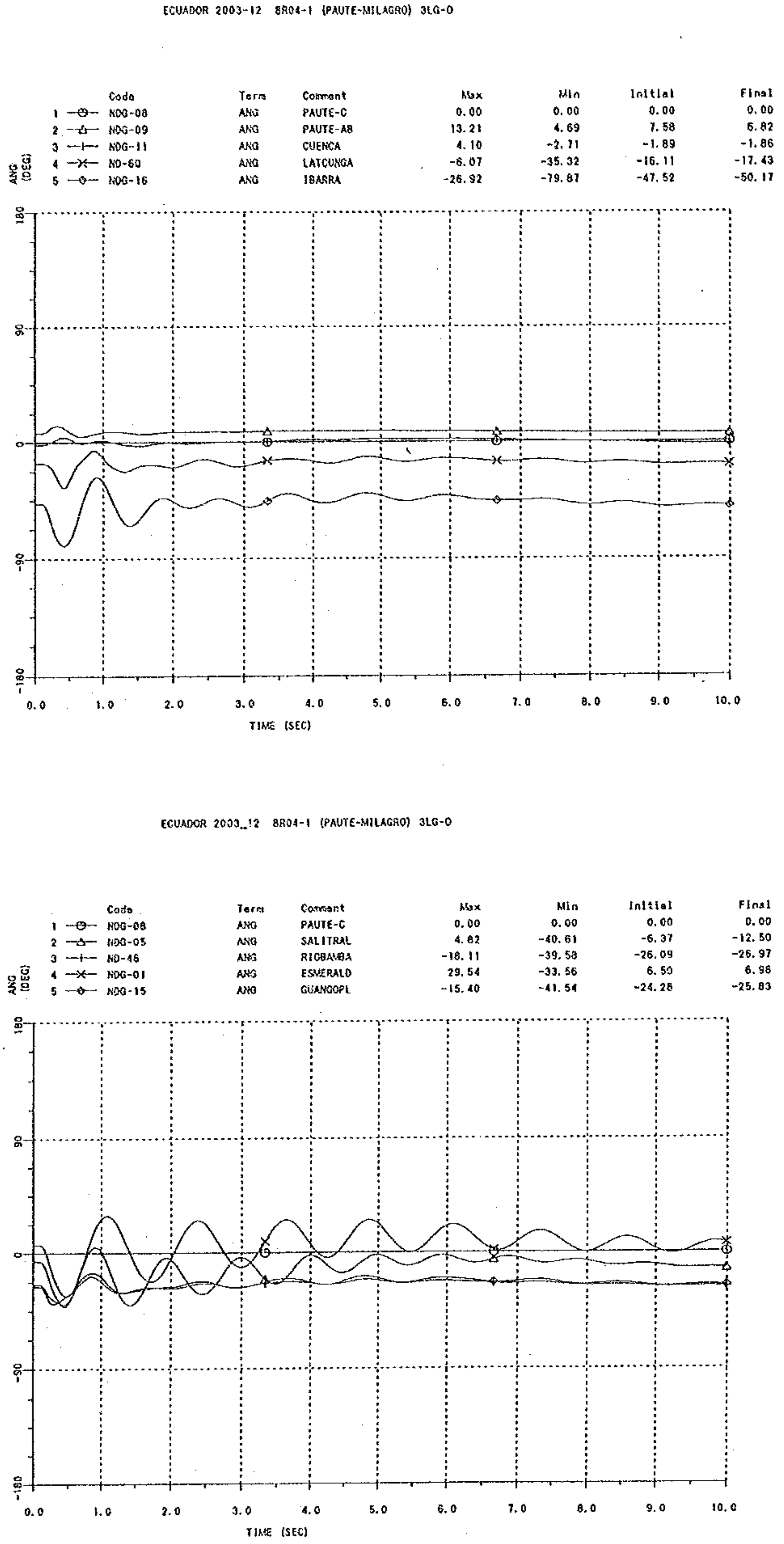


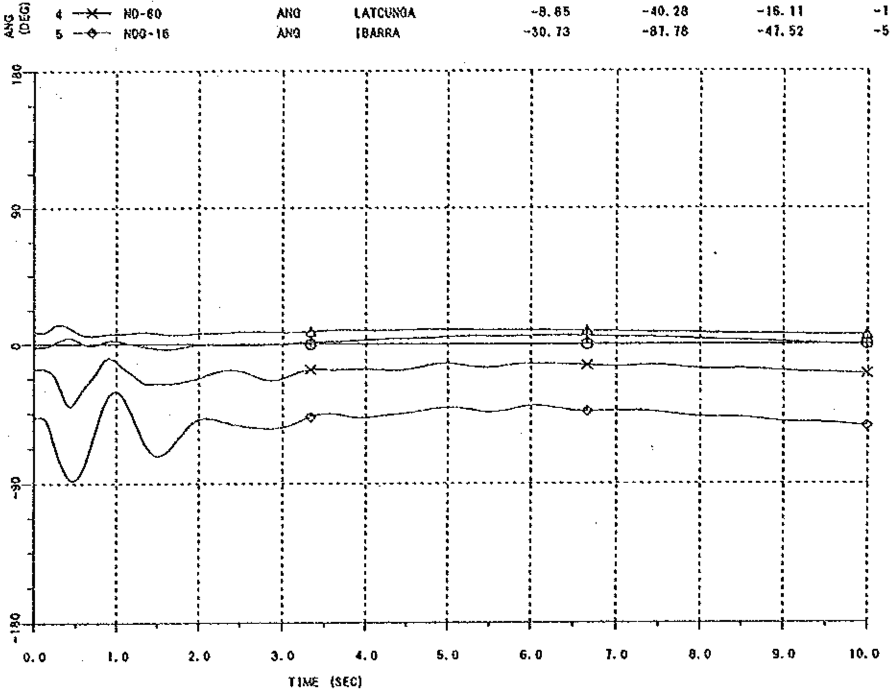
	Code	Term	Comment	Max	Min	Initial	Final
1 —⊖—	NDG-08	ANG	PAUTE-C	0.00	0.00	0.00	0.00
2 —△—	NDG-09	ANG	PAUTE-AB	13.21	4.69	7.58	6.82
3 —+—	NDG-11	ANG	CUENCA	4.10	-2.71	-1.89	-1.86
4 —×—	ND-60	ANG	LATCUNGA	-6.07	-35.32	-16.11	-17.43
5 —◇—	NDG-16	ANG	IBARRA	-26.92	-79.87	-47.52	-50.17

	Code	Term	Comment	Max	Min	Initial	Final
1 —⊖—	NDG-08	ANG	PAUTE-C	0.00	0.00	0.00	0.00
2 —△—	NDG-05	ANG	SALITRAL	4.82	-40.61	-6.37	-12.50
3 —+—	ND-46	ANG	RIOBAMBA	-18.11	-39.58	-26.09	-26.97
4 —×—	NDG-01	ANG	ESMERALD	29.54	-33.56	6.50	6.96
5 —◇—	NDG-15	ANG	GUANGOPL	-15.40	-41.54	-24.28	-25.83

Fig. 5-28 Power System Stability after 1 CCT Line Fault (under power flow condition of Fig. 5-22)

ECUADOR 2003-12 2CCT (PAUTE-MILAGRO) 3LG-0

	Code	Term	Comment	Max	Min	Initial	Final
1 —⊖—	NDG-08	ANG	PAUTE-C	0.00	0.00	0.00	0.00
2 —△—	NDG-09	ANG	PAUTE-AB	12.97	5.38	7.58	6.49
3 —+—	NDG-11	ANG	CUENCA	5.90	-3.25	-1.89	0.03
4 —×—	ND-60	ANG	LATCUNGA	-8.65	-40.28	-16.11	-19.19
5 —◇—	NDG-16	ANG	IBARRA	-30.73	-87.78	-47.52	-53.10



ECUADOR 2003-12 2CCT (PAUTE-MILAGRO) 3LG-0

	Code	Term	Comment	Max	Min	Initial	Final
1 —⊖—	NDG-08	ANG	PAUTE-C	0.00	0.00	0.00	0.00
2 —△—	NDG-05	ANG	SALITRAL	-5.39	-64.22	-6.37	-23.41
3 —+—	ND-45	ANG	RIOBAMBA	-19.45	-40.26	-26.09	-27.29
4 —×—	NDG-01	ANG	ESMERALD	29.00	-46.50	6.50	6.99
5 —◇—	NDG-15	ANG	GUANGOPL	-17.64	-49.53	-24.26	-27.92

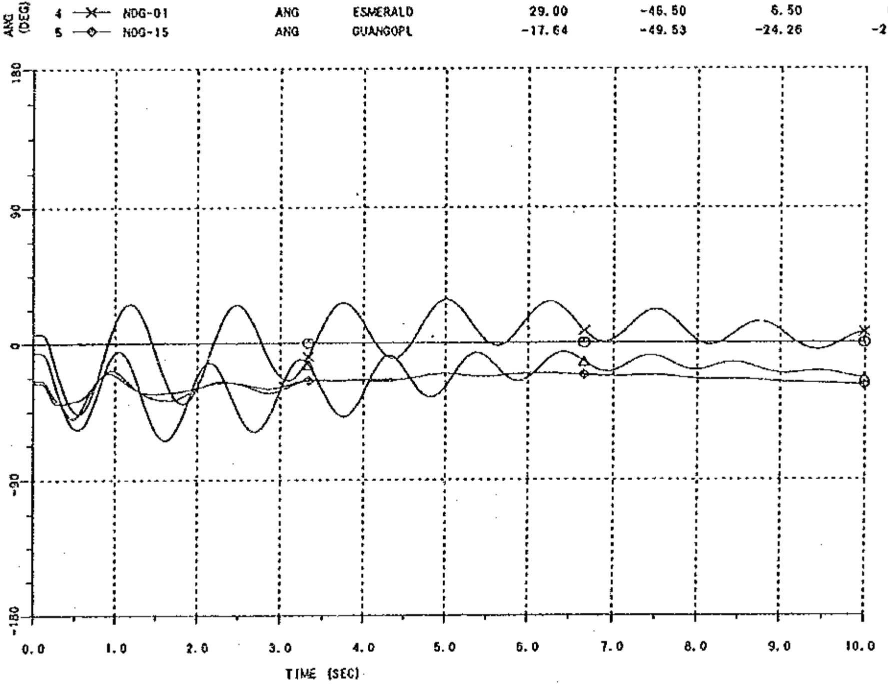


Fig. 5-29 Power System Stability after 2 CCT Line Fault (under power flow condition of Fig. 5-22)

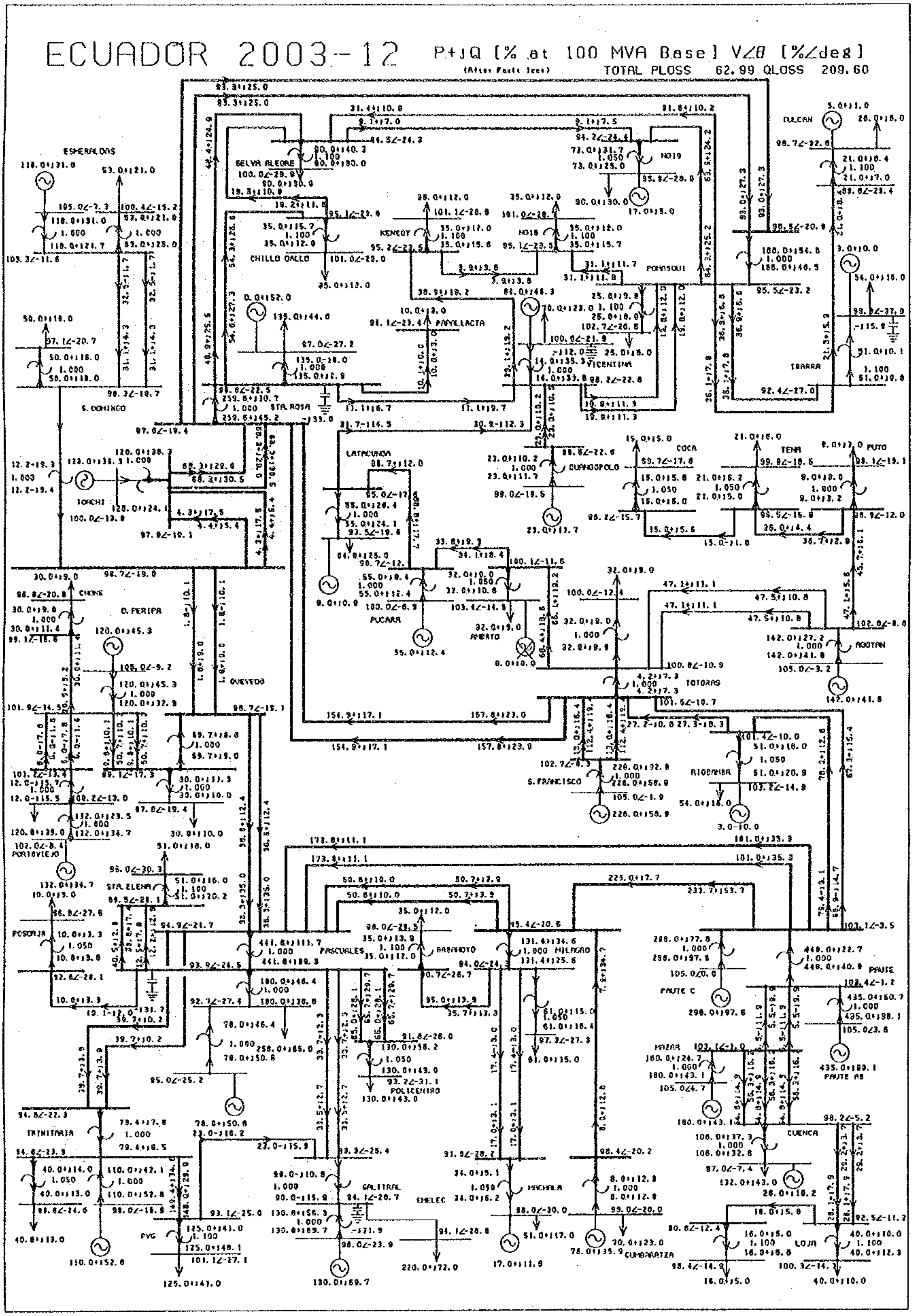


Fig. 5-30 Power Flow after Clearing of 1 CCT Line (corresponding to Fig. 5-22)

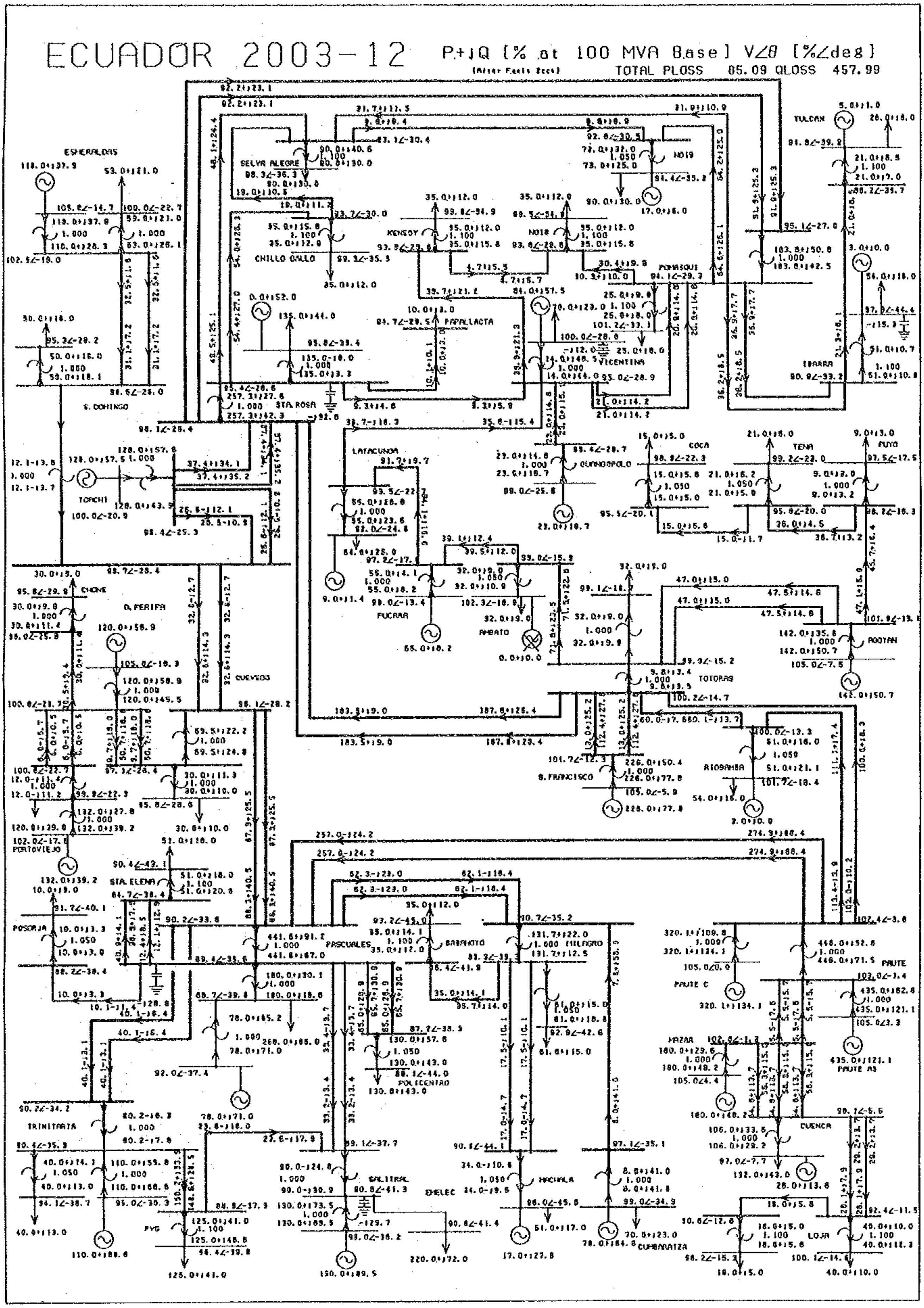


Fig. 5-31 Power Flow after Clearing of 2 CCT Line (corresponding to Fig. 5-22)

Table 5-1 Peak Loads at Substations (MW + jMVar) (1/2)

Substation	Mar. 1993 (Actual)	1998		2003	
		June	December	June	December
Sata Roas	111+j50	125+j41	132+j43	128+j42	135+j44
Vicentina	51+j18	64+j21	67+j22	67+j22	70+j23
Pomasqui	-	20+j7	21+j7	24+j8	25+j8
Selva Alegre	88+j40	86+j29	90+j30	86+j29	90+j30
S/E No. 19	55+j14	78+j26	82+j27	86+j29	90+j30
S/E No. 18	-	14+j5	15+j5	33+j11	35+j12
Kennedy	-	14+j5	15+j5	33+j11	35+j12
Chillo Gallo	-	14+j5	15+j5	33+j11	35+j12
Papallacta	5+j0	10+j3	10+j3	10+j3	10+j3
Ibarra	44+j13*	38+j11	40+j12	51+j15	54+j16
Tulcán	-	19+j6	20+j6	25+j8	26+j8
Santo Domingo	22+j14	34+j13	36+j14	48+j15	50+j16
Esmeraldas	22+j8	40+j18	42+j19	50+j20	53+j21
Quevedo	16+j6	22+j8	23+j8	29+j10	30+j10
Portoviejo	67+j17	96+j29	110+j30	114+j37	120+j39
Chone	-	24+j7	25+j7	29+j9	30+j9
Totoras	28+j7	23+j7	24+j7	30+j9	32+j9
Ambato	23+j7	24+j7	25+j7	30+j9	32+j9

* including Tulcán

Table 5-1 Peak Loads at Substations (MW + jMVar) (2/2)

Substation	Mar. 1993 (Actual)	1998		2003	
		June	December	June	December
Latacunga	-	54+j18	57+j19	61+j24	64+j25
Riobamba	30+j12	41+j12	43+j13	51+j15	54+j16
Puyo	-	6+j2	6+j2	9+j3	9+j3
Tena	-	18+j5	19+j5	20+j5	21+j5
Coca	-	8+j3	8+j3	14+j5	15+j5
Cuenca	37+j14	97+j32	102+j34	125+j41	132+j43
Loja	19+j5	28+j7	29+j7	38+j10	40+j10
Cumbaratza	-	8+j3	8+j3	15+j5	16+j5
Machala (230 kV)	-	53+j17	56+j18	67+j22	70+j23
Machala (138 kV)	48+j16	46+j15	48+j16	48+j16	51+j17
Milagro	26+j7	43+j11	45+j12	58+j14	61+j15
Babahoyo	21+j7	27+j19	28+j9	33+j11	35+j12
Pascuales	96+j34	187+j67	197+j70	245+j81	258+j85
Policentro	114+j40	119+j39	125+j41	124+j41	130+j43
Salitral	202+j74	204+j67	215+j71	209+j68	220+j72
PVG	-	95+j31	100+j33	119+j39	125+j41
Trinitaria	-	26+j9	27+j9	38+j12	40+j13
Posorja	6+j1	8+j2	8+j2	10+j3	10+j3
Sta. Elena	20+j7	30+j10	32+j11	48+j15	51+j16
Total	1,151+j411	1,843+j607	1,936+j635	2,238+j728	2,354+j763

Table 5-2 Machine Constant for Main Generators (2003)

	Capacity (MVA)	M (Sec)	Xd (%)	Xd' (%)	Xd" (%)	Xq (%)	Xq" (%)	Xe (%)	Tdo" (sec)	Tqo' (sec)
Paute-AB	550	6.6	109	35	19.5	74	19.5	10	0.05	0.14
Paute-C	639	6.6	109	35	19.5	74	19.5	10	0.05	0.14
Cuenca	30	5.8	128	28	22	80	22	14	0.04	0.1
Latacunga	6	5.2	91	40	22	58	22	14	0.04	0.1
Ibarra	12	13.4	107	40	22	66	22	14	0.04	0.1
Pisayambo	80	5.8	97.8	35	20.4	59	20.4	10	0.05	0.05
Riobamba	9	5.2	91.1	40.8	22	58	22	14	0.04	0.1
Agoyán	170	6.3	105	32	22	67	22	10	0.05	0.1
Tulcán	9	5.2	91	40	22	58	22	14	0.04	0.1
Vicentina	77.8	7.8	100	30	22	60	22	14	0.04	0.1
Salitral	196	11.9	163	24	14.2	141	14.1	10	0.05	0.05
Esmeraldas	156	15.6	122	26.2	20	109	20	10	0.05	0.05
Guangopolo	30.2	2.6	95	27	20	57	20	10	0.05	0.05
Santa Rosa	96	15.1	206	16	13	156	13	10	0.05	0.05
Pascuales	177.8	8.0	155	25	20	155	20	18	0.05	0.07
D. Peripa	144.4	7.5	100	30	22	60	22	14	0.04	0.1
San Francisco	282.2	7.5	100	30	22	60	22	14	0.04	0.1
Mazar	200	7.5	100	30	22	60	22	14	0.04	0.1
Portoviejo	156	8.0	155	25	20	155	20	18	0.05	0.07
Trinitaria	138.9	8.0	155	25	20	155	20	18	0.05	0.07
Toachi	166	7.5	100	30	22	60	22	14	0.04	0.1
No. 19	20	7.5	100	30	22	60	22	14	0.04	0.1
Machala	77.8	8.0	155	25	20	155	20	18	0.05	0.07

Table 5-3 Short-circuit Current (kA) (1/2)

(1) 230 kV busbars

	Mar. 1993 (Actual)	1998	2003
S. Rosa	5.1	5.6	7.7
S. Domingo	4.1	4.9	5.7
Quevedo	3.5	5.1	5.5
Pascuales	4.7	8.0	9.0
Milagro	4.9	6.9	7.5
Paute	10.8	11.9	13.4
Totoras	4.8	5.1	7.2
Riobamba	3.7	3.8	4.5
Trinitaria	-	6.6	7.2
Machala	-	2.4	2.4
S. Fransisco	-	-	5.7
Pomasqui	-	-	6.2
Toachi	-	-	7.5

(2) 138 kV busbars

	Mar. 1993 (Actual)	1998	2003
Ambato	5.0	5.1	5.4
Pisayambo	4.1	4.2	4.4
Latacunga	-	3.2	3.3
Vicentina	5.7	6.9	9.3
Guangopolo	4.5	5.5	6.8
Pomasqui	-	5.5	9.7
Ibarra	1.4	2.8	3.5
Pascuales	7.1	10.6	13.2
Salitral	6.7	9.7	10.8
S. Rosa	8.3	8.9	10.7
D. Peripa	-	5.4	5.5
Quevedo	3.6	6.0	6.3
Portoviejo	1.6	3.4	3.5
Esmeraldas	3.4	3.4	3.4
Paute	16.6	17.9	20.7
Mazar	-	-	12.5

