CHAPTER 7

CONSTRUCTION SCHEDULE, CONSTRUCTION COST AND ECONOMIC EVALUATION

CHAPTER 7. CONSTRUCTION SCHEDULE, CONSTRUCTION COST AND ECONOMIC EVALUATION

7-1 Construction Schedule

In order to complete the project before start of operation of the Michiquillay Mine, in effect, by the end of 1981, it will be necessary to proceed with work according to the construction schedule indicated in Table 7-1. The construction period required for the Project will be approximately two years. Therefore, it will be necessary to start surveying in the field around the middle of 1977 and to prepare final designs, specifications and the like around the middle of 1978.

7-2 Construction Cost

The construction cost as shown in Table 7-2 was computed calculating work quantities based on the results of preliminary design and taking into consideration the conditions in the field.

The conditions used in construction cost calculations were as follows:

(1) Scope of Construction Cost Calculation

Transmission Lines

220 kV Trujillo-Pacasmayo-Michiquillay Transmission Line

33 kV Michiquillay-Cajamarca Transmission Line

Substations

Trujillo Norte Substation lead-out facilities

Michiquillay Substation

Cajamarca Substation

Telecommunications Facilities

Telecommunications facilities relevant to Project facilities

Table 7-1 Construction Schedule

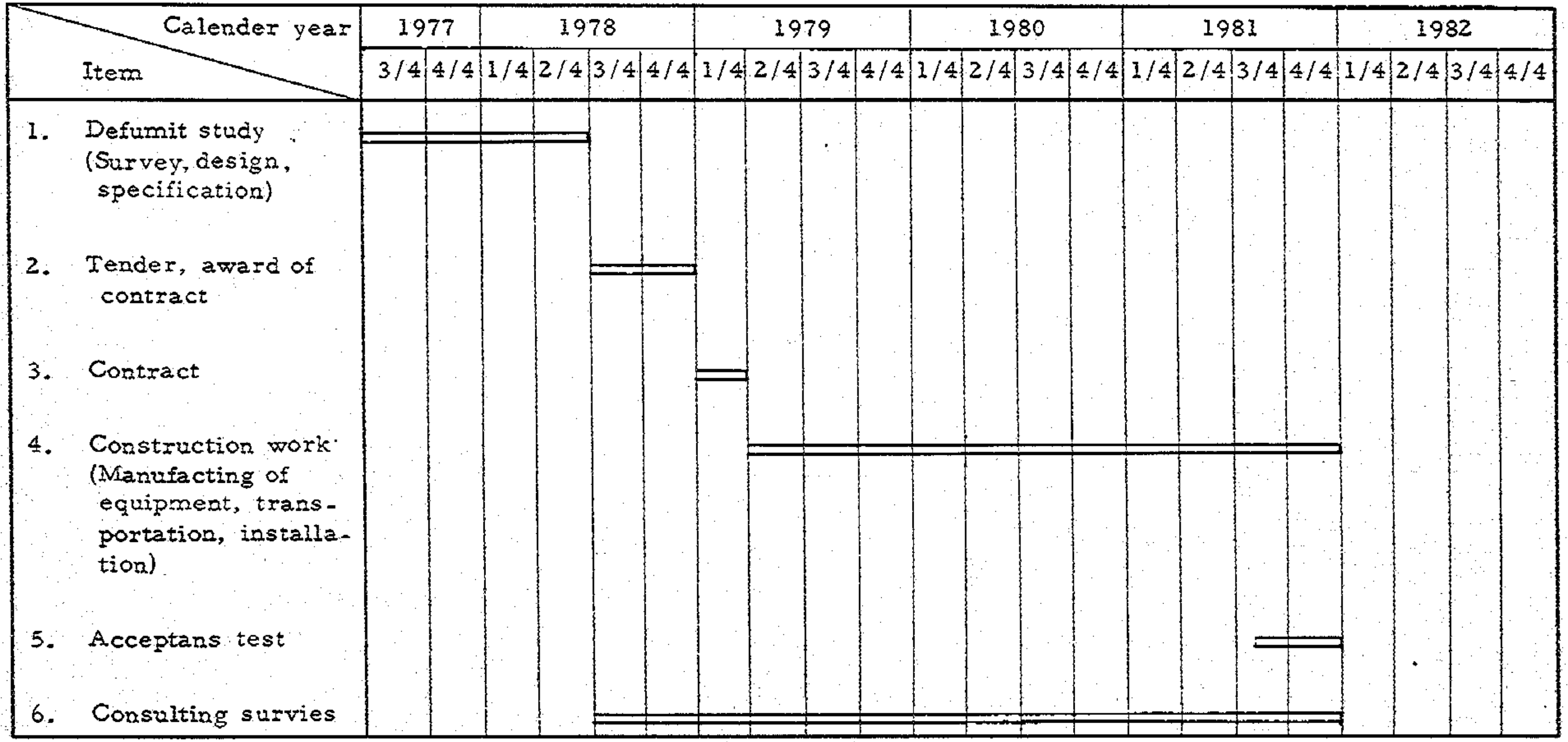


Table 7-2 Total Construction Cost

Unit: US$ 10^3

	Trujillo Norte - Michiquillay - Cajamarca			Pacasmayo - Michiquillay - Cajamerca		
	F. C	D. C	Total	F. C	D. C	Total
Transmission line						
220 kv Transmission line	6,273	4,803	11,076	3,896	3,386	7,282
33 kv Transmission line	154	110	264	154	110	264
Sub Total	6,427	4,913	11,340	4,050	3,496	7,546
Substation						
Trujillo Norte Substation	796	209	1,005			
Michiquillay Substation	3,228	1,168	4,396	3,228	1,168	4,396
Cajamarca Substation	457	143	600	457	143	600
Sub Total	4,481	1,520	6,001	3,685	1,311	4,996
Telecommunication Facilities						
Chimbote Substation	73	3	76			
Trujillo Norte Substation	190	45	235	190	45	235
Michiquillay Substation	207	48	255	207	48	255
Sub Total	470	96	566	397	93	490
Total of direct cost	11,378	6,529	17,907	8,132	4,900	13,032
Engineering and administration fee						
Field survey	100	380	480	60	220	280
Engineering and administration fee	448	1,343	1,791	326	977	1,303
Sub Total	548	1,723	2,271	386	1,197	1,583
Contingency	853	490	1,343	610	368	978
Maintenance equipment	263	45	308	263	45	308
Total of indirect cost	1,664	2,258	3,922	1,259	1,610	2,869
Construction cost	13,042	8,787	21,829	9,391	6,510	15,901
Interest during construction	1,304	879	2,183	939	651	1,590
Grand Total	14,346	9,666	24,012	10,330	7,161	17,491

(2) Land costs, indemnification costs and construction cost of housing for operation and maintenance personnel are not to be included.

(3) Major materials and equipment (steel towers, conductors, insulators, transforming equipment such as main transformers and circuit breakers, and telecommunications equipment) are all to be considered as imported.

(4) Construction materials such as cement and reinforcing steel are to be domestic products of Peru.

(5) Customs duties on imported equipment and materials, taxes on engineering fees and income taxes of foreign engineers are assumed to be exempted and are not to be included.

(6) Estimation of construction costs is to be based on commodity prices and wages as of April 1975 and escalations up to the time of start of construction are not to be considered.

(7) 7.5% of the total sum of direct construction cost for contingencies, 5% for administrative expenses, 5% for the engineering fee, and surveying expenses of the transmission line route are to be added to the direct construction cost.

(8) Equipment and materials for operation and maintenance are to be included on the basis of minimum necessary quantities.

(9) Interest during construction is to be calculated at 10% of the construction cost.

Furthermore, construction costs is estimated based on the actual costs for field construction work and also assuming that unit price of equipment at international market is proper at the present condition.

7-3 Evaluation of 220 kV Transmission and Transforming Facilities by Internal Rate of Return Method

The power rates to the Michiquillay Mine for cases of internal rates of return of the Project of 6%, 8% and 10% were calculated assuming that electric power for the Michiquillay Mine would be delivered at Trujillo or Pacasmayo at the nationally unified tariff rate described in Chapter 3, 3-2.

As a result, even at an internal rate of return of 10%, the charges will be less expensive than the generating cost of 27.8 mills/kWh in case of power generation constructing diesel generating facilities at Michiquillay.

The power rates at the Michiquillay Mine in the cases of various internal rates of return and delivery at Trujillo or Pacasmayo are given in Table 7-3. It should be noted that power supply to the cities of Cajamarca and Celendin were not included in the evaluations by internal rates of return.

The conditions used in calculations of internal rates of return were as follows:

Service life of transmission and transforming facilities:	30 years
Delivery point from ELECTROPERU:	Trujillo or Pacasmayo
Wholesale rate of ELECTROPERU:	14.7 mills/kWh
Transmission loss factor:	2.8% to 3.1%
Operation and maintenance costs of transmission and transforming facilities:	2.5% of construction cost

Table 7-3 Power Rate of Michiquillay Mine Delivered at Pacasmayo or Trujillo

(Unit: mills/kWh)

Delivery point of energy	Internal rate of return 6 %	8 %	10 %
Pacasmayo	19.1	20.0	21.1
Trujillo	20.9	22.2	23.7

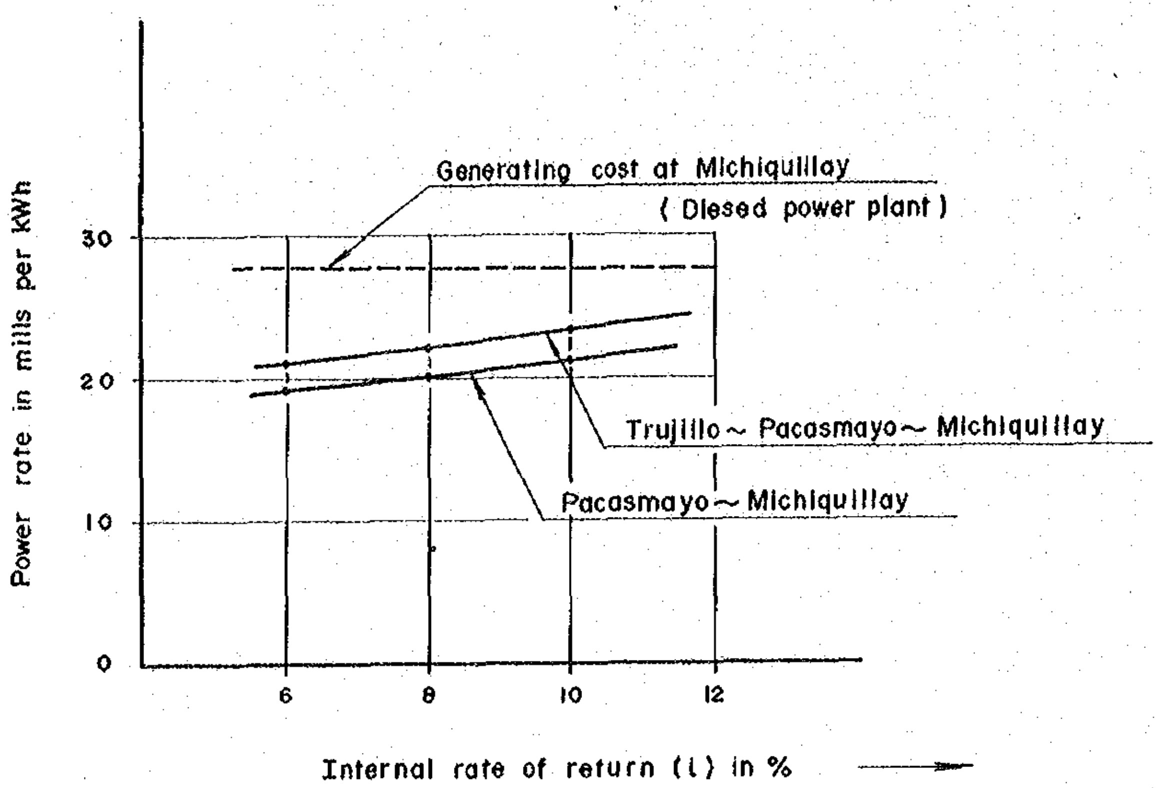


Fig. 7-1 POWER RATE IN MICHIQUILLAY

Table 7-4 Internal Rate of Return (Trujillo - Pacasmayo - Michiquillay)

i	Year	Construction cost (10^3 US$)	Energy cost at sending end: Energy demand (GWh)	Loss factor (%)	Requirement (GWh)	Unit rate (mills/kWh)	Cost (10^3US$)	Maintenance cost (10^3 US$)	Total cost (10^3 US$)	Revenue at receiving end: Unit rate (mills/kWh)	Revenue (10^3US$)	I.R.R. (i = 8.0): Present worth factor	Cost (10^3US$)	Revenue (10^3US$)
-3	1979	5,195										1.260	6,546	
-2	1980	10,392										1.166	12,117	
-1	1981	5,195										1.080	5,611	
1	1982		278.7	2.8	286.7	14.7	4,214	572	4,786	22.2	6,187	0.926	4,515	5,729
2	1983		278.7	2.8	286.7	14.7	4,214	572	4,786	22.2	6,187	0.857	4,102	5,302
3	1984		278.7	2.8	286.7	14.7	4,214	572	4,786	22.2	6,187	0.793	3,795	4,906
4	1985		278.7	2.8	286.7	14.7	4,214	572	4,786	22.2	6,187	0.735	3,518	4,547
5	1986		278.7	2.8	286.7	14.7	4,214	572	4,786	22.2	6,187	0.681	3,259	4,213
6	1987		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050	0.630	4,687	6,332
7	1988		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050	0.583	4,338	5,859
8	1989		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050		(52,488)	(36,888)
9	1990		452.7	3.1	467.2	14.7	6,868	572	7,440					
10	1991													
11	1992													
12	1993													
13	1994													
14	1995													
15	1996													
16	1997													
17	1998													
18	1999		ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto		7,440 x	10,050x
19	2000												10.371	10.371x
20	2001												x 0.583	0.583
21	2002												= 44,984	=60,765
22	2003													
23	2004													
24	2005													
25	2006													
26	2007		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050			
27	2008		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050			
28	2009		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050			
29	2010		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050			
30	2011		452.7	3.1	467.2	14.7	6,868	572	7,440	22.2	10,050			
Total		20,782	-	-	-	-	-	-	-	-	-	-	97,472	97,653

Table 7-5 Internal Rate of Return (Pacasmayo - Michiquillay)

i	Year	Construction cost (10³US$)	Energy demand (GWh)	Energy cost at sending end: Loss factor (%)	Requirement (GWh)	Unit rate (mills/kWh)	Cost (10³US$)	Maintenance cost (10³ US$)	Total cost (10³ US$)	Revenue at receiving end: Unit rate (mills/kWh)	Revenue (10³US$)	I.R.R. (i = 8.0): Present worth factor	Cost (10³ US$)	Revenue (10³ US$)
-3	1979	3,710										1.260	4,675	
-2	1980	7,435										1.166	8,669	
-1	1981	3,710										1.080	4,007	
1	1982		278.7	1.6	283.2	14.7	4,163	409	4,572	20.0	5,574	0.926	4,234	5,162
2	1983		278.7	1.6	283.2	14.7	4,163	409	4,572	20.0	5,574	0.857	3,918	4,777
3	1984		278.7	1.6	283.2	14.7	4,163	409	4,572	20.0	5,574	0.793	3,626	4,420
4	1985		278.7	1.6	283.2	14.7	4,163	409	4,572	20.0	5,574	0.735	3,360	4,097
5	1986		278.7	1.6	283.2	14.7	4,163	409	4,572	20.0	5,574	0.681	3,114	3,797
6	1987		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054	0.630	4,527	5,704
7	1988		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054	0.583	4,189	5,278
8	1989		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054		(44,319)	(33,234)
9	1990		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
10	1991													
11	1992													
12	1993													
13	1994													
14	1995													
15	1996													
16	1997													
17	1998													
18	1999		ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto		7,186 x	9,054 x
19	2000												10,371 x	10,371 x
20	2001												0.583 =	0.583 =
21	2002												43,449	54,743
22	2003													
23	2004													
24	2005													
25	2006													
26	2007		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
27	2008		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
28	2009		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
29	2010		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
30	2011		452.7	1.8	461.0	14.7	6,777	409	7,186	20.0	9,054			
Total		14,855	-	-	-	-	-	-	-	-	-	-	87,768	87,977

CHAPTER 8

SYSTEM ANALYSIS

CHAPTER 8. SYSTEM ANALYSIS

8-1 Outline of System Analysis

The supply of electric power to the Michiquillay Mine and communities in the surrounding area is to be done by the Central Power System and the Santa Power System to be tied to the former in 1978 by the Lima-Chimbote Interconnecting Transmission Line.

The Michiquillay Transmission Line is to be single-circuit with a transmission voltage of 220 kV and length of 240 km starting from Trujillo Norte Substation and passing by Pacasmayo, and in regard to this transmission line the problems in voltage regulation, steady-state stability, transient stability, and short-circuiting capacity have been examined.

8-2 Voltage Regulation

Voltage is regulated by generators, phase modifying equipment and transformer taps aiming at the balance of the reactive power of the system.

8-2-1 Conditions Studied

(1) System Structure and Years Studied

The power system analysis was made in connection with Santa Power System and its related power system, including the Central Power System simulated to be a one-generator system.

The years studied were the three stages of 1982 when the Michiquillay Mine is scheduled to commence operation, 1985 when it is considered the Lima-Chimbote Interconnecting Transmission Line and the Chimbote-Trujillo Line will both be expanded to double-circuits, and 1990, the last year of the study.

(2) Voltage Regulation Criteria

Voltage regulation was studied based on the conditions listed below.

- Bus voltage of the 220 kV system is to be 100±5%, and generator terminal voltage 100±5% (provided that this is within the rated power factor).
- The loads of the various substations are indicated in Table 8-1.
- The load power factors and P/N ratios of the various substations are indicated in Table 8-2.
- The power factors of synchronous motors used at the Michiquillay Mine are to be 0.9 running, and with this as an operating margin,

Table 8-1 Demand at Substation

Unit: MW and MVar

Substation	1982		1985		1990	
	Peak	Off Peak	Peak	Off Peak	Peak	Off Peak
Paramonga	58.0+j28.1	29.0+j14.0	58.5+j28.3	29.0+j14.0	68.0+j32.9	34.0+j16.5
Huacho	10.0+j4.8	5.0+j2.4	10.5+j5.1	5.0+j2.4	12.0+j5.8	6.0+j2.9
Callejon de Huaylas	28.0+j13.6	14.0+j6.8	29.0+j14.0	14.5+j7.0	31.0+j15.0	15.5+j7.5
Chimbote No. 1 (Incl. Norte, Sur)	64.0+j31.0	21.3+j10.3	70.0+j33.9	23.3+j11.6	94.0+j45.5	31.3+j15.1
SIDERPERU	157.0+j97.5	78.5+j48.6	159.0+j98.6	79.5+j49.2	161+j99.8	80.5+j50.0
Trujillo Norte	17.0+j8.2	5.7+j2.7	20.0+j9.7	6.7+j3.2	25.0+j12.1	8.3+j4.0
Trujillo Sur	32.0+j15.5	10.7+j5.2	41.0+j19.9	13.7+j6.6	75.0+j35.4	24.3+j11.8
Santiago de Cao	28.0+j17.4	14.0+j8.7	31.0+j19.2	15.5+j9.6	31.0+j19.2	15.5+j9.6
Michiquillay	26.8+j20.5	9.3+j6.6	29.8+j21.0	9.7+j6.8	47.3+j33.6	15.3+j10.8
Michiguillay sy. motors	15.2+j0	-	15.2+j0	-	24.7+j0	-
Pacasmayo (Incl. Cement Pacasmayo)			39.0+j18.9	13.0+j6.3	50.0+j24.2	16.7+j8.1
Chiclayo					670.0+j348.2	17.0+j8.2
Total	436+j236.6	187.5+j105.3	503.0+j268.6	209.9+j116.7	670.0+j348.2	264.4+j144.5

Table 8-2 P/N ratio and Power factor

Substation	P/N	P. F (P. U)
Paramonga	2	0.9
Huacho	2	0.9
Chimbote No. 1	3	0.9
SIDERPERU	2	0.85
Callejon de Huaylas	2	0.9
Trujillo Norte, Sur	3	0.9
Santiago de Cao	2	0.85
Michiquillay		0.8
Cajamarca	3	0.9
Pacasmayo	3	0.85
Chiclayo	3	0.9

Note: Peak/ Niyt=P/N

the load power factor is to be taken at roughly 1.0 carrying out only fine-tuning.

- The off-peak load of the Michiquillay Mine is to be the minimum load when the mine is closed (about 15 days out of the year).

8-2-2 Results of Voltage Regulation

The results of voltage regulation are given in Fig. A-4-2 through Fig. A-4-7.

For both peak hours and off-peak hours in 1982, 1985 and 1990, if slight amounts of condensers and reactors are provided, the 220 kV bus voltages of all of the substations can be maintained in a range of 95% to 105%.

(1) Phase Modifying Equipment

The phase modifying equipment required for peak and off-peak hours in 1982, 1985 and 1990 as a result of voltage regulation are indicated in Table 8-3.

Table 8-3 Reactive Power Facilities Required for Each Substation

Unit : MVA

Year / Substation	1982		1985		1990	
	S. C	ShR	S. C	ShR	S. C	ShR
Chimbote No. 1	*35	20	*35	20	*35	20
Trujillo Norte	-	-	-	10	-	30
Trujillo Sur	10	-	-	-	-	-
Pacasmayo			-	5	-	5
Michiquillay	15	10	15	10	9	10

Note: 1) S. C : Shunt capacitor
2) ShR : Shunt reactor
3) * : Capacity decided already

1) Shunt Capacitor

At the peak hours in 1982 when the Michiquillay Mine will start operation, there will be a surplus of about 100 MW in the Central Power System and it will be possible to supply electric power from the Central Power System to the Region Norte Power System. It would be possible to balance demand and supply in the Region Norte Power System if gas turbines were to be put into operation, but it was considered that the gas turbines would be stopped and kept for emergencies so that 40 MW would be received from the Central Power System.

Since the voltage of Michiquillay Substation would be governed by the voltage at Trujillo Norte Substation, the capacity of the shunt capacitor to be installed at Michiquillay Substation was taken to be such that the 220 kV bus voltage at Trujillo Norte would be 95 % or higher, in addition to which the 220 kV bus voltage of Michiquillay would be maintained at not less than 95%. As a result, a 15 MVA shunt capacitor will be required at Michiquillay Substation.

From 1982 and after, there will be a trend for the 220 kV bus voltage of Trujillo Norte Substation to be lowered due to increased loads in the Trujillo district, but this voltage condition will be improved in 1985 when the Lima-Chimbote Interconnecting Transmission Line and the Chimbote-Trujillo Line will be increased to double circuits.

With regard to coping with this voltage drop until the related transmission lines are strengthened, there will be no problem if the gas turbines at Trujillo is operated.

Therefore, if a 15 MVA shunt capacitor is installed at Michiquillay Substation, the target voltage of the substation can be maintained until there is an expansion of the Michiquillay Mine.

The shunt capacitor is to be installed at the 33 kV side of Michiquillay Substation, and will consist of two 7.5 MVA units in consideration of voltage fluctuation at the time of on and off of the capacitor.

2) Shunt Reactor

During off-peak hours the power flow in a transmission line will be light, and Var produced by line-to-earth capacitance of the transmission line will increase, and the voltage of the system will rise.

In such case, since the transmission line is as long as 240 km, the 220 kV bus voltage at Michiquillay during off-peak hours in 1982 will rise to around 114%. For this reason, a shunt reactor would be required at Michiquillay Substation.

In order to maintain the 220 kV bus voltage at 105% or lower, a 10 MVA reactor would be necessary and in consideration of voltage fluctuation between on and off of the reactor, two 5 MVA units will be installed at the 33 kV side.

Furthermore, a 20 MVA reactor directly connected with 220 kV line was considered for Chimbote No. 1 Substation. This is because, when the Chimbote No. 1 Substation is to be put in parallel with the transmission line, the voltage at the transmission line side will rise in comparison with the bus voltage, so that synchronization will be impossible. (When Trujillo Norte Substation is operated at 138 kV, voltage regulation is done by the Chimbote No. 1 Substation LTC tap and parallel operation will be possible at the 138 kV side.) For this reason, a 20 MVA reactor directly connected with 220 kV line is required at Chimbote No. 1 Substation. This will still be required even in case the transmission line becomes double-circuit.

(2) Regulating Transformer

The voltage of the various substations in Region Norte will vary according to the power flow of the Lima-Chimbote Interconnecting Transmission Line, and the voltage differences between peak and off-peak hour will be large. Since therefore, transformers without LTC are undesirable, the transformers adopted will have an on-load tap changer (LTC) at their 220 kV sides.

The proper LTC tap widths for the various substations are indicated in Table 8-4, and from the analysis results of voltage regulation the taps used are 95% to 101% for Michiquillay Substation and 93% to 103.5% for Trujillo Norte Substation, and if an allowance is provided to make to 220 kV ± 10 %, it will be possible to maintain the secondary-side voltages at target values.

Table 8-4 Tap Voltage of LTC (on-Load tap changer)

Substations	Bus voltage	1982		1985		1990	
		Peak hours	Off peak hours	Peak hours	Off peak hours	Peak hours	Off peak hours
Chimbote No. 1	220 kV	(99.8)	(101.2)	(102.1)	(104.0)	(101.1)	(102.6)
	138 kV	100.0	100.0	100.0	100.0	100.0	100.0
SIDERPERU	138 kV	(100.0)	(97.5)	(100.6)	(99.3)	(98.2)	(97.1)
	13.8 kV	97.5	95.0	97.5	97.5	96.5	95.0
Trujillo Norte	220 kV	(95.4)	(103.2)	(98.5)	(104.0)	(99.6)	(103.2)
	13.8 kV	93.0	103.5	95.0	100.0	95.0	100.0
"	138 kV	(99.7)	(98.5)	(100.6)	(101.7)	(101.2)	(100.9)
	13.8 kV	96.5	97.5	97.0	100.5	96.5	99.5
Trujillo Sur	138 kV	(98.8)	(98.1)	(100.0)	(101.2)	(97.7)	(99.9)
	13.8 kV	97.5	97.0	99.0	100.0	90.0	98.0
Santiago de Cao	138 kV	(98.7)	(98.0)	(99.4)	(101.2)	(100.1)	(100.4)
	13.8 kV	95.0	96.0	95.0	99.0	96.0	98.0
Pacaomayo	220 kV	-	-	(96.1)	(104.0)	(99.3)	(103.9)
	66 kV			91.0	101.5	100.0	101.0
Michiquillay	220 kV	(96.0)	103.7)	(95.7)	(103.0)	(99.6)	(103.1)
	33 kV	95.0	101.0	95.0	100.5	95.0	100.0
Chiclayo	220 kV	-	-	-	-	(97.8)	(103.9)
	138 kV					100.0	100.0

Note: 1) Transformers with LTC are to be installed in each substation

2) Figures indicate percent voltage based on 220kV and 138kV

3) Figures in parethesis indicate primary bus voltage in each substation

8-3 Transient Stability

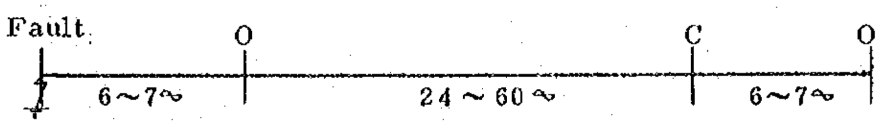
Transient stability analysis were made for one-circuit and 3 phase line to ground faults indicated in Table 8-5 for peak hours in 1985 when the Lima-Chimbote Interconnecting Transmission Line and the Chimbote-Trujillo Line will become double-circuit, and in 1990 when the situation would be that of power transmission from the Region Norte Power System to Lima.

Table 8-5 Transient Stability Analysis

Year	Transmission line	Kind of fault	Duty of circuit breaker	Juding	Fault point
1985 (Peak hours)	Chavarria-N. Paramonga	1 cct, 3LG, O-CO	0.12s-1.12s-1.24s	steady	Chavarria
	Chimbote-Trujillo	ditto	0.1s-0.5s-0.6s	ditto	Chimbote
	N. Paramonga-Chavarria	ditto	0.12s-1.12s-1.24s	ditto	N. Paramonga
1990 (Peak hours)	Chimbote-N. Paramonga	ditto	0.12s-1.12s-1.24s	ditto	Chimbote
	Trujillo-Chimbote	ditto	0.1s-0.5s-0.6s	ditto	Trujillo
	Alto Chicama-Trujillo	ditto	"	ditto	Alto Chicama

Note: Breaking action times of C.B for Lima-Chimbote Interconnecting Transmission Line are determined taking into consideration long distance of the line

The circuit breaker actions at both ends of the faulted transmission line were taken to be O-CO with the times as follows:



The preceding power flows are as indicated in Fig. A-4-4 and Fig. A-4-6 and the analysis results, as shown in the swing curves of Fig. A-4-9 through Fig. A-4-14, were stable. As seen for peak times in 1990, a fault between Chimbote and Paramonga (Chimbote side) will be severe for the transient stability of the Region Norte Power System and it is thought the transient stability limit of the Lima-Chimbote Interconnecting Transmission Line in power transmission from the Region Norte System to Lima will be about 160 MW. Should this capacity be exceeded, the Central Power System and the Region Norte Power System will be disconnected and stable power transmission cannot be expected. Consequently, the electric power development scheme for region Norte in the future must be carried out taking into consideration the power flow of the Lima-Chimbote Interconnecting Transmission Line.

8-4 Steady-state Stability

Supply of electric power to the Michiquillay Mine and surrounding communities will at the start of operation be done from the Santa Electric Power
System and the Central Power System which is to become interconnected in 1978 by the Lima-Chimbote Interconnecting Transmission Line. Since one third of the load at the Michiquillay Mine will be comprised by the use of synchronous motors for ore dressing, the capacity of Michiquillay to receive power will be determined by the steady-state stability of Lima-Santa-Michiquillay.

Steady-state stability analyses were made for peak hours in 1982 in the case of a load of 44 MW at Michiquillay Substation (load of synchronous motors, 15.2 MW) and the case of Michiquillay load of 84 MW taking into consideration a load increase of 40 MW at Trujillo and northward including Michiquillay. The power flows used in the steady-state stability analysis are shown in Fig. A-4-2 and Fig. A-4-8.

The examination was made subjecting a synchronous motor to a slight disturbance, and the judgment of stability or instability was made by whether the slippage, "S" of the synchronous motor converged on the original state or diverged. Furthermore, the steady-state stability was taken to be a specific one ignoring control systems such as AVR.

The results are shown in Fig. 8-1. The case of Michiquillay Substation load of 44 MW is stable. As for the case of an additional 40 MW, there is a continuation of vibration from slippage "S" but the damping constant has not been taken into consideration. If this were considered, it may be judged to be stable.

Consequently, at the start of operation in 1982, it will be possible to receive 44 MW of power from the Central Power System, and also in regard to the period after 1982, stable operation can be carried out even if there is an increase in load of about 40 MW at Trujillo and northward.

Furthermore, since the capacity of Michiquillay to receive power would be restricted by the steady-state stability of the Lima-Chimbote Interconnecting Transmission Line, the steady-state stability of the interconnecting line was studied by a stability discriminant matrix method (ρ method).

