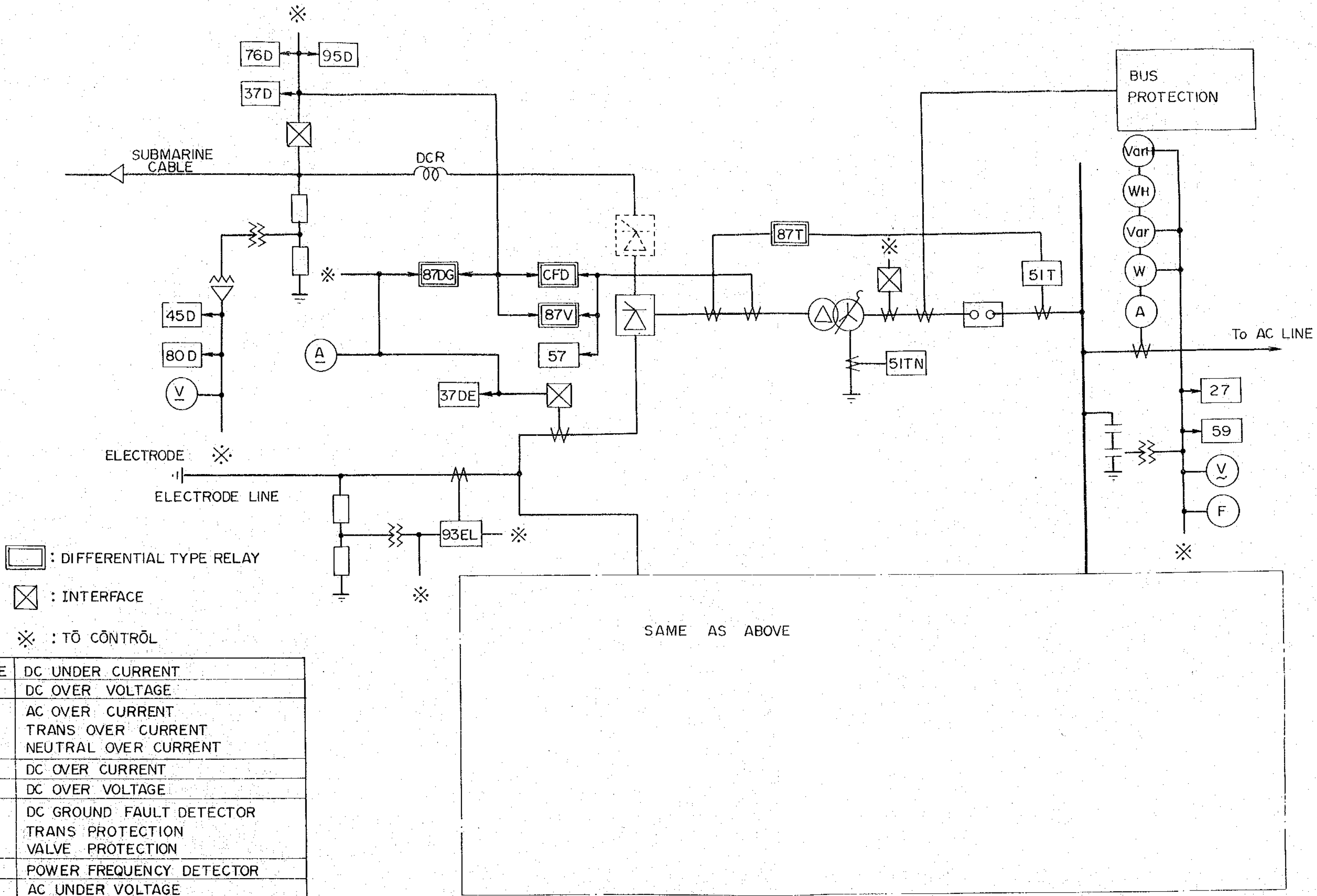
- Valve short circuit and grounding

  Overcurrent protection

- Commutation failure

  Differential protection and marginal angle detecting protection

Fig.6-16 HVDC SYSTEM PROTECTION BLOCK DIAGRAM (MONOPOLE)(BIPOLE)



37D, 37DE	DC UNDER CURRENT
45D	DC OVER VOLTAGE
51 51T 51TN	AC OVER CURRENT TRANS OVER CURRENT NEUTRAL OVER CURRENT
76D	DC OVER CURRENT
80D	DC OVER VOLTAGE
87DG 87T 87V	DC GROUND FAULT DETECTOR TRANS PROTECTION VALVE PROTECTION
95D	POWER FREQUENCY DETECTOR
27	AC UNDER VOLTAGE
59	AC OVER VOLTAGE
CFD	COMMUTATION FAILURE DETECTOR
93EL	OPEN CIRCUIT DETECTOR

- Grounding fault on the output side of the valve

  Overcurrent protection

- Grounding fault of main DC circuit

  Differential protection

- Abnormal pulse

  Pulse missing protection

c) Fault in control system

- Abnormal current control

  Overcurrent and under current protection

- Abnormal voltage control

  Overvoltage and under voltage protection

d) DC transmission line and electrode line

- DC transmission line

  Ground fault and line breaking protection

- Electrode line

  Mainly for protection of line breaking

(8) Operation of AC filter

i) Converter station will be provided with 5th, 7th, 11th, 13th and HP filters at the 1st stage and additional 11th, 13th and HP filters at the 2nd stage.

ii) Purposes of filter installation are:

- To absorb high harmonic current emerging from converter

- To generate part of reactive power to be required for converter

iii) Number of filter branches can be determined from filtration effect of filters.

iv) Wave form distortion D of the bus line in converter station can be attained as follows from realistic values for the HVDC plan:

$$D = \frac{\Sigma Uf}{u_1} \leqq 3 \sim 4\%$$

Uf : Higher harmonic wave voltage
u_1 : Fundamental wave voltage

For certain higher harmonic voltage

$$\frac{Uf}{u_1} \leqq 1\%$$

Those target values can be fully satisfied if optional converter load and continuous frequency variation could be restrained within ±0.2 Hz in the AC system.

(9) Operation of DC filter

i) Converter station will be provided with 6th and HP filters at the 1st stage and no more addition to them at the following stage.

ii) Purpose of filter installation is:

- To absorb higher harmonic waves to emerge from converter into DC side

In order to ensure same degree of filtration effect as AC filters, the value of high harmonic current to be outflown into DC transmission line may be set as follows, being regarded same as realistic value being used for HVDC plan in Japan.

$$PSO = \sqrt{\Sigma (Xf \times If)^2} \leqq 1 \sim 2A$$

Xf : Weighing factor specified by CCITT Standard

If : Higher harmonic current

6.4.6 Insulation Coordination

(1) Generating source of overvoltage

i) Overvoltage emerged on AC side

- Surge on transmission line
- Switching surge from on and off of lines and AC filters
- Ferro-resonance overvoltage by on and off of AC filters or transformers and AC system
- Overvoltage due to one pole temporary blocking of HVDC system

ii) Overvoltage emerged on DC side

- Surge on DC transmission line
- Overvoltage due to commutation failure

iii) Overvoltage emerged in converter

- Normal switching surge emerged by valve operation
- Overvoltage emerged from commutation failure
- Overvoltage to emerged from short circuit or grounding fault in converter output side

(2) Arrester arrangement

i) Arrester in primary side of transformer

Limitation of lightning and switching surge emerging from AC side and protection of transformer, filter, bus and other AC side equipment

ii) Valve arrester

Limitation of lightning surge emerging from both AC and DC sides and switching surge in DC side of converter and protection of thyrister valve

iii) Valve bridge arrester

Limitation of lightning and switching surge and protection of DC bus and transformer in coordination with valve arrester referred to above.

iv) DC line arrester

Limitation of lightning and switching surge and protection of DC reactor on line side, DC filter, DC bus and other DC side equipment.

Fig.6-17 LAYOUT OF JARO CONVERTER STATION (FIRST STAGE)

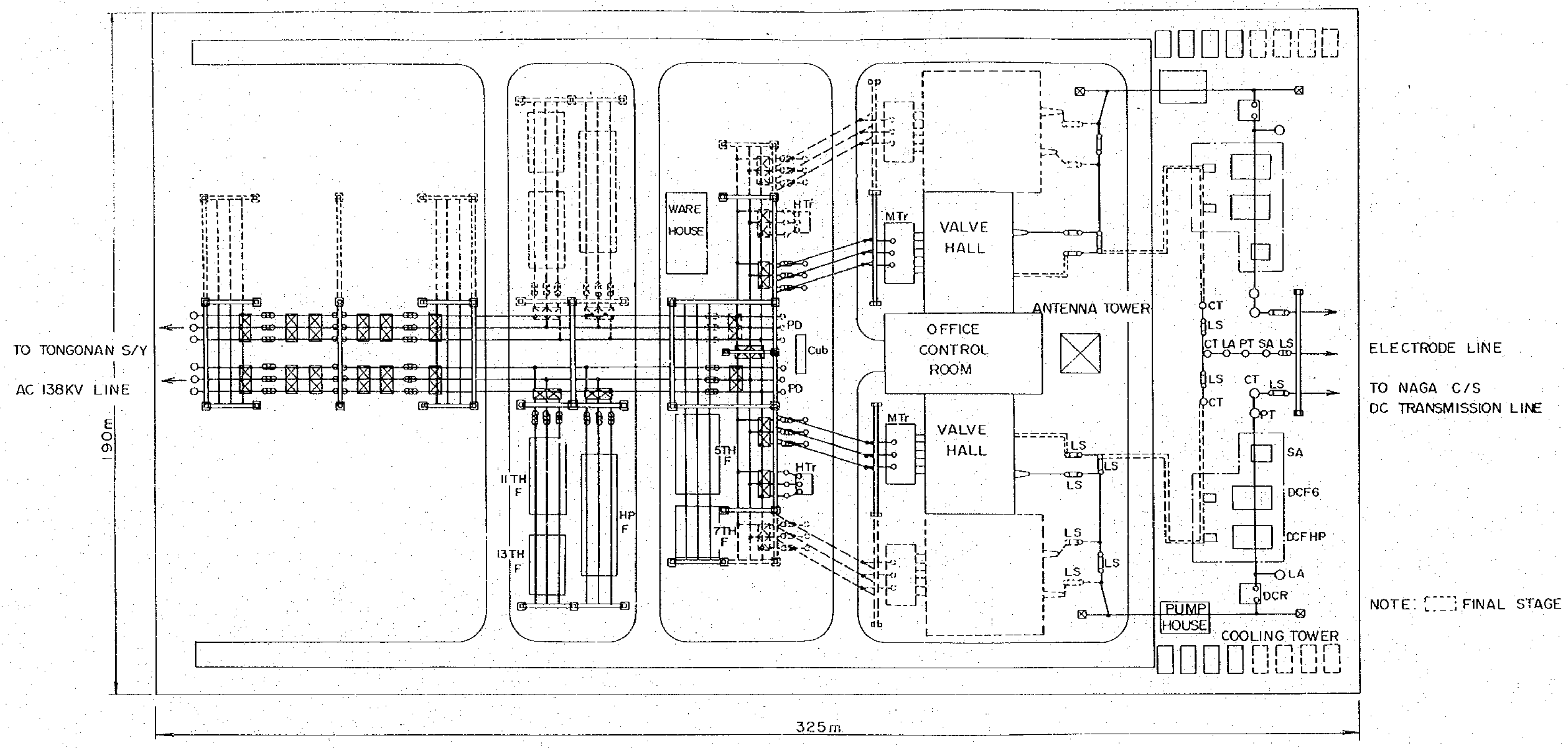
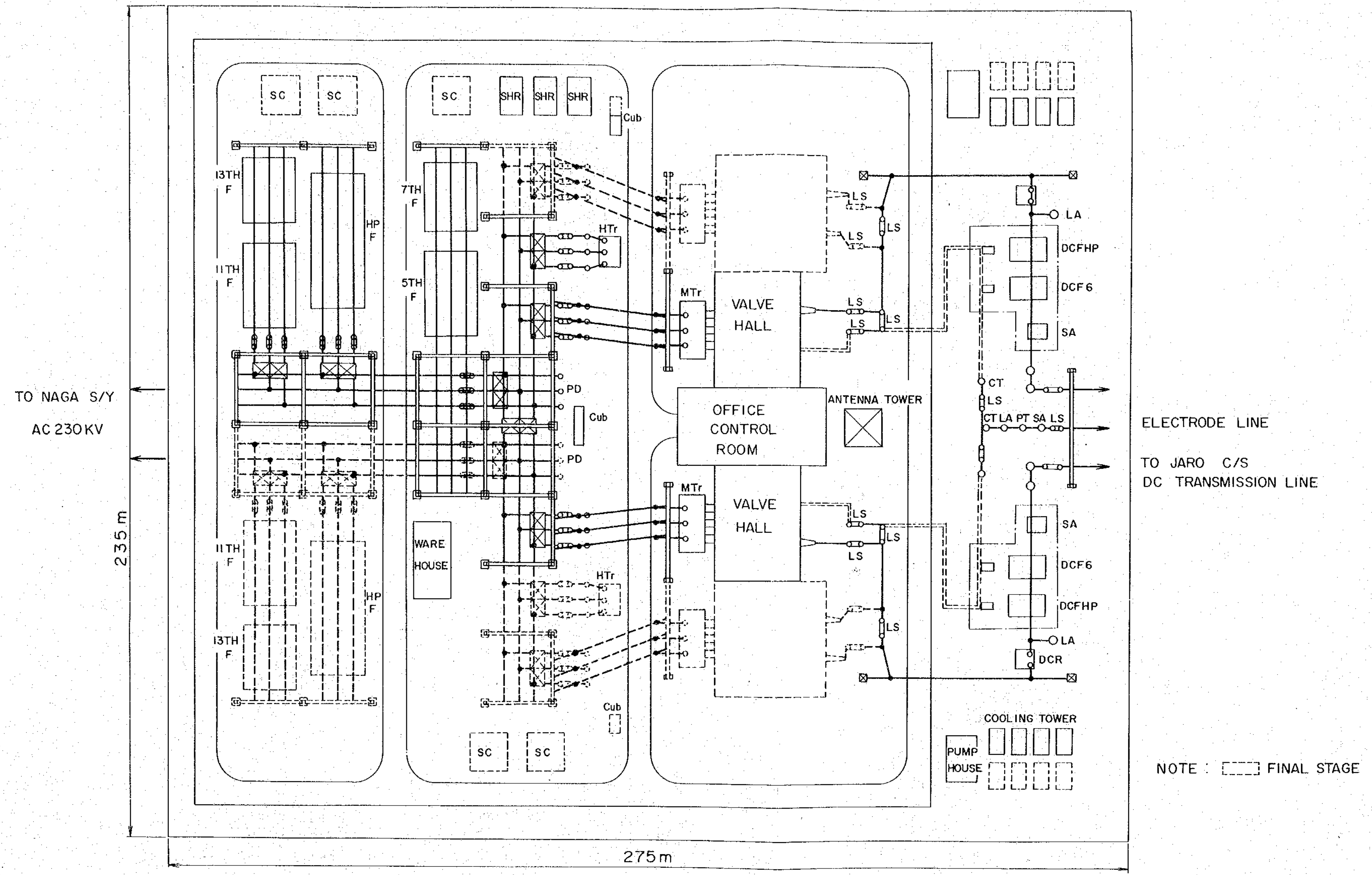


Fig.6-18 LAYOUT OF NAGA CONVERTER STATION (FIRST STAGE)



v) Electrode line arrester

Limitation of lightning surge emerging from electrode line and protection of DC equipment on electrode line side.

vi) Arrester on DC reactor valve side

Limitation to lightning and switching surge emerging from AC and DC sides and protection of DC reactor valve side.

