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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

INSTITUTO ECUATORIANO DE ELECTRIFICACION (INECEL)
THE REPUBLIC OF ECUADOR

STUDY
ON
SERVICE RELIABILITY IMPROVEMENT PROJECT
OF
NATIONAL INTERCONNECTED SYSTEM (SNI)

FINAL REPORT

JULY 1994

ELECTRIC POWER DEVELOPMENT CO., LTD.

PREFACE

In response to a request from the Government of the Republic of Ecuador, the Government of Japan decided to conduct a master plan study on Service Reliability Improvement Project of National Interconnected System (SNI) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Ecuador a study team headed by Mr. Katsuhiko Yamamoto of Electric Power Development Co., Ltd. five times during the period from February 1993 to March 1994.

The team held discussion on the project with the officials concerned of the Government of the Republic of Ecuador and conducted field survey at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Ecuador for their close cooperation extended to the team.

July, 1994

Kensuke Yanagiya
President
Japan International Cooperation Agency

July, 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya,

Letter of Transmittal

We are pleased to submit to you the Final Report on the National Interconnected System Service Reliability Improvement Study for the Republic of Ecuador.

In this Study, the existing facilities of the National Interconnected System of the Republic of Ecuador (SNI) have been examined, its future plan and system reliability have been evaluated, the survey tasks for the power system reliability improvement have been conducted through site surveys and domestic works, the improvement plans for existing power facilities and the future plans have been reviewed, and the priority of the commencement of projects has been studied.

This report consists of two volumes, the main text and the summary. This report presents the long ranged plan for power facility expansion, which is based on the survey of site conditions, the problems with the existing power systems which have been identified, and a sufficient level of power supply reliability with respect to future growth of power consumption. Therefore, it is deemed important to assure the implementation of this plan in order to secure the power system reliability.

We wish to take this opportunity to express our sincere gratitude to your Agency, Japanese Embassy in Ecuador, and governmental agencies of the Republic of Ecuador and INECEL.

With we sincere wish to have this Study contribute to the future development of the Republic of Ecuador, I am,

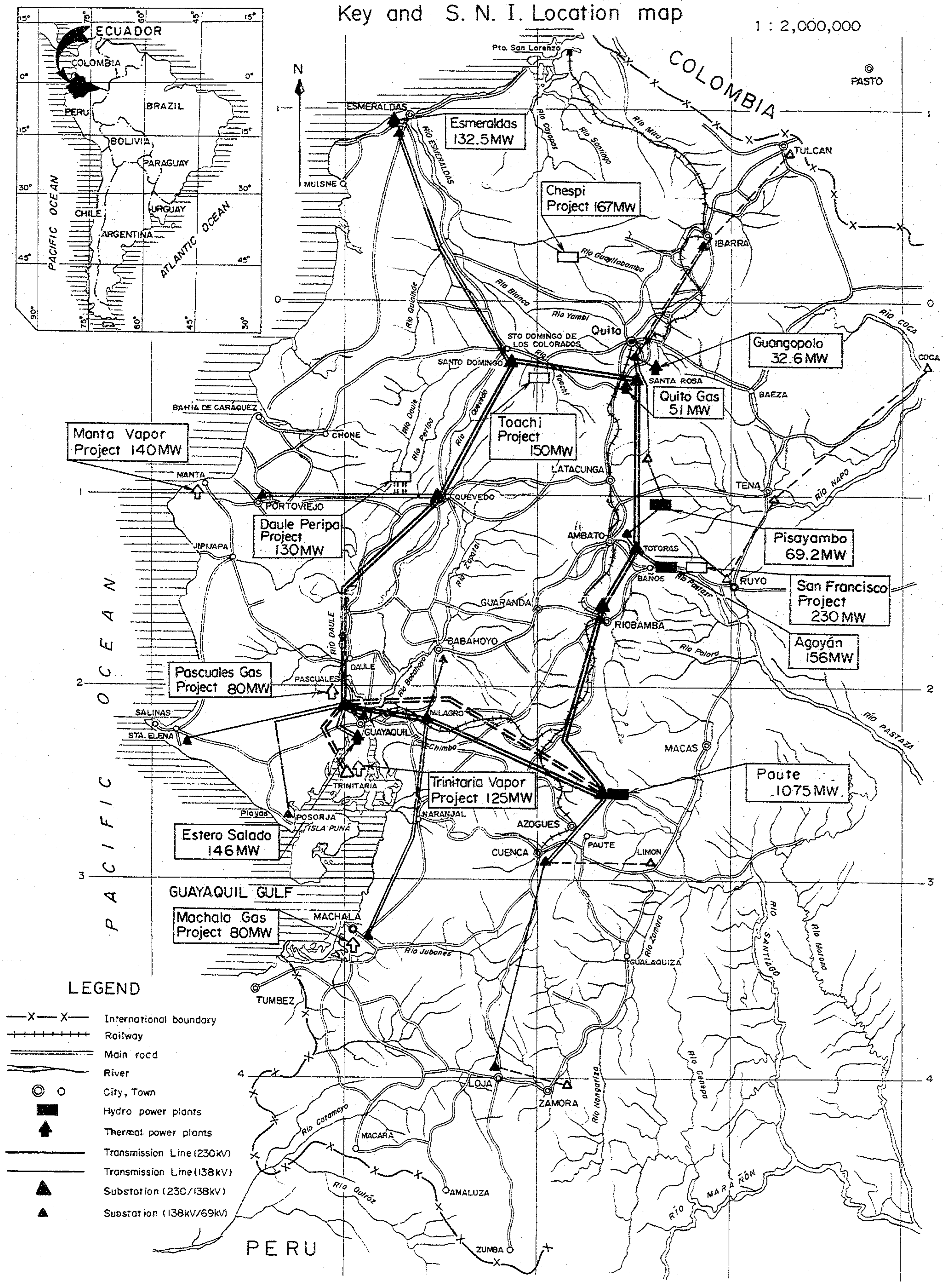
Yours truly,

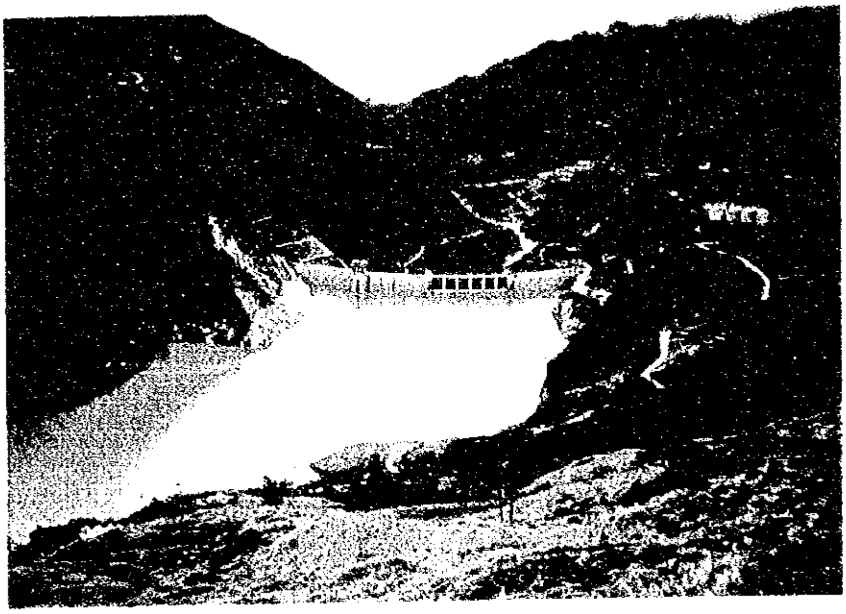
山本克彦

Katsuhiko Yamamoto
Team Leader
National Interconnected System Service
Reliability Improvement Study Team
for the Republic of Ecuador

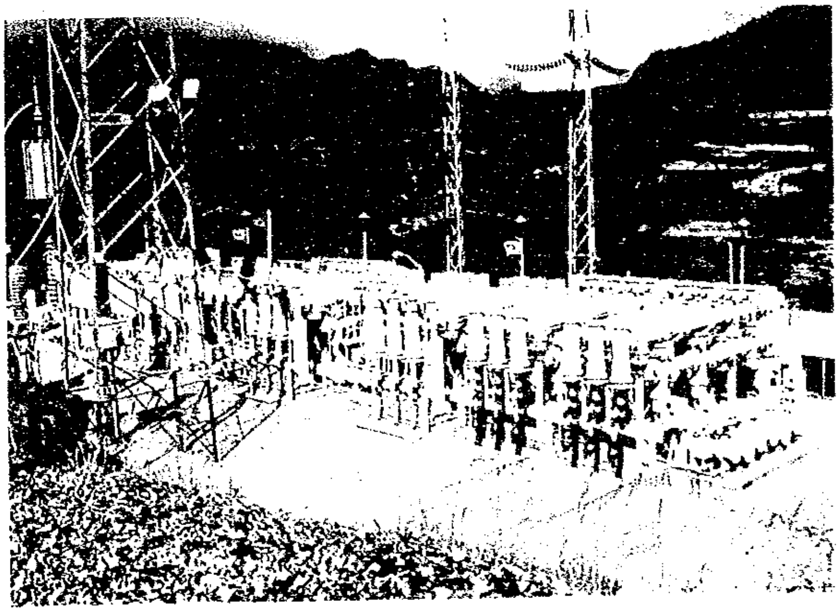
Key and S. N. I. Location map

1 : 2,000,000

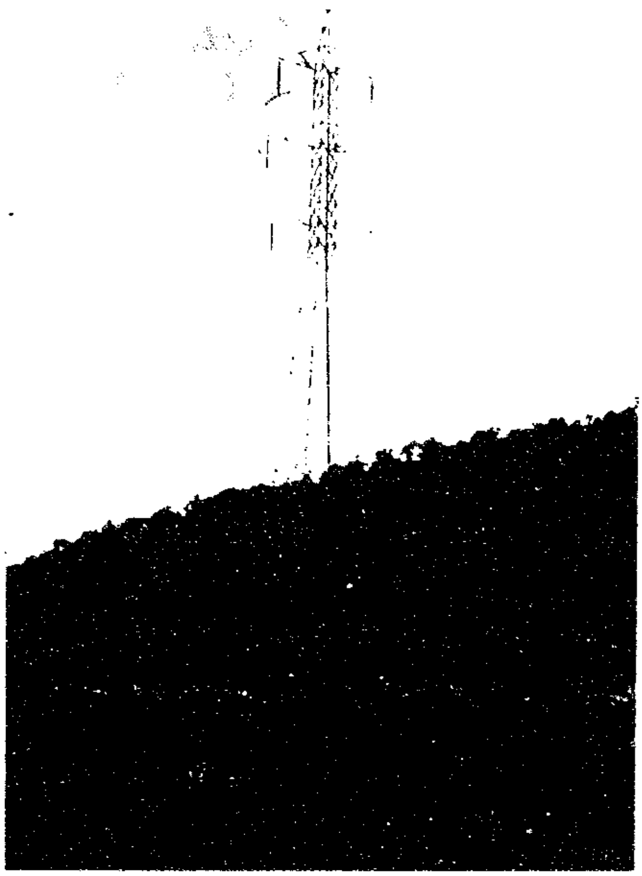




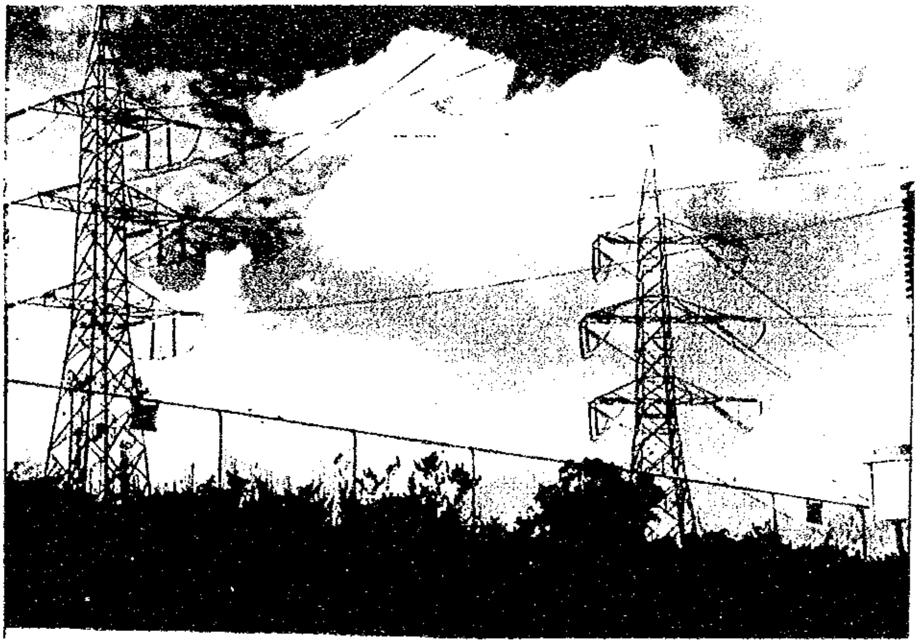
Reservoir of Paute Power Plant of SNI



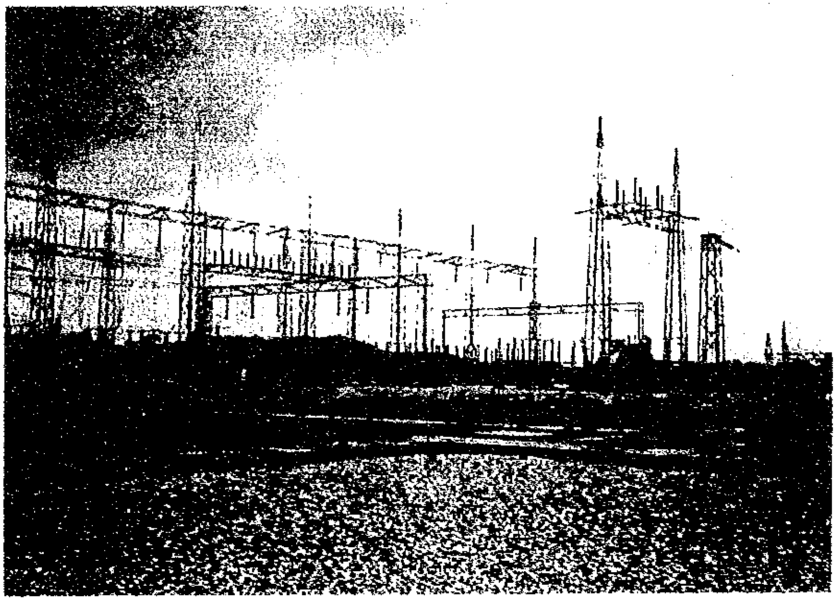
Out door substation of Paute Power Plant of SNI



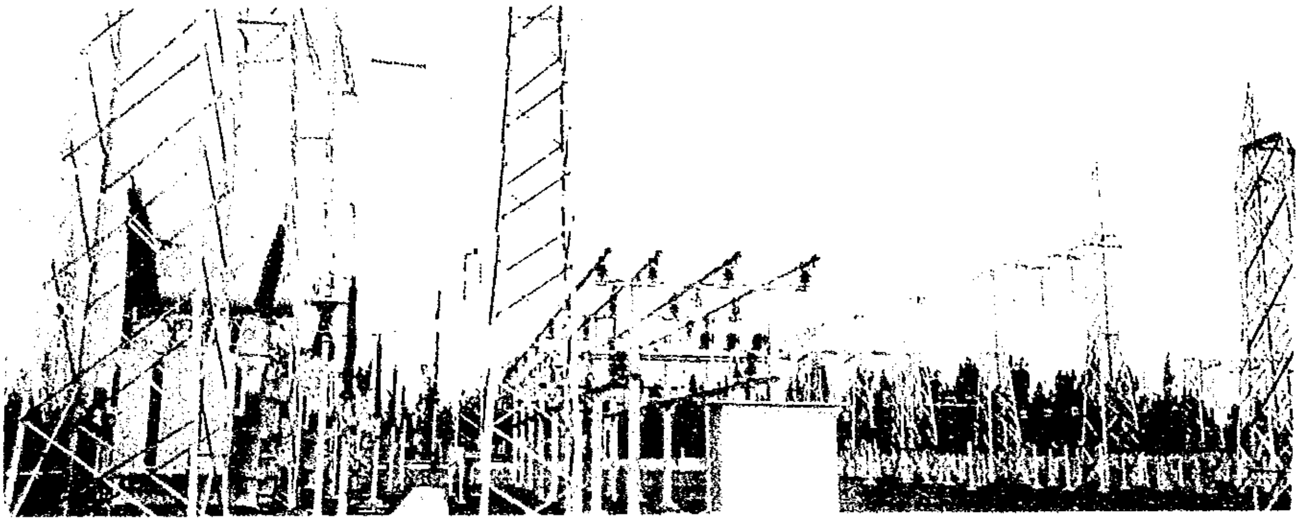
230 kV Transmission Line of SNI



230 kV Transmission Line of SNI
(The suburbs of Quito city)



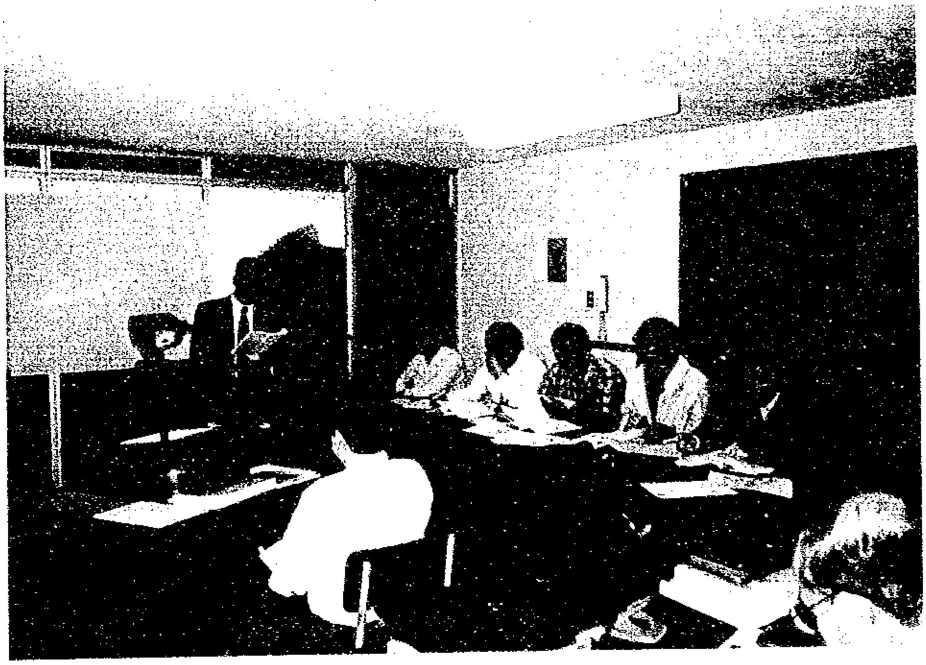
Pascuales Substation (230 kV)
(Guayaquil city)