Table 5-3 Short-circuit Current (kA) (2/2)

(2) 138 kV busbars

	Mar. 1993 (Actual)	1988	2003
Cuenca	3.4	3.9	5.3
Milagro	4.6	5.5	5.7
Babahoyo	2.0	2.1	2.1
Agoyán	4.8	4.8	5.1
Puyo	-	1.8	1.8
Loja	0.8	1.4	1.5
S. Elena	1.2	2.9	3.7
Posorja	1.3	1.4	1.4
Machala	2.0	2.0	2.0
Totoras	5.6	5.7	6.2
Policentro	5.2	6.9	7.9
Tena	-	1.0	1.0
Tulcán	-	1.3	1.5
Cumbaratza	-	0.9	1.0
Chone	-	1.9	1.9
Torinitaria	-	9.8	10.5
PVG	-	8.9	9.5
S. Alegre	5.5	6.0	8.1
C. Gallo	-	5.8	6.8
No. 18	-	5.5	7.9
No. 19	4.9	5.3	7.5
Kennedy	-	5.6	7.5
Papallacta	2.1	2.1	2.2
Coca	-	0.9	1.0
S. Domingo	4.6	5.1	5.5

Table 5-4 Frequency Drop and Load Shedding at Peak Time on March 3, 1993

Name of Electric Power Co., Ltd.		Steps of Load Shedding In %/MW[*1]						
		1	2	3	4	5	6	7
Emelec	Guayaquil	7.2/30	9.6/37	9.0/31	20.1/67	41.2/103	26.7/40	42.8/46
EE. Quito S.A.	Quito	7.0/23	10.0/30	10.0/27	20.0/49	14.9/29		19.5/33
Emelmanabi	Portoviejo	5.3/4	22.8/15	8.4/4	5.3/2			
Emelgur	Quevedo	7.1/1	15.0/2	8.8/1	22.8/3			
EER Centro Sus	Cuenca	7.0/4	10.0/6	10.0/5	20.0/9			
Emeloro	Machala			25.0/13		100.0/37		
EE Ambato	Ambato	7.0/4	10.0/5	10.0/4	20.0/8			
Emelnorte	Ibarra		14.5/7	12.0/5	19.0/6			
Emersa	Esmeralda		9.0/2	8.5/2	27.9/5			
EE Milagro	Milagro			6.2/2	16.2/4	100.0/22		
EE Riobamba	Riobamba	7.0/2	10.0/2	10.0/2	20.0/4			
EEP Sta. Elena	Sta. Elena		13.0/5	10.8/3	21.0/6			
EE Sto. Domingo	Sto. Domingo		5.0/1	7.2/2	9.3/2			
EER Sur	Loja							
Emelrios	Babahoyo					100.0/22		
EE Cotopaxi	Latacunga		9.0/6	2.6/2	18.4/12			
EE Bolivar	Guaranda							
EE Azoques	Cuenca				100.0/11			
Conditions								
Frequency drop	(Hz)	59.2	59.0	58.8	58.6	58.4	58.2	58.0
Load shedding	(MW)	68	118	103	188	213	40	79
Σ Load shedding	(MW)	68	186	289	477	690	730	809
Estimated frequency[*2]	(Hz)	59.5	59.9	60.1	60.8	61.6	61.6	61.7

[*1] Load shedding at each step will be done by frequency relays within 12 Hz
[*2] Calculated by the power system frequency constant for SNI K=1.38% MW/0.1 Hz

CHAPTER 6 SUPPLY RELIABILITY ANALYSIS

CONTENTS

Page

CHAPTER 6 SUPPLY RELIABILITY ANALYSIS

6.1 Analysis Method of Supply Reliability 6-1

6.2 Current Level and Future Forecast of Supply Reliability 6-3

6.2.1 Supply Reliability of December, 1991 6-4
6.2.2 Supply Reliability of December, 1998 6-4
6.2.3 Supply Reliability of December, 2003 6-5

6.3 Evaluation of Supply Reliability and Study of Alternative Plans 6-5

6.3.1 Supply Reliability of December, 1998 6-5
6.3.2 Supply Reliability of December, 2003 6-6

6.4 Necessity to retain the rated Voltage 6-6

6.5 Necessity to retain the rated Frequency 6-6

6.6 Recommendable Plan from the viewpoint of the Supply Reliability Analysis 6-8

List of Figures

Fig. 6-1 Border of South & North Zone -SNI-
Fig. 6-2 Flow Diagram of Interconnected System Reliability
Fig. 6-3 Record of Frequency

List of Tables

Table 6-1 Data of Power Station (North Zone) as of December, 1991
Table 6-2 Data of Power Station (South Zone) as of December, 1991
Table 6-3 Data of Power Station (North Zone) as of December, 1998
Table 6-4 Data of Power Station (South Zone) as of December, 1998
Table 6-5 Data of Power Station (North Zone) as of December 2003
Table 6-6 Data of Power Station (South Zone) as of December, 2003
Table 6-7 Data of Power Station (North Zone) as of December, 1998 (Alternative Plan)
Table 6-8 Data of Power Station (South Zone) as of December, 1998 (Alternative Plan)
Table 6-9 Data of Power Station (North Zone) as of December, 2003 (Alternative Plan)
Table 6-10 Data of Power Station (South Zone) as of December, 2003 (Alternative Plan)
Table 6-11 Data of Power Station (North Zone) as of December, 1998 (Recommendable Plan)
Table 6-12 Data of Power Station (South Zone) as of December, 1998 (Recommendable Plan)
Table 6-13 Data of Power Station (North Zone) as of December, 2003 (Recommendable Plan)
Table 6-14 Data of Power Station (South Zone) as of December, 2003 (Recommendable Plan)

CHAPTER 6 SUPPLY RELIABILITY ANALYSIS

As described in Section 1.3, "The Scope of Study", the supply reliability to be described in this chapter means the supply reliability from the viewpoint of the suppliers or organizations related to the electric utility industry. It is the supply reliability (LOLP; Expected shortage days) of SNI (including all power sources connected to 69KV in addition to 230KV and 138KV systems) considering the faults at the power plants, errors in power demand projections, and flow variation at the run-of-river hydro power plant. While interruption of service to the users occurs at the power generation section, substation/transmission line section or distribution section, this chapter, however, focuses on only the power generation section.

Regarding the electric power system's reliability in a broad sense, there are other problems in addition to the supply reliability (LOLP or service interruption probability). These are fluctuation from the rated voltage and rated frequency. We shall describe these problems separately hereto as they concern the power quality provided to the users.

6.1 Analysis Method of Supply Reliability

INECEL has prepared electric power development plans in which SNI is divided into two regions; north and south - as shown in Fig. 6-1.

Considering the balance between power demand and supply in each region, INECEL has formed a nationwide electric power system. The priority in these plans is to minimize overall cost, even at certain sacrifice of the supply reliability. Consequently, the demand/supply imbalance between the north and south has increased. In 1998, a supply shortfall of approx. 220MW is expected in the north and a supply excess of approx. 670MW is expected in the south.

In this study, we have, therefore, divided SNI into two regions; the north centered at Quito City and the south centered at Guayaquil City. We analyzed the isolated systems in each region based on the INECEL's data and the data submitted by the two local power companies; EMELEC and EEQ. We then conducted an reliability analysis by linking these two regions for which we used the analysis program described in Fig. 6-2 "Flow Diagram of Interconnected System Reliability".

This program consists of a single system composite probability distribution calculation program and an interconnected system reliability calculation program. The former program calculates the supply reliability in each single system in the north and south, for which the power plant fault distribution and demand variation distribution are synthesized. It also calculates the responding necessary auxiliary power. The latter program, considering the interconnected system, calculates the supply reliability in the interconnected system and the responding necessary auxiliary power, using the Monte Carlo method, to sample the supply ratio variation and demand variation.

In the single system composite probability distribution calculation program, the fault ratio per unit in the hydro power plant and that in the thermal power plant are handled as Poisson's distribution and binomial distribution. Demand variation distribution is treated as normal distribution around the predicted value. This calculates the auxiliary supply power required to satisfy the specified reliability in each single system.

With the interconnected system reliability calculation program, fault demand variation MW in each of the south and north systems is sampled by the Monte Carlo method to acquire the overcapacity or undercapacity of each system. When either an supply surplus or supply shortage occurs in a system, the excess or shortfall is calculated for supplying or receiving the power between the systems considering the interconnected system capacity. The length of the shortage (day) against the shortage (MW) of the responding power supply/receiving is calculated according to the demand duration curve. After frequent and repetitive sampling, the auxiliary power in each system is changed to bring the average value to the required LOLP. The auxiliary supply power in each interconnected system is acquired accordingly.

Due to insufficient data, we have not considered the demand variation by temperature nor the load diversity of the demand. The supply support rules between the south and north are described below. 5,000 samplings are provided.

(a) When the total available capacity in the system having supply surplus exceeds the total shortfall in the system having supply shortage, it supplies power in proportion to the ratio of surplus in the surplus system.

(b) When the total shortfall in the system with supply shortage exceeds the total available capacity in the system with supply surplus, the power is supplied in proportion to the shortage ratio.

(c) When the supply capacity throughout the systems is excessive, the power is supplied or received so that the surplus ratio becomes even throughout the systems within the range of total surplus capacity.

(d) When the capacity throughout the systems is short, the power is supplied or received so that the shortage ratio in all systems becomes even.

(e) In the case of a capacity bottleneck in interconnected system, however, support is provided within the capacity allowed in the interconnected system to satisfy the above (a), (b), (c) and (d).

6.2 Current Level and Future Forecast of Supply Reliability

Ecuador's electric power demand/supply conditions are severest in December because the demand for power peaks in December - at coincidentally the same time when there is the least river flow. Reliability in December, 1992, is a good indicator of the current state, although the demand for electric power in that particular month was exceptionally low as the electricity rate had been increased in October, 1992.

We discussed this matter with INECEL and decided to use December, 1991's reliability as being the current state. Also, we have studied the reliabilities in December, 1998 and December, 2003 as future prospects.

6.2.1 Supply Reliability of December, 1991

We calculated the supply reliability in December, 1991 by taking the previous three years' faults at the power plants and demand prediction errors over the 10 year span into consideration.

According to INECEL's data, the max. power demand in December, 1991, was 536MW in the north and 804MW in the south. The supply capacity including the power output at the power plants and the fault ratio is described in Tables 6-1 and 6-2.

According to calculations, the LOLP per month was 20 days in the single system in the north and 10 days in the single system in the south. In the interconnected SNI, however, it was 10 days in the north and 4.9 days in the south.

6.2.2 Supply Reliability of December, 1998

According to INECEL's power demand forecast, the max. power demand in December, 1998 will be 1,991MW nationwide. In the north, the demand will be 753MW and 1,238MW in the south.

According to INECEL's master power plan, the supply capacity in December, 1998 is as shown in Tables 6-3 and 6-4.

According to calculations based on these data, the LOLP was 20 days in the single system in the north, and 0 days in the single system in the south. In the interconnected SNI, however, supply reliability reached 0.05 day in the north and 0 days in the south.

6.2.3 Supply Reliability of December, 2003

According to INECEL's power demand forecast, the max. power demand in December, 2003, will be 2,595MW nationwide; 986MW in the north and 1,609MW in the south.

According to INECEL's master power plan, the supply capacity as of December, 2003, is as shown in Tables 6-5 and 6-6.

According to calculations based on these data, the LOLP was 15.2 days in the single system in the north, and 0.086 days in the single system in the south. In the interconnected SNI, supply reliability reached 0.33 days in the north and 0.058 days in the south.

6.3 Evaluation of Supply Reliability and Study of Alternative Plans

6.3.1 Supply Reliability of December, 1998

As confirmed in 6.2.2, reliability with the interconnected system in the north and south presents no problems. However, the LOLP in the single system in the north is 20 days, which is abnormal.

Contrarily, the LOLP in the south is 0 days due to over supply.

INECEL has a development plan for the south to correct this imbalance between north and south. We studied an alternative plan in which New T. Vapor 125MW (scheduled to start operation in 1995) and New T. Vapor 140MW (scheduled to start operation in 1997) are moved to the north. The supply capacity in this plan is as shown in Tables 6-7 and 6-8.

These calculations provided an LOLP of 14 days in the single system in the north and 0.02 days in the single system in the south.

LOLP in the interconnected SNI was 0.05 days in the north and 0.006 days in the south.

6.3.2 Supply Reliability of December, 2003

According to the INECEL plan, a new power source will be installed in the north by the year 2003. Therefore, we studied an alternative plan to move New T. Gas 80MW (scheduled to start operation in 2001 in the north) to the south, reversing the previously described alternative plan. The supply capacity in this plan is as shown in Tables 6-9 and 6-10.

These calculations provided an LOLP of 1.26 days in the single system in the north and 1.86 days in the single system in the south. The LOLP in the interconnected SNI reached 0.11 days in the north and 0.24 days in the south.

6.4 Necessity to retain the rated Voltage

Electrical equipment connected to the systems (lights and motors for the users, and transformers and generators for the supplier) are designed for operation at the rated voltage and satisfactory performance cannot be expected if used at a different voltage.

When the voltage is higher, the exciting current in the transformer increases to saturate the core, resulting in transformer deficiency.

When the voltage is lower, the phase modifying equipment connected to the third phase in the transformer does not operate at the rated output.

INECEL has set a goal of ±5% in the 230KV and 138KV systems and ±3% when transferring to local power companies at 69KV. They are making efforts to retain the rated voltage.

6.5 Necessity to retain the rated Frequency

It is necessary to retain the rated frequency for both users and suppliers alike for the following reasons;

(a) Stable power supply is extremely important for automated systems in which computers are incorporated. A dedicated stabilizing device is usually installed. It is important that the rated frequency be retained in order to reduce the load to this device.

(b) Motor speeds change according to the frequency. When using high speed pot motors in the textile industry and paper mills especially because uneven motor speeds results in uneven finished products. Obviously, even frequency is required.

(c) Electric clock malfunction is also caused by frequency change. In this case, it is more important to acquire an integration value of 0 rather than a 0 instantaneous frequency deviation.

(d) Stable frequency reduces the load to motor output controls. In the case of steam turbines, frequent output control interrupts the steam flow in the boiler and turbine system, thus adversely affecting the thermal stress.

(e) The flow at the link point between the local power company's system and SNI varies precisely in response to frequency change. To retain stable linkage, it is therefore, necessary to minimize the variation around the specified value (60Hz).

(f) The voltage at each section of the system fluctuates in accordance with frequency variation. When the frequency is retained at the specified value, the load to the voltage control is reduced which serves to also improves stability.

Consequently, the tolerance of frequency variation should be approx. ±0.1Hz. The frequency chart (2 days) acquired by the JICA research group during its on-site survey, shows that it escaped ±0.1Hz for 3.83 hours on February 18 (Thurs), 1993, and again for 1.75 hours on February 22 (Mon), 1993.(See Fig.6-3)

6.6 Recommendable Plan from the viewpoint of the Supply Reliability Analysis

According to the power flow for December, 1998 as shown in Fig. 5-13, the power at the Daule Peripa Hydro Power Plant 130MW (scheduled to start operation in December, 1996) and New T. Vapor 140MW in Manta (scheduled to start operation in December, 1997) flows mainly toward the north. Therefore, although situated in the south, these two power plants are able to be regarded as power sources for the north.

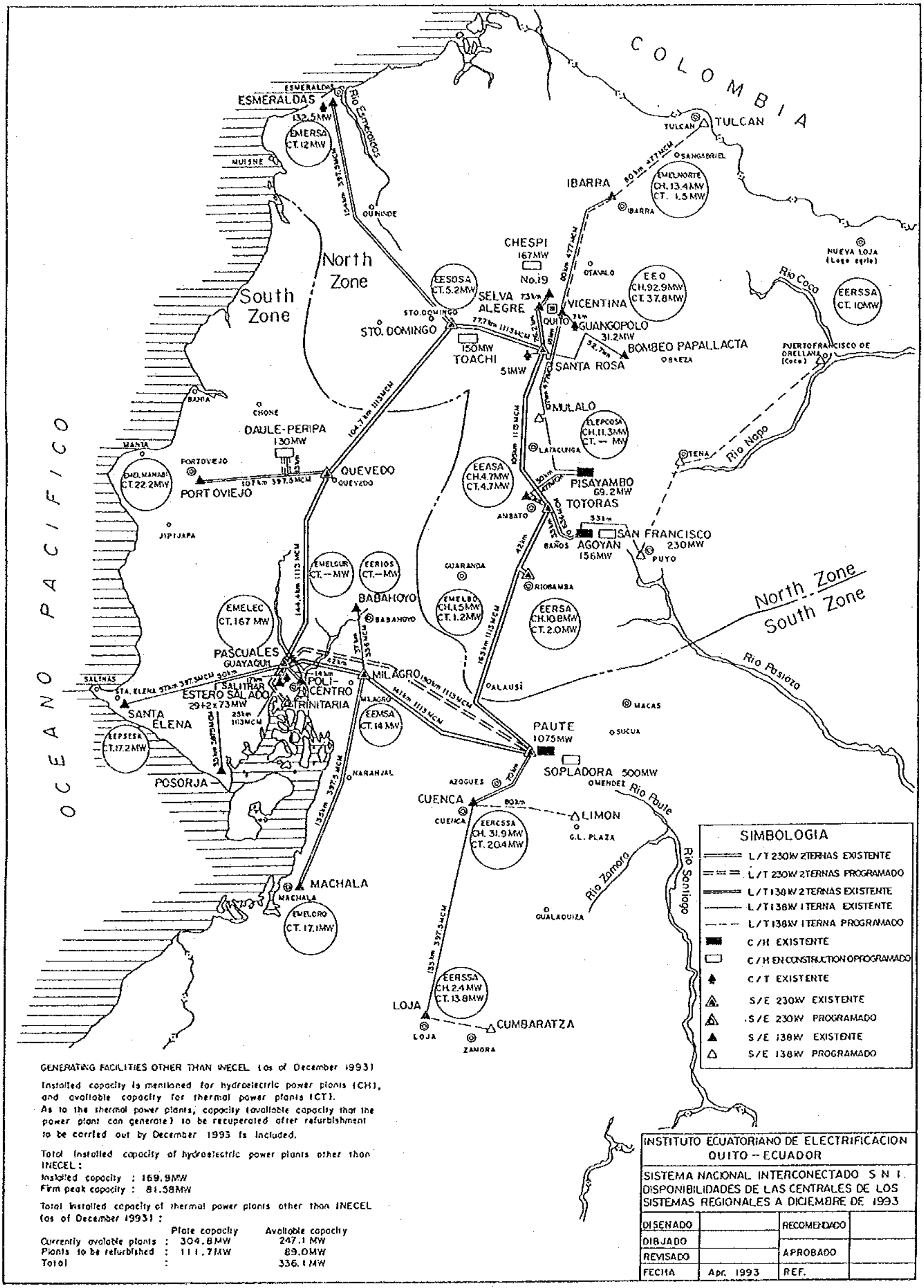
In the year 2003, a New T. Gas 80MW (scheduled to start operation in 2001) in the north will be able to remain as planned by INECEL because a New T. Vapor 125MW will be constructed in the south in 2004, though reliability in the south will be slightly lower than the north. The supply capacity in this recommendable plan is as shown in Tables 6-11 to 6-14.

In 1998, these calculations provided an LOLP of 16.4 days in the single system in the north and 0.01 days in the single system in the south. LOLP in the interconnected SNI was 0.05 days in the north and 0.003 days in the south.

In 2003, these calculations provided an LOLP of 0.37 days in the single system in the north and 3.23 days in the single system in the south. LOLP in the interconnected SNI was 0.04 days in the north and 0.27 days in the south.

Therefore, it is considered that INECEL's master plan is reasonable based on the supply reliability analysis.

And also it is recommended that Daule Peripa Hydro Plant and Manta Thermal Plant should be regarded as electric power resources of the north from the viewpoint of decreasing the difference between the north and the south.



GENERATING FACILITIES OTHER THAN INECEL (as of December 1993)

Installed capacity is mentioned for hydroelectric power plants (CH), and available capacity for thermal power plants (CT).
As to the thermal power plants, capacity (available capacity that the power plant can generate) to be recuperated after refurbishment to be carried out by December 1993 is included.

Total installed capacity of hydroelectric power plants other than INECEL:
Installed capacity : 169.9MW
Firm peak capacity : 81.58MW

Total installed capacity of thermal power plants other than INECEL (as of December 1993) :

	Plate capacity	Available capacity
Currently available plants :	304.8MW	247.1 MW
Plants to be refurbished :	111.7MW	89.0MW
Total :		336.1 MW

INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO – ECUADOR

SISTEMA NACIONAL INTERCONECTADO S N I.
DISPONIBILIDADES DE LAS CENTRALES DE LOS
SISTEMAS REGIONALES A DICIEMBRE DE 1993

DISENADO		RECOMENDADO	
DIBJADO		APROBADO	
REVISADO			
FECHA	Apr. 1993	REF.	

Fig. 6-1 Border of South & North Zone – SNI–

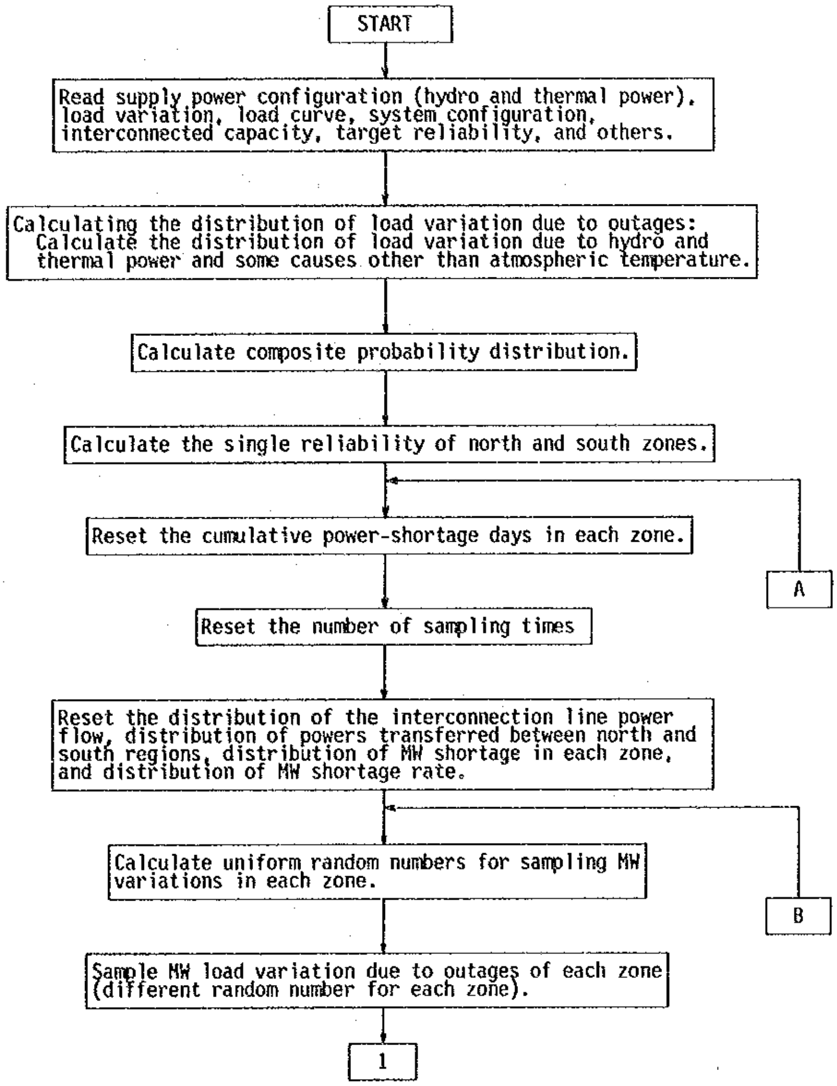


Fig. 6-2 Flow Diagram of Interconnected System Reliability (1/3)

