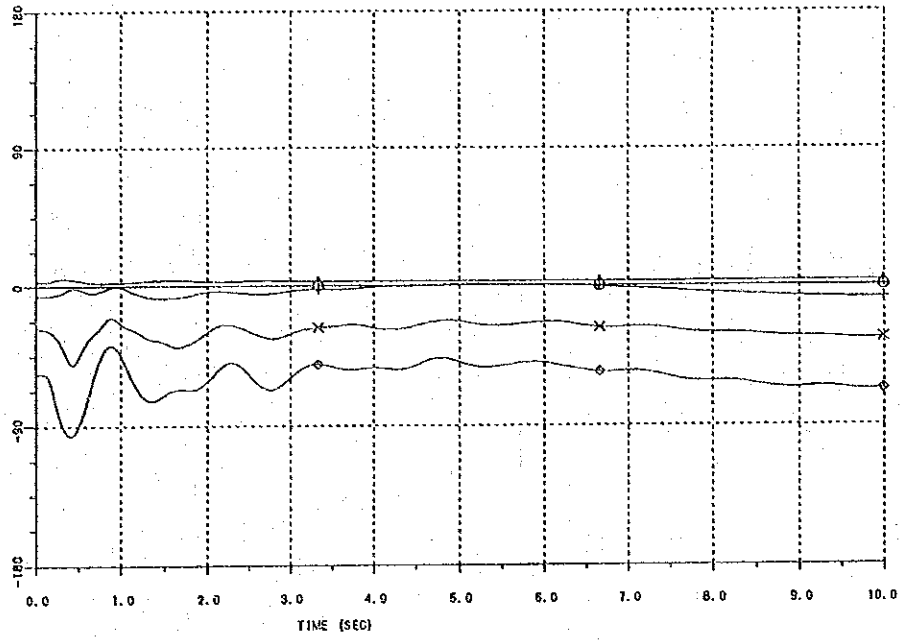
ECUADOR 1998-12 2CCT (PAUTE-MILAGRO) 3LG-O

	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	4.89	2.14	2.93	3.28
3	NDG-11	ANG	CUENCA	1.01	-7.85	-6.18	-7.77
4	ND-60	ANG	LATCUNGA	-20.35	-50.55	-27.68	-33.81
5	NDG-16	ANG	IBARRA	-38.02	-96.11	-56.56	-66.78



ECUADOR 1998-12 2CCT (PAUTE-MILAGRO) 3LG-O

	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	-0.23	-61.49	-7.70	-33.12
3	ND-46	ANG	RIOBAMBA	-25.60	-51.56	-32.38	-37.09
4	NDG-01	ANG	ESMERALD	37.41	-50.56	3.62	-3.03
5	NDG-15	ANG	GUANGOPL	-23.45	-52.29	-30.19	-37.98

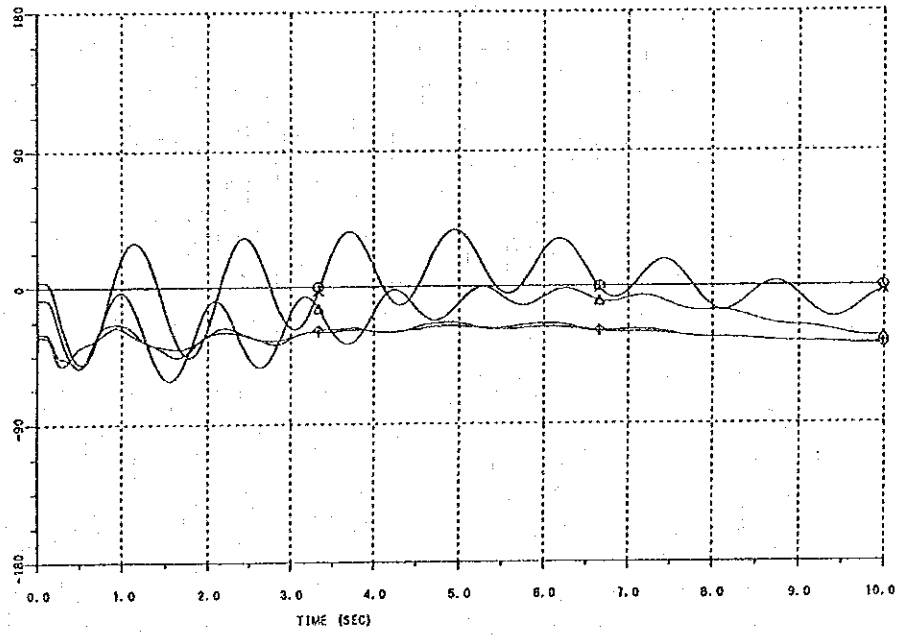


Fig. 5-9 Power System Stability after 2 CCT Line Fault (under power flow condition of Fig. 5-4)