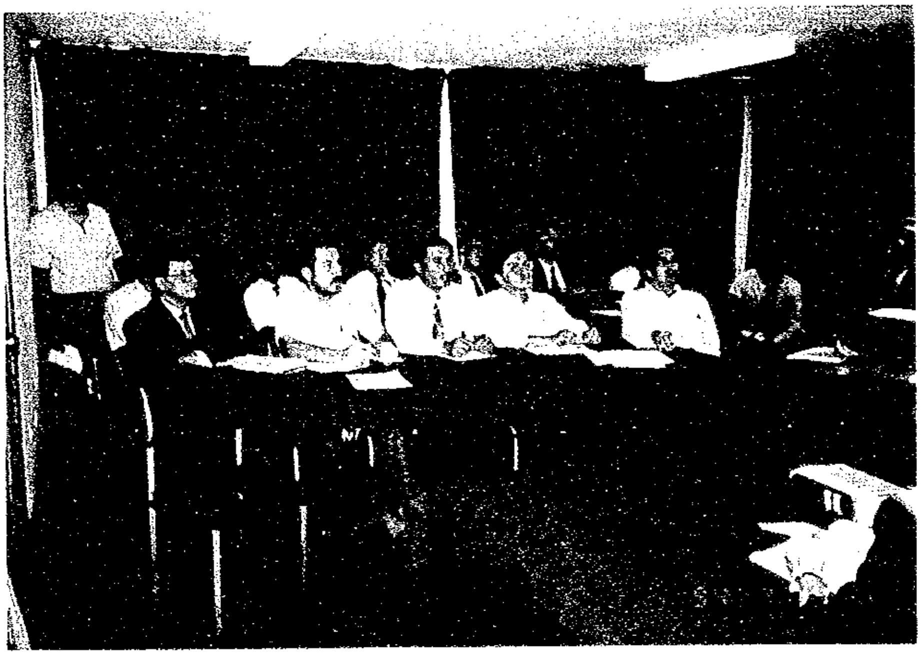
Totoras Substation (230 kV)

Technical Transfer
(Application of a personal computer and
Software donated by JICA)

Technical Transfer
(Operation of a personal computer and
Software donated by JICA)



Seminar of Technical Transfer



Seminar of Technical Transfer

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CONCLUSION AND RECOMMENDATIONS

CONCLUSION AND RECOMMENDATIONS

1. CONCLUSION

1.1 Conditions of Electricity

1.1.1 Power generation Facility

As of January, 1993, there are 2,278.2MW power generation facilities in SNI. Classified by corporation, INECEL generates 74.26% with local electric power companies generating 25.74%. Classified by power generation type, hydro power plants generate 64.5% with thermal power plants generating 35.5%.

The total power generation facility output increased approx. 4 times over the 10 years 1971/1981 and increased approx. 2.2 times in the 10 years 1981/1991.

As waterflow decreases in Ecuador during the dry season from November to February, the secured output of the hydro power plants drops to 1,209.4MW against a facility output of 1,470.1MW.

Also, the potential output of the thermal power plants has declined to 583.2MW against a facility output of 808.1MW due to inadequate maintenance. This provides a max. potential power generation of 1,792.6MW throughout the entire SNI, which is equivalent to 78.7% of the total facility output.

Ecuador's electricity consumption peaks in December. However, December's rainfall is very slight and the subsequent power shortfall provides a serious problem.

The Paute Hydro Power Plant is the main hydro power plant in SNI. This plant has a facility output of 1,075MW, representing 47% of the total SNI facility output (2,278.2MW), or 73% of that of the whole hydro power generation facility.

The potential power generation energy is 5,366.9GWh which is 50% of the total potential generation capacity, or 71% of the potential hydro power generation energy. Therefore, the total supply capacity of the SNI depends on the Paute Hydro Power Plant so much.

The effective reservoir capacity of the Paute Hydro Power Plant is 100,000,000m^3. (90,000,000m^3 as of the end of 1992) This is enough for 122 hours or approx. 5 days operation only, assuming the plant is operated at a total facility output of 1,075MW.

Approximately 3 million cubic meters of sedimentation accumulates every year within the dam. A dredging vessel (min. removal capacity/year; 500,000m^3 or 150m^3/h) has been operated since 1991 and removes approx. 1 million cubic meters of sediment annually. Thus, supply shortage (kW and kWh) in the dry season becomes a serious problem.

The major hydro power generation facilities belong to the Paute, Agoyán, and Pisayambo hydro power plants, all of which are located at the upstream reaches of the Amazon River. Their locations are concentrated and it is, therefore, necessary to disperse the plants appropriately throughout SNI. Such dispersal would (a) eliminate supply shortages during drought periods, (b) ensure power supply despite facility failure, and (c) increase transmission facilities to ensure supply not only under normal conditions, but also in the case of accidents.

In the majority of instances, the thermal power generation facilities are old. Adequate repair and maintenance have not been conducted due to shortages of auxiliary parts, thereby disabling the retention of sufficient facility output.

In the case of facilities owned by local electric companies, the related companies plan to carry out recovery measures in the near future.

Also, some gas turbine power plants such as Electro Quil (25MW x 1, 50MW x 1) and Electro Quito (33MW x 1) are under construction. These will be operated by a new company in 1993. These new power plants are countermeasures against power shortage due to the abnormally inadequate rainfall of 1992.

1.1.2 Power Transmission and Substation Facility

The electric system is installed as the SNI for the nationwide operation by INECEL. A loop of 230kV transmission lines form the trunk transmission network. A 138kV line links to the power stations or the local transmission lines.

There are 7 main substations with 230kV in SNI. Its total facility capacity is 1,451MVA, as of the end of 1992.

The facility capacity of the 138kV substations linked to these 7 substations is 1,618MVA. Each of three main substations with 230kV (Pascuales, Santa Rosa, Totoras) is equipped with one single phase auxiliary transformer. The Milagro, Sto. Domingo, and Quevedo substations share one single phase auxiliary unit. The Riobamba Substation, however, only has three single phase transformers with no auxiliary units. Of the substations with 138kV lines, the Santa Elena, Ibarra, and Loja substations have 3 phase autotransformers, sharing one auxiliary unit.

Since the demand for 138kV substations has increased, it is now time to consider installation of new units, including auxiliary units.

The routes of the 230kV and 138kV transmission lines forming the SNI are varied; a highly contaminated area along the Pacific coast, a high temperature/high humidity zone, along a large scale agricultural area in a tropical climate zone, and a mountainous area. Different maintenance methods are required for each area because the types of accident vary according to the local conditions.

1.2 Assumption of Demand for Electricity and Supply Plan

1.2.1 Demand Assumption

INECEL prepared long term demand assumption to the year 2010. In this study, we assumed the overall demand from a correlation between power consumption per capita and the economic growth ratio. Consequently, our assumed value was lower than INECEL's as a whole. However, ours did match the INECEL's relatively. Therefore, we use the INECEL's assumed demand, considering the margin for the demand/supply balance plan.

According to the assumed demand, the demand of 1,442MW (7,422GWh) of 1992 is expected to reach 1,991MW (10,462GWh) in 1998, and 2,595MW (13,654GWh) in the year 2003.

1.2.2 Power Supply Plan

As the result of this study, the firm output at the time cross section is 1,784MW (with the total install capacity of 2,278.2MW) as against the maximum demand of 1,442MW, and there is sufficient supply margin so long as the kW balance is concerned.

Concerning the annual kWh balance, however, the firm energy supply at the time cross section of 1992 is 6,875GWh, as against the maximum energy demand of 7,442GWh, that is, a supply shortage is excepted under INECEL's expansion plan. To deal with this situation, base thermal power plants such as Vapor will be required. However, this shortage have to be covered by gas thermal power plants which can be constructed with short lead time, and INECEL plans to construct gas thermal power plants in 1993 and 1994. There is no alternative to this plan in view of the short lead time.

The supply shortage in the kWh balance will continue after 1995. In dealing with the expected power supply shortage, INECEL's expansion plan is indispensable, and this plan must be implemented without delay. In addition to this plan, it will be required to construct a base thermal plant having 125MW capacity or so to supply additional kWh in 1997.

1.3 Power System Analysis

Although there was no particular problem with the short circuit current level and the overloading of transmission lines and transformers at each time section year of studies, concerning the operating voltage conditions in the 1993 time section, the operating voltage at a few substations in the northern region did not fell within the allowable range. Although the power system was stable in the 1993 time section, the system was near the stability limit.

In the study of 1993 time section, analytical studies were conducted on the actual power flow record at March time section. Even with no particular countermeasure, the above problems would be alleviated in 1998 and 2003 time sections as the transmission line from Paute to Pascuales is reinforced to 4 circuits, and the power development projects near Guayaquil and in the northern region are implemented according to INECEL's plan. And also Paute power station can operate nearly at the full output in June, the rainy season.

Year/Month	Output of Paute (MW)	Stability	
		1 cct	2 cct
1998. 6	1,008	O	X
	954	O	O
1998.12	915	O	O
2003. 6	954	O	X
	897	O	O
2003.12	798	O	O

However, some transformer tap changers (OLTC) and phase compensating condensers will be required in some substations in the northern region power system in 1998 and 2003 time sections in order to maintain voltage in steady state operations.

1.4 Supply Reliability Analysis

(1) LOLP 0.3 days/month of Supply Reliability will be secured up to 2003.

(2) An accumulation of data is not enough to make the most of software donated by JICA.

(3) Paute Hydroelectric Power Plant is a large scale hydroelectric power supply resource which accounts for 47% (1,075MW) of the total installed capacity of SNI of 2,279MW. And it has much influence on Supply Reliability. The outline of this hydroelectric power plant is as described below.

	Rated Output (MW)	Number of Units	Firm Output and Energy		Record of Energy Generation	Year of Commissioning
			(MW)	(GWh)		
Paute (Phase A&B)	500.0	5	438.5	2,456.7	3,481.8	1983
Paute (Phase C)	575.0	5	459.4	-	1,883.0	1992
Total	1,075.0	10	897.9	2,456.7	5,364.8	-

The proportions of the supplies of Paute Hydroelectric Power Plant in the total power supply of SNI are calculated based on the 1993 data for the dry season and presented below, together with the actual records of generation.

The total supply of SNI in 1993

Maximum power (MW): 1,532.0

Maximum energy (GWh): 7,868.0

The proportions of Paute in dry season and by actual records:

	Dry season	Actual record
For maximum power:	59%	70%
For maximum energy:	31%	68%

According to these data, the kW output in the dry season is short of actual record by 11% or a little less than 170MW, and the energy output in the dry season is short of actual record by 37% or a 2,900GWh. The shortage of 2,900GWh is equivalent to a thermal power plant of 330MW.

1.5 Load Dispatching Function and Protective Relay Systems

1.5.1 Load Dispatching Function

The load dispatching function is indispensable for systematic and efficient operation of power system, and the comprehensiveness of power system monitoring performance and promptness of response against power facility failures are the key factor in maintaining high supply reliability.

In attaining high supply reliability by load dispatching operations, suitable load dispatching organization and the automatic load dispatching systems supporting the dispatching operations are indispensable. Judging from the scale of the power system of SNI, a load dispatching organization having the central load dispatching office at Santa Rosa Substation premises at the top would be satisfactory. Concerning the automatic load dispatching systems, a system incorporating the first large scale computer in Ecuador is currently under construction, and this system is scheduled for commissioning in December, 1994. Although it is expected that more efficient load dispatching is expected with this system, the information transmission systems supplying this computer system as well as the load dispatching telephone lines will not be changed from the existing PLC systems, and this may leave some problems.

1.5.2 Protective Relay Systems

In the power systems of SNI, appropriate protective relay systems are being employed according to specific power system configurations, transmission line voltage classes and specific conditions of application. Concerning the relay systems for the 230kV systems, which are basically composed of parallel double circuit lines, the directional comparison system employing power line carrier are used.

The 138kV transmission lines are basically radial systems having parallel double circuit lines and single circuit lines, with single circuit loop systems adopted in certain sections. The protective relay systems are basically distance relays, and directional comparison relays and over-current relays are used in some sections.

Based on the study of operations of protective relay systems, several cases of protective relay malfunctions which caused power system faults have been found in the power system fault records of 1992 and 1993.

Although the proportion of power system faults caused by protective relay malfunctions is small in the total system faults, the details of the relay malfunctions are not known, and it is important to clarify these causes and prevent recurrence of such events, in view of the role of protective relays.

The settings of protective relays have been surveyed, but there was no particular problem.

1.6 Power Facility Expansion Plan

1.6.1 Power Generation Facilities

It is recommended, as the JICA's plan for power generation facility expansion to supply the demand for the period from 1992 to 2005, to develop the following power plants in the sequence illustrated.

Project Name	Installed Capacity	Year of Commissioning
(1) T. Gas (Estero Salado)	30.9	1993
(2) Rehabilitation - Diesel	62.5	
(3) Rehabilitation - Bunker	49.2	
(4) T. Gas (Electro Quil)[1)]	75.0	
(5) T. Gas (Electro Quito)[1)]	33.0	
(6) T. Gas (Pascuales)	80.0	
(7) Rehabilitation (Estero Salado)	146.0	
(8) T. Gas (Machala)	80.0	1994
(9) T. Vapor (Trinitaria)	125.0	1995
(10) Duale Peripa[2)]	130.0	1996
(11) T. Vapor (Manta)	140.0	
(12) T. Vapor	125.0	1997
(13) San Francisco[2)]	230.0	1999
(14) T. Gas (Santa Rosa)	80.0	2000
(15) Mazar[2)]	180.0	2001
(16) Toachi[2)]	150.0	2003
(17) T. Vapor (Santa Elena)	125.0	2004

Note: 1); Private power company facility, 2); hydroelectric power plant

1.6.2 Transmission and Substation Facilities

JICA's plan for expansion of transmission line and substation facilities for the period from 1993 to 2002, consistent to the power generation facility expansion plan, is as presented below.

Project Name	Year of Commissioning
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. Portoviejo S/S Expansion	1993
6. SNI S/S 138 kV Expansion	1995
7. Agoyán S/S 138 kV 1 Bay Expansion	1995
8. Puyo - Tena - Coca T/L	1995
9. Pascuales G/T, T/L	1993
10. Machala G/T, T/L	1994
11. Trinitaria V/T, T/L	1995
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 - Pomasqui T/L	2000
3. Guayaquil S/S Transformer 125 MVA	2000
4. Mulalo S/S Transformer 60 MVA	2000
5. Coca. Tena S/S Expansion	2001
6. G/T 2000 T/L	2000
7. Mazar H/P 138 kV 5 Bay	2001
8. Mazar - Cuenca T/L	2001
9. Toachi H/P 230 kV 4 Bay	2003
10. Pascuales - Sta. Elena 138 kV T/L	2001

1.6.3 Construction Cost

This Expansion Plan (period 1994 to 2003) requires a total funding of US$1,528,442,000. (Power facilities US$1,417,760,000, Transmission and Substation facilities US$110,682,000).

2. RECOMMENDATIONS

2.1 Assumption of Demand for Electricity and Supply Plan

(1) Regarding assumption of a long term demand to the year 2010, especially in the distant future, both the assumed value and actual value may differ significantly due to changes in national development plans, social conditions, and economic movement.

It is, therefore, necessary in the future to survey the actual demand and analyze the factors causing the errors between the assumed value and actual value.

Where significant changes are expected in demand for electricity in the future, the assumed demand must be reviewed.

(2) Should any power plant (especially the Paute Hydro Power Plant) not be operated at its rated output due to the dry season, the supply against demand will not provide marginal capacity and a supply shortfall, especially in kWh, is expected.

The regular maintenance and inspection are necessary as the preventive measures to ensure that all plants operate at their rated outputs. For the basic supply, this is especially important for the thermal power plants.

(3) According to INECEL data, the established output of the Paute Hydro Power Plant is approx. 890MW . This is calculated based on a 3 hour peak duration. However, the actual peak duration is 6 to 7 hours.

Since the Paute Hydro Power Plant provides approx. 47% of the total SNI facility output, the operation of this plant affects the supply significantly.

It is, therefore, necessary to review the supply and demand proportion of this plant within SNI and determine its firm output accordingly.

2.2 System Analysis

(1) In 2003, the phase compensating condenser with 18MVar will be required in Ibarra sub-station to keep the normal voltage.

(2) Some transformer tap changer (OLTC) will be required in the following substations in 1998, 2003.

1998:	Selva Alegre,	Chillo Gallo,	Kennedy,
	No. 18, No. 19,	Pomasqui	
2003:	Tena, Ambato		

2.3 Supply Reliability

(1) Thoroughness of operation rule of reservoir and securement of firm output of Paute Hydro Power Plant are indispensable.

(2) The present LOLP 0.3 days/month is desirable as an aim of supply reliability. In order to keep this, it is very necessary to reduce a rate of forced outages by maintaining existing facilities adequately and to develop new power sources on schedule.

(3) Improvement of accuracy is necessary in accumulation and management of data.

2.4 Load Dispatching Operations and Protective Relay Facilities

2.4.1 Load Dispatching Operations

(1) Load Dispatching System

Load dispatching is to direct the ever changing power system so that it operates systematically and uniformly. The load dispatching office must be able to send directions and be accessible under any circumstance. In emergencies such as abnormal weather or system failure the telephone line becomes congested. And it is common that the number of load dispatching instructions increase. Therefore, the delay of load dispatching instructions caused by telephone line failure will lower supply reliability. It is essential to install a direct telephone line between power plants, substations, and district load dispatching offices where instructions are sent directly.

(2) Data Transmission System

The system is to install a data logger type terminal at power plants and substations, etc., and connect it with the computer and modem (integrated modem) at the central load dispatching office. It is difficult to use it for transmission of telemeters where frequencies change continuously.

Therefore, to continuously indicate operation values such as system frequency, interconnecting line power flow and system voltage to recording meters or indicating instruments, and to closely monitor operations by a computer system it is necessary to use a data transmission system such as a Cyclic Digital Transmitter (CDT) which can send data continuously.

(3) Communication Method

In the future, the power system will expand greatly and will become more complex, and the data collected at the central load dispatching office will increase tremendously. To secure system reliability it will be necessary to change the protective relay into a micro carrier type one. Therefore, it will be necessary to employ a second communication method such as a micro wave radio network.

Because the Andes range runs north and south in the center of Ecuador and the large power source in the Amazon River Basin in the east is distant from large load centers, we recommend that the micro wave radio transmission method which can transmit long distances and is applicable in steep mountain areas be employed and used together with the existing PLC method.