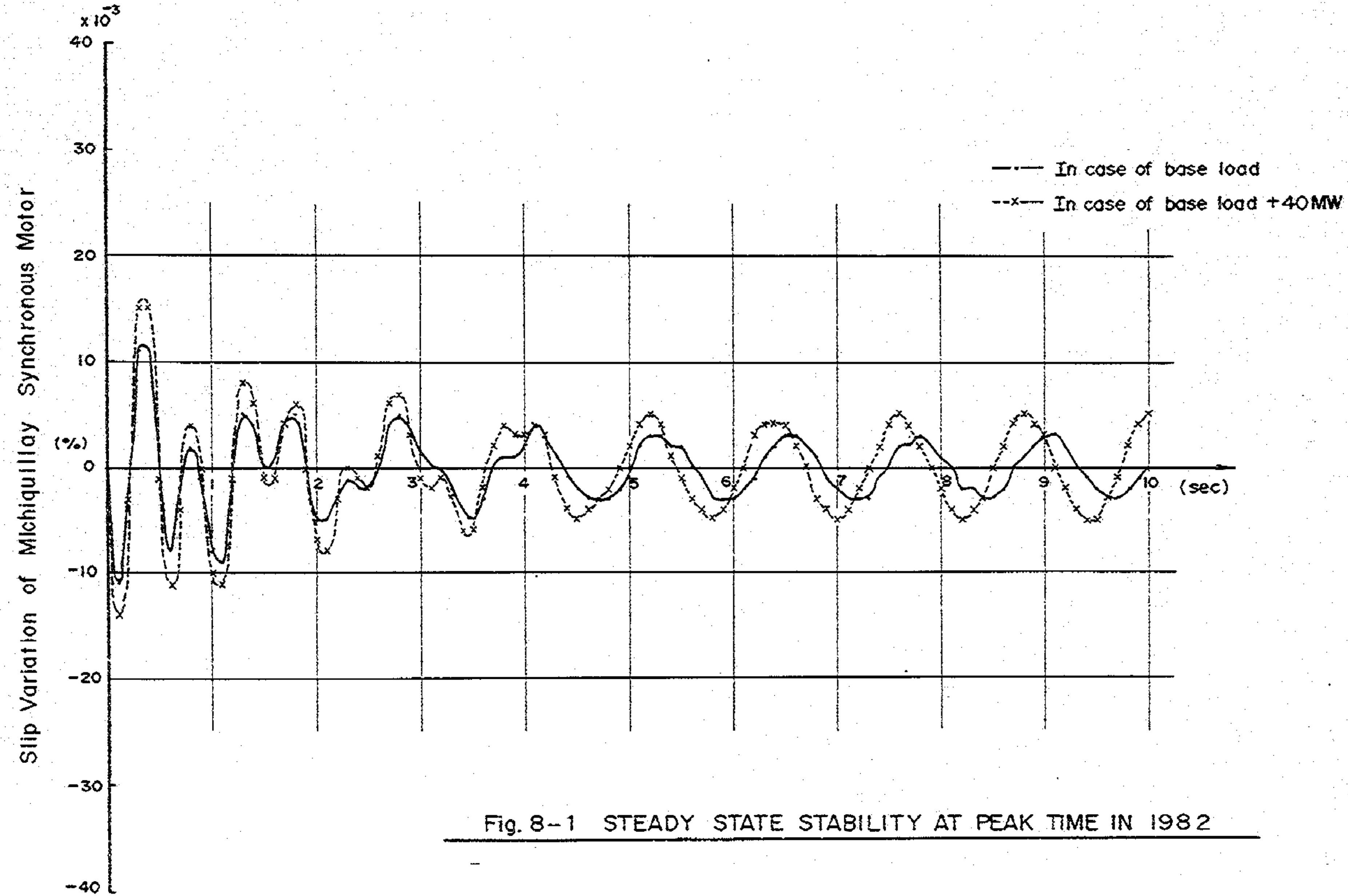


Fig. 8-1 STEADY STATE STABILITY AT PEAK TIME IN 1982

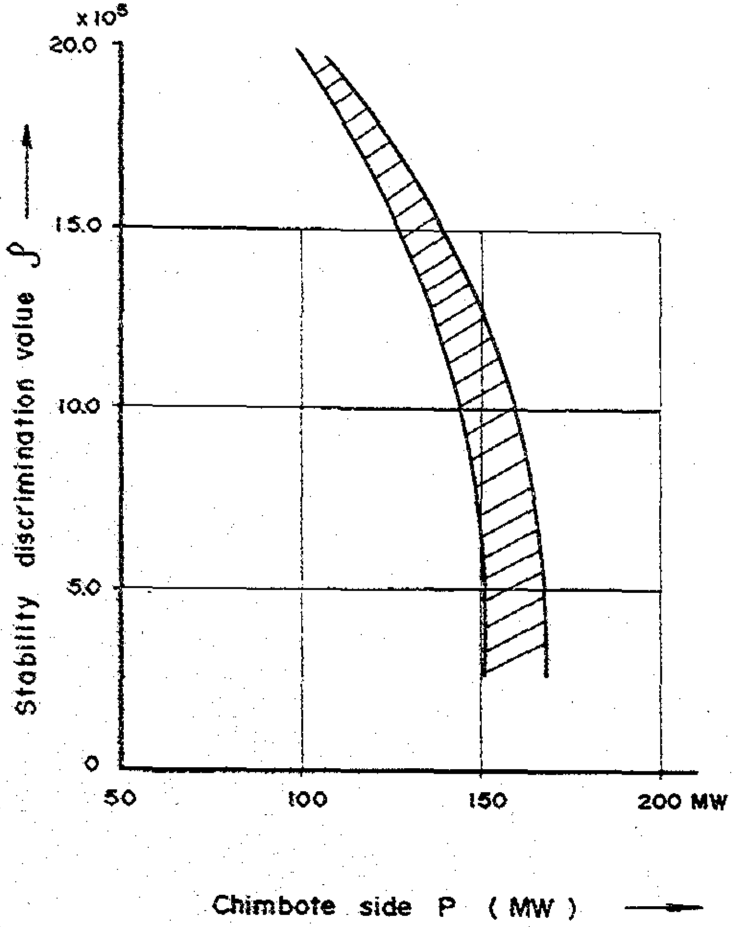


Fig. 8-2 STEADY STATE STABILITY
LIMA-CHIMBOTE LINE 1 CCT

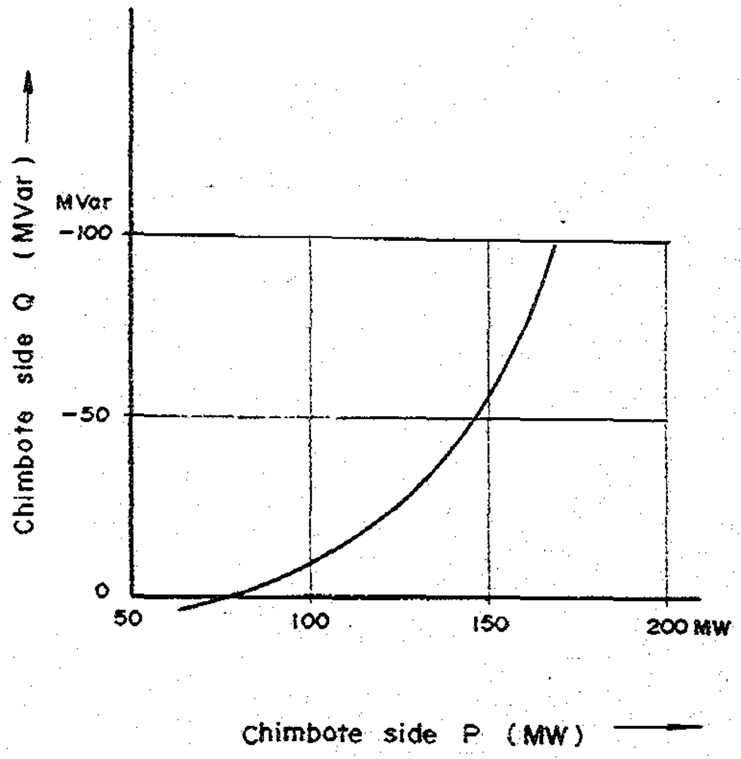


Fig. 8-3 CHARACTERISTICS CURVE P & Q
LIMA-CHIMBOTE LINE 1 CCT

The steady-state stability limit of the Lima-Chimbote Interconnecting Transmission Line, as seen in Fig. 8-2, is considered to be around 150 MW if ample measures regarding voltages are taken in the Chimbote district. However, as indicated in Fig. 8-3, in case 120 MW or more is received at the Chimbote side, there will be a substantial amount of reactive power supplied to the Lima side due to the incremental active power, and an abrupt increase in power condensers will occur.

When the power flow of Chimbote and northward becomes heavy, the transmission capacity will be decreased. Consequently, from the aspects of economy and operation of the Region Norte, 120 MW at the Chimbote side would be reasonable in the supply capacity of the Lima-Chimbote Interconnecting Transmission Line as single-circuit.

8-5 Protection of Transmission Line

The 220 kV Michiquillay Transmission Line is a single-circuit, long-distance transmission line with a length of 240 km and it is planned that Pacasmayo Substation near the midpoint will be π -connected in the future. With such a long-distance transmission line, depending on the location and condition at the fault point, the fault current may become small, and it may be hard to discriminate between the load current and the fault current, so that it will be difficult to rapidly and accurately detect faults over the entire protection zone from only one end.

Consequently, for the sake of rapid and accurate fault detection, a pilot relay system is to be adopted whereby faults can be judged by a combination of detection conditions at the two ends of a protection zone.

For reclosure, since this transmission line will continue to be single-circuit line in the future, high-speed, single-phase reclosing will be adopted.

8-5-1 Main Protection

The 220 kV Michiquillay Transmission Line will become a major trunk line in Region Norte, and high-speed and accurate fault detection must be performed from the standpoints of preventing burning of equipment, preventing spreading of faults and maintaining stability.

Therefore, as main protection, a carrier protective relay system is adopted whereby reliable judgment can be made whether the fault point is internal or external to the protection zone, and whereby high-speed, simultaneous opening can be done from both ends. As the transmission system for carrier signals, it is conceivable for either a power line carrier or microwave carrier system to be used for protection of long-distance transmission lines, and in consideration of economy, the power line carrier system will be taken.

Protective relay systems may be broadly divided into directional comparison and phase comparison types, and with such a long-distance transmission line (approximately 200 km or more) as this, both of these types have their respective problems which must be considered in application, and especially, with the phase comparison system, the charging current of the transmission line and the delay in signal transmission time (in case of the power line carrier system) are big problems to make application difficult.

Therefore, a directional comparison relay system will be adopted for this Project, and in application, considerations must be given to improving the protection level since there are cases in which the difference between the fault current and the load current will be small depending on conditions at the time of faulting.

8-5-2 Back-up Protection

In cases in which some kind of trouble should occur in the carrier protective relay system, or in which the apparatus cannot be used on such occasions as when inspection of the carrier portion is being made, detection of faults will become impossible, causing harmful effects on equipment and the power system so that back-up protection must be provided without fail.

For back-up protection, a directional distance relay system is to be adopted.

8-5-3 High-speed, Single-phase Reclosure System

Since the 220 kV Michiquillay Transmission Line will continue to be a single-circuit line in the future, a high-speed, 3-phase reclosure system cannot be applied, but against single-line instantaneous faults it must be made possible to perform high-speed, single-phase reclosure from the standpoints of system supply reliability and improvement of system stability. This is to be done only during main protection single-phase opening.

In general, the factor deciding high-speed reclosure time in an extra-high-voltage system is the time from disappearance of residual ions caused by the fault current until insulation recovery of the fault point has become complete.

With a 220 kV transmission line, a current zero period of roughly 15 cycles or more is required. For circuit breakers made for high-speed reclosure, they must be guaranteed to perform their special functioning responsibilities.

8-6 Voltage Rise Caused by Circuit Opening

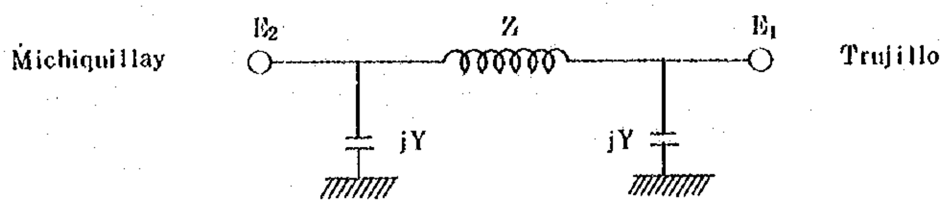
With a long-distance transmission line, there will be pronounced voltage rise due to Ferranti effect. Michiquillay Transmission Line is a long-distance line of 240 km, and in case of circuit breaking at the Michiquillay side, the voltage will rise to approximately 1.05 times the voltage at the Trujillo side.

Since Trujillo Norte Substation in 1982 will have a relatively small short-circuit capacity, the 220 kV side voltage will rise to 108% due to the charging capacity of 39 MVA of the transmission line. Therefore, the voltage at the Michiquillay side will be around 114%.

In order to restrain the voltage rise, it is necessary to adopt a transfer breaking system to open the circuit breaker at Trujillo Norte Substation.

Also in case of putting Michiquillay Substation in parallel with Trujillo Norte Substation, since there is voltage rise to about 114% at the Michiquillay side, it must be put in parallel by bringing the 10 MVA reactor at Michiquillay Substation into the system. The voltage at the Michiquillay side will drop below 105% in this case.

(Reference) Calculation of Ferranti Effect



$$E_2 = \frac{1}{jY} \cdot \frac{E_1}{Z + \frac{1}{jY}}$$

$$= \frac{E_1}{1 + jY \cdot Z}$$

$$= \frac{E_1}{1 + j0.0195(0.353 + j2.594)}$$

$$|E_2| = 1.0537\ |E_1|$$

8-7 Short-Circuit Capacity

The 3-phase short-circuit capacities in the Region Norte System in 1990 will be shown in Fig. A-4-15. In this case the calculations were made using for generators with all generators assumed as being in the system.

The short-circuit capacities in the Region Norte System are the following:

Chimbote Substation	220 kV bus	1,610 MVA
	138 kV bus	1,930 MVA
Trujillo Norte Substation	220 kV bus	1,570 MVA
	138 kV bus	1,080 MVA
Pacasmayo Substation	220 kV bus	930 MVA
	66 kV bus	350 MVA
Michiquillay Substation	220 kV bus	620 MVA
	33 kV bus	450 MVA
Chiclayo Substation	220 kV bus	630 MVA
	138 kV bus	550 MVA

Therefore, it will be sufficient for the breaking capacities of circuit breakers adopted for Michiquillay Substation to be as follows:

Circuit breaker for 220 kV	5,200 MVA
Circuit breaker for 33 kV	780 MVA

8-8 Voltage Rise Caused by One Line-to-Ground Fault and Fault Current

The single-line ground currents in 1982 and 1985 are shown in Fig. A-4-16 and Fig. A-4-17. In the case of 1985, these will be 1,020 A at the 220 kV bus of Michiquillay Substation, 1,180 A at the 220 kV bus of Pacasmayo Substation, and 2,080 A at Trujillo Norte Substation. Compared with 3-phase short-circuit currents, these are about 1.25 times higher at Michiquillay Substation and 1.1 times at Trujillo Norte Substation, but there will be no problem as the circuit-breaking capacities have been taken at 12.5 kA.

Studies of the voltage rises of sound phases during one line to ground faults were made for Trujillo Norte Substation, Pacasmayo Substation, Michiquillay Substation and a middle point between Pacasmayo and Michiquillay. The results are given in Table 8-6. The overvoltage multiples are based on 220 kV.

At the maximum, the voltage rise is 1.14 times for phase C of Pacasmayo Substation in 1985, and there will be no problem in overvoltage during one line-to-ground fault.

Table 8-6 Voltage Rise of Sound Phase at One Line-to-Ground Fault (phase A)

Year	Substation	Impedance		X_0/X_1 (R_0/X_1)	Times of overvoltage	
		Zo	Z1		phase B	phase C
1982	Trujilló Norte	9.9+j119.9	13.3+j186.0	0.645 (0.053)	0.937	0.943
	Michiquillay	3.9+j129.6	29.9+j356.6	0.363 (0.011)	0.906	0.886
	Pacasmayo	49.5+j263.7	24.7+j271.6	0.971 (0.182)	0.970	1.024
	Intermediate point between Pacasmayo and Michiquillay	41.8+j246.1	24.3+j293.8	0.838 (0.142)	0.950	0.998
1985	Trujillo Norte	9.0+j101.0	10.6+j137.9	0.732 (0.065)	0.953	0.958
	Michiquillay	4.2+j125.7	29.2+j321.3	0.391 (0.013)	0.911	0.889
	Pacasmayo	30.7+j204.4	22.8+j228.0	0.896 (0.135)	0.968	1.138
	Intermediate point between Pacasmayo and Michiquillay	35.5+j223.0	23.8+j260.8	0.855 (0.136)	0.958	0.995

Note: Figures indicate percent value of impedance based on 1000 MVA

Table 8-7 Break-down of Supply Capability

Unit: MW

Station	Installed Capacity	1982 Peak	1982 Off Peak	1985 Peak	1985 Off Peak	1990 Peak	1990 Off Peak
Carhuaquero	123	-	-	-	-	123	25
Gallito Ciege	23	-	-	-	-	23	0
San Juan	60	-	-	-	-	60	0
Alto Chicama	240	-	-	-	-	225	115
Trujillo Gas	20.5	0	0	20	0	0	0
Chimbote Gas	61.5	0	0	20	0	0	0
SIDERPERU	99	93	45	93	45	93	45
El Chorro	160	120	60	120	70	120	60
Canõn del Pato	150	125	60	125	70	125	60
Cahua	40	20	20	20	20	20	20
Central Sistema del Lima	-	92	5	118	8	-92	-56
Total	-	450	190	516	213	697	269
Total Demand (Except for loss)		436	187.5	503	209.9	670	264.4

APPENDIX

APPENDIX

A - 1 Alto Chicama Coal-burning Thermal Power Station

A-1. ALTO CHICAMA COAL-BURNING THERMAL POWER STATION

1. Foreword

According to the geological report on the Alto Chicama District made by a Polish survey mission, it is said that the reserves consist of 270 million tons of economical coal and 11 million tons of uneconomical coal and amount to a total of 281 million tons. Of this reserves, the approximately 77.5 million tons in Block F are included in the development project. The quality of the coal is anthracite of 11.9% ash, less than 3% volatile matter, heating value of 3,000 to 7,600 kcal/kg and average specific gravity of 1.58. Alternative Proposal No. 1 for the development project is for the case of coal production of 4,200 tons per day where a power station having 4 units of 120 MW output and total installed capacity of 480 MW would be built, while Alternative Proposal No. 2 is for the case of coal production of 2,000 tons per day where a power station having 4 units of 50 MW output and total installed capacity of 200 MW would be built, with start of power generation to be 200 MW in 1979. Since there is an adequate amount of coal as mentioned above and development is technically feasible, a scheme for an at-the-source thermal power station was born from the standpoints of effective utilization of energy resources and diversification of energy in Peru.

The site presently proposed for the power station is situated at an elevation of 2,700 m. Therefore, other than general matters which would be considered for a coal-burning thermal power station built at lowland, attention to the fact that the power station will be provided at high altitude and consideration given to burning of anthracite coal will be of special importance. This will be probably the first power station in the world built at such a high elevation as 2,700 m which will moreover burn anthracite coal. Therefore, it would be desirable for thorough studies to be made particularly of the points listed below at the stages of planning and design and of working design.

2. Considerations for Installation of Boiler at High Altitude

Consideration of reduction in atmospheric pressure becomes necessary in case of boiler installation at a high altitude. In concrete terms, air, combustion gases, feed water and steam can be considered as being influenced by reduction in atmospheric pressure, but of these, with respect to feed water and steam, the effects would be negligible with the normal high-pressure boiler, leaving the problems of air and combustion gases actually requiring measures to be taken. Boiler equipment which will need attention are the following:

(1) Air Fanning Equipment

At elevation of 2,700 m and atmospheric pressure of 0.73 atm, both volume and pressure of air fan equipment will be required to be approximately 40% greater than for a boiler installed at lowland.

(2) Boiler Proper

With air fanning equipment having both air volume and air pressure raised 40%, the following must be considered for the boiler proper:

1) In order to lower draft loss of combustion gases, the combustion gas velocities at the superheater, reheater and economizer must be lowered.

2) The combustion gas velocity must be lowered to be within the limits of gas velocity matching the properties of the fuel.

As measures to be taken for the above two, there are the two methods conceivable of enlarging the furnace-width of the boiler and of reducing the pitch between the tubes of the superheater, reheater and the economizer Which method is to be adopted must be judged depending upon the individual boiler.

Furthermore, arrangement of the heating surface area will differ depending on which of the above methods is adopted, but in any case a boiler larger than one installed at lowland would be required and the price will be roughly 20% to 30% higher than a lowland boiler. Smoke flues and air ducts accessory to the boiler proper will also need to be made larger.

(3) Fuel-burning Equipment

From the standpoint of combustibility, it will be necessary to increase air for combustion since there will be less oxygen in the air. This will also influence the capacities of fans. It will also be necessary to increase the sizes of the burner throat and wind box in consideration of increase in air and volume.

3. Considerations in Burning Anthracite Coal

The coal of Alto Chicama is said to have poor ignition and combustion properties because it is anthracite coal, it has less volatile matter (3%) compared with ordinary bituminous coal, and it has a high percentage of fixed carbon (87%) so that measures to overcome this character will be required. Consequently, the following measures should be taken in consideration of the combustibility in case of designing an anthracite-burning boiler:

(1) The pulverized coal equipment is to be such that takes into consideration particle size.

(2) The degree of complete combustion of pulverized coal particles will be higher, the longer the retention time of the coal particles in the furnace and thus the uncombusted portion will be reduced. The furnace configuration and the burner equipment are to be such that this will be

made possible. In concrete terms, the flame should be a U-shape flame and a vertically downward fired furnace structure making the retention time for combustion longer should be adopted.

However, in case of large fluctuations in boiler load, there will be a necessity for some amount of supplementary fuel (heavy oil) to be used. A figure on an anthracite-burning boiler (125 MW) is attached for reference.

4. General Matters to be Considered for Coal-burning Thermal Power Station

(1) Basic Principles in Planning Thermal Power Station

The transmitting end generating cost is used as a measure for judging the economy of a thermal power station. This generating cost will vary depending on capacity, steam conditions, types of boiler and turbine, equipment arrangement, type and unit price of fuel used, acquisition of construction site, type of building, etc., but these can be broadly divided into the following three elements:

a) Construction cost

b) Fuel cost (thermal efficiency)

c) Station service power ratio

(2) Construction Cost Economization Measures

Thermal efficiency will be lowered if unit construction cost is reduced extremely, while conversely, if thermal efficiency is made too high, the construction cost will rise. In order to lower construction cost, the primary principle is not to spend more than necessary on facilities which are not related to net output, while an ample period of time should be taken for examination of the design, and the resulting design should not have too much tolerances built in. The major items are indicated below.

a) The tolerances in rated capacities of main equipment should be made small.

b) The tolerances of auxiliary equipment should be made the minimums necessary.

c) Reserve equipment should be eliminated as much as possible.

d) Structures and buildings should be of simple designs matching the purposes of use.

e) The quality of the design coal should suit the quality of the fuel scheduled to be used.

f) The power station should be of large capacity insofar as possible.

(3) Power Station Thermal Efficiency Improvement Measures

The chief measures for improving thermal efficiency are listed below.

a) Selection of steam conditions

b) Suitable selection of turbine exhaust pressure

c) Lowering of boiler exhaust gas temperature

d) Reducing of moisture in coal

e) Improvement in combustion efficiency

f) Reduction in frequency of starting and stopping to reduce starting losses

g) Reduction in frequency of faulting to improve dependability

Although the discussion here has been limited to thermal efficiency, fuel costs comprise the greater part of the generating cost and the price of fuel is an item which will require special examination.

(4) Reduction in Station Service Power, Other Measures

The various conditions for economically operating a power station are as follows:

a) Reduction in electric power consumed for station service

b) Economization in coal conveyance costs

c) Economization in ash disposal costs

d) Economization in repair costs

e) Economization in personnel costs

5. Design Principles

It will be most desirable for an ample period of time to be allowed for design at the stage of planning construction. To shorten the work schedule without principle and slighting design will tend to result in uneconomical design, while construction cost may be increased due to adoption of an unsuitable construction method. When a project has not been subjected to sufficient study, the power station as a whole will not be consistent and an unbalanced equipment investment will result. Even with a good basic design, the whole must be unified at the stage of working design and well-examined basic factors must be incorporated. The major factors are indicated below.

(1) Ease of operation

(2) Suitable degree of automation

(3) High reliability

(4) Adoption of effective and suitable equipment

(5) Proper selection of tolerances in equipment

(6) Ease of maintenance

(7) Avoidance of special design and special equipment

(8) Use of readily procurable parts

The importance of design has been discussed in the above. This is because personnel costs and repair costs making up part of the generating costs will be practically impossible to lower once the facilities are completed.

6. Locating Conditions

The factors to be considered when examining locating conditions are the following:

(1) Proximity to load center

(2) Ease of procuring fuel

(3) Ease of ash disposal

(4) Availability of abundant condenser cooling water

(5) Availability of good-quality boiler feed water

(6) Good foundation ground and adequate space

(7) Lowland cost

(8) Feasibility of hauling in heavy equipment

(9) Scarcity of pollution problems

(10) Ease of leading out transmission line

7. Tolerances for Auxiliary Equipment

In considering tolerances for power generating facilities, there are cases when as a basic principle overload operation is considered and corresponding tolerances are worked in on the whole and cases when economical design is stressed and anything in excess of the installed capacity required for the projected output of the plant is eliminated. In case of planning with the principal aim a reduction in generating cost, what can be done at the planning stage and would be most effective is to economize on fuel costs which make up approximately one half of the generating cost and on consumption of station service power which is directly related to energy transmitted. Consequently, setting large tolerances for capacities of auxiliary plant equipment and possession of a large amount of reserve equipment should be forgone to reduce equipment costs while economization in station service power should be aimed for. Tolerances for principal auxiliary equipment would be as follows:

(1) Pulverized Coal Firing System

Five sets to be provided with 4 sets making up 100% of the rated capacity of the plant.

(2) Boiler Feed Water Pump

Three sets to be provided with operation of 2 sets providing 110% of capacity during output of the plant at rated capacity.

(3) Oil Firing System

Two sets to be provided having capacity 50% of maximum continuous rating of boiler.

(4) Circulating Water Pump

Two sets to be provided and tolerance for maximum design water circulation to be 0%.

(5) Draft Fan (Induced and Forced)

Two sets each to be provided with gas and air quantities to be 120% at operation of boiler at maximum continuous rating and air pressure to be 125% of air pressure required at maximum continuous rating operation.

(6) Motor

Capacities to be 105% to 110% of shaft driving forces of fans and pumps.

8. Conditions for Using Power Station

The conditions for using the power station and operation principles should be investigated and studied in advance and the results must be incorporated in the specifications of main equipment. The major items are indicated below.

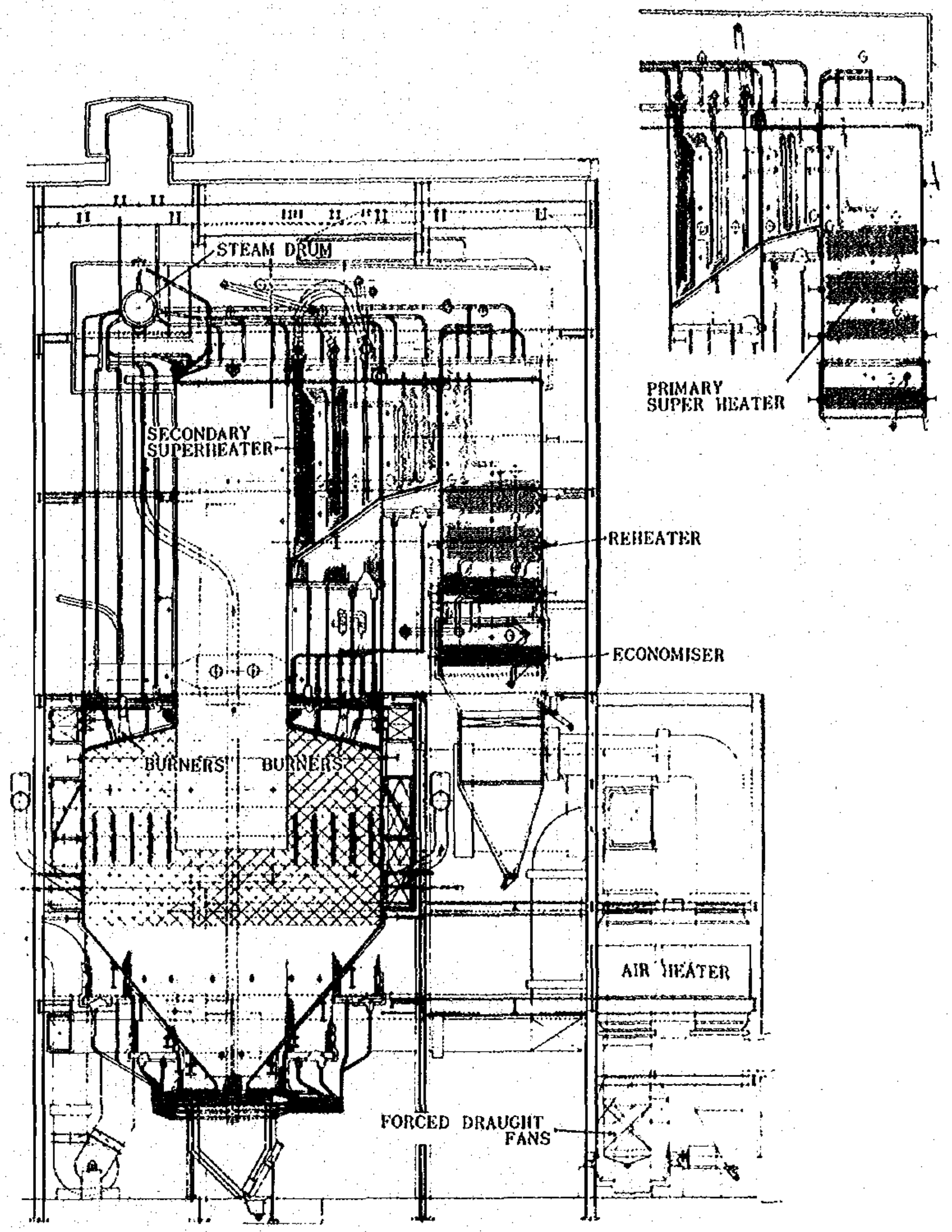
(1) System structure with transmission line, and protective apparatus

(2) Load variation pattern and variation speed

(3) Limits of minimum load and overload

(4) Permissible limits to frequency variation

(5) Starting time and quick starting



Max. continuous rating	420 t/hr (926,000 lb/hr)
Superheater outlet pressure	131 kg/sq.cm (1,863 lb/sq.in)
Final steam temperature	541°C (1,005°F)
Reheat steam temperature	541°C (1,005°F)
Feed water temperature	239°C (462°F)
Fuel	P.F. (anthracite coal)

A-2 Demand Forecast and Balance of Demand and Supply in the Central and Santa Power Systems

Table A-2-1 Maximum Demand Forecast Estimated By Japanese Mission

Unit: MW

System		1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Increase (%)
Central System	Sector Lima	600	655	714	779	850	927	1,011	1,103	1,204	1,313	1,433	1,563	1,706	1,861	2,030	9.1
	S. Paramonga-Huacho	-	-	62	65	66	67	68	68	69	69	71	73	75	78	80	2.1
	S. Cañete	3	3	3	4	4	4	4	4	5	5	5	5	5	5	6	5.1
	S. Chincha	3	4	4	4	5	5	5	5	6	6	6	7	7	8	8	7.3
	S. Pisco	16	16	17	17	17	18	18	19	19	20	20	21	22	23	23	2.6
	S. Ica	8	8	9	10	10	11	12	13	13	14	15	16	17	18	19	6.4
	S. Nazca	-	-	-	-	16	58	58	58	58	72	86	100	104	107	110	21.2
	S. Marcona Mining	115	115	115	115	115	115	115	115	115	115	117	119	122	124	126	0.7
	S. Huancavelica	-	-	20	35	36	37	39	40	42	43	44	45	47	48	49	7.8
	S. Centromin	209	248	289	349	392	401	410	419	429	439	448	457	466	475	485	6.2
	S. Huanuco	-	3	4	4	4	5	5	5	5	5	6	6	7	7	8	7.8
	S. Tarma	17	19	20	25	27	27	29	33	34	35	36	37	38	39	40	6.3
	S. Junin	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	6.5
	S. Pasco	0	1	1	2	2	2	2	3	3	4	4	4	5	5	5	13.2
	S. Jauja y Mantaro	-	3	3	4	4	5	5	5	6	6	6	6	6	6	7	6.8
	S. Huancayo	-	12	14	15	17	18	19	21	22	23	25	26	28	30	32	7.8
	Estimated new demand	-	-	-	-	-	-	-	-	-	-	60	64	67	71	75	5.7
	Total	971	1,087	1,275	1,429	1,566	1,701	1,801	1,912	2,031	2,170	2,384	2,551	2,724	2,907	3,105	8.7
Northern System	Sistema Santa	139	168	253	262	279	290	326	331	339	350	356	368	382	396	415	8.1
	Pacasmayo	(2)	(6)	(7)	(8)	(9)	(11)	(13)	(14)	(16)	18	20	22	24	27	29	21.0
	Lambayeque	(14)	(15)	(16)	(18)	(20)	(23)	(25)	(28)	(31)	(35)	(38)	(41)	(44)	(47)	(51)	9.7
	Cajamarca	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	9.4
	Celendin Michiquillay	-	-	-	-	-	-	40	40	40	40	40	65	65	65	65	6.3
	Total	141 (157)	171 (192)	256 (279)	265 (291)	283 (312)	294 (328)	370 (408)	376 (418)	384 (431)	413 (448)	422 (460)	461 (502)	477 (521)	495 (542)	516 (567)	9.6 9.6
Interconnected System	Maximum demand	1,112 (1,128)	1,258 (1,279)	1,531 (1,554)	1,694 (1,720)	1,849 (1,878)	1,995 (2,029)	2,171 (2,209)	2,288 (2,330)	2,415 (2,462)	2,583 (2,618)	2,806 (2,844)	3,012 (3,053)	3,201 (3,245)	3,402 (3,449)	3,621 (3,672)	8.8 (8.8)
	Resultant max. demand	1,045 (1,060)	1,082 (1,102)	1,439 (1,461)	1,592 (1,617)	1,738 (1,765)	1,875 (1,907)	2,040 (2,076)	2,151 (2,190)	2,270 (2,313)	2,428 (2,461)	2,638 (2,673)	2,831 (2,869)	3,009 (3,050)	3,198 (3,242)	3,404 (3,451)	8.8 (8.8)
	Transmission loss (more than 138 kV)	31 (32)	36 (36)	43 (44)	47 (49)	52 (53)	57 (57)	62 (62)	64 (65)	69 (69)	73 (74)	79 (80)	85 (86)	90 (91)	96 (97)	102 (103)	8.7 8.9
	Power demand at generating end	1,076 (1,092)	1,218 (1,238)	1,482 (1,505)	1,639 (1,666)	1,790 (1,818)	1,932 (1,964)	2,102 (2,138)	2,215 (2,255)	2,339 (2,382)	2,501 (2,535)	2,717 (2,753)	2,916 (2,955)	3,099 (3,141)	3,294 (3,339)	3,506 (3,554)	8.8 8.8

Note : Figures in parenthesis indicate the total demand including demand of Pacasmayo and Lambayeque systems which will be interconnected with Santa Power System in 1985 and after 1990 respectively.