6.4.7 Converter Station Layout (Fig. 6-17, 6-18)

(1) Layout

i) Site area for construction of Converter Station for both 1st and 2nd stages are as follows:

Naga C/S about 65,000 m^2

Jaro C/S about 62,000 m^2

ii) At the 1st stage, two (2) valve halls will be provided with control room in between them and two (2) more valve halls will be added at the 2nd stage.

iii) Equipment on both AC and DC sides will be separated by control room and valve hall in the center.

iv) Transformer for converter will be installed in contact with valve hall wall.

(2) Valve hall

i) Equipment in the valve hall are valves, arrester for valve protection, earthing device and secondary bushing of converter transformer.

ii) Air in valve hall should be kept clean at positive pressure.

iii) Valve constitutes 2 arms in series of air insulation and air cooled.

iv) Inner side of valve hall will be provided with shielding deck plate, so as to prevent outgoing of radio noise created in converter.

v) Cooling system including valve-cooling fan etc. will be provided in the under ground room.
Valve cooling system should preferably be designed as air (valve) - cooling water - air (outdoor) system.

(3) Control room

i) Control room will be divided into following component room.

- Control room
- Switchboard room
- Communication equipment room
- Auxiliary equipment room
- Cable room

ii) Communication equipment room will be shielded with iron plate.

(4) Station service system

i) Station service system will be separated by poles.

ii) Engine generator will serve for emergency power supply during stoppage of station service at Jaro converter station.

Naga converter station will receive emergency power supply from Naga substation. DC power for control and communication will be supplied by rectifier and converter station battery.

iii) Converter station battery is capable as emergency and security power source for about one hour and is utilized also for start-up of engine generator.

iv) Transformers for auxiliary equipment are separated by purposes.

6.4.8 Converter Station Equipment

(1) Main equipment rating (1st stage)

i) Thyrister valve

- No. of unit : 12 per each terminal (2-arm lamination)
- Type : Air insulated, air cooling system
- Structure : 2-arm lamination

- Rated DC voltage : 175 kV/1-arm
- Rated direct current : 1,290 A
- Rated DC output : 225 MW/group x 2
- Cooling system : Forced air/water cooling

ii) Transformer for converter

- No. of unit : 2/each terminal
- Type : 3 phase outdoor forced oil air-cooled

  With on load tap changer
- Rated voltage : Jaro 138 kV/154 kV

  Naga 230 kV/154 kV
- Rated voltage : Jaro 1,145A/1,053A

  (Primary/secondary) Naga 687A/1,053A
- Rated capacity : 280 MVA/280 MVA (at 20% impedance)

  (Primary/secondary)

iii) DC reactor

- No. of unit : 2 per each end
- Type : Outdoor forced-oil air-cooled
- Rated voltage : DC 350 kV
- Rated current : 1,290A
- Inductance : Approx. 0.8 H

iv) AC filter

- Composition : 5th, 7th, 11th, 13th, and HP
- Rated circuit voltage : Jaro 138 kV

  Naga 230 kV

- Rated capacitive capacity :	Jaro C/S	Naga C/S
5th 7th 11th 13th HP	135 MVA	135 MVA

v) DC filter and surge capacitor

- Compositional : 6th, HP and surge capacitor/ each terminal

- Rated circuit voltage: DC 350 kV

vi) Shunt reactor	Jaro C/S	Naga C/S
- No. of unit :	-	3
- Rated voltage :	-	Approx. 20 kV
- Rated lagging capacity :	-	30 MVA/unit

vii) Station service transformer

- No. of unit : 2/each terminal

- Type : Outdoor 3-phase forced-oil air-cooled

  With on load tap changer

- Rated voltage : (Primary/seconeary/ tertiary)

  Jaro 138 kV/3.3 kV

  Naga 230 kV/20 kV/3.3 kV

Naga Converter Station will be connected with shunt reactor on its secondary side.

- Rated capacity :
  (Primary/secondary)
  /tertiary)   Jaro   3 MVA/3 MVA

  Naga   90 MVA/90 MVA/3 MVA

viii) AC circuit breaker

	Jaro	Naga
- No. of unit :	11 units	6 units
- Type :	GCB type	GCB type
- Rated voltage :	145 kV	245 kV
- Rated breaking current :	20 kV	25 kV

6.5 Communication System

The construction of the HVDC transmission system will be executed as divided into stage 1 and stage 2. In case the construction of the communication system is divided into two stages, the construction to be executed in stage 2 is only a slight addition of the information transmission equipment. Therefore the communication system should be entirely completed in stage 1.

6.5.1 Design Conditions

The communication equipment required for this project will be designed based on the following conditions.

(1) Microwave radio equipment

- As for the frequency, the frequency band of 7 GHz is to be used with the topography, weather and so forth taken into account.

  For the propagation path over the sea or coastline, the diversity reception system is adopted in order to avoid the fading of radio wave.

- In order to obtain the reliability required for transmission of protection and control signals available for the DC transmission system, the interruption rate of the telecommunication line should be 1×10^{-4} or less.
- The equipment of 300 CH capacity type is to be used to provide sufficient channel capacity with expansion of channels in the future taken into account.

(2) Information transmission equipment for control and protection

- The transmission speed is 42 k bits/sec, since high speed transmission is required for control and protection signals.
- The dual systems is to be provided for transmission between both converter stations, because particularly high reliability is required.

(3) Information transmission equipment for supervision

- Although high transmission speed of signals is not particularly required, the high reliability and the numerous data transmission is required between both converter stations. Therefore, dual systems of transmission speed of 1,200 bits/sec are to be provided. Single system for low speed of 200 bits/sec is to be provided between Tongonan S/Y and Jaro C/S.

(4) Transmission line fault locator

- The transmission line fault locator in the section of overhead transmission line between Naga C/S and Jaro C/S is only taken up in this study. The section between Jaro C/S and Tongonan S/Y, is to be excluded from this project, because it is desirable that the system should be made collectively with in transmission lines which are installed in Tongonan S/Y side under separate project.

(5) Power supply facilities for communication equipment

a) For repeating station

Since each repeating station is located without distribution lines, a power supply facilities composed of solar cells and storage batteries is to be provided with ease of maintenance and economy taken into account. It is desirable that the power supply capacity is designed based on the solar radiation intensity (langley/day) of each point, but in this plan the capacity that supply of power even on cloudy or rainy day was selected referring similar data used.

b) Tongonan S/Y, Naga C/S and Jaro C/S

DC uninterruptible power system using floating charge system is adopted, and telephone lines for load dispatching and for maintenance are secured even on occurrence of house power service interruption.

(6) Others

a) Selection of locations of repeating stations

In this study the sites of repeating stations are selected on the map based on the results of field surveys in

Pasacao, Legaspi, Colomutan, Calbayog, Catbalogan and Bagahapi proposal so as to connect between Naga C/S and Jaro C/S.

For final selection of sites, however, it is necessary to carry out more detailed field surveys regarding topography, road conditions, path profil and so forth.

b) For the purpose of control, protection and supervision of Tongonan P/S, an information transmission equipment between Tongonan P/S ∿ Tongonan S/Y is required, but it should be excluded from this study since it will be done in other planning.

6.5.2 Required Equipment

The equipment required for this project are as shown in Table 6-5. The specifications of these equipment are as follows.

(1) Microwave radio installation

a) Microwave radio equipment

Frequency	: 7 GHz band
Transmitting power	: 0.1 W, 0.5 W
Channel capacity	: 300 CH
Redundancy method	: Twin pass system

b) Carrier terminal equipment

Multiplication method	: Frequency division system

Table 6-5 TELECOMMUNICATION EQUIPMENT LIST (Preliminary)

Use of Communication	Teleconmunication Equipment	Naga C/S	Pasacao R/S	Legaspi R/S	Calomutan R/S	Santa Magdalena C/T	Lipata C/T	Calbayog R/S	Catbalogan R/S	Bagahopi R/S	Jaro C/S	Tongonan S/Y	Equipment Specification
Communication Circuit for Telephone, Signal Transmission	Micro wave Radio Equipment												7GHz band, 300ch Twin-Path Heterodyne Repeating Transmitting output 0.1 ~0.5W With Antenna Wave guide.
	(Terminal type)	2									4	2	
	(Repeating type)		4	4	4			4	4	4			
	Multiplex Terminal Equipment	2									3	1	Frequency Division Multiplex System
	Local Terminal Equipment	1			1				1		1	1	
Repeater Statior Supervision	Supervisory Equipment	1	1	1	1			1	1	1	1	1	With Order Wire Telephone
Mobile Radio Telephone	VHF Radio Equipment												150 MHz band Press to talk System Transmitter output Base } Mobile } 10W Portable 1W With Antenna Cable
	(Base Station Type)	1			1	1	1		1		1	1	
	(Mobile Type)	4									4		
	(Portable Type)	10									10		
	Base Station Control Equipment	1			1	1	1		1		1	1	
Telephone for Maintenance, Operation Work	Telephone set	2									3	2	Party Line System Common Battery System.
Administrative Telephone	Autmatic Telephone Exchange	1									1		Subscribers Capacity 20L
Control, Protection Signal Transmission for Converter Station, Power Station and AC Transmission Line	CDT Equipment												Cyclic Degital Transmission System Transmission Speed High Speed 42 kb/s Low Speed 1200 b/s 200 b/s
	(High Speed Type)	2									3	1	
	(Low Speed Type)	2									3	1	
DC Power Supply for Telecommunication Equipment	Battery and Battery Charger	2									2	1	DC 24V DC 48V
	Solar Cell and Battery		1	1	1	1	1	1	1	1			DC 24V
Other Necessary Contrnc ts	Antenna Tower	1	1	1	1			1	1	1	1	1	Self-Supporting Type
	Repeater Station Building		1	1	1			1	1	1			Floor Space 4 x 4 m²
	Reflector											2 (6x8m²)	
	Fault Locator	1									1		Pulse rader Type
	Line Trap	2									2		
	Coupling Capacitor	2									2		

c) Antenna

Parabolic antenna : 3 m dia., 4 m dia

d) Reflector

6 m x 8 m : Two units

e) Repeating station

Number of stations : 6

The outline of each repeating station is shown in Fig. 6-19.

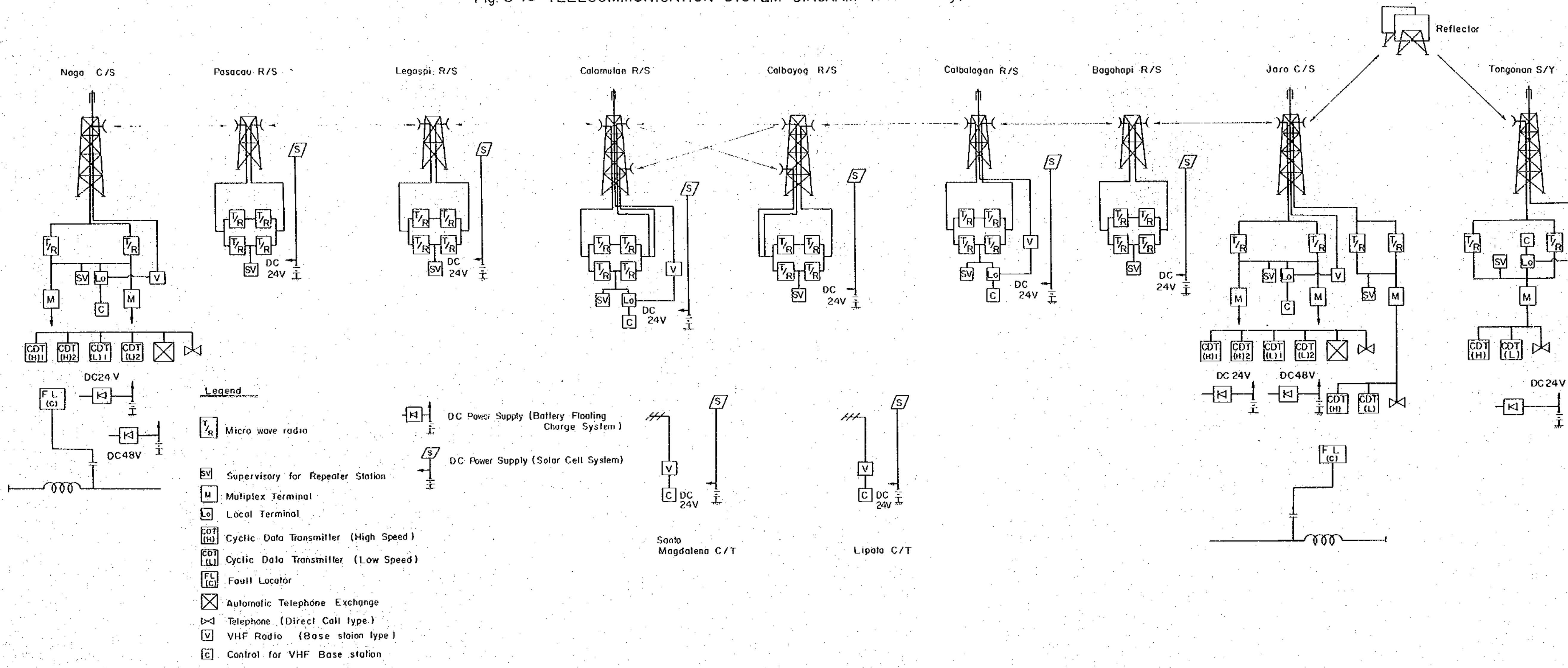
(2) Data transmission equipment for control, protection

Transmission speed	: 42 k bits/sec
Signalling system	: FS
Number of words	
Naga C/S to Jaro C/S	: 11 words
Jaro C/S to Naga C/S	: 11 words
Jaro C/S to Tongonan S/Y	: 11 words
Tongonan S/Y to Jaro C/S	: 11 words

(3) Data transmission equipment for supervision

Transmission speed	: 1,200 bits/sec or 200 bits/sec
Signalling system	: FS
Number of words	
Naga C/S to Jaro C/S	: 31 words
Jaro C/S to Naga C/S	: 31 words
Jaro C/S to Tongonan S/Y	: 6 words
Tongonan S/Y to Jaro C/S	: 12 words

Fig. 6-19 TELECOMMUNICATION SYSTEM DIAGRAM (Preliminary)



(4) Telephone equipment for maintenance and administration

a) Party-line telephone

Place of installation : Naga C/S, Jaro C/S, and Tongonan S/Y

b) Automatic switchboard

Capacity : 20 lines

(5) Overhead transmission line fault locating equipment

Method of orientation : Pulse radar system

Orientating area : from Naga C/S to Santa Magdalena C/T
and
from Jaro C/S to Lipata C/T