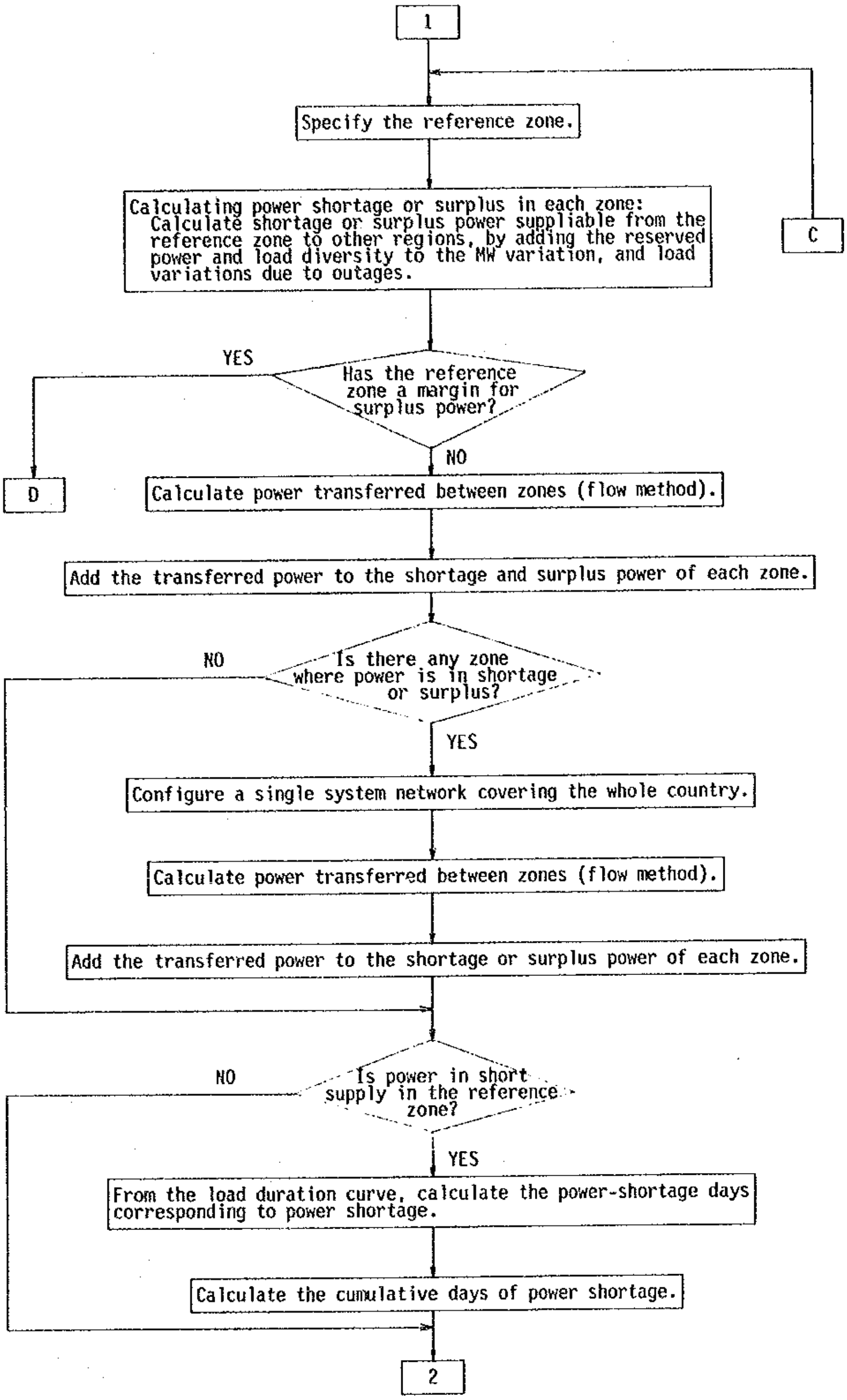


Fig. 6-2 Flow Diagram of Interconnected System Reliability (2/3)

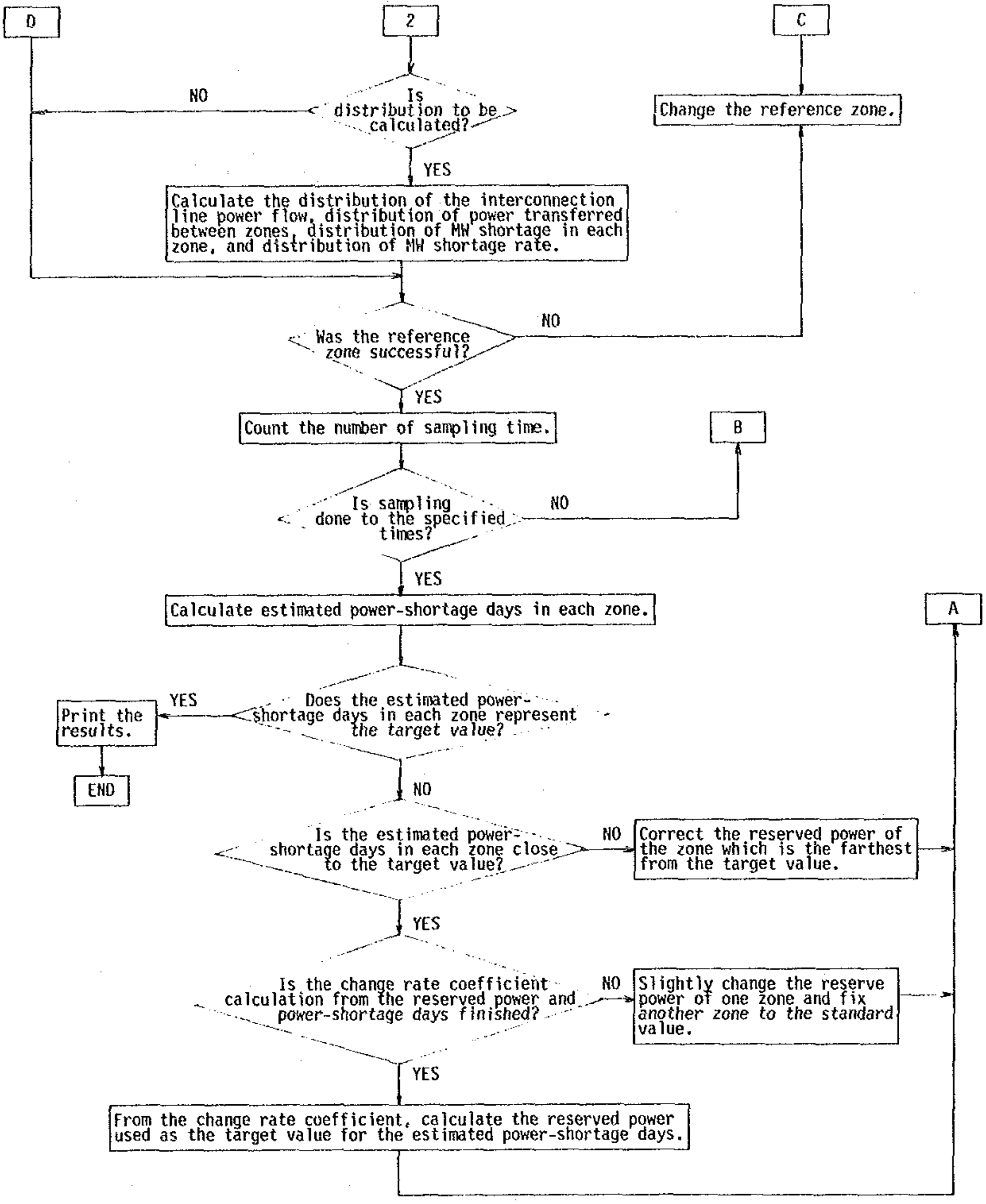


Fig. 6-2 Flow Diagram of Interconnected System Reliability (3/3)

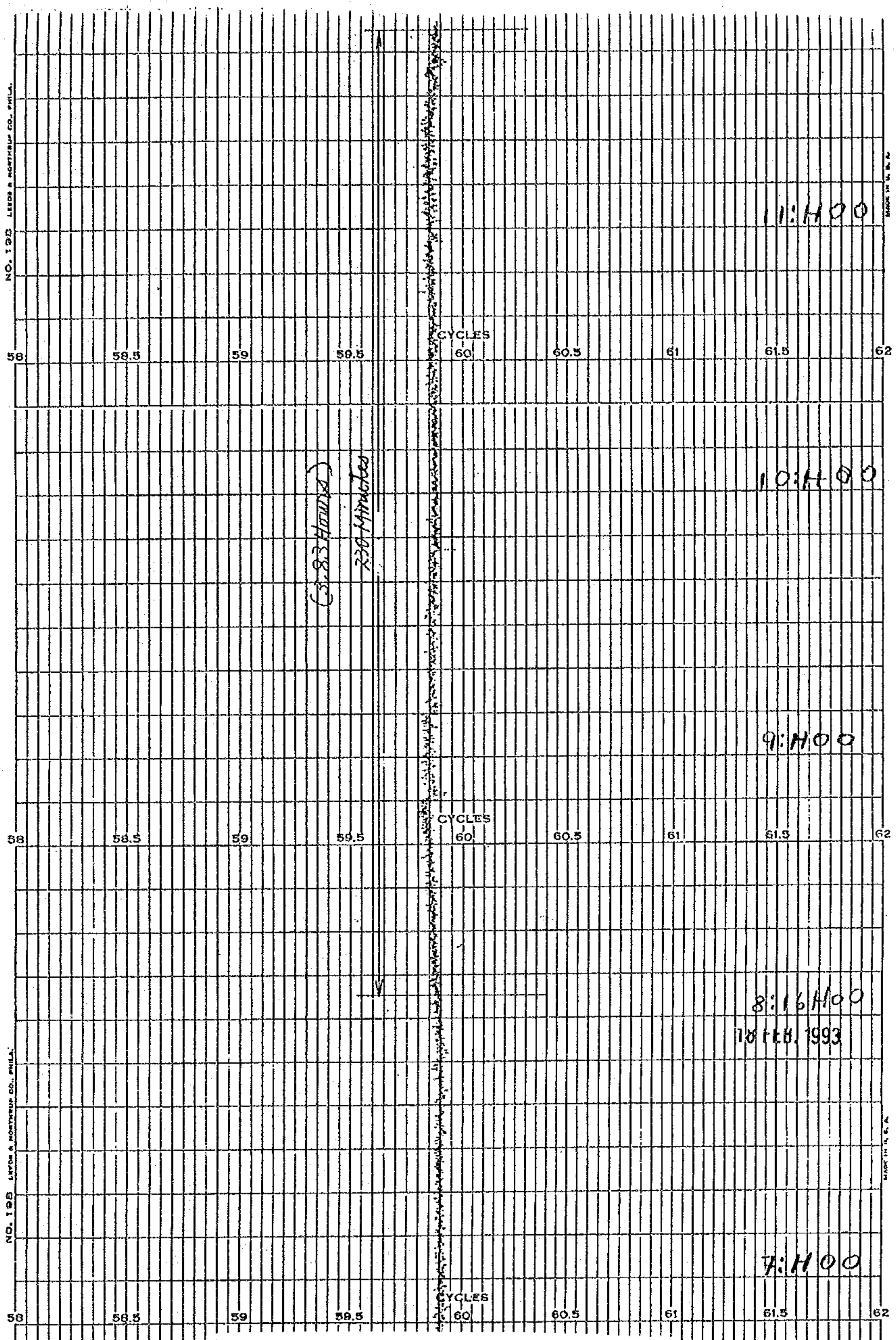


Fig. 6-3 Record of Frequency (1/2)

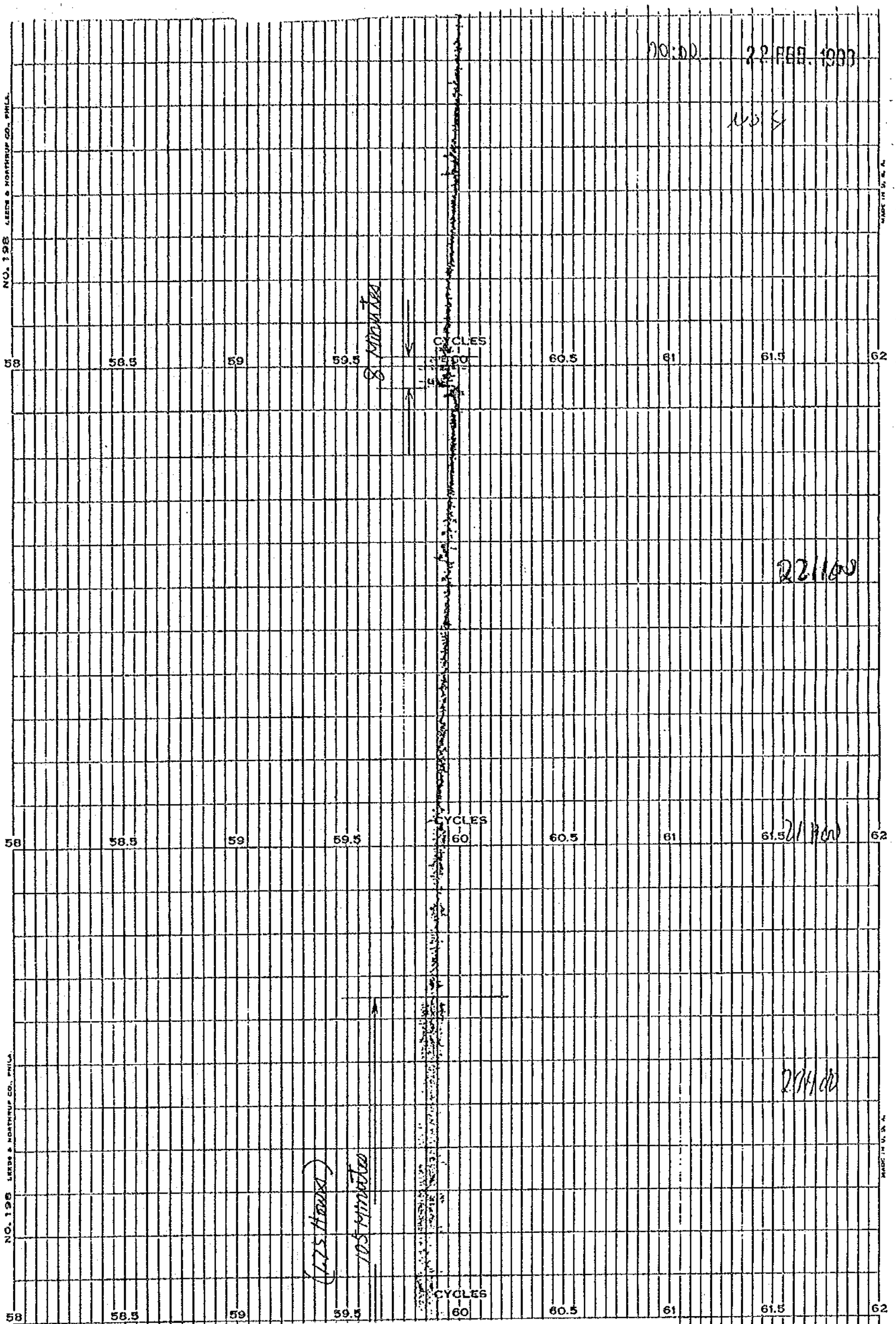


Fig. 6-3 Record of Frequency (2/2)

Table 6-1 Data of Power Station (North Zone) as of December, 1991

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.14
Pisayambo	H	69.20	65.40	2	32.70	0.66
Cumbayá	H	40.00	17.65	4	4.4125	3.84
Nayón	H	29.70	14.00	2	7.00	3.13
Pasochoa	H	4.50	2.25	2	1.125	0.36
Los Chillos	H	1.76	0.86	2	0.430	2.65
Others (18)	H	59.59	29.24	18	1.624	3.84*1
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	0.80*2
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	20.23
Diesel Guangopolo	T	31.20	24.30	6	4.05	17.54
S. Regionales Diesel	T	11.23	8.20	5	1.64	20.23*3
S. Regionales Bunker	T	11.44	10.00	2	5.00	17.54*4
Total			497.90	49		

Table 6-2 Data of Power Station (South Zone) as of December, 1991

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	1.87
Others (6)	H	34.32	27.23	6	4.54	3.84*1
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.48
Estero Salado (Gas)	T	30.94	20.00	1	20.00	0.80*2
Guayaguil Vapor #1	T	10.00	9.40	2	4.70	30.30
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	6.20
Guayaguil Gas	T	13.50	12.00	1	12.00	14.00
Guayaguil Vapor	T	33.00	31.60	1	31.60	5.10
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	8.05
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	10.73
S. Regionales Diesel	T	48.59	32.30	23	1.40	20.23*3
S. Regionales Bunker	T	45.78	31.40	10	3.14	17.54*4
Total			856.43	58		

Note: *1 Assumed the largest value in hydropower plants.
*2 Assumed by JICA.
*3,*4 Assumed the largest value in thermal plants.

Table 6-3 Data of Power Station (North Zone) as of December, 1998

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.154[*1]
Pisayambo	H	69.20	65.40	2	32.70	0.726[*1]
Cumbayá	H	40.00	17.65	4	4.4125	4.22125[*1]
Nayón	H	29.70	14.00	2	7.00	3.4375[*1]
Pasochoa	H	4.50	2.25	2	1.125	0.396[*1]
Los Chillos	H	1.76	0.86	2	0.430	2.915[*1]
Others (18)	H	59.59	29.24	18	1.624	4.22125[*1]
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	0.88[*1]
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	22.253[*1]
Gangopolo (Diesel)	T	31.20	24.30	6	4.05	19.294[*1]
S. Regionales Diesel	T	2.98	2.20	1	2.20	22.253[*1]
S. Regionales Bunker	T	11.23	8.20	5	1.64	19.294[*1]
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	22.253[*1]
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	19.294[*1]
Total			534.30	63		

Note: *1 10% up of 1991's data

Table 6-4 Data of Power Station (South Zone) as of December, 1998

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.057*1
Paute (C)	H	575.00	459.40	5	91.88	2.057*2
Daule Peripa	H	130.00	86.00	2	43.00	0.500*2
Others (6)	H	34.32	27.23	6	4.54	0.500*2
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.528*1
Estero Salado (Gas)	T	30.94	20.00	1	20.00	0.88*1
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	6.82*1
Guayaguil Vapor	T	33.00	31.60	1	31.60	5.610*1
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	8.885*1
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	11.803*1
S. Regionales, Diesel	T	33.84	22.80	17	1.3411	22.253*1
S. Regionales, Bunker	T	21.58	11.40	4	2.85	19.294*1
S.R. Rehab. Diesel	T	41.895	36.80	20	1.84	22.253*2
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	19.294*2
Electro Quil (Gas)	T	75.00	74.00	2	37.00	14.00*2
Electro Quito (Gas)	T	33.00	32.00	2	16.00	14.00*3
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.80*2
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.80*2
New T. Vapor (1995)	T	125.00	117.50	1	117.50	0.80*2
New T. Vapor (1997)	T	140.00	132.00	2	66.00	0.80*2
Total			1,905.23	81		

Note: *1 10% up of 1991's data
*2 Assumed by JICA
*3 Assumed by INECEL

Table 6-5 Data of Power Station (North Zone) as of December, 2003

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.1848[*1]
Pisayambo	H	69.20	65.40	2	32.70	0.8712[*1]
Cumbayá	H	40.00	17.65	4	4.4125	5.0655[*1]
Nayón	H	29.70	14.00	2	7.00	4.1250[*1]
Pasochoa	H	4.50	2.25	2	1.125	0.4752[*1]
Los Chillos	H	1.76	0.86	2	0.430	3.498[*1]
S. Francisco	H	230.00	226.00	2	113.00	0.50[*2]
Toachi	H	150.00	128.80	2	64.40	0.50[*2]
Others (18)	H	59.59	29.24	18	1.62	5.0655[*1]
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	1.06[*1]
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	26.7036[*1]
Guangopolo (Diesel)	T	31.20	24.30	6	4.05	23.1528[*1]
S. Regionales Diesel	T	2.98	2.20	1	2.20	26.7036[*1]
S. Regionales Bunker	T	11.23	8.20	5	1.64	23.1528[*1]
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	23.3657[*3]
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	20.2587[*3]
New T. Gas (2001)	T	80.00	78.00	1	78.00	0.80[*2]
New T. Gas (2003)	T	30.00	27.00	1	27.00	0.80[*2]
Total			994.10	69		

Note: *1 20% up of 1991's data
*2 Assumed by JICA
*3 5% up of 1998's data

Table 6-6 Data of Power Station (South Zone) as of December, 2003

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.4684*1
Paute (C)	H	575.00	459.40	5	91.88	2.4684*1
Daule Peripa	H	130.00	86.00	2	43.00	0.525*1
Mazar	H	180.00	107.80	2	53.90	0.50*2
Others (6)	H	34.32	27.23	6	4.54	5.0688*1
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.6336*1
Estero Salado (Gas)	T	30.94	20.00	1	20.00	1.056*1
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	8.184*1
Guayaguil Vapor	T	33.00	31.60	1	31.60	6.732*1
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	10.626*1
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	14.1636*1
S. Regionales Diesel	T	33.84	22.80	17	1.3411	26.7036*1
S. Regionales Bunker	T	21.58	11.40	4	2.85	23.1528*1
S.R. Rehab. Diesel	T	41.895	36.80	20	1.84	20.2587*3
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	21.22*3
Electro Quil (Gas)	T	75.00	74.00	2	37.00	15.40*3
Electro Quito (Gas)	T	33.00	32.00	1	32.00	15.40*3
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.84*3
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.84*3
New T. Vapor (1995)	T	125.00	117.50	1	117.50	0.84*3
New T. Vapor (1997)	T	140.00	132.00	2	66.00	0.84*3
Total			2,013.03	82		

Note: *1 20% up of 1991's data
*2 Assumed by JICA
*3 5% up of 1998's data

Table 6-7 Data of Power Station (North Zone) as of December, 1998 (Alternative Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.154
Pisayambo	H	69.20	65.40	2	32.70	0.726
Cumbayá	H	40.00	17.65	4	4.4125	4.22125
Nayón	H	29.70	14.00	2	7.00	3.4375
Pasochoa	H	4.50	2.25	2	1.125	0.396
Los Chillos	H	1.76	0.86	2	0.430	2.915
Others (18)	H	59.59	29.24	18	1.62	4.22125
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	0.88
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	22.253
Gangopolo (Diesel)	T	31.20	24.30	6	4.05	19.294
S. Regionales Diesel	T	2.98	2.20	1	2.20	22.253
S. Regionales Bunker	T	11.23	8.20	5	1.64	19.294
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	22.253
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	19.294
New T. Vapor (1995)*	T	125.00	117.50	1	117.50	0.80
New T. Vapor (1997)*	T	140.00	132.00	1	66.00	0.80
Total			783.80	66		

Note: * Originally planned in the South Zone

Table 6-8 Data of Power Station (South Zone) as of December, 1998 (Alternative Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.057
Paute (C)	H	575.00	459.40	5	91.88	2.057
Daule Peripa	H	130.00	86.00	2	43.00	0.500
Others (6)	H	34.32	27.23	6	4.54	4.224
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.528
Estero Salado (Gas)	T	30.94	20.00	1	20.00	0.88
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	6.82
Guayaguil Vapor	T	33.00	31.60	1	31.60	5.610
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	8.855
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	11.803
S. Regionales Diesel	T	33.84	22.80	17	1.3411	22.253
S. Regionales Bunker	T	21.58	11.40	4	2.85	19.294
S.R. Rehab. Diesel	T	41.895	36.80	20	1.84	22.253
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	19.294
Electro Quil (Gas)	T	75.00	74.00	2	37.00	0.80
Electro Quito (Gas)	T	33.00	32.00	2	16.00	0.80
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.80
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.80
Total			1,655.73	78		

Table 6-9 Data of Power Station (North Zone) as of December, 2003 (Alternative Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.1848
Pisayambo	H	69.20	65.40	2	32.70	0.8712
Cumbayá	H	40.00	17.65	4	4.4125	5.0655
Nayón	H	29.70	14.00	2	7.00	4.1250
Pasochoa	H	4.50	2.25	2	1.125	0.4752
Los Chillos	H	1.76	0.86	2	0.430	3.498
S. Francisco	H	230.00	226.00	2	113.00	0.50
Toachi	H	150.00	128.80	2	64.40	0.50
Others (18)	H	59.59	29.24	18	1.62	5.0655
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	1.06
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	26.7036
Guangopolo (Diesel)	T	31.20	24.30	6	4.05	23.158
S. Regionales, Diesel	T	2.98	2.20	1	2.20	26.7036
S. Regionales, Bunker	T	11.23	8.20	5	1.64	23.1528
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	23.3657
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	20.2587
New T. Gas (2003)	T	30.00	27.00	1	27.00	0.80
New T. Vapor (1995)*	T	125.00	117.50	1	117.50	0.84
New T. Vapor (1997)*	T	140.00	132.00	2	66.00	0.84
Total			1,165.60	71		

Note: * Originally planned in the South Zone

Table 6-10 Data of Power Station (South Zone) as of December, 2003 (Alternative Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.4684
Paute (C)	H	575.00	459.40	5	91.88	2.4684
Daule Peripa	H	130.00	86.00	2	43.00	0.525
Mazar	H	180.00	107.80	2	53.90	0.50
Others (6)	H	34.32	27.23	6	4.54	5.0688
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.6336
Estero Salado (Gas)	T	30.94	20.00	1	20.00	1.056
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	8.184
Guayaguil Vapor	T	33.00	31.60	1	31.60	6.732
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	10.626
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	14.1636
S. Regionales Diesel	T	33.84	22.80	17	1.3411	26.7036
S. Regionales Bunker	T	21.58	11.40	4	2.85	23.1528
S.R. Rehab. Diesel	T	41.895	36.80	20	1.84	20.2587
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	21.220
Electro Quil (Gas)	T	75.00	74.00	2	37.00	15.40
Electro Quito (Gas)	T	33.00	32.00	2	16.00	15.40
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.84
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.84
New T. Gas (2001)*	T	80.00	78.00	1	78.00	0.80
Total			1,841.53	81		

