PERUSAHAAN UMUM LISTRIK NEGARA
AGENCY OF MINISTRY OF MINES AND ENERGY
GOVERNMENT OF THE REPUBLIC OF INDONESIA

REPORT
on
FEASIBILITY STUDY
of
EAST JAVA POWER SYSTEM EXPANSION PROJECT

FEBRUARY, 1985

THE JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

It is with great pleasure that I present this Feasibility Study Report on the East Java Power Expansion Project to the Government of the Republic of Indonesia.

This report embodies the result of a series of field surveys carried out in East Java area from February to August, 1984 by a Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Republic of Indonesia to the Government of Japan.

The survey team, headed by Mr. Taikichi SHUKU, held close discussions on the project with the officials concerned of the Government of the Republic of Indonesia, conducted a wide-ranging field survey and has prepared this report.

I hope that this report will be useful as a basic reference for development of the Project and contribute to the promotion of friendly relations between our two countries.

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

February, 1985

Keisuke Arita

Keisuke ARITA
President
Japan International Cooperation Agency

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INTRODUCTION AND SUMMARY

CHAPTER 1 INTRODUCTION AND SUMMARY

1.1. Introduction

1.1.1. Background of the Study

The East Java Province covers an area of 47,922 km^2 and has a population of approx. 29 million (in 1980) which is increasing at an annual rate of approx. 1.3%.

The geographical area of the East Java Province is only approx. 2.5% of the whole Indonesia, while the present economic activities in East Java share over approx. 20% of the whole Indonesia in terms of agricultural products, number of manufacturing industries etc.

The National Five-year Development Plan (REPELITA I), starting in 1969, has set the following targets for the East Java Province.

(1) Further promotion of industrial, commercial and services activities in Surabaya and its suburbs.

(2) Intensification of the agricultural sector in the central area of the Province, especially plantations in Malang, and development of food processing industries in Malang and its suburbs.

(3) Development of mining and forestry industries around Madiun.

(4) Rehabilitation and strengthening of the irrigation facilities in the eastern low developed area around Jember so as to increase agricultural production for export.

(5) Development of the eastern end area around Banyuwangi as a center of various manufacturing and shipbuilding industry.

In line with the set targets, the government of Indonesia made and is still making great efforts to modernize the economic activities in the country. The second Five-year Development Plan (REPELITA II) for 1974 to 1978, with the aim of annual economic growth of 7.5% was duly completed and furthermore, for the third Five-year Development Plan (REPELITA III) for 1979 to 1983, an aim of annual economic growth of 8% was established. But because of low level of oil price in recent years, the target could not be achieved.

In the forth Five-year Development Plan (REPELITA IV) for 1984 to 1989, the target of annual mean growth rate was forecast to decrease to 5%. Along with these developments, the power demand in the East Java Province has been increased at an annual rate of approx. 10% for the past years from 1970 to 1976. The rate of annual increase in sales energy during 1977 to 1981 is more than 30% due to the rapid economic growth and industrial development throughout the Province. In and after 1982, however, the rapid growth rate of energy sales has slowed.

To cope with such power demand increase, Perusahaan Umum Listrik Negara (PLN) has been steadily implementing the East Java Transmission and Distribution Network Project since 1971 in order to rehabilitate and expand the transmission line, substation and distribution facilities in the Province.

From 1984, some projects in Surabaya and Malang financed by Asian Development Bank (ADB) was committed.

For the execution of Loss Reduction Project by Power XII, on the other hand, a loan from International Bank for Reconstruction and Development (IBRD) was allocated. An expansion program from 1986 to 1987 by Power XIV of IBRD Loan was also determined. In addition, an Acceleration Program for urban and rural electrifications is in progress financed by the Government of Indonesia.

These five projects have been planned to cope with the increase of power demand from 1984 to 1986/87.

It is clear from the above that the problem now facing East Java was early realization of a Short-term Implementation Program to provide for the power demand after 1987/88.

The on-going expansion program will only overcome the immediate problem. But many problems must be reviewed from the Long-term perspective. The Long-term Master Plan was therefore prepared to address this issue.

1.1.2. Objective and Scope of Work

The first objective of this study is to prepare the Short-term Implementation Program. This will cope with the increase of power demand from 1987/88 to 1988/89, carry out a Feasibility Study, and accelerate for the execution of the program.

The second objective is to study the City Development Program in Surabaya and other cities as well as Rural Electrification Program, and to prepare the Long-term Master Plan based on the long-term power facilities installation plan for the above programs up to 2004.

The third objective is to suggest a solution for the problems occurring due to the specification of equipment and materials and power system operation.

The forth objective is the technical transfer of knowledge on demand forecast, system planning methods and computer operation for demand forecast and system analysis.

This study was executed in accordance with the "Scope of Work" agreed on December 7, 1983 between the Japan International

Cooperation Agency (hereinafter called JICA) and PLN.

The Work required for this study will include the followings:

1) Load Forecast

2) Review of existing, on-going and formulated power systems: power generation, transmission line, substation, distribution, load dispatching and communication system.

3) Studies on the Short-term Implementation Program (∿ 1988/89) and the Long-term Master Plan (∿ 2004).

4) Establishment of demand forecast, power system planning methods by computer and training of PLN Engineers.