(6) Submarine cable oil pressure supervising device

a) VHF radio unit

Frequency : 150 MHz band

Transmitting power : 10 W

b) Power supply device for the above

Solar cell : DC 24 V, 100 W

Storage battery : 170 AH

(7) Mobil wireless telephone equipment for line maintenance

Maintenance : 150 MHz band

Frequency : For base station : 10 W

For mobil station: 10 W

For portable station: 1 W

Method of speech : Press-to-talk system

(8) Power supply device for telecommunication

a) For repeating station

Solar cell	: DC 24 V, 300 W or 400 W
Storage battery	: 800 AH or 1,200 AH

b) Naga C/S, Jaro C/S, Tongonan S/Y

Battery charger

24 V 150 A	: Jaro C/S
100 A	: Naga C/S
75 A	: Tongonan S/Y
48 V 3 A	: Jaro C/S and Naga C/S

Storage battery

24 V 700 AH	: Jaro C/S
500 AH	: Naga C/S
400 AH	: Tongonan S/Y
28 V 210 AH	: Jaro C/S and Naga C/S

(9) Dispatching communication equipment

Common battery system

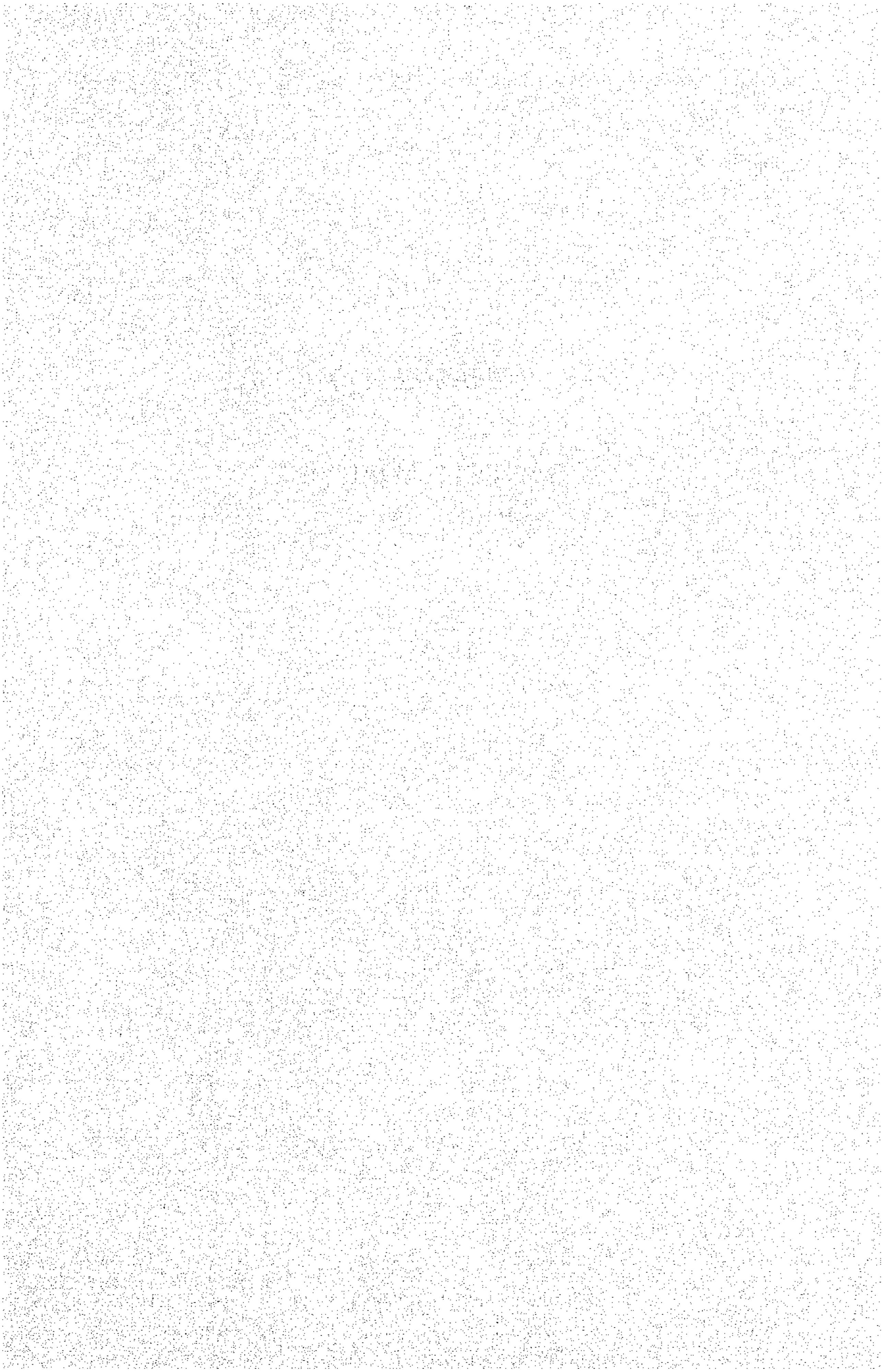
Place of installation : Naga C/S - Jaro C/S

and

Jaro C/S - Tongonan S/Y

CHAPTER 7

SYSTEM ANALYSIS



CHAPTER 7 SYSTEM ANALYSIS

In order to ensure stable transmission from the Leyte geothermal power plants into the Luzon power grid, studies have been made with regard to power flow and voltage at normal operation and stability at ground fault of the transmission line to the HVDC interconnected system.

In the case of power transmission from the Leyte geothermal power plant through the HVDC system, there would exist no fear factor essentially involved in stability of synchronized operation between the said geothermal plant and the Luzon grid.

However, it should be noted that Naga Converter Station as the power receiving end of the HVDC system is situated on the sending end of the EHV 500 kV transmission system for Tiwi and Manito geotherma power plants at the southern part of Luzon.

Because of this situation, power to be generated from the Leyte geothermal power plants, along with generated power at Tiwi and Manito, will be transmiteed through the EHV 500 kV (230 kV) over a distance of about 300 km, by way of Kalayaan, to San Jose. Therefore, the transmission capacity of the HVDC system will be determined depending mainly upon the degree of stability in the southern part of Luzon grid including Tiwi and Manito.

As the result of system analysis, it has been confirmed that the power of 400 MW in 1986 and 900 MW in 1993 will be able to send without any problem, by installing power system stabilizer at Tiwi, Manito and other power plants.

7.1 Premises

7.1.1 System Conditions

(1) Power System

Luzon - Samar - Leyte grid (Fig. 7.1)

(2) Demand

As per demand forecast presented by NAPOCOR (Table 7.1 and 7.2)

Power factor is set at 95 percent uniformity.

(3) Power Supply

Operation priorities are given as follows to power generating sources of different patterns:

① Hydro power ② Nuclear power ③ Geothermal power
④ Coal-fired power ⑤ Oil-fired power

(4) Years Under Study

1986	400 MW HVDC transmission power	
1991	600 MW	"
1993	900 MW	"

Fig. 7-1 Luzon Grid Single Line Diagram ~ 1993

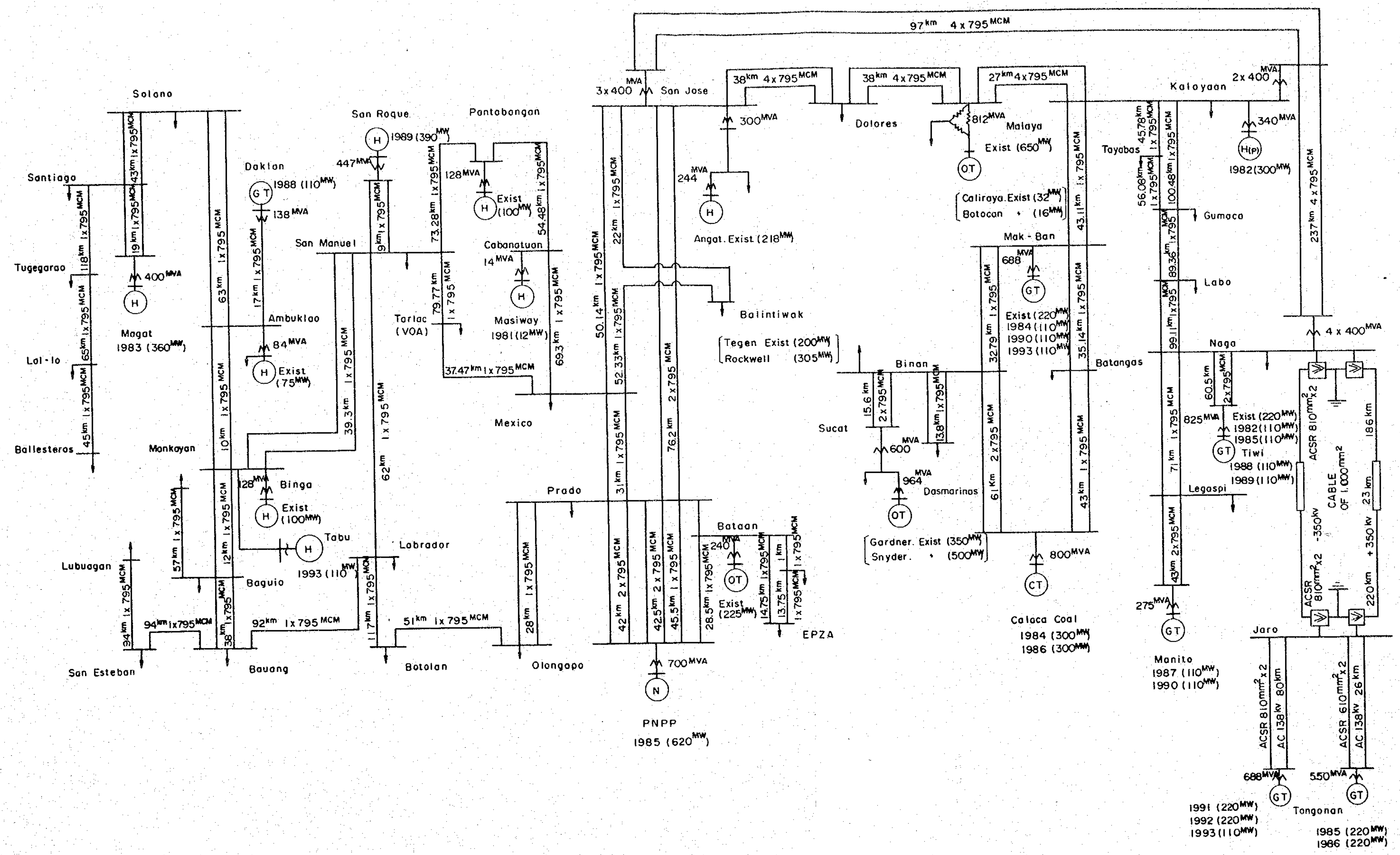


Table 7-1.(1) Bulk Substation Forecasted Load (NAPOCOR Area)

(MW)

Substations	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Ballesteros										9.5	10	10.5	11	12	13	14	14
San Estaban	-	-	30	37	43	49	56	64	72	82	93	96	102	109	116	123	132
Bauang		43	22	24	25	27	29	41	44	52	66	81	86	92	98	104	111
Baguio		65	70	77	78	83	91	98	102	108	110	111	117	124	132	141	150
Ambukiao *(Beckel)		30	30														
Mankayan	-	-	-	41	48	50	53	53	54	56	58	58	62	66	70	75	80
Lubagan	-	-	9	9	9	9	10	12	15	20	25	37	40	42	45	48	51
Lal-Lo	-	-	-	3	4	4	4	5	5	5	6	6	6	7	7	8	8
Tuguegarao	-	-	9	10	13	15	19	23	25	16	16	14	15	16	17	18	19
Santiago	-	-	13	17	17	19	20	18	19	21	22	24	26	27	29	31	33
Solano	-	-	1	2	3	3	3	3	6	8	9	11	12	12	13	14	15
San Manuel		48	51	35	36	39	42	43	42	44	46	49	52	56	59	63	67
Labrador		-		22	25	27	30	33	36	40	44	49	52	56	59	63	67
Botolan		-	9	10	12	14	15	16	17	18	18	19	20	22	23	24	26
Olongapo		93	91	93	94	95	101	102	104	105	106	108	115	122	131	139	148
Prado		24	24	25	26	28	29	31	33	34	36	38	41	43	46	49	52
BTPP		32	33	34	35	36	37	39	40	41	43	44	47	50	53	57	60
EPZA		20	23	27	31	34	36	38	40	41	44	45	48	51	55	58	62
Mexico		83	88	92	94	100	104	111	116	123	131	139	148	158	168	179	191

Table 7-1.(2) Bulk Substation Forecasted Load (NAPOCOR Area)

(MW)

Substations	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Terlac		28	29	30	31	33	34	36	38	40	42	44	47	50	53	57	60
Cabanatuan		36	41	46	50	57	66	76	89	105	123	146	155	166	177	188	200
Angat (34.5 kW)		36	-	-	-												
San Jose (34.5 kV)		40	42	43	45	47	49	50	57	54	56	58	62	66	70	75	80
Kalayaan		-	-	15	16	17	19	20	22	23	25	27	29	31	33	35	37
Caliraya		7	10	-	-	-											
Mak-Ban		18	19	20	21	23	24	25	27	39	32	35	37	40	42	45	48
Dasmarinas		20	23	25	28	30	32	36	39	43	45	50	53	56	60	64	69
Batangas		42	45	49	50	54	58	61	66	72	81	90	96	102	109	116	123
Gumaca		6	7	8	9	9	10	11	12	13	15	15	16	17	18	19	21
Labo		4	4	7	9	9	10	10	11	11	12	12	13	14	15	15	17
Naga		17	18	20	21	23	26	29	31	34	36	40	44	45	48	51	55
Lagaspi		20	22	24	26	24	27	29	32	34	37	41	44	46	50	53	56
NAPOCOR Total		699	763	845	899	958	1034	1113	1189	1282.5	1387	1497.5	1595	11698	1809	1926	2052

Table 7-2 Bulk Substation Forecasted Load (MERALCO Area)

(MW)

Substation \ Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total Load	2100	2240	2400	2565	2745	2940	3145	3365	3600	3850	4120	4390	4670	4975	5300	5645
NAPOCOR Load	699	763	845	899	958	1034	1113	1189	1282.5	1387	1497.5	1595	1698	1809	1926	2052
MECO Load	1401	1477	1555	1666	1787	1906	2032	2176	2317.5	2463	2622.5	2795	2972	3166	3374	3593
Sucat group Balibago, Calauan Cardner, Malibay Rockwell, Taguig	505	529	551	591	631	669	713	760	808	861	921	981	1045	1118	1185	1262
San Jose group Balintawak, Bocaue Malinta, N-Port Novaliches, Sta Mesa Tegen	630	672	709	762	819	875	934	1006	1070.5	1136	1202.5	1283	1362	1446	1548	1648
Dolores group Dolores, Marikina Rosario, St. Antony Teresa	235	244	257	272	293	313	331	350	373	396	424	451	480	512	545	580
Malaya group Malaya, Botocan	31	32	33	36	38	43	47	53	58	62	66	71	75	80	85	91
Toyabas	-	-	5	5	6	6	7	7	8	8	9	9	10	10	11	12

7.1.2 Calculation Conditions

(1) Power Flow Calculation

- Voltage, to satisfy requirement of 100 5% in each bus
- Generator, not exceeding its specified power factor
- To be within limit of specified thermal capacity for transmittion line and transformer

(2) Short-Circuit Capacity

- Transient reactance (Xd') is used as generator reactance.
- Load and back impedance in the DC system are assumed to be infinite.