Note: * Originally planned in the North Zone

Table 6-11 Data of Power Station (North Zone) as of December, 1998 (Recommendable Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.154
Pisayambo	H	69.20	65.40	2	32.70	0.726
Cumbayá	H	40.00	17.65	4	4.4125	4.22125
Nayón	H	29.70	14.00	2	7.00	3.4375
Pasochoa	H	4.50	2.25	2	1.125	0.396
Los Chillos	H	1.76	0.86	2	0.430	2.915
Daule Peripa*	H	130.00	86.00	2	43.00	0.500
Others (18)	H	59.59	29.24	18	1.621	4.22125
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	0.80
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	22.253
Guangopolo (Diesel)	T	31.20	24.30	6	4.05	19.294
S. Regionales Diesel	T	2.98	2.20	1	2.20	22.253
S. Regionales Bunker	T	11.23	8.20	5	1.64	22.253
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	22.253
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	19.294
New T. Vapor (1997)*	T	140.00	132.00	2	66.00	0.80
Total			752.30	67		

Note: *Originally planned in the South Zone

Table 6-12 Data of Power Station (South Zone) as of December, 1998 (Recommendable Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.057
Paute (C)	H	575.00	459.40	5	91.88	2.057
Others (6)	H	34.32	27.23	6	4.54	4.224
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.528
Estero Salado (Gas)	T	30.94	20.00	1	20.00	0.88
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	6.82
Guayaguil Vapor	T	33.00	31.60	1	31.60	5.610
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	8.855
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	11.803
S. Regionales, Diesel	T	33.84	22.80	17	1.3411	22.253
S. Regionales, Bunker	T	21.58	11.40	4	2.85	19.294
S.R. Rehab. Diesel		41.895	36.80	20	1.84	22.253
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	19.294
Electro quil (Gas)	T	75.00	74.00	2	37.00	14.00
Electro Quito (Gas)	T	33.00	32.00	2	16.00	14.00
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.80
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.80
New T. Vapor (1995)	T	125.00	117.50	1	117.50	0.80
Total			1,687.23	77		

Table 6-13 Data of Power Station (North Zone) as of December, 2003 (Recommendable Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Agoyán	H	156.00	154.90	2	78.00	0.1848
Pisayambo	H	69.20	65.40	2	32.70	0.8712
Cumbayá	H	40.00	17.65	4	4.4125	5.0655
Nayón	H	29.70	14.00	2	7.00	4.1250
Pasochoa	H	4.50	2.25	2	1.125	0.4752
Los Chillos	H	1.76	0.86	2	0.430	3.498
Daule Peripa*	H	130.00	86.00	2	43.00	0.525
S. Francisco	H	230.00	226.00	2	113.00	0.50
Toachi	H	150.00	128.80	2	64.40	0.50
Others (18)	H	59.59	29.24	18	1.62	5.0655
Esmeraldas (Vapor)	T	132.50	125.00	1	125.00	1.06
Santa Rosa (Gas)	T	51.00	45.00	3	15.00	26.7036
Guangopolo (Diesel)	T	31.20	24.30	6	4.05	23.1528
S. Regionales Diesel	T	2.98	2.20	1	2.20	26.7036
S. Regionales Bunker	T	11.23	8.20	5	1.64	23.1528
S.R. Rehab. Diesel	T	13.15	10.40	6	1.733	23.3657
S.R. Rehab. Bunker	T	41.00	33.80	9	3.756	20.2587
New T. Vapor (1997)*	T	140.00	132.00	2	66.00	0.84
New T. Gas (2001)	T	80.00	78.00	1	78.00	0.80
New T. Gas (2003)	T	30.00	27.00	1	27.00	0.80
Total			1,212.10	73		

Note: * Originally planned in the South Zone

Table 6-14 Data of Power Station (South Zone) as of December, 2003 (Recommendable Plan)

Power Station	H/T	Installed Capacity (MW)	Firm Output (MW)	Number of Unit	Unit Output (MW)	Average Rate of Forced Outage (%)
Paute (A,B)	H	500.00	438.50	5	87.70	2.4684
Paute (C)	H	575.00	495.40	5	91.88	2.4684
Mazar	H	180.00	107.80	2	53.90	0.50
Others (6)	H	34.32	27.23	6	4.54	5.0688
Estero Salado (Vapor)	T	146.00	140.00	2	70.00	0.6336
Estero Salado (Gas)	T	30.94	20.00	1	20.00	1.056
Guayaguil Vapor #2	T	20.00	19.00	2	9.50	8.184
Guayaguil Vapor	T	33.00	31.60	1	31.60	6.732
Estero Salado (EMELEC)	T	21.25	15.00	1	15.00	10.626
Estero Salado (EMELEC)	T	90.00	80.00	4	20.00	14.1636
S. Regionales Diesel	T	33.84	22.80	17	1.3411	26.7036
S. Regionales Bunker	T	21.58	11.40	4	2.85	23.1528
S.R. Rehab. Diesel	T	41.895	36.80	20	1.84	20.2587
S.R. Rehab. Bunker	T	8.176	6.00	2	3.00	21.220
Electro Quil (Gas)	T	75.00	74.00	2	37.00	15.40
Electro Quito (Gas)	T	33.00	32.00	2	16.00	15.40
New T. Gas (1993)	T	80.00	78.00	1	78.00	0.84
New T. Gas (1994)	T	80.00	78.00	1	78.00	0.84
New T. Gas (1995)	T	125.00	117.50	1	117.50	0.84
Total			1,795.03	78		

CHAPTER 7 LOAD DISPATCHING DUTIES AND PROTECTIVE RELAY SYSTEM

CONTENTS

Page

CHAPTER 7 LOAD DISPATCHING DUTIES AND PROTECTIVE RELAY SYSTEM

7.1 Load Dispatching Duty and Power System Operation 7-1

7.1.1 Current Conditions of SNI 7-2

7.1.2 Current Conditions of Load Dispatching Duties . . . 7-5

7.2 New Load Dispatching Facility and Load Dispatching Duties 7-9

7.2.1 New Load Dispatching Command Facility 7-9

7.2.2 Future Plan in Load Dispatching Facility 7-13

7.2.3 Present State and Future Plan for Communication Facility 7-17

7.2.4 Demand Projection and Power Generation Plan 7-20

7.2.5 Recovery Operations for Faults 7-21

7.3 Protective Relay Facilities 7-23

7.3.1 Current Conditions of Protective Relay Facilities . 7-23

7.3.2 Protective Relay System 7-28

List of Figures

Fig. 7-1 INECEL National Energy Control Center Central System
Fig. 7-2 Protective Relay System
Fig. 7-3 230 kV SNI Primary Protection
Fig. 7-4 230 kV SNI Secondary Protection
Fig. 7-5 230 kV SNI Secondary Protection Coordination
Fig. 7-6 138 kV SNI Protection

List of Tables

Table 7-1 Number of Faults
Table 7-2 Causes of Faults
Table 7-3 Characteristics for Protective Relay System

CHAPTER 7 LOAD DISPATCHING DUTIES AND PROTECTIVE RELAY SYSTEM

7.1 Load Dispatching Duty and Power System Operation

The load dispatching duty is the function of monitoring the power stations and substations constituting the power system, and successfully operating the power system having constantly changing conditions to realize a comprehensive and economical operation. Thus, the duty is also called as the power system operation.

The power system operation functions can be classified into the power balance operation and the power system operation. The objective of the power balance operation is to assure the sufficient power supplies to meet the power demand which changes from one moment to another, thereby maintaining a stable system frequency by balancing the demand and supply of power in the system, and operating the hydroelectric and thermal power sources in efficient and economical combination.

The objective of power system operation is to successfully transmit the power generated at power plants, to the consumption points in the power system, and to comprehensively operate the whole power system in an economical manner by controlling the transmission and substation facilities to maintain proper voltage values. For this operation, the load dispatching system must be established, and a variety of load dispatching commands and information must be transmitted and received by dedicated communication lines between the load dispatching office and power plants/substations.

In the power system operation, the protective relay systems of the major power system consisting of 230 kV lines and 138 kV lines have an important function.

In particular, the protective systems of the 230 kV system are established based on the proposition of loop operation. The transmission line fault recovery procedure is related to the power supply reliability (reduction of power supply interruption time).

7.1.1 Current Conditions of SNI

(1) Power System Configuration

The total installed capacity of the power generation facilities in SNI is 2,278.2 MW as of January, 1993 which is composed of 1,470.1 MW hydroelectric facilities and 808.1 MW thermal facilities.

SNI is composed of 230 kV, double circuit transmission lines which are formed into a ring extending for 820 km. 138 kV and 69 kV transmission systems are radially connected to this main 230 kV system.

The major power supply source of SNI is Paute Hydroelectric Power Plant (1,075 MW), which account for 47% of the total installed capacity.

The total sending end demand connected to SNI is 1,372 MW as of the end of 1992. The annual energy generation in this year was 7,002 GWh.

In 1992, the maximum power generation of Paute Hydroelectric Power Plant was 851 MW, and the annual energy generation was 3,295 GWh, which account for 62% and 47%, respectively, of the total power and energy generation of SNI.

Concerning the thermal power generation facilities, Estero Salado (73 MW x 2) and Esmeraldas (132.5 MW), the steam power plants owned by INECEL, account for a large proportion, but these plants are often shut down as cold reserves in recent days. During the dry season when the hydroelectric supply capacity falls, however, these power plants are connected to SNI as supply sources.

The gas turbine and diesel power plants are treated as emergency power supplies, but they also have the role of reactive power sources that maintain the power system voltage.

For 230 kV and 138 kV transmission lines, the power line carrier directional comparison relay systems are used. And those on 230 kV systems are capable of single phase and 3-phase reclosing. At present, however, these reclosing functions are locked out, and the 3-phase clearing system is used to cut off faulted lines.

There are 19 local power companies, including EMELEC and EEQ, which are connected to SNI.

(2) Frequency Control

The power system frequency is stabilized when the supply and demand on the power system are balanced. In Ecuador, there are few large loads that fluctuates and disturbs the balance of supply power in a short period, and relatively stable power system operation is realized by the governor-free operation of hydroelectric power plants. However, it would be desirable to install the automatic frequency control system (AFC) in future to further reduce the frequency deviation band, due to following reasons.

(a) With economic growth, it is expected that various industrial products will be manufactured domestically, and it would be desirable to reduce the fluctuation of motor speed to improve the uniformity of products.

(b) Since it is expected that electric clocks and electronic equipment will be more extensively used, it would be required to further improve the accuracy of such equipment.

(c) The power system voltage and power system stability should be further improved.

(d) The power flows on SNI should be further stabilized.

The allowable deviation band of frequency will be determined based on the above requirements and the capacity of frequency regulation. In Japan, ±0.1% is selected as an approximate target.

(3) Voltage and Reactive Power Control

The electrical equipments have their own rated voltage, and it is important to use them at rated voltage in order to maintain the equipment efficiency and prolong their lives.

For the power system, the voltage and reactive power control has important roles of realizing sound operation of equipment in the power system, in reducing the transmission loss, improving the power system stability, etc.

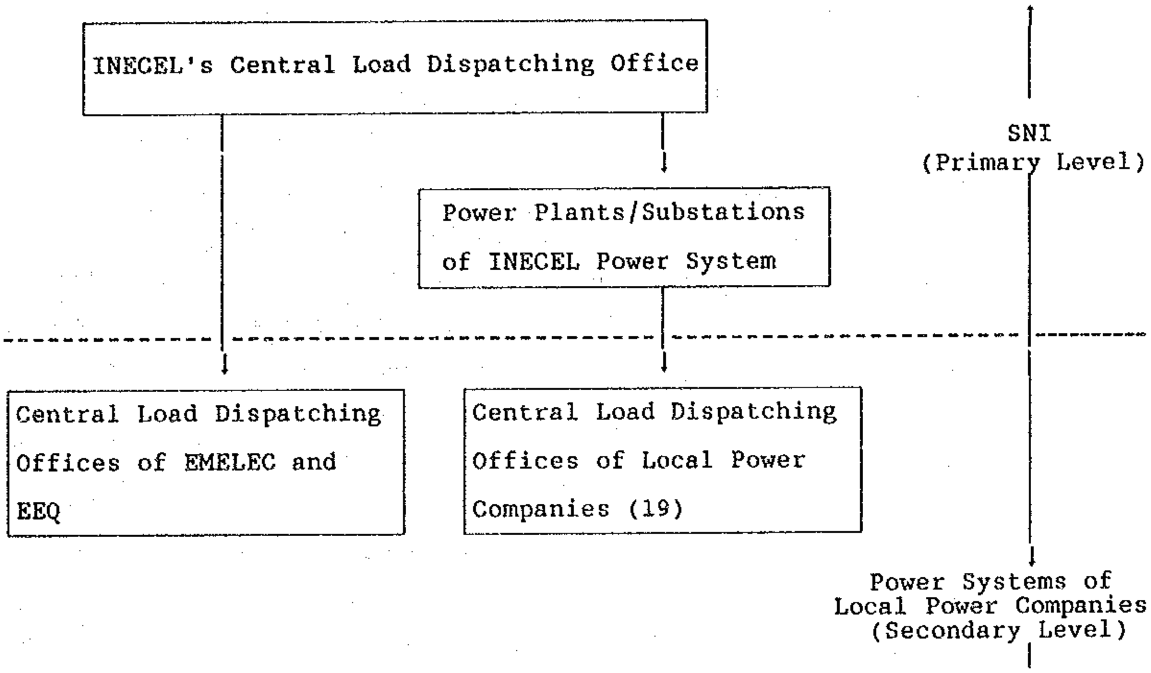
Concerning the current performance of voltage and reactive power control in SNI of Ecuador, appreciable efforts are being exercised to maintain proper voltage values by the regulation of hydroelectric power plant generators, switching of power condensers, shunt reactors and on-load tap changers of transformers in substations, and phase compensation of gas turbine generators at Santa Rosa Power Plant. However, proper voltage values are not always maintained due to biased distribution of power supply sources, the shortage of phase compensation equipment, and the difficulty of monitoring voltage values of the national interconnection system at load dispatching centers, and future improvement is desirable.

The permissible voltage deviation band in Japan is stipulated in the Electric Utility Industry Law as being 101V±6V or 202V±20V at end use terminals. It is important that the allowable band of voltage deviation is specified in Ecuador, too, to assure the high quality power supply.

7.1.2 Current Conditions of Load Dispatching Duties

In order to successfully operate a power system, the load dispatching command system must be organized to operate each electric facility in the related power systems systematically and comprehensively. For this purpose, the information concerning the accurate conditions of the whole power system must be gathered to the load dispatching office.

The load dispatching command system of current SNI, as of March 1993, is organized as illustrated below.



The Central Load Dispatching Office of INECEL directly commands the load dispatching of the electric facilities in the large load centers of Guayaquil and Quito, and the load dispatching commands for other power companies are transmitted to the load dispatching offices of local power companies via the Operating Units in INECEL's power plants and substations.

(1) Current State of Load Dispatching Facilities

The center of the load dispatching systems of INECEL, as of March 1993, is the Central Load Dispatching Office located in the premises of Santa Rosa Substation which systematically and comprehensively operates the SNI. Concerning its facility, it is equipped only with telephone channels employing power line carrier systems, and no telemetering facility or circuit breaker status information (ON and OFF of circuit breakers) is provided.

The information on power system operation is collected from each electric facility station by means of telephone conversation, which takes approximately 25 minutes per station, and the information thereby obtained is input to the personal computer of the load dispatching office by the manual operation of operators for logging and information storage.

Concerning the telephone facility which plays an important role in the load dispatching operation, the lines are not dedicated lines for load dispatching. Therefore, the telephone communication for general conversation is restricted when a first report of failure is received from an affected electric facility station. When the telephone traffic is heavy, or telephone communication is impossible, the report of failure may be delayed, and thereby impede the load dispatching commands for fault recovery operation.

(2) Monitoring Duties at Load Dispatching Office

The load dispatching command system may function smoothly and effectively with a proper load dispatching system which matches the actual status of the power system. For this Load Dispatching System, adequate facility is not provided as mentioned above, and a part of the monitoring duties and reactive power control functions, which should be performed by the load dispatching office are entrusted to electric facility stations. Therefore, there are risks that prompt response can not be realized in the events of abnormal meteorological conditions or power system failures.

The duties of load dispatching office is to operate the whole power system in a comprehensive and economical manner, and the importance of these duties increases with the development of the national economy and the progress of electrification rate.

(3) Load Fluctuation and Its Prediction

Generally speaking, the load fluctuates by seasons, by the day in a week, and during a day in periodic manners. Such fluctuations may be caused by the meteorological conditions that affect heating and air conditioning load, and social conditions such as television broadcast of sports events including soccer matches. At present, the factors causing load seasonal and daily fluctuations in Ecuador is small, because the air temperature change is little throughout a year, and there is no large power demand from industrial plants. Therefore, the actual records of load fluctuation more or less coincide with load projections, and accurate load projections can be made in a short term.

INECEL hears the requests of power reception from local power companies which are connected to SNI to formulate the power generation plan of the next day, and INECEL balances its supply power with demand by monitoring the receiving power of each local power company.

(4) Fault Recovery Operation

INECEL defines the following three types of faults as the most important faults in view of their effect on the total power system.

(a) Fault of generator unit at Paute Hydroelectric Plant
(b) Fault on 230 kV, main transmission lines
(c) Fault at interconnection points with EMELEC and EEQ which supply the two large load centers of Guayaquil City and Quito City

The total installed capacity of Paute Hydroelectric Power Plant is now 1,075 MW with the completion of Phase-C. However, a generator unit fault or transmission line fault occurring near Paute Hydroelectric Power Plant could collapse the whole power system, because the Paute Plant is a large, concentrated power supply source in the 230 kV power system.

Therefore, it is planned to shed the loads in 7 steps by means of frequency relays, in order to prevent the collapse of the whole power system. (See Section 5.4.1.)

The basic concept and the procedure of power system fault recovery are as presented below.

(a) When power systems are separated, the systems in which the voltage survived are controlled for voltage regulation.

(b) For the system which experiences a total blackout, the circuit breakers at interconnection point with SNI are opened, and the power generating facilities in that power system are started to recover the system operation.

(c) For the Southern Power System, which center is EMELEC Power System, the power generation facilities of EMELEC and the Estero Salado (73 MW x 2) unit steam power plant of INECEL are use to recover the power system again.

(d) For Northern Power system, which center is EEQ, the power generation facilities of EEQ, Pisayambo Hydroelectric Power Plant (34.6 MW x 2) and Agoyan Hydroelectric Power Plant (78 MW x 2) are mainly used to recover the power systems other than the 230 kV system.

(e) To recover the 230 kV power system, one transmission line leading from Paute Hydroelectric Power Plant (C) to the Southern Power System is charged. After the interconnection with the Southern Power System is restored, the line up to Santa Rosa Substation is charged to recover the Northern Power System.

The synchronization of the Southern Power System to the Northern Power System is done at Santa Rosa Substation.

(f) After the establishment of interconnection between the Southern Power System and the Northern Power System via 230 kV interconnection line is confirmed, the remaining power systems are recovered one by one.

(g) Finally, the second 230 kV line is charged from Paute Hydroelectric Power Plant, to restore the normal power system configuration.

7.2 New Load Dispatching Facility and Load Dispatching Duties

The load dispatching command system forms a hierarchical system with the Central Load Dispatching Office presiding on the top. The load dispatching offices at each hierarchy must promptly and successfully perform its functions according to its level by maintaining close contact with one another for the comprehensive operation of the power system.

Therefore, the introduction of high-speed and accurate information transmission system and the electronic computing system, designed to automatically process various information, is indispensable.

7.2.1 New Load Dispatching Command Facility

It is desirable to design the new load dispatching command system by taking into account the following factors.

(a) The high-speed, bulk information transmission system, designed to accurately and promptly grasping the monitored power system conditions, to enhance the power system monitoring functions.

(b) Introduction of a computer system having sufficient processing capacity to absorb the load dispatching operations that increase in volume and complexity with the expansion of power system, and to automate the routine procedures.

(c) The computer system having the simulation function for enhancement of skill and expertise of operators.

Fig. 7-1 shows the new load dispatching command system.

(1) Functions of New Load Dispatching Command Facility

It is desirable that the computer system of the new Central Load Dispatching Office has the following functions.

(a) Monitoring Duties

1) Demand/Supply Balance Monitoring

The power system frequency, the interconnection line kW and kWh deviation (the difference from projected value), and the marginal regulating capacity of power plant are automatically monitored, and alarms are actuated when these values exceed the monitoring target values, in order to assure the balance between demand and supply, to maintain the rated frequency and the rated time difference, and to economically distribute power output among power plants.

2) Voltage Monitoring

The bus voltage and reactive power flow at power plants and substations of SNI, and the marginal regulation capacity of voltage and reactive power, are constantly monitored in order to maintain the rated voltage values, and to appropriately distribute the reactive power.

3) Reliability Monitoring

In order to facilitate appropriate responsive actions to deal with the changes in the power system conditions that might lead to a power system accident, and prompt and suitable recovery operations, the target values of the power flows in SNI, the reserve capacity in the power system blocks as well as the whole power system, the changes in circuit breaker status, the power system frequency, and the abnormal changes of the interconnection line power flow are monitored, to detect occurrence of faults.

(b) Planning Duties

Accurate load forecasting system is established based on the data of domestic economic activities and meteorological conditions, and the economical operation plans of hydroelectric and thermal power plants are computed and formulated.

(c) Logging and Statistics Duties

The load dispatching data collected by on-line data transmission systems are edited to defined format, tabled, and printed.

(d) Education and Training of Operators

If a duplex computer system (2 computer systems are operated with one system functioning as the on-line machine and another as a stand-by system) is adopted, the stand-by system can be used as a simulator for education and training of operators by supplying the simulated power system data representing the fault recovery process or situations leading to a power system accident.

(2) Information Transmission System

The information transmission system which is being planned for the new load dispatching system of INECEL consists of data logging terminal units which are installed at "daughter stations" of power plants and substations, and these units are connected to the computer system of the Central Load Dispatching Office via modems (modulators and demodulators). In this system, the cyclic data transmission and interrupting data transmission can be used together. Since too much load will be placed on the equipment to hamper other functions of the system if a short cyclic time interval is used in the cyclic transmission (the cycles will be increased), the transmission cycle is restricted and the channels can not be used for telemetering transmission of continuous variables such as power system frequency. Therefore, the power system operation variables, such as power system frequency, interconnection line power flow, power system voltage, must be recorded on recording indicators in daughter stations. In order to realize a more sophisticated computer monitoring system, more advanced information transmission system which is capable of transmitting continuous variables, such as CDT (cyclic digital transmitter), must be adopted.

(3) Dedicated Telephone System for Load Dispatching Operation

The load dispatching operation is a commanding duty to organize the operations of the power system which conditions change from one moment to another, and it is imperative that commands and communications are transmitted under all circumstances. Under abnormal meteorological conditions and emergency conditions created by power system accidents, the load dispatching commands are issued most frequently, thereby creating a heavy telephone traffic. Under such circumstances, interruption or delay of telephone communication could reduce the power supply reliability. For this reason, it is indispensable to install dedicated telephone systems from the Central Load Dispatching Office to the power plants and substations as well as local load dispatching offices, to where the load dispatching commands are directed.

7.2.2 Future Plan in Load Dispatching Facility

(1) Load dispatching facility

Generally, the load dispatching facility consists of the following equipment items:

- Load dispatching panel or monitoring panel
  A panel installed in the load dispatching office, for monitoring the state of the power system, indicating the connection state of the power system, the supply demand state, the weather conditions, etc.

- Load dispatching instruction console
  A console equipped with equipment items needed for sending load dispatching instructions and for monitoring the system, such as telephones to various sites, CRT displays and control switches.

- Automatic load dispatching system
  General term for those systems which, using computers, etc., automatically execute and process load dispatching tasks.

- Load frequency control device
  A device for automatically regulating the output power of the frequency regulation power station, for the purpose of regulating the frequency of the power system

- Telemeter
  A device for transmitting the electric power, voltage, dam water level and other measured values to a remote location, after their conversion into electric signals, over a communication line, for display or recording by the receiving device

- Supervision unit
  A unit for transmitting binary data such as the open-close

state of a switch to a remote location over a transmission line for display by the receiver unit, normally incorporated in the load dispatching panel

- Cyclic digital data transmission device (CDT device)
  A device for digitalizing numbers of data produced by a power station or other system and cyclically transmitting them, after arraying them into a predetermined sequence.