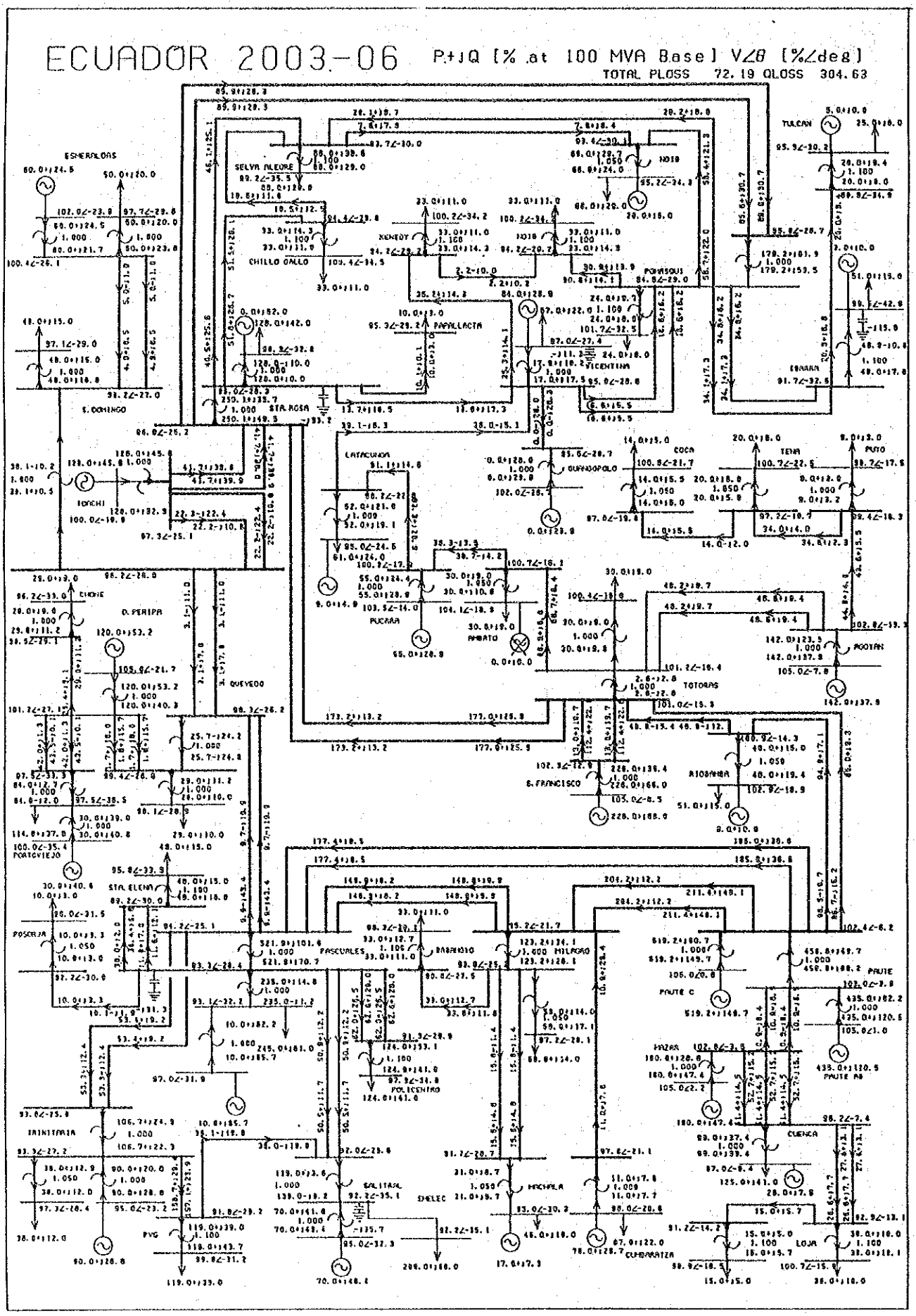


Fig. 5-10 Power Flow In June, 2003

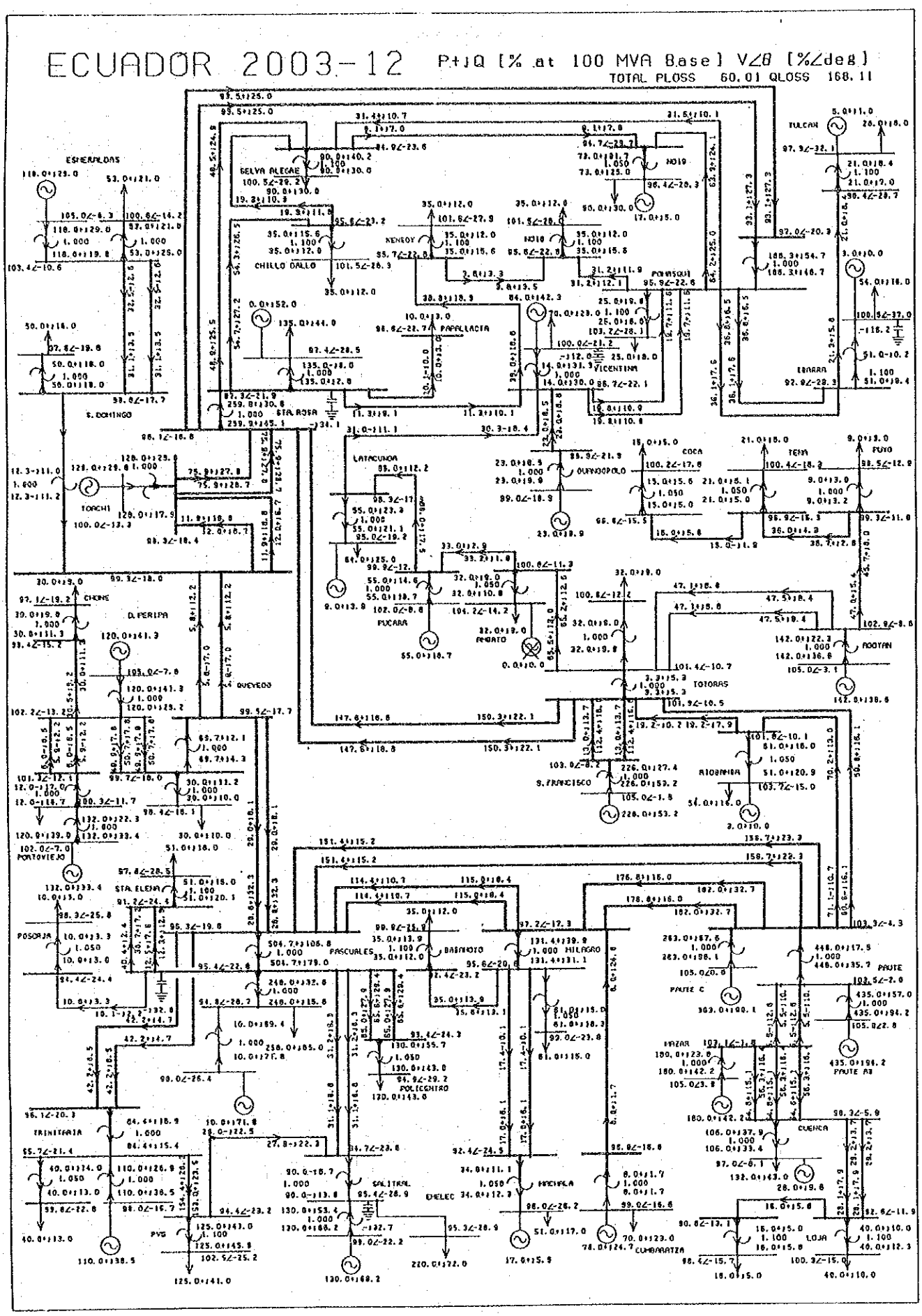
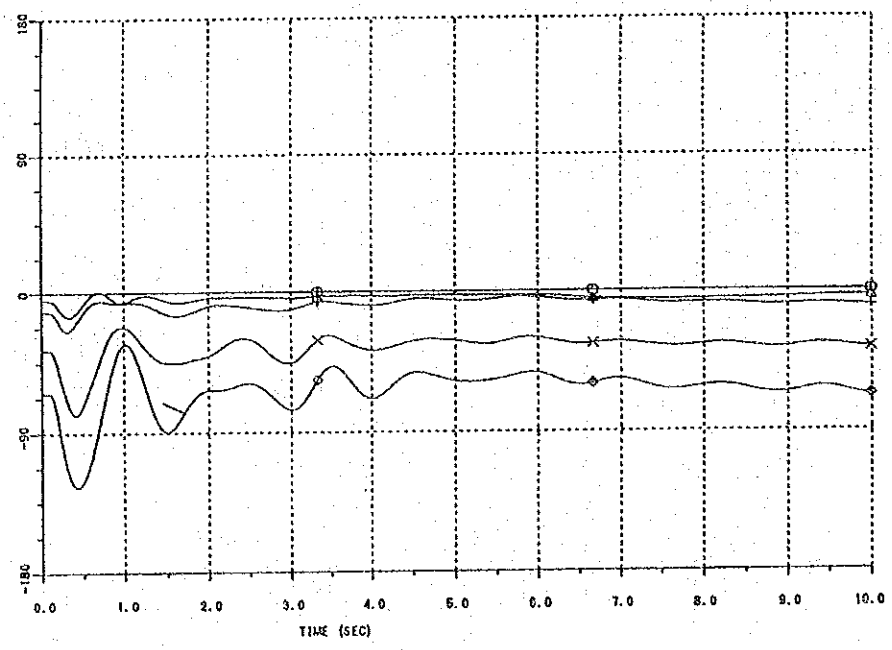


Fig. 5-11 Power Flow in December, 2003

ECUADOR 2003-06 BR04-1 (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	0.78	-15.51	-4.47	-3.46
3	NDG-11	ANG	CUENCA	-3.74	-24.60	-12.10	-9.93
4	ND-60	ANG	LATCUNGA	-22.15	-78.35	-36.74	-35.94
5	NDG-16	ANG	IBARRA	-33.00	-125.13	-64.34	-66.98



ECUADOR 2003-06 BR04-1 (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	-15.93	-147.09	-68.99	-79.03
3	ND-45	ANG	RIOBAMBA	-25.09	-74.12	-38.75	-38.35
4	NDG-01	ANG	ESMERALD	32.76	-82.49	-9.62	-5.66
5	NDG-15	ANG	GUANGOPL	-39.90	-101.98	-57.59	-59.10

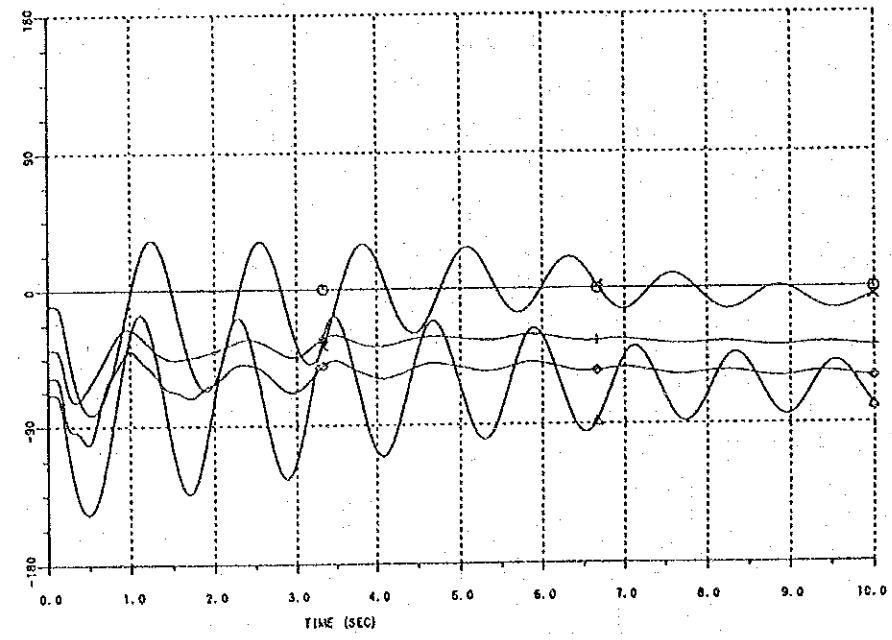
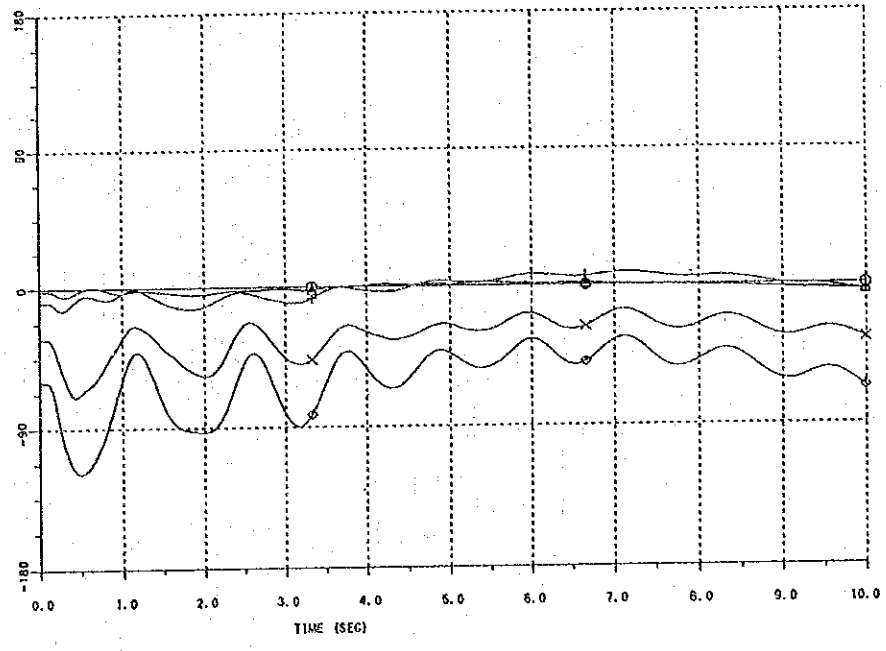


Fig. 5-12 Power System Stability after 1 CCT Line Fault (under power flow condition of Fig. 5-10)

ECUADOR 2003-06 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	2.46	-4.91	-1.43	-3.69
3	NDG-11	ANG	CUENCA	8.17	-14.00	-8.72	-4.27
4	ND-60	ANG	LATCUNGA	-15.78	-69.52	-32.41	-35.04
5	NDG-16	ANG	IBARRA	-33.62	-118.63	-59.91	-66.35



ECUADOR 2003-06 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	4.98	-172.21	-65.03	-78.53
3	ND-46	ANG	RIOBAMBA	-16.33	-61.98	-35.07	-35.30
4	NDG-01	ANG	ESMERALD	64.86	-104.92	-4.98	1.42
5	NDG-15	ANG	GUANGOPL	-33.16	-99.57	-53.29	-57.58