(4) Power Supply Management

The main power source of SNI is the Paute hydro power plant which generates 47% of the entire installed capacity. The supply reliability is affected greatly by how Paute power station is operated.

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.

Considering the current power source structure, the kW and kWh shortages of the Paute power plant during the dry season will sharply lower the system's supply reliability.

It is necessary to analyze past river discharge data on the most dry year during the dry season, the 3-day average dryness (L3), etc., and set the minimum water reserve of the Paute reservoir, and include it in the operation rules. Although it may be not economical, it is also necessary to study and improve operation of existing thermal power plants such as Estero Salado and Esmeraldas, and include them in the base power source soon in order to retain the water reserve of Paute reservoir.

2.4.2 Protective Relay Facilities

The mission of protective relay facilities is to quickly and accurately detect trouble in its territory and eliminate the trouble, and also to prevent the expansion of the trouble by not reacting to trouble outside its territory.

With the expansion of the power system and the system structure becoming more complex it may be necessary to study a new protective relay method in order to improve protective relay reliability. For the operation of existing facilities, the followings are recommended.

(1) Grasping system failure

Use automatic system recorder (OSC), etc., to grasp what the trouble is and analyze the phenomenon to evaluate the protective relay facility and to prevent failures of power facilities such as the transmission line.

(2) Measure to prevent reoccurrence of protective relay failures

Failures due to defects of the protective relay facility will prevent it from doing its work. Therefore it is necessary to systematize the investigation for the cause and take measures to prevent the reoccurrence of similar failures.

(3) Protective relay facility maintenance

Protective relay failures due to protective relay or operation setting defects will affect the power system greatly.

Therefore, it is necessary to prevent failures caused by protective relay facility defects before it happens. To do this we must grasp its operation status by daily inspections, and perfect maintenance by periodically conducting operation characteristic and sequence tests to confirm and maintain the function of the protective relay.

2.5 Power Facilities Expansion Plan

2.5.1 Power Generating Facilities

In order to meet future increase of power demand it is necessary to construct new power sources as planned in the Power Generating Facility

Expansion Plan (JICA plan). But the commissioning time must be delayed considering the current status of construction fund procurement and the progress of the construction. Therefore we expect that between 1994 - 1998 there will be a shortage of energy supply against increased power demand that will continue for a long period of time. Therefore it is necessary for electric power related institutions and the government to immediately take the following measures to smoothly carry out electric power development plans.

(1) Procure funds and speed up construction of Machala gas turbine power plant planned to be commissioned in December, 1994.

(2) Procure construction funds for Trinitaria steam turbine power plant planned to be commissioned in December, 1995.

(3) Make procurement of funds definite so that Daule Peripa hydro power plant planned to be commissioned in December, 1996, will be constructed in the planned period.

(4) Construct a new steam turbine thermal power plant (125 MW) to be commissioned in December, 1997, in addition to the INECEL expansion plan to keep the energy (kWh) balance during droughts.

(5) Make construction fund procurement definite for the San Francisco hydro power plant project. In order for this power plant to be commissioned and incorporated into SNI by December, 1999, it is necessary to start construction by the end of 1994.

(6) Make procurement of funds for the execution design of the Mazar and Toachi hydro project concrete, and start the execution design early.

2.5.2 Transmission and Substation Facilities

(1) Concerning the projects in the transmission line and substation expansion plan, the construction project of SNI Phase D2, Paute-Pascuales-Trinitaria Transmission Line must be completed as soon

as possible due to the following reasons.

a) Although Paute Power Plant has a capacity of 1,075MW, this power plant can not be operated at an output near rated capacity because of the limit of transmission capacity.

The result of power system analysis indicates that the power plant can not be operated over 870MW with the current transmission line.

For this reason, the transmission lines between Paute-Milagro-Pascuales must be expanded (its capacity enlarged) at an early opportunity in order to effectively utilize the installed capacity of Paute Power Plant.

b) This transmission line is also required because the output of Trinitaria Thermal Power Plant (125MW), which is scheduled for commissioning in December of 1995, will be transmitted via Trinitaria Substation and Pascuales-Trinitaria Transmission line.

(2) In addition to the transmission line and substation expansion projects, the financing schedules and construction schedules for all projects in SNI or Subtransmission Plan which are related to the power plant facility expansion plans must be formulated, so that work schedules of the transmission line/substation projects are completely coordinated with the related power plant development projects.

2.5.3 Inspection and Maintenance of Existing Power Facilities

(1) Power plants

Aged power plants are increasing every year. Prolonging power plant life is a measure taken not only because closing existing plants or constructing new plants are difficult, but because it is more economical to repair and maintain existing power plants rather than building new ones. Although this measure is taken for reasons like equipments must be used longer than its designed life, conducting inspections and maintenance, and preventing failures will make the power supply more stable.

Currently, during the wet season the supply capability is sufficient if hydro power plants such as Paute are operating at rated output. But during droughts, if the base thermal plant fails, the energy supply (kWh) will become short. It is necessary to inspect and maintain the facilities carefully so that they will operate normally. To maintain a stable power supply it is essential to allot operation and maintenance expenses and keep spares ready.

Deterioration examination, preventive maintenance and facility improvement measures for power plants are explained in Table A-1-1 - A-1-5.

(2) Transmission and Substation Facilities

Unlike power plants it is difficult to stop transmission and substation facilities for a long period and conduct an overhaul. For stable operation of transmission and substation facilities, and to improve power supply reliability, it is necessary to monitor the equipment while in operation and prevent outages and prolong life using the collected data.

According to the INECEL outage statistics, the number of power supply outages per year is 8.7 for 230kV and 26.3 for 138kV transmission facilities, and 9 for 230/138kV and 12 for 138/69kV substations.

To improve power supply reliability of these transmission and substation facilities it is necessary to carefully inspect and maintain the equipments to prevent outages and make maintenance and control complete.

Measures to improve substation facility reliability are explained in Table A-1-7 - A-1-9 and transmission facility inspection chart is shown in Table A-1-10 - A-1-14.

(3) Spare Transformer

Concerning the spare transformers to be installed in major 230 kV substations of SNI, one unit of single phase spare transformer each is required at Milagro, Sto. Domingo and Quevedo Substations as the power demand increases in future. 3 phase transformer is recommended in adopting a spare transformer for 138kV substation, and this transformer must be used as a spare transformer which is common to several substations.

(4) The followings may be observed from analyzing outage statistics of transmission and substation facilities

a) Of the 230kV loop trunk line, the number of outages between Paute - Milagra is extremely high. It is necessary to find out the cause and take measures.

b) 138kV Pascuales - Santa Elena line and Pascuales - Posorja line, as mentioned earlier are highly polluted areas. Although the lines were shutdown often for scheduled maintenance between 1990 - 1991 the number of outages recorded was high. But although scheduled shutdown time decreased greatly in 1992, the number of outages also decreased greatly. This is due to the improvement of maintenance.

c) In high temperature heavy rainfall tropical climate areas such as around 138kV Santo Domingo - Esmeraldas line and Milagro - Machala line, the vegetation growing under the transmission line, like creepers, grows very fast. Banana, Abaka (Manila hemp) and coco palm which grow under transmission lines in large high-profit plantation area also grow very fast. The high temperature and these vegetation cause the lines to droop causing grounding failures. Lines also droop when airplanes spraying agricultural chemicals touch the lines. The outage rate is high. It is necessary to look into the causes and take measures to prevent them.

As explained, the type of outages and the method of maintenance differ depending on the area. As SNI transmission lines extend from substations in the mountain region to the tropical rain forest area in the east, it will become necessary to set new measures against accidents caused by animals and vegetation.

CHAPTER 1 INTRODUCTION

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CHAPTER 1 INTRODUCTION

1.1 Background of Study

Generally speaking, an electric power utility is one of the essential infrastructures of a nation for social and economic development, it is necessary to inexpensively supply high quality and high reliability electric power by its electric power utility according to the needs of electric energy consumers.

The electric power industry of the Republic of Ecuador (to be termed Ecuador hereinafter) is being operated by INECEL (INSTITUTO ECUATORIANO DE ELECTRIFICACION) under Ministry of Energy and Mine, the 19 local electric utility companies, and electric utility services managed by some local governments. (refer to Fig. 1-1)

INECEL maintains and operates the national interconnected system of Ecuador (Sistema Nacional Interconectado, to be termed SNI hereinafter). The development of SNI's major power generation, power transmission and substation facilities is also the major commitment of INECEL. INECEL owns, as of January of 1993, 74% of the total power generation facilities amounting to 2,278.2 MW, 100% of 230 kV trunk transmission lines that extend 820 km, 93% of 138 kV trunk transmission lines that extend 1,170.5 km, and 5,833 MVP (include for stepup transformer for Generations) of substations of the Republic of Ecuador, and supplies power to local electric power companies. INECEL plans to deal with the future increase of power demand by developing approximately 1,100 MW of generating capacity by year 2005, plus expanding the associated power transmission and substation facilities.

These facts clearly indicate that INECEL plays an important role for the social and economic development of Ecuador by means of SNI.

When we examine SNI from the point of view of power supply/demand balance and the features of power system, we can find the following conditions.

(1) The load centers are locally concentrated. (The two large cities of Quito and Guayaquil account for 70% of the total power demand.)

(2) The large power sources are locally concentrated. (Paute Hydroelectric Power Plant only accounts for 47% of the total installed capacity.)

(3) The load centers are separated from power sources by a great distance. (The power transmission distance between Paute and Quito is approximately 310 km, and between Paute and Guayaquil approximately 180 km.)

(4) The power transmission system is physically large in comparison to the load to be supplied. (The total extension of the 230 kV ring system is 820 km.)

(5) The large power source of Paute Hydroelectric Power Plant has an excessive output capacity in comparison to the dam reservoir capacity, thereby having insufficient regulating capacity, and its output is affected by the variation of river flow.

These characteristics of SNI described above can be identified by a macroscopic power system analysis, and the following problems can be pointed out.

(a) Power demand/supply balance problem (unstable power supply capability).

(b) Transmission line capacity problem. (Paute-Milagro-Pascuales)

(c) Power system stability problem.

These problems would impose particular constraints on the operation of individual power plants, substations and transmission lines.

These problems lying behind SNI are the impediments in realizing a reliable, high quality power supply. Therefore, it is required to immediately evaluate the reliability of the current and future SNI Power System quantitatively as well as qualitatively, with the objective of improving the quality of power supply.

Under the circumstances as described above, Ecuador has requested the Government of Japan for the technical assistance in the Study on Service Reliability Improvement Project of National Interconnected System (SNI) of Ecuador.

1.2 Objective of Study

The objectives of this Study are defined as below.

(1) The on-site survey and the study works in Japan shall be implemented to establish the methodology of evaluating the reliability of SNI.

(2) The reliability levels of existing power facilities and future plan shall be evaluated to identify the improvements to be applied to the existing power facilities and to review the future plan, and a recommendation on the project priority order and other items shall be presented.

(3) In the Recommendation, the preliminary designs of the projects which need to be implemented and the related project costs shall be included.

In addition, a set of Reports shall be developed on the subjects of study referred to above, to transfer technology to the counterparts of Ecuador through the process of this Study.

1.3 Scope of Study

The following factors are the elements which represent the quality of the power to be supplied by the electric utility industries to the consumers.

(1) The supply of electric power is not interrupted. (There is no blackout.)

(2) The quality of electric power supplied is high. (The voltage and frequency of the supplied power are constant, and no high harmonic is included.)

Item (1) above is the continuity of service, which, in other words, is the elimination of blackout. The factors that create power supply interruption at the customer ends are as listed below, in macroscopic terms.

(a) The absolute amount of supply capacity is insufficient in comparison to the demand. (The supply to some customers is interrupted by the intention of the supplier.)

(b) The supply capacity is somehow sufficient to meet the demand, but the supply falls short of demand under certain cases when the characteristics of the supply sources are taken into account. (Power supply to some customers is interrupted.)

(c) The power supply is constrained by the performance of power transmission system. (Power supply is constrained by transmission line capacity, voltage regulation limit, etc.)

(d) The power supply is interrupted by transmission line faults. (Power system stability.)

(e) Power supply is interrupted by other events caused by human actions or natural disaster. (Collapse of transmission line towers, floods, etc.)

The power supply reliability can be expressed by the measure of supply reliability. This measure can be evaluated by the frequency of supply interruptions or duration of interruption at the customer ends, or evaluated statistically in terms of the variation of supply capability and the load variations in reference to Item (b) above.

The subjects of this Study are the transmission lines of 138 kV or higher voltage which constitute the National Interconnection System of SNI, and the substations and generators having 5 MVA or larger capacity which are connected to SNI. **The reliability measure dealt with in this Study Report is the reliability level at supply end (transmission bus of power plants) which is obtained by a statistical methodology by treating the supply capability reference to the demand, to evaluate the supply interruption of Item (b) above.**

The supply interruptions quoted in Items (c) and (d) above are caused by the performance of the transmission system including substations. These factors shall be evaluated by the on-site survey and power system analysis, and the results shall be included in the Recommendation.

The elements which represent the quality of the power supplied are the voltage fluctuation, frequency deviation and distortion of voltage waveform. These elements affect the electrical equipments relying on the power supply in various ways. When the voltage fluctuates, the luminance of lights change or flicker, or the torque of electrical motive forces may vary. When the frequency deviates, the motor speed may vary or electric clocks may turn inaccurate. For electronic applications such as computer systems, all of the above three elements may have adverse effect. These problems related to the quality of electric power shall be evaluated based on the on-site survey and power system analysis, and only qualitative recommendations shall be presented.

1.4 Site Survey

JICA Team started to study this task from Feb., 1993 and dispatched the site survey mission to Ecuador as follows;

<Local survey>

1st: Feb. 17 - Mar. 16, 1993;	Inception report, electric facility survey
2nd: Jul. 27 - Aug. 10, 1993;	Submission and explanation of progress report
3rd: Oct. 18 - Nov. 1, 1993;	Simulation of supply reliability software
4th: Jan. 10 - Jan. 27, 1994;	Submission and explanation of interim report, seminar
5th: Mar. 11 - Mar. 25, 1994;	Submission and explanation of draft final report

1.5 Member of Survey Team

The Study Mission for this survey consisted following 8 experts, who worked on their respective areas of expertise.

Leader/Coordination	Katsuhiko Yamamoto
Power System Planning	Toshimasa Fujiuchi
Power System and Operation Planning	Makio Suzuki
Generating and Substation Equipment	Hisao Sudo
Protective Relay System	Tomoyoshi Hasebe
Transmission Line Equipment	Hiroshi Katsukawa
Power System Analysis	Hiroshi Kagami
Reliability Analysis	Ryuichi Abe

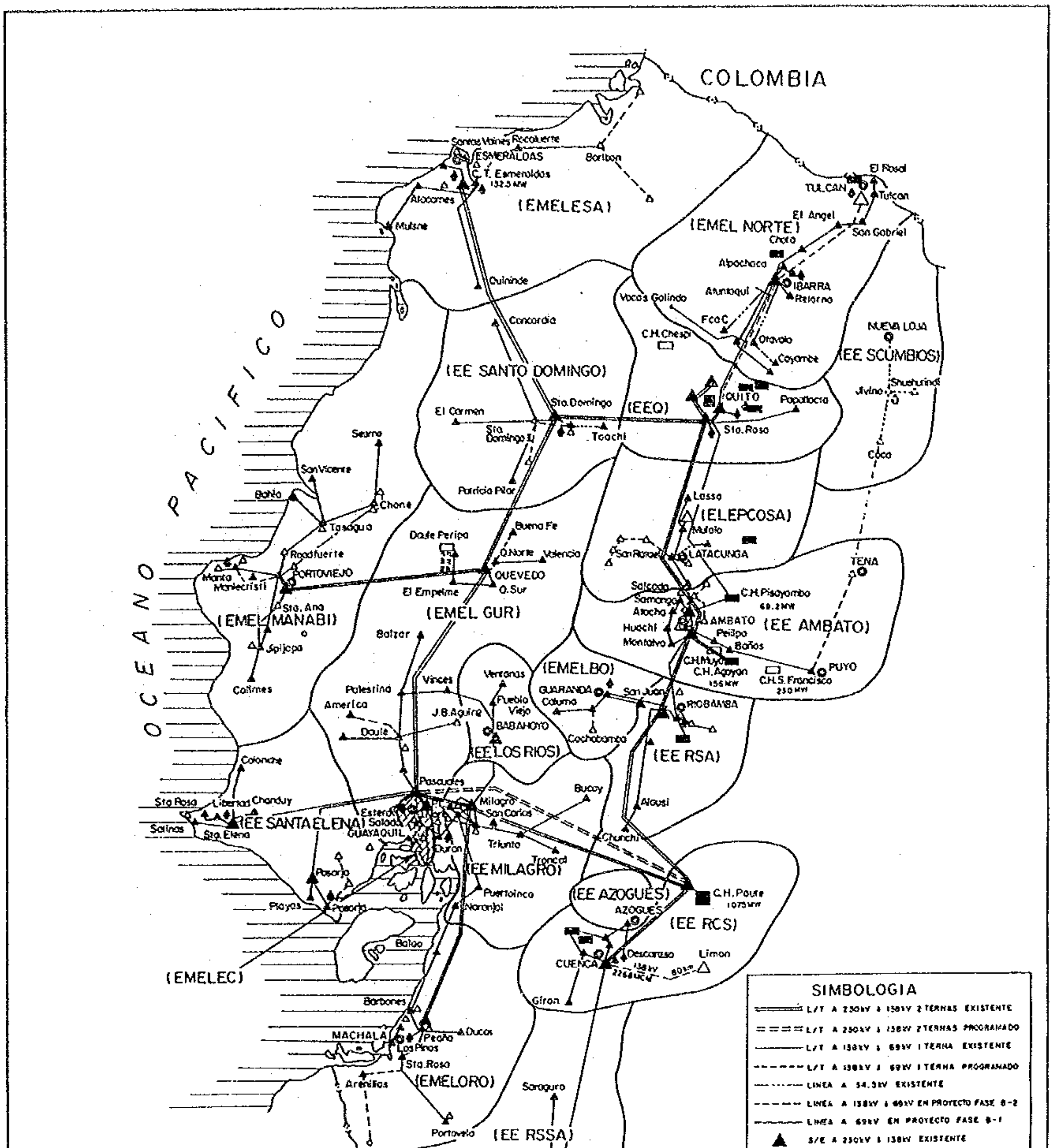

Fig. 1.1 Section of Regional Power Companies

CHAPTER 2 GENERAL DESCRIPTION OF REPUBLIC OF ECUADOR

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CHAPTER 2 GENERAL DESCRIPTION OF REPUBLIC OF ECUADOR

2.1 Geography

The Republic of Ecuador is located in the northwestern part of the South American Continent, just on the equator. The country borders Colombia to the north, Peru to the east and south, and the Pacific Ocean to the west. The Galapagos Island in the Pacific Ocean are the territory of Ecuador. The land area is approximately 280,000 km^2, and is the fourth smallest nation in the South America, next to French Guiana, Uruguay, and Guyana. The Andes Range, which runs from Colombia crosses the middle of this nation down to Chile in the south, and this mountain range is split to the eastern range and the western range, thereby creating a basin of 1,800 to 3,000 m elevation. Much of the national population is found in this basin area. The two mountain ranges include Chimborazo Mountain (6,310 m), the highest mountain of the nation, as well as more than 30 volcanoes. Active volcanoes include Cotopaxi Mountain (5,897 m), which is known as the highest active volcano in the world, and two other volcanoes.