- Remote monitoring control device
  A device for monitoring and controlling the power station, substation or switching station from a remote location over a transmission line

- Power system training simulator
  A device for training power system operators by means of a computer-simulated electric power system or the like

- CRT display
  A computer input/output device consisting of a cathode-ray tube for displaying the computer output data or for inputting data to the computer

- Other devices
  Facsimile units, meteorological observation system, etc.
  These devices were examined one by one, in connection with their use in the new load dispatching office automatic power dispatching system (Fig.7-1) scheduled for operation start within 1994, with the requirements for effective operation of the future greatly expanding and sophisticating power dispatching facility well taken into consideration.

(a) Load dispatching panel (incl. telemeter, supervision unit, etc.)

The load dispatching panel is installed for the purpose of macroscopically monitoring the power system conditions, and is configured to be capable of manually executing the required minimum power supply control operation through the use of its monitoring function, even when the control computer fails. For enabling this, the monitored data transmitted by the data transmission device must be branched to the load dispatching panel, in addition to the computer, but such branching is hardly realizable with the communication system (MODEM system) to be started this time, and the result is a low dependability in power dispatching operation. To overcome this shortcoming, therefore, the adoption of a different data transmission system and a more sophisticated load dispatching panel incorporating telemeters and supervision units in the future plan is advisable.

(b) Load dispatching instruction console

The load dispatching instruction console should be provided at least with an exclusive load dispatching single-stroke-actuation type telephone directly connected to the load dispatching office, to the power station and to the substation for prompt action in accidents and other emergency cases in order to secure higher power system operation reliability. For this, however, securing the needed communication line from the current communication system in Ecuador is difficult, as will be described in 7-2-3.

(c) Load frequency control device

With conventional electric power system, a load frequency control device for the entire power system is installed in the central load dispatching office, and when the power system is disintegrated by accidents or the like, the isolated power station regulates the frequency with its own load frequency control device or does it in the governor-free mode.

With SNI, also, the maintenance of the total system frequency at a proper level and the improvement of time difference should be achieved by the load frequency regulation function of the computer in the central load dispatching office, but the data transmission system of the present automatic load dispatching system is not fully capable of transmitting cyclic control signal in the units of several seconds.

(d) Cyclic digital data transmission (CDT) device

Although not adopted in the current automatic power dispatching system, when a CDT system is to be used for load frequency control in a future load dispatching panel in the central load dispatching office, the adoption of a new communication system becomes indispensable.

(e) Power system training simulator

This system is effective in improving the technical capability of power dispatching operators, and the training with it should be repeated at a regular interval.

The automatic power dispatching system adopted in Ecuador this time is expected to pose some inconvenience for the power dispatching operators because of the lack of high-speed large volume transmission of power dispatching data resulting from the limited number of communication lines and the restricted capability of the communication system. In view of the unavoidable demand for high speed large volume communication to be required by the future great expansion and sophistication of the power system, early adoption of a new data communication system based on the firm commitment to communication lines and communication system improvement is desirable.

In addition, the computer-based automatic power dispatching system is usually required to be upgraded including the replacement of the computer and the peripheral units once in every 10 to 15 years for efficient operation, in order to cope with the degrading process capability, facility superannuation and depreciation, in the face of the expected enormous size growth and sophistication of the power dispatching system.

7.2.3 Present State and Future Plan for Communication Facility

The present electric power system maintenance communication facility of INECEL is limited to the power line carrier (PLC). Without any wireless system such as microwave systems, various key operations such as high speed ever-ready communication data transmission line and the in-house telephone lines interconnecting the planning branch and the maintenance branch in the INECEL Headquarters, are not available.

An exclusive communication system for electric power operation is indispensable for stable and economical operation of increasingly huge and complicated electric power system, and with the rapid increase of data converging to the central power dispatch office, the adoption of microwave carrier system for the protection relay system for securing high system reliability is thought to become indispensable in the future.

In addition, for a satisfactory power operation communication facility, the following requirements must be satisfied:

(a) Securing data transmission lines

For each power station sub-station, for monitoring and controlling, the communication system and lines for high-speed large volume ever-ready transmission are required.

(b) Securing telephone line

- Power dispatch instruction telephone line
  To each power dispatching office, power station and substation comprising a power dispatching instruction system, exclusive telephone lines are to be connected.

- Maintenance telephone line
  A dial type in-house telephone network connecting the headquarters with the maintenance organization and connecting among the maintenance organizations is needed for close communication and efficient operation

- Maintenance mobile communication lines
  A mobile communication network for the communication with the patrol units for transmission line maintenance and for river control should be installed.

- Other communication lines
  A paging network within the premises of power stations and substations and for communication with patrol members at unattended electric facility stations is to be installed.

(c) Securing system protection lines

Number of channels corresponding to the type of transmission line protection system and to the number of transmission line are to be secured.

(d) Securing communication power supply

An exclusive power supply for the communication systems for emergency use during power failure resulting from damage at electric facility stations are to be installed.

(1) Types of communication systems

(a) Power line carrier (PLC) system

Because the power transmission line as utilized as the communication line is not subject to wind and flood, and because the transmission line always passes through the power station, substations and switching stations, the PLC system is effective for communication between the power station, substations and the switching stations, but it is not usable for communication with the headquarters building, etc. where no transmission line is passing. The limited number of circuits, up to 12 or so, is also a problem with this system.

(b) Carrier transmission line system, communication cable system

Exclusive communications lines may be installed overhead or underground. They are subject to electromagnetic induction and noise, and are vulnerable to disaster when installed on the road-side electric poles, but their installation cost is low.

They are frequently adopted for short distance communications.

(c) Microwave wireless communication system

Its merits are high reliability, installation possibility across mountains and sea where wires cannot be installed, the large number of channels, 60 to 960 channels with the analog system, and the long distance, up to 50 km, transmission without relaying.

On the other hand, its installation cost is higher than other systems, but because of the large channel capacities, the cost per channel is lower.

(d) Optical fiber communication system

With its exclusive merits of non-induction, low loss and wide transmission band width, the optical fiber communication is advantageous for high reliability and large volume communication. In the area of power industry, the optical fiber combination areal and underground lines consisting of optical fiber cables built in the core of the areal or underground transmission lines are in the process of commercial application, promising to become the main high-speed, high reliability communication system in the future.

(2) Communication systems recommended for future plan

In Ecuador, where high Andes range is running longitudinally through the country, and main power source regions in the Amazon upstream area in the east is very far from the large power consumption region. Therefore the microwave wireless communication system capable of long distance communication across steep mountain areas is recommended for parallel use with the existing PLC system.

7.2.4 Demand Projection and Power Generation Plan

The short-term demand projection is developed for the next one day, and this is generally established by the following procedures.

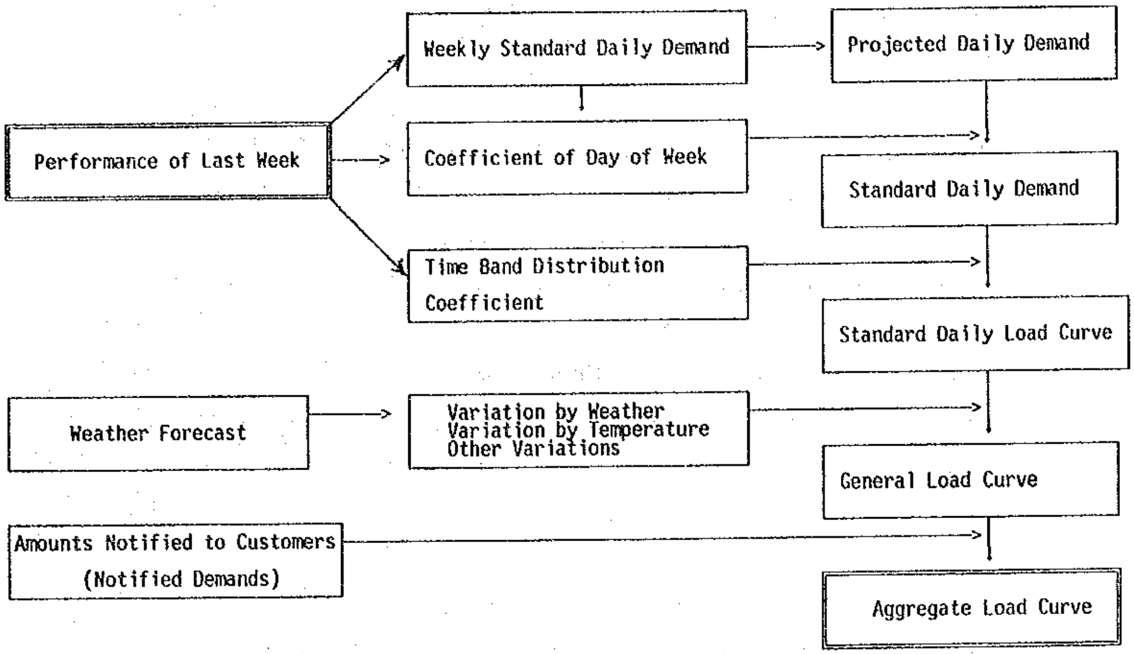
<1> Annual demand plan (power supply plan for the fiscal year)
<2> Demand plan for the next half year (review of annual demand plan)
<3> Monthly demand projection
<4> Weekly demand projection
<5> Demand projection of the next day

The annual demand plan is important in formulating the major schedules of the year such as the annual shutdown schedule, reservoir operation schedule and thermal power plant fuel supply schedule. The demand projection for the next half year is established by reviewing the economic trend, demand performance and meteorological performance in the preceding half year.

The annual demand projection and the weekly demand projection are practical schedules which are developed, generally based on the annual shutdown schedule, reservoir operation schedule and fuel supply schedule derived from the annual demand plan, and by taking into account the performance in the previous month and the month before. The demand projection of the next one day is derived from these monthly and weekly projections, and the power generation schedule of the next day is determined.

The procedure of the development of the demand projection of the next one day is illustrated in the chart below. The demand variation due to meteorological conditions is an important factor in formulating the projection of the next day, and keen attention must be paid on the weather forecast.

(Example of Projection of Next One Day)



7.2.5 Recovery Operations for Faults

Even after the new load dispatching command system is introduced and various load dispatching information is processed on-line, the fundamental strategy of fault recovery will not be altered from the current practice. However, it is required to fully utilize the automatic monitoring functions of the new system. When monitoring alarms are actuated, the line power flows and system voltages must be regulated to prevent system failures before they occur. And it is required to preserve a suitable size of spinning reserve capacity at large supply sources such as Esmeraldas Thermal Power Plant and Estero Salado Thermal Power Plant, in order to prevent supply interruption and cascading system fault which may be caused by faults on the transmission lines from major power supply sources.

In principle, it is attempted to restore the power system conditions before the occurrence of a fault by spontaneous actions (actions taken by the responsibility of electric facility stations without waiting for the command of the Central Load Dispatching Office). The scope of actions to be taken by electric facility stations must be defined beforehand to realize prompt recovery action in power system faults.

The following operations may be entrusted to electric facility stations.

(1) Opening of the line circuit breaker when the other end of the line is opened (to the no-load, line charging status).

(2) The first attempt to close the line circuit breaker which is opened by the transmission line fault (with unsuccessful reclosing operation). (When the re-charging operation fails, this shall be reported to the Central Load Dispatching Office immediately, and the load dispatching command must be waited for the subsequent actions.)

At the receiving end, the line circuit breaker is closed after confirming the presence of normal line voltage.

(3) The opening operation of line circuit breakers which remained closed when a total blackout occurred.

(4) Emergency operations for prevention of propagation of a fault.

7.3 Protective Relay Facilities

7.3.1 Current Conditions of Protective Relay Facilities

(1) 230 kV Transmission Systems

The protective relay facilities of 230 kV transmission systems are installed at both ends of transmission lines connected to power plants and substations. They consist of a total of 30 terminal equipments for 7 transmission line sections, which consist of 6, parallel double circuit lines (24 terminals) and 1 π section (6 terminals).

The protective relay systems are the directional comparison systems employing power line carriers, equipped with automatic reclosing performance.

The manufacturers of protective relay systems are GEC (supplying 26 sets), ABB (2 sets), and GE (2 sets).

Among these terminal sets, the manufacturers of corresponding line terminals are different for the line section between Totoras-Paute and the π section connecting Riobamba Substation; which are GEC for Totoras vs. ABB for Paute, and GEC for Totoras and GE for Riobamba, and GE for Riobamba and ABB for Paute.

(2) 138 kV Transmission Systems

The protective relay facilities of 138 kV transmission systems are installed at the terminals of transmission line sections connecting power plants and substations, which consist of 32 terminals for 8 sections of parallel double circuit lines, and 20 terminals for 10 sections of single circuit lines. Of these 20 line sections, 3 sections (4 terminals) are not equipped with protective relay facility or unknown, and the total number of the protective relay facilities are 48 terminals.

The 3 sections having no protective relay facilities are Milagro

- Babahoyo (no facility at Babahoyo terminal), Pascuales - Posorja (no facility at Posorja), and S. Rosa - Selva Alegre (no facility at Selva Alegre), or, a total of 4 terminals lack for the protective relay facility.

For the protective relay facilities, the distance relay systems are mainly used, with some directional comparison system and over current systems.

The manufacturers of protective relay systems are: GEC (14 sets), GE (18 sets) and Mitsubishi (16 sets).

The manufacturers are different at corresponding terminals in 5 sections of parallel double circuit lines (including the lack of protection at one terminal), and 3 sections of single circuit lines, as listed below.

Parallel double circuit sections (5 sections):

<1> Pascuales (GE) - Salitral (Mitsubishi)
<2> Pascuales (GE) - Policentro (GEC)
<3> Quevedo (Mitsubishi) - Portoviejo (GEC)
<4> S. Rosa (Mitsubishi) - Selva Alegre (unknown)
<5> Totoras (Mitsubishi) - Agoyan (GEC)

Single circuit sections (3 sections):

<1> Pascuales (Mitsubishi) - Posorja (none)
<2> S. Rosa (Mitsubishi) - Vicentina (GE)
<3> Ambato (GE) - Totoras (GEC)

(3) Fault Statistics of SNI Power System

(a) Past Trend of System Faults

The numbers of fault occurrences, according to the fault statistics of SNI Power System are presented in Table 7-1.

The numbers of faults have increased from 119 in 1991 to 175 in 1992 (an increase of 47% from the previous year). The numbers of faults leading to load interruption have also increased from 77 in 1991 to 87 in 1992 (an 12% increase over the previous year).

The specific circumstances and causes of these power system faults are classified into 14 categories as presented in Table 7-2.

That is:

<1> Due to protective relays.
<2> Due to control systems.
<3> Due to protective relay setting.
<4> Due to main protection.
<5> Due to mechanical troubles.
<6> Due to vegetation under conductors.
<7> Due to insulation clearance.
<8> Due to meteorological conditions.
<9> Due to drought.
<10> Due to power swing.
<11> Due to sabotage.
<12> Due to human errors.
<13> Due to other causes.
<14> No reporting.

The tendencies in these faults are discussed below.

(b) Number of Transmission Line Faults among System Faults

The numbers of transmission line faults among the system faults of SNI have increased from 15 in 1991 to 35 in 1992 in the 230 kV systems (an increase of 133% over the previous year), and from 47 in 1991 to 59 in 1992 in the 138 kV system (an increase of 25% over the previous year).

The proportion of transmission line faults among the total system faults was 62 faults among 119 faults, or 52% of the total in 1991, and 94 faults among 175 faults, or 53.71% in 1992. The proportion of transmission line faults in the total system faults is large.

(c) Number of Faults Related to Protective Relay Systems

Among transmission line faults, those related to protective relay facilities, corresponding to Items <1> through <4> of the 14 items listed above, was 0 fault on 230 kV lines, and only 1 fault on 138 kV lines, which is under Item <3>, "Due to protective relay setting".

In 1992, 0 fault occurred on 230 kV lines, and 8 faults on 138 kV lines. 6 of these 8 faults occurred in the same line section (Sto. Domingo - Esmeraldas) "due to protective relays" (Item <1>). The remaining 2 faults were "due to main protection" (Item <4>), which also occurred in the same line section (Pascuales - Policentro).

(d) Considerations Based on Power System Fault Statistics

(i) Clarification of Power System Fault Phenomenal

Looking at the current power system fault statistics, there is no statistical records on the power system faults, although only the fault causes are classified and made into statistical data.

Because of this nature, it is important to utilize such recording instruments as the power system automatic recorders (OSC) which can record the voltage/current values and the operations of protective relay elements before and during the faults, so that the power system fault phenomena can be clarified.

By clarifying the power system fault phenomena, it becomes possible to utilize the fault statistics for evaluation of protective relay system and for prevention of faults on power facilities.

(ii) Prevention of Faults Caused by Protective Relay Systems

The number of faults related to the protective relay systems in the power system faults of SNI is small, as discussed in Paragraph (C) above. Concerning the fault causes, however, it is observed that faults caused by "protective relays" and "main protections" recur in the same line section.

Although the details of fault causes are not known, faults due to malfunction of protective relay systems occur repeatedly. Therefore, it is required to survey the type, characteristics, location of faults and faults conditions of the protective relays and to take actions for prevention of recurrence of similar failures.

(iii) Maintenance and Supervision of Protective Relay Systems

The protective relay systems are installed with the objective of removing faults from power systems, maintaining the stability of power system, etc. If the functions of the protective relay systems can not be maintained due to the malfunction of the systems or inadequacy of protective relay setting in operation, the effect of such shortcoming on the power system is grave.

For this reason, it is important to clarify the operating conditions of protective relay systems by daily patrols, periodical operational tests and sequence tests of protective relay systems, and to exercise efforts in the maintenance and supervision of protective relay systems, so that the power system faults due to malfunction of protective relay systems can be prevented.

7.3.2 Protective Relay System

(1) Circuit Configuration of Protective Relay System

The configuration of the protective relay system is presented in Fig. 7-2.

(a) In the 230 kV transmission systems, the main protection and back-up protection, including their instrument transformers, are made of independent circuits. (However, the current transformer (CT) circuits of some main protection systems are connected to the line side of circuit breakers, thereby forming the "blind spot" of protection.)

(b) In the 138 kV transmission systems, the protective relay systems are basically divided into two types, with one type having circuit condition similar to Item (a) above, and another consisting of the main protection only.

(2) Protective Relay System

(a) In the 230 kV transmission systems, the directional comparison system is used for the main protection, and the distance relay system is used for the back-up protection.

The signal transmission system of the main protection is the power line carrier system, with the signal constantly transmitted under normal conditions and its frequency shifted in faulty conditions.

The automatic reclosing systems have the high-speed automatic reclosing system (with deenergized time of 1 second or less), capable of single phase and three phase automatic reclosing performance.

(b) In the 138 kV transmission systems, the distance relays are mostly used. In some cases , the directional comparison system or the over-current relay system is used.

(3) Protective Relay Setting

Concerning the protective relay setting, diagrams of the relations between main protections and back-up protections and the diagrams of operation time coordination based on the protective relay setting tables supplied by INECEL are formulated, to study whether

<1> the relays operate by the load impedances, and

<2> the operation time coordinations are maintained between adjacent line sections.

The load impedance values were calculated from the power transmission capacity values as given in Table.

Conductor Specification	Capacity (P)	Voltage (V)	Load Impedance (ZL)	Note
1,113 MCM	448 MVA	230 KV	106 Ω <±30	$ZL = \frac{(V\ [kV])^2 \times 0.9}{P\ [MVA]}$
477 MCM	158 MVA	138 KV	108 Ω <±30	
397.5 MCM	141 MVA	138 KV	122 Ω <±30	

The result of this study are as follows;

(a) 230 kV System

The protective relay setting values of the 230 kV System is given in Fig. 7-3 and Fig. 7-4

The operation time coordination diagram of back-up protections is given in Fig. 7-5.

1) Concerning the setting of the main protection relays and backup protection relays, there is no line section where the relays are miss-operated by the load impedance.

2) Based on the examination of the time setting coordination of backup relays between adjacent line sections, there are line sections where the time setting of the 3rd stage conflicts with the 2nd stage reach of the adjacent section.

(b) 138 kV System

The protective relay setting valves and operation time coordination diagram are is given in Fig. 7-6(1/9~9/9).

In the study of the setting of protective relays, only the setting at the opposed terminals was studied for the three line sections which have no protective relay systems or unknown, in both ends (described in 7.3.1 (2)).

Based on study of the protective relay setting, the following setting reviews are recommended.

1) At Cuenca terminal of Cuenca-Loja section, the 1st stage reaches and the 2nd stage reaches of the short circuit/ground relays have the same value. Therefore, the protection reach should be set at a zone that provides a backup protection for the protection or transformer protection at Loja terminal, and the setting of the 2nd stage should be set at around 120% - 150% for both short circuit and grounding relays.

2) At Pascuales terminal of Pascuales-Sta. Elena section, the difference between the 1st stage setting and the 2nd stage setting of the short circuit/ground relays is little. Therefore, the protection reach

should be set to a zone that provides a backup protection for bus protection or transformer protection at Sta. Elena terminal, and the setting of the 2nd stage should be set at around 120% - 150% for both short circuit and grounding relays.

(4) Considerations on Protective Relay Systems

In the power systems of SNI, the protective relay systems are selected in reference to the status of power systems, voltage classes of transmission line and the power system to which the protective relays are applied. That is, the protective system is directional comparison system in the 230 kV systems, and distance relay system or overcurrent relay system in 138 kV systems.

The general features of these protective relay systems are illustrated in Table. 7-3.

Each protective relay system has its own advantages and disadvantages. In the directional comparison system, it is difficult to apply the automatic multiple phase reclosing system because the faulted phase can not be identified in a multiple fault, and the detection of feeble grounding fault is also difficult. With the overcurrent relay system, there is the problem with the operation time coordination when both terminals have power sources, because the relay does not have directional sensitivity.

In future, when the protective relay systems are to be replaced because of aging or needs of power system, the above problems must be considered.

As other examples of protective relay systems, there are such relay systems as the individual phase comparison system and current differential system, which are adopted in 275 kV and 500 kV systems. However, in order to adopt these systems, the transmission capacity of information which can be carried by the existing power line carrier system is not sufficient, and a high speed and large capacity signal transmission systems, such as microwave communication facilities are required.