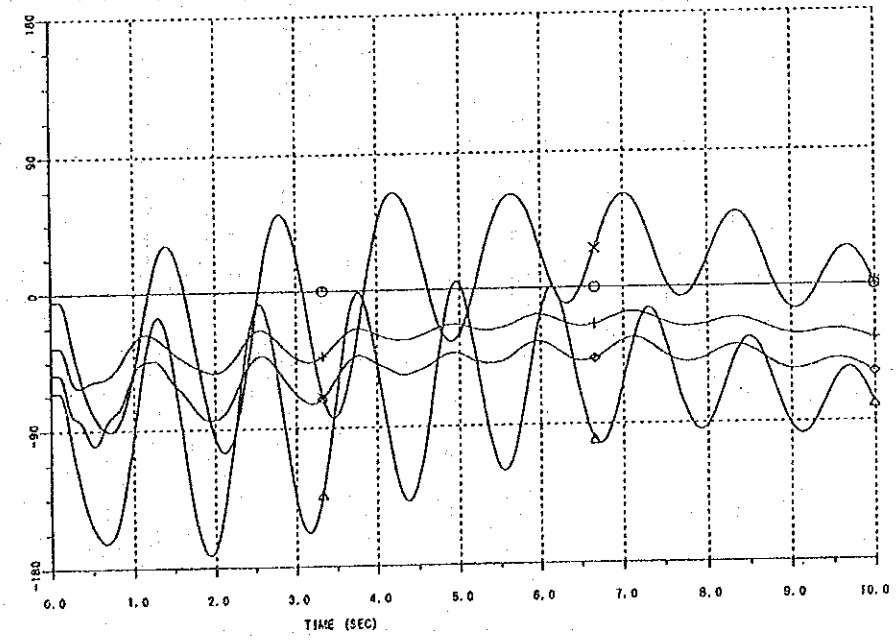


Fig. 5-13 Power System Stability Analysis at 2 CCT Line Fault (under power flow condition of Fig. 5-14)

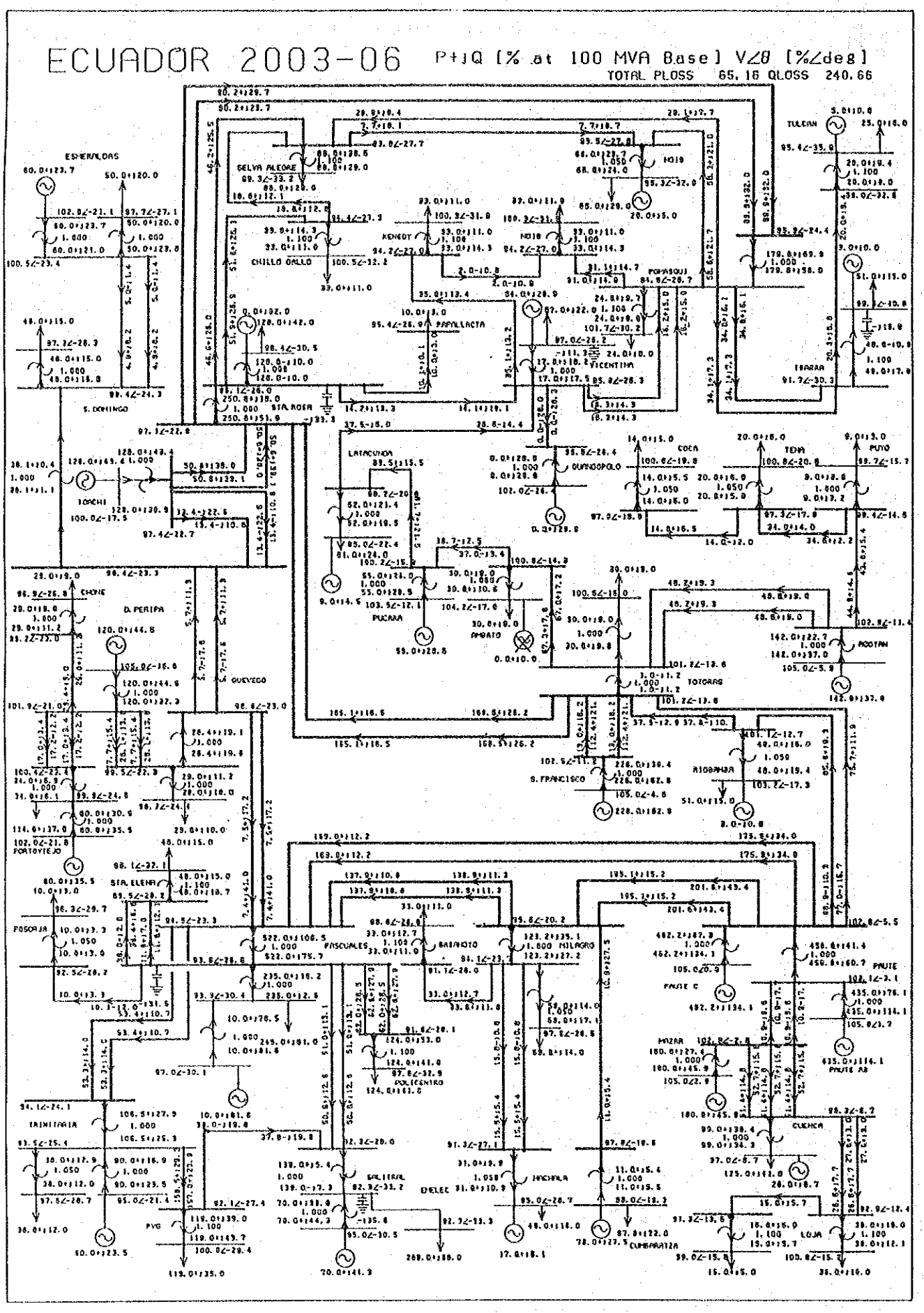
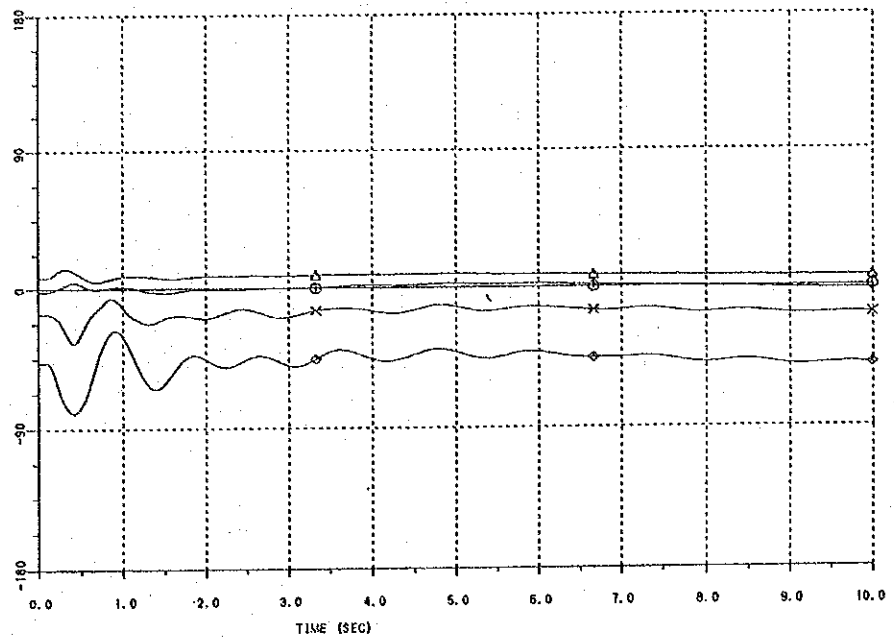


Fig. 5-14 Power Flow in June, 2003 (Case of small output at Paute)

ECUADOR 2003-12 BR04-1 (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	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



ECUADOR 2003_12 BR04-1 (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	4.82	-40.61	-6.37	-12.50
3	ND-46	ANG	RIOBAMBA	-18.11	-39.58	-26.09	-25.97
4	NDG-01	ANG	ESMERALD	29.54	-33.56	8.50	6.96
5	NDG-15	ANG	GUANGOPL	-15.40	-41.54	-24.26	-25.83

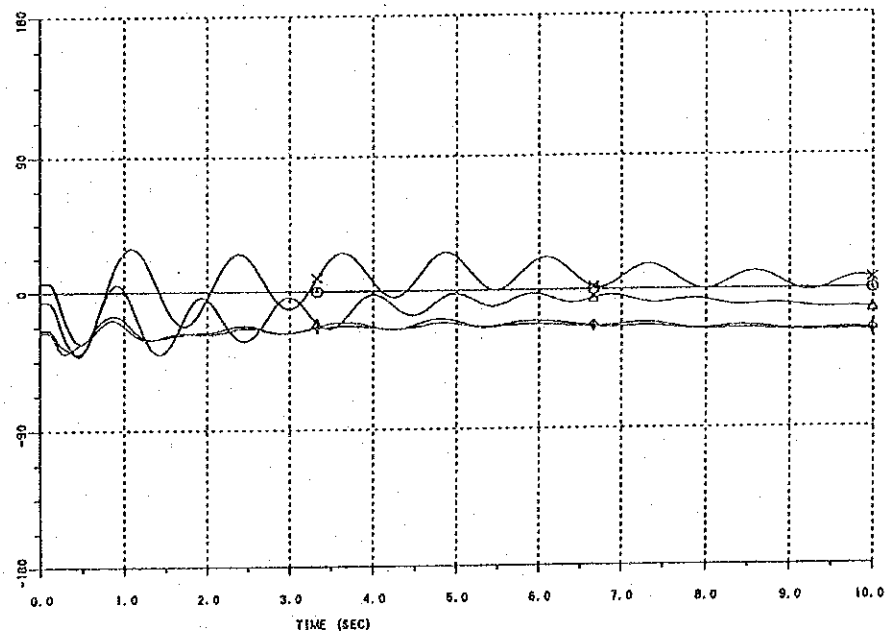
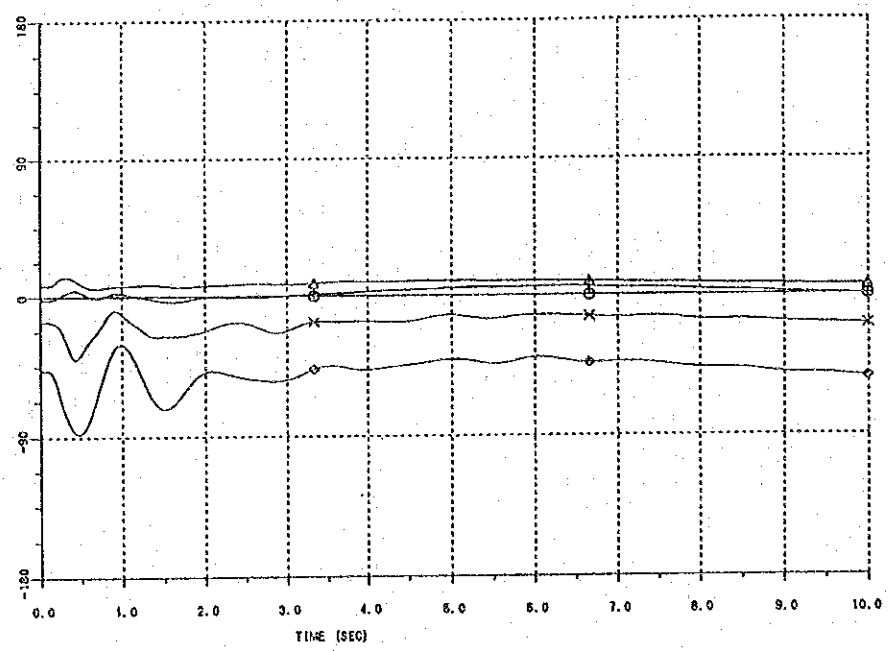