Table A-2-2 Energy Demand Forecast Estimated By Japanese Mission

Unit: GWh

		1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1970	Increase (%)
Central System	Sector Lima	3,153	3,442	3,752	4,094	4,467	4,872	5,313	5,797	6,328	6,901	7,531	8,215	8,966	9,781	10,669	9.1
	S. Paramonga-Huacho	-	-	312	326	334	337	337	344	347	350	361	373	385	397	410	2.3
	S. Cañete	6	7	8	9	10	10	11	12	13	13	14	14	15	16	16	7.3
	S. Chincha	22	28	33	37	40	43	46	47	48	50	51	53	55	57	59	7.3
	S. Pisco	39	46	53	58	61	64	67	69	71	73	75	79	80	83	86	5.8
	S. Ica	36	39	43	47	51	55	59	63	67	71	75	79	84	88	94	7.1
	S. Nazca	-	-	-	-	56	317	319	320	321	403	484	570	598	616	635	27.4
	S. Marcona Mining	638	638	638	638	638	638	638	638	638	638	651	664	677	690	704	0.7
	S. Huancavelica	-	-	170	211	215	223	230	238	246	253	259	266	273	281	288	4.5
	S. Centromin	1,517	2,006	2,107	2,559	2,877	2,843	3,009	3,078	3,147	3,221	3,279	3,351	3,418	3,487	3,556	6.3
	S. Huanuco	-	9	11	13	14	15	17	18	19	20	22	23	25	26	28	9.2
	S. Tarma	91	97	104	130	135	137	146	169	175	181	185	190	195	200	205	6.0
	S. Junin	1	1	1	2	2	2	3	3	4	4	4	5	5	5	6	13.7
	S. Pasco	1	2	3	3	4	5	5	6	7	8	8	9	10	11	12	19.4
	S. Jauja y Mantaro	-	6	7	8	9	10	11	12	13	14	14	15	15	16	17	8.4
	S. Huancayo	-	35	40	45	49	53	58	63	69	74	79	86	92	99	107	9.0
	Estimated new demand	-	-	-	-	-	-	-	-	-	-	254	340	372	393	416	13.2
	Total	5,504	6,356	7,282	8,180	8,962	9,624	10,269	10,877	11,513	12,274	13,356	14,330	15,265	16,246	17,308	8.5
Northern System	Sistema Santa	631	830	1,128	1,185	1,340	1,421	1,721	1,784	1,868	1,926	1,958	2,005	2,072	2,138	2,213	9.4
	Pacasmayo	(11)	(25)	(30)	(35)	(40)	(45)	(52)	(58)	(65)	70	75	80	85	90	95	16.6
	Lambayeque	(66)	(73)	(79)	(86)	(93)	(102)	(110)	(120)	(132)	(140)	(155)	(170)	(180)	(190)	(200)	8.2
	Cajamarca Celendin	8	9	10	11	13	13	14	15	15	17	17	18	19	20	21	7.1
	Michiquillay	-	-	-	-	-	-	278	278	278	278	278	452	452	452	452	6.3
	Total	639 (716)	839 (937)	1,138 (1,247)	1,196 (1,317)	1,353 (1,486)	1,434 (1,581)	2,013 (2,175)	2,077 (2,255)	2,161 (2,358)	2,291 (2,431)	2,328 (2,483)	2,555 (2,725)	2,628 (2,808)	2,700 (2,890)	2,781 (2,981)	10.9 10.7
Interconnected System	Energy demand	6,143 (6,220)	7,195 (7,293)	8,420 (8,529)	9,376 (9,497)	10,315 (10,448)	11,058 (11,205)	12,282 (12,444)	12,954 (13,132)	13,674 (13,871)	14,565 (14,705)	15,684 (15,839)	16,885 (17,055)	17,893 (18,073)	18,946 (19,136)	20,089 (20,289)	8.8 8.8
	Transmission loss (more than 138 kV)	185 (186)	218 (218)	254 (255)	282 (284)	311 (313)	333 (336)	370 (373)	391 (393)	412 (416)	437 (441)	471 (475)	507 (511)	537 (542)	568 (574)	603 (608)	8.8 8.8
	Energy requirement at generating end	6,328 (6,406)	7,413 (7,511)	8,674 (8,784)	9,658 (9,781)	10,626 (10,761)	11,391 (11,541)	12,652 (12,817)	13,345 (13,525)	14,086 (14,287)	15,002 (15,146)	16,155 (16,314)	17,392 (17,566)	18,430 (18,615)	19,514 (19,710)	20,692 (20,897)	8.8 8.8

Note : Figures in parenthesis indicate the total demand including demand of Pacasmayo and Lambayeque systems which will be interconnected with Santa Power System in 1985 and after 1990 respectively.

Table A-2-3 Maximum Demand Forecast Estimated by MEM

Unit: MW

		1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Increase (%)
Central System	Sector Lima	623	730	789	848	958	1,028	1,102	1,183	1,271	1,366	1,450	1,558	1,676	1,802	1,940	8.5
	S. Paramonga-Huacho	-	-	62	65	66	67	68	68	69	69	71	73	75	78	80	2.1
	S. Cañete	3	3	3	4	4	4	4	4	5	5	5	5	5	5	6	5.1
	S. Chincha	3	4	4	4	5	5	5	5	6	6	6	7	7	8	8	7.3
	S. Pisco	16	16	17	17	17	18	18	19	19	20	20	21	22	23	23	2.6
	S. Ica	8	8	9	10	10	11	12	13	13	14	15	16	17	18	19	6.4
	S. Nazca	-	-	-	-	16	58	58	58	58	72	86	100	104	107	110	21.2
	S. Marcona Mining	115	115	115	115	115	115	115	115	115	115	117	119	122	124	126	0.7
	S. Huancavelica	-	-	20	35	36	37	39	40	42	43	44	45	47	48	49	7.8
	S. Centromin	209	248	289	349	392	401	410	419	429	439	448	457	466	475	485	6.2
	S. Huanuco	-	3	4	4	4	5	5	5	5	5	6	6	7	7	8	7.8
	S. Tarma	17	19	20	25	27	27	29	33	34	35	36	37	38	39	40	6.3
	S. Junin	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	6.5
	S. Pasco	0	1	1	2	2	2	2	3	3	4	4	4	5	5	5	13.2
	S. Jauja y Mantaro	-	3	3	4	4	5	5	5	6	6	6	6	6	6	7	6.8
	S. Huancayo	-	12	14	15	17	18	19	21	22	23	25	26	28	30	32	7.8
	Estimated new demand	-	-	-	-	-	-	-	-	-	-	60	64	67	71	75	5.7
	Total	994	1,162	1,350	1,498	1,674	1,802	1,892	1,992	2,098	2,223	2,401	2,546	2,694	2,848	3,015	8.3
Northern System	Sistema Santa	-	256	357	395	413	475	488	501	516	580	556	572	589	607	627	7.1
	Pacasmayo	-	19	21	22	23	35	38	40	43	46	50	53	56	60	64	9.8
	Lambayeque	-	-	-	-	95	98	102	105	107	113	121	126	131	136	142	4.1
	Cajamarca-Michiquillay	-	-	-	-	-	-	49	50	50	50	51	53	54	56	57	1.9
	Total	-	275	378	417	531	608	677	696	716	789	778	804	830	859	890	9.5
Interconnected System	Maximum demand	994	1,437	1,728	1,715	2,205	2,410	2,569	2,688	2,814	3,012	3,179	3,350	3,524	3,707	3,905	10.3
	Resultant max. demand	934	1,351	1,624	1,800	2,073	2,265	2,415	2,527	2,645	2,831	2,988	3,149	3,313	3,485	3,671	10.3
	Transmission loss (more than 138 kV)	28	41	49	54	62	68	72	76	79	85	90	94	99	105	110	10.3
	Power demand at generating end	962	1,392	1,673	1,854	2,135	2,333	2,487	2,603	2,724	2,916	3,078	3,243	3,412	3,590	3,781	10.3

Table A-2-4 Energy Demand Forecast Estimated By MEM

Unit: GWh

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Increase (%)
Sector Lima	3,274	3,838	4,148	4,476	4,941	5,325	5,741	6,193	6,683	7,213	7,644	7,854	8,916	9,635	10,414	8.6
S. Paramonga-Huacho	-	-	312	326	334	337	337	344	347	350	361	373	385	397	410	2.3
S. Cañete	6	7	8	9	10	10	11	12	13	13	14	14	15	16	16	7.3
S. Chincha	22	28	33	37	40	43	46	47	48	50	51	53	55	57	59	7.3
S. Pisco	39	46	53	58	61	64	67	69	71	73	75	77	80	83	86	5.8
S. Ica	36	39	43	47	51	55	59	63	67	71	75	79	84	88	94	7.1
S. Nazca	-	-	-	-	56	317	319	320	321	403	484	570	598	616	635	27.4
S. Marcona Mining	638	638	638	638	638	638	638	638	638	638	651	664	677	690	704	0.7
S. Huancavelica	-	-	170	211	215	223	230	238	246	253	259	266	273	281	288	4.5
S. Centromin	1,517	2,006	2,107	2,559	2,877	2,843	3,009	3,078	3,147	3,221	3,279	3,351	3,418	3,487	3,556	6.3
S. Huanuco	-	9	11	13	14	15	17	18	19	20	22	23	25	26	28	9.2
S. Tarma	91	97	104	130	135	137	146	169	175	181	185	190	195	200	205	6.0
S. Junin	1	1	1	2	2	2	3	3	4	4	4	5	5	5	6	13.7
S. Pasco	1	2	3	3	4	5	5	6	7	8	8	9	10	11	12	19.4
S. Jauja y Mantaro	-	6	7	8	9	10	11	12	13	14	14	15	15	16	17	8.4
S. Huancayo	-	35	40	45	49	53	58	63	69	74	79	86	92	99	107	9.0
Estimated new demand	-	-	-	-	-	-	-	-	-	-	254	340	372	393	416	13.2
Total	5,625	6,752	7,678	8,562	9,436	10,077	10,697	11,273	11,868	12,586	13,459	13,969	15,215	16,100	17,053	8.2
Sistema Santa	-	1,114	1,348	1,703	1,855	2,226	2,311	2,389	2,464	2,533	2,646	2,710	2,781	2,856	2,937	7.7
Pacasmayo	-	91	103	108	115	143	153	165	176	188	206	220	228	250	267	8.6
Lambayeque	-	-	-	-	487	503	516	532	548	564	600	617	636	657	(680)	3.4
Cajamarca-Michiquillay	-	-	-	-	-	-	283	284	285	287	294	301	308	315	323	1.7
Total	-	1,205	1,451	1,811	2,457	2,872	3,263	3,370	3,473	3,572	3,746	3,848	3,953	4,078	4,207	10.1
Energy demand	5,625	7,957	9,129	10,373	11,893	12,949	13,960	14,643	15,341	16,158	17,205	17,817	19,168	20,178	21,260	10.0
Transmission loss (more than 138 kV)	168	238	273	311	356	388	418	439	460	484	516	534	575	611	637	10.0
Energy requirement at generating end	5,793	8,195	9,402	10,684	12,249	13,337	14,378	15,082	15,801	16,642	17,721	18,351	19,743	20,789	21,897	10.0

Table A-2-5 kW and kWh Balance in Central Power System

Year	Power demand 1/		Power supply capability															
			EE.EE.AA Dependable		Mantaro Dependable		Centromin Dependable		Marcona Dependable		Sheque Dependable		Restitucción Dependable		Lima thermal Dependable		Total Dependable	
	Max. demand (MW)	Energy demand (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)
1976	971	5,504	528	2,822	342	2,990	141	965	42	245	-	-	-	-	-	-	1,053	7,022
1977	1,089	6,356	528	2,822	682	3,060	141	965	42	245	-	-	-	-	-	-	1,393	7,092
1978	1,213	6,970	528	2,822	682	3,060	141	965	42	245	-	-	-	-	-	-	1,393	7,092
1979	1,364	7,854	528	2,822	682	3,060	141	965	42	245	-	-	-	-	113	767	1,506	7,859
1980	1,500	8,628	528	2,822	682	3,060	141	965	42	245	-	-	-	-	113	767	1,506	7,859
1981	1,634	9,287	528	4,015 2/	682	3,060	141	965	42	245	293	680	-	-	113	767	1,799	9,732
1982	1,733	9,932	528	4,015	682	3,060	141	965	42	245	293	680	-	-	113	767	1,799	9,732
1983	1,844	10,533	528	4,015	682	3,060	141	965	42	245	585	1,792	-	-	113	767	2,091	10,844
1984	1,962	11,166	528	4,015	682	3,060	301	1,875	42	245	585	1,792	-	-	113	767	2,251	11,754
1985	2,101	11,924	528	4,015	682	3,060	301	1,875	42	245	585	1,792	-	-	113	767	2,251	11,754
1986	2,313	12,995	528	4,015	682	3,060	301	1,875	42	245	585	1,792	180	895	225	1,533	2,543	13,415
1987	2,478	13,957	528	4,015	682	3,060	301	1,875	42	245	585	1,792	180	895	225	1,533	2,543	13,415
1988	2,649	14,880	528	4,015	682	3,060	301	1,875	42	245	585	1,792	180	895	338	2,300	2,656	14,182
1989	2,829	15,849	528	4,015	682	3,060	301	1,875	42	245	585	1,792	180	895	563	3,833	2,881	15,715
1990	3,025	16,898	528	4,015	682	3,060	301	1,875	42	245	585	1,792	180	895	563	3,833	2,881	15,715

Note : 1/ : Power demand of Paramonga and Huacho was excluded from the power demand of the Central Power System

2/ : Additional energy due to operation of Sheque Power Plant

Table A-2-6 KW and kWh Balance in Santa Power System

Year	Power demand[1/]		Power supply capability													
			Cauha Dependable		Cañon del Pato Dependable		El Chorro Dependable		Gasturbine Dependable		SIDERPERU Dependable		Alto Chicama & Others Dependable		Total Dependable	
	Max. demand	Energy demand	Power	Energy	Power	Energy	Power	Energy	Power	Energy	Power	Energy	Power	Energy	Power	Energy
1976	139	631	-	-	75	630	-	-	164	144	-	-	-	-	239	774
1977	168	830	-	-	75	630	-	-	164	144	-	-	-	-	239	774
1978	315	1,450	40	175	125	655	-	-	5/ 82	72	66	605	-	-	313	1,507
1979	327	1,522	40	175	125	655	-	-	82	72	66	605	-	-	313	1,507
1980	345	1,687	40	175	125	655	-	-	82	72	66	605	-	-	313	1,507
1981	357	1,771	40	175	125	655	-	-	82	72	66	605	-	-	313	1,507
1982	438	2,350	40	175	125	655	120	1,046	82	72	66	605	-	-	433	2,553
1983	444	2,421	40	175	125	655	120	1,046	82	72	66	605	-	-	433	2,553
1984	453	2,508	40	175	125	655	120	1,046	82	72	66	605	-	-	433	2,553
1985	482	2,641	40	175	125	655	120	1,046	82	72	66	605	-	-	433	2,553
1986	493	2,689	40	175	125	655	120	1,046	82	72	66	605	54	368	487	2,921
1987	534	2,928	40	175	125	655	120	1,046	82	72	66	605	54	368	487	2,921
1988	552	3,013	40	175	125	655	120	1,046	82	72	66	605	2/ 185	1,019	618	3,572
1989	573	3,097	40	175	125	655	120	1,046	82	72	66	605	3/ 308	1,695	741	4,248
1990	596	3,191	40	175	125	655	120	1,040	82	72	66	605	4/ 368	2,256	801	4,809

Note : 1/ : Power demand of Paramonga and Huacho was included in the power demand of the Santa Power System

2/ : 180 MW × 0.9 + 23 MW (Galito Ciego)

3/ : 180 × 0.9 + 23 + 123 (Carhuaquero)

4/ : 180 × 0.9 + 23 + 123 + 60 (San Juan)

5/ : Retire of gas turbine 82 MW

Table A-2-7 kW and kWh Balance in Interconnected System

Year	Power demand		Power supply capability					
			Central power system Dependable		Santa power system Dependable		Total Dependable	
	Max. demand (MW)	Energy demand (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)
1976	1,076	6,328	1,053	7,022	239	774	1,292	7,796
1977	1,218	7,413	1,393	7,092	239	774	1,632	7,866
1978	1,482	8,674	1,393	7,092	313	1,507	1,706	8,599
1979	1,639	9,658	1,506	7,859	313	1,507	1,819	9,366
1980	1,790	10,626	1,506	7,859	313	1,507	1,819	9,366
1981	1,932	11,391	1,799	9,732	313	1,507	2,112	11,239
1982	2,102	12,652	1,799	9,732	433	2,553	2,232	12,285
1983	2,215	13,345	2,091	10,844	433	2,553	2,524	13,397
1984	2,339	14,086	2,251	11,754	433	2,553	2,684	14,307
1985	2,501	15,002	2,251	11,754	433	2,553	2,684	14,307
1986	2,717	16,155	2,543	13,415	487	2,921	3,030	16,336
1987	2,916	17,392	2,543	13,415	487	2,921	3,030	16,336
1988	3,099	18,430	2,656	14,182	618	3,572	3,274	17,754
1989	3,294	19,514	2,881	15,715	741	4,248	3,622	19,963
1990	3,506	20,692	2,881	15,715	801	4,809	3,682	20,524

A - 3 Pacasmayo Diesel Power Plant

A-3. PACASMAYO DIESEL GENERATING FACILITIES

In case it is assumed that power supply to the Michiquillay Mine is to be made by construction of diesel generating facilities at Pacasmayo and a 220 kV transmission line, the major particulars and construction costs of the generating and transmitting facilities would be indicated below.

1) Transmission Line

Sector: Pacasmayo - Michiquillay
Length: 140 km
Voltage and number of circuits: 220 kV, 1 cct
Construction cost: US$10,156 x 10^3

2) Transforming Facilities

Michiquillay: Lead-out facilities
Transformer, 80 MVA
Construction cost: US$5,683 x 10^3

3) Telecommunications Facilities

One set as required
Construction cost: US$774 x 10^3

4) Pacasmayo Diesel Plant

Installed capacity: 11 MW x 6 units
Construction cost: US$30,029 x 10^3
Unit construction cost per kW: US$455/kW
Expense ratio: 16%

The benefit-cost ratios comparing the energy cost at the Michiquillay Mine in case of construction of a diesel plant at Pacasmayo and supply by a transmission line of 140 km and the generating cost in case of supply constructing a diesel plant at the Michiquillay Mine will be shown in Table A-3-1.

Table A-3-1 Comparision of Generating Cost at Michiquillay

(unit : mills/kWh)

	Diesel plants at Michiquillay (B)	Supply through interconnected transmission line (C)	(B)/(C)	(B)-(C)
Present fuel price in Peru	27.83	22.90	1.22	4.93
International market fuel price	35.74	30.97	1.15	4.77

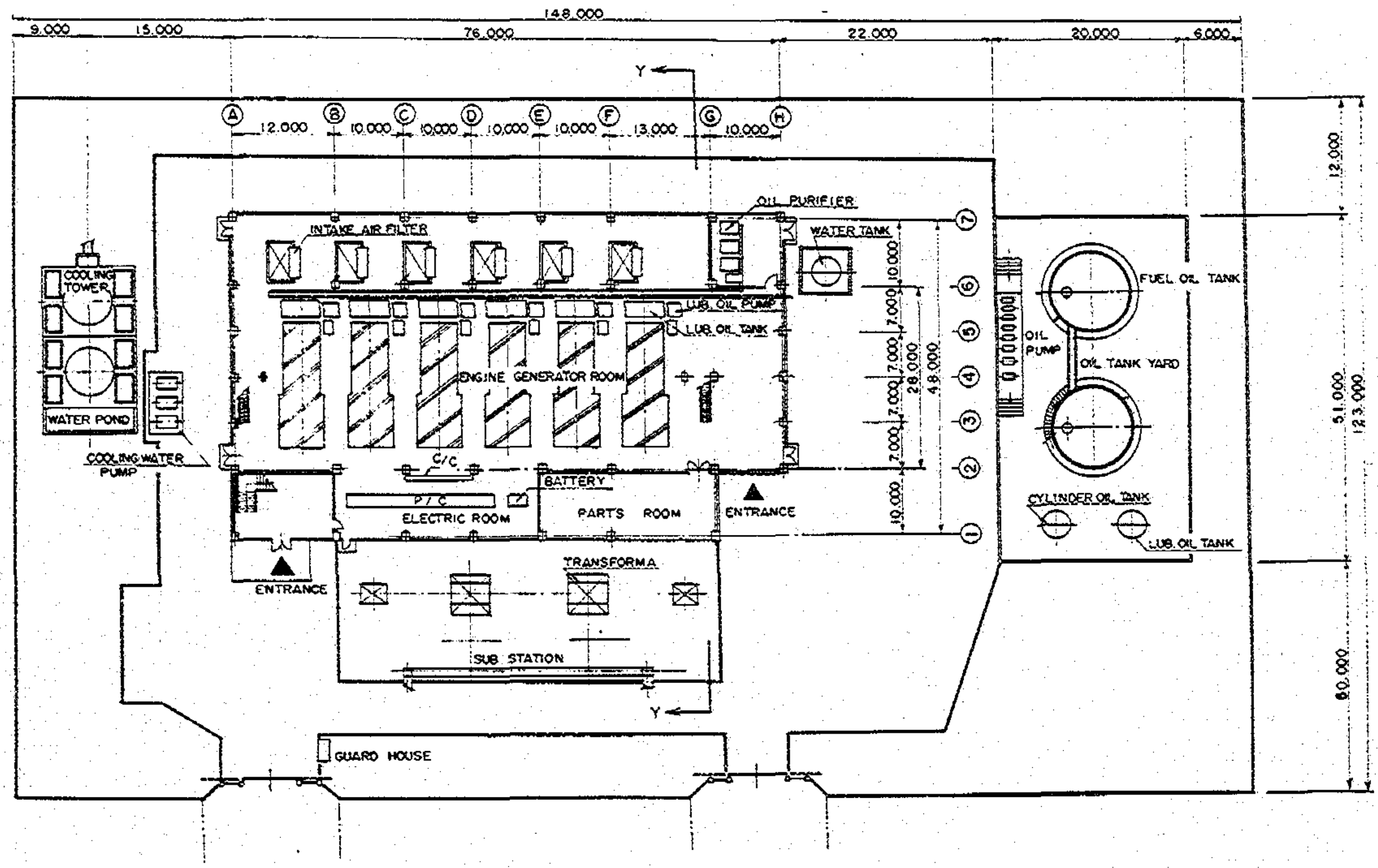


Fig. A-3-1 DIESEL GENERATING POWER PLANT LAY OUT (66 MW)

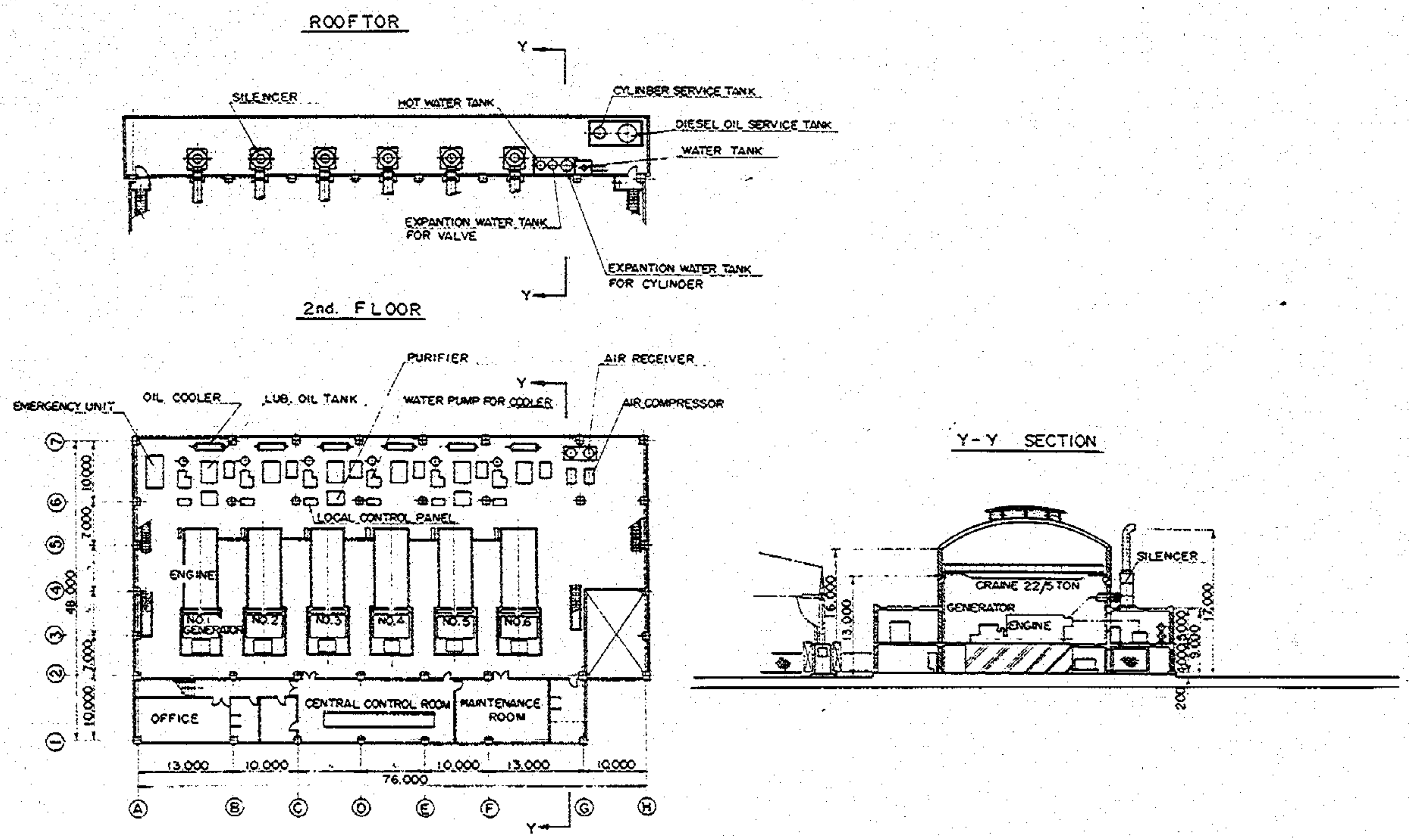


Fig. A-3-2 DIESEL GENERATING POWER PLANT LAY OUT

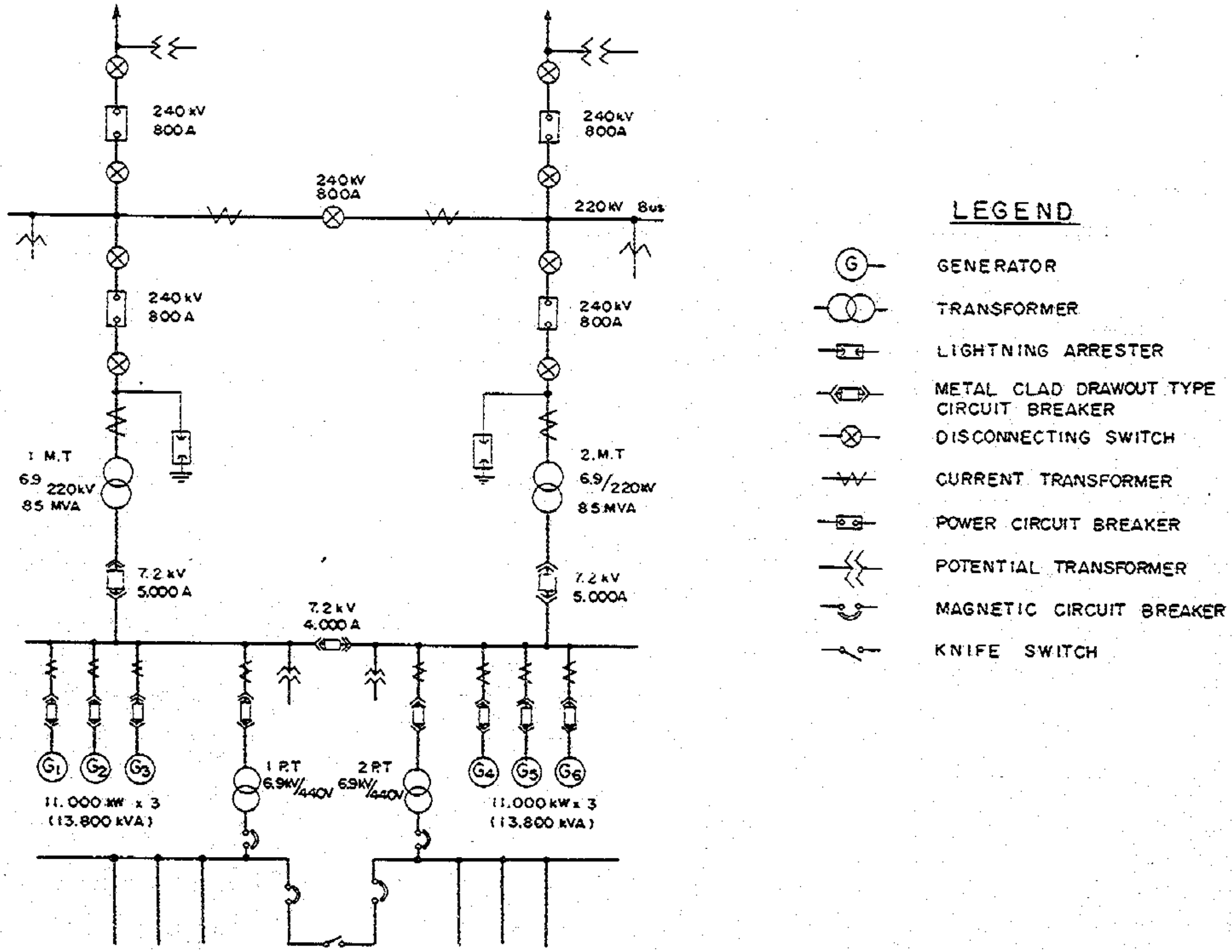
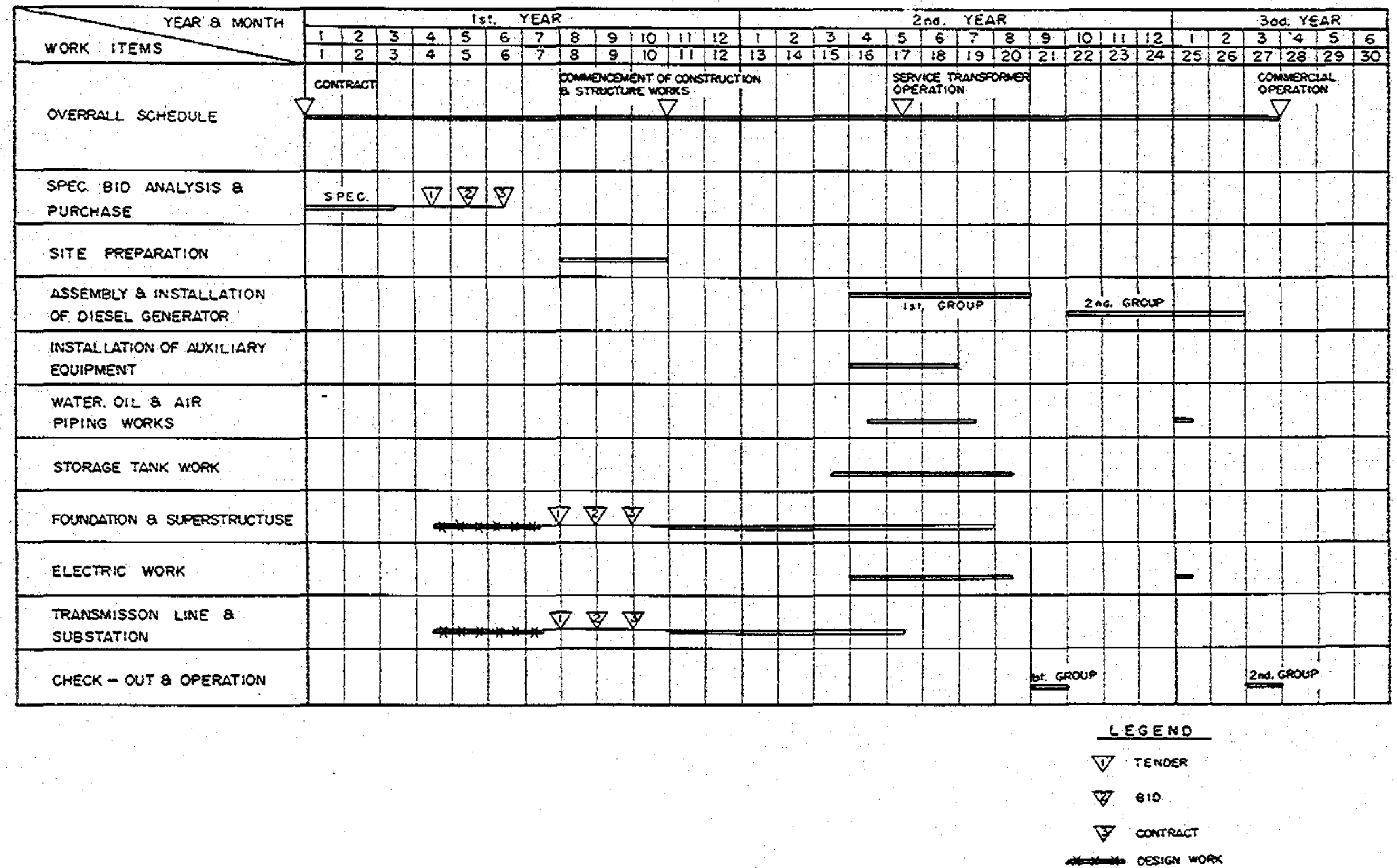