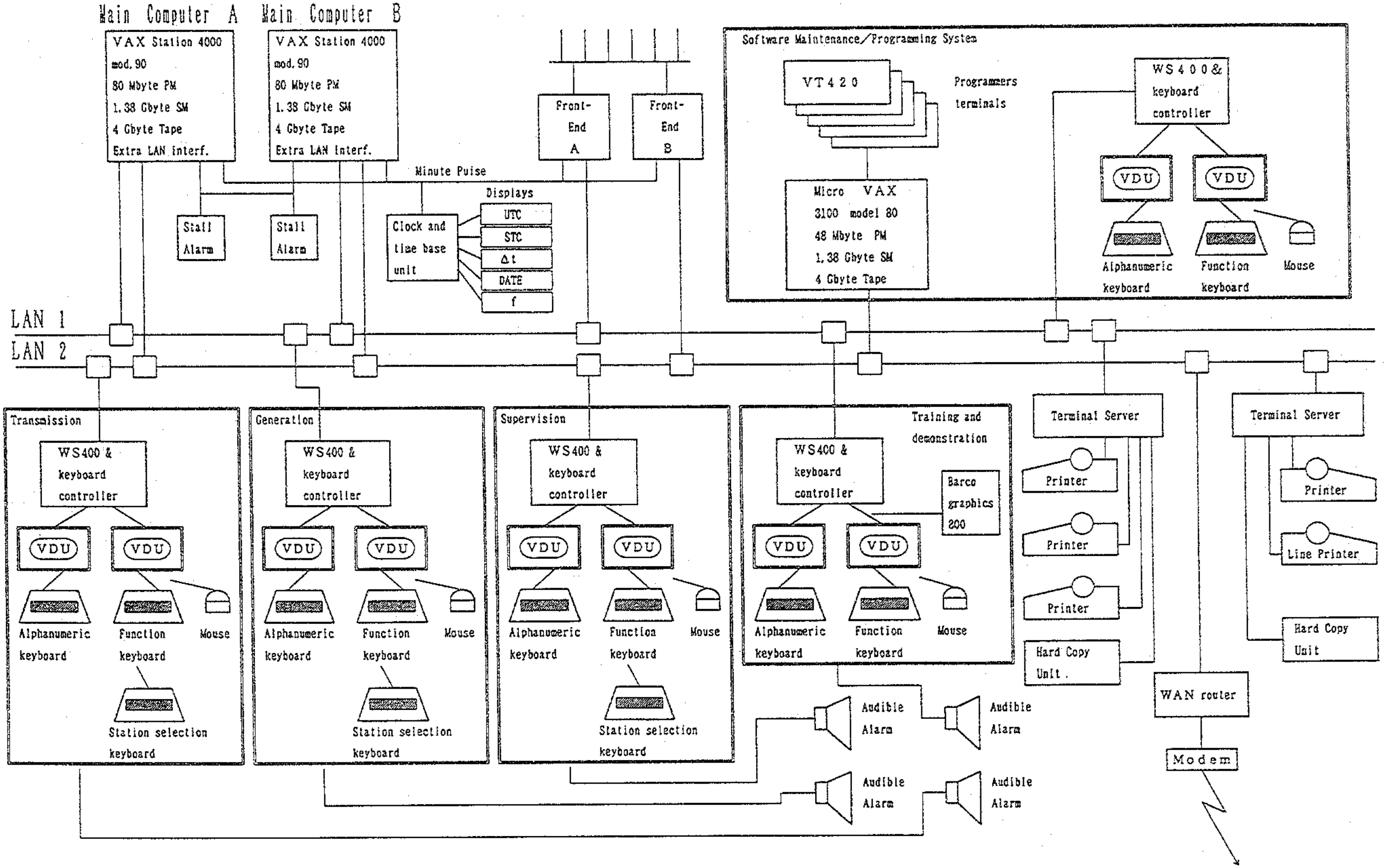
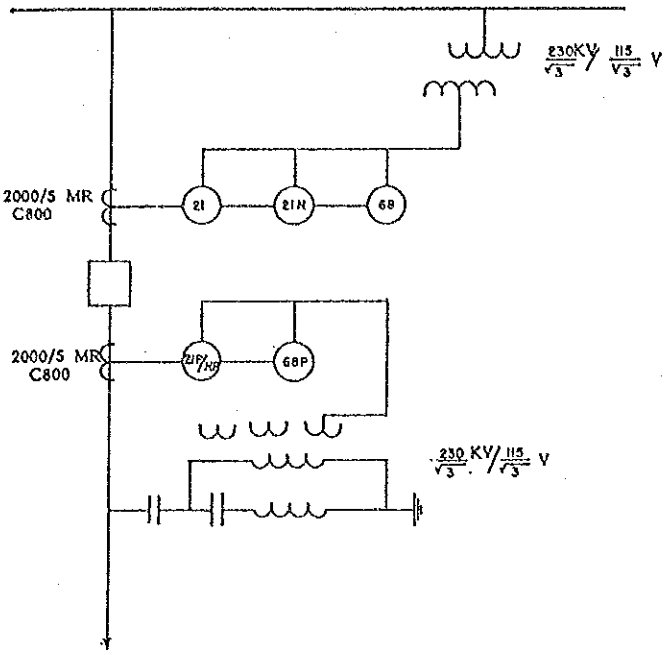


Fig 7-1 INECEL National Energy Control Center Central System

230 KV LINE PROTECTION



138 KV LINE PROTECTION

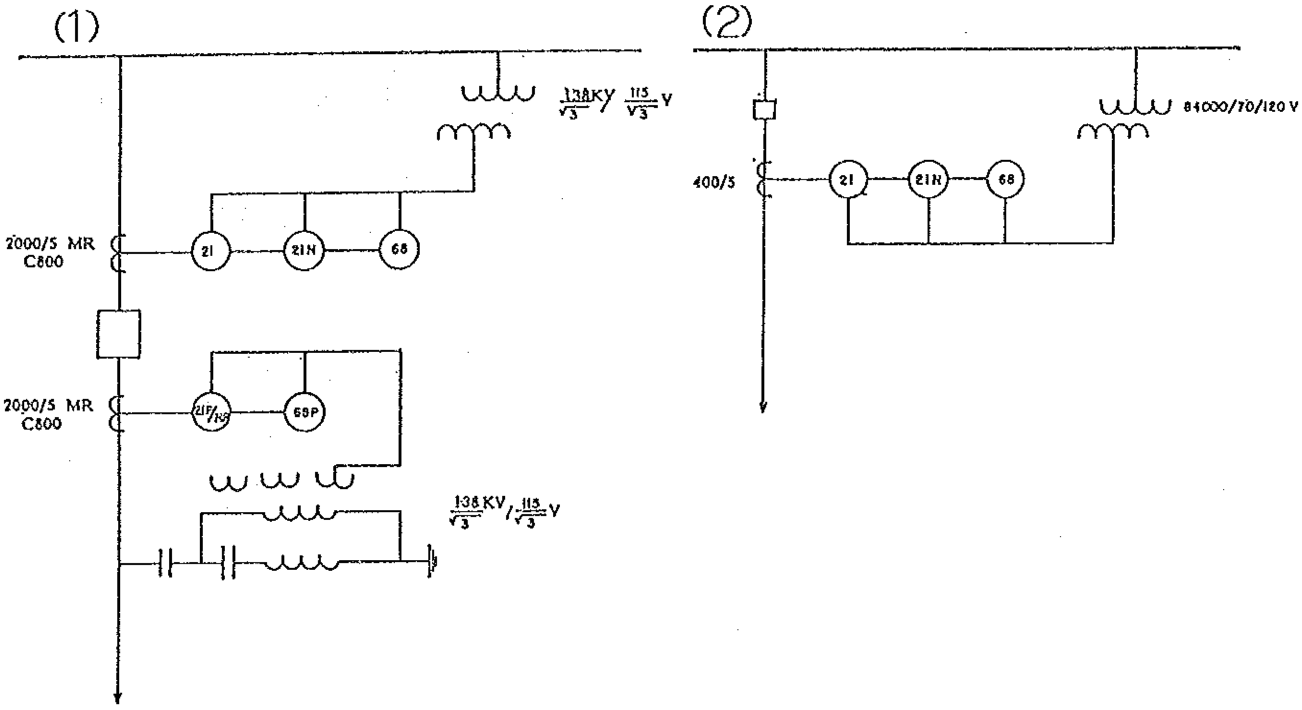


Fig. 7-2 Protective Relay System

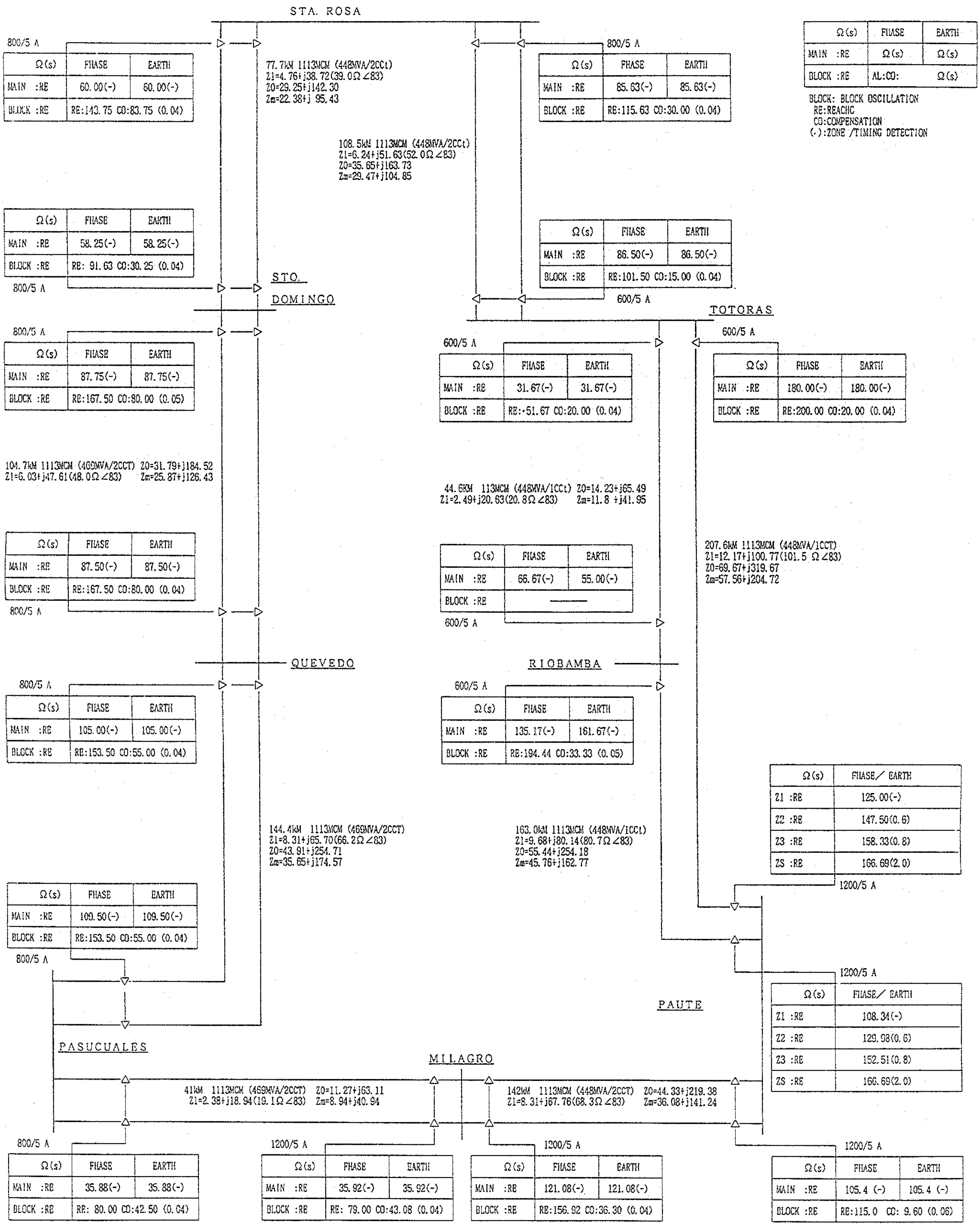
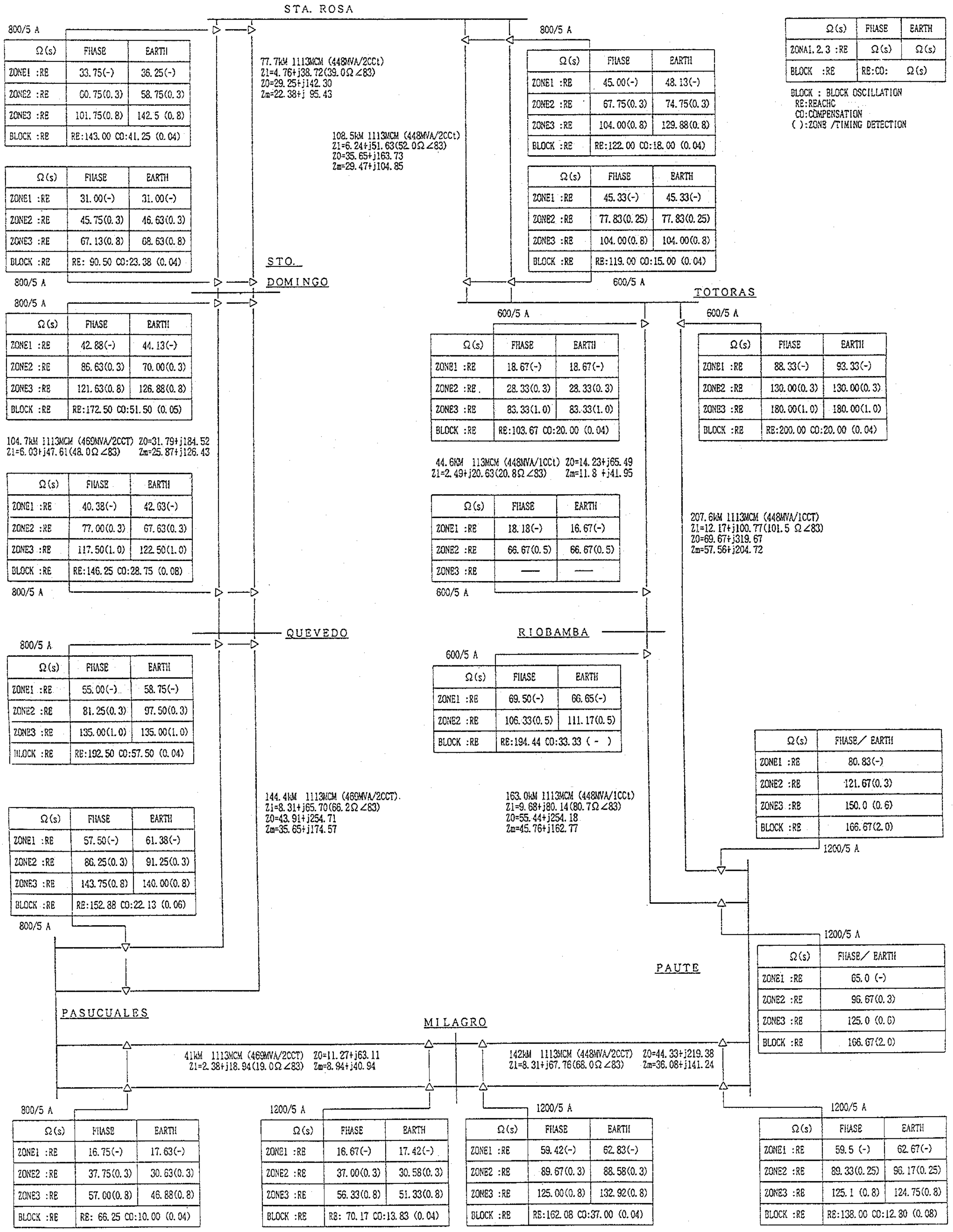


Fig. 7-3 230kV SNI Primary Protection



Ω(s)	FHASE	EARTH
ZONA1.2.3 :RE	Ω(s)	Ω(s)
BLOCK :RE	RE:CO: Ω(s)	

BLOCK : BLOCK OSCILLATION
RE:REACHC
CO:COMPENSATION
( ):ZONE /TIMING DETECTION

800/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	33.75(-)	36.25(-)
ZONE2 :RE	60.75(0.3)	58.75(0.3)
ZONE3 :RE	101.75(0.8)	142.5 (0.8)
BLOCK :RE	RE:143.00 CO:41.25 (0.04)	

Ω(s)	FHASE	EARTH
ZONE1 :RE	31.00(-)	31.00(-)
ZONE2 :RE	45.75(0.3)	46.63(0.3)
ZONE3 :RE	67.13(0.8)	68.63(0.8)
BLOCK :RE	RE: 90.50 CO:23.38 (0.04)	

800/5 A

800/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	45.00(-)	48.13(-)
ZONE2 :RE	67.75(0.3)	74.75(0.3)
ZONE3 :RE	104.00(0.8)	129.88(0.8)
BLOCK :RE	RE:122.00 CO:18.00 (0.04)	

Ω(s)	FHASE	EARTH
ZONE1 :RE	45.33(-)	45.33(-)
ZONE2 :RE	77.83(0.25)	77.83(0.25)
ZONE3 :RE	104.00(0.8)	104.00(0.8)
BLOCK :RE	RE:119.00 CO:15.00 (0.04)	

600/5 A

800/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	42.88(-)	44.13(-)
ZONE2 :RE	86.63(0.3)	70.00(0.3)
ZONE3 :RE	121.63(0.8)	126.88(0.8)
BLOCK :RE	RE:172.50 CO:51.50 (0.05)	

Ω(s)	FHASE	EARTH
ZONE1 :RE	40.38(-)	42.63(-)
ZONE2 :RE	77.00(0.3)	67.63(0.3)
ZONE3 :RE	117.50(1.0)	122.50(1.0)
BLOCK :RE	RE:146.25 CO:28.75 (0.08)	

800/5 A

600/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	18.67(-)	18.67(-)
ZONE2 :RE	28.33(0.3)	28.33(0.3)
ZONE3 :RE	83.33(1.0)	83.33(1.0)
BLOCK :RE	RE:103.67 CO:20.00 (0.04)	

Ω(s)	FHASE	EARTH
ZONE1 :RE	18.18(-)	16.67(-)
ZONE2 :RE	66.67(0.5)	66.67(0.5)
ZONE3 :RE	—	—

600/5 A

600/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	88.33(-)	93.33(-)
ZONE2 :RE	130.00(0.3)	130.00(0.3)
ZONE3 :RE	180.00(1.0)	180.00(1.0)
BLOCK :RE	RE:200.00 CO:20.00 (0.04)	

800/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	55.00(-)	58.75(-)
ZONE2 :RE	81.25(0.3)	97.50(0.3)
ZONE3 :RE	135.00(1.0)	135.00(1.0)
BLOCK :RE	RE:192.50 CO:57.50 (0.04)	

Ω(s)	FHASE	EARTH
ZONE1 :RE	57.50(-)	61.38(-)
ZONE2 :RE	86.25(0.3)	91.25(0.3)
ZONE3 :RE	143.75(0.8)	140.00(0.8)
BLOCK :RE	RE:152.88 CO:22.13 (0.06)	

800/5 A

600/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	69.50(-)	66.65(-)
ZONE2 :RE	106.33(0.5)	111.17(0.5)
BLOCK :RE	RE:194.44 CO:33.33 (-)	

Ω(s)	FHASE/ EARTH
ZONE1 :RE	80.83(-)
ZONE2 :RE	121.67(0.3)
ZONE3 :RE	150.0 (0.6)
BLOCK :RE	166.67(2.0)

1200/5 A

1200/5 A

Ω(s)	FHASE/ EARTH
ZONE1 :RE	65.0 (-)
ZONE2 :RE	96.67(0.3)
ZONE3 :RE	125.0 (0.6)
BLOCK :RE	166.67(2.0)

800/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	16.75(-)	17.63(-)
ZONE2 :RE	37.75(0.3)	30.63(0.3)
ZONE3 :RE	57.00(0.8)	46.88(0.8)
BLOCK :RE	RE: 66.25 CO:10.00 (0.04)	

1200/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	16.67(-)	17.42(-)
ZONE2 :RE	37.00(0.3)	30.58(0.3)
ZONE3 :RE	56.33(0.8)	51.33(0.8)
BLOCK :RE	RE: 70.17 CO:13.83 (0.04)	

1200/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	59.42(-)	62.83(-)
ZONE2 :RE	89.67(0.3)	88.58(0.3)
ZONE3 :RE	125.00(0.8)	132.92(0.8)
BLOCK :RE	RE:162.08 CO:37.00 (0.04)	

1200/5 A

Ω(s)	FHASE	EARTH
ZONE1 :RE	59.5 (-)	62.67(-)
ZONE2 :RE	89.33(0.25)	96.17(0.25)
ZONE3 :RE	125.1 (0.8)	124.75(0.8)
BLOCK :RE	RE:138.00 CO:12.30 (0.08)	

Fig. 7-4 230kV SNI Secondary Protection

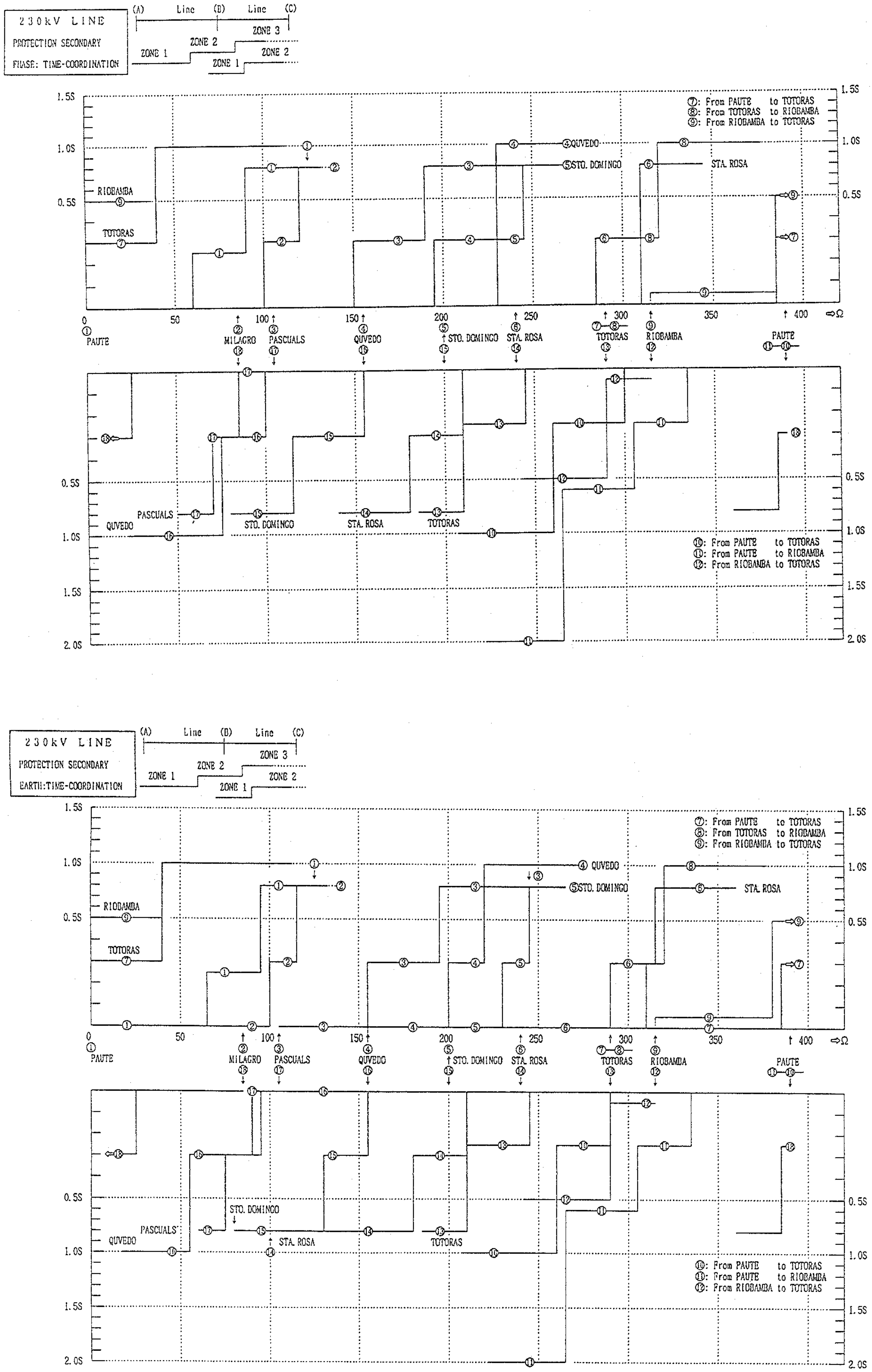
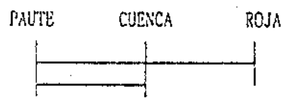


Fig. 7-5 230kV SNI Secondary Protection Coordination

138kV SNI PROTECTION

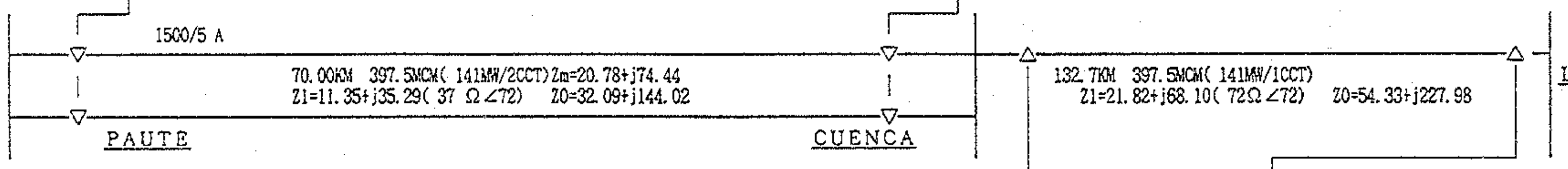


	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATIONS
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

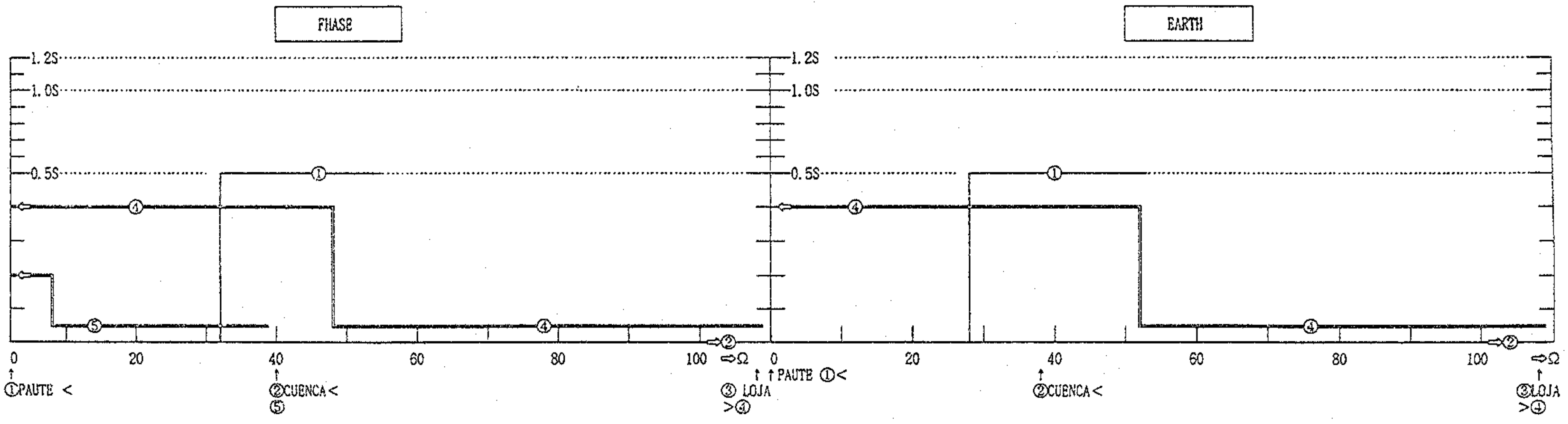
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	54.59(-)	30.00(-)	51.00(0.5)	——	— / —
EARTH	54.92(-)	29.70(-)	52.00(0.5)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	81.84(-)	31.44(-)	60.48(0.2)	——	— / —
EARTH	55.68(-)	33.84(-)	60.48(0.2)	——	