Fig. 5-15 Power System Stability after 1 CCT Line Fault (under power flow condition of Fig. 5-11)

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

	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	-3.26	-1.89	0.03
4	ND-60	ANG	LATCUNGA	-5.85	-40.28	-16.11	-19.19
5	NDG-18	ANG	IBARRA	-30.73	-87.78	-47.52	-53.10



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

	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-46	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

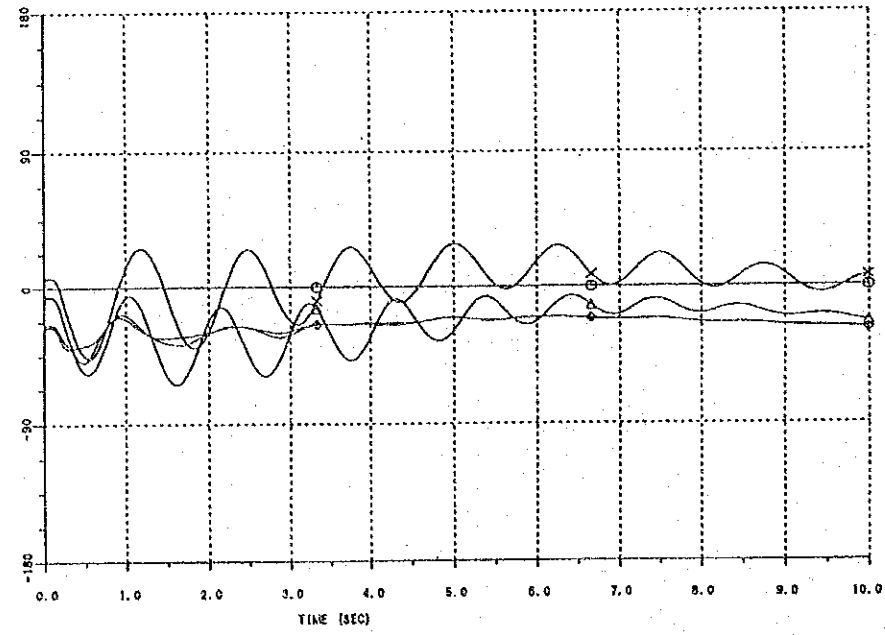


Fig. 5-16 Power System Stability after 2 CCT Line Fault (under power flow condition of Fig. 5-11)

CONTENTS

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.

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".

6.2 Current Level and Future Forecast of Supply Reliability

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 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 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 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

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.

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.

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

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.

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 Portoviejo (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. This is a recommendable plan.

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 Portoviejo 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.

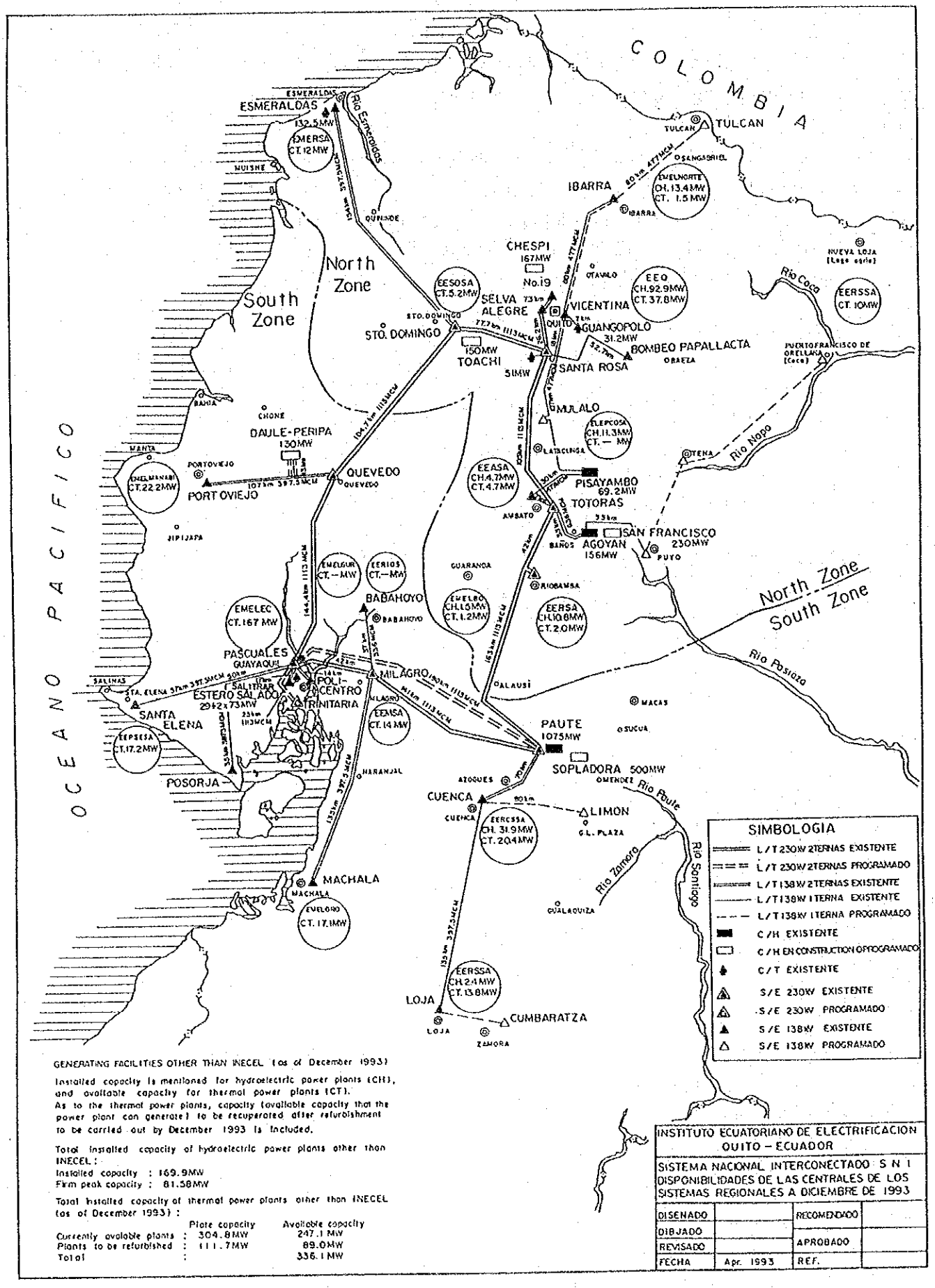


Fig. 6-1 Border of South & North Zone -SNI-

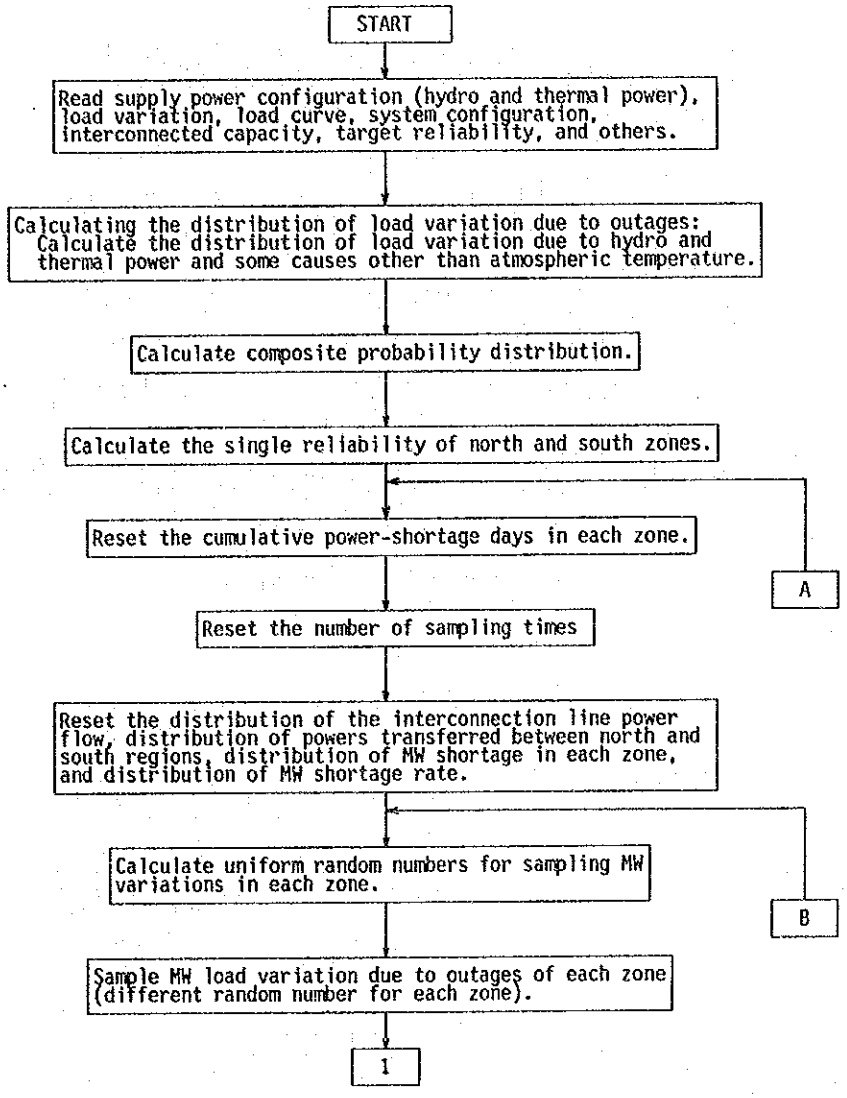


Fig. 6-2 Flow Diagram of Interconnected System Reliability (1/3)