Fig. A-3-3 SINGL DIAGRAM OF DIESEL POWER PLANT
66 MW

Table. A-3-2 CONSTRUCTION SCHEDULE FOR DIESEL GENERATING PLANT



Itemized list of Diesel Power Plant Equipment (66 MW)

Items	Discription
1. Fuel Oil System	
(1) Diesel oil unloading pump	20 m^3/h, 5 kg/cm^2
(2) Diesel oil storage tank	800 kl
(3) Diesel transfer pump	20 m^3/h, 5 kg/cm^2
(4) Flow meter & filter	
(5) Diesel oil Bufer tank	30 kl
(6) Purifier	6000 l/hr
(7) Diesel oil service tank	10 kl
(8) Heavy oil unloading pump	20 m^3/h, 5 ks/cm^2
(9) Heavy oil storage tank	3000 kl
(10) Heavy oil transfer pump	20 m^3/h, 5 kg/cm^2
(11) Flowmeter & filter	
(12) Heavy oil buffer tank	30 kl
(13) Heavy oil purifier	6000 l/kr
(14) Heavy oil steam heater	
(15) Heavy oil service tank	10 kl
(16) Heavy oil supply pump	10 m^3/h, 5 kg/cm^2
(17) Drain tank	1000 l
(18) Drain discharge pump	10 m^3/h, 5 kg/cm^2
(19) Sludge transfer pump	5 m^3/h, 3 kg/cm^2
(20) Sludge storage tank	30 kl

Items	Discription
2. Lub. oil system	
(1) Lub. oil unloading pump	10 m^3/h, 2.5 kg/cm^2
(2) Lub. oil storage tank	30 kl
(3) Lub. oil transfer pump	10 m^3/h, 5 kg/cm^2
(4) Main oil pump	120 m^3/h, 7 kg/cm^2
(5) Lub. oil cooler	200 m^2
(6) Lub. oil tank for turbo-charger	100 l
(7) Lub. oil purifier	6000 l/hr.
(8) Filters	
3. Cylinder oil system	
(1) Cyl. oil unloading pump	10 m^3/h, 2.5 kg/cm^2
(2) Cylinder oil storage tank	30 kl
(3) Cyl. oil transfer pump	10 m^3/h, 5 kg/cm^2
(4) Cyl. oil service tank	2000 l
4. Steam system	
(1) Exhaust gas boiler	600 kg/h, 7 kg/cm^2
(2) Auxiliary boiler	3000 kg/h, 7 kg/cm^2
(3) Water service tank for aux. boiler	1500 l
5. Water system	
(1) Fresh water tank	60 kl
(2) Water feed pump	7 m^3/h, 11 kg/cm^2
(3) Hot water tank	400 l
(4) Valve cooling water tank	1000 l

Items	Discription
(5) Valve cooling water pump	10 m^3/h, 3 kg/cm^2
(6) Cyl. cooling water tank	3000 l
(7) Cyl. cooling water pump	400 m^3/h, 2.5 kg/cm^2
(8) Cooling tower	4000 m^3/h, 43°C/32°C
(9) Water treatment equipment	14 tons/hr.

6. Air system

(1) Air compressor	100 m^3/h, 25 kg/cm^2
(2) Air receiver	4000 l, 25 kg/cm^2
(3) Air filter & reduser	

7. Diesel engine	out put	14,500 ps
	speed	520 rpm
	No. of cyl.	18 cylinder
	fuel consumption	146 g/ps. h.
8. Turbo generator & accessories		
	Rated capacity	13,800 kVA
	Terminal voltage	72,000 V
	Frequency	60 Hz
	Power factor	85 %
9. Transformer (Mim)	Phase	3
	Rated voltage	220,000 V
	Capacity	
(Auxiliary)	Capacity	

10. House service switch gears

(1) 440 V power center

(2) 440 V control center

(3) Control panels

Items	Discription
11. Out-door Substation	
(1) Circuit breaker	
(2) Disconnecting switches	
(3) Compressed air supply system	
12. Auxiliary apparatus:	
(1) Emergency electric power	200 kVA
(2) D.C. Battery & rectifier	
(3) Inter-communication equipment	
(4) Fire protection equipment	
(5) Over head traveling craine	22/5 ton
13. Civil & building works	
(1) Power house	
(2) Substation	
(3) Guardman's house	
(4) Water treatment house	
(5) Water treatment pond	
(6) Cooling tower pond	
(7) Raw water intake	
(8) Fuel oil strage tank yard	
(9) Fuel oil treatment room	

A - 4 Analysis of the Interconnected Power System

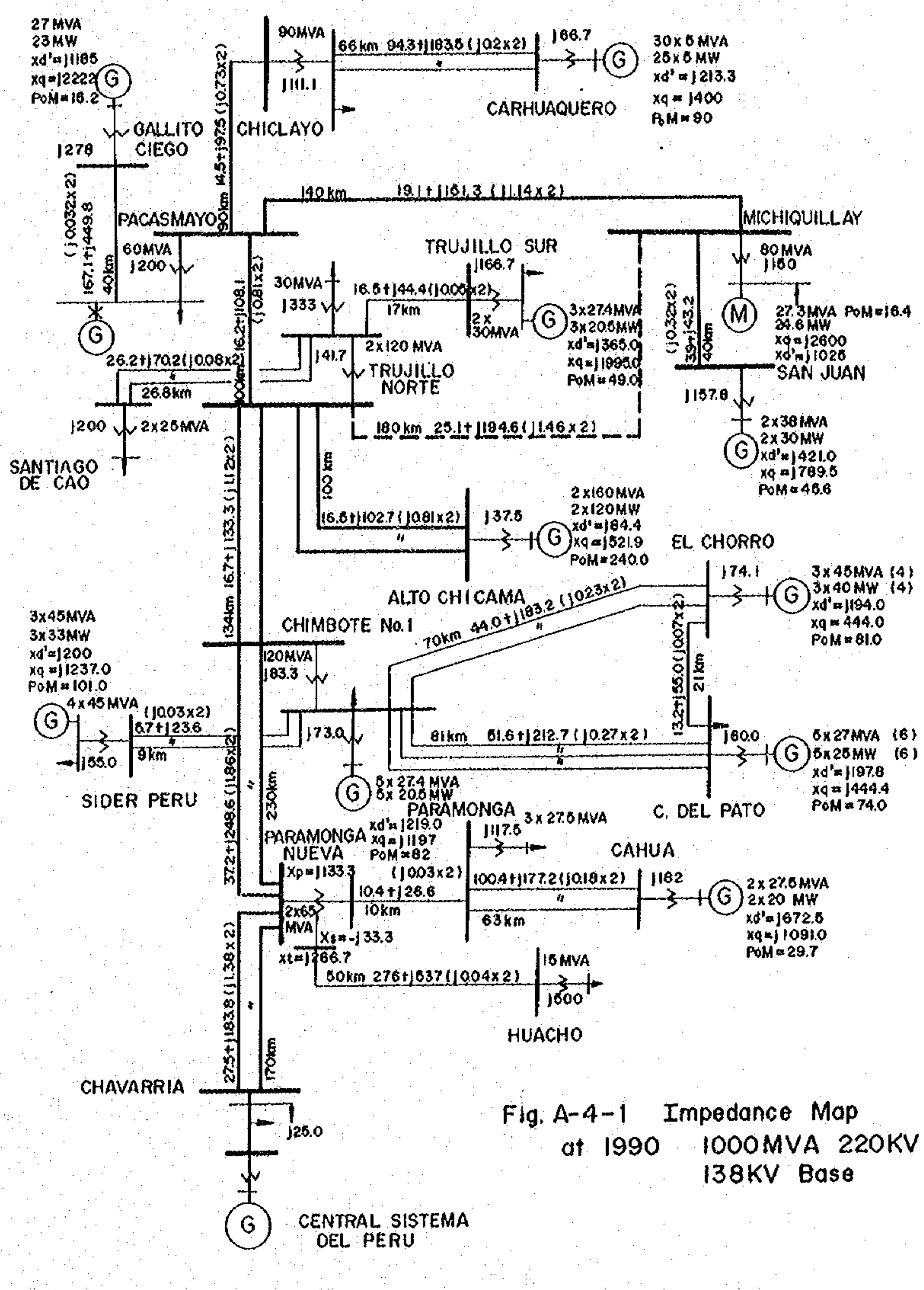


Fig. A-4-1 Impedance Map at 1990 1000MVA 220KV 138KV Base

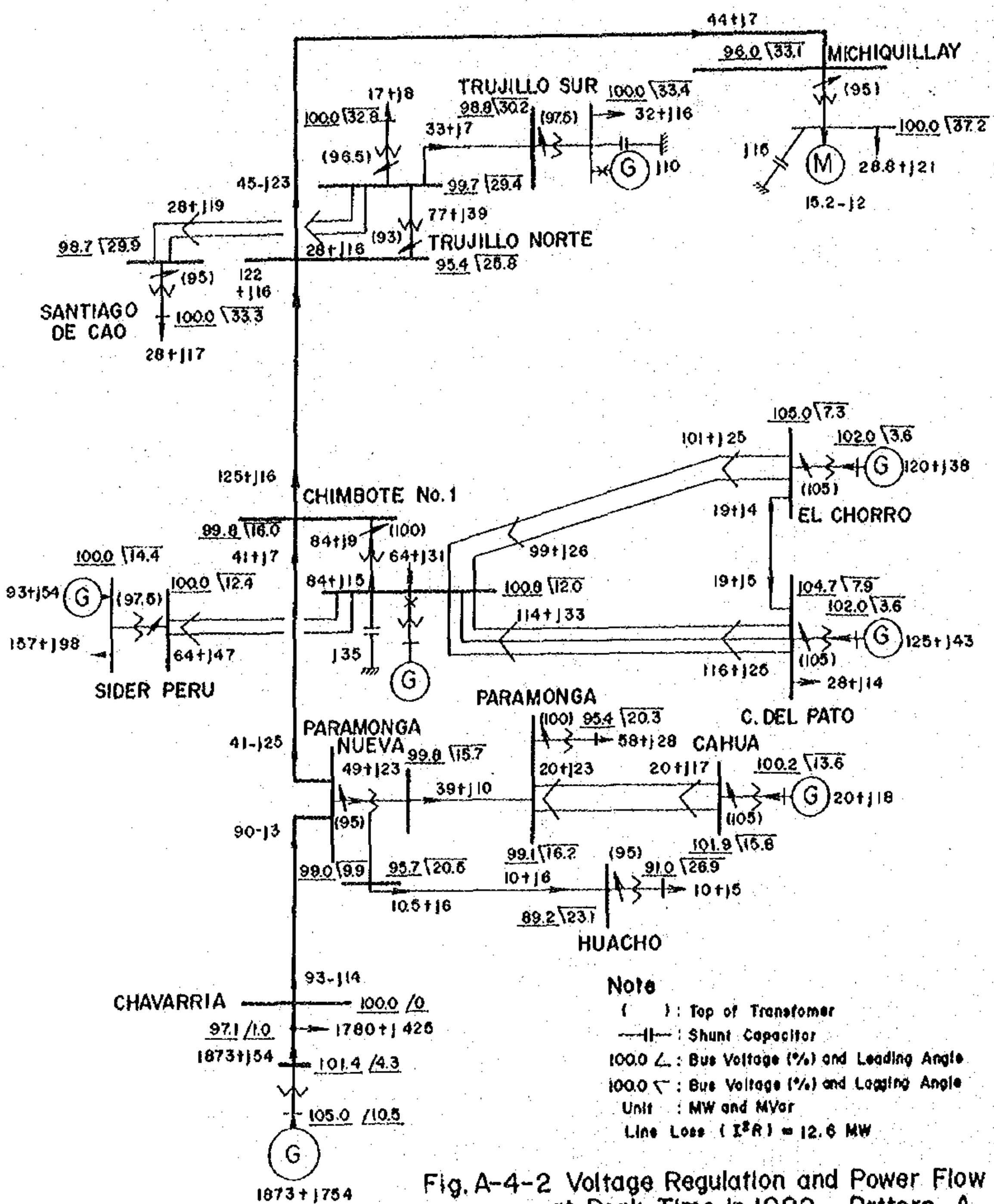
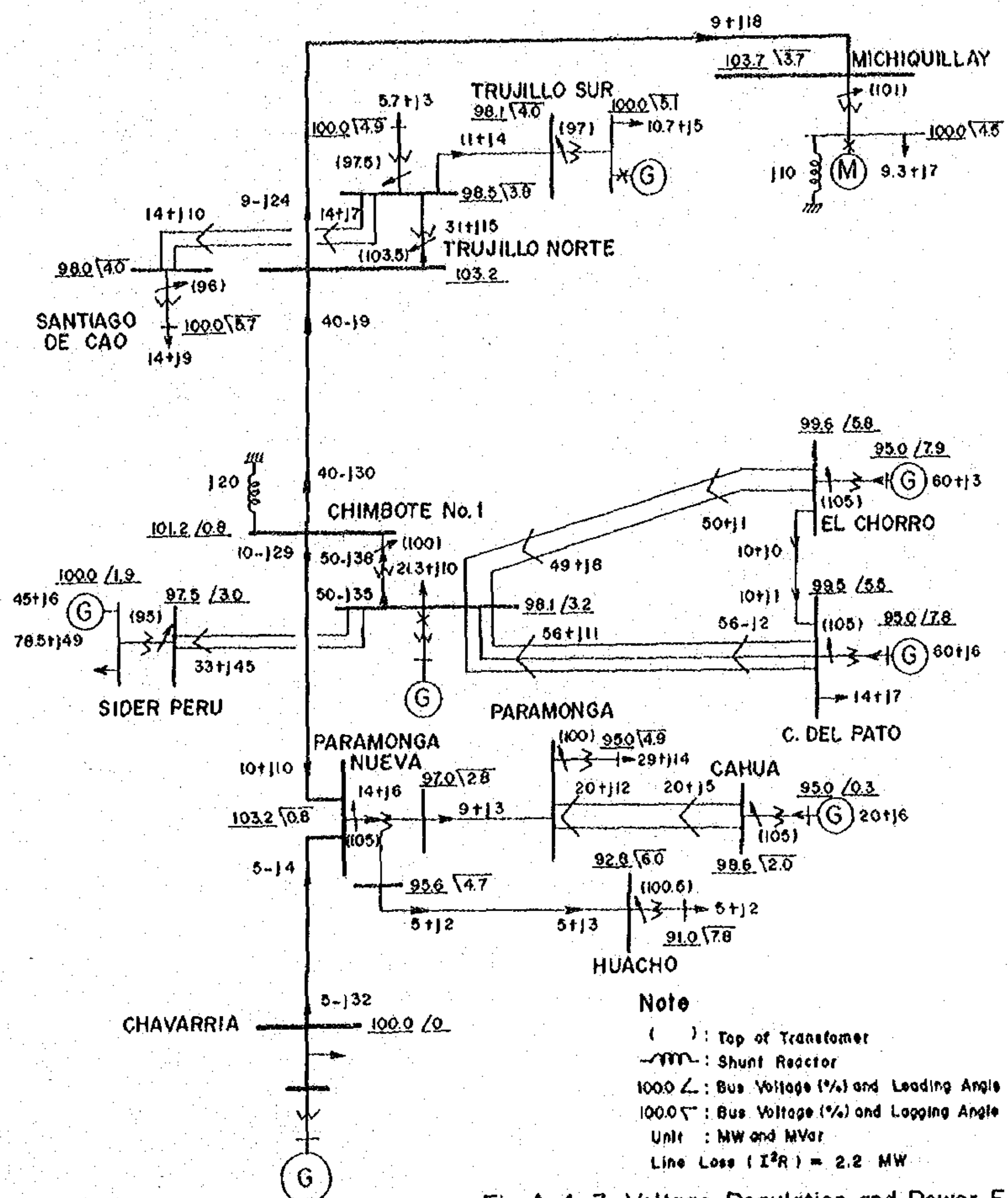