The land of Ecuador can be geographically classified into three areas, the coastal zone along the Pacific Ocean, the plateau between Andes Ranges, and the eastern tropical jungle zone that extends from the source of Amazon River.

2.2 Climate

Although the land of Ecuador is located just on the equator, the diverse geography and the tidal currents of Humboldt Current (cold current) and Middle American Current (warm current) create a variety of climate. That is, a northern part of Pacific coast and the western half of Amazon basin have high temperature, high humidity climate (with the annual average temperature of 25°C and annual precipitation of 3,000 to 6,000 mm), and the inland side of the Pacific coast plain has a tropical, high temperature, high humidity climate (with average temperature of 14°C to 26°C, with relatively little rain and humidity of around 80%), the high lands with elevation of 3,000 m or so have a tropical mild climate (with distinctive dry and wet seasons), and mountain lands with elevation of more than 3,000 m have tropical, high elevation climate (with precipitation of 1,000 mm to 2,000 mm, rains every day in the wet season, and humidity of 60% to 80%).

2.3 Population

The total population of Ecuador is estimated to be 10.782 millions as of 1990. The population growth rate in recent years has been 2.8%. The population per 1 km^2 area is 39. A 49% of the population lives in major cities, such as Quito, Ambato, Ibarra, Riobamba and Cuenca, which are located in the central plateau among Andes Mountain Ranges. Another 48% lives in the Pacific coast area such as Guayaquil, and 3% lives in the eastern, Amazon River basin.

2.4 Economy and Energy Resources

2.4.1 Economy

Ecuador was originally an agricultural nation, and its tropical agricultural products such as banana, cacao and coffee have been the major export commodities. However, the oil field discovered in the eastern area by the end of 1960's has been successfully put to production, and when the export of crude oil was started in 1972, a boom of oil well discovery occurred, although the production from each well was not very large. The crude oil export increased with time, and the nation achieved a remarkable economic growth in 1970's which has been leveraged by the income from oil wells. The Government initiated a 5-year economic development program based on this oil income, to accomplish the construction of infrastructures, electric power development, and industrialization.

The economic growth declined, however, in 1980's due to the depressing international oil market. After evaluating this economic difficulty thereby encountered, the Government has introduced barter systems one by one into the international trade, and strengthened its restrictions on unnecessary import commodities. The domestic currency was devaluated in 1982 and 1983, and the Government was busy in negotiating out the extension of public loans. These efforts were rewarded, and together with the successful recovery of the production of major agricultural export commodities as well as the increase of oil production and export, the international trade surplus in 1984 reached 1.1 billion dollars. Also, the negotiations of the extension of public loans turned out favorably. The oil production as well as its transportation from the wells in the northeastern area to the coastal zone continued to increase, amounting to 300,000 barrels per day, thereby marking the record since the starting of crude oil production in 1972.

In recent years, the fish processing industry is remarkably growing. In 1992, the export of non-traditional products, such as tuna, fishes, flowers and shrimps, accounts for 60% of the total export.

The population, population growth, gross national products, and the gross national products per capita during period 1970-1990 are illustrated in Table 2-1.

2.4.2 Energy Resources

(1) Oil

Ecuador is an oil-exporting nation. The oil production was started in 1972, and the nation produces 300,000 barrels per day in 1985. The production cost is relatively high, because most of the production wells are located in the eastern area, and the oil has to be transported to the port of Esmeraldas in the Pacific coast by means of pipelines across the Andes. The confirmed reserve is 1.5 billion barrels as of 1982, and it is estimated there is a total reserve of 3 billion barrels including the unconfirmed reserves.

(2) Natural Gas

The natural gas fields have been discovered in Guayaquil Bay and Shushufindi of Amazon Basin. The reserve in Guayaquil is estimated to be 377 billion cubic feet.

(3) Hydroelectric Power

There are abundant water power resources of high head along the rivers that flow from the eastern and western Andes ranges to the Pacific Ocean to the West and Amazon River to the east. (Hydro-potential: 21,520 MW, Amazon basin: 90%, Pacific coast: 10%)

Table 2-1 Economic Indices

Year	Population (1,000)	Growth Rate (%)	GDP ($ million)	Income per Capita (Dollars)
1970	6,060.5	3.17	1,629	269
1971	6,239.5	3.12	1,602	257
1972	6,432.2	3.09	1,874	291
1973	6,628.8	3.06	2,489	375
1974	6,829.5	3.03	3,711	543
1975	7,034.5	3.00	4,310	613
1976	7,242.9	2.96	5,317	734
1977	7,454.5	2.92	6,655	893
1978	7,670.8	2.90	7,654	998
1979	7,893.3	2.90	9,359	1,186
1980	8,123.4	2.92	11,733	1,444
1981	8,361.3	2.93	13,946	1,668
1982	8,606.1	2.93	13,354	1,552
1983	8,857.4	2.92	11,114	1,255
1984	9,114.9	2.91	11,510	1,263
1985	9,377.9	2.89	11,890	1,268
1986	9,647.1	2.87	10,515	1,090
1987	9,922.5	2.85	9,450	952
1988	10,203.7	2.83	9,129	895
1989	10,490.2	2.81	9,972	951
1990	10,781.6	2.78	10,741	996

(Curtesy of the Central Bank)

CHAPTER 3 POWER DEMAND AND SUPPLY STATUS

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CHAPTER 3 POWER DEMAND AND SUPPLY STATUS

3.1 General Description of Power Demand and Supply Status

The electric power demand of a nation is roughly proportional to the population distribution and the population density.

The population of Ecuador was 10.78 millions as of 1990, which corresponds to a population density of 39 per 1 km^2, and the land of this country is sufficiently wide in proportion to its population. Looking at the population distribution, 49% of the total population are concentrated in the central plateau zone where major cities such as Quito, Ambato, Riobamba and Cuenca are located. Another 48% of the population is found on the Pacific coast areas such as Guayaquil City, and only 3% lives in the eastern area. In particular, the concentration of population in the two cities, Quito and Guayaquil is remarkable, and approximately 70% of the total electric power demand is located in these two cities which form two major load centers of the nation.

The total electric energy consumption of the nation was 5,449 GWh according to a statistics of 1992. The energy consumption in each consumer category consists of 39.4% residential, 30.4% industrial and 14.9% commercial, and 15.3% is consumed by street lighting and other uses (see Table 3-1). That is, the proportion of the residential load is large. Although the electric energy consumption by non-industrial sectors is high, the electrification rate is still low in the rural areas, being 52%, although this rate is as high as 94% in the urban areas. The national average electrification rate was 75% as of 1992, and the electrification of rural areas must be further advanced in future (see Table 3-2). The power transmission loss of Ecuador, including the distribution system, is high, being approximately 24% or higher.

The peak power demand of a year normally occurs in December, and the load factor in recent years has been approximately 60%. The peak in the daily load curve is observed at 19 to 20 hour in the evening, indicating that the power demands are dominantly non-industrial. An example of daily load curve is presented in Fig. 3-1.

Concerning the electricity tariff, the average unit price as of 1992 was 62.81 sucres/kWh (3.97 US-cents/kWh), which is suppressed to a fairly low value in comparison with neighboring nations.

The trends of the total energy sales and the total energy generation are presented in Table 3-3. In the past 10 years, the annual average growth of total demand was 6%. It is anticipated that the electric energy demand will continue to grow steadily in future, unless there is unexpected changes in economic status and other factors.

3.2 Electric Power Utility

The electric power industry in the Republic of Ecuador is being operated by INECEL under the Ministry of Energy and Mine, the 19 local electric power companies and some local governments.

INECEL maintains and operates SNI, and engaged in the development of power generation, power transmission and substation facilities for this national grid. Specifically, INECEL maintains and operates Paute Hydroelectric Power Plant, which is a representative power plant in Ecuador, Estero Salado Thermal Power Plant and other power stations, 230 kV trunk transmission grid, 138 kV transmission lines, 69 kV sub-transmission lines, and substations connected to these major power systems, to wholesale the power to local power companies.

As of January, 1993, INECEL owns approximately 1,692 MW of power generation facilities, 230 kV transmission lines with a total extension of 820 km, 138 kV transmission lines with a total extension of 1,170.5 km, and substations connected to 69 kV or higher voltage systems amounting to 3,102 MVA in total capacity except for stepup transformer for generators.

Among local power companies, EMELEC (Empresa Electrica Ecuador, Inc.) is a corporation controlled by American private capitals, and this company distributes power to Guayaquil City, the largest load city and the largest load center in Ecuador, and also engaged in some power generation business. Local power companies other than EMELEC are controlled by the capital of INECEL, and depend on INECEL for financial and technical assistance.

3.3 Present State of Electric Power Supply Facilities

3.3.1 Power Generation Facilities

The power supply facilities in Ecuador consist of hydroelectric power plants and thermal power plants such as steam turbine, gas turbine and diesel engine plants.

The public power generation facilities are owned by INECEL and 19 local power companies. In certain isolated areas and islands, there are public power generation facilities of local governments (municipal, town and village), and there are also private power generation facilities for in-house power supplies. These facilities are either small hydroelectric plants or diesel power plants, and geothermal power and wind power have not been introduced.

As of Jaunary 1993, a total of 2,278.2 MW of power generation facilities are included in SNI, of which 74.26% are owned by INECEL, 25.74% by local power companies. To classify these facilities by the type of primary energy, 64.5% are hydroelectric plants and 35.5% thermal plants.

Owner	INECEL		Local Power Companies*)		Total (SNI)	
Power Plant Type	MW	%	MW	%	MW	%
Hydroelectric	1,300.2	76.9	169.9	29	1.470.1	64.5
Thermal	391.6	23.1	416.5	71	808.1	35.5
Total: MW	1,691.8	100	586.4	100	2,278.2	100
%	74.26		25.74		100	

Note: *) The figures of local power companies do not include the facilities of Sucumbios Power Company (hydro 0.4 MW, thermal 11.03 MW) which can not be connected to the National Grid.

Public power facilities in the eastern and Galapagos areas are not included for the same reason as above. (Hydro 1.69 MW, thermal 11.52 MW)

The installed capacity of each ownership and primary energy classification are given in Table 3-4. The growth of hydroelectric and thermal facilities in each year from 1965 to 1991 is illustrated in Table 3-5. The total power generation capacity has quadrupled in the 10 years from 1971 to 1981, and has grown to approximately 2.2 times in the 10 years from 1981 to 1991.

The natural river flows in Ecuador decrease during the dry season from November to February in every year. For this reason, the firm output of hydroelectric power plants is 1,209.4 MW as against the total installed capacity of 1,470.1 MW. The output of thermal power plant has been decreased from 808.1 MW to 583.2 MW because the maintenance work has been insufficient. The maximum power capability in the whole SNI is 1,792.6 MW, which is 78.7% of the total installed capacity. The installed capacity and the power capability of hydroelectric and thermal power plants as of January of 1993 are given in Table 3-6. "List of Hydroelectric Power Plants" of Table 3-7 illustrates the name, output and number of units of hydroelectric power plants which are operable as of January, 1993. In the Table, the installed capacity quoted as "Others" on the column of power plant name, which is 169.9 MW, is the sum of installed capacity of local power companies such as Quito Electric Power and Centro Sur Electric Power. The power capabilities of these facilities is reduced to approximately 70 MW, according to a survey of INECEL, due to such factors as the reduction of efficiency of water turbines and generators. The power generation and energy generation of hydroelectric power plants of each local power company are given in Table 3-8.

"List of Thermal Power Plants" of Table 3-9 gives the name, output, number of unit, etc. of thermal power plants (including gas turbine plants and diesel power plants) as of January, 1993. The fuel used are all petroleum based, with relatively large thermal power plants using bunker oil and others diesel oil.

"Thermal Power Station of Regional Companies" of Table 3-10 (1/4-4/4) gives the currently available power output and scheduled shutdown kilowatts of thermal power plants owned by local power companies.

The major hydroelectric power plants belonging to SNI are Paute and Agoyán Power Plants which are owned by INECEL.

Paute Power Plant has been built in two stages, with stage 1 (phase A and B) commissioned to service in 1983 with 500 MW output (100 MW x 5 units), and stage 2 (phase C) commissioned in 1992 with 575 MW output (115 MW x 5 units). The installed capacity of Paute Power Plant is 1,075 MW, which account for 47% of the total installed capacity of SNI of 2,278.2 MW, and 73% of the total hydroelectric installed capacity. The energy capability of Phase 1 Project is 3,481.9 GWh (annual average), with that of Phase 2 Project 1,888 GWh, accounting for about 50% of the total energy capability or 71% of the total hydroelectric energy capability. That is, the supply capability of SNI heavily depends on Paute Power Plant.

The effective storage capacity of Paute Hydroelectric Plant is 100,000,000 m^3 (currently being 90,000,000 m^3), which lasts only 122 hours when the plant is operated at its full installed capacity of 1,075 MW, or 250 hours (approximately 10 days) when it is operated at 500 MW of Phase 1 Project. In Amaluza Dam, sedimentation is currently in progress at a rate of 3 million m^3 per annum. A pump dredging vessel (with minimum annual dredging capacity of 500,000 m^3 per annum, 150 m^3/h) is in operation since 1991, to discharge sedimentation of approximately 1 million m^3 per annum. This vessel is currently dredging an area which is up to 500 m to the upstream of the dam. It is planned to commission one more dredging vessel by year 2000, to have the two vessels dredge 2.5 million m^3 of sedimentation up to 3 km from the dam, and to discharge the remaining sedimentation of 0.5 million m^3 by means of the sand flush tube during floods.

The electric power of Paute Power Plant is transmitted to Guayaquil and Quito areas. There is currently a 230 kV, double circuit transmission line from Paute to Guayaquil, INECEL assumes that the power transfer limit per circuit is 250 MW, and the transfer limit of the two circuit is defined as 400 MW by considering possible line faults. The peak of power consumption in Ecuador occurs in December, and since this time coincides with the season of little precipitation, the power supply shortage in this country is a serious problem.

Parameters of Paute and Agoyán Hydro Power Plants are given on this page and the next page.

Paute Power Plant Parameters

1.	Catchment Area		
	Azuay Province		
	Paute River		
	Catchment Area	5,218.6 km^2	
2.	Reservoir		
	Total Storage Capacity	120,000,000 m^3	
	Effective Storage Capacity	100,000,000 m^3	
	Maximum Water Level	EL 1,991 m	
	Minimum Water Level for Operation	EL 1,935 m	
3.	Dam		
	Type	Concrete arch type	
	Concrete Volume	1,200,000 m^3	
	Dam Height	170 m	
	Crest Length	400 m	
4.	Headrace	A, B	C
	Type	Pressure tunnel	Pressure tunnel
	Length	6,070 m	6,140 m
	Diameter	5.0 m	7.8 - 5.1 m
	Discharge	100 m^3/s	105 m^3/s
5.	Penstock		
	Length	960 m	920.46 m
	Diameter/Length	3.75 m	4.4/507.3 m 4.2/412.2 m 4.4/4.2/3 m
6.	Powerhouse		
	Type	Underground	Underground
	Length	123 m	78.5 m
	Height	42 m	42.5 m
	Turbine Center Level	WL 1,323 m	EL 1,323 m
7.	Water Turbine		
	Number of Units	5	5
	Type	Vertical Pelton (6 nozzle)	Vertical Pelton
	Output	116 MW	122 MW
	Head	650 m	657 m
	Discharge	20.16 m^3/s	20.62 m^3/s
	Speed	360 rpm	360 rpm
	Manufacturer	Hydro Art (Italy)	Hydro Art (Italy)
8.	Generator		
	Number of Units	5	5
	Type	Vertical, 3 phase AC	Vertical, 3 phase AC
	Capacity	111/127.7 MVA	127.7 MVA
	Power Factor	0.9	0.9
	Voltage	13.8 kV	13.8 kV
	Manufacturer	Siemens (Sweden)	AEG (Germany)
9.	Transformer		
	Number of Banks	5	5
	Capacity	111/127.7 MVA	134 MVA
	Voltage	13.8/138 kV	13.8/230 kV
10.	Switchyard		
	Type	Outdoor GIS (SF_6)	Outdoor GIS (SF_6)
	Voltage	245 kV	245 kV
	Current	2,000 A	2,000 A
11.	Energy Generator		
	Yearly Average	3,481.9 GWh	1,883 GWh
	Firm	2,456.7 GWh	——

Agoyán Power Plant Parameters

1.	Catchment Area	
	Tungurahau Province	
	Pastaza River	
	Catchment Area	8,237 km^2
2.	Reservoir	
	Total Storage Capacity	2,000,000 m^3
	Effective Storage Capacity	760,000 m^3
	Effective Drawdown	6.00 m
	Maximum Water Level	EL 1,651 m
3.	Dam	
	Type	Concrete gravity type
	Concrete Volume	178,000 m^3
	Dam Height	43 m
	Crest Length	300 m
4.	Headrace	
	Type	Pressure tunnel
	Length	2,378 m
	Diameter	6.0 m
5.	Penstock	
	Length	121.90 m
	Diameter	5.50 m
6.	Powerhouse	
	Type	Underground
	Length	50.4 m
	Width	18 m
	Height	34.1 m
	Turbine Center Level	EL 1,488 m
7.	Water Turbine	
	Number of Units	2
	Type	Vertical Francis
	Output	78 MW
	Head	149 m
	Discharge	60 m^3/sec
	Speed	225 rpm
	Manufacturer	Mitsubishi Heavy Industries
8.	Generator	
	Number of Units	2
	Type	Vertical shaft, rotating field, 3 phase AC
	Capacity	85 MVA
	Voltage	13.8 kV
	Power Factor	0.9
	Manufacturer	Mitsubishi Electric Corporation
9.	Transformer	
	Number of Banks	2
	Capacity	85 MVA
	Voltage	13.8/138 kV $\pm$ 5% kV
10.	Energy Generation	
	Yearly Average	1,080 GWh
	Firm	692 GWh
11.	Pastaza River Flow Rate	
	Yearly Average	124 m^3/s
	Firm	60 m^3/s
	Flood	
	20 year	1,700 m^3/s
	1000 year	6,000 m^3/s

Agoyán Power Plant has an installed capacity of 156 MW (78 MW x 2 units), with the yearly average energy generation capability of 1,119 (Average) GWh and firm energy capability of 724.9 GWh (firm). The plant was commissioned to service in 1987. The effective storage capacity of the reservoir is 760,000 m^3, providing approximately 3 hours of peak operation capability under normal conditions. The reservoir is flushed twice a month in the average by means of discharging floods. A sedimentation of 4 m in depth can be completely discharged in a day or two by means of 2 flushing gates.