5) Identification of the Short-term Implementation Program and the Long-term Master Plan.

6) Preparation of schedule of construction quantities and detailed cost estimates for the Short-term Implementation Program and the Long-term Master Plan.

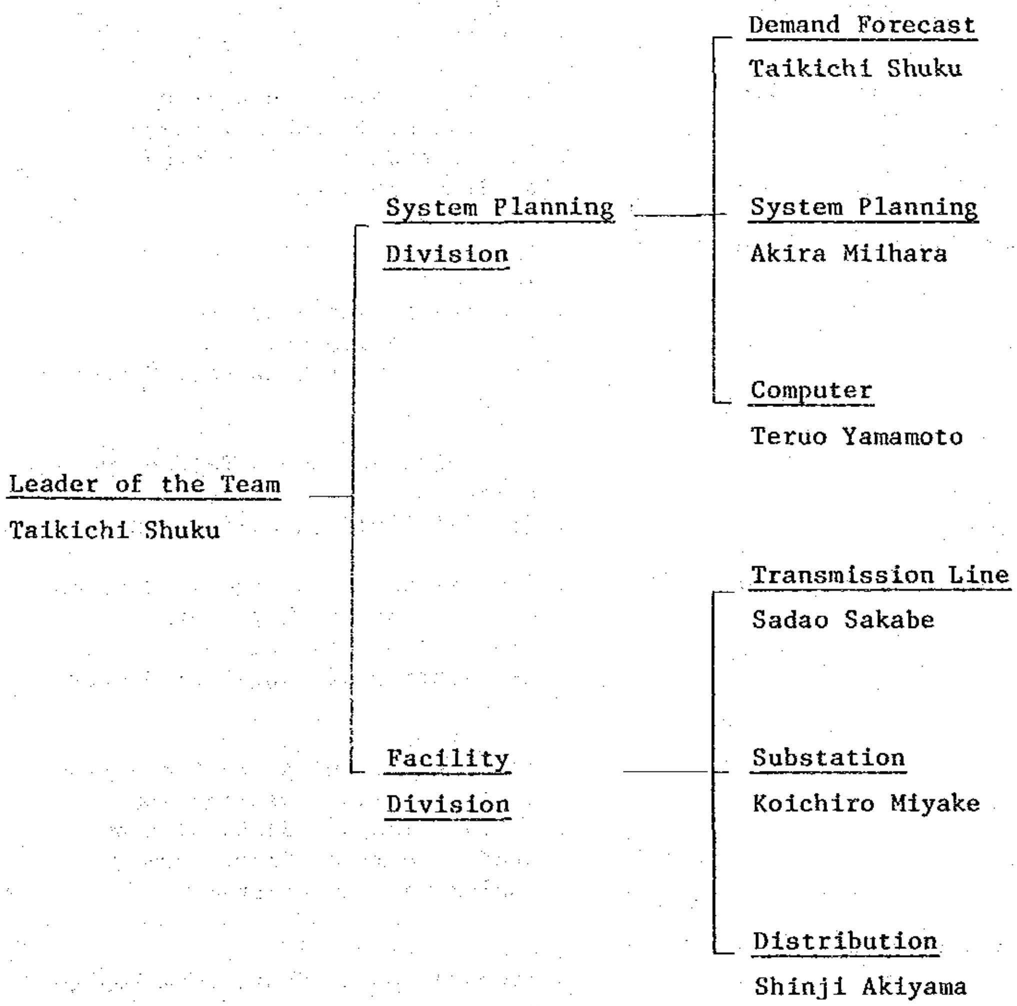
7) Assessment of technical and economic feasibility for the Short-term Implementation Program and the Long-term Master Plan.

8) Preparation of construction schedule for the Short-term Implementation Program.

1.1.3. Formation of the Survey Team

(1) Organization of the Survey Team

This feasibility study was carried out by the following team organization:



(2) Responsibilities

Assignments and functions of each of the personnel are as follows:

Name		Assignments and Functions
Taikichi Shuku	Home Office	General manager in charge . Power Demand Forecast . Economic Evaluation & Financial Analysis . General review of reports
	Site	General manager in charge . Initial Field Investigation . Explanation and discussion of draft reports
Sadao Sakabe	Home Office	. Transmission Line & Telecommunication . Preparation of Short-term Implementation Program . Preparation of Long-term Master Plan
	Site	. Transmission Line & Telecommunication . Initial Field Investigation
Koichiro Miyake	Home Office	. Substation, Relay and Protection . Preparation of Short-term Implementation Program . Preparation of Long-term Master Plan
	Site	. Substation, Relay and Protection . Initial Field Investigation . Explanation and discussion of draft report of Short-term Implementation Program
Shinji Akiyama	Home Office	. Distribution . Preparation of Short-term Implementation Program . Preparation of Long-term Master Plan
Akira Miihara	Home Office	. System Planning . System analysis of Short-term Implementation Program . System analysis and computalization of Long-term Master Plan

Name		Assignments and Functions
	Site	. Explanation and discussion of draft report of Short-term Implementation Program . Explanation and discussion of draft report of Long-term Master Plan
Teruhiko Yamamoto	Home Office	. Computer . Computerlization of demand forecast . Computerlization of Long-term Master Plan and training of PLN Personnel
	Site	. Explanation of computer and training of power demand forecast

(3) Schedule of Survey in the Site

1st time :	February 9	-	March 9, 1984	(30 days)
2nd time :	May 22	-	June 15, 1984	(25 days)
3rd time :	July 12	-	August 25, 1984	(45 days)
4th time :	November 26	-	December 9, 1984	(14 days)

1.2. Summary and Conclusions

1.2.1. Demand Forecast and System Planning

(1) Demand Forecast

The energy demand for the short-term (1984/85 - 1988/89), the mid-term (1989/90 - 1993/94), the former half period ot the long-term (1994/95 - 1989/90) and the latter half period of the long-term (1999/2000 - 2003/04) were fore-case by the following method.