Fig. A-4-2 Voltage Regulation and Power Flow at Peak Time in 1982 Pattern A



Note

( ) : Tap of Transfomer

～ : Shunt Reactor

100.0 ∠ : Bus Voltage (%) and Leading Angle

100.0 ⌐ : Bus Voltage (%) and Lagging Angle

Unit : MW and MVar

Line Loss (I^2R) = 2.2 MW

Fig.A-4-3 Voltage Regulation and Power Flow at Off Peak Time in 1982 Pattern A

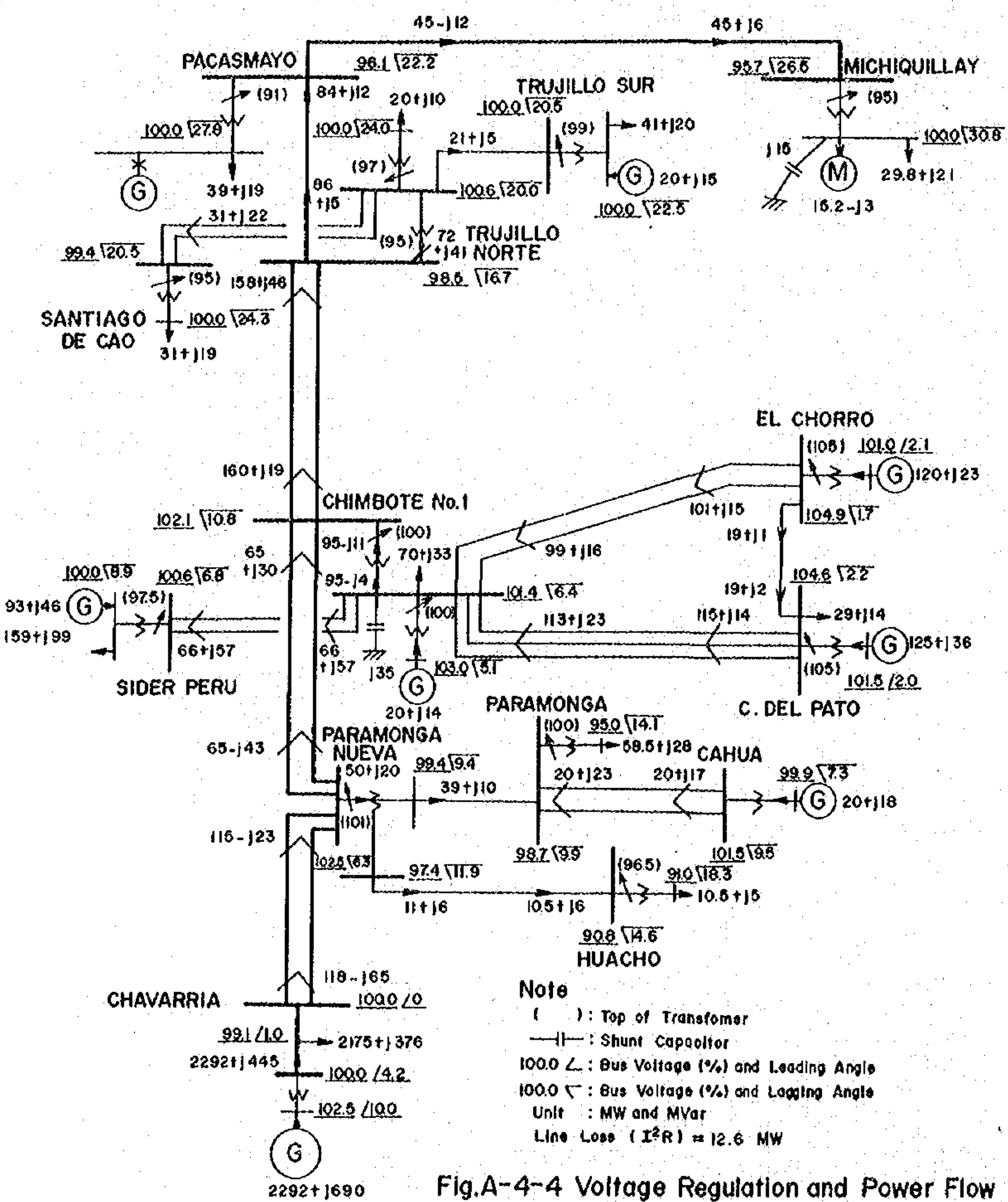


Fig.A-4-4 Voltage Regulation and Power Flow at Peak Time in 1985 Pattern A

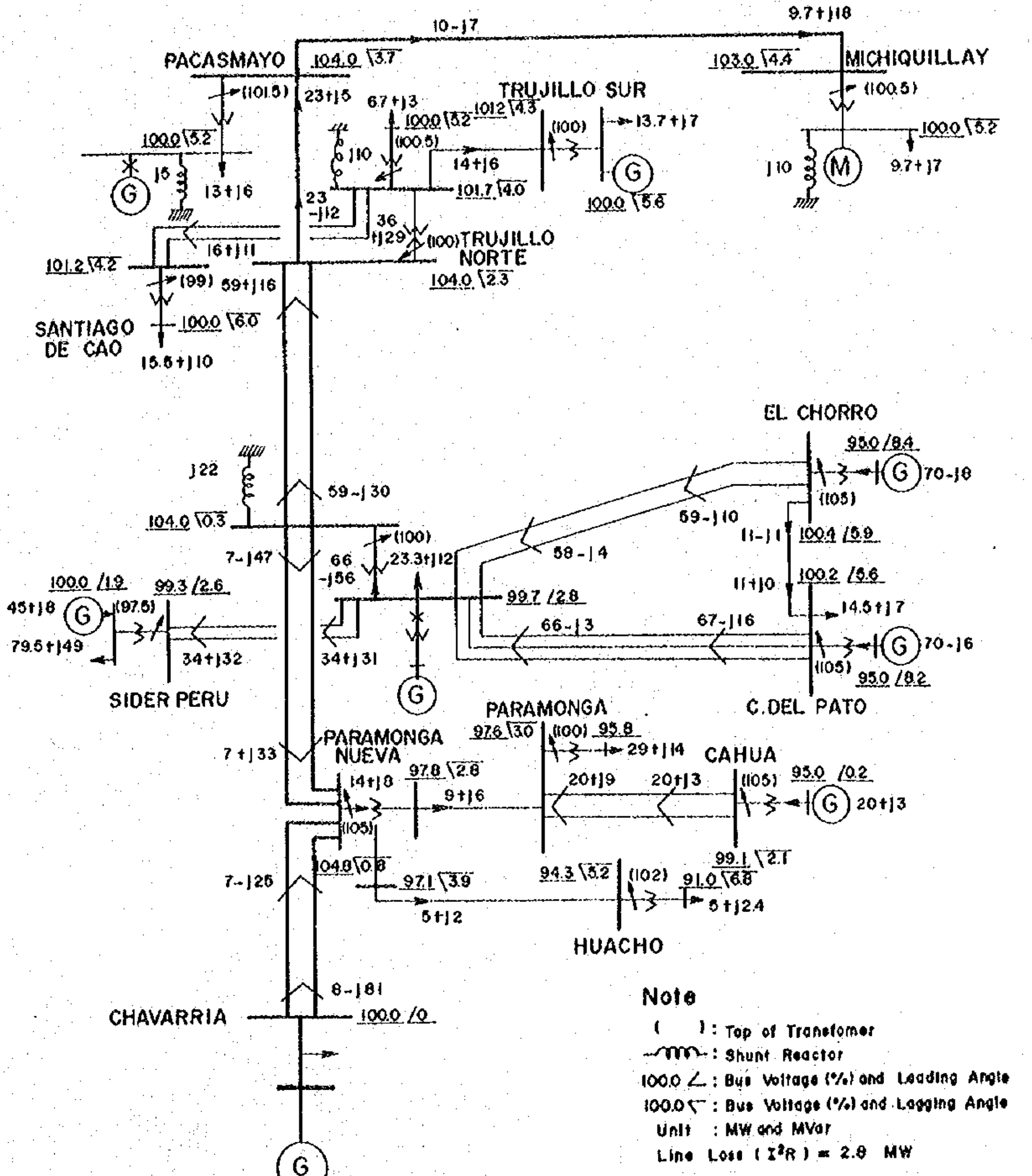


Fig.A-4-5 Voltage Regulation and Power Flow at Off Peak Time in 1985 Pattern A

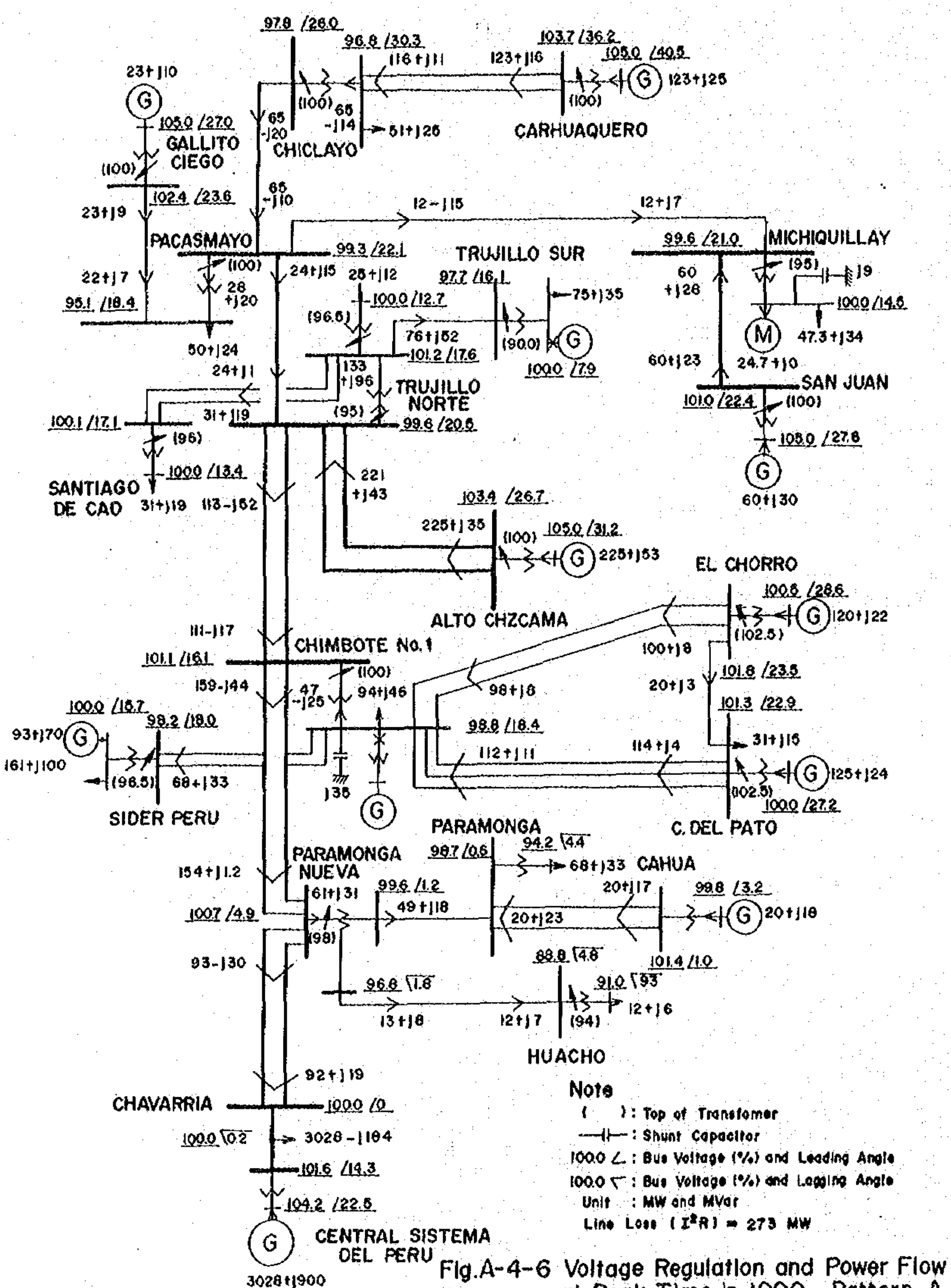


Fig.A-4-6 Voltage Regulation and Power Flow at Peak Time in 1990 Pattern A

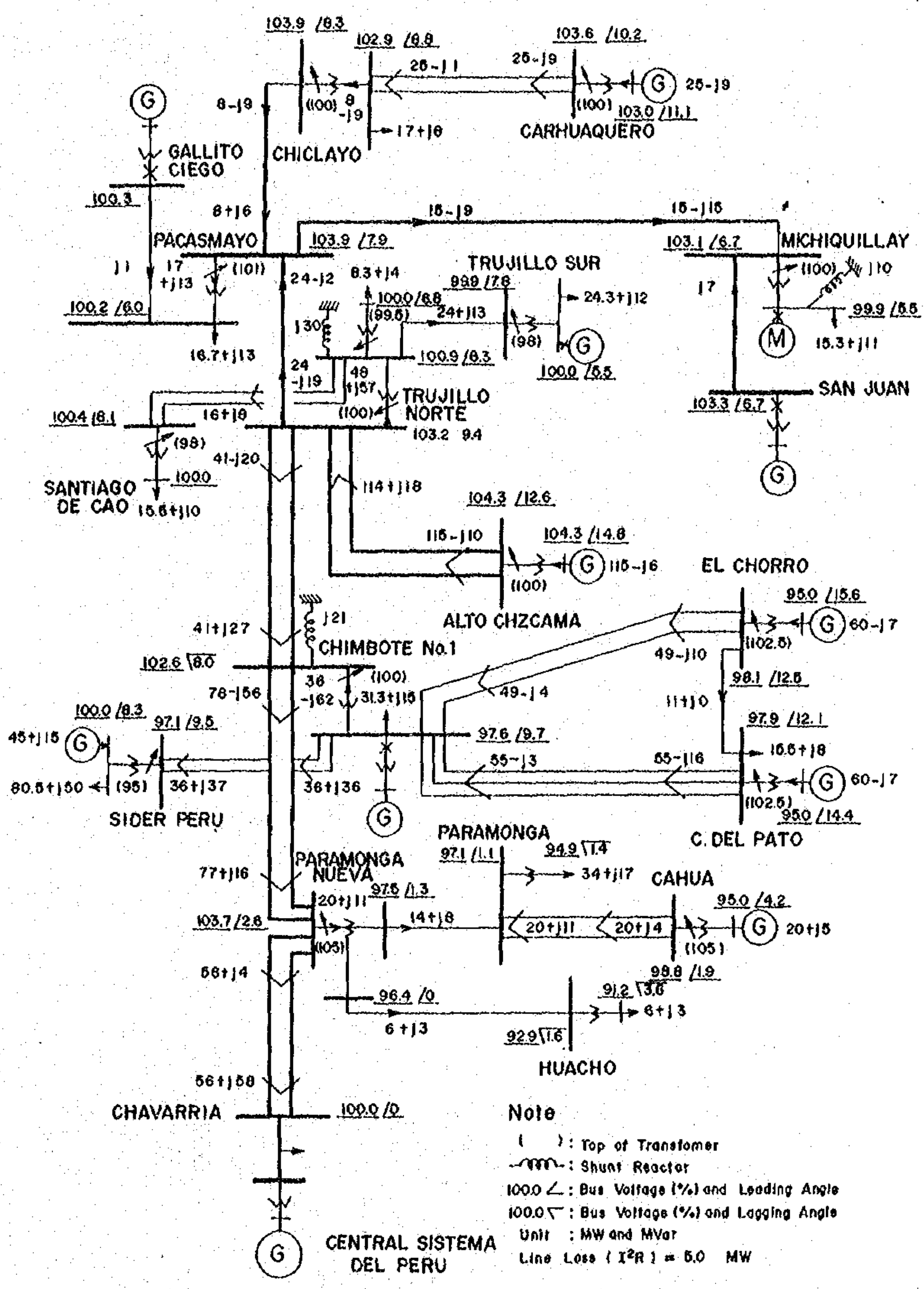


Fig. A-4-7 Voltage Regulation and Power Flow at Off Peak Time in 1990 Pattern A

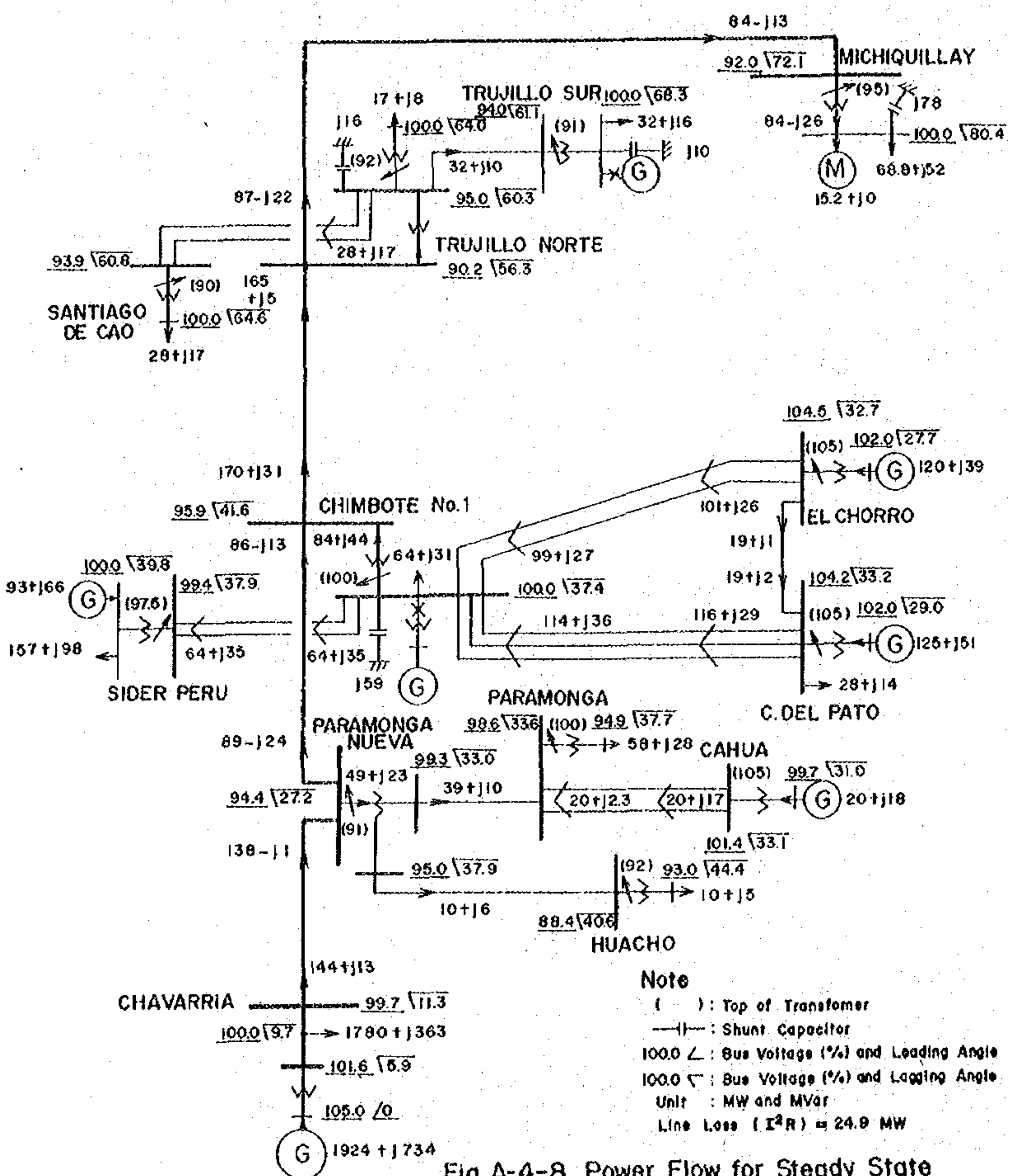


Fig.A-4-8 Power Flow for Steady State Stability at Peak Time in 1982

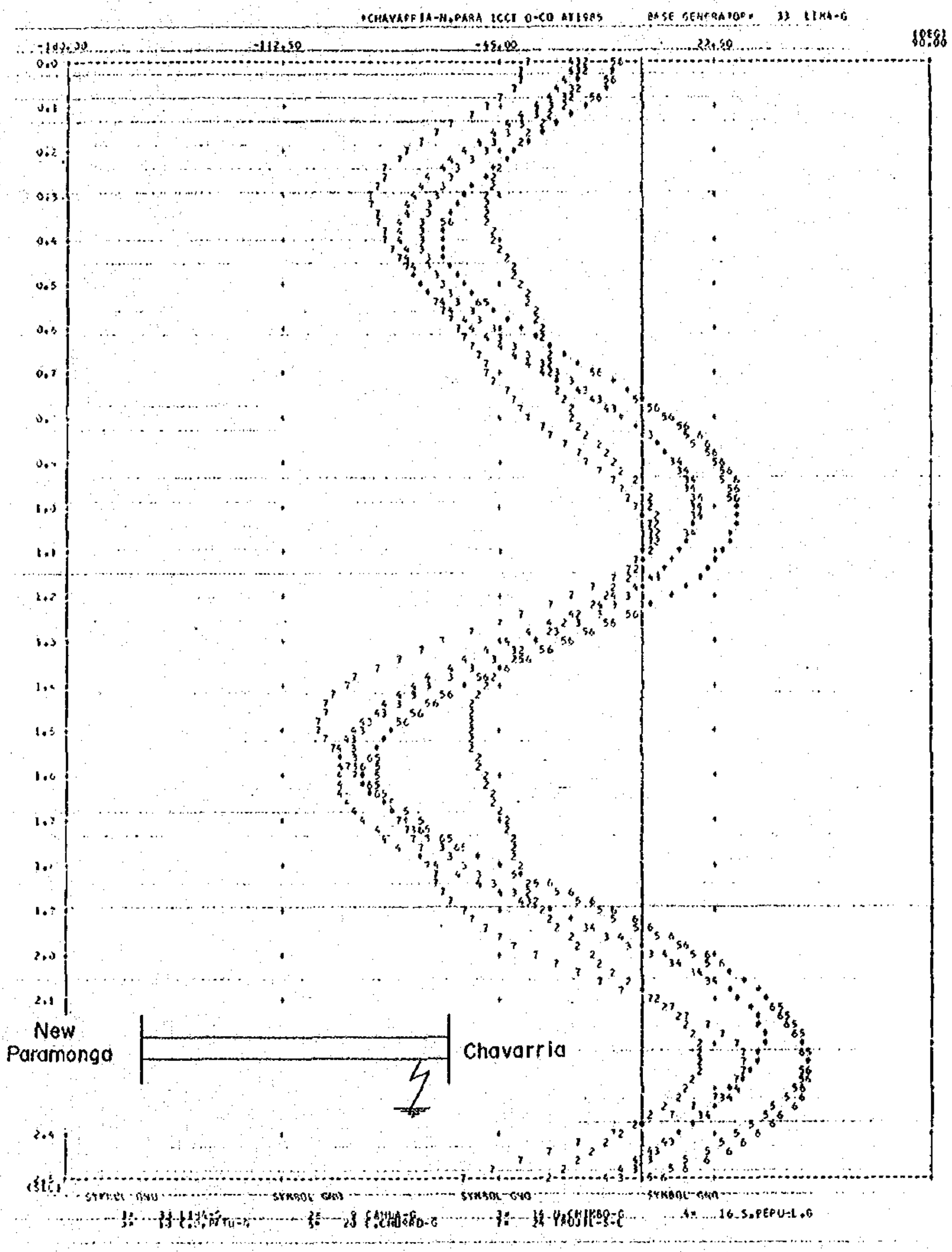


Fig. A-4-9 TRANSIENT STABILITY AT 1985
* CHAVARRIA - N. PARAMONGA 1 CCT 3LG 0-CO

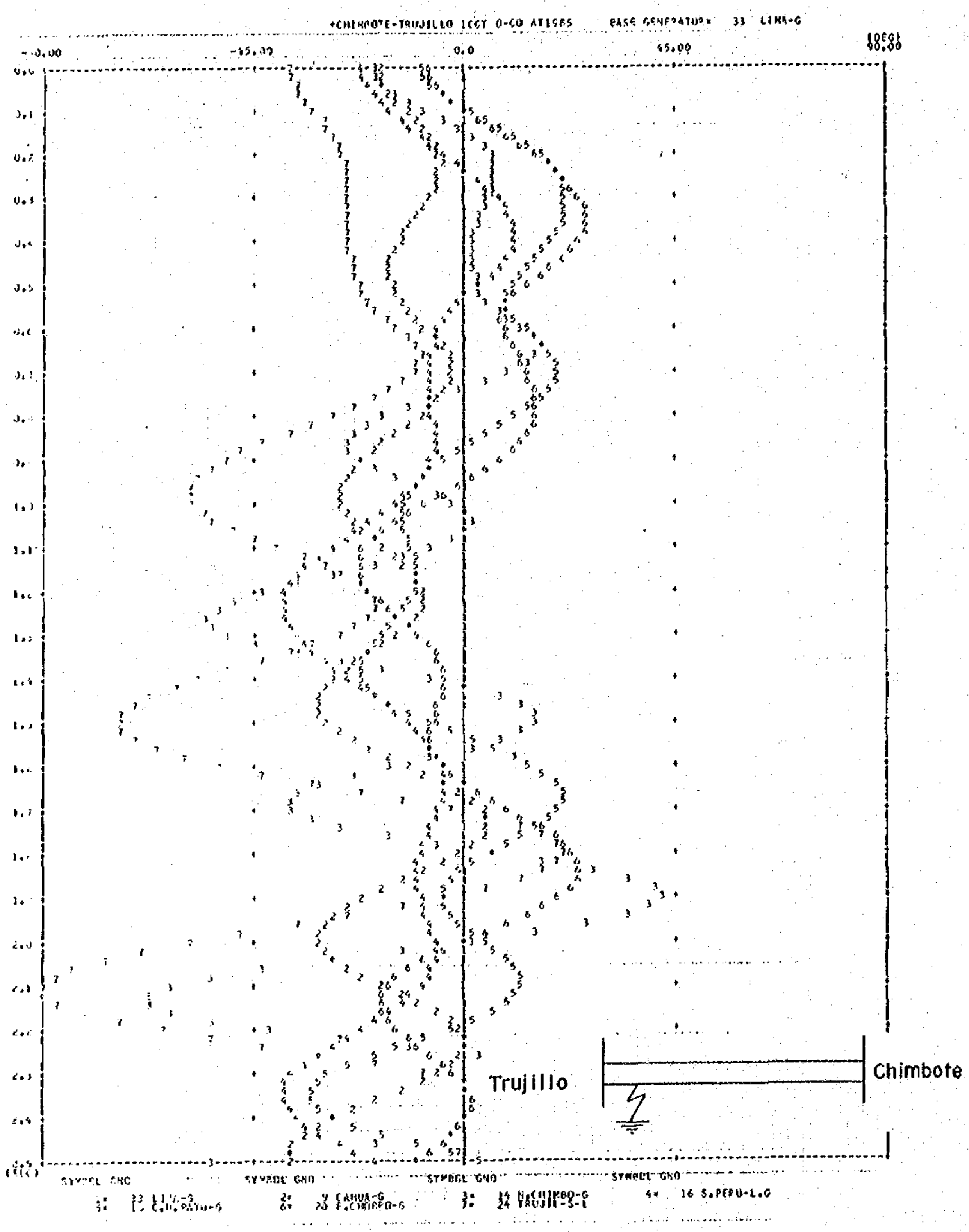


Fig. A-4-10 TRANSIENT STABILITY AT 1985
* CHIMBOTE- TRUJILLO 1CCT 3LG 0-CO

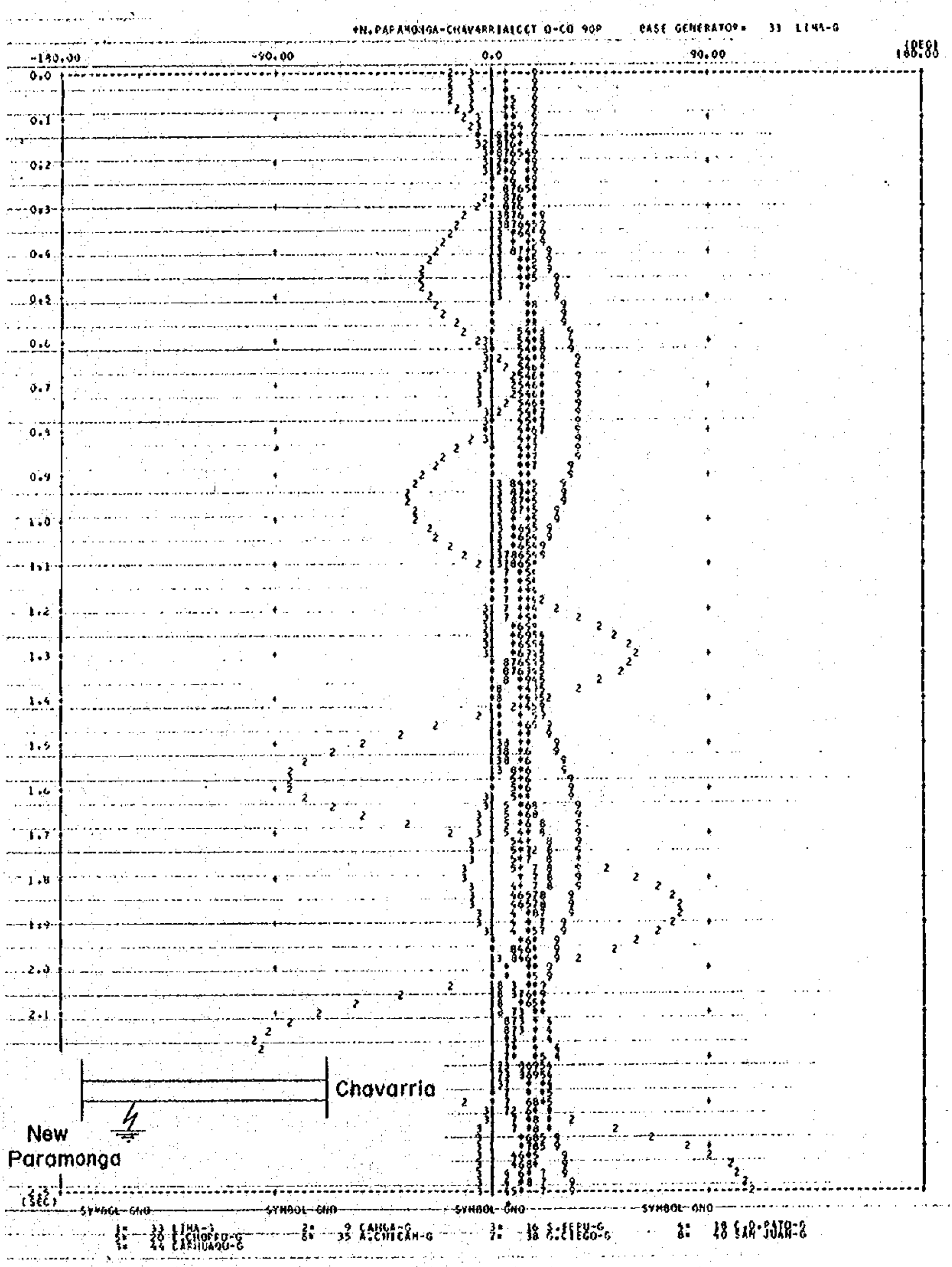


Fig. A-4-11 TRANSIENT STABILITY AT 1990
* N. PARAMONGA – CHAVARRIA 1 CCT 3LG O–CO

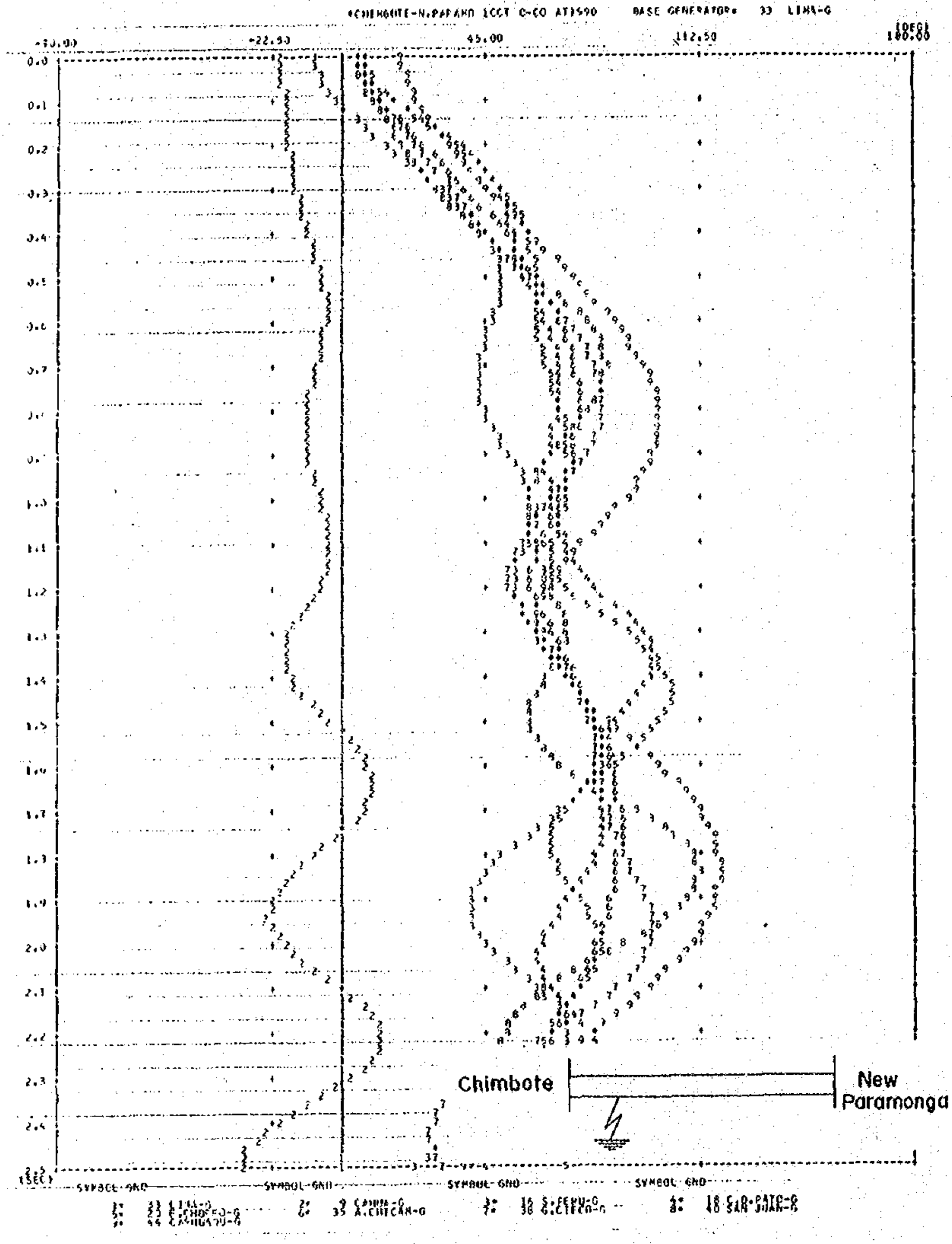


Fig. A-4-12 TRANSIENT STABILITY AT 1990
*CHIMBOTE - N. PARAMONGA 1CCT 3LG O-CO

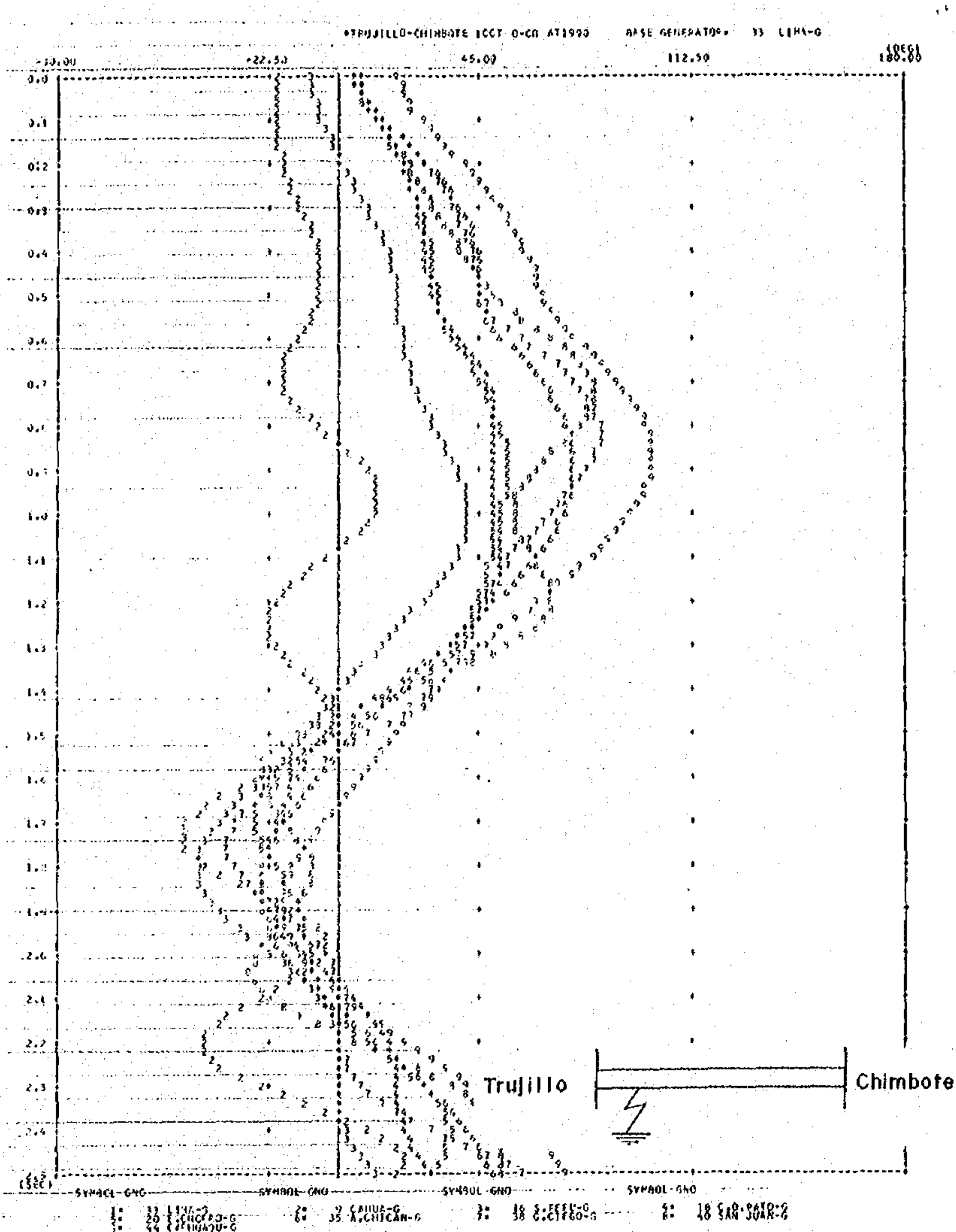


Fig. A-4-13 TRANSIENT STABILITY AT 1990
* TRUJILLO- CHIMBOTE 1CCT 3LG O-CO

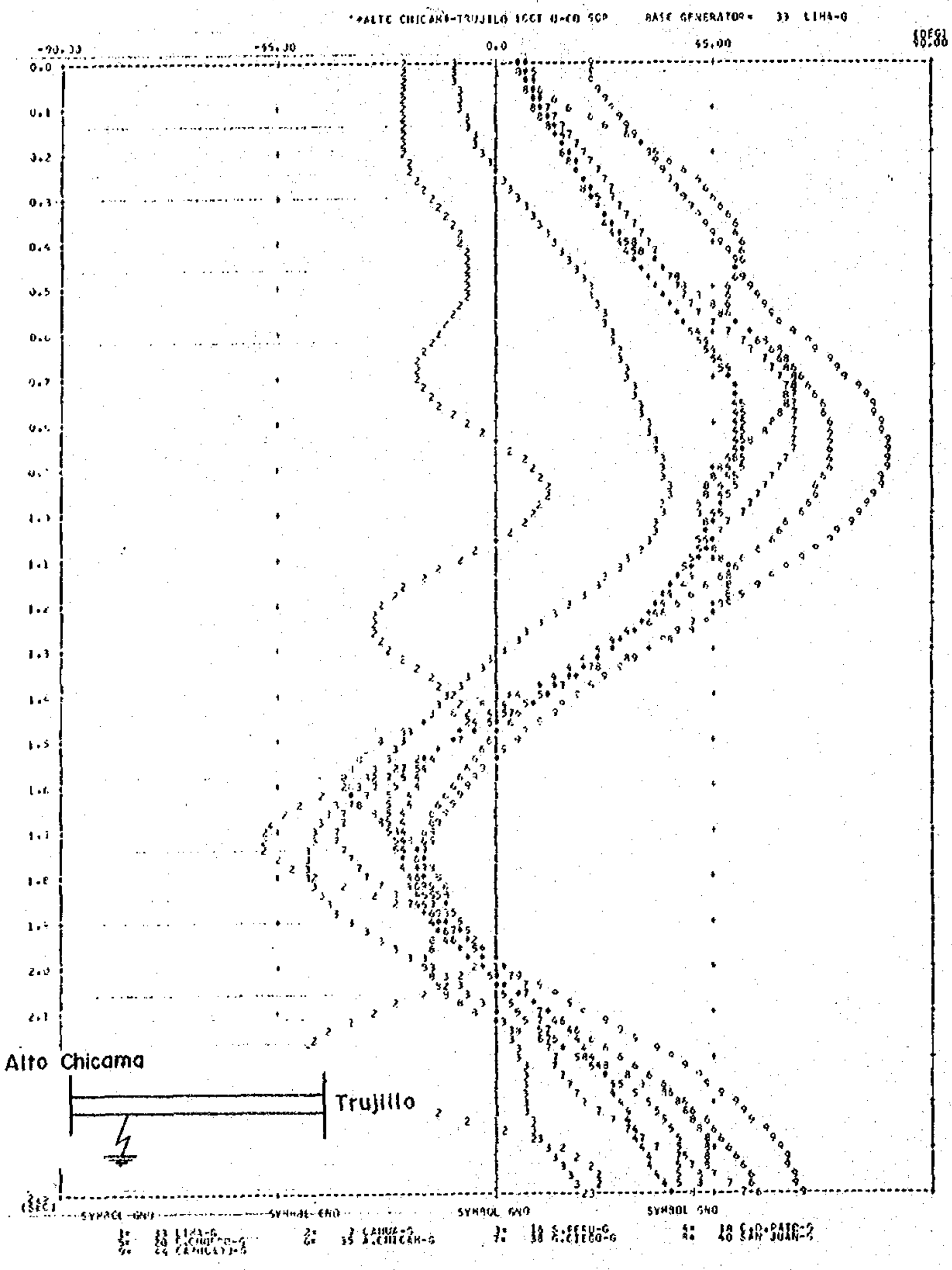


Fig. A-4-14 TRANSIENT STABILITY AT 1990
* ALTO CHICAMA - TRUJILLO ICCT 3LG O-CO

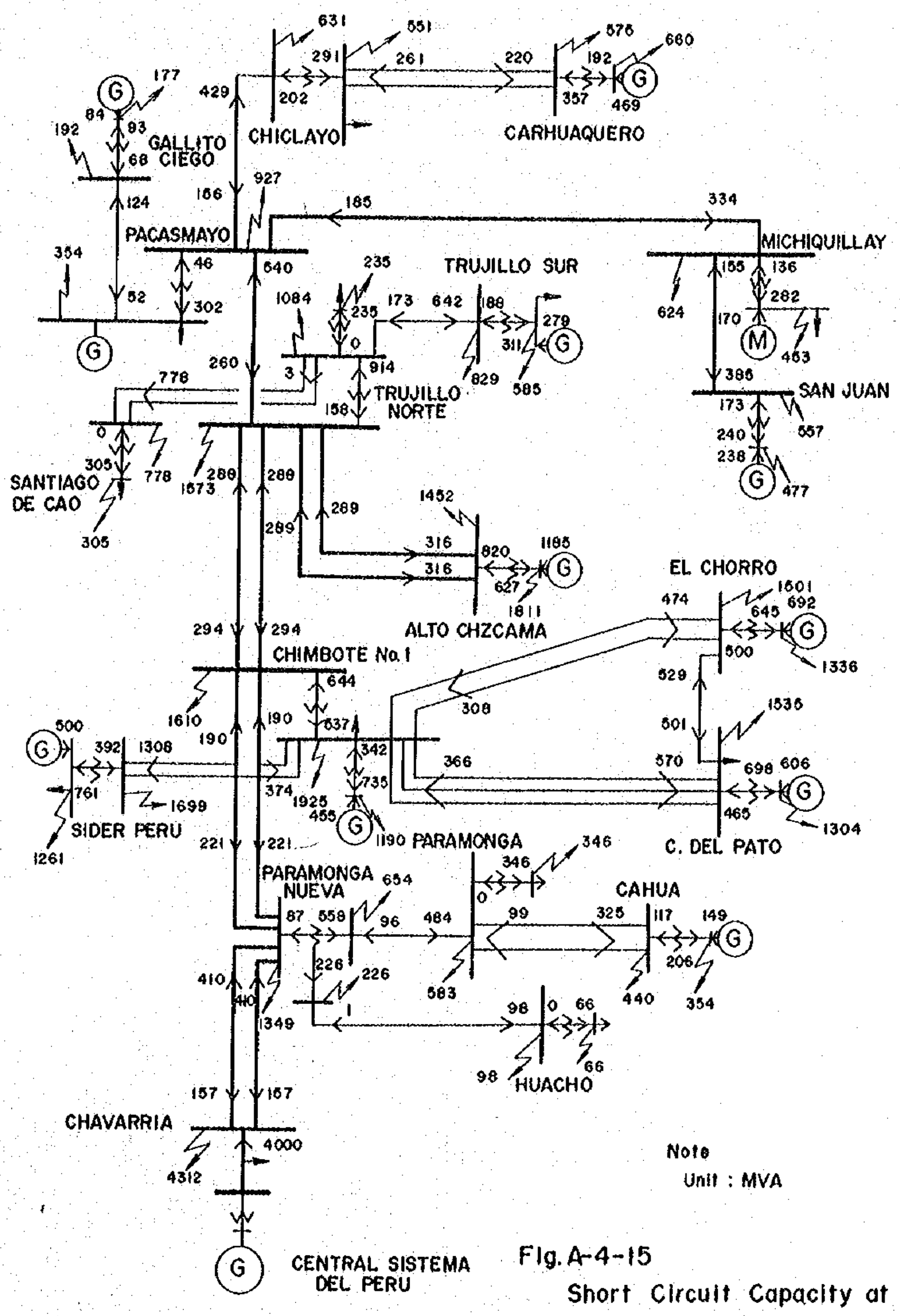


Fig. A-4-15

Short Circuit Capacity at 1990

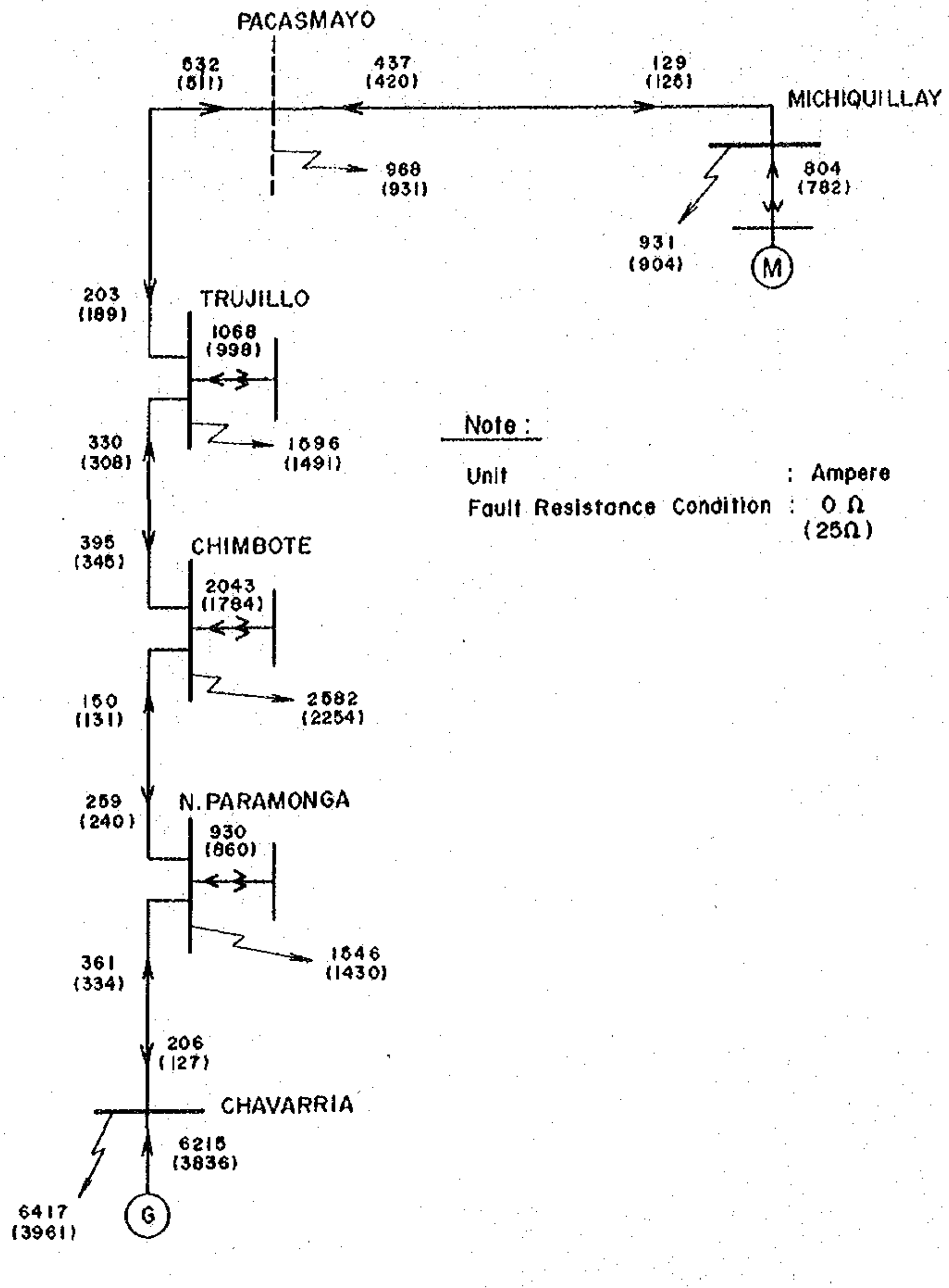