(3) Stability

1) Protective conditions against fault

- One circuit 3LG of EHV 500 kV-designed line at the inverter station (NAGA)
- Fault clearing time : 0.1 sec. (6 Hz)
- DC system block - deblock (300 ms)
- No high-speed reclosing

2) Conditions for stable operation

- Swing curve of all generators, to show a damping tendency
- DC system, to be kept free from hunting
- No large fluctuation of voltage and frequency after fault cleared.

Refer to Fig. 7.1 for power plant generating capacity, substation capacity and line length and Fig. 7.2 for inpedance map of Luzon grid.

7.2 Calculation Results

7.2.1 Year 1986

Peak power flow and short-circuit capacity in the year 1986 are shown in Fig. 7.3 and Table 7.4 respectively. No problems involved in both thermal capacity and breaking capacity.

In the meantime, the calculation result on stability at grounding fault on 3-phases in one circuit of EHV 500 kV-designed transmission line between Kalayaan and Naga assures sufficient stability as shown in Fig. 7.5.

Although the HVDC system may block its operation during the time of failure due to drop of AC voltage, it would resume operation to its original capacity of 400 MW upon reinstatement of AC voltage after fault cleared.

From the result above, it is fully assured that by 1986 the EHV 500 kV transmission line will be able to serve well even if operated at 230 kV. Incidentally, since frequency at Leyte geothermal power plants may be apt to rise up largely during restriction upon the transmittion power of the HVDC system at

Fig. 7-2 Impedance Map In 1993

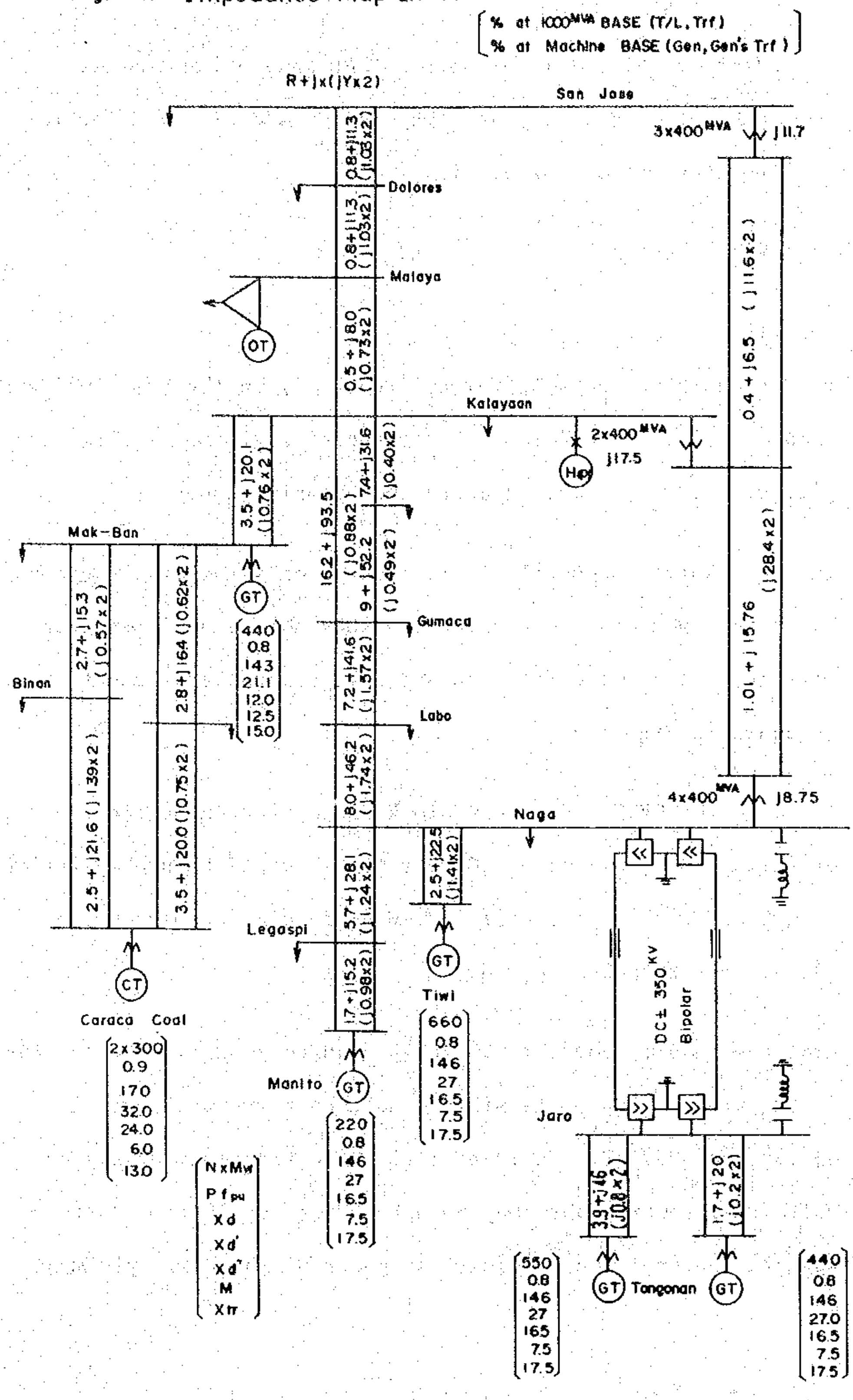


Fig. 7-3 Peak Power Flow In 1986

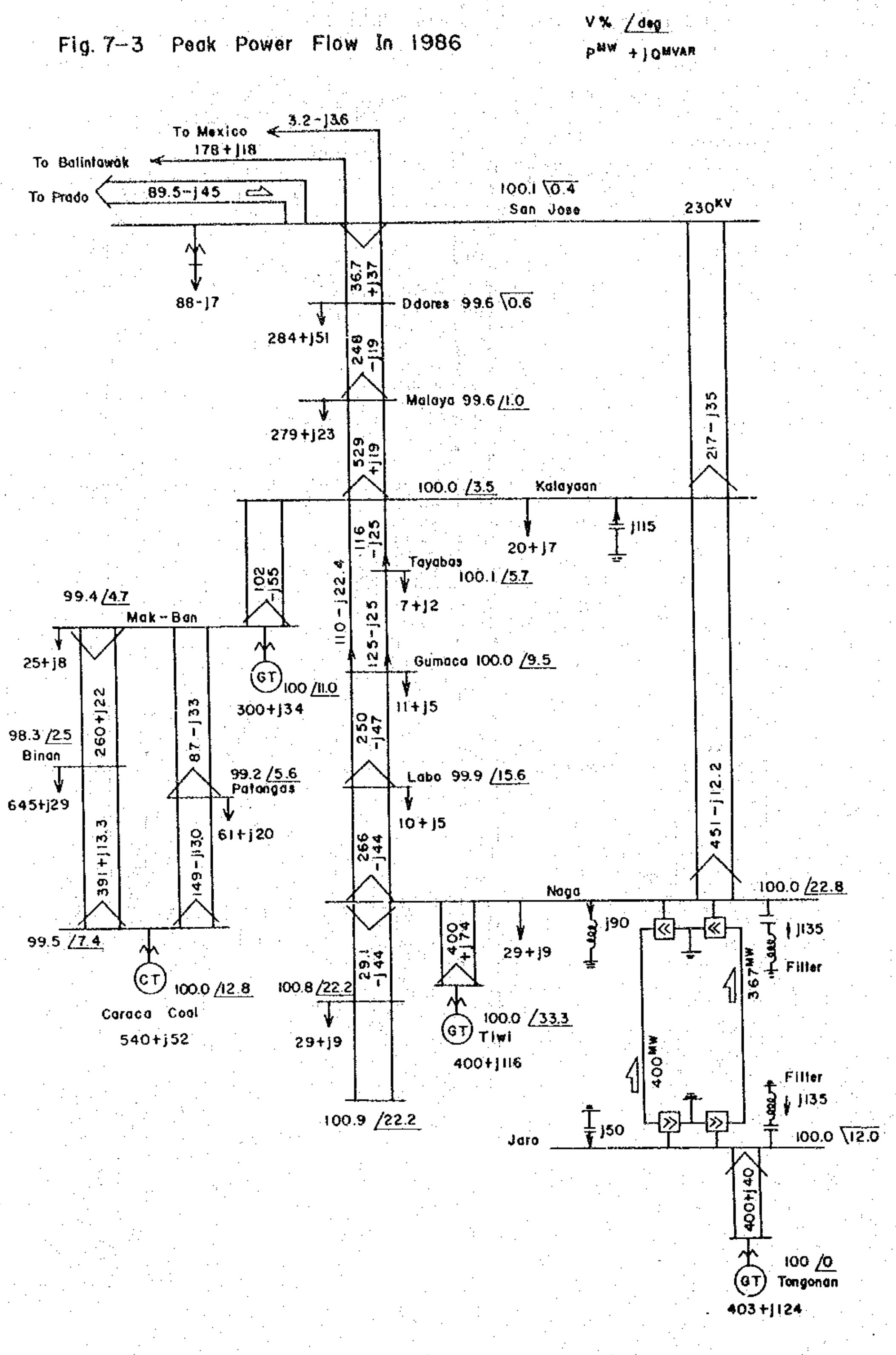


Fig. 7-4 Short Circuit Current In 1986 (A)

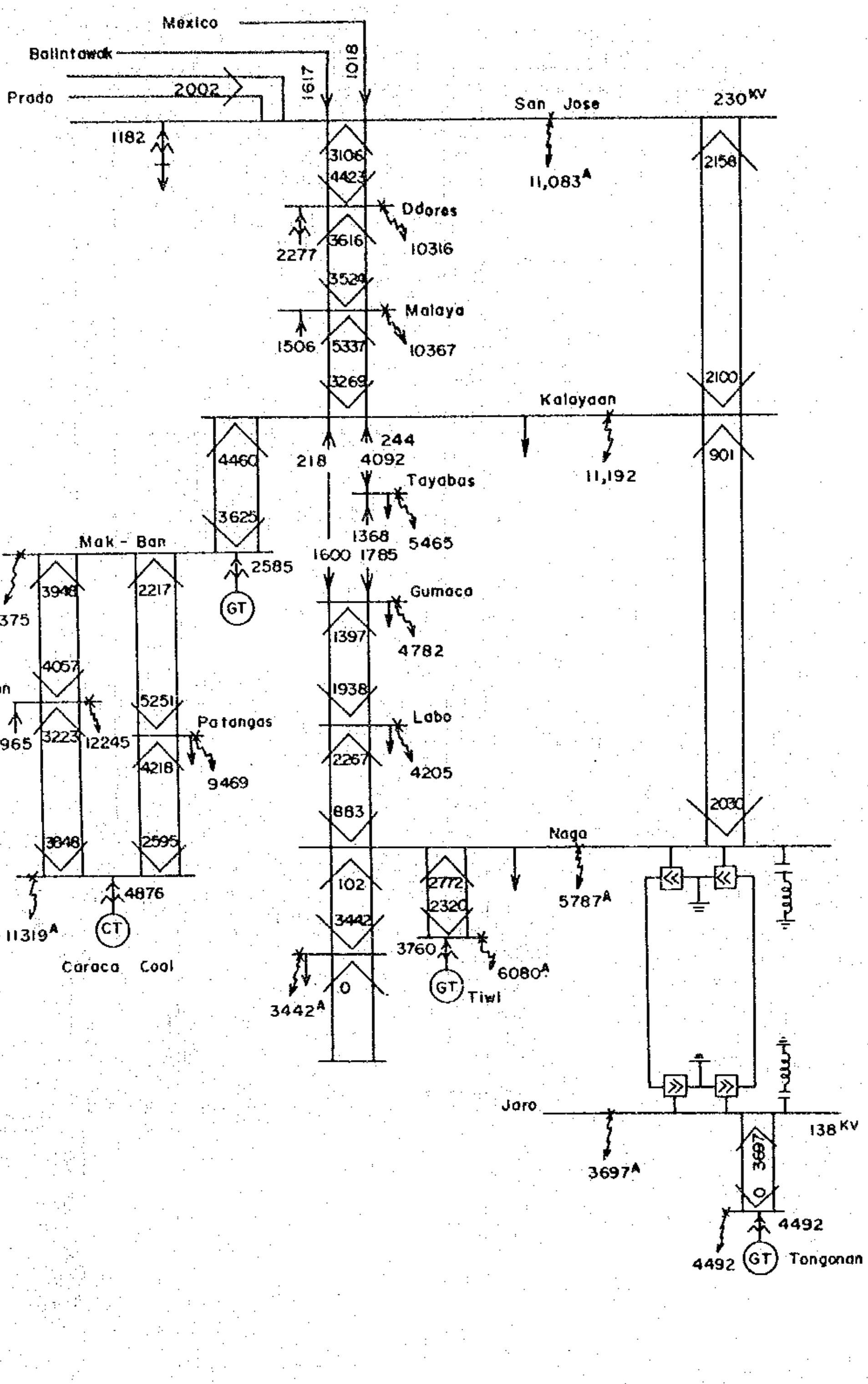


Table 7-3 Capacity of Phase Modifire at C/S MVA
(Filter MVA)

Approx. value*

Site \ Year	1986	1991	1993
Naga C/S	(135) Filter -90 (Reactor)	(225) -50 (Reactor)	(225) 150 (Condenser)
Jaro C/S	(135)	(225)	(225)
Tongonan Pf = 0.9	50	80	100
Pf = 0.95	90	140	180