(a) Load Forecast by Macro Approach

Assuming that the growth rate of GDP for each of the planning terms is 5% and the elasticity and regional coefficient for each term are as shown in the following table, the demand forecast in the specific year during each of the terms under study was forecast by the macro approach, and the result of demand forecast is summarized below.

Demand Forecast by Macro Approach

Term	Specific Fiscal Year	Elasticity	Regional Coefficient	Growth Rate (%)	Forecast Energy (GWh)
Actual Record	1982/83				1,798
Short-term	1988-89	2.5	1.25	16.0	4,380
Mid-term	1993/94	2.5	1.1	14.0	8,433
Former Half of Long-term	1989/99	2.25	1.1	12.0	14,862
Latter Half of Long-term	2003/04	2.0	1.0	10.0	23,935

(b) Forecast of Residential Demand

The energy sales for residential use by Cabang were calculated from the product of unit energy consumption per household, number of households and rate of electrification in Cabang. The parameters used for the forecast of residential demand were assumed by adjusting the extension of past trend and the forecast energy by Macro Approach.

- The unit sold energy for each of Cabang in 1982/83 was used as the base for original unit energy consumption per Cabang. The above unit sold energy for each of the Cabang in 1982/83 was modified by adjusting the forecast energy by Macro Approach.

- The number of households was estimated based on the forecast population by Cabang and estimated number of persons per household.

- The Gompertz Growth Curve was used as the rate of electrification for each Cabang.

(c) Forecast of Commercial and Public Demands

The commercial and public demands by Cabang were projected by the product of the unit energy consumption, relevant ratio of number of commercial and public consumers to residential consumers, and number of residential consumers. The actual record of each Cabang for 1982/83 was used to estimate the relevant ratio of number of commercial and public consumers to residential consumers. The number of residential consumers was quoted from that estimated in Item 1.2.1.(a).

The unit energy consumption was assumed by adjusting the forecast energy by Macro Approach.

(d) Adjustment for Forecast of non-industrial Demand

The industrial demand can be forecast more clearly in comparison with non-industrial demand. The difference between the total forecast energy by macro approach and the energy calculated for industrial demand was used as the macro forecast energy demand for non-industrial use.

The study was made on how to make adjustment of the difference between macro non-industrial demand and calculated demand.

General tendency of unit energy consumption is expected as below.

The rate of increase of the electrification ratio will be comparatively large and that of the unit energy consumption will be almost constant in the years of very near future. After that, the rate of increase of the electrification ratio is forecast to be weakened with the increase of the unit energy consumption. The adjusted unit energy consumption indicates above tendency.

Therefore, the adjustment method by unit energy consumption was adopted as the forecast energy of non-industrial demand.

(e) Forecast of Industrial Demand

The industrial demand was forecast by steps of macro forecast of industrial demand, analysis of trend of industrial demand and industrial demand forecast by Cabang.

. Macro forecast

The industrial demand in a specific year was forecast by the estimated elasticity of industrial electric energy consumption to GDP. The result of macro forecast is shown below.

Industrial Demand by Macro Method

Term	Specific Fiscal Year	Elasticity	Growth Rate of Load (%)	Forecast Energy (GWh)
Short-term	1988/89	4.0	20.0	2,622
Mid-term	1993/94	3.0	15.0	5,274
Former Half of Long-term	1998/99	2.5	12.5	9,504
Latter Half of Long-term	2003/04	2.5	12.5	17,127

. Trend of Industrial Demand

It is obvious that the demands forecast by the macro method are on the trend of a geometric mean value of the exponential growth and the linear growth. Therefore, the total demands in each year were forecast by this method.

. Forecast of Industrial Demand by Cabang

The ratios of industrial energy sales to residential energy sales in the past record and short-term demand forecast by Cabang indicate individual characteristic peculiar to each Cabang. The individual characteristic was taken into account to obtain the trend in each Cabang. The industrial demand in Cabang forecast by the same trend was adjusted so that the total of industrial demands forecasted for all Cabang may be equal to the macro forecast of industrial demand. The total industrial demand in East Java thus forecasted is summarized in Table 1.2.-1.

(f) Population Forecast by Cabang

PLN forecast the population increase by the exponential formula. There is a possibility that the population forecast may be over-estimated after the mid-term and long-term. Analysis of the population forecast in East Java made by the Statistical Bureau of Indonesia indicates that the growth curve is most suitable method for the forecast of population. The population forecast by Cabang was made by a modified logistic curve to which the increase of population and the record of population by Cabang were most closely related.