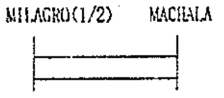


	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	—	73.47(-)	73.47(0.3)	——	— / —
EARTH	—	72.00(-)	72.00(0.3)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	——	59.21(-)	115.38(0.4)	——	/
EARTH	——	58.50(-)	115.38(0.4)	——	



138kV SNI PROTECTION

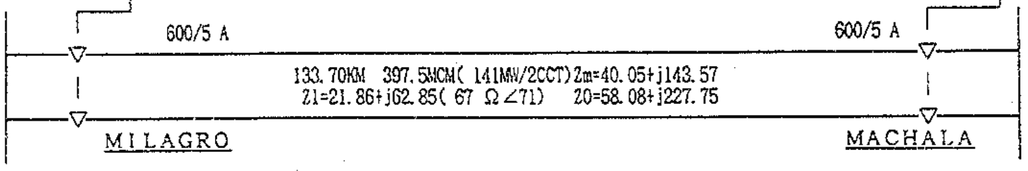


	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATIONS
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	——	54.50(-)	91.00(0.3)	——	— / —
EARTH	——	59.00(-)	107.10(0.3)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE:/ CO:
FHASE	——	54.50(-)	158.00(0.3)	——	— / —
EARTH	——	59.00(-)	125.00(0.3)	——	



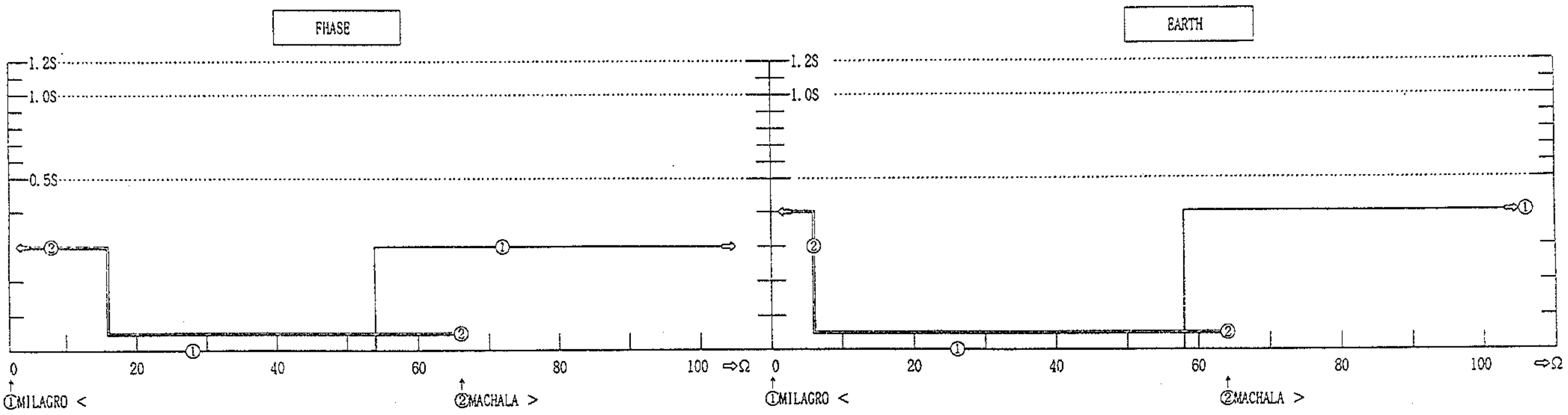
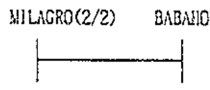


Fig. 7-6 138kV SNI Protection (1/9)

138kV SNI PROTECTION

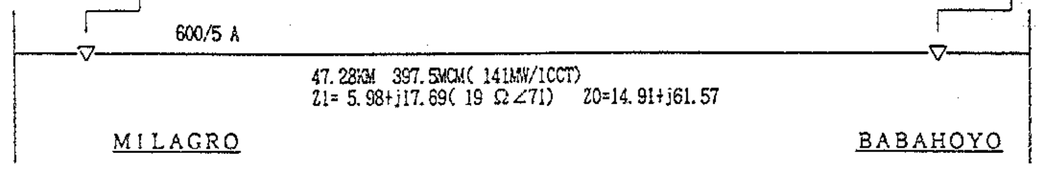


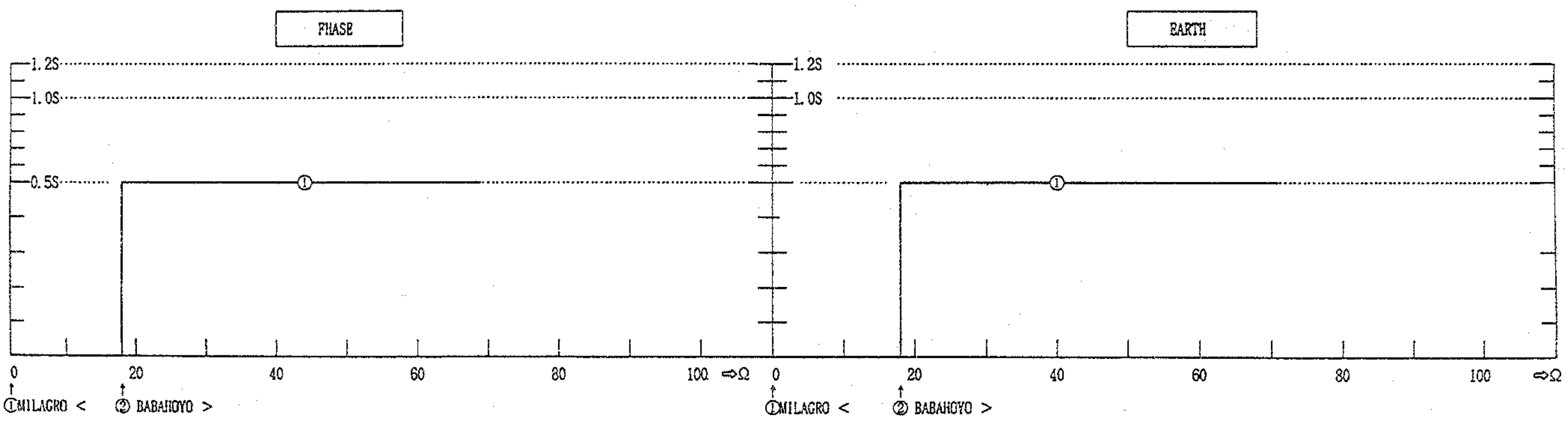
	MAIN	SECONDARY	BLOCK
PHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATIONS
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

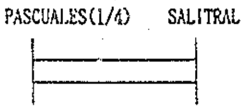
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RB:/ CO:
PHASE	——	18.80(-)	68.10(0.5)	——	— / —
EARTH	——	18.80(-)	68.10(0.5)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RB:/ CO:
PHASE	——	——	——	——	— / —
EARTH	——	——	——	——	





138kV SNI PROTECTION

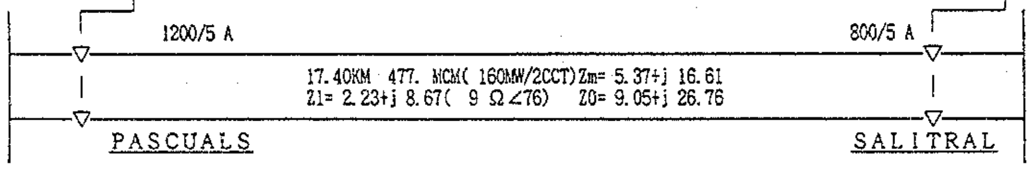


	MAIN	SECONDARY	BLOCK
PHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RB:REACHC
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	13.05(-)	7.15(-)	18.05(0.3)	30.00(0.8)	— / —
EARTH	13.05(-)	7.70(-)	12.65(0.3)	24.75(0.8)	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	15.15(-)	7.20(-)	20.10(0.3)	——	— / —
EARTH	16.20(-)	7.35(-)	15.30(0.3)	——	



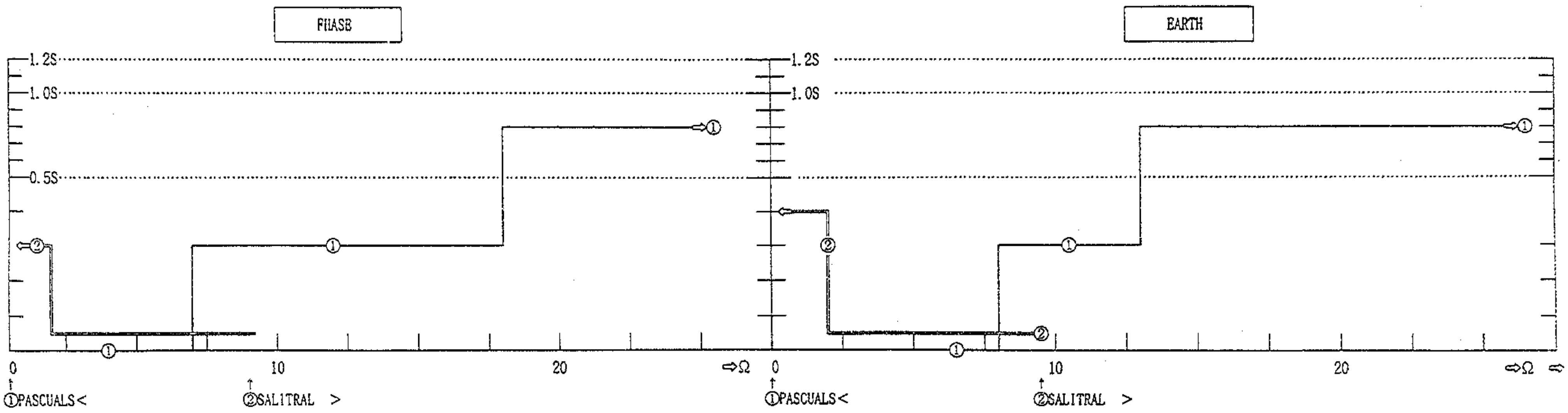


Fig. 7-6 138kV SNI Protection (2/9)

138kV SNI PROTECTION

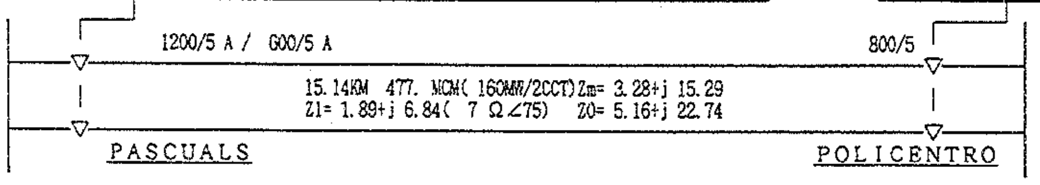
PASCUALES(2/4) POLICENTRO

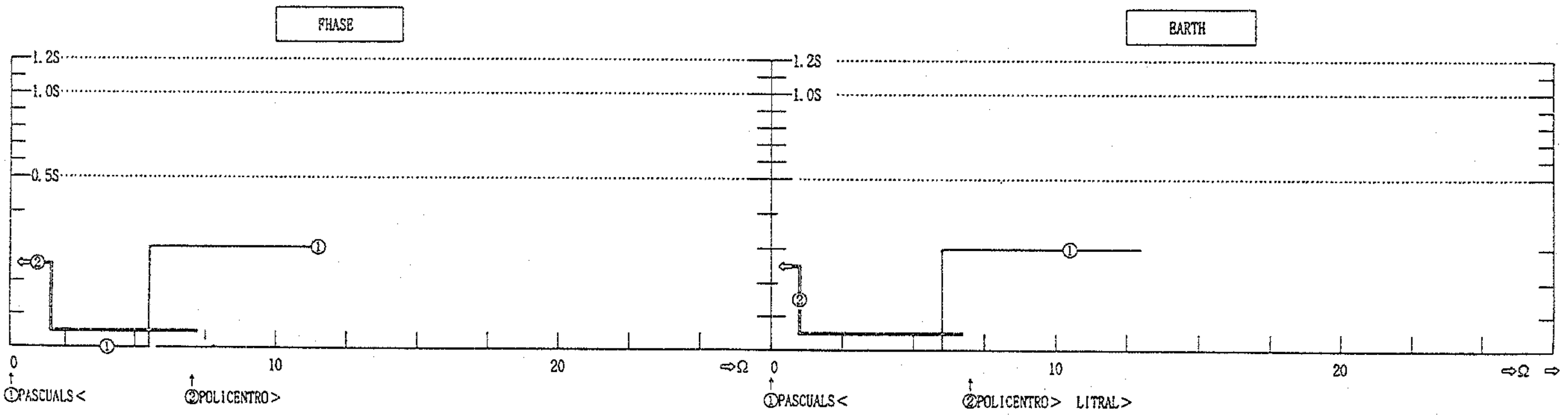
	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACHC
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	14.20(-)	5.80(-)	11.50(0.3)	——	— / —
EARTH	14.15(-)	5.65(-)	12.90(0.3)	——	

	MAIN			SECONDARY		
Ω(s)	ZONE1	ZONE2	ZONE3	ZONE1	ZONE2	ZONE3
FHASE, EARTH	5.70(-)	10.80(0.25)	14.03(0.6)	5.70(-)	8.63(0.25)	14.03(0.6)





138kV SNI PROTECTION

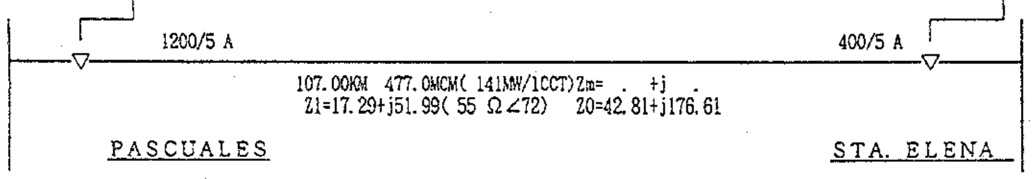
PASCUALES(3/4) SAT. ELENA

	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	54.70(-)	59.80(0.25)	——	— / —
EARTH	——	53.50(-)	59.00(0.25)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FASE	——	43.65(-)	82.05(0.25)	——	—/ —
TIERRA	——	43.65(-)	83.10(0.25)	——	



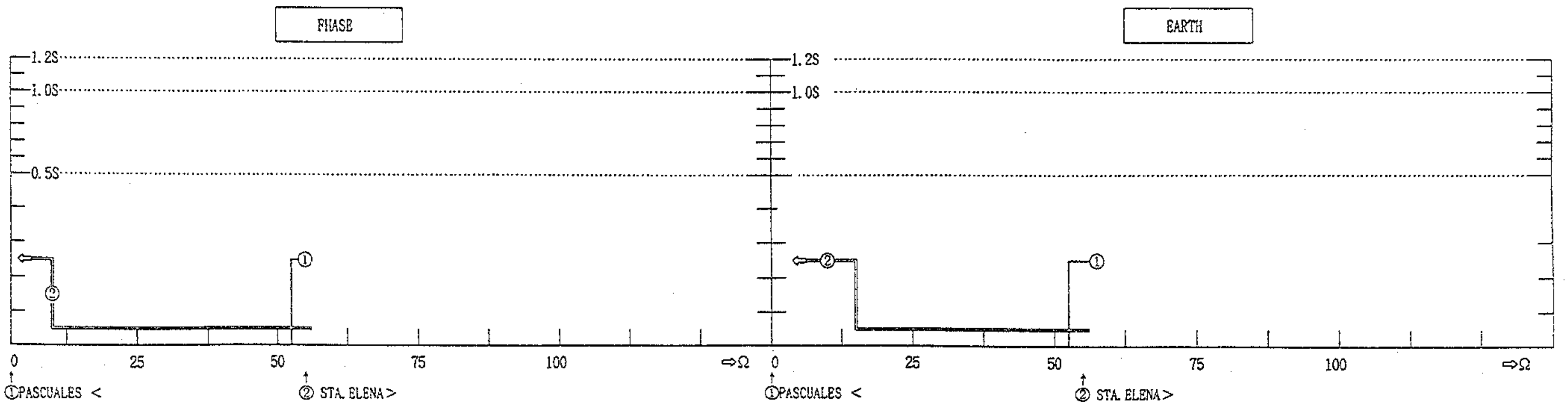
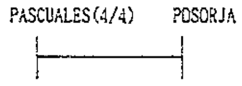


Fig. 7-6 138kV SNI Protection (3/9)

138kV SNI PROTECTION

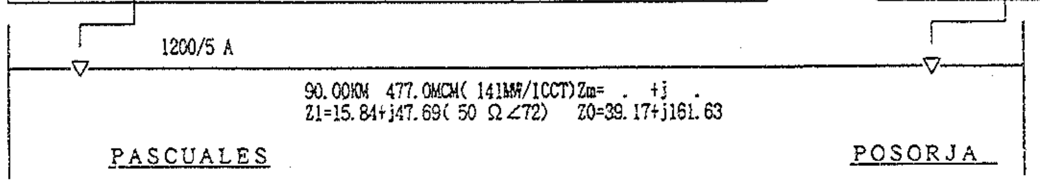


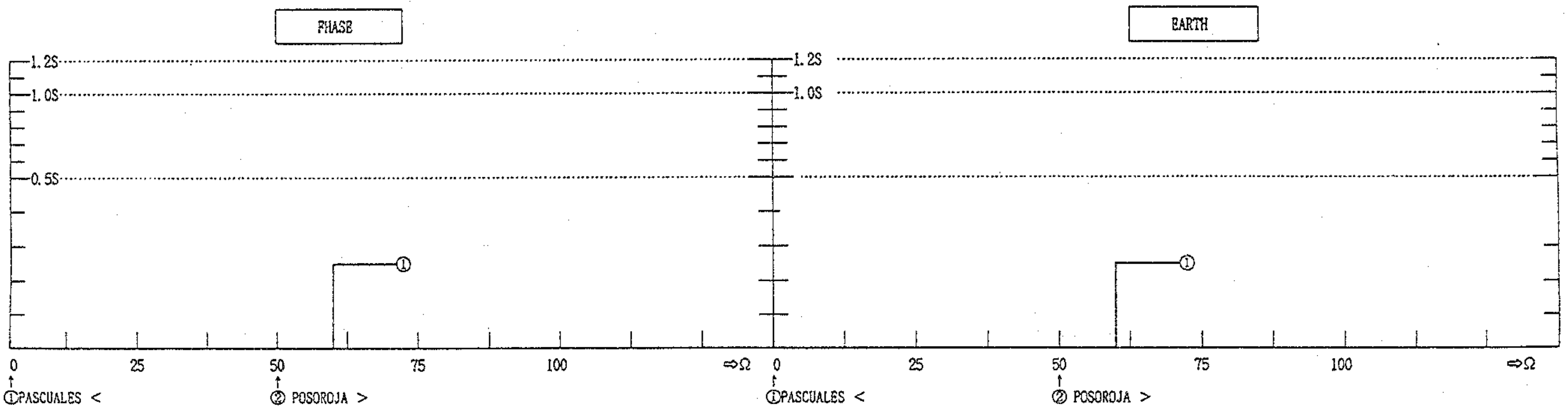
	MAIN	SECONDARY	BLOCK
PHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

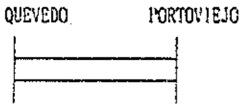
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	——	61.70(-)	74.10(0.25)	——	— / —
EARTH	——	61.00(-)	74.50(0.25)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	——	——	——	——	— / —
EARTH	——	——	——	——	





138kV SNI PROTECTION

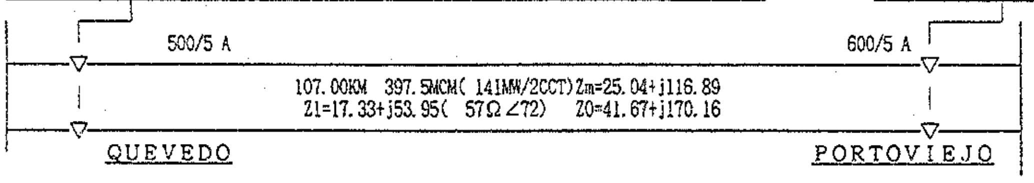


	MAIN	SECONDARY	BLOCK
PHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	84.72(-)	24.12(-)	43.80(0.4)	——	— / —
EARTH	87.00(-)	29.04(-)	47.52(0.4)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
PHASE	54.80(-)	24.10(-)	34.20(0.3)	56.70(0.8)	— / —
EARTH	54.80(-)	31.50(-)	47.20(0.3)	59.00(0.8)	



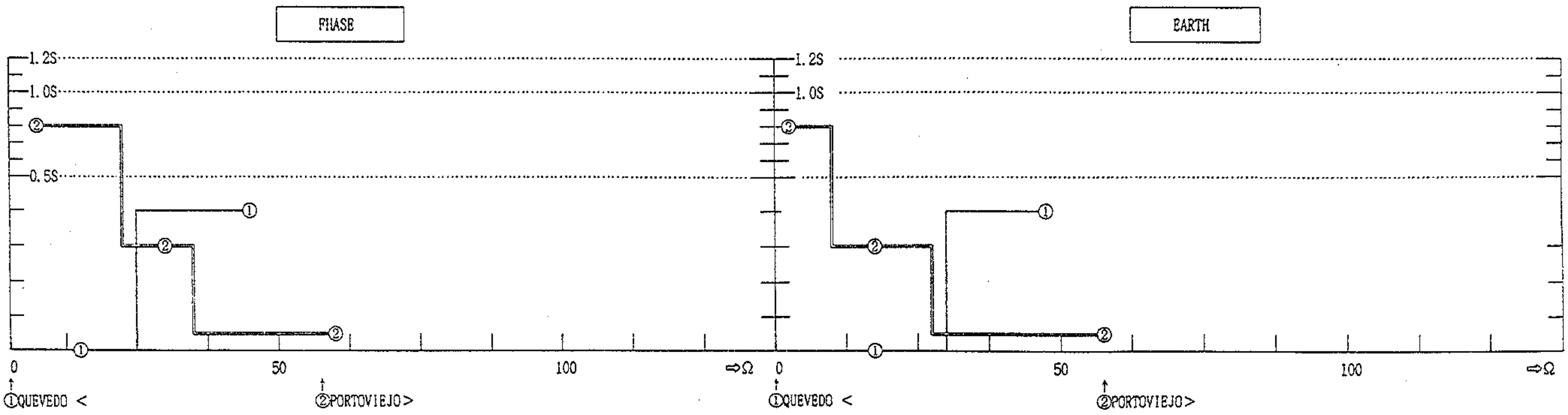
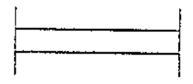


Fig. 7-6 138kV SNI Protection (4/9)