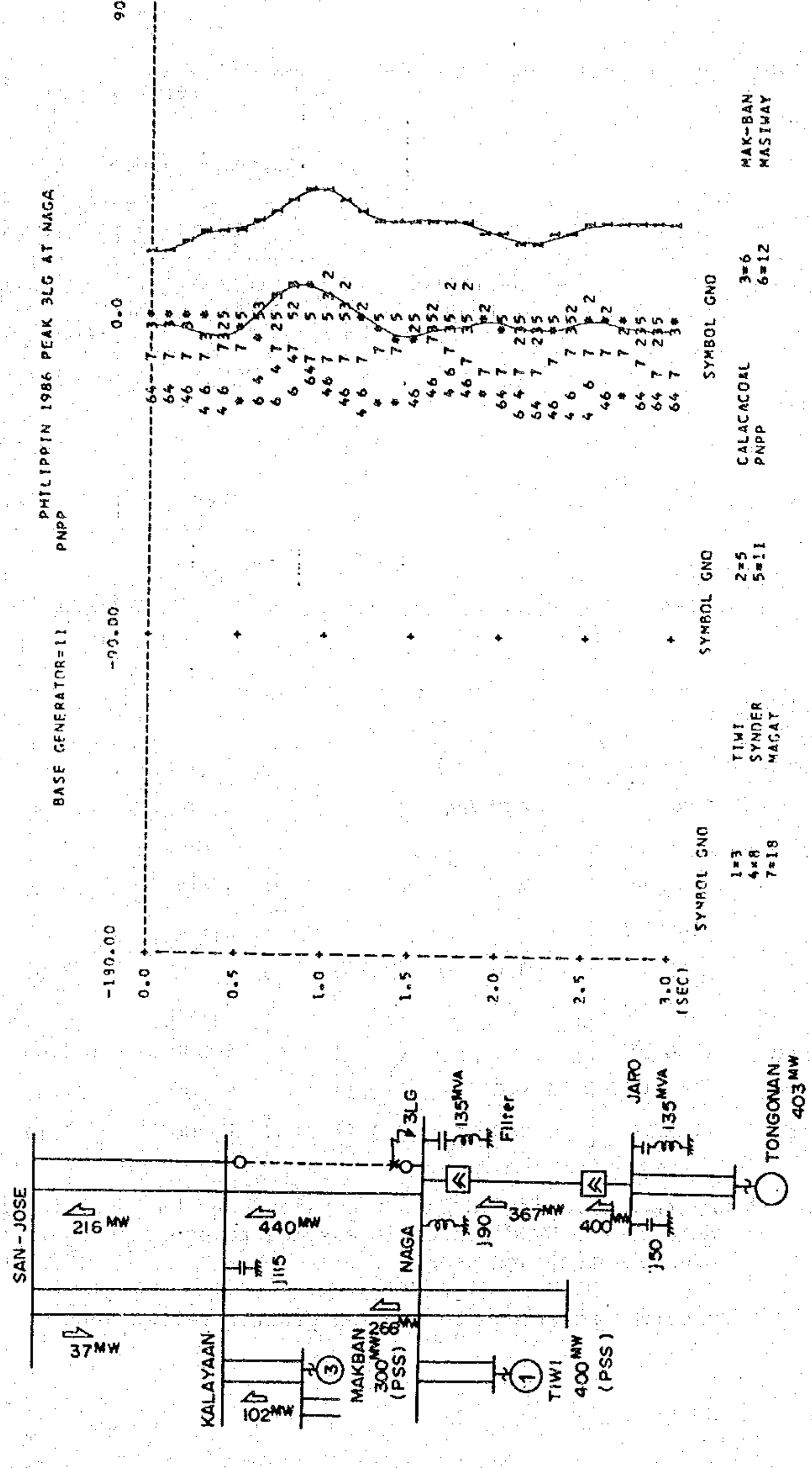
Table 7-4 Short-circuit Capacity at Majar C/S MVA (KA)**

Site \ Year		1986		1993	
San Jose	500 kV	-		5,000 MVA	(5.8 KA)
"	230 kV	4,400 MVA	(11.0 KA)	5,100	(12.8)
Kalayaan	500 kV	-		5,000	(5.8)
"	230 kV	4,500	(11.3)	5,000	(12.6)
Naga	500 kV	-		3,600	(4.2)
"	230 kV	2,300	(5.8)	3,600	(9.0)
Mak-Ban	230 kV	4,900	(12.3)	5,200	(13.1)
Binan	230 kV	4,900	(12.3)	5,000	(12.6)
Rockwell	115 kV	4,400	(22.1)	4,500	(22.6)
Jaro	138 kV	900	(3.7)	1,900	(8.1)

Note: * Required capacity in Jaro C/S will change by power factor of Tongonan P/S HVDC System is assumed to operate under rated power at night and peak.

** Transient reactance is used as generator reactance.

Fig. 7-5 Stability In 1986 (HVDC)



the time of fault, it is necessary to provide coordinated control between the Leyte power plants and HVDC system by such way possible as putting the HVDC system into overload operation for a few seconds after recovery from fault.

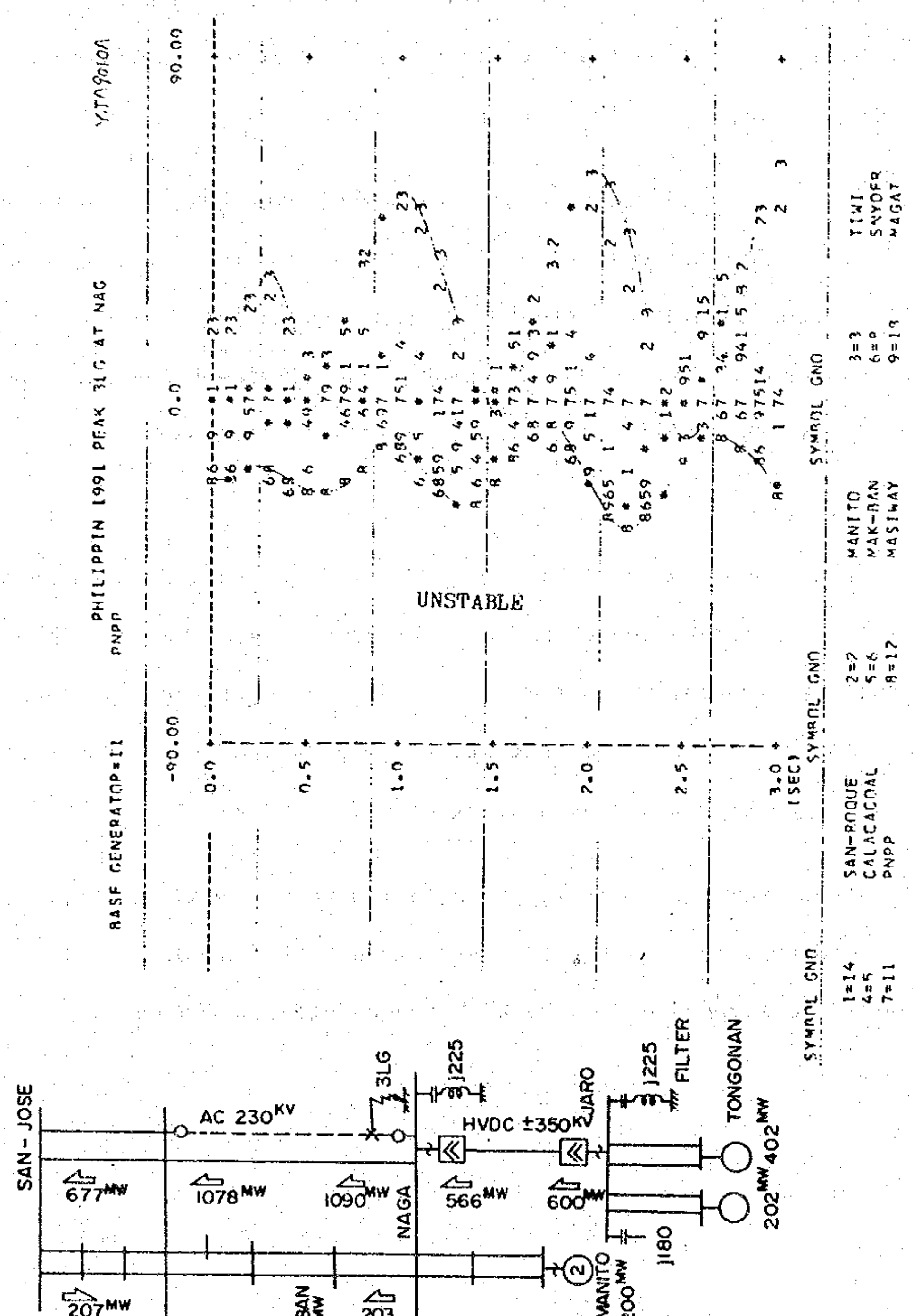
Besides the above requirement, it is advisable that in order to ensure stabilized operation of the Luzon grid the power system stabilizer should be introduced, from this target year on, into each proposed power plant of Calaca Coal, Tiwi and Mak-ban. No power system stabilizer will be required at Tongonan.

7.2.2 Year 1991

It is planned that by 1991 the HVDC system transmission capacity will be increased to 900 MW (±350 kV in bipole). In fact, however, since the generating capacity to be developed at the Leyte geothermal power source is estimated at 660 MW, the real HVDC transmission power will be at a level of 600 MW or so.

As noted from the stability calculation result shown in Fig. 7.6, it is necessary that the 500 kV-designed EHV transmission line should be stepped up to 500 kV between Kalayaan and Naga.

Fig. 7-6 Stability In 1991
(EHV 230kv Operation)



7.2.3 Year 1993

Fig. 7.7 shows the future power flow map envisaging 900 MW transmission through the HVDC system in 1993. The calculation result at 3-phase fault on one circuit of the EVH 500 kV transmission line between Kalayaan and Naga suggests that stability will be assured by installation of the power system stabilizer at Manito in addition to Calaca Coal, Tiwi and Mak-Ban.

Such power system stabilizer will not be required, for Tongonan as it will be operated almost indpendently.

Fig. 7-7 Peak Power Flow In 1993

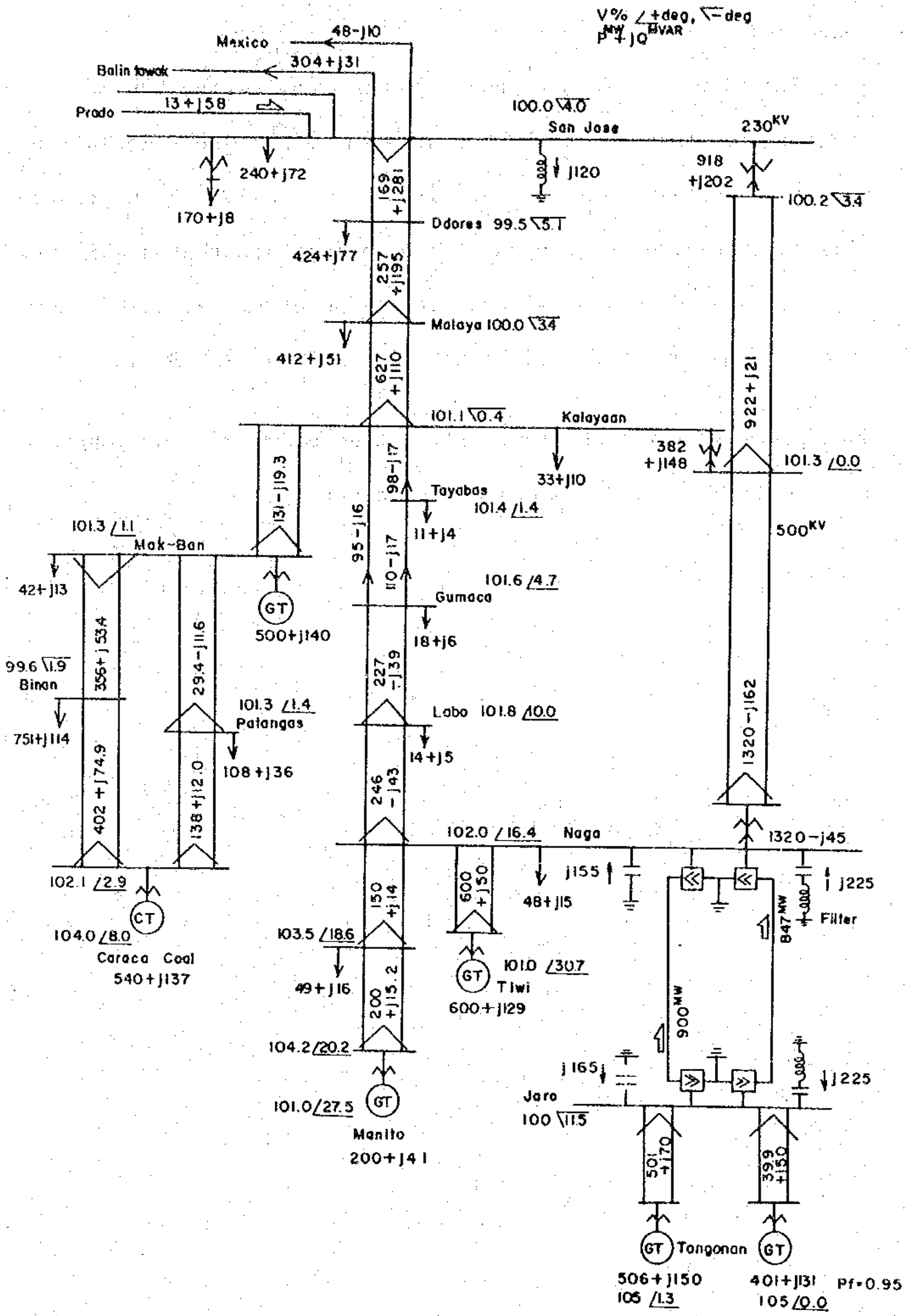


Fig. 7-8 Short Circuit Current In 1993 (A)