60 personnel are employed in Agoyán Power Plant including the Power Plant Manager. These include 16 operators (4 shifts x 4) and 20 maintenance personnel. The organization chart of Agoyán Power Plant is given in Fig. 3-2 The maintenance and inspection works are performed according to an annual plan. The plant is shut down for inspection in every 3 to 4 month, and detained inspection is performed once in 4 to 5 years. It is planned to overhaul Unit-1 in 1993, for which instructors (100 man-days) will be dispatched from the main equipment manufacturer. There is no serious problem, except for some corrosion of water turbine runners and a little decoloring of generator stator coil end.

The water turbine inlet valves are bi-plane type, for which the water sealing packing has been replaced twice. Spare parts for 2 water turbine runners, 1 guide vane, generator coils, bearing metals, and transformer bushing are stored in the power plant, and an inventory of general spare parts is sufficient for operation of 5 years. The performance of maintenance work, in hydroelectric power plants in general as well as in Agoyán, is fairly good.

The hydroelectric power generation facilities, typified by Paute, Agoyán and Pisayambo (69 MW) are all located on the upstream of Amazón River, and concentrated in a certain location of this Country. It would be necessary to find suitable power plants sites in SNI, in view of the possible supply capacity shortage in drought, assurance of supply capability in the event of failure of power plant, and the requirement for additional power transmission facilities in assuring power supply during normal and accident conditions of the power systems.

Typical Hydro Power Plant of Regional Electric Power Companies are El Ambi (8 MW) in the Northern System (EMEL NORTE Co.) and Guangopolō (15.5 MW), Cumbayá (40 MW) and Nayón (29.7 MW) in the Pichincha System (EEQ Co.), which are constructed on the river flowed in the Pacific Ocean, and Alao (10.5 MW) in the Central North System (RIOBAMBA Co.) and Saucay (24 MW), Saymirin (6.4 MW) etc., which are located on the upstream of Amazón River.

The total installed capacity of thermal power plants as of January 1993 is 808.1 MW, of which the thermal power facilities owned by INECEL account for 391.6 MW, or 48.4% of the total, while the thermal power facilities owned by other power companies is 416.5 MW (EMELEC 187.8 MW, EEQ 43.6 MW, others 185.1 MW). Major thermal power plants are Estero Salado 146 MW (73 MW steam turbine x 2, 30.9 MW gas turbine x 1), Esmeraldas 132.5 MW (132.5 MW steam turbine x 1), Quito Gas Turbine 51 MW and Guangopolo Diesel Engine 31.2 MW owned by INECEL, Aníbal Santos 144.25 MW (33 MW steam turbine x 1, 21.25 MW gas turbine x 1, 22.5 MW gas turbine x 4) and Planta Vapor 43.5 MW (5 MW steam turbine x 2, 10 MW steam turbine x 2, 13.5 MW gas turbine x 1) owned by EMELEC, and Diesel Bunker Quito (Central G. Gernandez), 34.3 MW, (5.85 MW diesel x 6) owned by EEQ. Out of power plants owned by local power companies, only 304.8 MW are operable, and the remaining facilities are not available for operation either by aging or shortage of spare parts.

Estero Salado (Gonzalo Cevallos) Power Plant of INECEL has 2 units of 73 MW steam turbine (with 2-pole generators of 85,883 MVA rating at 0.85 power factor, manufactured by Mitsubishi) and 1 unit of 30.9 MW gas turbine (manufactured by GE). The steam turbines are operated at maximum output in dry seasons, but operated at 20% to 30% output in wet seasons. These turbines are operated up to 66 MW of unit output, because the turbine internal pressure is high and the steam leaks into the condenser. Overhauls are performed at a frequency of once in 10 to 15 years. The overhaul on Unit-2 (commissioned in 1980) was performed in 1992, but this problem has not been fixed due to shortage of budget. The overhaul of Unit-1 will be conducted in 1993. The periodical inspection is applied in every 7,000 hours of operation. The auxiliary machines, except the main unit, are inspected every year. The temperature relay of generator stator is left broken because the budget is not finalized, and the generators are operated without protection against temperature rise. The gas turbine is operated during morning and evening peak load periods, and as a reserve capacity during abnormal conditions, and it is not operated otherwise. Concerning the maintenance of gas turbine, a air compressor has been replaced during an inspection. This unit has experienced only minor troubles, and there is no serious problem

Aníbal Santos Power Plant of EMELEC is located adjacent to Estero Salado Power Plant described above, and the switchyard of the former power plant is separated form the latter by a 69 kV circuit breaker. The power plant is equipped with one 33 MW steam turbine (GE) and five, 21 MW gas turbines (4 GE units and 1 Hitachi unit). The available output of the steam turbine is currently reduced, and the turbine can be operated up to 30 MW. However, this unit will be overhauled in June, 1993. The gas turbines are operated similarly to those in Estero Salado Power Plant.

Generally speaking, many thermal power plants are aged. The repair works are insufficient due to shortage of spare parts, and power plants can not maintain their installed capacity. It is planned to repair the thermal units owned by local power companies in near future (see Table 3-6). Gas turbine power plants, such as Electro Quil (25 MW x 1, 50 MW x 1) and Electro Quito (33 MW x 1) are being constructed by the new Company in order to deal with the extraordinary drought of 1992, and they will be commissioned to service in the middle of 1993.

3.3.2 Substation Facilities

The power systems in Ecuador are being improved to create SNI which is to be comprehensively operated by INECEL. The 230 kV transmission lines will form the backbone transmission grid of double loop lines, and 138 kV lines will function as the interconnection lines to local areas.

There are 7 key substations which form the 230 kV looped transmission system of SNI. The total substation capacity connected to this loop system is 1,451 MVA as of the end of 1992. The total capacity of the 138 kV substations interconnected to this loop system is 1,618 MVA. Auto-transformers are frequently used in these substations. The three, 230 kV substations (Pascuales, Santa Rosa, Totoras) have transformer sets which consist of 3 single phase units plus 1 standby unit, and designed to withstand the outage of one auto-transformer. On the other hand, in Milagro, St. Domingo and Quevedo Substations, 1 phase of common spare unit is provided. Riobamba Substation has 3, single phase transformers and no spare transformer is provided. Concerning 138 kV substations, Santa Elena, Ibarra, and Loja Substations have 3 phase auto-transformers, and provided with one, common spare transformer. The loads on 138 kV substations are increasing, and a mobile transformer is used at Babahoyo. INECEL plans to have 60 to 100 MVA spare capacity in order to assure supply reliability.

The total capacity of step-up transformers in power plants is 2,731 MVA, including both 230 kV and 138 kV transformers. Except for the 230 kV/138 kV interconnection transformer installed at Paute Power Station, three phase transformers are used. The name, voltage, capacity and year of commissioning of each substation are given in Table 3-11. (1/4-4/4)

A typical substation of INECEL in the Northern Area is Santa Rosa Substation located at the suburb of Quito (commissioned in 1982). The main transformers are 1 bank of 230/138/13.8 kV, 375 MVA (3 x 125 MVA + 1 spare unit) and 1 bank of 138/46/13.8 kV, 75 MVA. 2 circuits each of 230 kV transmission lines are extended from this substation to Totoras and Santo Domingo Substations, to form the ring transmission grid of SNI. 2 circuits of 138 kV transmission lines are extended to Selva Alegre Substation, and 1 circuit each to Papallacta and Vicentina Substations. As to the power supply from INECEL to local power companies, EMEL NORTE is provided from 138 kV Vicentina to Ibarra transmission line and EEQ is provided from the 75 MVA bank in this substation at 46 kV via the 138 kV distribution substations respectively.

230 kV circuit breakers are SF_6 type manufactured by Mitsubishi Electric or Magrine Galileo (Italy). The protective relays for 230 kV transmission lines are manufactured by GEC for Totoras Line and by UK for Santo Domingo Line. The protective relays for 138 kV, Salva Alegre Line were manufactured by Mitsubishi. The 230 kV lines circuit breakers are operated by the single phase reclosing mode when there is one-line-to-ground faults. The circuit breakers are also operated by three-phase reclosing mode when the line load is light. No single phase reclosing is performed on 138 kV lines.

There is a gas turbine power plant (17 MW x 3 units) adjacent to Santa Rosa Substation, and 2 units out of these 3 units can be operated for phase compensation (25 MVA lead and 10 MVA lag per unit).

The Central Load Dispatching Office is installed in this substation, and load dispatching information from each electric station is gathered by telephone communication. The new Central Load Dispatching Office, incorporating a computer based monitoring/control system, is being constructed in the premises of this substation.

The typical 230 kV substation of INECEL in the Southern Area is Pascuales Substation (commissioned in 1982) located at Guayaquil. The main transformers consist of 1 bank of 230/138/13.8 kV, 375 MVA (3 x 125 MVA + 1 spare unit) and 1 bank of 138/69/13.8 kV, 150 MVA (3 x 50 MVA + 1 spare unit). 2 banks of 10 MVA reactor are installed on the tertiary windings.

2 circuits each of 230 kV transmission lines run from this substation to Milagro and Quevedo Substations, and 2 circuits each of 138 kV transmission lines run to Salitral and Policento Substations.

The power supply by INECEL to local power companies such as EMELEC and EMELGUR is provided at 69 kV via the 150 MVA transformer bank of this substation and 138 kV distribution substations. The 230 kV circuit breakers are SF_6 gas breakers manufactured by Mitsubishi Electric. The transmission line protection relay systems employ the power line carrier relays as main protection and distance relays (both manufactured by GE) as backup protection. Single phase reclosing mode is used against one-line-to-ground faults. Three phase reclosing system is currently not used due to power system stability problem.

Pascuales Substation is the maintenance center in Guayaquil District, where the operation and maintenance works for the 7 substations (Pascuales, Salitral, Policento, Santa Elena, Posorja, Milagro, Machala) in this district are implemented collectively. The operation and maintenance works was started in 1982, and they are divided to 230 kV section (main part), 138 kV section and 69 kV section (related to other power companies). The operation shift duty is composed of three shift, four crew system, and a shift of three operators deals with the Central Load Dispatching Office and operates switchboard and plant substation equipment. The maintenance crew consists of 4 personnel engaged in electrical/mechanical jobs and 7 personnel engaged in transmission line maintenance.

There were examples of transformer failures in the area under Pascuales as described below.

(1) Pascuales Substation, 230/138/13.8 kV, 125 MVA single phase transformer (supplied by Osaka Transformer Corp.)
Oil leaked from packing of bushing connection flanges due to abnormal temperature change, affecting 4 transformers including the spare.

(2) Portoviejo Substation (commissioned in 1978), 138/69/13.8 kV, 75 MVA transformer (supplied by Ansaldo of Italy).

Failure of insulator due to tensile force, affecting all of three phases.

(3) Policentro Substation (commissioned in 1990), 138/69/13.8 kV, 50 MVA single phase transformer (supplied from Italy).
Bushing failure.

(4) Milagro Substation (expanded in 1978), 138/69/13.8 kV, 33 MVA single phase transformer.

Water ingress from tank upper packing, due to improper fastening of bolts.

(5) Salitral Substation (commissioned in 1977), 138/69/13.8 kV, 50 MVA single phase transformer (supplied by Mitsubishi Electric). No failure has been experienced.

Routine maintenance and inspection works and fault recovery procedures are implemented by the maintenance personnel of the substation according to the Manual (prescribing the frequency of inspection, inspection items, required number of workers, required time, etc.). The formulation of the maintenance plan, implementation and evaluation are performed on a nation-wide basis by the National Interconnected System Operation Direction (DOSNI) at Quito. The administrative regions for operation and maintenance are divided to 4 Districts of the nation, and requests for maintenance work are placed on DOSNI from these Districts.

DOSNI coordinate the requests from the maintenance sections of hydroelectric and thermal power plants as well as transmission line/substation maintenance sections with the Central Load Dispatching Office to determine the outage schedule, and dispatch the schedules to each district.

A typical step-up substation of power plant is the substation which steps up the generator voltage of Paute Power Plant. This substation is equipped with 2 banks of 230/138/13.8 kV, 375 MVA (125 MVA x 3-single phase units + 1 spare unit), 5 banks of 230/13.8 kV, 3-phase, 135 MVA unit, and 10 MVA x 1 reactor bank is connected to the tertiary winding of the 375 MVA bank. 2 circuits each of 230 kV transmission line are extended to Milago and Riobamba Substations, 2 circuits of 138 kV transmission line are extended to Cuenca Substation. The power from INECEL to local power companies is supplied by stepping down the voltage from 138 kV to 69 kV.

In the substation design of INECEL, the design is standardized by classifying the substation equipments into those at elevation below

1,000 m above sea level (Zone-1) and those at elevation above 1,000 m (Zone-2). The major design parameters are as presented below.

(a) Standard Impulse Insulation Strength (BIL)

Rated Voltage (kV)	BIL (kV) Zone-1	Bil (kV) Zone-2
230	750	1,050
138	550	750
69	350	450
13.8	110	150

(b) Short Circuit Capacity

Rated Voltage (kV)	Short Circuit Capacity (kA r.m.s.)
230	20
138	20,40
69	20
13.8	12

(c) Clearance

Rated Voltage (kV)	Phase-to-Phase Clearance (m)	Line-to-Ground Clearance (m)
230	4.5	4
138	3	3
69	2	2

(d) Bus System

230 kV;	double bus, with exception of single bus of Trinitaria.
138 kV and 69 kV;	single bus or inspection bus system
34.5 kV;	single bus system

(e) Circuit Breaker Type

For 230 kV and 138 kV;	dead tank type or insulator type SF, gas CB.
For 69 kV and 34.5 kV;	bulk oil type or small oil type oil CB or gas CB.

(f) Line Switch Type

For 230 kV and 138 kV;	horizontal opening, motor operated type
For 69 kV and 34.5 kV;	horizontal opening, motor or manually operated type

(g) Lightning Arrester Type

230 kV, 138 kV, 69 kV and 34.5 kV;	value type or zinc-oxide type.

3.3.3 Transmission Line Facilities

(1) Present Facilities

At present, the main backbone of the transmission system is SNI (Sistema Nacional de Interconnectado (see Fig.3-3)). This interconnection system comprises the 230 kV, double circuit loop transmission system extending for approximately 820 km, which connects the hydroelectric and thermal power plants of INECEL, including Paute Hydroelectric Power Plant, to the pacific coast load center including Guayaquil City and load centers in mountain areas including Quito City, and the double circuit and single circuit 138 kV transmission lines, having a total length of approximately 1,170 km and extending radially from the 8 primary substation located on the 230 kV loop system, as well as 11 substations and 5 power plants connected to these radial transmission lines.

The secondary transmission systems (Sistema de Subtransmission) of 19 local power companies, which are connected to the 69 kV sides (with some exceptions) of the 19 substation of SNI described above, interconnect all public electric power facilities in the Pacific coast and mountain areas.

(2) History of SNI

The history of SNI is relatively new, and it started when the 138 kV, single circuit transmission line from Ambato-Pisayambo (Pucará) to Vicentina (Quito), extending 155 km, was built in 1977 together with the construction of Pisayambo Hydroelectric Power Plant.

At this time, INECEL was engaged in Phase A and B project of Paute Hydroelectric Project. An U.S. consulting firm, International Engineering Co., was contracted, established standards and tentatively selected a transmission line route under cooperation of INECEL engineers as a part of this SNI.

INECEL implemented transmission line constructions in several phases thereafter, to attain the current status.

(3) 230 kV Loop Trunk Line of SNI

The 230 kV loop transmission lines, which form the backbone of SNI, run along routes having variety of geographical features. These are described below according to Fig. 3-3 and Table 3-12.

(a) Paute to Milagro

The line starts from the outdoor substation (elevation; 1,600 m) of Paute Power Plant and runs west, over the Western Range of Andes Plateau, goes straight down the western slope to reach the eastern edge of the Pacific Coast Plain, crosses plantations of banana and cacao and sugar cane, and reaches Milagro Substation. The distance is 141 km.

(b) Milagro to Pascuales

The line runs further westward, crosses sugar cane fields and paddy fields, crosses Babahoyo River and Daule River, to reach Pascuales Substation (elevation; 40 m). The total distance is 42 km, and a half of this section is swampy land.

(c) Pascuales to Quevedo

The line runs to the north from Pascuales, crosses plantations of paddy, banana, cacao, abaci (Manila hemp), etc. as well as tropical forest, to reach Quevedo Substation (elevation; 200 m). The total distance is 144 km.

(d) Quevedo to Santo Domingo

The line passes the hilly area to the northeast of Quevedo to reach Santo Domingo Substation (elevation; 600 m). There are large plantations of abaci, banana and palm. The total distance is 105 km.

(e) Santo Domingo to Santa Rosa

The line goes to the east from Santo Domingo, climbing steep western slope of the Andes, crosses a 3,300 meter ridge, to reach Santa Rosa Substation (elevation; 3,000 m) which is located on the Central Plateau of Andes. The distance is 78 km.

(f) Santa Rosa to Totoras

The line runs to the south from Santa Rosa, passes a gentle hilly ground (elevation: 3,300 m) that forms the saddle between Cotopaxi Mountain and Illiniza Mountain, goes through the Central Plateau of Andes, to reach Totoras Substation (elevation; 2,600 m). The total distance is 105 km. There are some pine and eucalypti forests and farm lands along the line, but it runs mostly on mountain lands having little vegetation.

(g) Totoras to Riobamba

The line runs to the south on a gentle hilly ground (elevation; 3,000 m) to reach Riobamba Substation (elevation; 2,700 m). The distance is 42 km. There are some orchards, farmlands and pasture lands along the line, but it runs mostly on mountain lands having little vegetation.

(h) Riobamba to Paute

The line from Riobamba runs further south on the Central Plateau of Andes, then turns to southeast and reaches Paute Power Station. The distance of this section is 163 km. The route is mostly on mountains, although there are some farm lands and pasture lands. One feature of this line is that only No. 1 circuit of the line is connected to Riobamba Substation by π-connection, and No. 2 circuit runs directly from Totoras Substation to Paute Power Station.