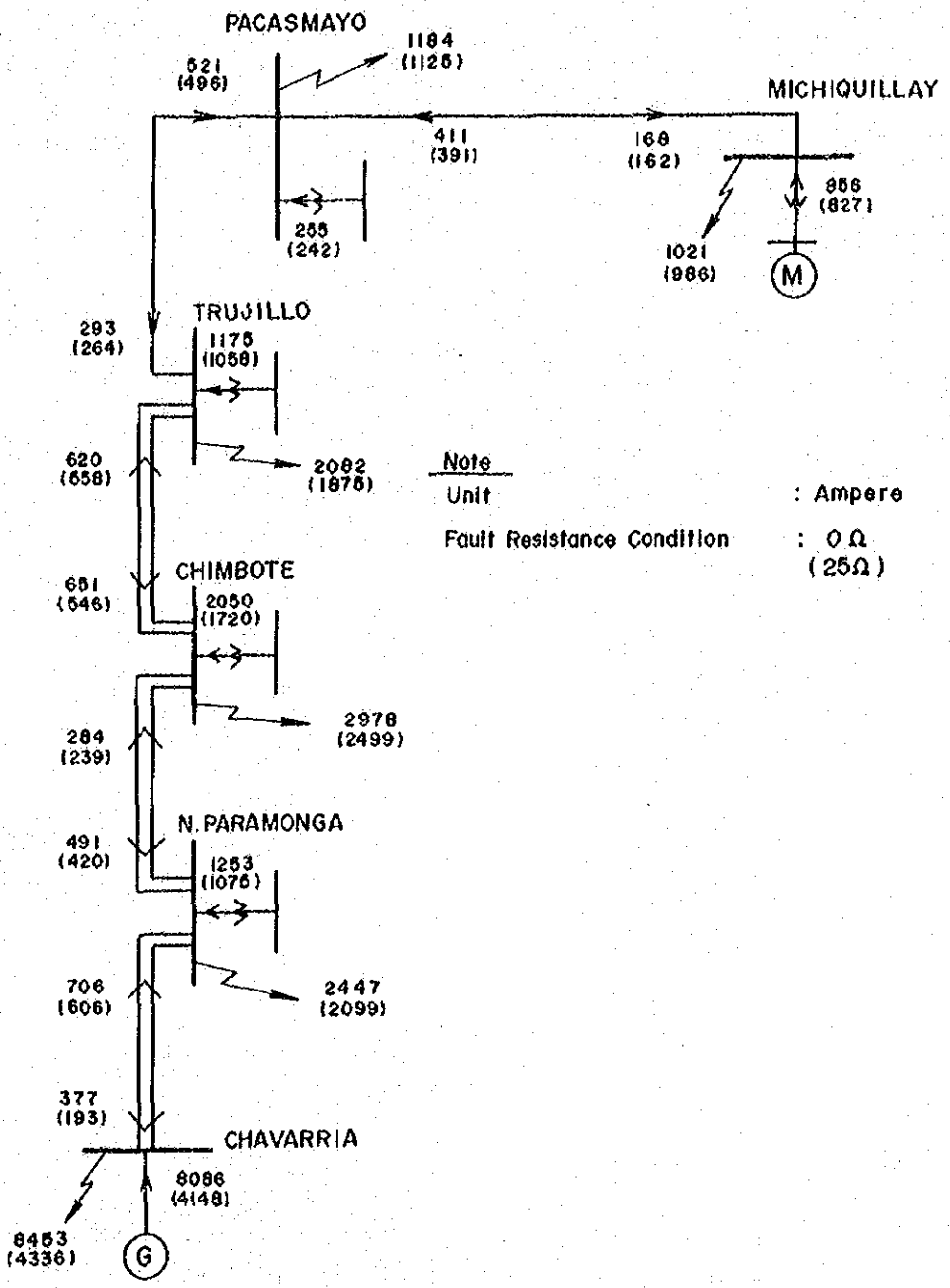


Fig. A-4-16 GROUNDING CURRENT (ILG) IN 1982



Note

Unit : Ampere

Fault Resistance Condition : 0 Ω (25Ω)

Fig. A-4-17 GROUNDING CURRENT (ILG) IN 1985

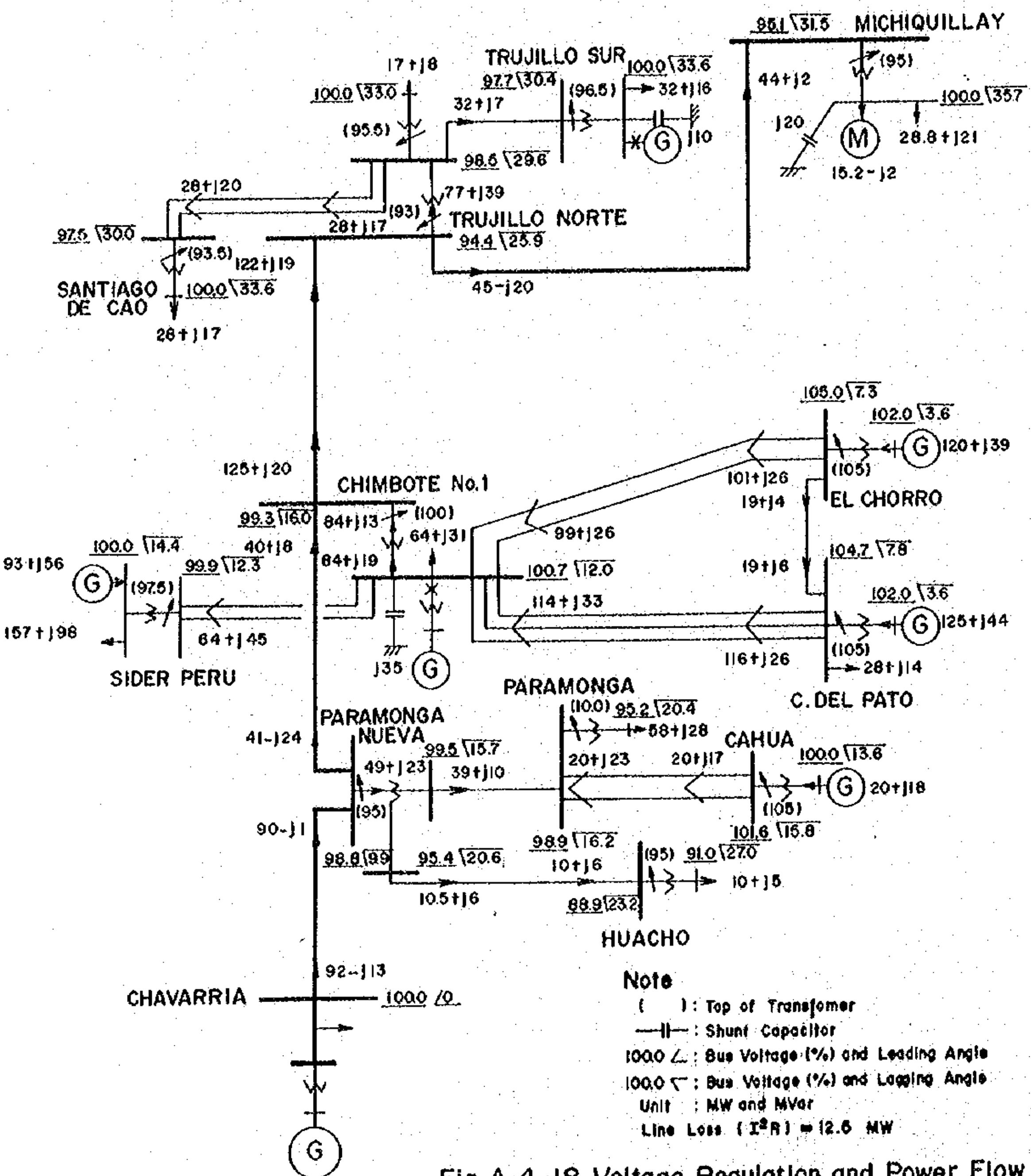


Fig. A-4-18 Voltage Regulation and Power Flow at Peak Time in 1982 Pattern B

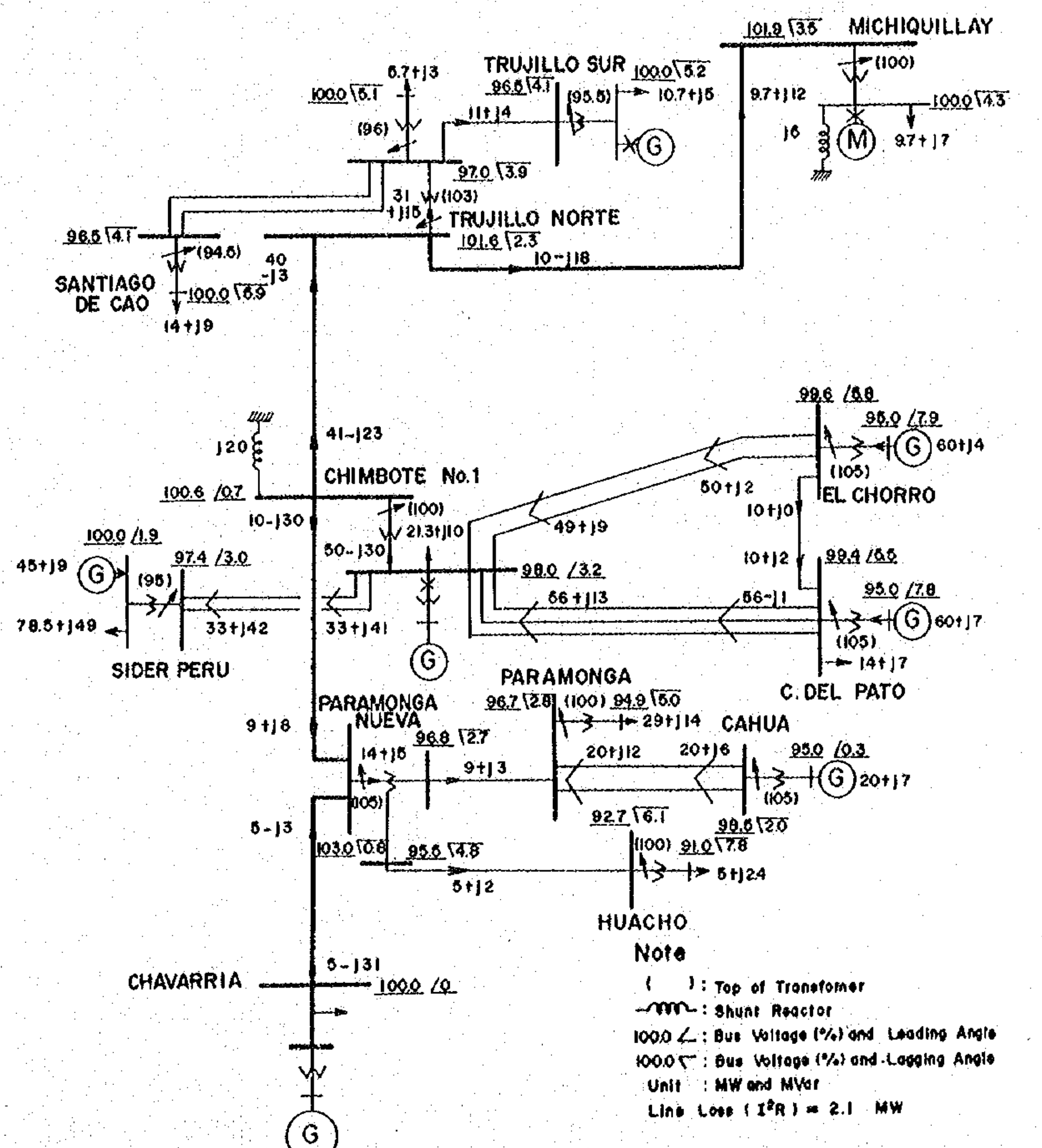


Fig. A-4-19 Voltage Regulation and Power Flow at Off Peak Time in 1982 Pattern B

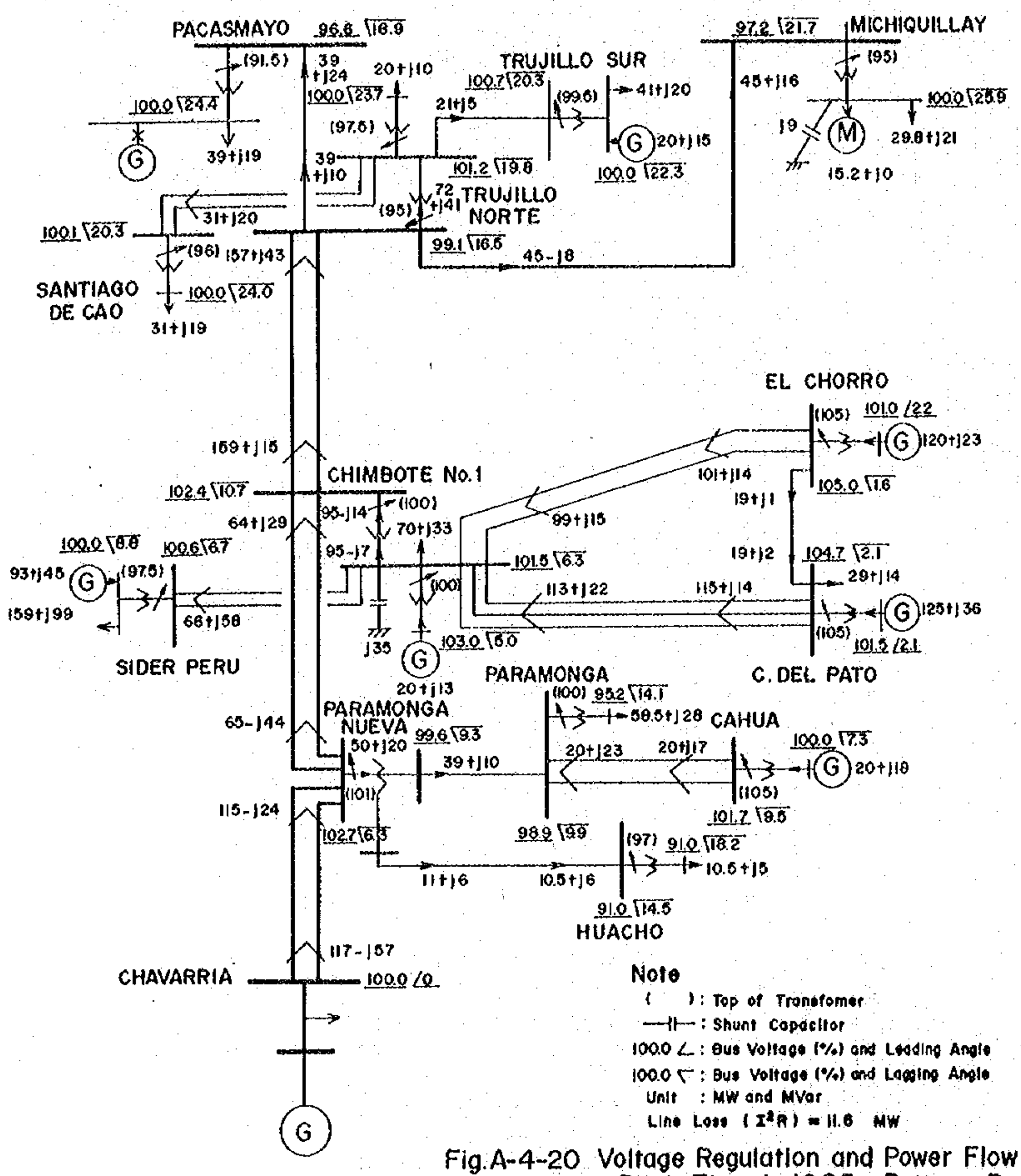


Fig.A-4-20 Voltage Regulation and Power Flow at Peak Time in 1985 Pattern B

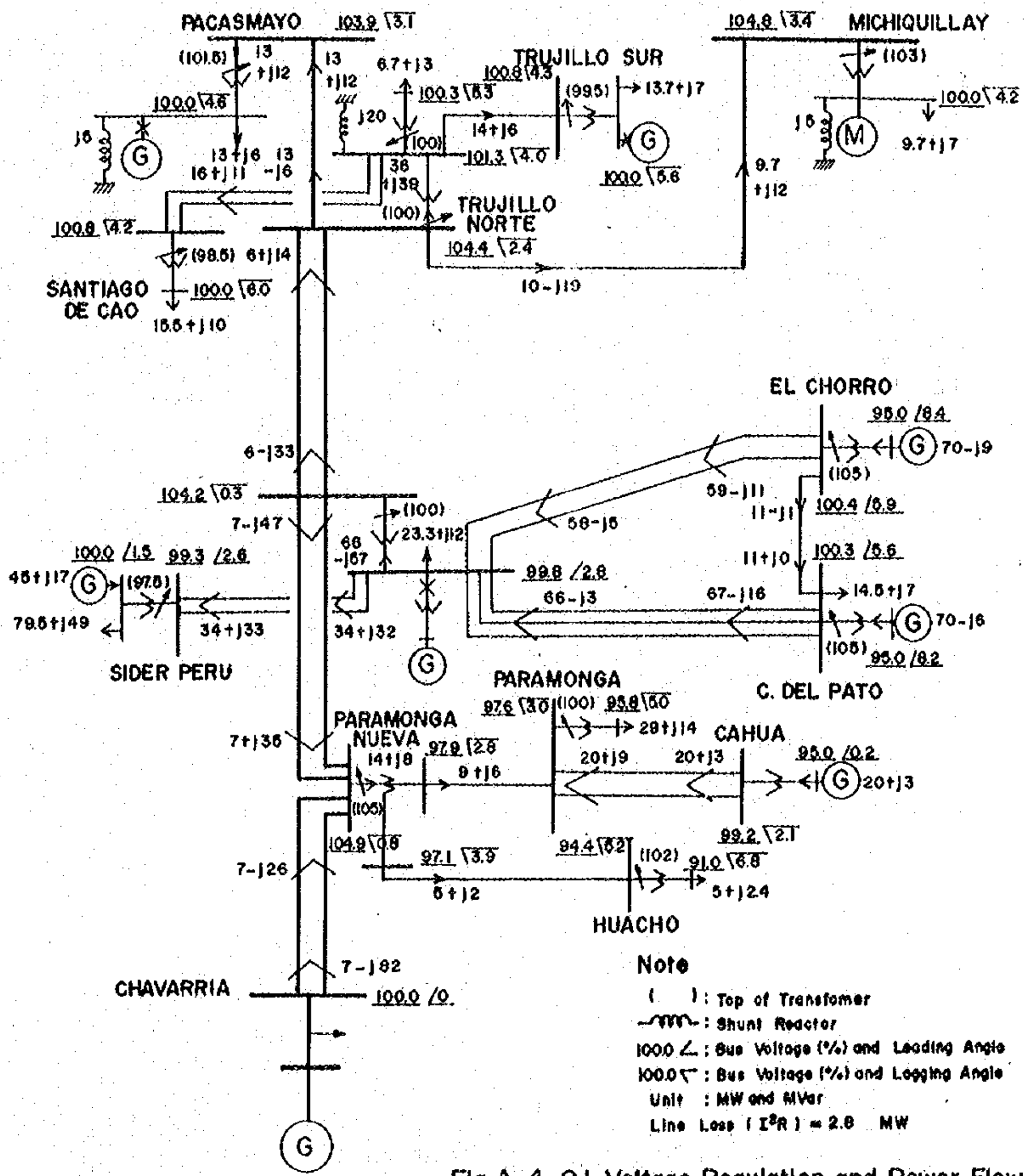
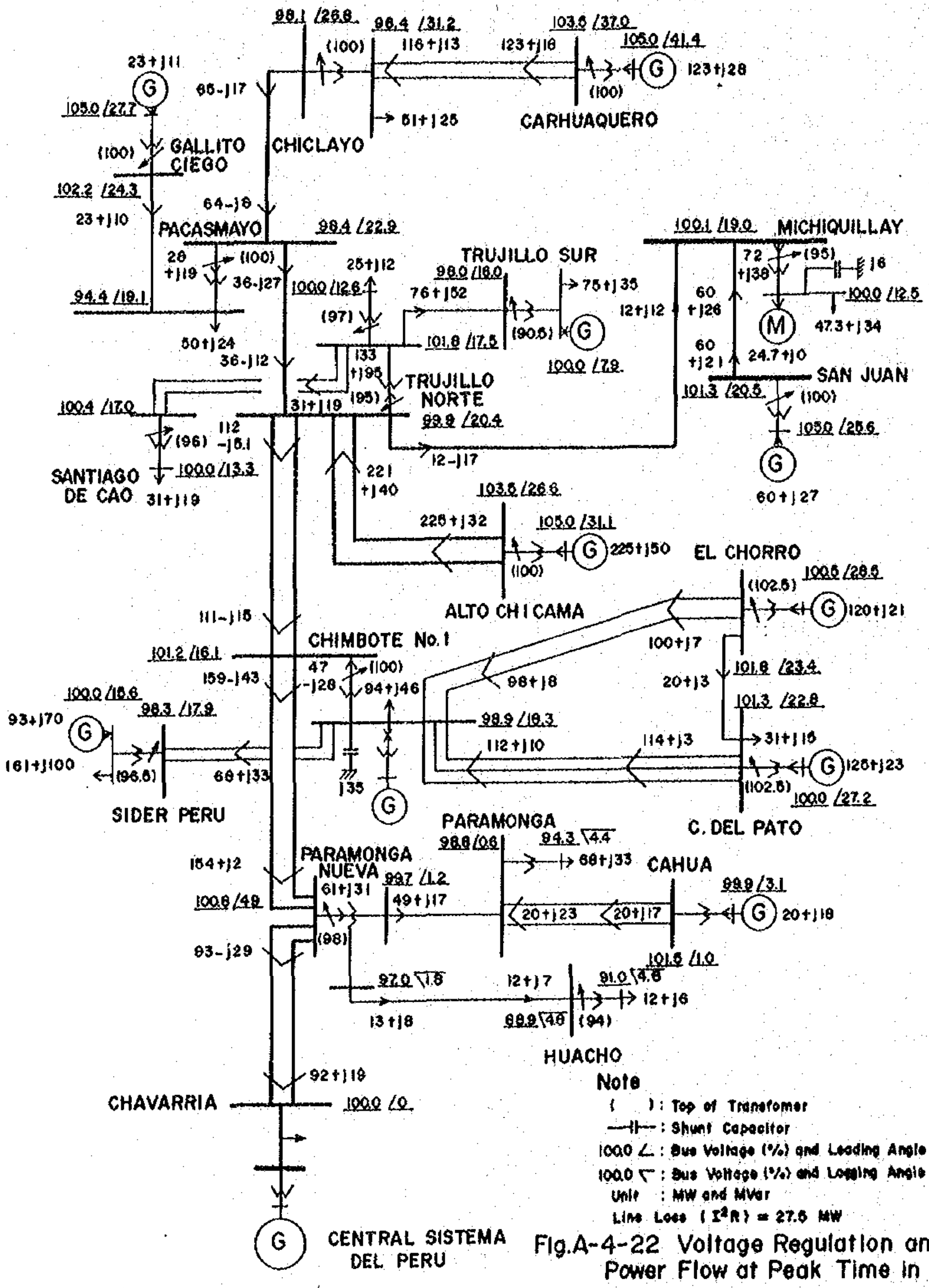


Fig.A-4-21 Voltage Regulation and Power Flow at Off Peak Time in 1985 Pattern B



Note
( ) : Top of Transfomer
—||— : Shunt Capacitor
100.0 ∠ : Bus Voltage (%) and Leading Angle
100.0 ⟨ : Bus Voltage (%) and Lagging Angle
Unit : MW and MVar
Line Loss (I^2R) = 27.6 MW

Fig.A-4-22 Voltage Regulation and Power Flow at Peak Time in 1990 Pattern B

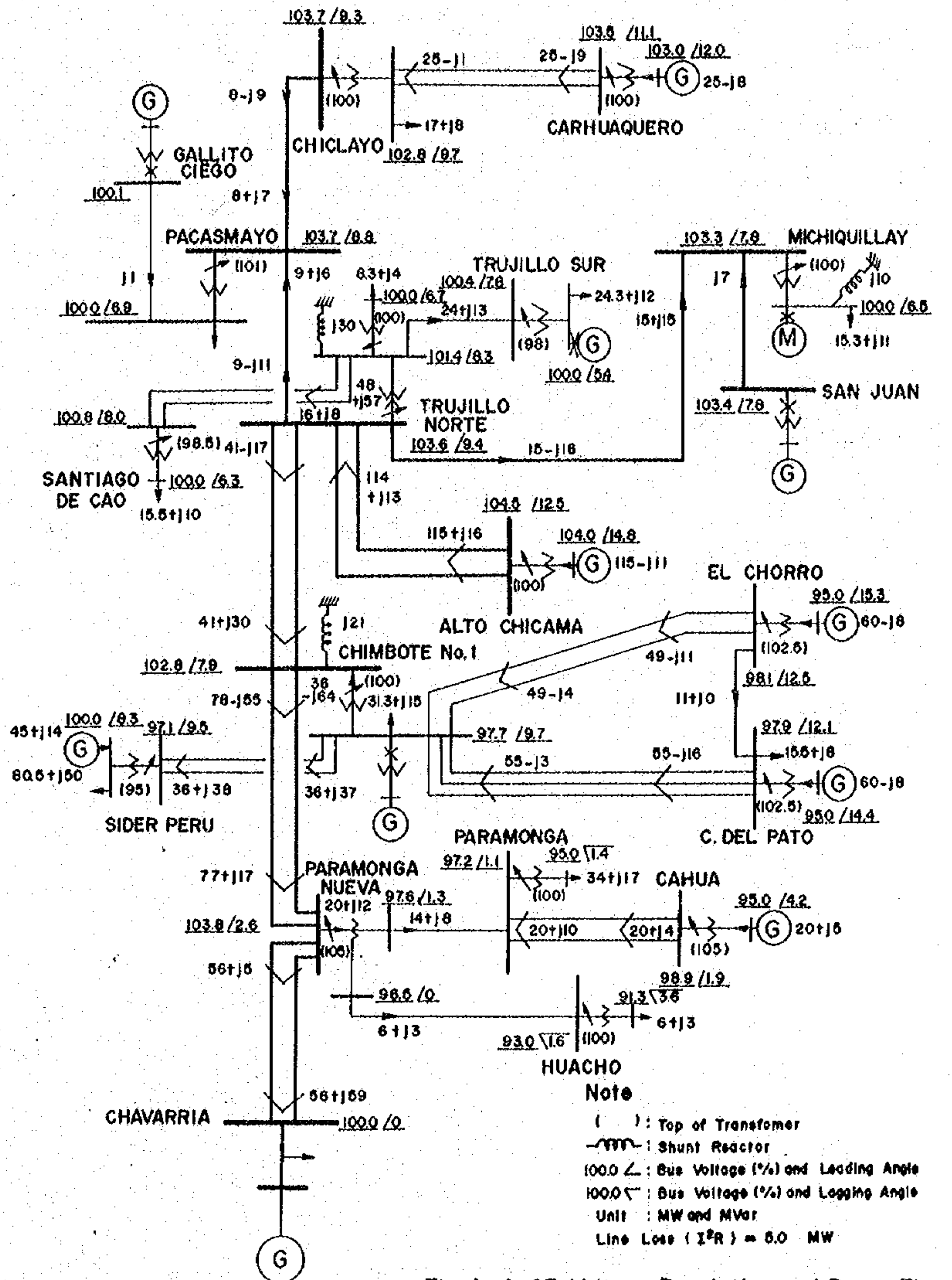


Fig. A-4-23 Voltage Regulation and Power Flow at Off Peak Time in 1990 Pattern B

A - 5 New Power Development Projects

A-5. INTERCONNECTIONS WITH CHICLAYO AND NEW POWER DEVELOPMENT PROJECTS

A-5-1 Interconnection with Chiclayo District

In case there should be an interconnection between the Chiclayo district and the Santa Power System, the following merits of interconnection would be conceivable:

1 Improvement in supply dependability

2 Savings in reserve supply capacity

3 Scale merits for newly brought-in power sources

However, the economical and effective timing of interconnection will be decided by the growth of power demand in the district or the timing of construction of new power sources in the surrounding area which are worth interconnecting.