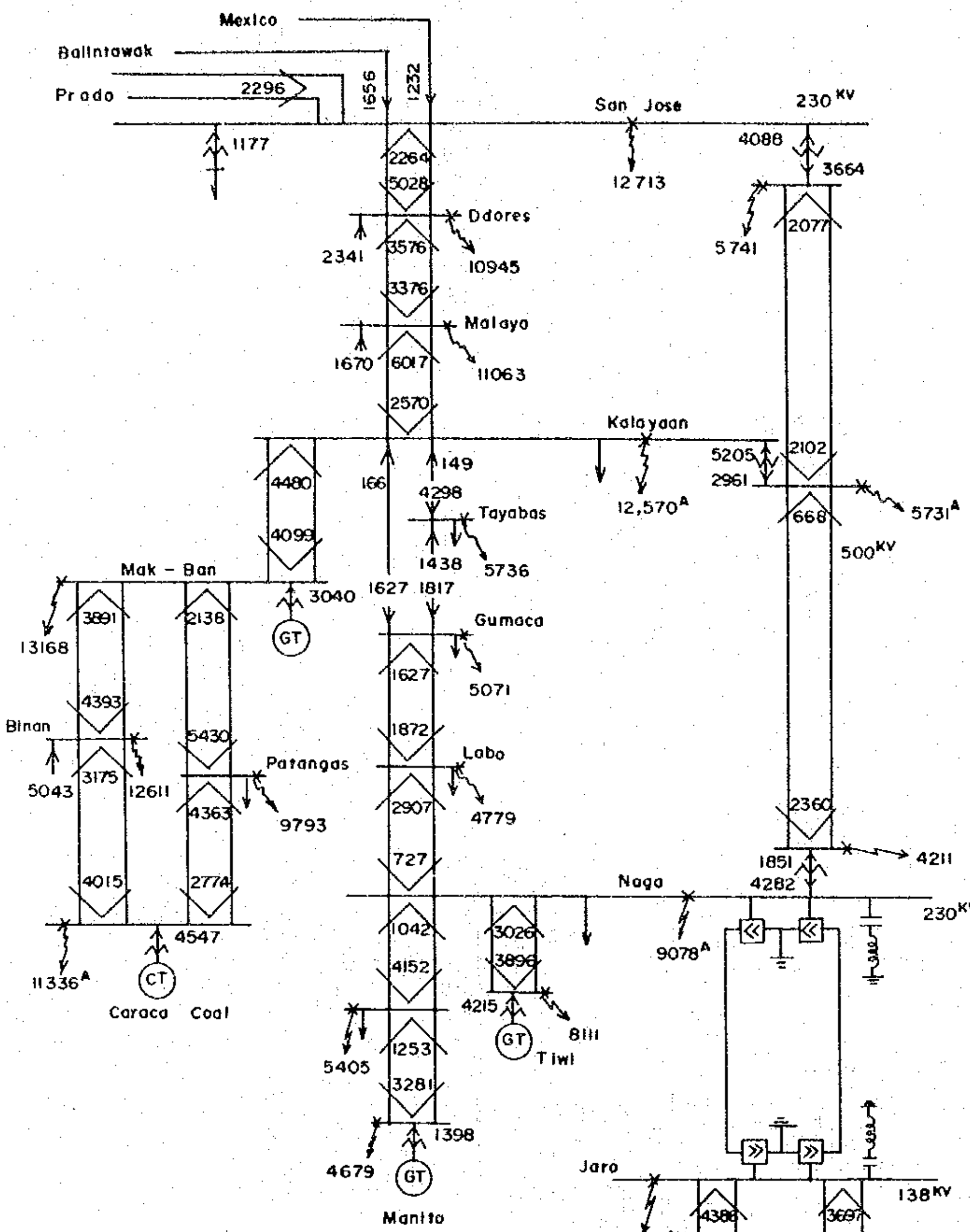
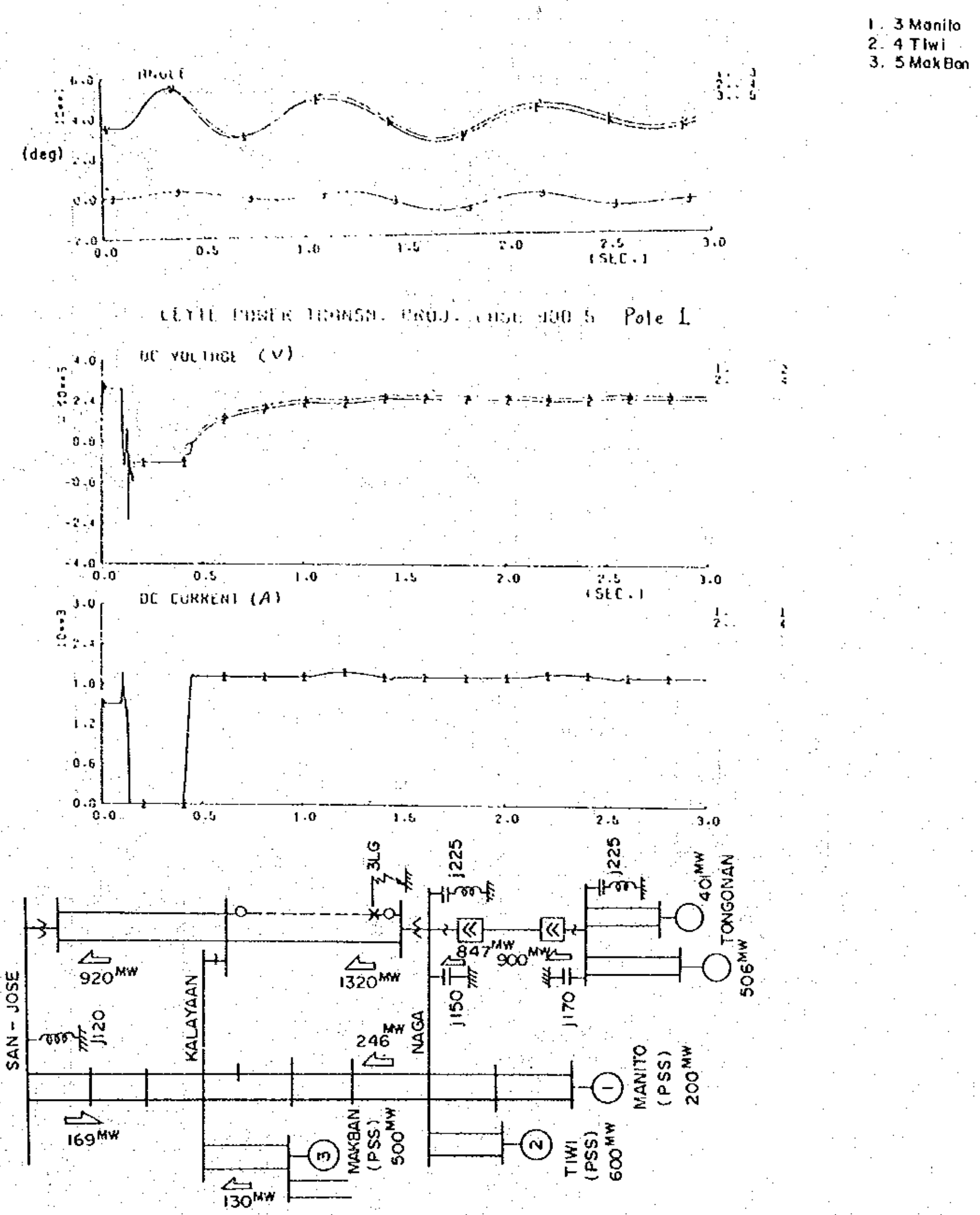


Fig. 7-9 Stability In 1993 (HVDC)



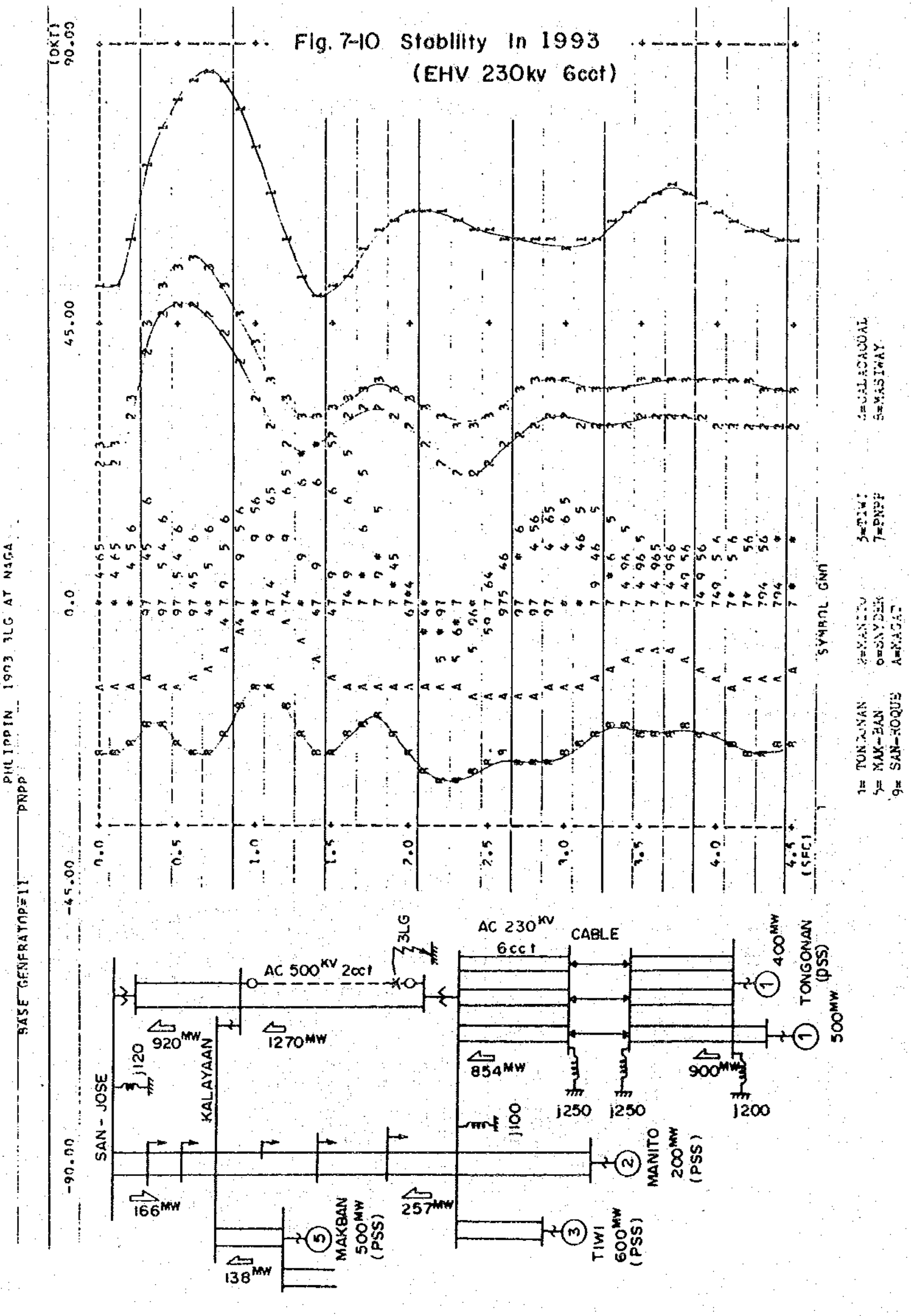


Fig. 7-10 Stability In 1993 (EHV 230kv 6cct)

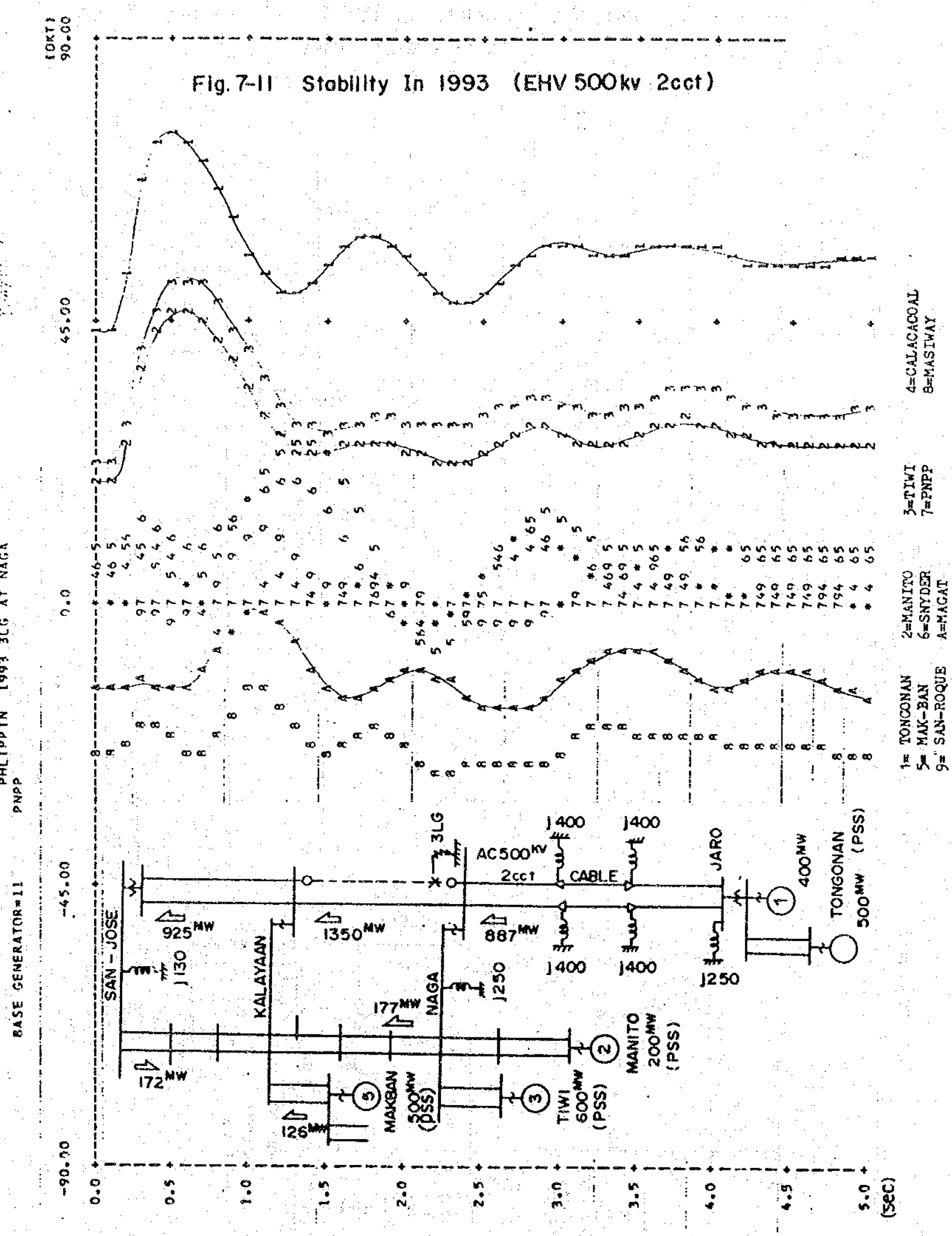


Fig. 7-11 Stability In 1993 (EHV 500kv 2cct)

7.3 Summary and Conclusion

(1) The 400 MW Transmission by the Leyte HVDC system at the first stage toward 1986 is entirely feasible without any difficulty under the system constitution as proposed by NAPOCOR Plan. The EHV 500 kV-designed transmission line of San Jose - Kalayaan - Naga linkage can serve well even at operating voltage of 230 kV.

(2) At the time of 600 MW transmission in 1991 at the 2nd stage, total transmission power from the southern part of Luzon to Kalayaan and San Jose will reach about 1400 MW on the generating side, including 660 MW at Tiwi and 220 MW at Manito together with 660 MW from the Leyte geothermal power plants. Therefore, in view of total system stability, it is considered necessary that the designed voltage of the transmission line should be stepped up to 500 kV operating voltage by 1991.

(3) To improve stability of Tiwi, Manito and other power generating plants, it is adivsable that by 1986 the power system stabilizer should be provided for each generating unit at Twiwi, Manito, Mak-Ban and Calaca Coal. Especially, Tiwi and Manito generating sources, at least, scheduled for initial operation in the near future should require installation of the ultra rapid response AVR with the power system stabilizer.

(4) It is recommended that main new power plants, in addition to Tiwi, Manito and Mak-Ban, which are scheduled for future commercial operation, should preferably be provided with power system stabilizers. If power system stabilizers can be installed at the beginning of plant construction, their merit is that they can serve effectively for significant improvement of stability, in addition to the fact that such installation cost is nearly neglegible as compared with the cost for the main part of generator. However, since Tongonan can be regarded as the independent generation source for the time being, the plant will not require installation of the power system stabilizer.

(5) Control for the HVDC system at normal and abnormal operation will require full coordination with the Leyte geothermal power source, so that any fluctuation of frequency and voltage in the Leyte-Samar system will be acceptable to the Leyte geothermal power plant. Because of such requirement, study must be made, at the detailed design stage, for full coordination with performance characteristics of AVR, governor and protective device of the Leyte geothermal power plants.