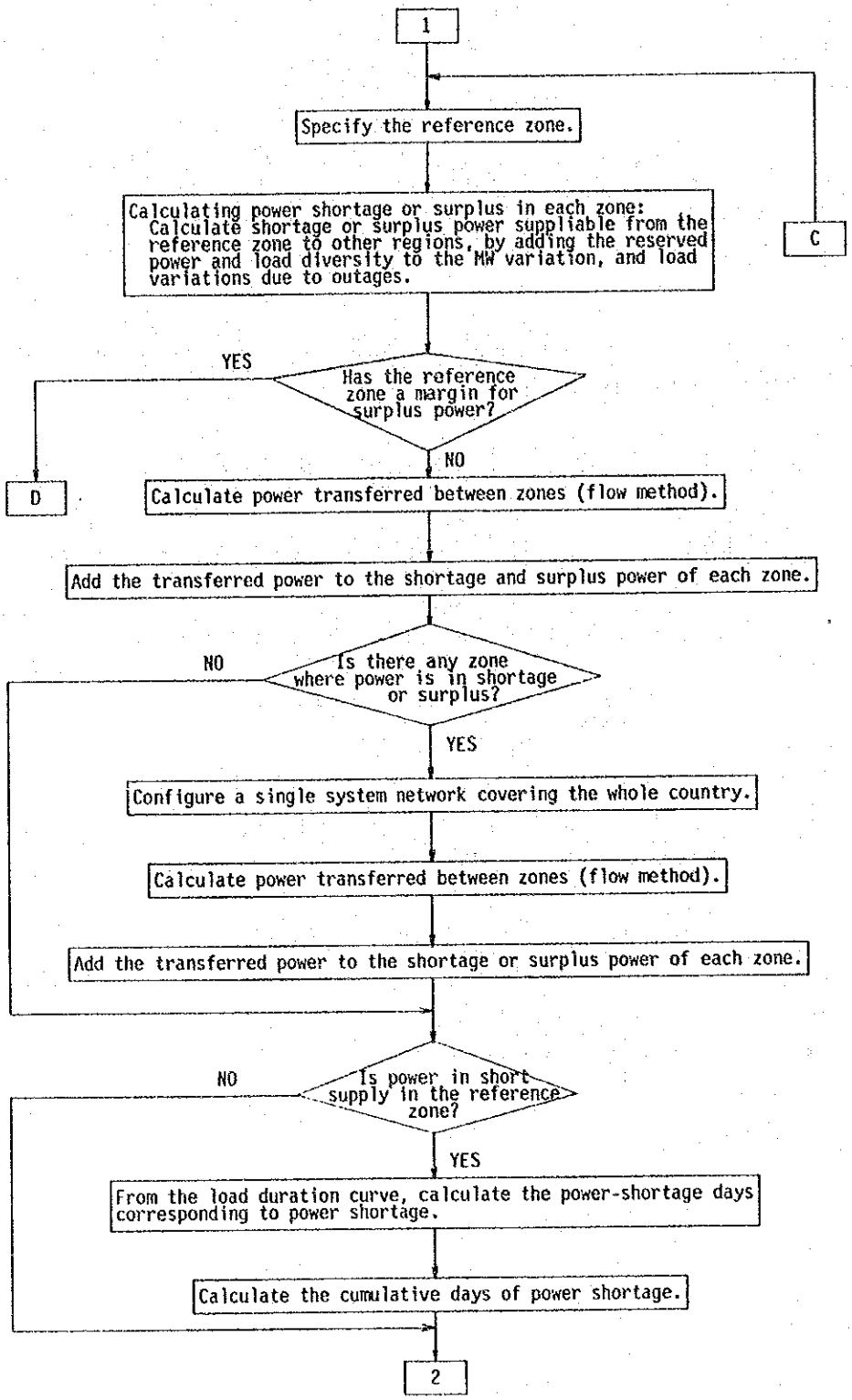


Fig. 6-2 Flow Diagram of Interconnected System Reliability (2/3)

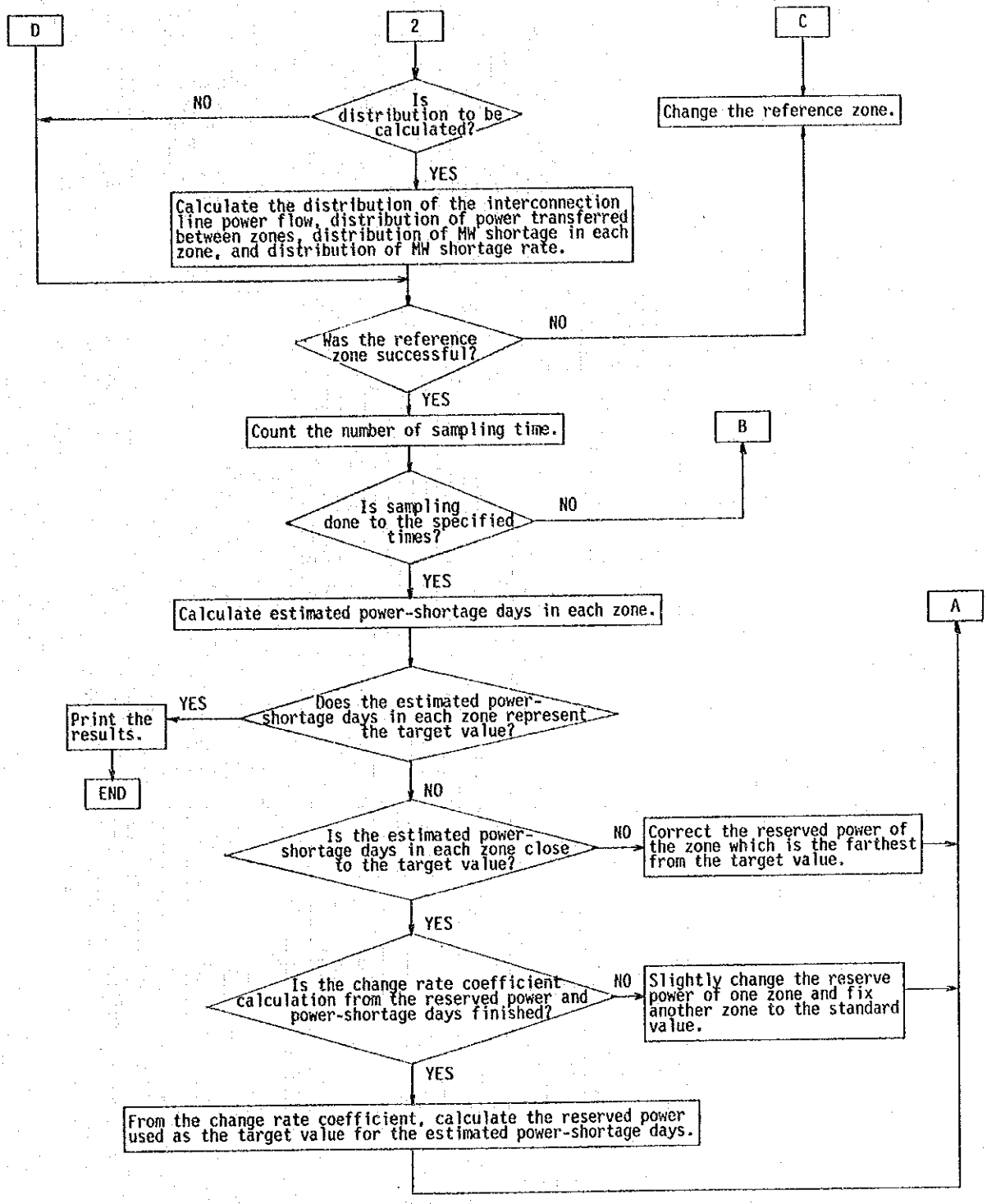


Fig. 6-2 Flow Diagram of Interconnected System Reliability (3/3)