(4) Expansion of Paute-Pascuales Line to 4 Circuits and Formation of 230 kV, Semi-Loop Line around Guayaquil City

The construction work to expand the 230 kV, Paute-Pascuales Line to 4 circuits having increased transmission capacity, and SNI Phase D2 for the construction of a semi-loop transmission line from Pascuales Substation to Trinitaria which is a harbor and industrial district in the southern part of Guayaquil City, which is the first stage of the construction work to build the extra-high voltage loop system around Guayaquil City, that is essential for the power supply to this city of Ecuador, are being implemented under the Yen Loan of the Japanese Government (EC-P5). The construction will be completed by the end of 1995 at the latest, to drastically increase the power supply reliability for that city. The new transmission line has the same specification as the old transmission line. The transmission line route runs such areas as described below.

(a) Paute to Pascuales

The transmission line route runs almost in parallel to the north side of the existing 230 kV transmission line from Paute via Milagro to Pascuales. The new line is not connected to Milagro Substation, but it provides a direct connection between Paute Power Station and Pascuales Substation. The distance of this section is 190 km.

(b) Pascuales to Trinitaria

The line runs from Pascuales Substation on a hilly land to the north of Salitral Substation. The foundation condition is generally good in the hilly land, but the foundation work for steel towers would be difficult in the elevation zero area of Guayas River delta area from Salitral to Trinitaria. Therefore, the line will be supported in this section by artistically designed steel towers to be built in the right-of-way of Guayaquil loop highway until it reaches Trinitaria. The length of this section of the line is 25 km.

(5) Design of 230 kV Transmission Line

As described above, the 230 kV loop transmission line of S.N.I. will be built along a route on which the elevation changes substantially, from the high land of 3,500 m elevation to elevation 0-m above sea level. Since an uniform insulation design can not be applied to this line, INECEL has standardized the insulation design of this line by dividing the line to Zone-1 (elevation 1,000 m or less above sea level) and Zone-2 (elevation over 1,000 m above sea level). The basic design parameters are presented below.

(a) Conductor Clearance to Ground

Conductor temperature:
Normal condition; 60°C for Zone-1, 45°C for Zone-2
Emergency condition; 80°C for Zone-1 and Zone-2

		Normal	Emergency
Where traffic is low		7.5 m	6.0 m
Crossing with Class 2 Road			
	Zone-1:	9.0 m	7.7 m
	Zone-2:	8.3 m	7.0 m
Crossing with Class 1 Road			
	Zone-1:	10.2 m	8.9 m
	Zone-2:	9.5 m	8.2 m

(b) Steel Tower (Galvanized, Angle Steel Self-Supporting Structure)

1) Surface wind load 60 kg/m²
2) Circular pipe wind load 18 kg/m²
3) Conductor weight, ACSR 1,113 MCM "Bluejay" 1.867 kg/m
4) Conductor weight, ACSR 1,113 MCM "Finch" 2.129 kg/m
5) Ground wire weight, 3/8" galvanized steel strand 0.407 kg/m
6) Suspension insulator string weight, Zone-1 60 kg
7) Suspension insulator string weight, Zone-2 92 kg
8) Strain insulator string weight, Zone-1 64.5 kg
9) Strain insulator string weight, Zone-2 96.5 kg
10) Loading condition
    a) Vertical
    Total weight of conductors, ground wires and insulator strings at the longest span plus 200 kg of maintenance weight.
    b) Vertical Overload
    Simultaneous application of the following loads at suspension or strain point by construction work and repair work is assumed:

* Twice the weight of conductors
* Total weight of one conductor and one ground wire
* Weight of two ground wires

c) Lateral Load

The following two types of load are considered:

* Maximum wind velocity of 60 km/h (for Zone-1 and Zone-2, according to meteorological data from 1962 to 1982).
* Load created by angle (lateral load due to directional angle of line).

d) Longitudinal Load (along the line)

The following cases are considered:

* Imbalance in the direction of line
* Dead end stringing
* Conductor stringing
* Broken conductor (combinations of one ground wire or two ground wires, one conductor or two conductors, one ground wire and one conductor)

e) Uplift force at a strain tower is considered.

11) Design of Steel Tower

Form of steel tower is different in Zone 1 and Zone 2 according to the design parameters described above. Representative example for each form of suspension steel tower is shown in Fig. 3-4.

(c) Conductor and Ground Wire

The economical span length and economical conductor size of 230 kV transmission line have been examined, to have the following conclusion.

1) Economical Span Length

a) Zone-1: 350 m

b) Zone-2: 400 m

2) Selected Conductor

a) Suspension tower (for span of 700 m or less): ACSR 1,113 MCM "Bluejay" single conductor

b) Strain tower or suspension tower with span of more than 700 m): ACSR 1,113 MCM "Finch" single conductor

c) Ground wire: high tension steel 3/8"

(d) Insulator String

a) Zone-1: 10" x 5¾" insulators x 14/string

b) Zone-2: 10" x 5¾" insulator x 15~20/string (3,500 m above sea level)

(e) Number of Ground Wire

IKL is 30 in Zone-1, and 50 in Zone-2. Based on this, the number of ground wires was selected as one in Zone-1 (30° shielding angle) and two in Zone-2 (20° shielding angle).

(6) Electric Parameters and Transmission Capacity of 230 kV Transmission Line

(a) Electric Parameters

The electric parameters as determined by the conductor arrangement at a suspension tower are as Table 3-13:

(b) Transmission Capacity

With wind velocity of 0.6 m/sec and radiation coefficient of 0.5, the transmission capacity in normal condition (conductor temperature, Zone-1; 60°C, Zone-2; 45°C) and emergency condition (conductor temperature, Zone-1 and Zone 2; 80°C), at the highest elevation of Zone-1 and Zone-2 (1,000 m and 3,500 m respectively) are as below:

	Temperature (°C)	Transmission Capacity (MVA)
Zone-1:	60	339
	80	453
Zone-2:	45	297
	80	465

(7) 138 kV Transmission Line

The 138 kV transmission lines of SNI are shown in Table 3-14. These are mostly radial transmission lines which are constructed in order to connect the hydroelectric power plants and thermal power plants of INECEL and load centers in remote areas to the 230 kV loop transmission lines. As the length and transmission capacity of each 138 kV line are different, the design of these lines can not be standardized as in the case of 230 kV lines. Also, the transmission lines which were built after the construction of Milagro-Babahoyo Line in 1984 uses only strain and dead-end steel towers for both single circuit lines and double circuit lines, and steel reinforced concrete poles of domestic production are used for suspension support structures. The major 138 kV transmission lines among the lines of SNI illustrated in Fig. 3-3 are described below.

(a) Vicentina-Ibarra-Tulcan Line

The line runs from Vicentina Substation in Quito City along the hill on the north side of the city, crosses Guayllabamba Canyon at the equator, passes the volcanic ash plateau with little vegetation, passes the fertile farmland of Northern Area, and reaches Ibarra Substation of SNI located in the south of Ibarra City. The total distance is 80 km. The line had only one circuit on double circuit towers, but the stringing of another circuit is currently under way to convert the line to double circuit in 1993.

To the north from Ibarra Substation, the line passes the hills and farm lands of the Central Plateau of Andes until it reaches Tulcan Substation to be constructed by SNI in Tulcan City at the border of the Republic of Colombia. This section is 70 km long, and large vegetation such as trees is scarce. This section is currently under construction, and will be completed by 1994. The conductor is ACSR 477 MCM.

(b) Agoyán-Totoras Line

The line runs west from the outdoor substation of Agoyán Power Plant which was constructed at elevation 1,620 m above sea level on Pastaza River that runs east from the Central Plateau of Andes. The line climbs the slope on the right bank of the river at a downstream of Agoyán Dam, passes the plateau behind Baños Town, goes down to the bank of Patate River. Then the line is pulled up the slop at an steep angle, again runs on the hills, and reaches Totoras Substation of SNI (2,600 m above sea level) which is located to the east of Ambato City. The total length is 32.9 km, and no large vegetation, except for eucalypti beneath the line. The line is a double circuit facility on double circuit design towers, with conductors being ACSR 636 MCM. In near future, a single circuit is installed to Agoyán Substation. It is being planned to upgrade the existing Baños-Puyo Line (53 km long) to 138 kV, and extend to Tena-Coca, to supply the major load centers of Pastaza Province, Napo Province and Sucumbio Province in the eastern area under SNI.

(c) Paute-Cuenca-Loja Line

The line runs southwest from Paute Powr Station (1,600 m above sea level) along Paute River, and across hilly lands and farm lands to reach Cuenca Substation (2,400 m above sea level) outside Cuenca City, for a distance of 70 km which is a route having ups and downs. There is little vegetation except eucalypti beneath the line. The facility is a double circuit line on double circuit towers, having ACSR, 397.5 MCM conductors. From Cuenca Substation to Loja, the line passes plains and hills of the Central Plateau of Andes. In this section, too, there is little vegetation of large size that could form obstruction beneath conductors. The facility is a single circuit line on double circuit tower, having ACSR 397.5 MCM conductors. The total length is 135 km. A 138 kV transmission line built on single circuit towers and having ACSR 266.8 MCM conductors, with a total length of 70 km, will be completed in 1993 from Cuenca to Limon of Morona Santiago Province of middle Orient Area, which will be tentatively operated at 69 kV. Another 138 kV, single circuit line on single circuit tower, having ACSR 266.8 MCM conductors, with a total length of 52 km, is under construction from Loja Substation to Cumbaratza of Zamora Chinchipe Province in the southern Orient Area. This line will be completed in 1994, and will be tentatively operated at 69 kV.

(d) Santo Domingo-Esmeraldas Line

The line runs north by northwest from Santo Domingo Substation of SNI (600 m above sea level) through large plantations of palm, abaci, banana, etc. and tropical forest in the Pacific coastal plain, to reach the thermal power plant in the southern suburb of Esmeraldas City. The vegetation beneath the line in this area are tropical plants which grow relatively quickly. The vertical clearance of the conductors, including the effect of conductor sag, must be watched. This line is a double circuit line built on double circuit towers, having ACSR 397.5 MCM conductor. The line length is 154 km.

(e) Quevedo-Portoviejo Line

The line runs west from Quevedo Substation of SNI through farmlands of banana, cacao and palm, as well as tropical forests, crosses Daule River and passes hilly land in the eastern part of Manabi Province. Then the line enters an area where vegetation is little, and reaches Portoviejo Substation. The line is a double circuit facility on double circuit towers, having ACSR 397.5 MCM conductors, with a total length of 107 km. When Daule Peripa Hydroelectric Power Plant is constructed in future, the line will be connected to this power station by π-connection.

(f) Pascuales-Salitral Line

The line runs south from Pascuales Substation of SNI along the hilly ground (elevation; 100 to 300 m) to the west of the substation to reach Salitral Substation. The line length is 17.2 km, and the line is a double circuit facility installed on double circuit tower. The conductors are ACSR 477 MCM. The geology of the hilly ground on which this transmission line passes is mostly limestone, where large tropical woods are scarce. There is the Rocafuerte Cement Plant and its limestone quarry on the western side of this hilly ground, and attention must be paid on the contamination of line insulators by the dust from the quarry.

This transmission line is an interconnection line for Estero Salado Thermal Power Plants and also serves as the loop circuit for the western part of Guayaquil City.

(g) Pascuales-Santa Elena Line and Pascuales-Posorja Line

The conductors of Santa Elena Line and Posorja Line are strung on the same support structures for the section of 45 km to the west from Pascuales Substation to Las Juntas Point. One circuit from Las Juntas runs further west for 62 km and connected to Santa Elena Substation, while another circuit stretches to the south for 53 km and connected to Posorja Substation.

Only strain towers and dead end towers are used as the support structures of these transmission lines, and domestic steel reinforced concrete poles are used for suspension structures. The conductors are ACSR 397.5 MCM, and insulators are fog insulators.

Santa Elena Peninsula where these two transmission lines pass have very little precipitation, and the land is turned to desert by the salt blown from the sea. The pollution is insulators in this area is severe, and it is reported that insulators are periodically replaced and washed.

(h) Milagro-Machala Line

The line runs south from Milagro Substation of SNI through large plantation areas of sugar cane, paddy, pastures, and cacao, as well as the largest banana plantation in Ecuador, to reach Machala Substation. This transmission line is a double circuit structure, and many steel reinforced concrete poles area used as support structures, similarly to Santa Elena Line. The conductors used area ACSR 397.5 MCM. This area is generally tropical, and there area large plants which grow quickly underneath the line conductors. Trimming of trees under the line conductors is difficult in highly productive plantations such as banana field. There have been accidents of light airplanes spraying insecticide contacting the power line.

(8) Design of 138 kV Transmission Line

The environments on the routes of 138 kV transmission line are also extremely varied, and a uniform design criteria can not be established. Therefore, the transmission line environmental conditions are classified to Zone 1 and Zone 2, similarly to the 230 kV transmission lines, and the following standards are established.

(a) Conductor Ground Clearance

Conductor temperature:	Normal condition;		Zone 1 at 60°C, Zone 2 at 45°C
	Emergency condition;		Zone 1 and Zone 2 at 80°C
	Normal Condition		Emergency Condition
Where traffic is low:		6.80 m	5.50 m
Intersection with Class 2 road:	Zone 1;	7.80 m	6.50 m
	Zone 2;	8.30 m	7.00 m
Intersection with Class 1 road:	Zone 1;	9.00 m	7.70 m
	Zone 2;	9.50 m	8.20 m

(b) Support Structure of 138 kV Transmission Line

As discussed before, the galvanized steel structures are used as the support structures of 138 kV transmission lines in Zone 2. In Zone 1, however, steel reinforced concrete poles, which are domestically manufactured under the technical guidance of INECEL, are being introduced for the suspension structures in Zone 1. The type of suspension support structures of 138 kV transmission lines is presented in Fig.3-5.

(c) Economical Span of 138 kV Transmission Line

The economical span of 138 kV transmission lines (the distance between poles) is defined as below.

Zone 1:	320 m
Zone 2:	330 m

(d) Conductor and Ground Wire

Conductor:	ACSR 266.8 MCM "Patridge" ACSR 397.6 MCM "Brant" ACSR 477 MCM "Flicker" ACSR 636 MCM "Rock"
Ground Wire:	Galvanized high tension steel strand cable, 3/8"

(e) Insulator String

a) Zone 1: 20" x 5¾" insulator, 9 insulators/string
b) Zone 2: 10" x 5¾" insulator, 13 insulators/string
c) Zone 1: fog type insulator, 8 insulators/string (high salt pollution area)

(9) Maintenance of INECEL transmission lines

INECEL transmission lines are maintained by transmission line belonging to the four local offices of DOSNI; Paute (southeast), Pascuales (southwest), Santa Rosa (northeast), and Santo Domingo (northwest). These facilities carry out regular patrols, regular inspection/maintenance, fault patrols, recovery, and clearing beneath the lines. However, the differences in the natural environmental conditions prevailing along the transmission lines appear to provide difficulties in providing uniform inspection and in determining the required maintenance standards. Especially, it affects the 138 KV lines. Also, the number of faults is remarkably high in the plains along the Pacific Coast.

Table 3-15-A shows the fault statistics of every INECEL transmission line for the periods 1990 and 1992.

Table 3-16 shows the frequency and time of outage (planned outage) for repairs and inspection during the same period.

(10) Statistics and analysis of transmission line faults

For service suspension (excluded reclosing success) among all transmission faults, it is extremely important to collect precise statistics over a long term and analyze the results accordingly. The result should be used as future reference for the review of design standards, when planning the facility improvement, and when revising inspection/maintenance standards. This will improve overall supply reliability.

Although we requested DOSNI of INECEL to provide the necessary fault statistics related data, we were only able to acquire the data for the three years; 1990, 1991 and 1992. In this data, transmission fault causes were analyzed only for 1991 and 1992. (See Table 7-2) Also, the data did not report 40% of the faults in 1991 and 31% of the faults in 1992.

Transmission fault statistics can not be used for the study of facility improvement unless analysis results are accumulated for 5 to 10 years. For instance, we use the above described data to calculate the 'number of faults/100km' which indicates the frequency of transmission fault occurrence. The result is described in the following table to be compared with that in Japan.

Number of Faults/100 km

Faults/100 km						
Country	Voltage (kV)	1990	1991	1992	Total Length (km)	Notes
Ecuador	230 138	0.73 2.40	0.85 2.80	1.46 1.62	820 1,167.5	INECEL INECEL
Japan	More than 7 km	-	0.48	0.79	82 x 1000	10 E.P.Co.

Note: The fault statistics data in Japan includes all the transmission and distribution lines (more than) of 9 electric power companies and EPDC.

Fault ratio according to voltage;

Less than 33KV; 47.47%

44KV - 77KV; 44.78%

110KV - 154KV with 3-phase reclosing device; 7.02%,

More than 187KV with 3-phase reclosing device; 0.74%

(during 1962 - 1967)

The transmission lines providing extremely high fault rates among all SNI transmission lines are shown below.

High Faults Rate T/L in SNI

Name of Transmission Line	Voltage (kV)	1990	1991	1992	Length (km)
Riobamba - Totoras	230	4.76	0	2.38	42
Paute - Milagro	230	2.13	2.13	6.38	141
Milagro - Machala	138	3.88	3.10	6.20	129
Pascuales - Posorja	138	6.12	4.08	1.02	98
Pascuales - Sta. Elena	138	5.61	5.61	0	107
Sto. Domingo - Esmeraldas	138	1.95	3.90	2.60	154
Cuenca - Loja	138	2.96	2.22	0.74	135

The result of fault analysis is shown in Fig. 3-7. In the figure, 43 faults (more than 27%) occurrence indicates that the precision of the statistics has been extremely damaged and must be improved.

(11) Suggestions based on the fault statistics and its analysis result

(a) The number of faults along the 230KV ring trunk line between Paute and Milagro is remarkably high. It is necessary to pursue the causes and provide suitable countermeasures.

(b) The 138KV Pascuales - Santa Elena line and Pascuales - Posorja line are a highly damaged area as described earlier. Despite frequent planned outage for inspection and repair in 1990 and 1991, they showed a high fault ratio. In 1992, however, fault occurrence was greatly reduced despite reduced planned outage time, indicating that the maintenance method has been improved.

(c) Vegetation, especially the trailing weeds grow extremely fast along the transmission lines such as the 138KV Santo Domingo - Esmeraldas line and Milagro - Machala line which are situated in tropical zones with high temperatures and heavy rainfalls.

Bananas, abaca and palms are planted beneath the transmission lines on large farms and also grow very fast.

The heat also stretches the power lines and causes them to sag to the ground or other conductive structures and plants, there by causing grounding faults.

The high fault ratio is also caused by low flying, light crop dusting aircraft which contact the lines. Another factor which causes grounding fault are aeronautic indicators (two to three 70cm diameter red plastic balls suspended from an overhead earth-wire), which pulls the earth-wire down as rainwater accumulates inside them. (These aeronautic indicators have now been improved.)