138kV SNI PROTECTION

STO. DOMINGO ESMERALDAS

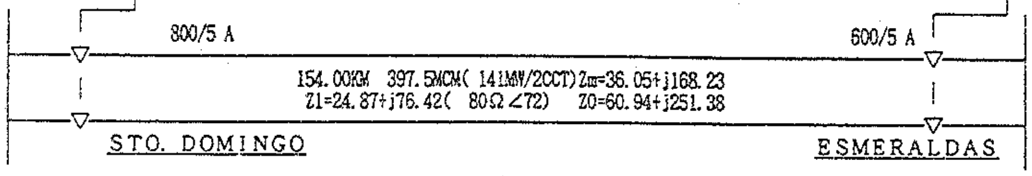


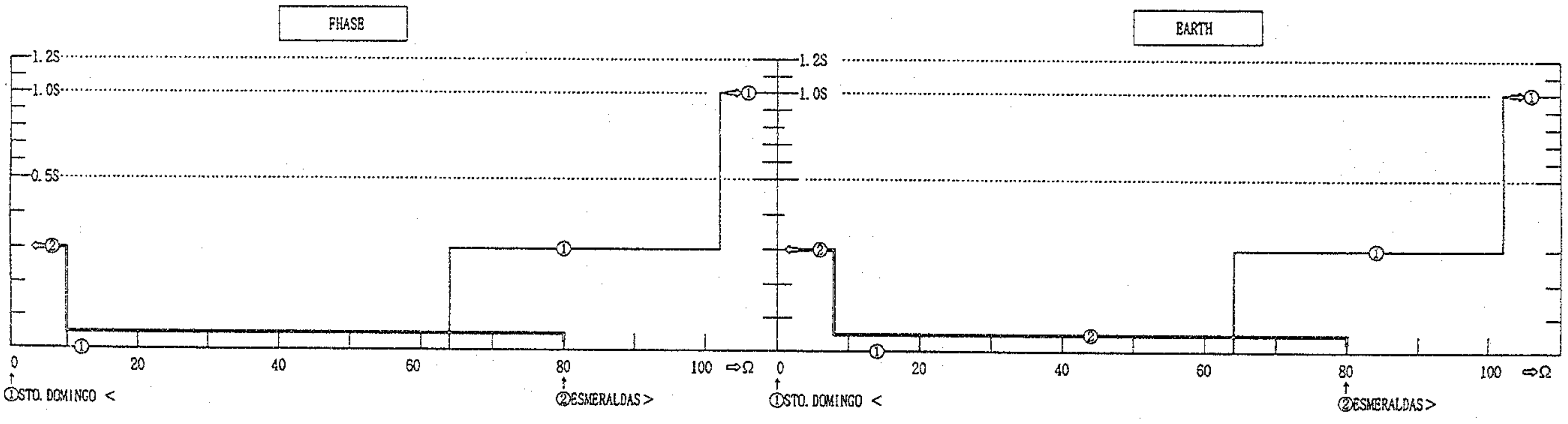
	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	120.00(-)	64.20(-)	102.00(0.3)	168.00(1.0)	— / —
EARTH	120.00(-)	64.20(-)	102.00(0.3)	168.00(1.0)	

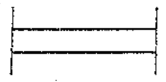
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	119.60(-)	70.20(-)	105.00(0.3)	145.30(0.8)	— / —
EARTH	119.60(-)	71.50(-)	125.30(0.3)	162.70(0.8)	





138kV SNI PROTECTION

STA. ROSA(1/3) SELVA ALEGRE

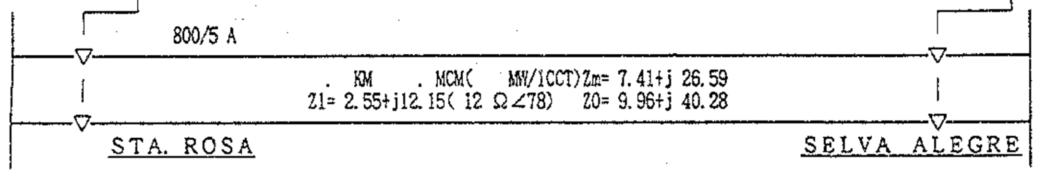


	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACHC
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	9.90(-)	20.63(0.4)	——	— / —
EARTH	——	10.65(-)	22.50(0.4)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	——	——	——	— / —
EARTH	——	——	——	——	



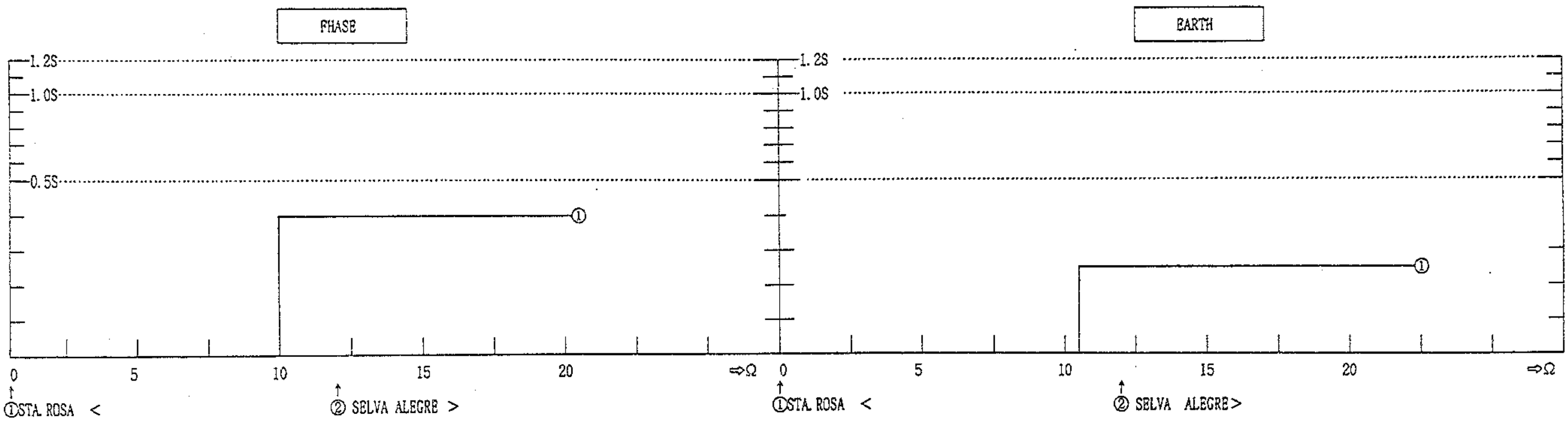
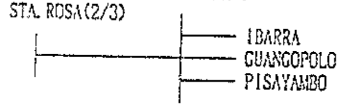


Fig. 7-6 138kV SNI Protection (5/9)

138kV SNI PROTECTION

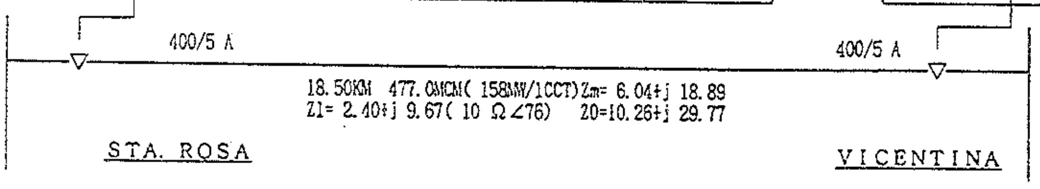


	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

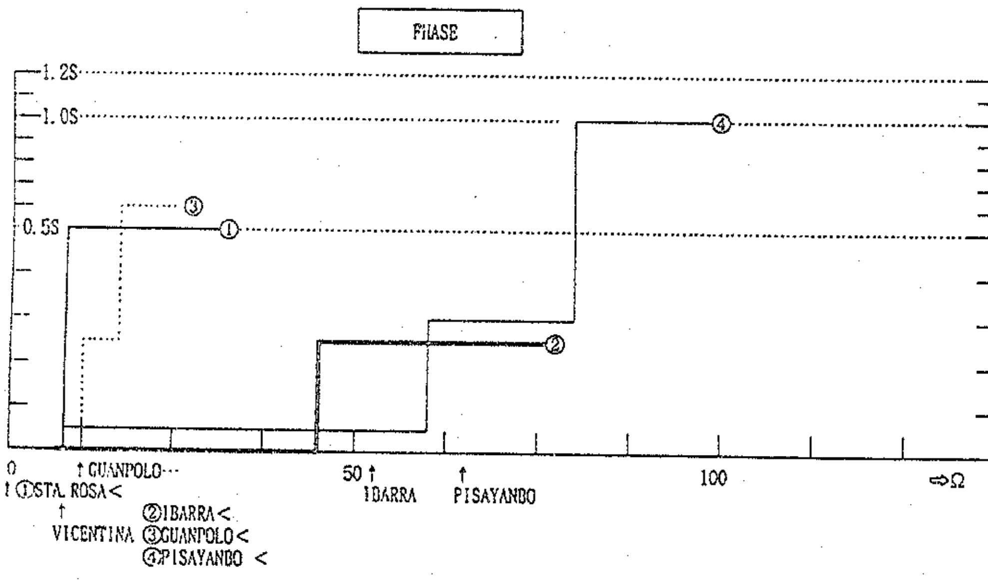
BLOCK: BLOCK OSCILLATION
RE:REACHC
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

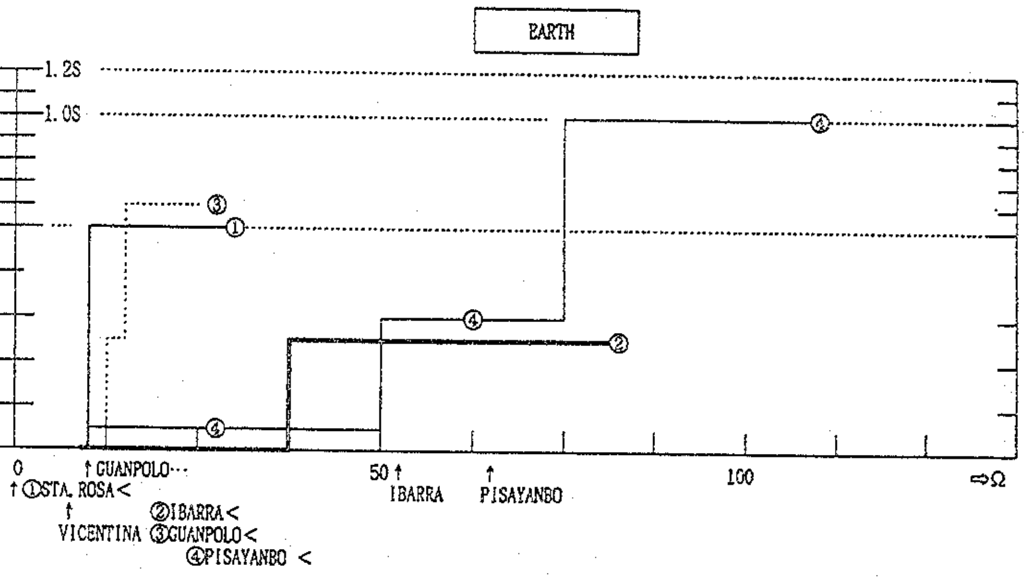
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	33.00(-)	7.95(-)	33.53(0.5)	——	— / —
EARTH	37.20(-)	8.48(-)	33.75(0.5)	——	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	20.40(-)	7.65(-)	12.75(0.3)	45.45(0.8)	— / —
EARTH	20.70(-)	7.65(-)	12.75(0.3)	45.45(0.8)	

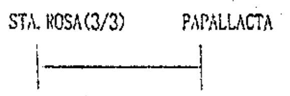


18.50KM 477.0MCM(158MW/1CCT)Zm= 6.04+j 18.89
Z1= 2.40+j 9.67(10 Ω∠76) Z0=10.26+j 29.77





138kV SNI PROTECTION

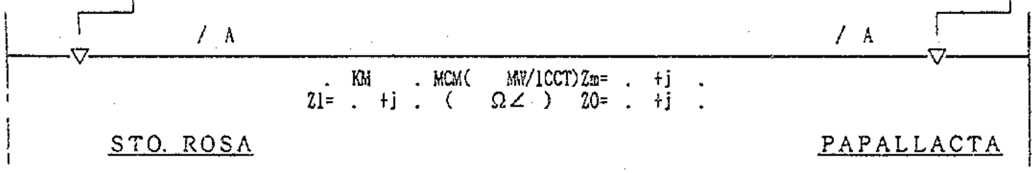


	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

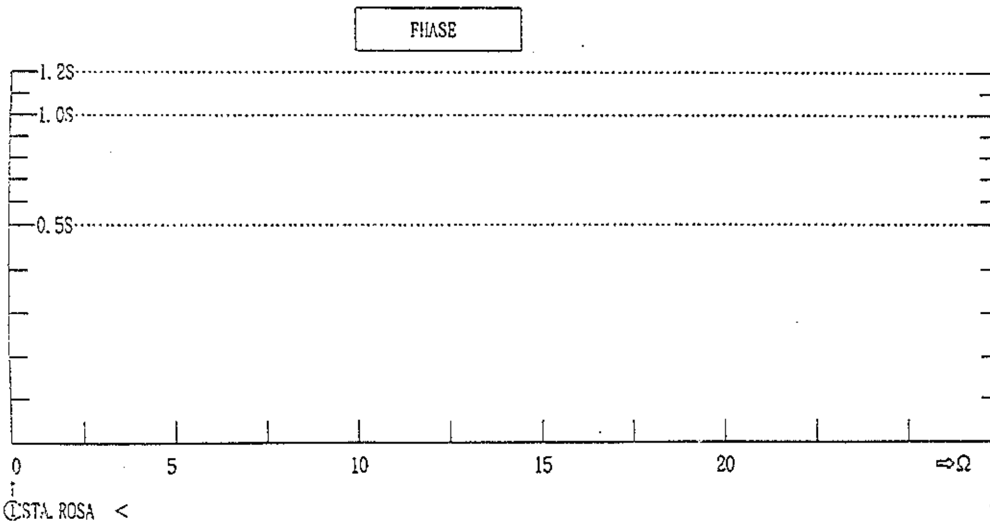
BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE					/
EARTH					

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE					/
EARTH					



. KM . MCM(MW/1CCT)Zm= . +j .
Z1= . +j . (Ω∠) Z0= . +j .



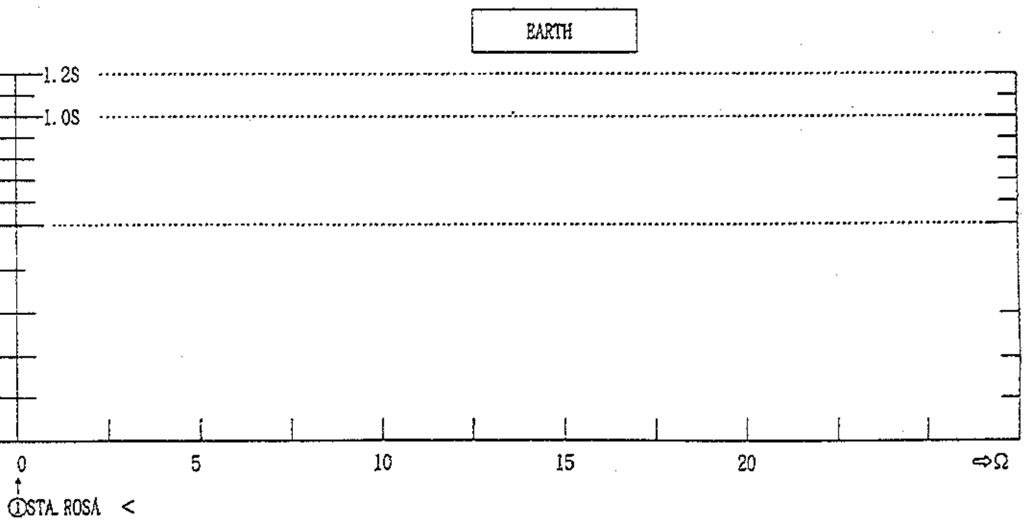
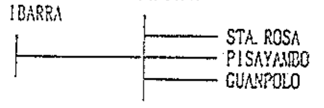


Fig. 7-6 138kV SNI Protection (6/9)

1 3 8 k V S N I P R O T E C T I O N

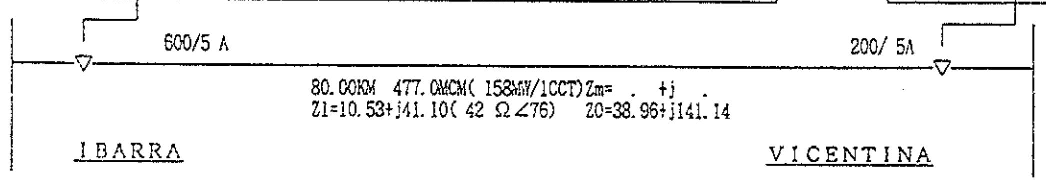


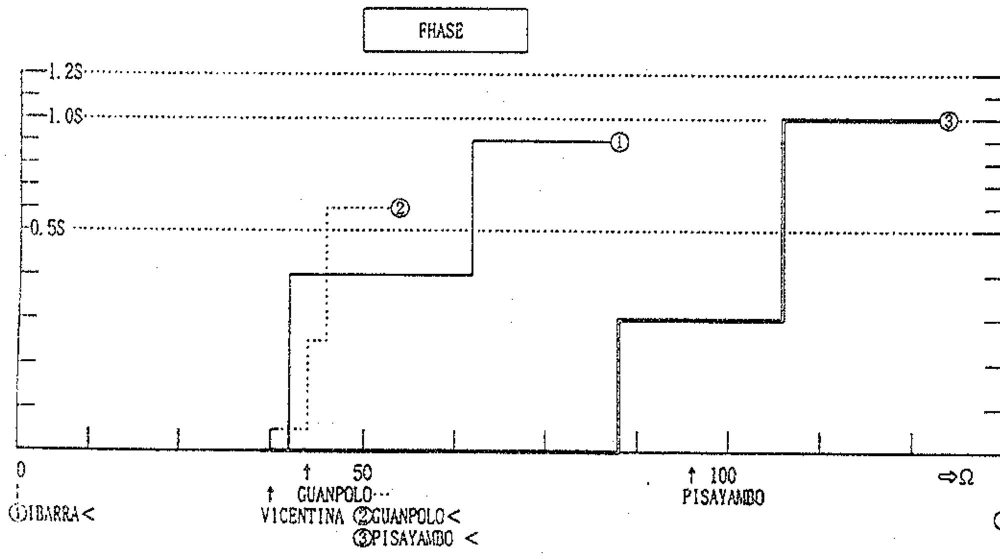
	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

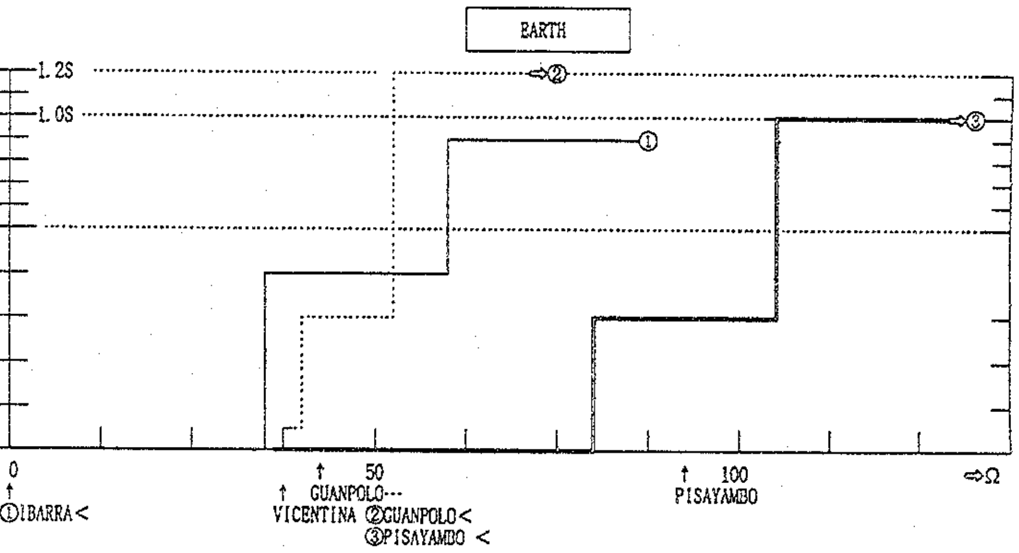
BLOCK: BLOCK OSCILLATION
RE:REACHC
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARY

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	39.50(-)	66.70(0.4)	85.70(0.9)	— / —
EARTH	——	37.00(-)	62.50(0.4)	90.90(0.9)	

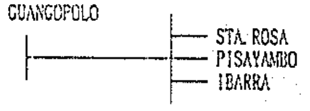
	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	36.00(-)	69.00(0.25)	99.00(0.8)	— / —
EARTH	——	36.00(-)	69.00(0.25)	99.00(0.8)	







1 3 8 k V S N I P R O T E C T I O N

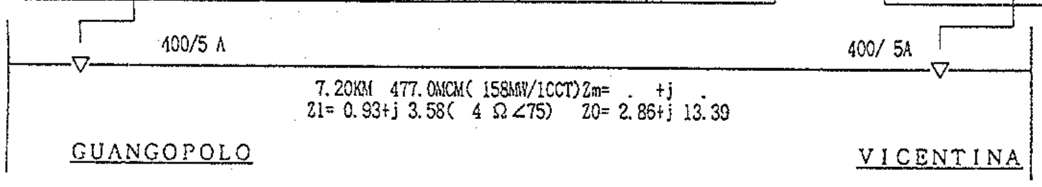


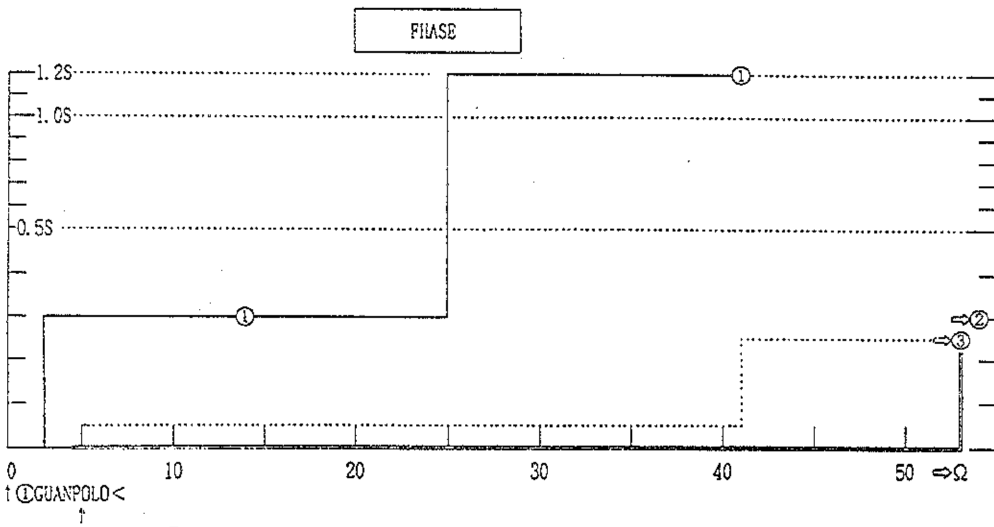
	MAIN	SECONDARY	BLOCK
FHASE	Ω(s)	Ω(s)	RE: /CO: Ω(s)
EARTH	Ω(s)	Ω(s)	

BLOCK: BLOCK OSCILLATION
RE:REACH
CO:COMPENSATION
( ):ZONE/TIMING DETECTION
CT: PRIMARY / SECONDARYA

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	3.15(-)	25.05(0.3)	40.50(1.2)	— / —
EARTH	——	2.85(-)	15.00(0.3)	37.50(1.2)	

	MAIN	SECONDARY			BLOCK
Ω(s)	RE	ZONE1	ZONE2	ZONE3	RE: / CO:
FHASE	——	3.30(-)	6.00(0.4)	15.00(0.6)	— / —
EARTH	——	(-)	6.00(0.25)	15.00(0.6)	





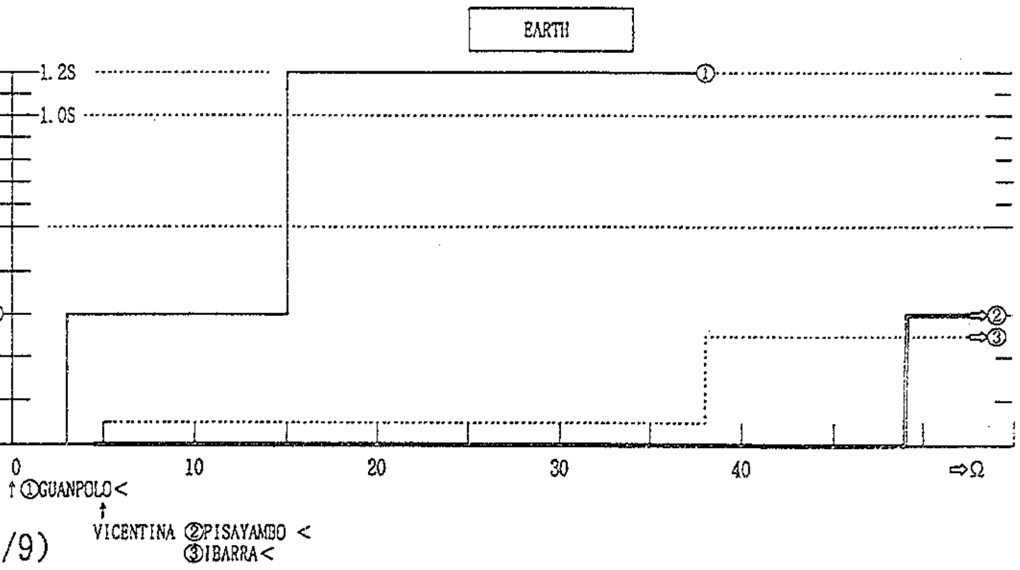


Fig. 7-6 138kV SNI Protection (7/9)