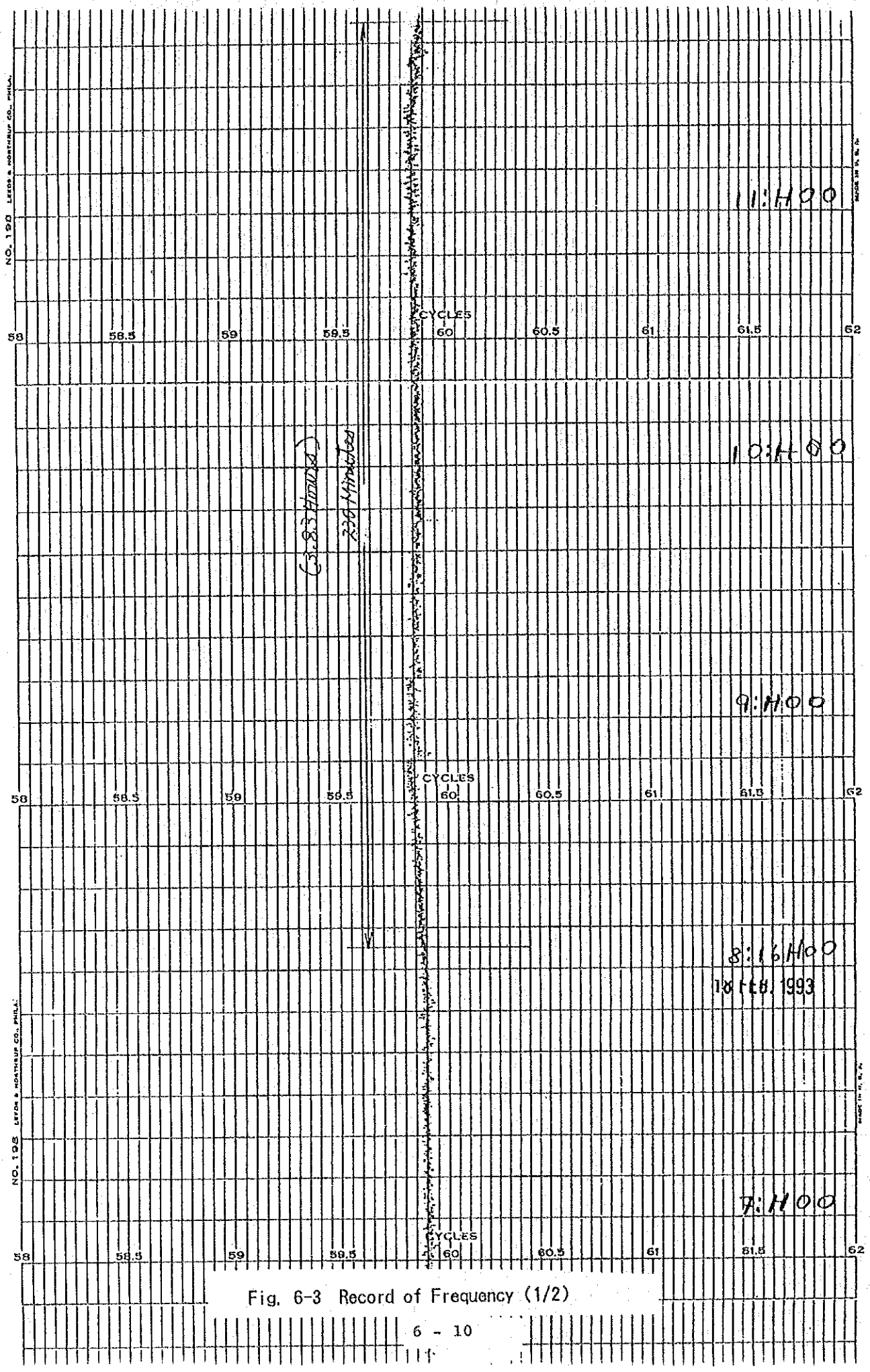


Fig. 6-3 Record of Frequency (1/2)

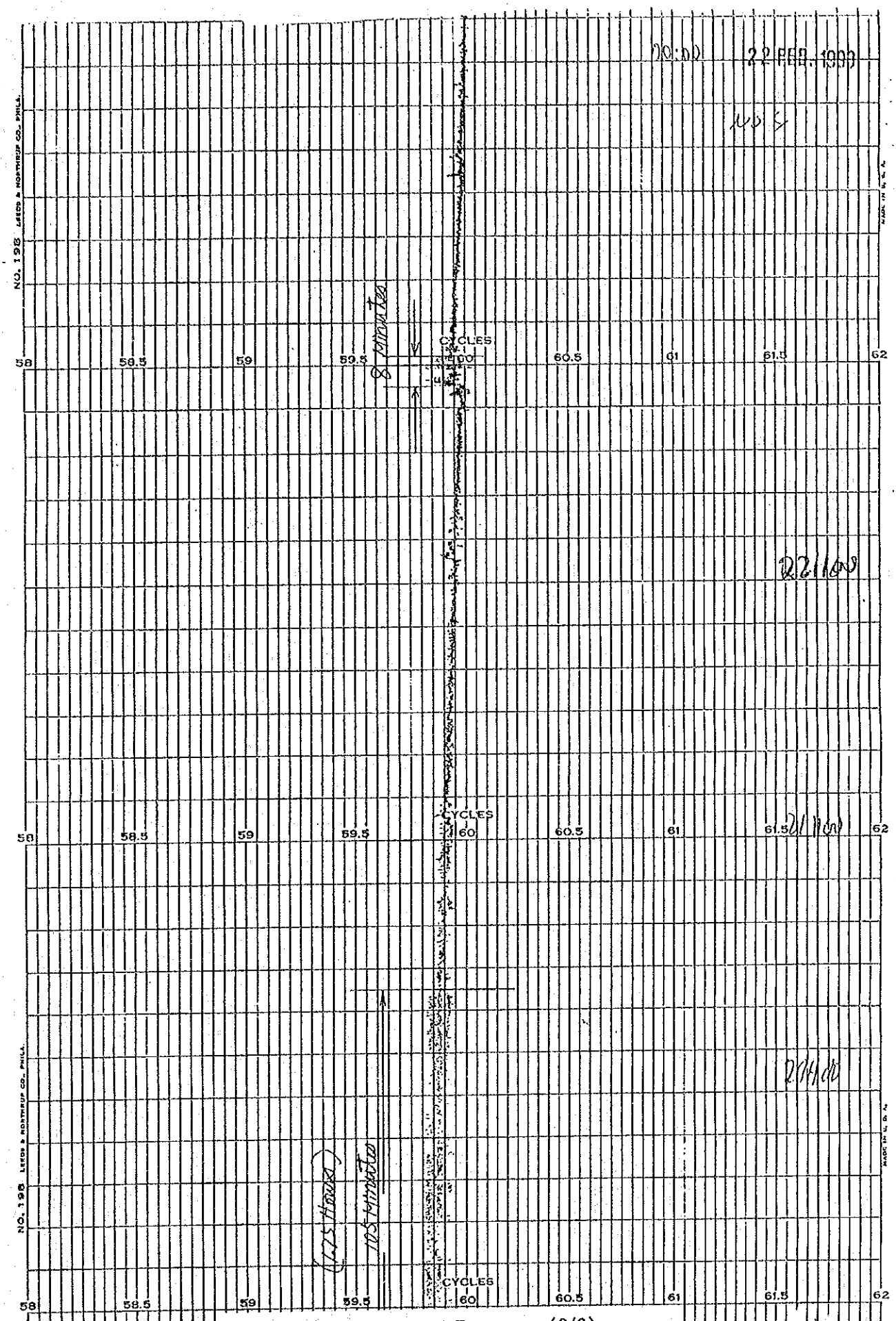


Fig. 6-3 Record of Frequency (2/2)

CONTENTS

CHAPTER 7 LOAD DISPATCHING DUTIES AND PROTECTIVE RELAY SYSTEM

7.1 Load Dispatching Duty and Power System Operation

7.1.1 Current Conditions of SNI

(1) Frequency Control

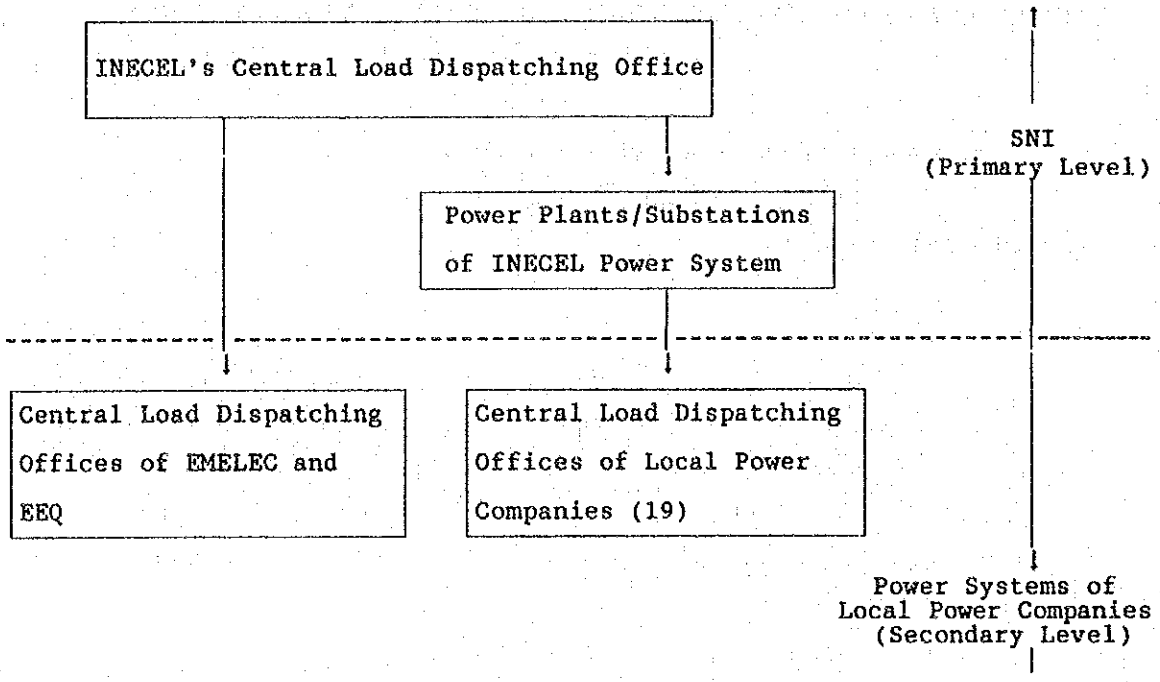
In Ecuador, there are few large loads that fluctuates and disturbs the balance of supply power in a short period, and relatively stable power system operation is realized by the governor-free operation of hydroelectric power plants.

(2) Voltage and Reactive Power Control

Concerning the current performance of voltage and reactive power control in SNI, 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.

7.1.2 Current Conditions of Load Dispatching Duties

The load dispatching command system of current SNI, as of March, 1993, is organized as illustrated on the next page.



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.

(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.

(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

7.2.1 New Load Dispatching Command Facility

(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
  2) Voltage Monitoring
  3) Reliability Monitoring
(b) Planning Duties
(c) Logging and Statistics Duties
(d) Education and Training of Operators

(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

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. (refer to Fig. 7-1)

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.