These causes must be thoroughly and the appropriate countermeasures provided.

As described, maintenance methods and fault causes vary depending on local characteristics. As the SNI transmission lines are extended in the future from a substation in the mountainous area to the tropical rain forest in the east region, they will face new faults caused by different vegetation and wild life. Different countermeasures will, therefore, be required to combat new forms of fault.

The vegetation along the transmission lines causes the highest ratio of 1ϕ earth faults. Depending on the type of vegetation involved, clearing seems difficult as it involves providing compensation.

INCEL's clearing guidelines are shown in Fig. 3-6 and below. These guidelines are classified for three types of plants and applied to each type separately.

Type A: The clearing of plantations results in providing extremely costly compensation as it incurs the destruction of product. Therefore, only the trunks and branches that reach 'z' height in the following table shall be cut down to minimize the clearing dimensions.

Type B: Where the transmission line is installed through a plantation (bananas, sugar cane, etc.), all the vegetation within the minimum dimensions specified for the safety of plantation workers and/or for the safety of the line shall be cut.

Type C: If the transmission line is installed where the height of the forest, woods and plants must be considered, the plants in the zone 2h+XA(width) shall be cleared.

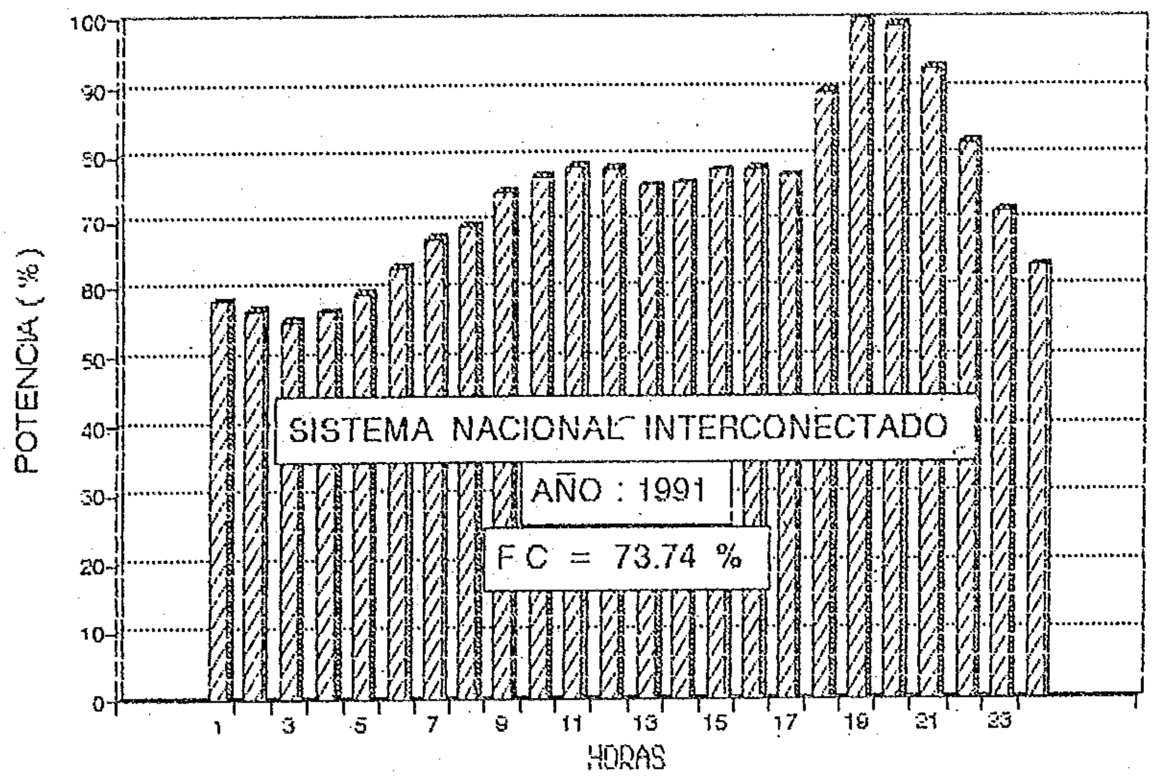
	138 kV			230 kV	
Distance	Zone 1 (m)	Zone 1* (m)	Zone 2 (m)	Zone 1 (m)	Zone 2 (m)
X	6.80	8.30	7.00	7.50	7.50
Y	8.30	3.30	4.00	4.00	4.00
Z	3.50	5.00	3.50	3.50	3.50

*: Banana plantation zone (Milagro-Machala Transmission line)

(12) Electric parameters of 138 kV Transmission Line are as table 3-13.

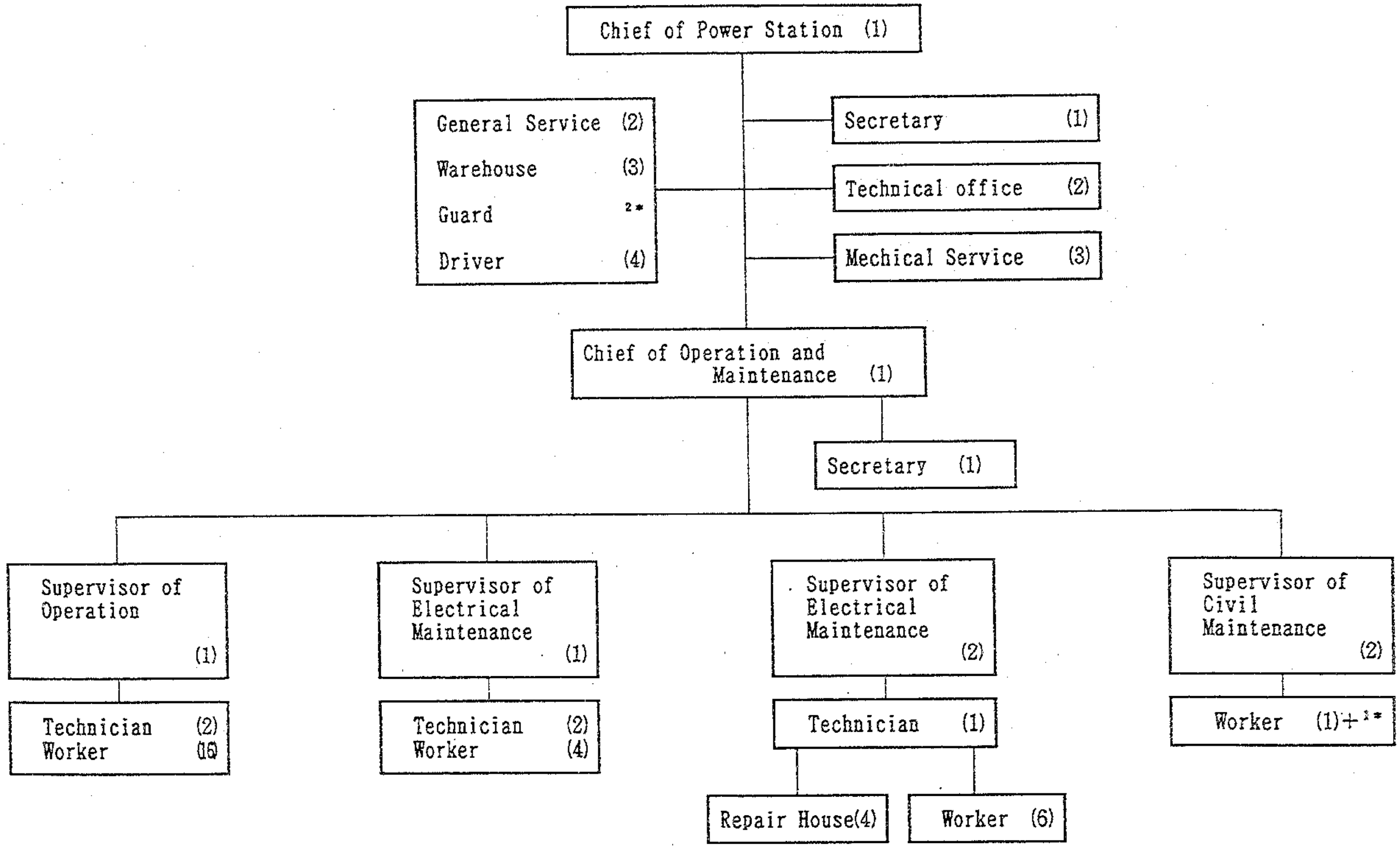
CURVA DE CARGA DIARIA

DIA DE MAXIMA DEMANDA



CURVA DE CARGA DIARIA - SNI			
HORA	POTENCIA (%)	HORA	POTENCIA (%)
1	58.04	13	75.50
2	56.64	14	75.89
3	55.25	15	77.78
4	56.41	16	78.07
5	58.92	17	77.03
6	62.80	18	89.53
7	67.39	19	100.00
8	69.27	20	99.03
9	74.65	21	92.89
10	76.91	22	81.84
11	78.38	23	71.41
12	78.01	24	63.01