(g) Adjustment of Industrial Demand

The power requirement for cement factories planned for installation inside the jurisdiction of Pamekasan Cabang is large. This demand can not be projected by the trend analysis. The power requirement for cement factories was projected on the basis of PLN program. The additional requirement derived from the difference between the initially estimated power demand from cement factories and the industrial demand in the Pamekasan Cabang forecast in Item 1.1.(4) was added to the industrial demand.

The adjusted industrial demand is shown in Table 1.2.-1. Adding this extra load, the total industrial demand has exceeded the industrial demand forecast by the Macro Method by 4 - 7%.

(h) Summary of Demand Forecasts in East Java

The summary of the demand forecasts in East Java is presented in Table 1.1.-1. and 1.1.-2.

TABLE 1.1-1 SUMMARY TABLE OF DEMAND FORECAST

Item	Result	Short-term	Mid-term	Long-term Former	Long-term Latter
Target Fiscal Year	82/83	88/89	93/94	98/99	2003/04
Macroscopic Forecost					
Growth Rate of GDP(%)		5.0	5.0	5.0	5.0
Elasticity		2.5	2.5	2.25	2.0
Regional coefficient		1.25	1.1	1.1	1.0
Growth Rate of Energy(%)		*1 16.0	14.0	12.0	10.0
Total Target Energy(GWh)	1,819	4,432	8,533	15,038	24,219
Microscopic Forecast					
Residential					
Population(1000psns)	30,427	33,566	35,965	38,240	40,424
No.of HHS (1000)	6,762	7,459	7,992	8,498	8,983
Electrification Ratio(%)	9.5	19.0	28.7	39.6	49.0
No.of Consumers(1000)	643	1,416	2,297	3,319	4,404
Energy(GWh)	688	1,496	2,540	3,791	4,976
Commercial					
No.of Consumers(1000)	32	69	113	165	221
Energy(GWh)	107	225	376	556	727
Public					
No.of Consumers(1000)	6	14	24	36	49
Energy(GWh)	146	308	515	759	987
Exc.Industry Tl.Energy	941	2,029	3,431	5,106	6,690
Industry					
Elasticity		4.0	3.0	2.5	2.5
Growth Rate of Energy(%)		20	15	12.5	12.5
Target Energy(GWh)	878	2,622	5,274	9,504	17,127
Calculated Energy(GWh)	878	2,622	5,235	9,850	17,940
Adjustment of Pamekasan		95	337	320	220
Adjusted Industrial Energy		2,717	5,572	10,170	18,160
Tl.CalculatedEnergy(GWh)	1,819	4,651	8,666	14,955	24,629
Tl Adjusted Energy(GWh)	1,819	4,746	9,003	15,275	24,849
Average Growth Rate(%)		*1 17.3	13.7	11.2	10.2

Note:*1 shows compound growth rate between 82/83 and 88/89

TABLE 1.1-2 SUMMARY OF DEMAND FORECAST IN EAST JAVA

Item	Unit	1982/83	1988/89	1993/94	1998/99	2003/04
Residential						
Energy sales	GWh	688	1,496	2,540	3,791	4,976
Average growth rate	%		13.8	11.2	8.3	5.6
Commercial						
Energy sales	GWh	107	225	376	556	727
Average growth rate	%		13.2	10.8	8.1	5.5
Public						
Energy sales	GWh	146	308	515	759	987
Average growth rate	%		13.2	10.8	8.1	5.4
Industry						
Energy sales	GWh	878	2,717	5,572	10,170	18,160
Average growth rate	%		20.7	15.4	12.8	12.3
Total energy sales	GWh	1,819	4,746	9,003	15,275	24,849
Average growth rate	%		17.3	13.7	11.2	10.2
Loss rate	%	18	12.7	12.7	12.7	12.7
Required energy	GWh	2,218	5,436	10,313	17,497	28,464
Yearly load factor	%	66	68	70	72	74
System peak at 150kV	MW	384	919	1,682	2,774	4,390

(2) Regional Load Forecast

The past monthly growth of contract capacity by region in each of the zone was put in the computer to develop the growth of contract capacity (kVA) according to category of power use with the growth curve. This curve was used to allocate the total load forecast under Item 1.1. to the regional loads in each zone. (Refer to The Method of Forecasting Load by Region based on the Historical Data of Sales: Appendix A).

As for large customers supplied by 70 kV or above, available information was taken into account by individual loads.

The average weekday peak hours load imposed on each Substation at the ends of the 1st, 2nd, 3rd and 4th Stages are shown in Table 2.2-3(1) - (5).

(3) System Planning

The optimum and most economical plan for system expansion, integrating transmission lines, substations and distribution lines and covering the period until March, 2004 was worked out in 4 stages (1st Stage: until March, 1989, 2nd Stage: until March, 1994, 3rd Stage: until March, 1999, and 4th Stage: until March, 2004). Eash stage is based on the aforementioned peak load forecasts.

The scope of the 1st Stage will be described in the following 1.2.2. and Chapter 3. Therefore, the system expansion plan for the 2nd to 4th Stages are dealt here.

(a) General Concept of Planning

(i) Larger capacity equipment was planned for use in order to avoid the necessity to install additional equipment for at least 5 years. This will avoid the additional cost necessary for repeated addition of smaller capacity equipment. As for various expansion patterns, economic examinations will be mentioned in Chapter 5.