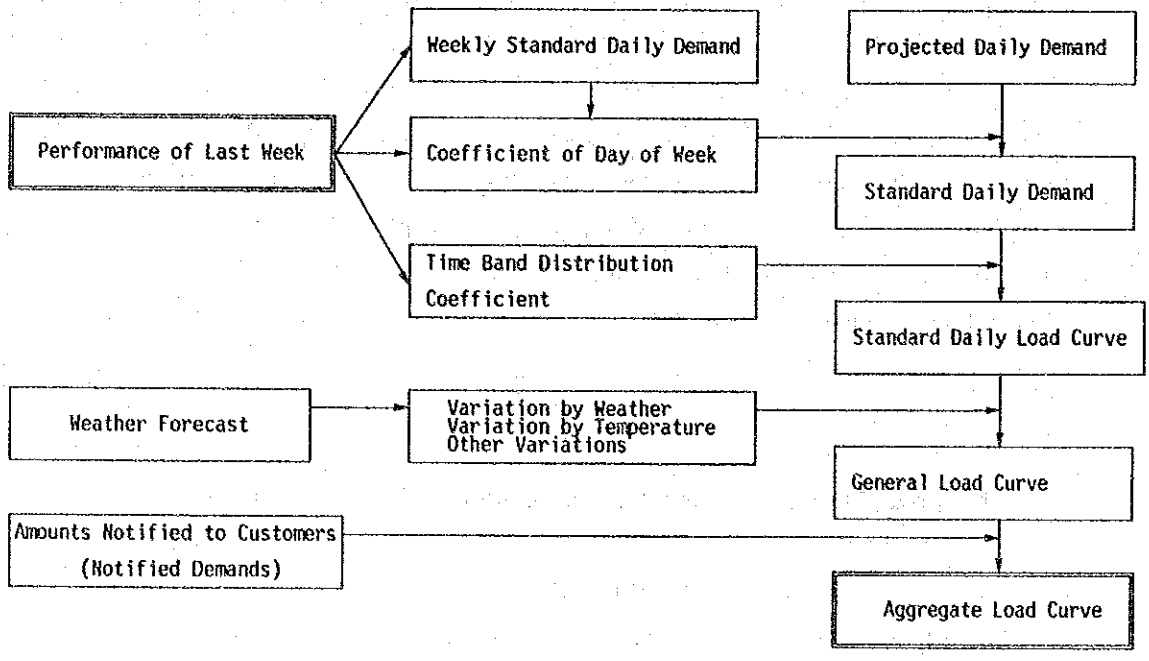
An exclusive communication system for electric power operation is

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.

7.2.4 Demand Projection and Power Generation Plan

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 in daily load dispatching operations, 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.

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.

(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.

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

(3) Fault Statistics of SNI Power System

The fault statistics of SNI is based on INCEL's data of 1991, 1992.

(a) Past Trend of System Faults

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).

(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, were 0 fault on 230 kV lines and only 1 fault on 138 kV lines in 1991.

In 1992, 0 fault occurred on 230 kV lines, and 8 faults on 138 kV lines.

(d) Considerations Based on Power System Fault Statistics

(i) Clarification of Power System Fault Phenomenal

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.

(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 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

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

(a) In the 230 kV transmission systems, the main protection and back-up protection, including their instrument transformers, are made of independent circuits.

(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 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.

(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

(a) the relays operate by the load impedances, and

(b) the operation time coordinations are maintained between adjacent line sections.

The result of this study has any particular problems.

(4) Considerations on Protective Relay Systems

In 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.

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.

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.

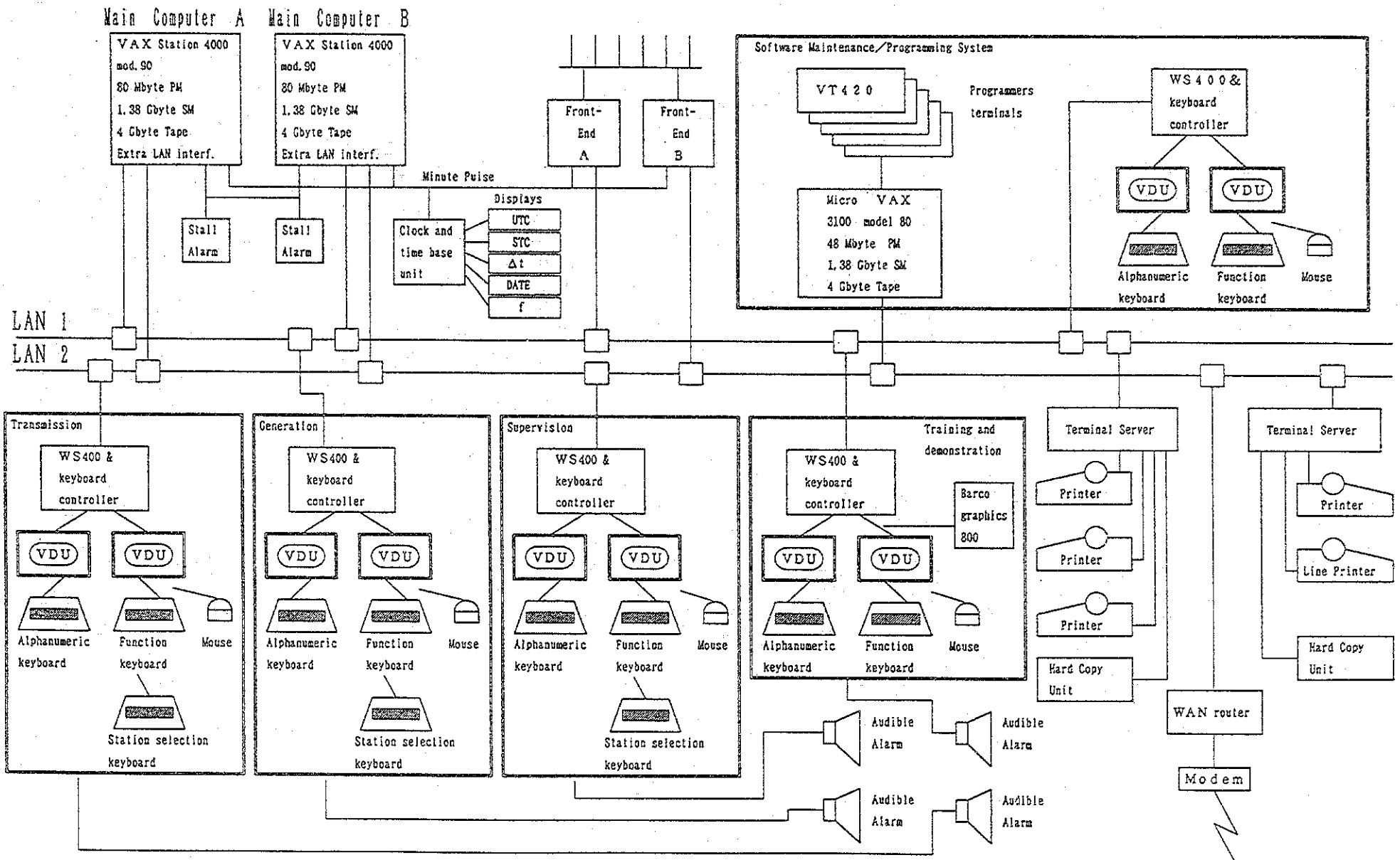


Fig 7-1 INECEL National Energy Control Center Central System

CONTENTS

CHAPTER 8 POWER FACILITIES EXPANSION PLAN

In this chapter, the expansion plan up to 2003 for the power generation, the power transmission line and the substation facilities, based on the power system analysis and supply reliability analysis conducted by the JICA investigation mission, which in turn is based on the development plan of the electric power facilities of INECEL, is described.

8.1 Power Generation Facility

8.1.1 Selection of Facility Expansion Plan

In selecting the optimum facility expansion plan, the computer models in its study of the master plan by INECEL were utilized. With the model which allows year by year evaluation of expansion, and which allows electric system simulation study for the annual demand compliance possibility of various facility expansion scenarios, the model for sequential generation and the model for operation simulation, the setting of the current values of the annual expenses of the representative expansion proposals and plans was possible.

8.1.2 Power Generation Facility Expansion Plan

(1) Existing power generation facilities

SNI comprises the facilities of INECEL and other local power companies connected to the 230 kV circle grid, and as of January 1993, of the national total power generation capacity of 2,278.2 MW (hydroelectric: 1,470.1 MW, thermal power: 808.1 MW) the share of INECEL is 1,696.8 MW (hydroelectric: 1,300.2 MW, thermal power: 391.6 MW). (refer to 3.3.1 Power generation facilities)

(2) Power generation facilities under construction

(a) Gas turbine power stations of private power generation utilities

Motivated by the power deficit resulting from the abnormal water shortage in 1992, the construction of Electro Quil gas turbine power station, 75 MW (25 MW x 1 and 50 MW x 1) and Electro Quito gas turbine power station, 33 MW, was started for completion in 1993.

(b) Rehabilitation of thermal power stations

According to the recent survey on the thermal power generation facilities currently in operation belonging to regional power systems, the total installed output capacity is 304,789 kW and the maximum generation capacity is 248,900 kW, as of January 1993, and according to the survey on the thermal power generation facilities requiring rehabilitation, the total installed output capacity is 111,724 kW and the maximum available generation capacity is 89,000 kW.

The rehabilitation work is scheduled for completion within 1993, to increase the power output total of SNI.

(c) Gas turbine power stations of INECEL

INECEL reviewed the power development plan up to 1996, and as a result, decided to construct two emergency gas turbine power stations, 30.9 MW and 80 MW, by December 1993, and according to a technology-economy study, Estero Salado power station in Guayaquil City and SNI Pascuales power station were selected as the sites of these gas turbine power units.

With these gas turbine power generation units to be incorporated into SNI, sufficient power will be supplied

during the water shortage months of January and February in 1994, to create great reliability and assurance for SNI.

Since December 1993, Estero Salado Power Station has been under commercial operation, but Pascuales Power Station has been in course of construction and will be put into operation by December 1994.

(3) Power generation facility development plan

For the purpose of meeting the power demand during the period from 1993 to 2004, the following prioritized development plans are recommended as a JICA proposal, as a minimum cost power generation facility plan. This JICA plan is based on the INECEL master plan with some modification made in consideration of the supply-demand balance (kWh).

Project Name	Station Output	Operation Start Year
T. gas (Estero Salado)	30.9	1993
Rehabilitation - Diesel	62.5	
Rehabilitation - Bunker	49.2	
T. gas (Electro Quil)[1)]	75.0	
T. gas (Electro Quito)[1)]	33.0	
T. gas (Pascuales)	80.0	
Rehabilitation (Estero Salado)	146.0	
T. Vapor (Trinitaria)	80.0	1994
T. gas (Machala)	125.0	1995
Daule Peripa[2)]	130.0	1996
T. vapor (Manta)	140.0	
T. vapor	125.0	1997
San Francisco[2)]	230.0	1999
T. gas (Santa Rosa)	80.0	2000
Mazar[2)]	180.0	2001
Toachi[2)]	150.0	2003
T. vapor (Santa Elena)	125.0	2004

Note: 1) Power facility of private utilities, 2) Hydroelectric power station

8.2 Transmission Line and Substation Expansion Plan

(1) The transmission line and substation expansion plan for the immediate 10 years is divided to the short-term plan (1993 to 1995), the medium-term plan (1996 to 1998) and the long term plan (1993 to 2002). These plans are described below.