Fig. 3-1 Daily Load Curve



※Extra-employee

Fig.3-2 Organization Chart of "AGOYAN" Hydro Power Station

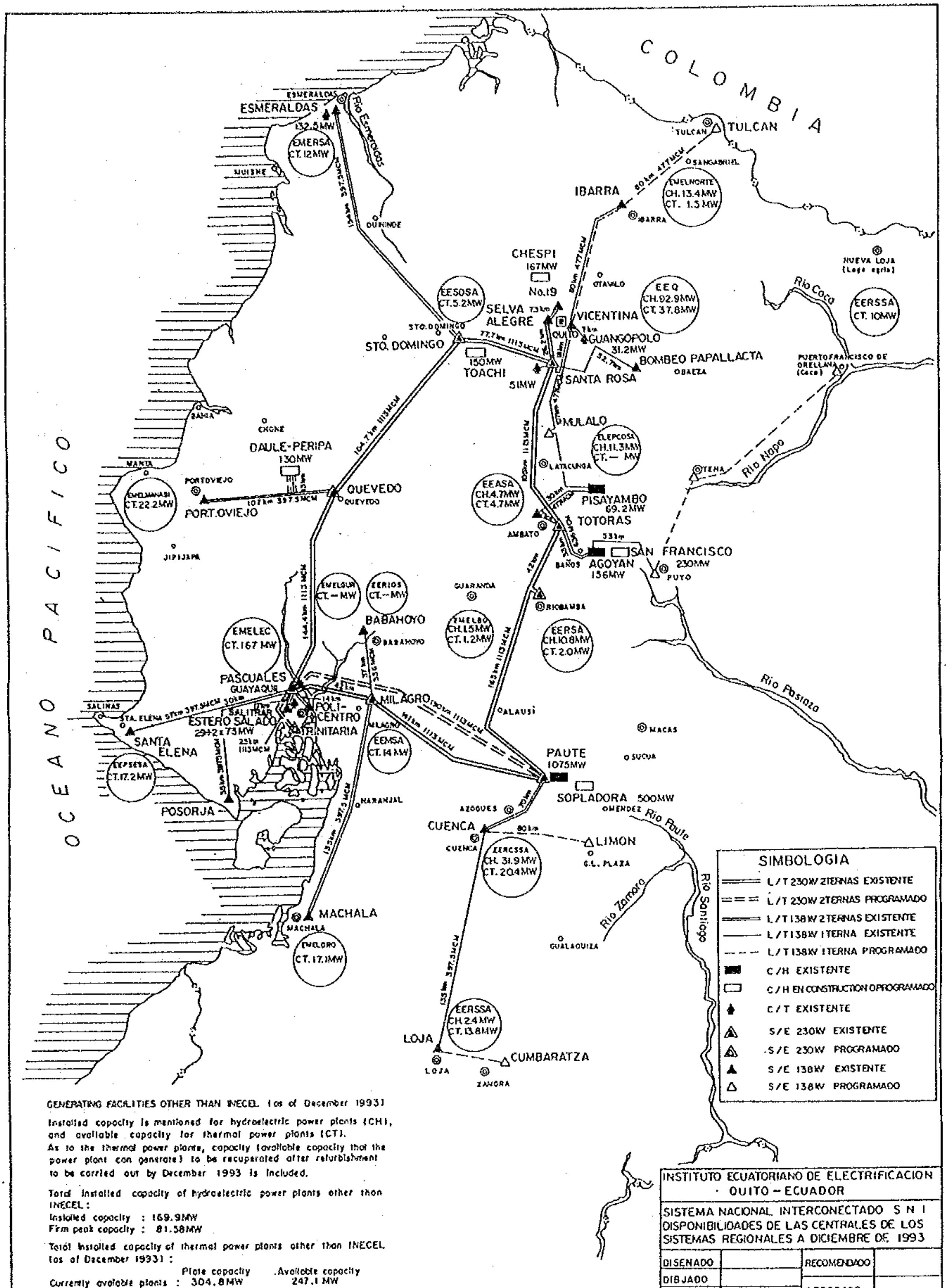


Fig. 3-3 Location Map —SNI—

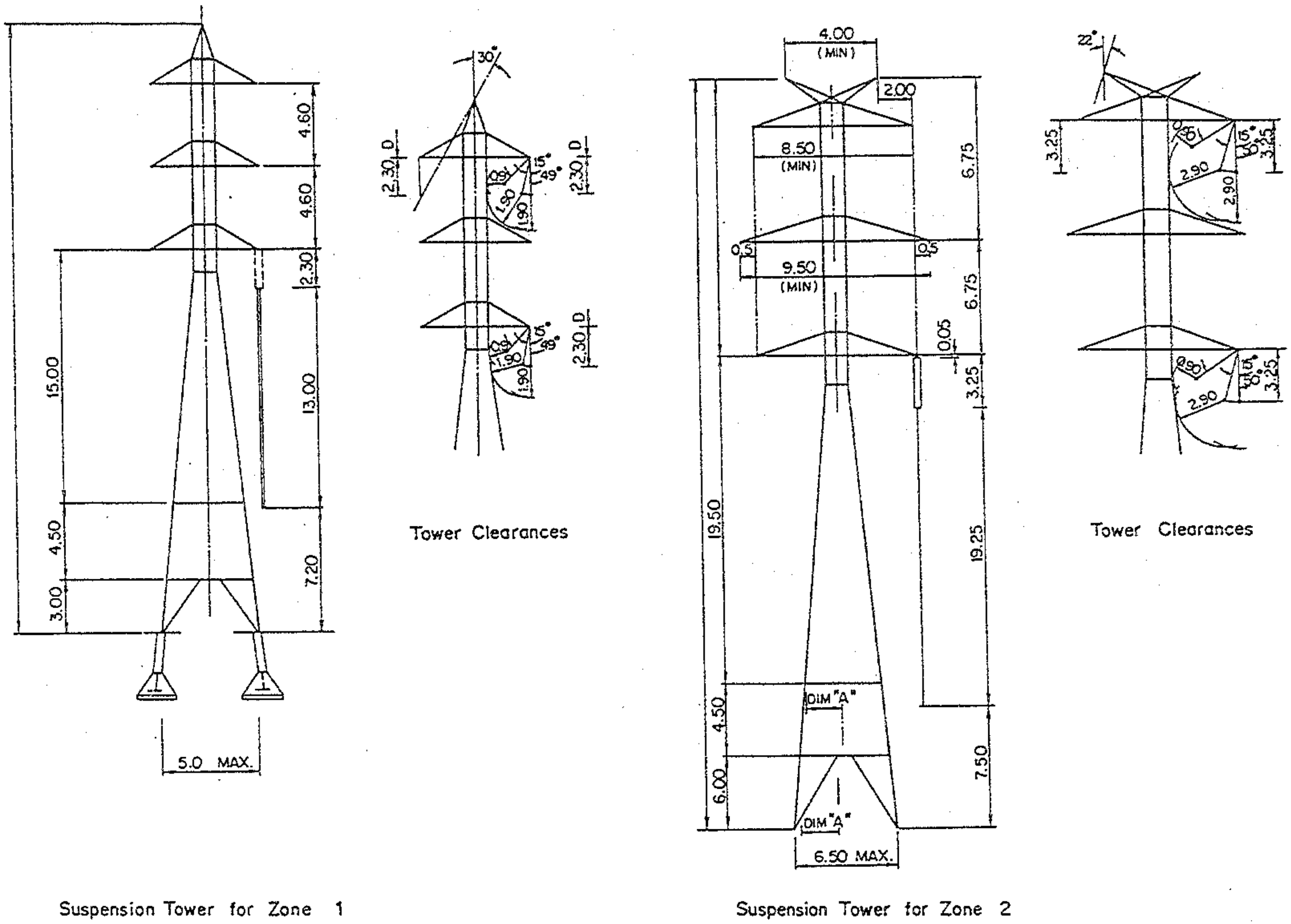


Fig. 3-4 230kV Steel Tower

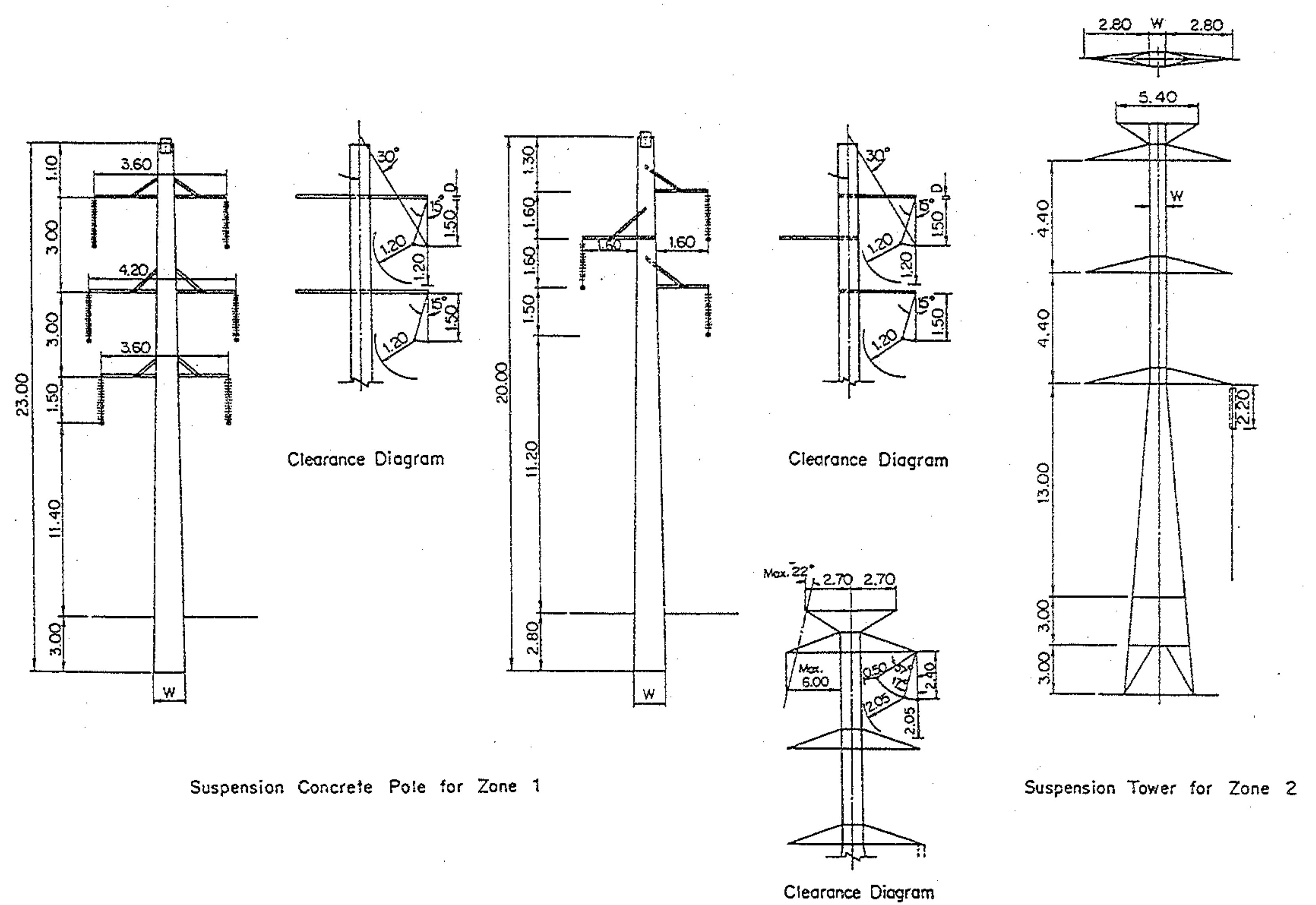


Fig. 3-5 138kV Concrete pole and Steel Tower

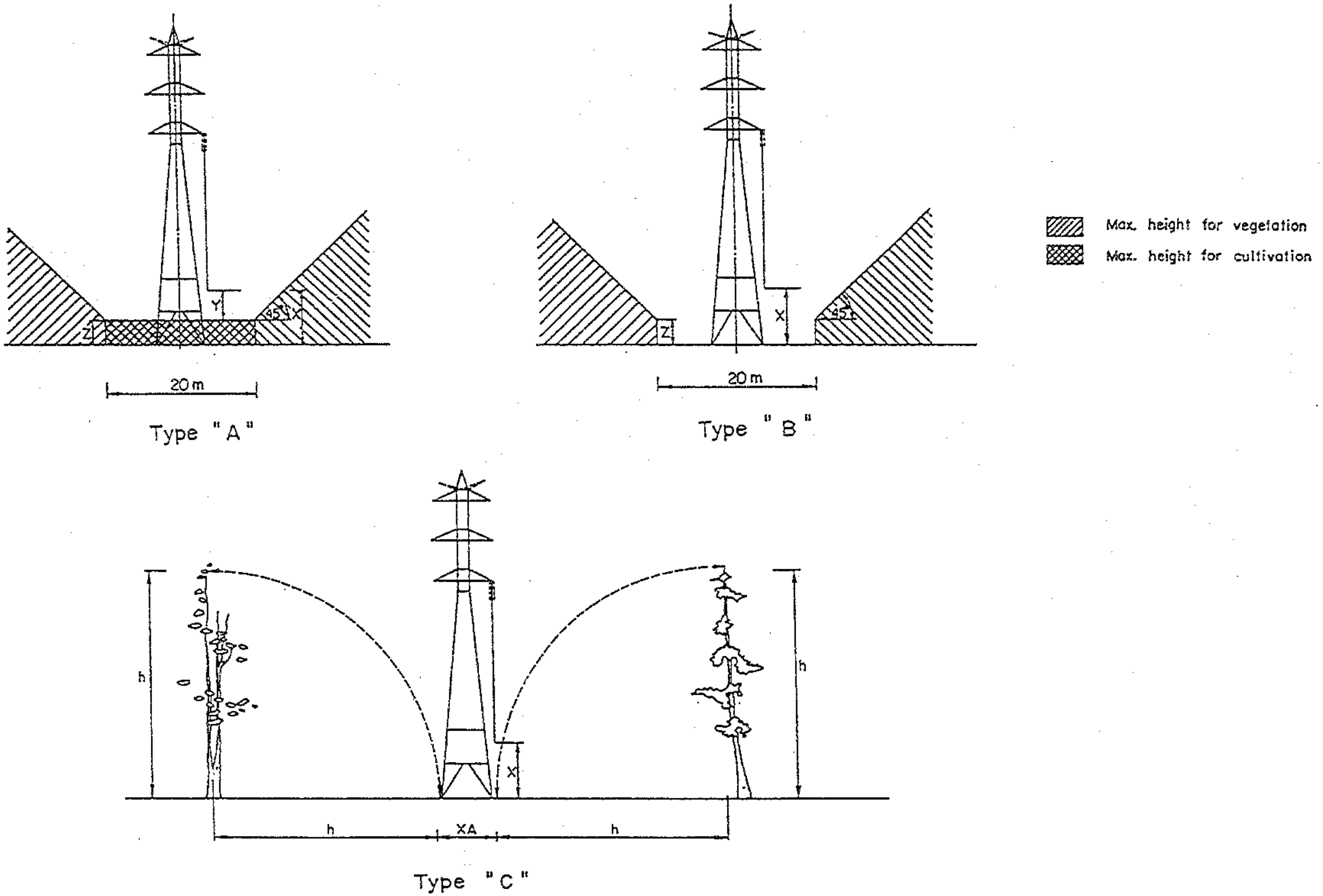
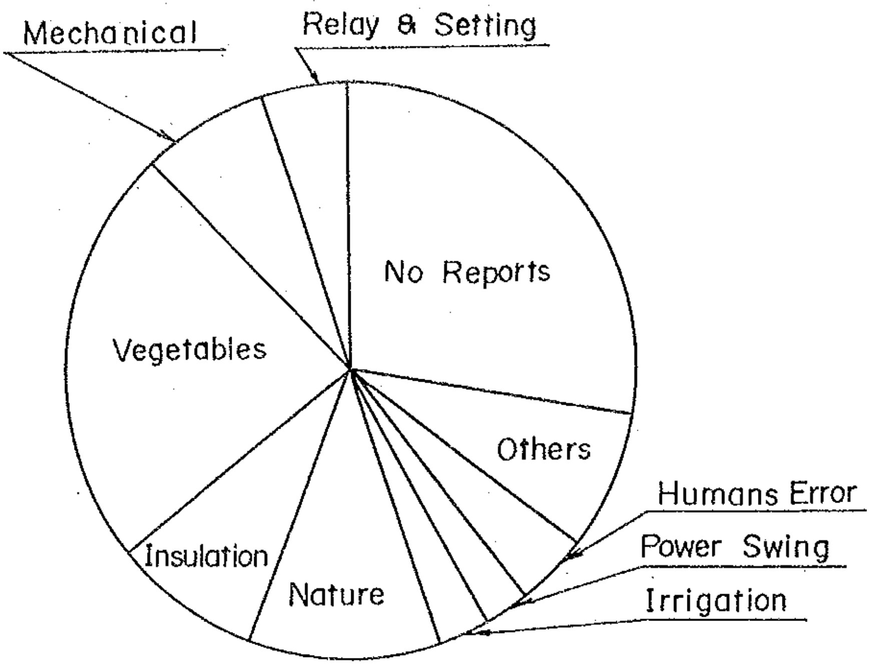


Fig. 3-6 Clearance of Right of Way Guide for Deforestation

In case of S N I (230kV & 138kV)
1991 - 1992



In case of Japan (More than 7kV)
1965-1974. 9 E.P. Co & EPDC

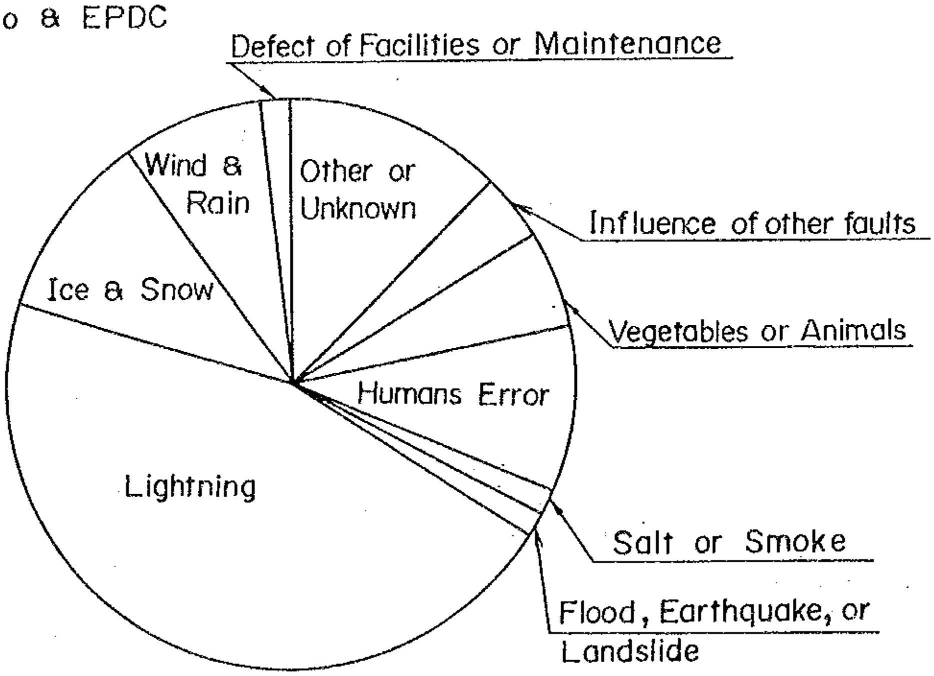


Fig. 3-7 Causes of Faults

Table 3-1 Trend of Domestic Electric Energy Consumption and Maximum Power

Year	Energy Consumption(GWh)								Genera-tion (GWh)	Maximum Power (MW)
	Energy (GWh)					Loss (GWh)				
	Residential	Industrial	Commercial	Another	Total	Distribution	Transmission	Others		
1980	1,035	930	381	253	2,599	392	5	83	3,080	
1981	1,116	1,035	414	259	2,824	449	22	98	3,393	
1982	1,212	1,079	457	320	3,068	565	52	134	3,819	638
1983	1,338	1,069	494	336	3,237	588	64	126	4,015	684
1984	1,331	1,061	514	382	3,288	725	130	74	4,217	726
1985	1,388	1,192	548	410	3,538	776	153	79	4,546	800
1986	1,508	1,266	606	450	3,830	865	198	79	4,972	922
1987	1,671	1,364	673	495	4,203	898	206	81	5,388	1,027
1988	1,694	1,399	689	535	4,317	1,029	204	83	5,633	1,057
1989	1,720	1,425	691	579	4,451	1,062	217	76	5,770	1,120
1990	1,873	1,525	725	674	4,797	1,205	250	109	6,361	1,240
1991	2,015	1,671	771	808	5,267	1,341	245	139	6,992	1,340
1992	2,148	1,658	813	830	5,449	1,414	239	126	7,228	1,442

Table 3-2 Percent of Electrification

Year	Electrification									
	Population (Urban Area)			Population (Suburban Area)			Population (Total)			Propose of Electrification
		Electriviation			Electrification			Electrification		
	Thousand	Thousand	(%)	Thousand	Thousand	(%)	Thousand	Thousand	(%)	Thousand
1980	3,604	3,171	88.0	4,023	915	22.7	7,645	4,109	53.8	701
1981	3,781	3,369	89.1	4,057	1,049	25.9	7,850	4,433	56.6	777
1982	3,968	3,579	90.2	4,092	1,203	29.4	8,061	4,782	59.3	846
1983	4,119	3,732	90.6	4,118	1,293	31.4	8,244	5,028	61.0	902
1984	4,275	3,891	91.0	4,144	1,391	33.6	8,431	5,288	62.7	851
1985	4,437	4,057	91.4	4,170	1,495	35.9	8,623	5,560	64.5	1,020
1986	4,606	4,231	91.9	4,196	1,607	38.3	8,819	5,847	66.3	1,086
1987	4,781	4,411	92.3	4,222	1,728	40.9	9,019	6,148	68.3	1,157
1988	4,962	4,600	92.7	4,249	1,858	43.7	9,224	6,465	70.1	1,230
1989	5,150	4,796	93.1	4,275	1,998	46.7	9,434	6,798	72.1	1,309
1990	5,346	5,001	93.5	4,302	2,148	49.9	9,648	7,148	74.1	1,405
1991	5,467	5,126	93.8	4,400	2,240	50.9	9,867	7,365	74.6	1,497
1992	5,591	5,254	94.5	4,500	2,336	51.9	10,051	7,590	75.2	1,580

Table 3-3 Saled Energy and Generated Energy

Year	Saled energy (GWh)								Generated Energy (GWh)		Maximum Power (MW)
	Saled					Loss					
	Resid.	Inds.	Comm.	Others	Total	Dist.	Trans.	Others	Generated	Total	
1980	1035	930	381	253	2599	392	5	84	3080	3080	
1981	1116	1035	414	259	2824	449	22	98	3393	3393	
1982	1212	1079	457	320	3068	565	52	134	3819	3819	638
1983	1338	1069	494	336	3237	588	64	126	4015	4015	684
1984	1331	1061	514	382	3288	725	130	74	4217	4217	726
1985	1388	1192	548	410	3538	776	153	79	4546	4546	800
1986	1508	1266	606	450	3830	865	198	79	4972	4972	922
1987	1671	1364	673	495	4203	898	206	81	5388	5388	1027
1988	1694	1399	689	535	4317	1029	204	83	5633	5633	1057
1989	1720	1425	691	579	4415	1062	217	76	5770	5770	1120
1990	1873	1525	725	674	4797	1205	250	109	6361	6361	1240
1991	2016	1672	771	808	5267	1341	245	139	6992	6992	1340
1992	2148	1658	813	830	5449	1414	239	126	7228	7228	1442

Table 3-4 Installed Capacitry of Power Station
(MW)
As of January, 1993

Enterprise / Type of Generation	S.N.I	Regional System	Municipal Corporation	Orient & Galapagos	Total of Public Service	Independent Service	Total of National Service
Hydroelectric	1,300.20	170.27	1.54	0.15	1,472.16	13.30	1,485.46
Thermal-Electric	391.64	428.09	1.23	10.29	831.25	117.15	948.40
- Vapor (Bunker)	278.50	63.00	0.00	0.00	341.50	0.00	341.50
- Diesel (Diesel)	0.00	169.43	1.23	10.29	180.95	117.15	298.10
- Diesel (Bunker)	31.20	115.91	0.00	0.00	147.11	0.00	147.11
- Gas (Diesel)	81.94	79.75	0.00	0.00	161.69	0.00	161.69
Total	1,691.84	598.36	2.77	10.44	2,303.41	130.45	2,433.86
%	69.51	24.59	0.11	0.43	94.64	5.36	100.00

Note: Regional System includes capacity of sucumbios power company which cannot operate in parallel to the national power system and small station with the capacity less than 500 kW.

Table 3-5 Annual Electric Power Installed Capacity (MW)

Year	S.N.I			Regional System			Municipal Corporation			Total		
	Hydro	Thermal	Sum	Hydro	Thermal	Sum	Hydro	Thermal	Sum	Hydro	Thermal	Sum
1965	0.0	0.0	0.0	51.6	74.8	126.4	8.8	5.4	14.2	60.4	80.2	140.6
1966	0.0	0.0	0.0	72.7	78.0	150.7	8.8	5.2	14.0	81.5	83.2	164.7
1967	0.0	0.0	0.0	82.5	84.1	100.6	9.0	5.2	14.2	91.5	89.3	180.8
1968	0.0	0.0	0.0	79.6	100.6	180.2	9.1	4.3	13.4	88.7	104.9	193.6
1969	0.0	0.0	0.0	89.0	106.0	195.0	8.9	4.1	13.0	97.9	110.1	208.0
1970	0.0	0.0	0.0	90.0	136.4	226.4	9.0	4.9	13.9	99.0	141.3	240.3
1971	0.0	0.0	0.0	89.0	160.5	249.5	9.0	5.5	14.5	98.0	166.0	264.0
1972	0.0	0.0	0.0	89.0	181.5	270.5	9.1	4.8	13.9	98.1	186.3	284.4
1973	0.0	0.0	0.0	87.2	203.0	209.2	8.4	3.6	12.0	95.6	206.6	302.2
1974	0.0	0.0	0.0	118.6	258.9	377.5	8.5	5.9	14.4	127.1	264.8	391.9
1975	0.0	0.0	0.0	121.1	301.3	422.4	7.3	3.6	10.9	128.4	304.9	433.3
1976	0.0	0.0	130.2	123.4	350.9	474.3	7.2	4.0	11.2	130.6	354.9	485.5
1977	70.0	60.2	130.2	126.5	395.7	522.2	7.1	1.7	8.8	203.6	457.6	661.2
1978	70.0	133.2	203.2	134.6	436.5	571.1	7.2	1.6	8.8	211.8	571.3	783.1
1979	70.0	133.2	203.2	139.0	463.2	602.2	5.9	2.0	7.9	214.9	598.4	813.3
1980	70.0	206.2	276.2	139.0	540.6	679.6	5.9	1.9	7.8	214.9	748.7	963.6
1981	70.0	257.5	327.5	154.9	568.2	723.1	3.9	1.7	5.6	228.8	827.4	1,056.2
1982	70.0	382.5	452.5	154.0	578.1	732.1	1.2	1.3	2.5	225.2	961.9	1,187.1
1983	570.0	382.5	952.5	154.0	570.7	724.7	3.3	1.6	4.9	727.3	954.8	1,682.1
1984	569.2	375.5	944.7	155.3	528.8	684.1	0.4	1.6	2.0	724.9	905.9	1,630.8
1985	569.2	375.5	944.7	166.8	398.3	565.1	0.4	1.6	2.0	736.4	775.4	1,511.8
1986	596.2	375.5	944.7	169.8	398.3	568.1	0.4	1.6	2.0	739.4	775.4	1,514.8
1987	725.2	375.5	1,100.7	166.8	543.0	709.8	0.4	1.6	2.0	892.4	920.1	1,812.5
1988	725.2	375.5	1,100.7	172.5	466.9	639.4	0.6	0.9	1.5	898.3	843.3	1,741.6
1989	725.2	375.5	1,100.7	172.5	466.7	639.2	0.6	0.9	1.5	898.4	843.1	1,741.4
1990	725.2	391.6	1,116.8	170.8	429.9	600.7	0.0	0.0	0.0	896.0	821.5	1,717.5
1991	1,300.2	391.6	1,691.8	170.5	438.4	608.9	0.0	0.0	0.0	1,470.7	830.0	2,300.7