(ii) Addition of the 25 kV to 30 kV systems within a few years was proposed in order to minimize the number of types of equipment by simplification of voltage classes. Even the 70 kV system was not planned for expansion except in areas of exceptional need, where it was designed to be stepped up to 150 kV gradually, thus minimizing the need for addition of 150/70 kV transformers.

(iii) It is important to transmit the power from power sources to load centers on the shortest possible route. This reduces of power losses, saves installation costs and improves supply reliability by simplification of the system design. In this system planning, priority was given to designing the most efficient means of receiving power and transmission lines configuration, considering the direction of power flow.

(b) Proposed Scope of System Expansion

(i) Construction of New Distribution Substations

(2nd Stage)

Karang Pilang Substation (complete in 1989/90), Kepanjen Substation (1990/91), Semanbung Substation

(1990/91), Benowo Substation (1992/93), Tanggul Substation (1989/90), Genteng (1989/90) and Jombang Substation (1989/90).

(3rd Stage)
Simokerto Substation, Ngiwo Substation, Trosobo and Ketintang Substation.

(4th Stage)
Sidosermo, Tanggul, Genteng and Asembagus Substations.

(ii) Addition of Distribution Transformers in the Existing Substations

The expansion plan for the distribution transformers was designed to maintain an adequate level of loading on each transformer under the load forecast for each of the distribution substations. The details of the proposed expansion plan are shown in Table 4.1-6.

It was planned to upgrade the total effective utilization factor (which is obtained by dividing the total peak load for every substation by their total target loading on it) from 58.6% at the end of the 2nd Stage to 58.2% at the end of the 3rd Stage, then reaching finally 66.2% at the end of the 4th Stage.

(iii) Step-up of 70 kV Receiving Substation to Receive Power at 150 kV

As mentioned in the General Concept of Planning, it is proposed to boost the 70 kV receiving substations to 150 kV at the time of addition of transformers. The schedule of this step-up work is summarized below.

Stage/Year of commissioning	Name of Substation	Method of Power Receiving
II/1989	Sawahan	Reconstruction of the 70 kV Tandes-Sawahan Transmission Line
II/1990	Polehan	Reconstruction of the 70 kV Kebonagung-Polehan Transmission Line
II/1992	Lawang	1π incoming from the 150 kV Bangil-Kelonagung Transmission Line
II/1993	Driyorejo	1π incoming from the 150 kV Krian-Babatan Transmission Line
II/1993	Buduran (Sidoarjo)	2π incoming from the 150 kV Waru-Bangil Transmission Line
III/1994	Blimbing	1π incoming from the 150 kV Bangil-Kebonagung Transmission Line
III/1996	Tulungagung	Construction of the 2 circuits 150 kV Kediri-Tulungagung Transmission Line
III/1997	Sengkaling	Step-up to 150 kV of the Kebonagung-Sengkaling Transmission Line (designed for 150 kV)

(iv) Reinforcement of Transmission Lines

(2nd Stage)

- Reinforcement of Power Supply Capability and Improvement of Reliability of line to the Tandes Substation.

The Gresik Thermal Power Station, assuming its output to be 320 MW, will be able to supply its generated power singly up to the Tandes and Sawahan Substations until the end of the 2nd Stage but it will not be able to supply its power to the Tandes Substation from the 3rd Stage.

In the 2nd Stage, power will be supplied to the Tandes Substation by 1π branch from the 150 kV Gresik-Waru Transmission Line. At the beginning of the 3rd Stage, this branch line will be extended to the Krian Substation, thus supplying power to the Tandes Substation on the 2 circuits transmission lines directly from the Krian Substation.

- Construction of 500 kV/150 kV Substation associated with Construction of the Paiton Thermal Power Station.

The Paiton Thermal Power Station is scheduled to be commissioned in Oct. 1989, with an initial capacity of 400 MW, which will be further expanded in stages and transmitted on the EHV transmission lines.

In order to supply part of the generated power to the eastern part of East Java Province (east of Probolinggo), 500 kV/150 kV transformers with a capacity of 300 MVA will be installed for completion in 1989/90 in the premises of the Paiton Thermal Power Station, and 500 kV/150 kV transformers with a capacity of another

500 MVA will be installed in 1990/91 at the same substation.

. Addition of 150 kV One Circuit to Paiton-Situbondo-Jember.

Following the completion of the EHV Paiton Substation, an additional 150 kV circuit will be strung for completion in 1989/90 on the 150 kV Paiton-Situbondo-Jember Transmission Line, in order to reinforce the power supply capability to Situbondo, Jember and Banyuwangi.

(3rd Stage)

. Introduction of EHV Transmission Line in Eastern Part of Surabaya

At the beginning of the 3rd Stage, an EHV transmission line will be connected by 1 connection to the Sukolilo Substation or a new station to be constructed near it, to supply the power to Rungkut, Kenjeran and Simpang. The required capacity of the transformers will be 500 MVA in 1994/95 and another 500 MVA in 1995/96. Regarding of this work, the existing 70 kV bus bar at the Sukolilo Substation will be disused.