(6) System design should be considered so as to enable interconnection of both Leyte-Samar system and HVDC system at Tongonan Switch Yard. By this arrangement the running reserve

capacity will be jointly made available by both Luzon grid and Leyte-Samar grid, so that surplus geothermal power in the Leyte-Samar system can be utilized effectively (for transmission to Luzon grid).

(7) Whether oil-fired power plants existing in Manila and its environs should remain in operation or should be abolished must be decided after extensive study to determine their serviceability as the reserve capacity to be required in case of forced or scheduled outage of large power generating units of nuclear (620 MW) and coal-firing (300 MW) and the Leyte HVDC system and also after full review of power flow and voltage conditions at normal or abnormal operation of the power system. It is considered necessary, however, that those oil-fired power plants should still be operated appropriately, for the 115 kV transmission system in particular, as countermeasures against any possible overload and voltage drop until drastic measures will have been completed for the 115 kV system.

(8) Short-circuit capacity for the Luzon, Leyte and Samar EHV systems is estimated at 5,000 MVA at maximum by 1993. Short-circuit capacity for 230 kV Naga Converter Station and 138 kV Jaro Converter Station is estimated at 3,600 MVA and 1,900 MVA respectively, which would not cause any problem at all with regard to breaking capacity.

CHAPTER 8

CONSTRUCTION COST AND SCHEDULE

CHAPTER 8 CONSTRUCTION COST AND SCHEDULE

8.1 Construction Cost

(1) Basic Conditions

i) General

In calculating the construction cost of the Leyte Power Transmission Project, labor charges and prices as of March 1981 were used and considerations were given to the natural and regional conditions of the routes for overhead transmission lines and submarine cables, landing point of the submarine cable, planned cable terminal and electrodes, electrode line route and planned converter station sites.

Out of the construction cost, expenses on items that are available in the Philippines were calculated on Peso basis and the others were calculated in a foreign currency.

ii) Calculation range of construction cost

The construction cost were calculated in the following range. Quantity for each construction phase was calculated based on the preliminary design of the project, and in addition to the direct expenses calculated for contracting, indirect expenses necessary to execute this project were calculated in.

Since the project is divided into the first stage and second stage, execution range was determined and the construction cost was calculated for each period.

a) Calculation Range of Construction Cost

	1st Stage	2nd Stage
- AC 138 KV overhead transmission lines	26 km	80 km
- DC ±350 KV overhead transmission lines	406 km	-
- DC ±350 KV submarine cables	23 km	-
- Converter Station	Installation of Jaro C/S and Naga C/S	Expansion of Jaro C/S and Naga C/S
- Electrodes	Managasnas and Pasacao electrodes	-
- Electrode lines	60 km	-
- Telecommunications equipment	Microwave from Tongonan S/Y to Naga C/S, and others	-

b) Expenses for Electrical Equipment

All converter equipment (converter and telecommunications equipment such as thyristor valves, transformers, filters and switchgears) and transmission line materials (towers, conductors, insulators, submarine cables, electrodes, etc.) shall be manufactured and supplied by foreign countries.

For expenses on these imported items, FOB Japan prices which can be internationally competitive, maritime transportation expenses and insurance fees were calculated into the foreign currency part. The unloading expenses and inland transportation expenses of these items in the Philippines and expenses on materials and installation that are obtainable in the country were calculated in the domestic currency.

The submarine cables, converter station equipment, electrodes and telecommunications equipment shall be supplied with installation and test. Expenses necessary for the installation and test such as expenses acrued in obtaining services of foreign country manufacturers' engineers, design expenses of special structures (valve halls, control rooms, etc.), and special materials for them, were calculated in the foreign currency part. Expenses on land formation and buildings were calculated into the domestic currency.

c) Temporary Facility and Others

Expenses for temporary buildings needed for construction management of this project and vehicles were calculated in the domestic currency.

d) Engineering and Administrative Expenses

On these expenses, expenses for detailed design (DS) of this project and supervision (SV) by consultants that would be forthcoming were calculated in the foreign currency part. Expenses needed for construction management by NAPOCOR were calculated into the domestic currency. Expenses necessary for detailed surveys of submarine cables and electrode sites required for detailed design (DS) were calculated in the foreign currency part.

e) Training Cost

Expenses required for training of NAPOCOR engineers on the operation and management of HVDC system were calculated in the foreign currency part.

f) Contingency

An amount equivalent to 5% of the foreign currency and 15% of the domestic currency for the DC ±350 KV transmission lines (inclusive of submarine cables), AC 138 KV overhead transmission lines, converter stations, electrodes, electrode lines and telecommunications equipment is added as contingency.

g) Interest During the Construction

Interest rates of 3% per annum and 10% per annum are calculated into the foreign currency and Pesos respectively as the interests of the fund needed for execution of this project.

h) Escalation of Construction Cost

Escalation as outlined in the following was calculated to the foreign and domestic currency to the direct construction expenses of 1981, based on agreement with NAPOCOR in estimating the construction cost of this project:

Year	Foreign Currency	Domestic Currency
1981	10%	15%
1982	9%	15%
1983	8%	15%
1984	7%	15%
1985	7%	15%
1986 onward	the same	the same

(2) Total Construction Cost and Construction Cost by Year

The total construction cost was calculated based on the construction schedule, implementation plan and estimation conditions of construction cost of the first and second stage. The total construction cost based on 1981 prices is shown below:

(Unit: US$1,000)

	Foreign Currency	Domestic Currency	Total
First stage	185,365	67,502	252,867
Second stage	86,923	21,795	108,718
Total	272,288	89,297	361,585

4 years and 3 years are scheduled for the first and second stage of this project, and the total construction cost was distributed (as shown in Tables 8-1 and 8-2) assuming the following payment terms for the foreign currency and domestic currency.

	At the time of			
	Contract	FOB	Arrival	Completion
Foreign Currency				
Overhead lines and materials & equipment for electrode lines	10%	60%	30%	-
Submarine cables and electrodes	10%	60%	-	30%
Converter and telecommunications equipment	10%	80%	-	10%
Domestic Currency				
Materials and labor costs	Work accomplished basis			

Table 8-1 Fund Requirement at First Stage

Unit : 1,000 U.S. Dollars

Item	1982			1983			1984			1985			Construction cost		
	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total
A. Convertor stations															
Naga Station															
DC equipment	—	—	—	3,224	0	3,224	25,786	0	25,786	3,224	0	3,224	32,234	0	32,234
AC equipment	—	—	—	400	0	400	3,186	0	3,186	400	0	400	3,986	0	3,986
Civil works & building	—	—	—	124	1,567	1,691	862	3,119	3,981	0	1,071	1,071	986	5,757	6,743
Installation & others	—	—	—	29	29	58	1,657	1,276	2,933	1,043	471	1,514	2,729	1,776	4,505
Jaro Station															
DC equipment	—	—	—	3,162	0	3,162	25,286	0	25,286	3,162	0	3,162	31,610	0	31,610
AC equipment	—	—	—	214	0	214	1,714	0	1,714	214	0	214	2,142	0	2,142
Civil works & building	—	—	—	133	1,790	1,923	862	3,214	4,076	0	1,271	1,271	995	6,275	7,270
Installation & others	—	—	—	29	29	58	1,676	1,314	2,990	1,076	495	1,571	2,781	1,838	4,619
Sub-total				7,315	3,415	10,730	61,029	8,923	69,952	9,119	3,308	12,427	77,463	15,646	93,109
B. Transmission lines															
DC line															
DC 350 kV overhead line															
Materials	—	—	—	8,207	0	8,207	29,102	0	29,102	3,954	0	3,954	41,263	0	41,263
Installation	—	—	—	432	3,467	3,899	1,722	18,881	20,603	256	5,190	5,446	2,410	27,538	29,948
DC 350 kV submarine cable															
Materials	—	—	—	2,800	0	2,800	16,803		16,803	8,487	0	8,487	28,090	0	28,090
Installation	—	—	—	148	0	148	883	381	1,264	442	143	585	1,473	524	1,997
AC 138 kV line															
Materials	—	—	—	390	0	390	3,492	0	3,492	0	0	0	3,882	0	3,882
Installation	—	—	—	20	0	20	184	1,000	1,184	0	1,005	1,005	204	2,005	2,209
Electrode & electrode lines	—	—	—	286	0	286	1,210	999	2,209	348	538	886	1,884	1,537	3,381
Sub-total				12,283	3,467	15,750	53,396	21,261	74,657	13,487	6,876	20,363	79,166	31,604	110,770
C. Telecommunication facility	—	—	—	606	73	679	1,843	66	1,909	3,013	590	3,603	5,462	729	6,191
D. Temporary facility & others					271	271		271	271		267	267		809	809
Direct cost (A+B+C+D)				20,204	7,226	27,430	116,268	30,521	146,789	25,619	11,041	36,660	162,091	48,788	210,879
E. Contingency				1,010	1,084	2,094	5,813	4,578	10,391	1,281	1,656	2,937	8,104	7,318	15,422
F. Engineering & adm. costs	2,152	100	2,252	1,400	952	2,352	1,780	952	2,732	1,752	952	2,704	7,084	2,956	10,040
G. NPC's engineer educational cost	—	—	—	—	—	—	78	0	78	78	0	78	156	0	156
Sub-total	2,152	100	2,252	2,410	2,036	4,446	7,671	5,530	13,201	3,111	2,608	5,719	15,344	10,274	25,618
Total cost (A through G)	2,152	100	2,252	22,614	9,262	31,876	123,939	36,051	159,990	28,730	13,649	42,379	177,435	59,062	236,497
H. Interest during the construction	32	5	37	404	473	877	2,602	2,739	5,341	4,892	5,223	10,115	7,930	8,440	16,370
Indirect cost (E+F+G+H)	2,184	105	2,289	2,814	2,509	5,323	10,273	8,269	18,542	8,003	7,831	15,834	23,274	18,714	41,988
I. Total construction cost in 1981 price	2,184	105	2,289	23,018	9,735	32,753	126,541	38,790	165,331	33,622	18,872	52,494	185,365	67,502	252,867
J. Escalation	269	21	290	5,041	3,651	8,692	39,101	22,537	61,638	13,482	15,456	28,938	57,893	41,665	99,558
K. Total cost required (I+J)	2,453	126	2,579	28,059	13,386	41,445	165,642	61,327	226,969	47,104	34,328	81,432	243,258	109,167	352,425

Table 8-2 Fund Requirement at Second Stage

Unit : 1,000 U.S. Dollars

Item	1988			1989			1990			Construction cost			Total (1st & 2nd)		
	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total	F.C.	D.C.	Total
A. Convertor stations															
Naga Station															
DC equipment	2,519	0	2,519	20,176	0	20,176	2,519	0	2,519	25,214	0	25,214	57,448	0	57,448
AC equipment	424	0	424	3,419	0	3,419	424	0	424	4,267	0	4,267	8,253	0	8,253
Civil works & building	19	76	95	1,048	2,428	3,476	0	214	214	1,067	2,718	3,785	2,053	8,475	10,528
Installation & others	14	9	23	1,376	1,086	2,462	852	367	1,219	2,242	1,462	3,704	4,971	3,238	8,209
Jaro Station															
DC equipment	2,495	0	2,495	19,967	0	19,967	2,495	0	2,495	24,957	0	24,957	56,567	0	56,567
AC equipment	124	0	124	976	0	976	124	0	124	1,224	0	1,224	3,366	0	3,366
Civil works & building	19	76	95	1,048	2,352	3,400	0	214	214	1,067	2,642	3,709	2,062	8,917	10,979
Installation & others	14	9	23	1,352	1,105	2,457	857	367	1,224	2,223	1,481	3,704	5,004	3,319	8,323
Sub-total	5,628	170	5,798	49,362	6,971	56,333	7,271	1,162	8,433	62,261	8,303	70,564	139,724	23,949	163,673
B. Transmission lines															
DC line															
DC 350 kV overhead line															
Materials	—	—	—	—	—	—	—	—	—	—	—	—	41,263	0	41,263
Installation	—	—	—	—	—	—	—	—	—	—	—	—	2,410	27,538	29,948
DC 350 kV submarine cable															
Materials	—	—	—	—	—	—	—	—	—	—	—	—	28,090	0	28,090
Installation	—	—	—	—	—	—	—	—	—	—	—	—	1,473	524	1,997
AC 138 kV line															
Materials	1,371	—	1,371	8,234	0	8,234	4,113	0	4,113	13,718	0	13,718	17,600	0	17,600
Installation	72	—	72	433	2,834	3,267	216	4,254	4,470	721	7,088	7,809	925	9,093	10,018
Electrode & electorde lines	—	—	—	—	—	—	—	—	—	—	—	—	1,844	1,537	3,381
Sub-total	1,443	0	1,443	8,667	2,834	11,501	4,329	4,254	8,583	14,439	7,088	21,527	93,605	38,692	132,297
C. Telecommunication facility	—	—	—	—	—	—	—	—	—	—	—	—	5,462	792	6,191
D. Temporary facility & others	—	71	71	—	71	71	—	67	67	0	209	209	0	1,018	1,018
Direct cost (A+B+C+D)	7,071	241	7,312	58,029	9,876	67,905	11,600	5,483	17,083	76,700	15,600	92,300	238,791	64,388	303,179
E. Contingency	354	36	390	2,901	1,482	4,383	580	822	1,402	3,835	2,340	6,175	11,939	9,658	21,597
F. Engineering & adm. costs	961	576	1,537	890	476	1,366	876	476	1,352	2,727	1,528	4,255	9,811	4,484	14,295
G. NPC's engineer educational cost	—	—	—	26	0	26	26	0	26	52	0	52	208	0	208
Sub-total	1,315	612	1,927	3,817	1,958	5,775	1,482	1,298	2,780	6,614	3,868	10,482	21,958	14,142	36,100
Total cost (A through G)	8,386	853	9,239	61,846	11,834	73,680	13,082	6,781	19,863	83,314	19,468	102,782	260,749	78,530	339,279
H. Interest during the construction	126	43	169	1,180	677	1,857	2,303	1,607	3,910	3,609	2,327	5,936	11,539	10,767	22,306
Indirect cost (E+F+G+H)	1,441	655	2,096	4,997	2,635	7,632	3,785	2,905	6,690	10,223	6,195	16,418	33,497	24,909	58,406
I. Total construction cost in 1981 prices	8,512	896	9,408	63,026	12,511	75,537	15,385	8,388	23,773	86,923	21,795	108,718	272,288	89,297	361,585
J. Escalation	6,103	1,582	7,685	52,753	27,286	80,039	14,847	22,295	37,142	73,703	51,163	124,866	131,596	92,828	224,424
K. Total cost required (I+J)	14,615	2,478	17,093	115,779	39,797	155,576	30,232	30,683	60,915	160,626	72,958	233,584	403,884	182,125	586,009

The indirect cost, which mainly consist of engineering fees, administrative expenses, educational expenses, contingency and interest during the construction, are US$41,988,000 for the first stage and US$16,418,000 for the second stage, a total of US$58,406,000, which is 19.3% of the total direct construction expenses.