Regarding development of a new power source, there is a plan for a Carhuaquero Hydroelectric Power Project (123 MW) 70 km east of Chiclayo, but the time at which construction will be carried out has not yet been decided.

A study was made on the economical timing for interconnection comparing the merit of savings in reserve supply capacity which is of especially great economic effect for the Chiclayo district and the expense of an interconnecting transmission line.

The result was the time at which the load at Chiclayo reaches above 73 MW, and estimated from the load forecast of Table A-2-1, this would be around the year 1995.

Conditions Used in Evaluation of Interconnection (Present worth in 1975)

o Interconnecting Line

1) Transmission Line

Sector : Pacasmayo - Chiclayo
Length : 80 km
Voltage and number of circuits: 220 kV, 1 cct
Construction cost: US$3,600 x 10^3

2) Transforming Facilities

Pacasmayo: Lead-out facilities, 1 cct
Chiclayo : Lead-in facilities, 1 cct
Transformer, 60 MVA x 1 unit
Construction cost: US$3, 120 x 10^3 (including telecommunications facilities)

o On-site Diesel Plant (Reserve Supply Capacity Saved)

Capacity: 10 MW x 1 unit
Construction cost: US$4,550 x 10^3
Unit construction cost per kW: US$455/kW
Expense ratio: 16.93%

o Reserve Supply Capacity for Chiclayo

The proper amount of reserve supply capacity will differ depending on the composition of the reserve capacity and the ratio of its largest unit to the system capacity, but in the case of Chiclayo it was taken to be 15% of the total power demand.

A-5-2 Interconnection between Michiquillay System and New Power Development Projects

Surveys of hydroelectric power sources such as the Yangas, San Juan and Crisnejas have been made in Departamento de Cajamarca and its surrounding area and development of these sources will be carried out in time. It will be most effective for these hydroelectric power sources to be interconnected with the Michiquillay System in view of their development scales and geographical conditions, and by this interconnection it will be possible to improve the dependability of supply to the Michiquillay Mine and the surrounding area, and also to lower the cost of electric power.

Regarding transmission lines, transmission costs will vary depending on transmission capacities, construction costs of the transmission lines, transmission losses and voltages, but in case of interconnection with the abovementioned power sources, it is considered that 220 kV will be economical as the transmission voltages in case of transmission capacity of 40 MW or more and 138 kV in case of transmission capacity of less than 40 MW.

As for the electric power of the at-the-source thermal power development project at Alto Chicama, the plan is for an ultimate capacity of 450 MW, and due to conditions of geography and power system relations, this should connect directly with Trujillo Substation.

A - 6 Alternative Transmission Line Route for Michiquillay Transmission Project

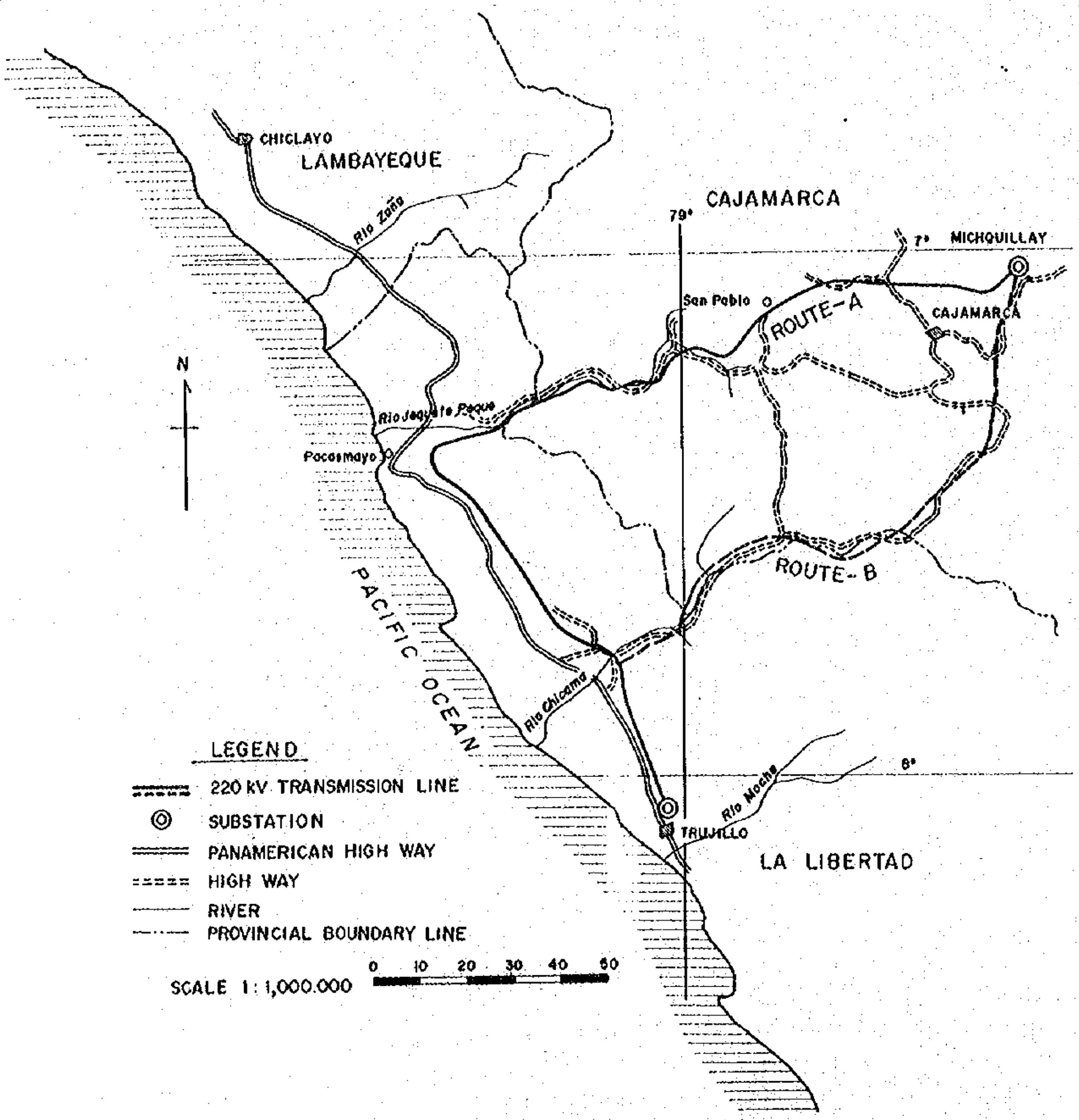
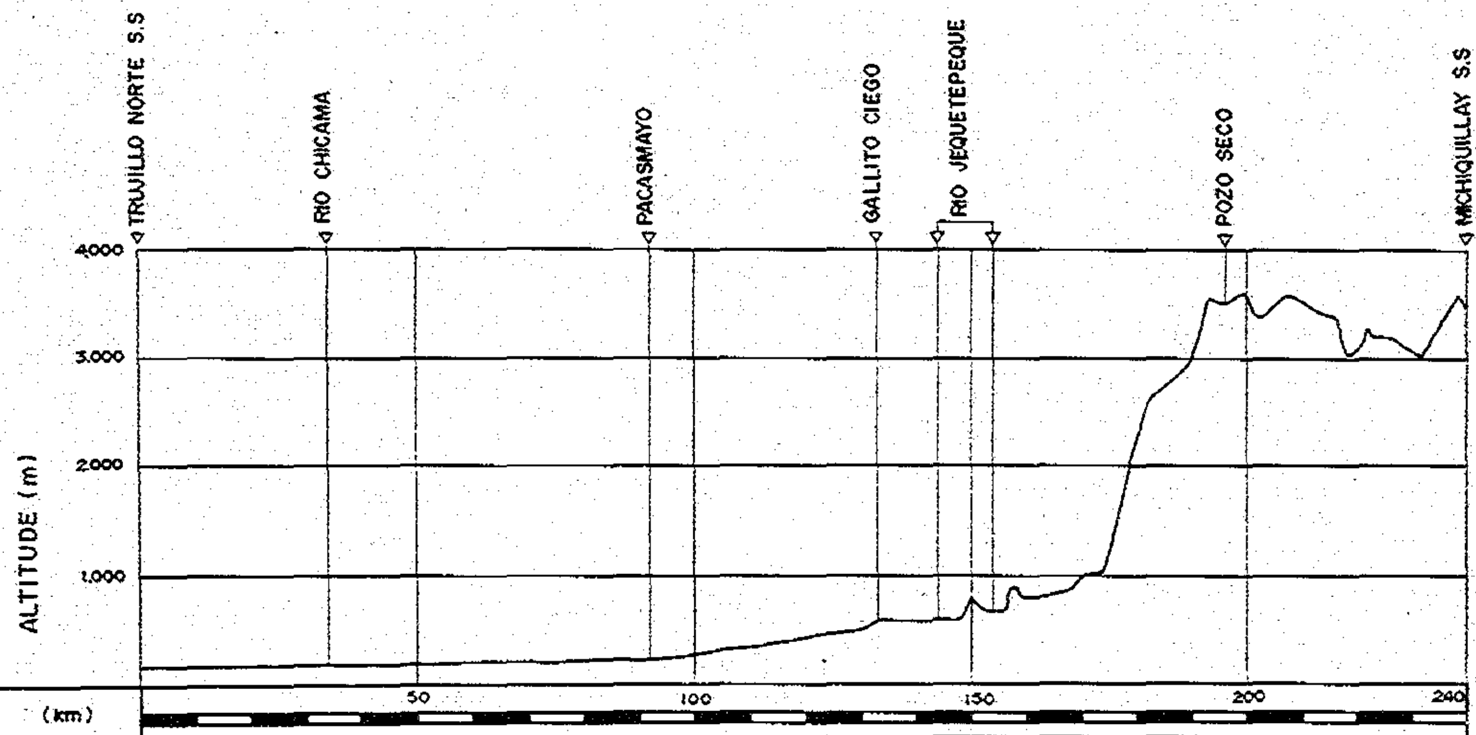


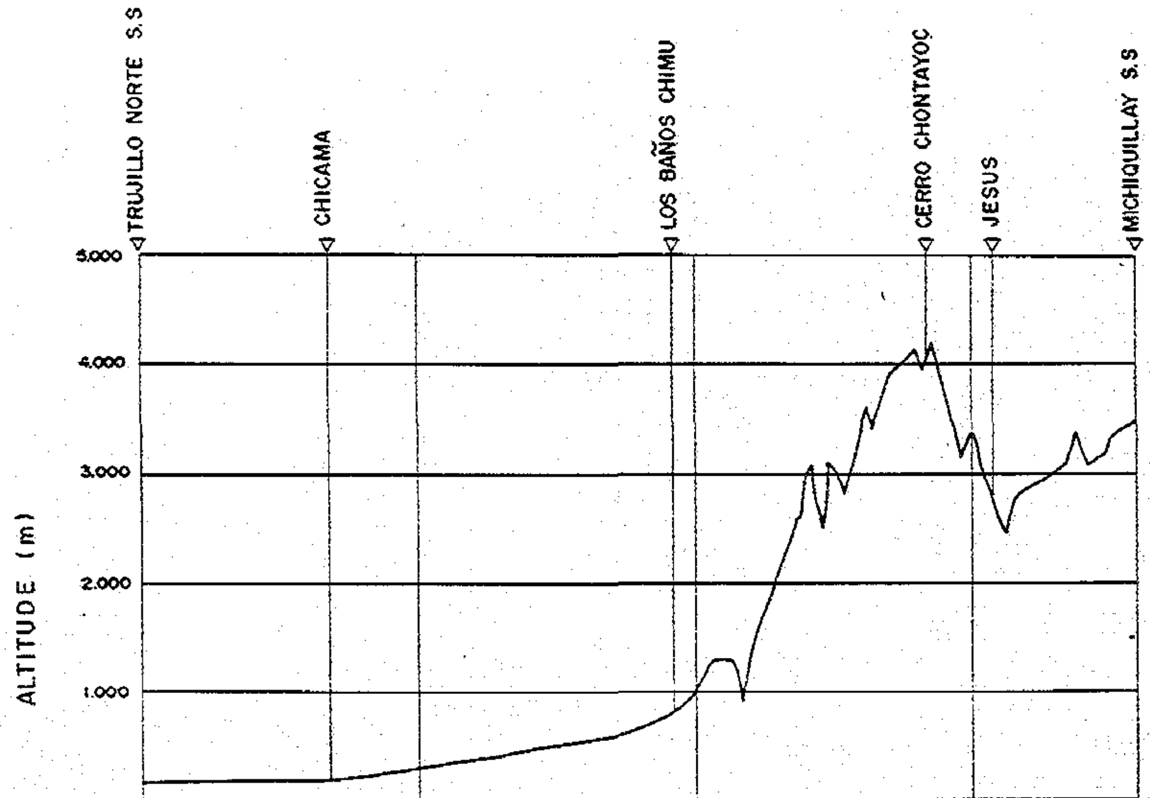
Fig. A-6-1 GENERAL MAP OF ALTERNATIVE ROUTE FOR MICHIQUILLAY TRANSMISSION LINE PROJECT



DESIGN SECTION	ZONE 1	ZONE 2	ZONE 3	ZONE 4
WORST LOADING CONDITION	5° C, 40 kg/m²		0° C 4.5 kg/m²	-10° C, 50 kg/m²
NUMBER OF INSULATOR DISCUS	21 (Fog Type)	13	16	17
CONDUCTOR	400 mm² ACAR	410 mm² ACSR	520 mm² ACSR	610 mm² ACSR
OVER HEAD GROUND WIRE	NONE		90 mm² GSC	

Fig. A-6-2 PROFILE OF MICHIQUILLAY TRANSMISSION LINE

ROUTE A



LENGTH (km)	50	100	150	180
DESIGN SECTION	ZONE 1	ZONE 2	ZONE 3	ZONE 4
WORST LOADING CONDITION	5° C, 40 kg/m²		0° C 45kg/m²	−10°C, 50 kg/m²
NUMBER OF INSULATOR DISCUS	21 (Fog Type)	13	16	18
CONDUCTOR	400 mm² ACAR	410 mm² ACSR	520 mm² ACSR	610 mm² ACSR
OVER HEAD GROUND WIRE	NONE		90 mm² GSC	

Fig.A-6-3 PROFILE OF MICHIQUILLAY TRANSMISSION LINE
ROUTE B (ALTERNATIVE)

A・7 Funds Required and Repayment Schedule

A-7. FUNDS REQUIRED AND REPAYMENT SCHEDULE

A-7-1 Funds Required

The total construction cost of this power transmission and transforming project is shown in Table 7-2 in Chapter 7. The construction cost required for the 220 kV transmission and transforming facilities for power supply only to the Michiquillay Mine is given below, provided that interest during construction is not included.

Construction cost	US$20,782 x 10^3
Foreign currency portion	US$12,364 x 10^3
Domestic currency portion	US$8,418 x 10^3

The funds required by year, the amortization plan, etc. are shown in Tables A-7-1, A-7-2 and A-7-3. With respect to interest on funds procured and period of amortization, the following were assumed for both foreign and domestic currency portions:

Interest per annum, 3.5%

Repayment method, 7 years grace, 18 years principal amortization in equal installations

A-7-2 Energy Sales Revenue

Energy sales revenue was determined based on receiving power at the substation in Trujillo at Peru's nationally unified wholesale rate of 14.7 mills/kWh with an internal rate of return of 8% for the Project. Assuming energy sales to the Michiquillay Mine at a rate of 22.2 mills/kWh, the energy sales revenue would be US$6,187 x 10^3 in 1982 and US$10,050 x 10^3 in 1987.

A-7-3 Expenses and Depreciation Costs

Maintenance and operation costs and administrative expenses were calculated at 2% and 0.5% of total construction cost respectively. Depreciation was calculated by the fixed amount method with service life and residual value of each type of facility assumed as indicated below.

	Service Life	Residual Value
Transmission facilities	30 years	10%
Transforming facilities	30 years	10%
Telecommunications facilities	10 years	0%

A-7-4 Amortization Plan

The funds reserved for amortization of loans will be the net profit in ordinary revenue and expenditures and the depreciation reserve. Calculating the cash balance assuming amortization based on the energy sales revenue described in A-7-2 and the terms of loan described in A-7-1, the operation will be in the black from 1983 as indicated in Tables A-7-1 and A-7-2 and it is thought amortization can be amply made with the power demand of the Michiquillay Mine alone.

Table A-7-1 Statement of Income

Unit: 10^3 US$

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(A) Gross revenue				6,187	6,187	6,187	6,187	6,187	10,050	10,050	10,050	10,050
Energy sales (GWh)				278.7	278.7	278.7	278.7	278.7	452.7	452.7	452.7	452.7
Unit sales power rate (mills/kWh)				22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
(B) Total operation cost				5,548	5,548	5,548	5,548	5,548	8,202	8,202	8,202	8,202
1. Operation and maintenance				458	458	458	458	458	458	458	458	458
2. Administration cost				114	114	114	114	114	114	114	114	114
3. Depreciation				762	762	762	762	762	762	762	762	762
4. Purchased energy				4,214	4,214	4,214	4,214	4,214	6,868	6,868	6,868	6,868
Annual purchased energy (GWh)				286.7	286.7	286.7	286.7	286.7	467.2	467.2	467.2	467.2
Unit price (mills/kWh)				14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
(C) Operating income (A) - (B)				639	639	639	639	639	1,848	1,848	1,848	1,848
(D) Financial expendidure (Interest)	91	364	636	727	727	727	727	727	687	647	607	566
(E) Net income (C) - (D)	-91	-364	-636	-88	-88	-88	-88	-88	1,161	1,201	1,242	1,282

Table A-7-2 Statement of Cash Flow

Unit: 10^3 US$

	1970	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(A) Cash receipt	5,195	10,392	5,195	1,401	1,401	1,401	1,401	1,401	2,610	2,610	2,610	2,610
1. Operating income before interest				639	639	639	639	639	1,848	1,848	1,848	1,848
2. Depreciation				762	762	762	762	762	762	762	762	762
3. Exterior borrowing	5,195	10,392	5,195									
(B) Cash disbursment	5,286	10,756	5,831	727	727	727	727	1,882	1,842	1,802	1,761	1,721
1. Construction expenditure	5,195	10,392	5,195									
2. Interest	91	364	636	727	727	727	727	727	687	647	606	566
3. Amortization of debit (Capital)								1,155	1,155	1,155	1,155	1,155
(C) Cash balance (A) - (B)	-91	-364	-636	674	674	674	674	-481	768	808	849	889
(D) Accumlated total	-91	-455	-1,091	-417	257	931	1,605	1,124	1,892	2,700	3,549	4,438

Table A-7-3 Amortization Schedule

Unit: 10^3 US$

	Year	Borrowing: Transmission line	Borrowing: Substation facilities	Borrowing: Communication system	Borrowing: Total	Redamption: Principal	Redamption: Interest	Redamption: Total	Outstanding balance	Interest during construction
1	1979	4320	791	84	5,195				5195	91
2	1980	3248	6272	872	10,392				15587	364
3	1981	1344	2950	901	5,195				20782	636
4	1982								20782	727
5	1983								20782	727
6	1984								20782	727
7	1985								20782	727
8	1986					1155	727	1882	19627	
9	1987					1155	687	1842	18472	
10	1988					1155	647	1802	17317	
11	1989					1155	606	1761	16162	
12	1990					1155	566	1721	15007	
13	1991					1155	525	1680	13852	
14	1992					1155	485	1640	12697	
15	1993					1155	444	1599	11542	
16	1994					1155	404	1559	10387	
17	1995					1155	364	1519	9232	
18	1996					1155	323	1478	8077	
19	1997					1155	283	1434	6922	
20	1998					1155	242	1397	5767	
21	1999					1155	202	1357	4612	
22	2000					1155	161	1316	3457	
23	2001					1155	121	1276	2302	
24	2002					1155	81	1236	1147	
25	2003					1147	40	1187	[illegible]	

APPENDIX

A-8. GENERATING COST AT TRUJILLO NORTE SUBSTATION

The following assumptions were made in estimation of the generating cost at Trujillo Norte Substation of the Central Power System and the Santa Power System supplying electric power to the Michiquillay Mine which will start operation in 1982:

(1) Power would be supplied by 138 kV and 220 kV transmission lines from the Sheque, El Chorro and Yuncan hydroelectric power stations which are to be added around the time of start of operation of the Michiquillay Mine in 1982 (see Table A-8-1).

(2) The generating costs of Sheque and Yuncan hydro power stations allow for price increases since the oil crisis and each of them is assumed to be the same as the generating cost of 12.3 mills/kWh of El Chorro Hydroelectric Power Station revisec by current prices.

(3) The transmission lines to be the basis for calculating power transmission costs up to Trujillo Norte Substation are to be the transmission lines directly related to the above three power stations and 220 kV Lima-Chimbote-Trujillo transmission line (see Table A-8-2).

Table A-8-1 Generating Cost of Hydro Power Stations

Name	Installed Capacity (MW)	Dependable energy (GWh)	Unit energy cost (mills/kWh)	Time of Compleatión of Feasibility Report (Year)
Sheque	585	1,792	8.7	1971
El Chorro	160	1,046	12.3	1975 (revised)
Yuncan	160	910	4.1	1966
Total	905	3,748	–	–

The 138 kV and 220 kV transmission lines to be constructed in the Central and Santa Power System by 1982 in connection with the above three hydroelectric power stations, and the construction costs and annual costs at current prices for these transmission lines are as indicated in Table A-8-2.

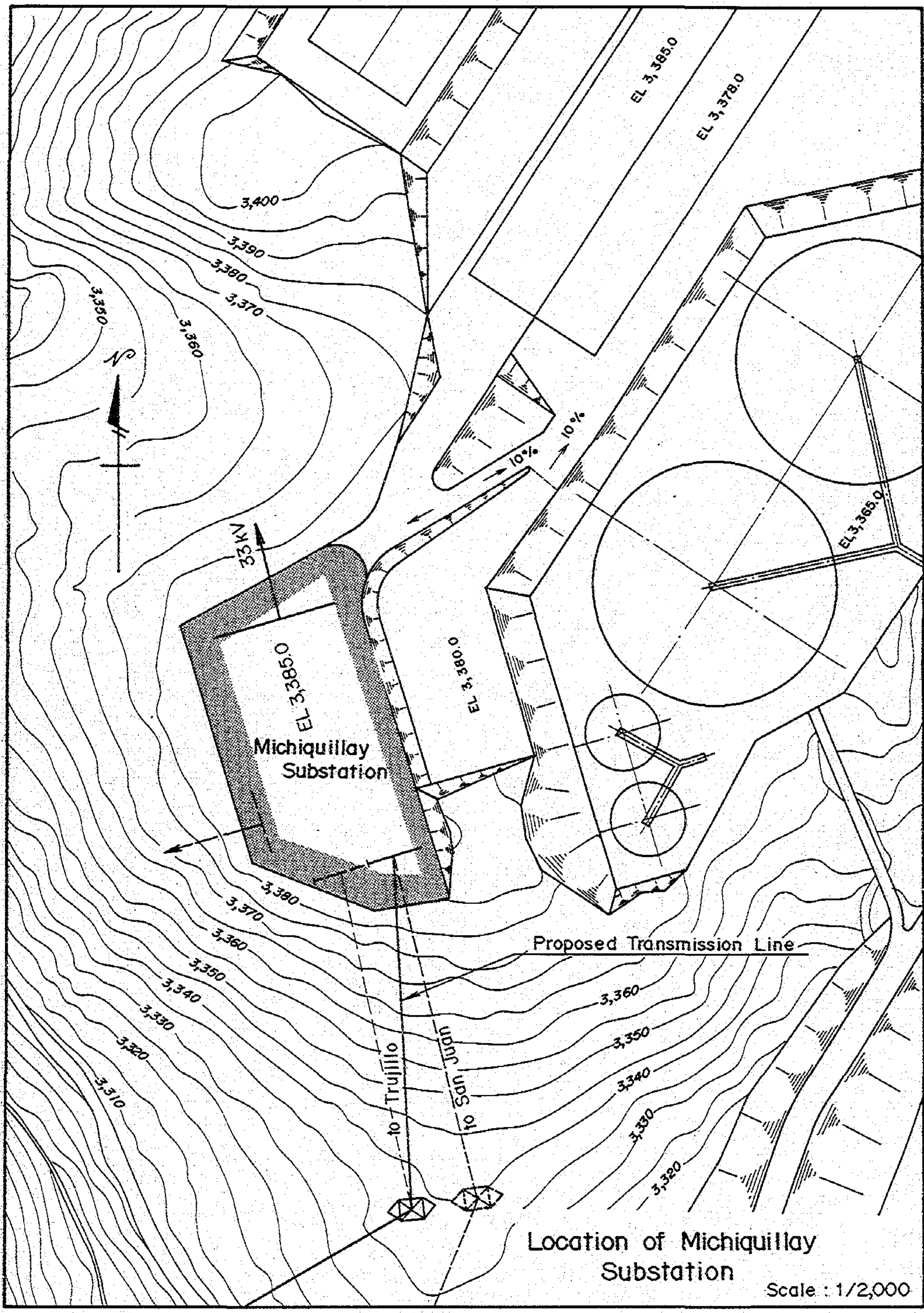
Table A-8-2 Annual Cost of Transmission Lines

Section	Length (km)	Voltage (kV)	No of cct	Construction cost (10^3 US$)	Annual cost (10^3 US$)
Sheque-Chavarria	70	220	2	4,480	590
La Oroya-Pomacocha	60	220	1	2,820	370
Lima-Chimbote	400	220	1	18,800	2,460
Chimbote-Trujillo	130	220	1	6,100	800
El Chorro-Chimbote	70	138	2	3,950	510
Total	730	–	–	36,150	4,730

The annual cost obtained from the above Table A-8-2, being divided by the dependable energy of the three hydroelectric power stations results in transmission cost of 1.3 mills/kWh.

Adding to this transmission cost the previously-mentioned generating cost of 12.3 mills/kWh, the generating cost at Trujillo Norte Substation will be 13.6 mills/kWh. This cost is roughly equal to the current wholesale price of 14.7 mills/kWh, and it is shown that it was appropriate for the current wholesale price to have been employed in cost comparisons of methods of supplying electric power to the Michiquillay Mine.

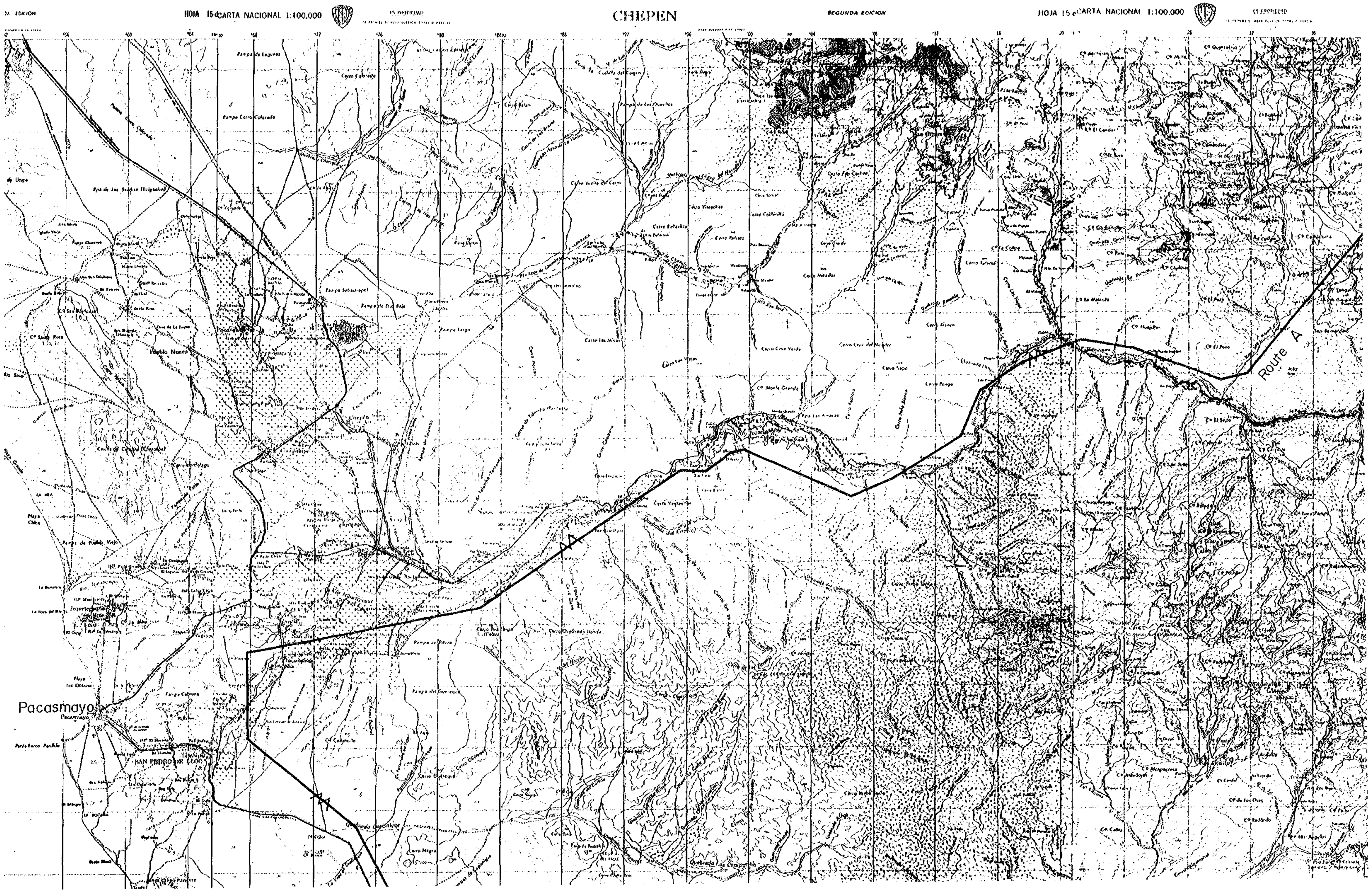
Further, the nationally unified wholesale rate of Alternative "C" is approximately equal to the generating cost of 13.6 mills/kWh of the 220 kV system in case of receiving power from the Central and Santa Power Systems at Trujillo Norte Substation on start of operation of the Michiquillay Mine in 1982.