. 150 kV Ring Line in Surabaya

At the beginning of the 3rd Stage, a 150 kV ring transmission line will be completed with the construction of the 150 kV Sukolilo Substation-Perak Power Station transmission line connected to the 70 kV transmission line route between Ujung and Sukolilo, in order to enhance the effect of improvement of power supply capability with the completion of the above EHV Transmission Line and promote power supply reliability. To accommodate this ring line, the 70 kV Perak-Ujung Transmission Line will be reconstructed during the period of the 2nd Stage so as to enable stringing together 150 kV power conductors.

. Reinforcement of Power Supply Capability to Malang and Bangil with the Construction of the 150 kV Krian-Kebonagung Transmission Line.

Even after the transmission system east of the Probolinggo Substation is supplied by the Paiton Thermal Power Station, the Krian-Waru-Bangil Transmission Line will be almost fully-loaded by the end of the 3rd Stage. Therefore, a 150 kV 2 circuit transmission line between Krian and Kebonagung will be constructed by the end of the 3rd Stage.

. Completion of the Krian-Tandes Transmission Line

As mentioned in the 2nd Stage Work, the Krian-Tandes Transmission Line will be commissioned at the beginning of the 3rd Stage. In order to secure a right-of-way for the optimum route for this transmission line, the timing of construction may possibly be required to be advanced.

. Reinforcement of Power Supply Capability to Banyuwangi and Bali Island

The total load in Situbondo, Bondowoso, Jember, Banyuwangi and Bali Island will exceed the capacity of the existing and by then completed transmission line; particularly the voltage drop will be considerable. In the future, a substation which will function as a power supply center to the east of Situbondo or north of Banyuwangi will become necessary. Therefore, a 150 kV transmission line will be constructed during the period of the 3rd Stage on a route along the east-northern coast between the Situbondo Substation and Banyuwangi S/S.

(4th Stage)

. Reinforcement of Power Supply Capability to Mojokerto and Kediri

The construction of many smaller capacity hydro power stations are planned in the south of Kediri. However, the Krian-Mojokerto Transmission Line will be almost full-loaded in the beginning of the 4th Stage. Accordingly, a new 150 kV transmission line between Krian and Kediri is to be planned. In the beginning of the 4th Stage, the Krian-Mojokerto section will be commissioned as part of the proposed 150 kV Krian-Kediri transmission line, thus reinforcing the power supply capability to Mojokerto with the parallel use of the existing 150 kV transmission line between Krian and Mojokerto.

(v) Increase of Capacity of Primary Substations

In the event any large capacity generating plant other than many smaller capacity hydro power stations is not constructed, addition of transformers with a total capacity of 3,000 MVA including 500 MVA for the 2nd Stage, 1000 MVA for the 3rd Stage and 1000 MVA for the 4th Stage will be required for the Krian Substation, in addition to the extensions of 1000 MVA for the Sukolilo Substation and of 800 MVA for the Paiton Substation.

Accompanied with the addition of these transformer capacities, an EHV additional circuit will become necessary for the purpose of receiving power from Central Java.

(vi) Installation of Shunt Capacitors

Shunt capacitors with kVA shown in Table 2.4-5 will be required to be installed in the system, in order to reduce power losses and control variations in voltage.

(c) Recommendation of Development of Large Capacity Generating Sources in East Java Province

This system planning is based on the assumption that only new power sources included in the existing power source development program will be put into the power system. Therefore, the power to be received on EHV transmission line from Central Java and West Java will reach 950 MW, and the power received at the Krian Substation is estimated to reach 1,920 MW at the end of the 4th Stage, if we take into account the power of 74.1 MW to be transmitted to Bali Island. Hence, it is desirable that some additional large power plants following Paiton P/S should be planned.

Further, as the power transmitted to the central and south part of East Java by 150 kV lines will also increase considerably, it is advisable to consider the introduction of EHV lines to this area.

(4) System Analysis

The locations for installation of shunt capacitors are shown in Table 2.4-5. Drawings 2.4-2 (1) - (4) indicate the results of calculation of power flow based on the load forecast by substations and the necessity of installing shunt capacitors.

It is necessary to constrain the fault current at 25 kA, 20 kA and 20 kA in the respective 150 kV system, 70 kV system and 20 kV system, considering the capacity of circuit breakers and short time current capacity of overhead ground wires. The results of examining the short circuit capacity of the power system at the end of the 4th Stage are shown in Fig.2.4-3. Accordingly, the loop on the secondary sides of the following groups of transformers will generally need to be open.

Group of 150/20 kV transformers	-	in principle not permitted to loop in
Group of 150/70 kV transformers	-	generally permitted to loop in
Group of 500/150 kV transformers	-	not permitted to loop in at the Krian Substation only

This demonstrates the need to divide the loop into more than 2 systems on the secondary side of 500/150 kV transformers at the Krian Substation at the end of the 4th Stage.

1.2.2. Short-term Expansion Program

(1) Construction Cost of Short-term Program

(a) The estimation of Construction Cost

The construction cost is composed of:

(Foreign Currency Portion)

- Purchase cost of foreign-made equipment, and indirect foreign currency (for distribution line only).
- Instrument and tool cost and purchase cost of vehicles (for transmission line only).
- Guidance fee by foreign experts (Substation only).