Assuming that the construction progresses smoothly and the construction for the first period is completed by the end of 1985 and that for the second stage by the end of 1990, increases of 39.4% and 114.9% to the first and second stages respectively by escalation are estimated over the construction cost calculated based on 1981 prices. In other words, the total construction cost in anticipation of the escalation is US$325,425,000 for the first stage and US$233,584,000 for the second stage. These amounts can be broken down to foreign currency and domestic currency as US$243,258,000 and US$109,167,000 for the first stage and US$160,626,000 and US$72,958,000 for the second stage, respectively.

8.2 Construction Schedule

Figs. 8-1 and 8-2 show the first and second stage construction schedules, respectively.

For the purposes of lowering dependency on petroleum and utilization of natural resources, early realization of the project is most desirable, and along with the Tongonan geothermal power generation project, the completion of this project is projected to 1985 for the first stage and 1990 for the second stage.

The construction period, starting from detailed designing and preparation of specifications up to completion of the construction, is determined as 45 months for the first stage and 36 months for the second stage. About 33 months are estimated for construction of the converter stations starting from contracting up to completion of the construction, and during the 33 months designing, manufacturing, transportation, installation and testing on the transmission lines, electrodes, electrode lines and telecommunications equipment must be completed.

The following basic points were taken into consideration when determining the construction schedule.

Fig. 8-1 Schedule Leyte Power Transmission Project (First Stage)

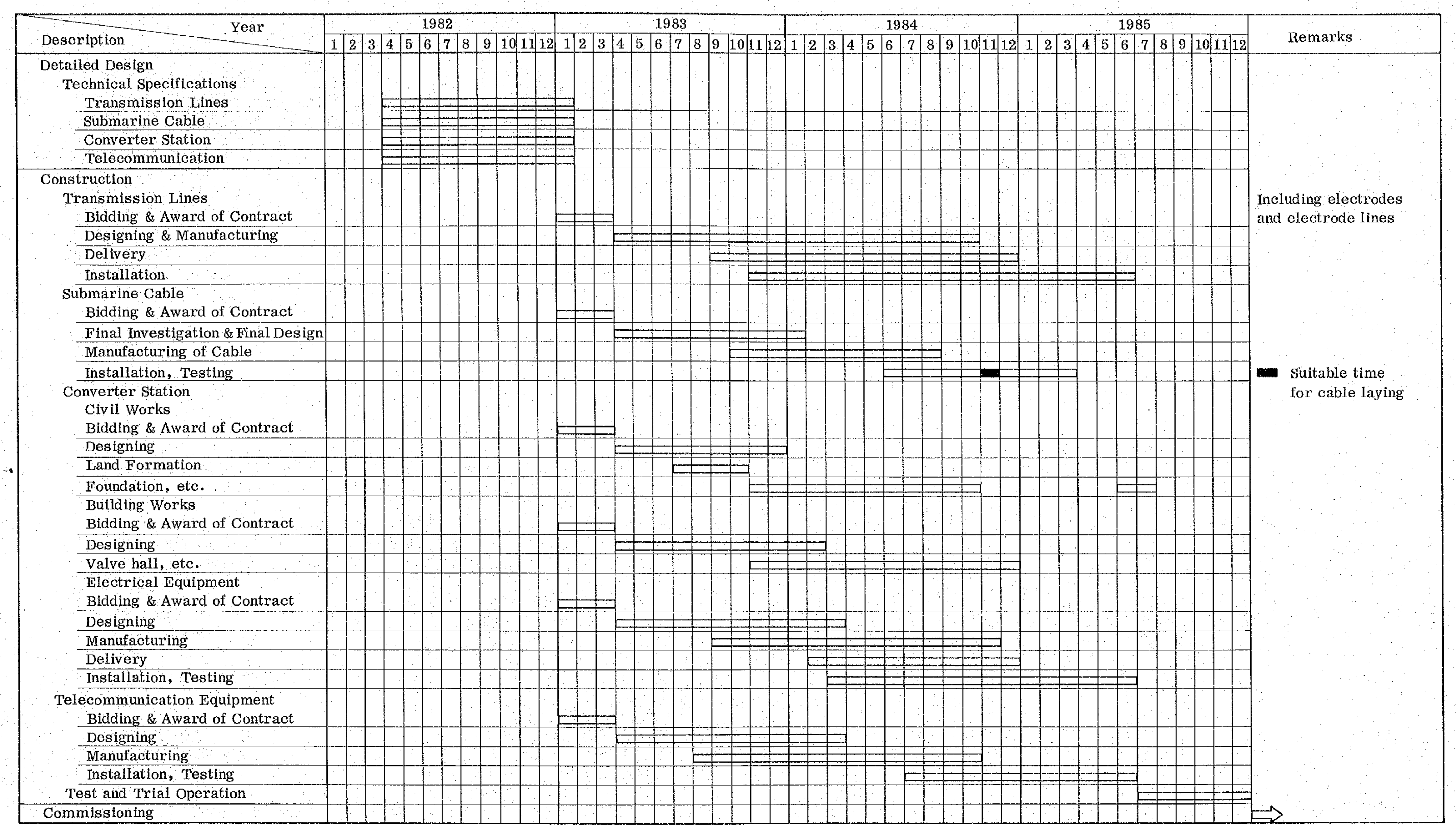
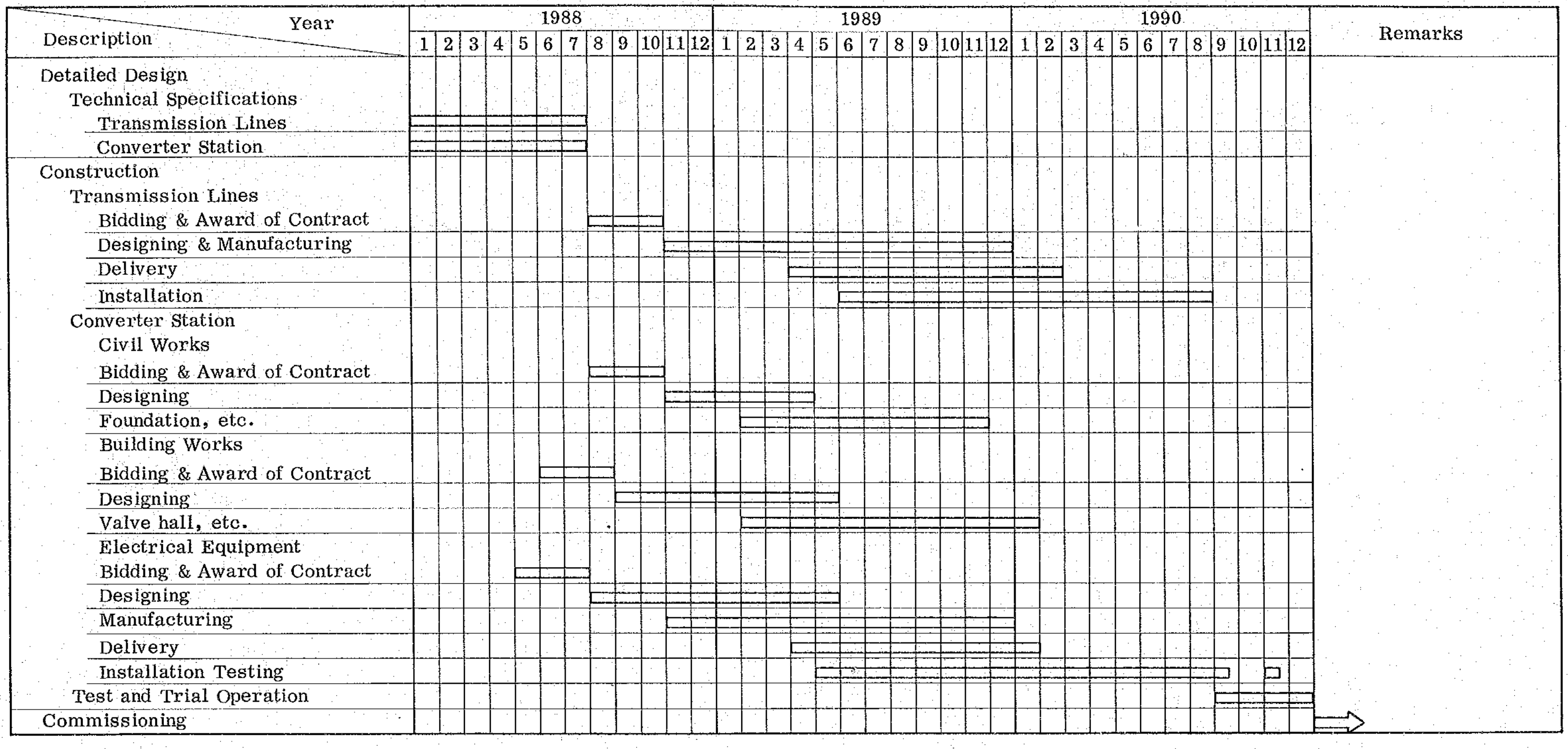


Fig. 8-2 Schedule Leyte Power Transmission Project (Second Stage)



(1) Overhead Transmission Line Installation

During the first stage, overhead transmission lines of AC 138 KV (26 km) and DC ±350 kV (406 km) shall be installed simultaneously.

i) Amount of Work and Construction Schedule

The amount and sections of construction are as shown below.

Construction Section		Amount
AC 138 KV overhead transmission lines	1 section	26 km
DC ±350 KV overhead transmission lines (within the Leyte and Samar islands)	2 sections	218 km
DC ±350 KV overhead transmission lines (within the Luzon island)	2 sections	186 km
DF ±350 KV, crossing the San Juanico strait	1 section	1.7 km

Based on progress of installing about 6 km per month upon study of the construction schedule, it takes about 20 months to complete installing the DC ±350 KV overhead transmission lines including final test within the Leyte and Samar islands.

ii) Transportation Period of Equipment and Materials

Materials for towers, conductors and insulators shall be imported and 2 months are estimated for maritime and overland transportation.

iii) Manufacturing of Steel Tower

About 3 months are needed before the manufacturer starts making the towers after receiving an order. During the 3 months the towers are designed, materials are arranged, a model is built and tests on them are conducted.

The estimated amount of iron for the towers is about 16,000 tons, and the manufacturing period in the factory is about 16 months based on production capacity of average 1,000 tons a month.

(2) Submarine Cable Installation Schedule

As described in the preliminary design clause of Chapter 6, installation of the DC ±350 KV submarine cables is a special work. The final submarine cable route and installation schedule are determined based on detailed geological survey. However, detailed survey on the marine phenomena and sea bottom conditions at the scheduled route of the submarine cables should be conducted beforehand so that basic points of installation route, cable terminal positions and cable types should be predetermined.

1) Field Survey and Final Design

the contractor for the submarine cable shall receive the order based on the NAPOCOR construction specifications, conduct supplementary surveys on the designated cable route and cable terminal location, complete final designs of the installation work and receive approval on the cable test piece from NAPOCOR. The period required for these works is set as 10 months.

The preferable season of the submarine geological survey is from April to June due to the meteorological conditions in the region.

ii) Cable Manufacturing Process

The cables shall be manufactured in a unit length of 1,000 m and connected for the number required for the route lengths.

Since 7 days are needed to make one connection, if two of single core cables are to be installed, the time required in the plant for cable connection is about 7 months.

iii) Cable Installation

Prior to start installing the cable, about 5 months are needed for preparation of the cable landing and cable terminal sites.

November is selected for the installation as the sea phenomena is comparative favorable for the work, and one month is planned for the installation in consideration of trial cruising.

4 months are planned for protection work of the cables, connection to the cable terminal and testing. This makes a total of 10 months for the cable installation work.

(3) Installation of Electrodes and Electrode Lines

As described in the preliminary design clause of Chapter 6, installation of electrodes is a special work, and the final electrode type (on land or in the sea) and electrode site are determined based on detailed surveys of the planned electrode installation site.

However, the detailed surveys of the planned electrode installation site should be conducted beforehand and determination of the electrode type and electrode installation site is made prior to starting the construction work for this project.

The electrode and electrode line works shall be condcuted in series at each side of Jaro C/S and Naga C/S and the installation timing is matched to that of the transmission lines.

(4) Converter Station Construction Schedule

Construction related to converter stations, among construction of DC series facilities, can be divided into two categories; one is related to civil engineering work and the other is electrical. The electrical work, the main part of which is installation of electrical equipment like converter, requires the longest time and how soon the equipment can be installed is a decisive factor to the total construction time.

Since it is possible to completely prepare the building and outdoor facilities to contain the equipment which is manufactured in overseas before they are delivered to the site, construction schedule for the entire equipment can be determined by the time lengths for designing, manufacturing, transportation, installation and tests of HVDC equipment.

i) Designing

The design work shall be started immediately after concluding the contracts. The time length required for designing greatly varies by the type of equipment. Generally, it can be said that 4 to 6 months are needed for thyristor valves and converter transformer and 10 to 12 months are needed for control and protection equipment.

ii) Manufacturing

Manufacturing requires the longest time, i.e., 12 to 15 months for thyristor valves, 8 to 10 months for converter transformers and DC reactors, and 8 to 12 months for switchboard and switchgears.

All of them must be manufactured under well prepared circumstance and severe quality control setup.

iii) Transportation and Installation

Transportation arrangement must be made coping to the installation schedule of each equipment so that there would be no waste of time and work at the field.

Especially, on the heavy items to the Jaro C/S, the transportation must be carried out systematically based on prior surveys.

Since many devices containing semiconductors are used, like thyristor valves, the installation must be supervised very carefully so as not to degrade the quality of these devices.

3 to 5 months are planned for the installation process.

iv) Field Tests

Various testings shall be conducted after installing the equipment. The testing will be conducted on individual device first, and when all tests in the converter stations end, the whole DC transmission system shall be tested. The system performance is then adjusted, set to the normal operation state, and the performance is checked.

Accordingly, to obtain electricity for these testings is essential to realize smooth execution of all processes.

6 months are planned for testing of all equipment assuming that all construction and installation are completed as planned.

(5) Construction of Telecommunications Equipment

Designing, manufacturing, installation and testing of telecommunications equipment shall be carried out matching to construction of the converter stations, and the telecommunications equipment shall be completed by 1985 in the timing of the project completion.

However, in order to realize this, the formal procedures related to approval of microwave system as required by the Philippines authority must be managed by NAPOCOR under the responsibility of NAPOCOR and the approval will have been obtained in time of the construction schedule.

Further surveys are needed to check the location of the repeating stations, and to confirm existence of no obstacles between repeating stations and possibility of installing the repeating station in advance.

(6) Second Stage Construction Schedule

The main work in the second stage, which is tentatively scheduled for 1990 completion, is additional installation of HVDC main circuit and the final equipment of ±350 KV, 900 MW shall be installed.

Additional installation of AC 138 KV switching equipment, AC filters, Var compensator and AC 138 KV transmission lines are needed and scheduled as the necessary equipment resulting from additional installation of the above mentioned HVDC circuit.

These installation schedules are planned in the same way as those for the first stage.