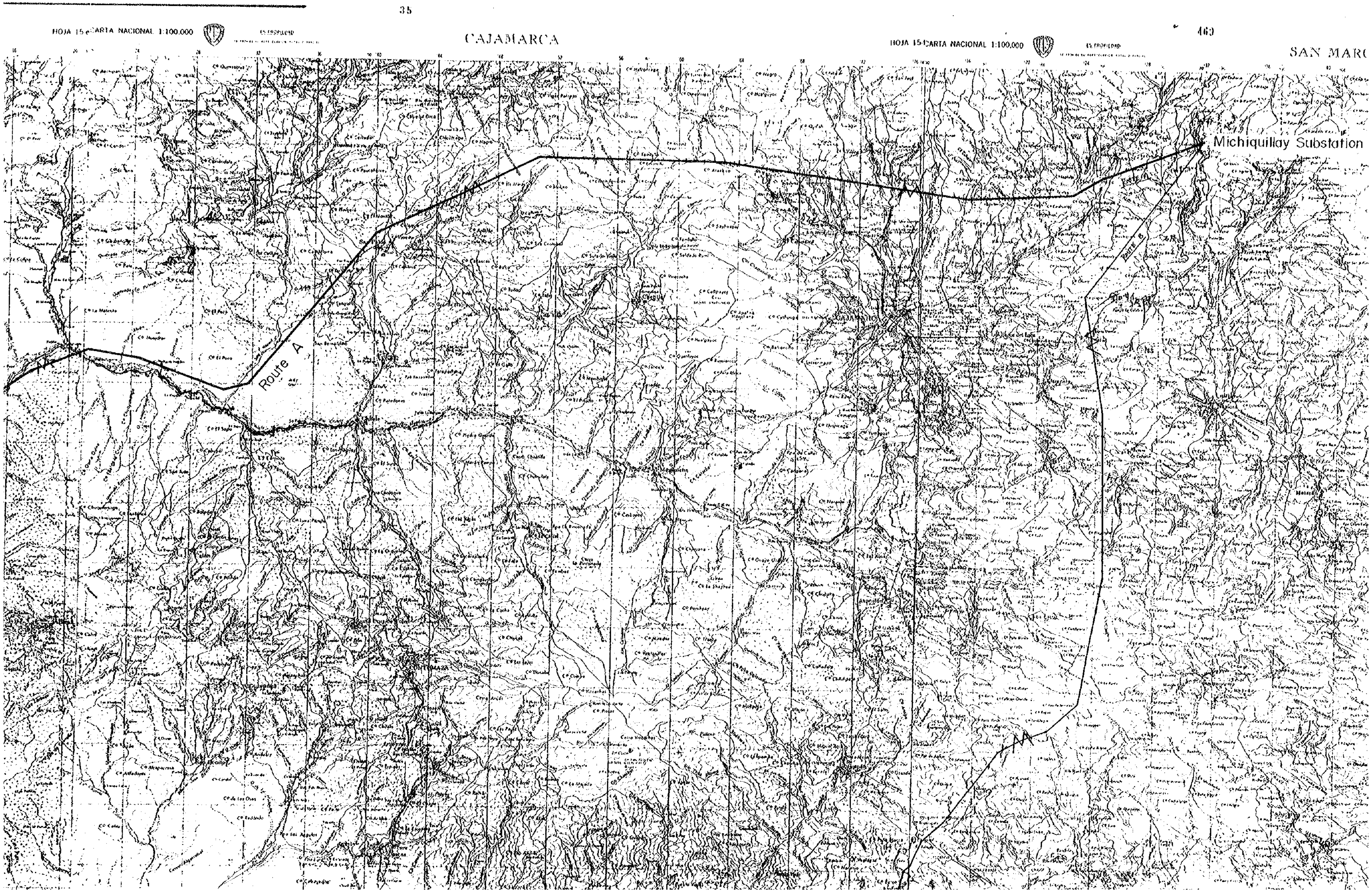
Location of Michiquillay Substation

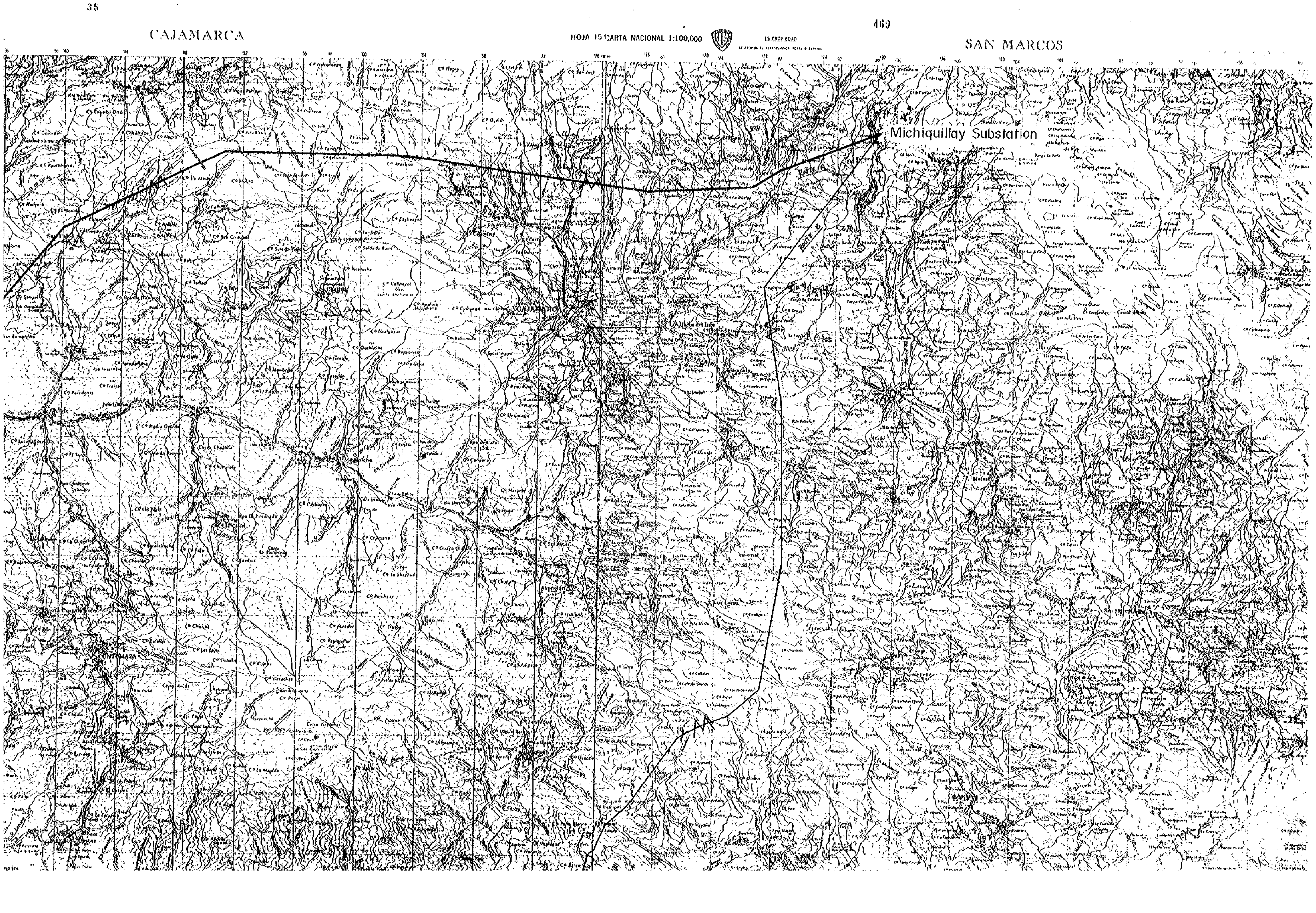
Scale : 1/2,000

Michiquillay Transmission Line Route



ıission Line Route

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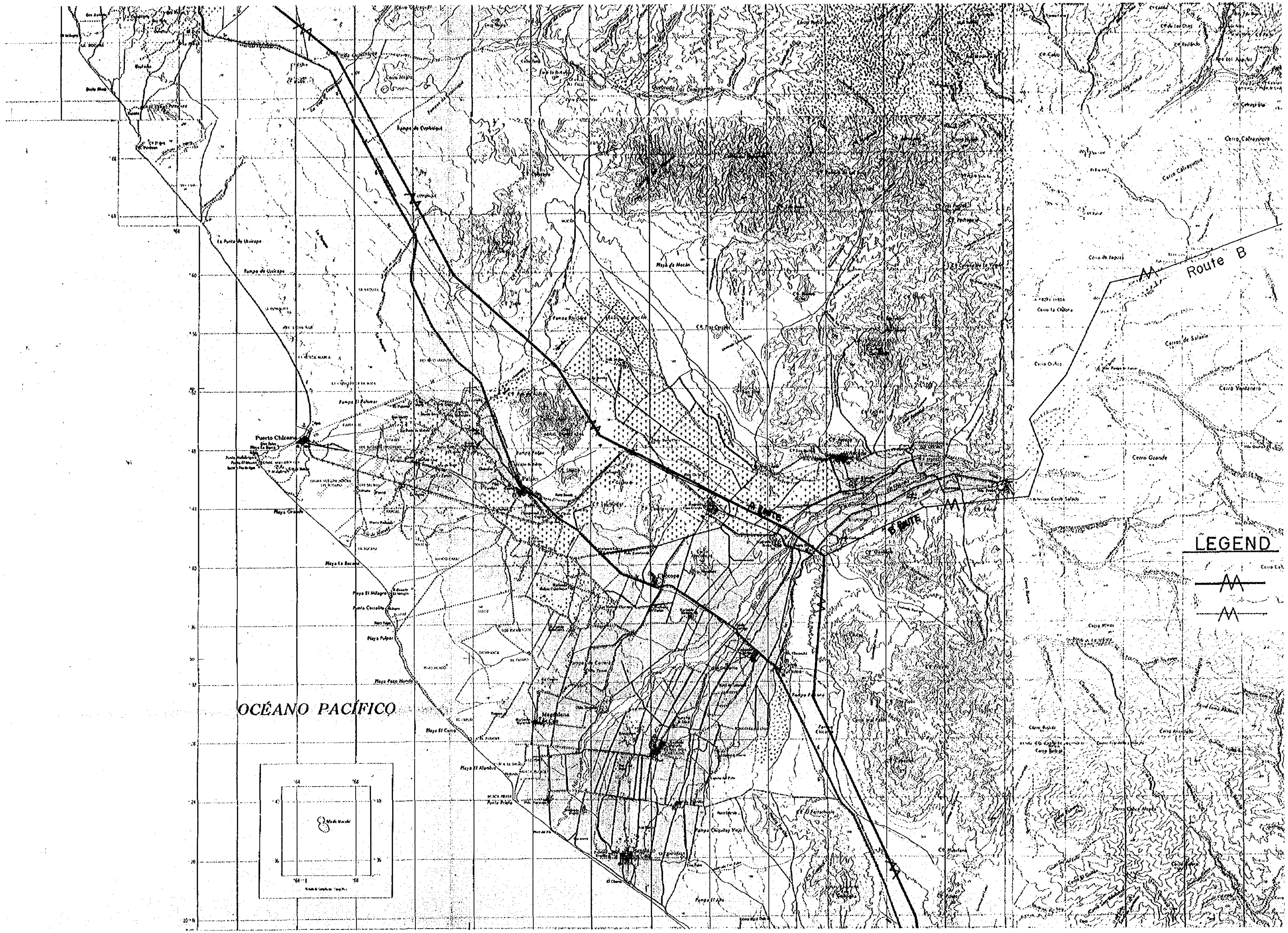
CAJAMARCA
CARTA NACIONAL 1:100,000
469
SAN MARCOS
Michiquillay Substation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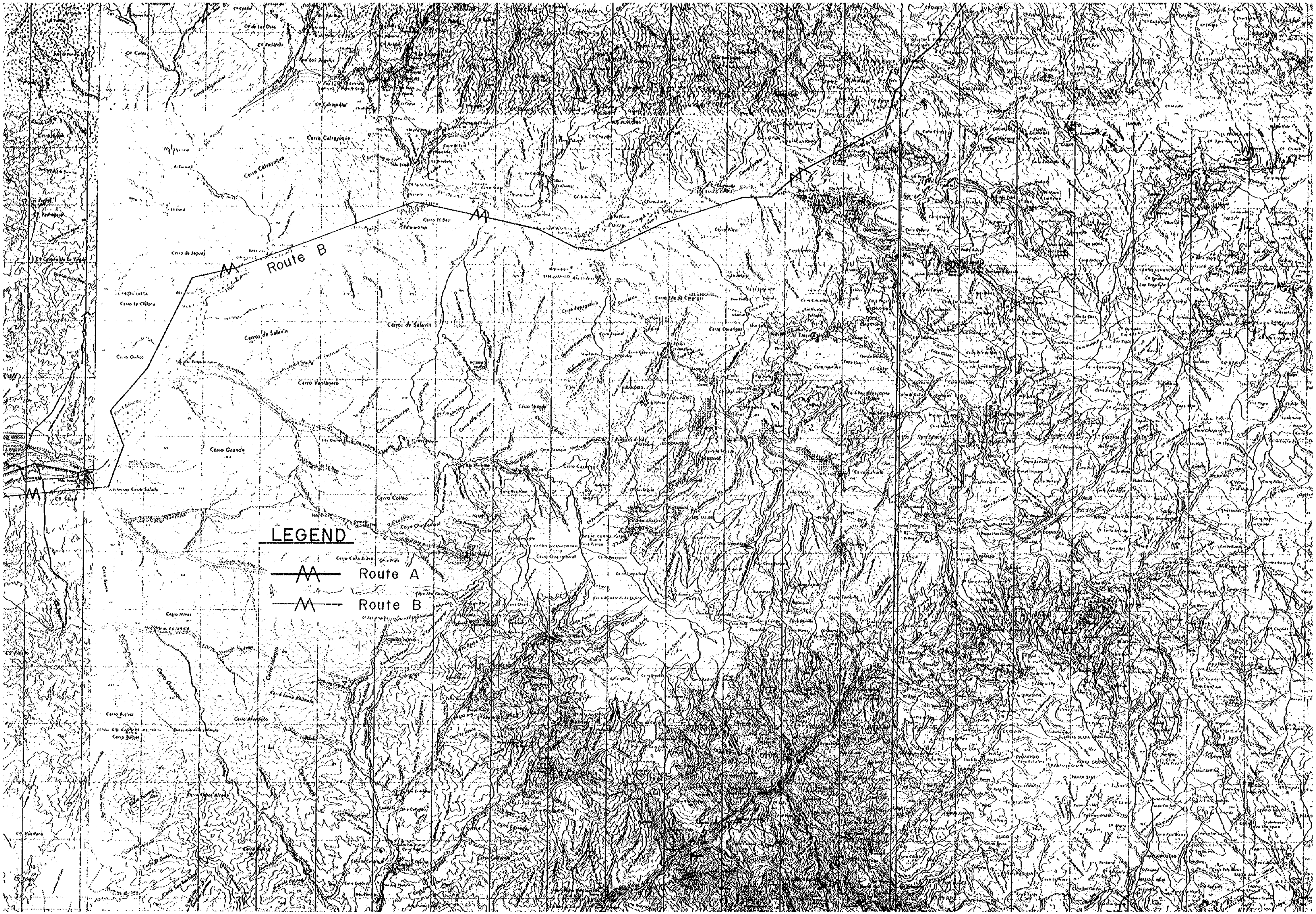
LEGEND
OCÉANO PACÍFICO
Puerto Chicama
Cerro Grande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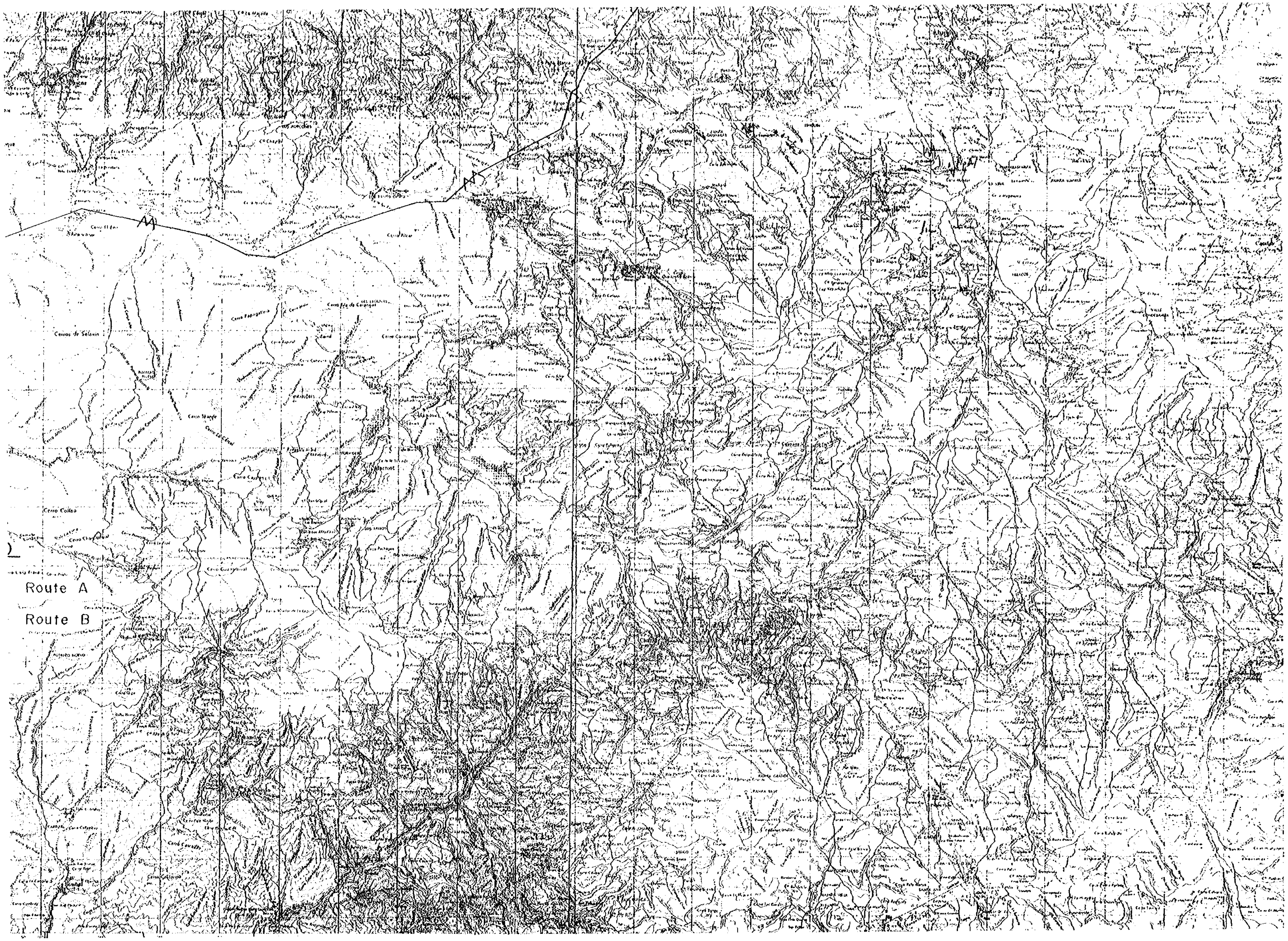
Route A
Route B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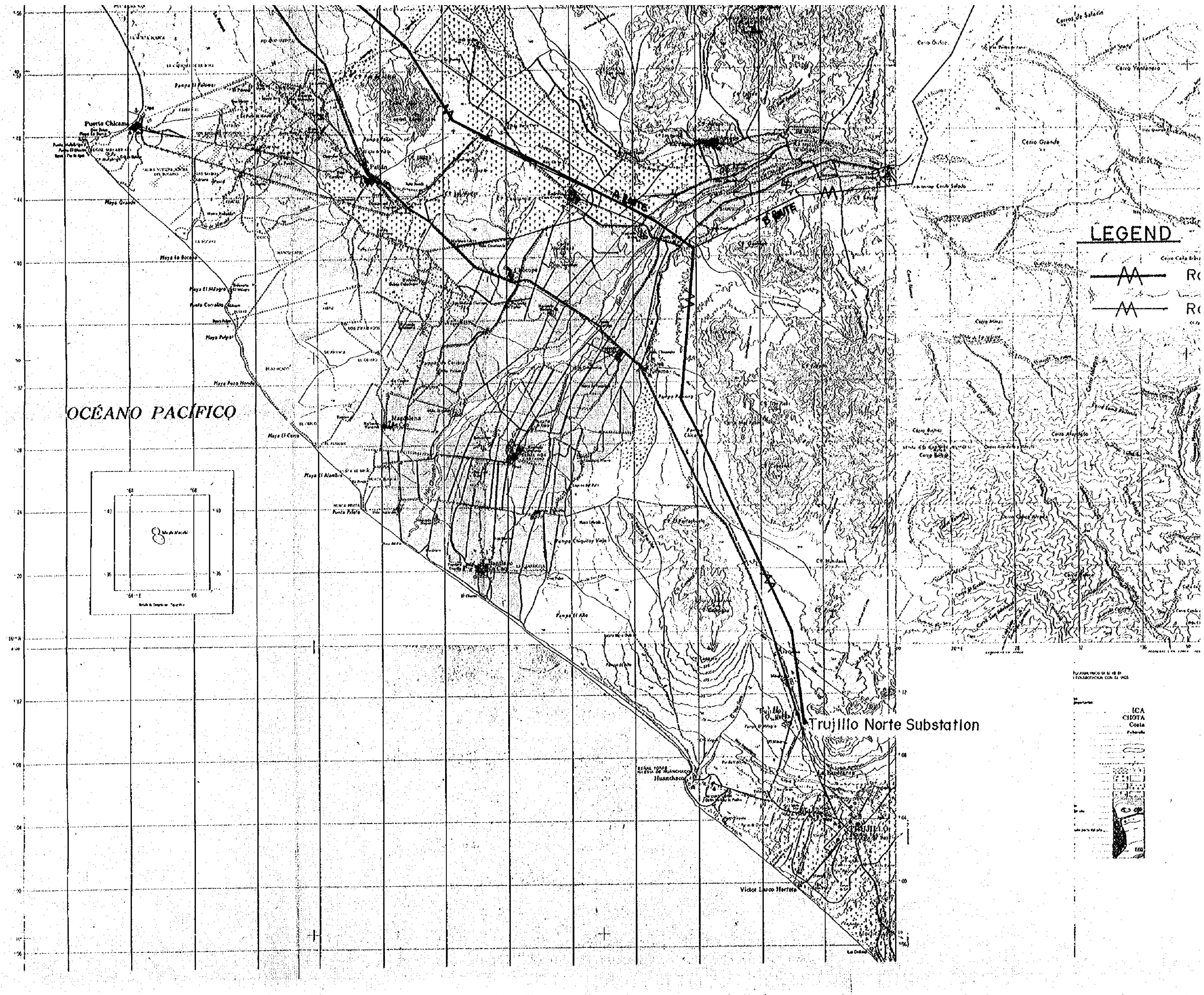
Route B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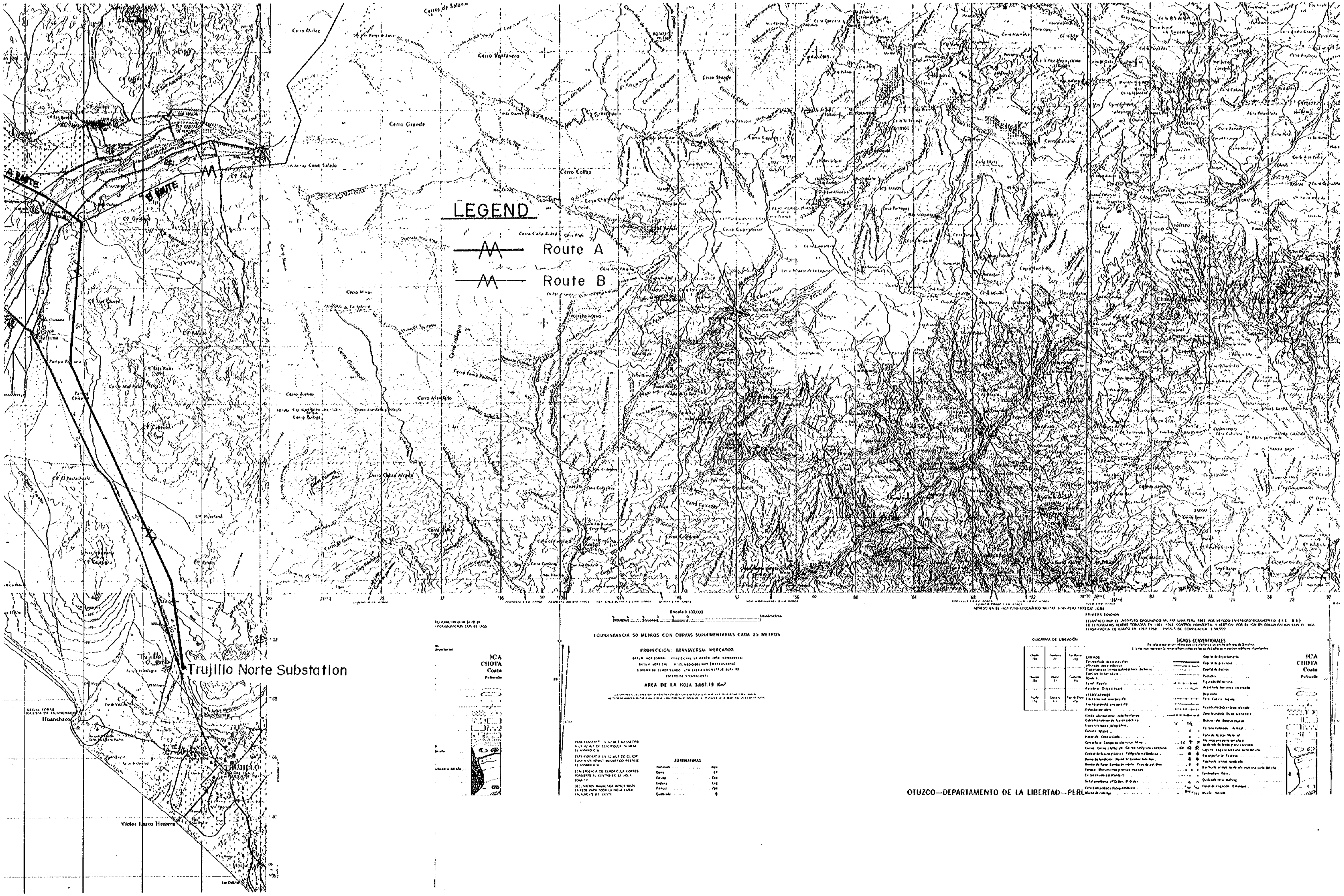
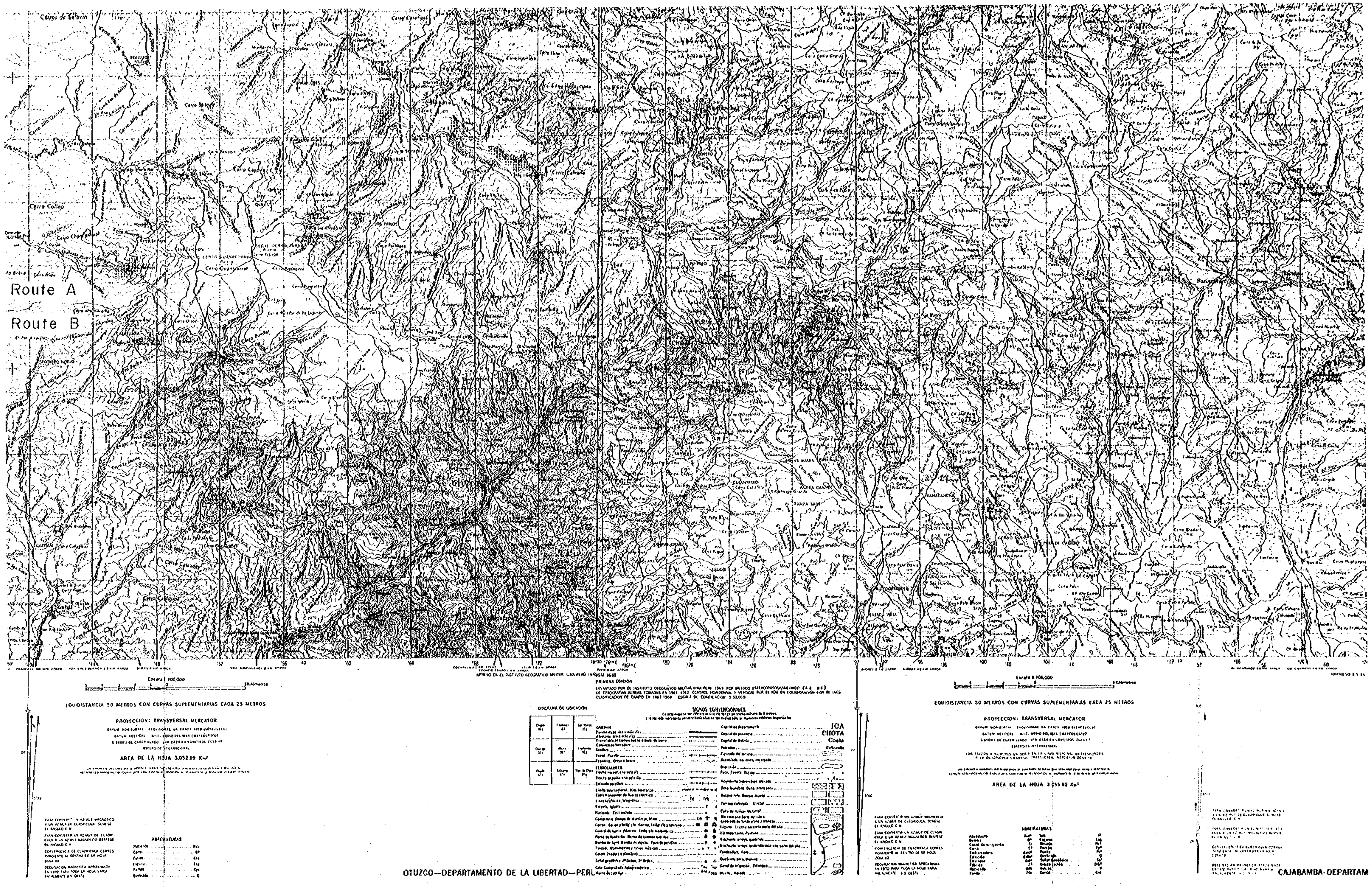
LEGEND
Trujillo Norte Substation
Puerto Chicama
Huanchaco
Cerro Grande


LEGEND
Route A
Route B
Trujillo Norte Substation
OTUZCO—DEPARTAMENTO DE LA LIBERTAD—PERU


Route A
Route B
EQUIDISTANCIA 50 METROS CON CURVAS SUPLEMENTARIAS CADA 25 METROS
PROYECCION: TRANSVERSAL MERCATOR
SIGNOS CONVENCIONALES
ICA
CHOTA
ABREVIATURAS
OTUZCO—DEPARTAMENTO DE LA LIBERTAD—PERU
CAJABAMBA-DEPARTAM