Project Name	Commissioning Year
A. Short Term Plan	
1. SNI Phase C	1994
2. SNI Phase D1	1994
3. SNI Phase D2	1995
4. Cuenca - Limon T/L	1993
5. Portoviejeo S/S Expansion	1994
6. SNI S/S Expansion	1995
7. Agoyán S/S 138 kV 1 Bay Expansion	1994
8. Puyo - Tena - Coca T/L	1995
9. Pascuales G/T, T/L	1994
10. Machala G/T, T/L	1995
11. Trinitaria V/T, T/L	1996
B. Medium Term Plan	
1. Milagro - Machala 230 kV/T/L	1996
2. Daule P. - Chone 138 kV T/L	1997
3. Cuenca S/S Transformer 40 MVA	1997
4. Guayaquil S/S Transformer 50 MVA	1996
5. Cuenca - Loja T/L 2nd circuit	1998
6. Manta V/T, T/L	1997
C. Long Term Plan	
1. S. Francisco - Totoras T/L	1999
2. Sta. Rosa - Pōmasqui T/L	2000
3. Guayaquil S/S Transformer 125 MVA	2000
4. Mulalo S/S Transformer 66 MVA	2000
5. Coca. Tena S/S Expansion	2001
6. GT 2000 T/L	2001
7. Mazar H/P 138 kV 5 Bay	2001
8. Mazar - Cuenca T/L	2001
9. Toachi H/P 230 kV 4 Bay	2002
10. Pascuales - Sta. Elena 138 kV T/L	2001

(2) Improvement plan of Substation Facilities

There are some substations in the northern regions of SNI where it is difficult to maintain the normal operating voltage. It seems that the on-load tap changers have to be installed in these substations, and the phase compensating condensers must be installed on the busses or the tertiary windings of transformers in other substations as shown below.

Transformer Tap Positions and Phase Compensating Condensers

Substation Name	1998	2003
Transformer Tap		
Selva Alegre	105%	110%
Chillo Gallo	105%	110%
Kennedy	105%	110%
No. 18	105%	110%
No. 19	105%	110%
Pomasqui	110%	110%
Chillo Gallo	-	110%
Tena	-	105%
Ambato	-	105%
Phase Compensating Condenser		
Vicentina	12 MVar	12 MVar
Salitral	36 MVar	36 MVar
Pascuales	36 MVar	36 MVar
Santa Rosa	36 MVar	36 MVar
Ibarra	-	18 MVar

Note: The phase compensating condensers are composed of single phase condensers, and the condensers of each phase are connected by a star connection, and a series reactor is inserted at the neutral point.

8.3 Construction Schedule and Construction Cost

(1) Power Generating Facilities

The JICA Plan for power generation and supply, which has been designed to meet the power demand increase during the period from 1992 to 2002, is described in the Power Generation Facility Expansion Plan of Section 8.1. It is required to somewhat revise the schedule dates of commissioning of power plants in this Plan, considering the current progress in construction works and fund preparations. The revised construction schedule is presented in Table 8-1, and the construction costs and the investment schedule are presented in Table 8-2.

In reference to this modified construction schedule, there will be a period during which the supply energy falls short of the energy demand from 1994 to 1998. During this period, power supply interruptions will occur frequently during the dry season if it becomes difficult to secure sufficient energy supply by hydroelectric plants such as Paute. Such a situation could make it difficult to secure sufficient level of energy supply reliability, thereby seriously impeding the social and economic development of this nation.

In view of this situation, it is required to make all efforts on the early procurement of construction funds and assurance of construction schedule, so that the Power Generation Facility Expansion Plan is implemented according to the original schedule.

(2) Transmission and Substation Facilities

The Transmission and Substation Facilities Expansion Plan of SNI is as presented in Section 8.2 The schedules of this series of expansion plans is presented in Table 8-3, and the necessary investment schedule is presented in Table 8-4.

This Expansion Plan requires a total funding of US$ 110,682,000 for the 10 year period from 1994 to 2003.

Table 8 - 1 Construction Schedule of Powr Generation Facilities

Project	Year												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
T. Gas (Pascuales)		Operation ▼											
T. Gas (Machala)	Construction ▼		Operation ▼										
T. Vapor (Trinitaria)	Construction ▼			Operation ▼									
T. Vapor (Manta)		Construction ▼			Operation ▼								
Hydro (Daule Peripa)	Completion of Design ▼	Finance ▼	Construction ▼			Operation ▼							
T. Vapor (-)		Construction ▼				Operaton ▼							
Hydro (S. Francisco)		Finance ▼	Const-ruction ▼				Operation ▼						
T. Gas (Santa Rosa)					Finance ▼	Construction ▼		Operation ▼					
Hydro (Mazar)		Completion of Design ▼	Finance ▼	Construction ▼									
Hydro (Toachi)				Completion of Design ▼	Finance ▼	Construction ▼				Operation ▼			
T. Vapor (St. Elena)						Finance ▼	Construction ▼					Operation ▼	

Table 8 - 2 Investment Schedule of Power Facilities Plan

Unit: USDollars

Project	Operation Year	Installed Capacity (MW)	Total Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
T.Gas (Pascuales)	94/12	80	30,826	30,826										
T.Gas (Machala)	95/12	80	30,826	27,743	3,083									
T. Vapor (Trinitaria)	96/12	125	141,987	63,895	63,895	14,199								
T. Vapor (Manta)	97/12	270	178,878		30,398	50,066	80,464	17,880						
Hydro (Daule Peripa)	98/12	130	-	-	-	-	-							
T. Vapor (-)	98/12	80	141,989		24,138	39,757	63,895	14,199						
Hydro (S.Francisco)	99/12	230	195,867		7,320	45,589	56,039	58,015	28,904					
T.Gas (Santa Rosa)	2000/12	80	30,826						27,743	3,083				
Hydro (Mazar)	01/12	180	308,999				16,890	53,439	110,214	90,819	37,637			
Hydro (Toachi)	03/12	150	229,840						39,093	45,968	57,400	68,952	18,387	
T. Vapor (St. Elena)	04/12	125	141,989								24,138	39,757	63,895	14,199
Total			1,431,959	122,464	128,834	149,611	217,288	143,533	205,934	139,870	119,235	108,709	82,282	14,199

Table 8-3 Construction Schedule of SNI Transmission Line and Substation

Project	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Note
A. Short Term Plan :											
1. SNI Phase C											
2. SNI Phase D1											
3. SNI Phase D2											
4. Cuenca - Limon T/L											Completed in 1993
5. Portoviejo S/S Expansion											Completed in 1993
6. SNI S/Ss Expansion											
7. Agoyan S/S 138kV 1 Bay Expansion											
8. Puyo - Tena - Coca T/L											
9. Pascuales G/T, T/L											Completed in 1993
10. Machala G/T, T/L											
11. Trinitaria V/T, T/L											
B. Medium Term Plan :											
1. Milagro - Machala 230kV T/L											
2. Daule P - Chone 138kV T/L											
3. Cuenca S/S Transformer 60 MVA											
4. Pascuales S/S Transformer 90MVA											
5. Cuenca - Loja 2nd Circuit T/L											
6. Manta V/T, T/L											
C. Long Term Plan :											
1. S. Francisco - Totoras T/L											
2. Sta. Rosa - Pomasqui T/L											
3. Pascuales S/S Transformer 225 MVA											
4. Mulalo S/S Transformer 40 MVA											
5. Coca, Tena S/S Expansion											
6. G/T 2001 T/L											
7. Mazar H/P 138kV 5 Bay											
8. Mazar - Cuenca T/L											
9. Toachi H/P 230kV 4 Bay											
10. Pascuales - Sta. Elena 138kV T/L											

Table 8 - 4 Investment Schedule of SNI Transmission Line and Substation (1/2)

Unit : 10^3US$
Exchage rate: 1US$=1,283 Sucres(Jan/1992)

Project	Budget Total	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Note
A. Short Term Plan												
1. SNI Phase C	1,048	1,048										
2. SNI Phase D1	926	443	483									
3. SNI Phase D2	11,169	8,724	2,445									
4. Cuenca - Limon T/L	0											Completed in 1993
5. Portoviejo S/S Expansion	0											Completed in 1993
6. SNI S/Ss Expansion	6,400	6,400										
7. Agoyán S/S 138kV 1 Bay Expansion	758	591	167									
8. Puyo - Tena - Coca T/L	13,075	9,134	3,941									
9. Pascuales G/T, T/L	0											Completed in 1993
10. Machala G/T, T/L	1,343	1,343										
11. Trinitaria V/T, T/L	2,089	1,257	832									
B. Medium Term Plan:												
1. Milagro-Machala 230kV T/L	14,553	948	7,350	3,334	2,921							
2. Daule P. - Chone 138kV T/L	5,287		289	3,532	1,466							
3. Cuenca S/S Transformer 60 MVA	1,651		98	1,125	428							
4. Pascuales S/S Transformer 90 MVA	1,971	119	1,338	514								
5. Cuenca - Loja 2nd circuit T/L	3,383			209	2,302	872						
6. Manta V/T, T/L	4,819			285	3,278	1,256						

Table 8 - 4 Investment Schedule of SNI Transmission Line and Substation (2/2)

Unit : 10^3US$
Exchage rate: 1US$=1,283 Sucres(Jan/1992)

Project	Budget	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Note
	Total											
C. Long Term Plan:												
1. S. Francisco - Totoras T/L	8,189				493	5,574	2,122					
2. Sta. Rosa - Pomasqui T/L	11,608				711	5,558	3,028	2,311				
3. Pascuales S/S Transformer 225 MVA	3,368				236	1,815	672	645				
4. Mulalo S/S Transformer 40 MVA	1,523					96	1,035	392				
5. Coca, Tena S/S Expansion	2,885						107	1,766	1,012			
6. G/T 2001 T/L	1,319						789	530				
7. Mazar H/P 138kV 5 Bay	2,408							147	1,635	626		
8. Mazar - Cuenca T/L	2,778						162	1,891	725			
9. Toachi H/P 230kV 4 Bay	1,772										1,772	
10. Pascuales - Sta. Elena 138kV T/L	6,360						382	4,327	1,651			
Total	110,682	30,007	16,943	8,999	11,835	15,171	8,297	12,009	5,023	626	1,772	

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