(Local Currency Portion)

- Labour cost
- Purchase cost of local materials
- Right-of-way cost
- Administration cost of PLN

The construction cost applied to this study is the product of standard unit construction cost by the quantity. The unit cost is divided into various categories by design criteria, as the case may be.

Construction cost is the total of all the above. Cost estimation was made by reference to price quotations in recent construction contracts and the world market price research. To obtain a reasonable estimate of construction cost, a comparative study was made with other projects.

i) Unit costs of transmission line

For correct cost estimation, the transmission line was divided into various categories according to a line route length and kind of soil. Unit costs were estimated based on the actual costs for East Java Project I to III stages. They are about the same as the unit costs for acceleration Project and lower than those of IBRD (Power XV).

ii) Unit costs of substation

The unit costs for the substation are based on those of IBRD (Power XV). They are the total of IBRD unit costs and guidance fee, including some allowance for data transferring costs from new substation to be required with Waru A.C.C. program.

iii) Unit costs of distribution line

The unit costs for distribution line including indirect foreign currency portion are also based on those of IBRD (Power XIV).

(b) Construction Quantity and Cost Estimation for Two Years Construction

i) Construction Quantity

Construction quantity was estimated from the construction projected in two years construction program (1987/88 - 1988/89). The construction quantity estimated in the short-term program is shown in the following table.

Transmission Line Facilities

Construction Item \ Voltage	150 kV		70 kV	
	No. of Con-struction	Line Length (km)	No. of Con-struction	Line Length (km)
Power source line for new substation	5	277.0	1	70
Power source line for thermal P/S construction	1	39.4	0	0
Additional 2nd c.c.t. for reliability improvement	1	4.5	4	181.2
Reinforcement and countermeasures for power loss reduction	0	0	2	65.0
Total	7	320.9	7	316.2

Substation Facilities

Voltage	150 kV		70 kV		20 kV	
Construction Item	Quantity	Capacity (MVA)	Quantity	Capacity (MVA)	Quantity	Capacity (MVA)
Transmission line bay (No. of lines)	28	0	13	-		
Primary transformer (150kV/70kV)	4	200	-	-		
Distribution Transformer (150kV/20kV, 70kV/20kV)	22	570	4	80		
Total Transformer	26	770	4	80		
Shunt Capacitor					5	55

Distribution Line Facilities

Construction item	Year	1987/88	1988/89	Total
20 kV Line (km)		115	489.5	604.5
Pole Mounted Transformer	(Unit)	332	994	1,326
	(MVA)	53	159	212
L.V. Line (km)		498	1,939.9	2,437.9

ii) Cost Estimation

- Direct Construction Cost

Direct construction cost is obtained by multiplying the standard unit construction costs by construction quantity.

- Engineering Fee

Engineering fee is composed of manning fee and other necessary direct costs for engineering services.

- Physical Contingency

Physical contingency was estimated at 10% of direct construction cost. It includes the cost of shunt capacitor for 55 MVA at 5 S/S.

- Price Escalation

Price escalation was estimated as follows:

- Foreign currency portion : 5% per year
- Local currency portion : 12% per year

- Total Construction Cost and Annual Expense

Total construction cost and annual disbursement schedule are summarized as below:

Total Cost (US$ Million)

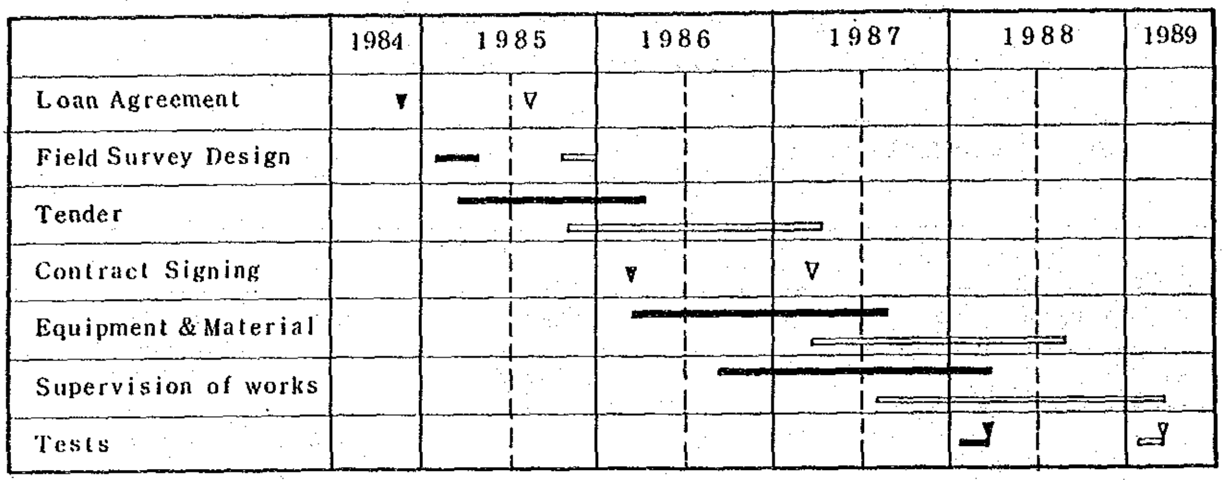
Currency / Item	F.C.	L.C.
Direct Cost	87.292	38.775
a) T/L	12.697	10.539
b) S/S	35.839	14.793
c) D/L	38.756	13.344
Physical Contingency	8.729	3.878
Engineering Costs	6.639	1.647
Escalation	11.442	11.014
Total	114.102	55.314

Disbursement Schedule

Currency / Year	F.C.	L.C.
1984/85	0.338	0.125
1985/86	24.780	17.280
1986/87	49.649	23.127
1987/88	32.291	11.995
1988/89	7.044	2.787
Total	114.102	55.314

(c) Construction schedule for two years construction program (1987/88 to 1988/89)

Construction schedule was prepared with a view to maintaining the completion target of the Project, subject to the Feasibility Study being completed in July 1984. (See Table below)



Note: Black shows 1st year (1987/88) construction program.
White shows 2nd year (1988/89) construction program.

As seen in the Table, actual construction period is generally short. The main requirement for maintaining the schedule is, therefore, to streamline the loan arrangements and PLN's internal procedures. In addition, the construction will be completed as soon as possible.

(2) <u>Justification of Short-term Program</u>

(a) Technical Justification

Standard of plannings for facilities of transmission line, substation and distribution line in the Short-term Program was concluded as follows:

(i) Transmission line facilities

Since the capacity of transmission line facilities cannot be changed easily, it is only possible for new transmission line to secure the transmission capacity in power system plan for 2003/04.

The main object is to supply power to the distribution substation for the new transmission line in the Short-term Program.

To meet these conditions, standard conductors (150 kV - 330 mm^2 A.C.S.R., 70 kV - 300 MCM A.C.S.R.) were applied. However, since the transmission line supplying power to Ngawi S/S is taken in by 2π incomer from existing transmission line (240 mm^2 A.C.S.R.), 240 mm^2 ASCR to meet existing transmission line was planned.

Addition of 2nd c.c.t. was planned considering the reliability of transmission line in particular. To put it concretely, extension of the transmission line supplying power to the substations in Surabaya city in case of 150 kV transmission line as well as addition of 2nd c.c.t. to all lines of 70 kV transmission line due to its high fault rate were formulated.

To use the larger size conductors, rehabilitation of trite 70 kV transmission line was formulated considering the power supply system as well as the effectiveness of loss reduction of the transmission line.

(ii) Substation facilities

Planning of a construction of new substations were formulated on the basis of forecast load, promotion of electrification, voltage drop of M.V. distribution line, land acquisition and etc. In the Long-term Plan, nine new substations were planned for construction in Surabaya city.

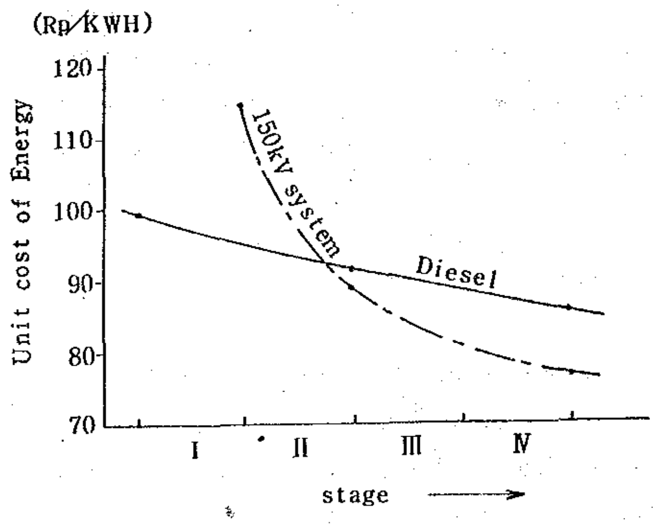
In Surabaya City, the first new substation was planned for construction in southern Surabaya where an early additional power requirement was anticipated because of early industrialization of the area.
A new substation was planned in Babatan, south Surabaya.

In Madura island, the following two projects were considered to cope with the increasing power demand:

- Expansion of 150 kV trunk transmission line throughout the island after power interconnection with Java island.

- Extension of diesel power stations

As a result, the former project was selected due to low unit cost of power and high electrification efficiency.



In local areas, new four substations, possible to expect the increase of load in the future, was formulated to construct in the areas where the rate of voltage drop of M.V. distribution line was more than 5%. Besides, a new substation was constructed to secure the power for construction work of Paiton thermal power station.

In order to extend the transformer facilities of existing substation, it was necessary to consider substations whose necessary capacity exceeded the existing capacity.

Further extensions of transformers whose capacity would not need to be supplemented for five years following the initial extension were considered.

When the capacity of existing transformers were estimated, it was supposed the case of fault with regard to trite 70/20 kV transformers, and considered the transmitted power through distribution line from neighbor S/S with regard to substation with only one unit of transformer.

(iii) Distribution facilities

Giving a priority to distribution facilities, the expansion planning is now in progress in the East Java Province for three years during 1984/85 to 1986/87. The priority was shifted to the categories of transmission/substation facilities in 1987/88, therefore, expansion of distribution facilities was limited to two Cabangs; Pamekasan and Kediri, which were not included in the planning of 1986/87.

1988/89 are the final stage of five-years plan.

Planning for distribution facilities were reviewed in all Cabangs in the East Java Province to give the construction priority.

Construction quantity was estimated to be close to the average of past four years.

(b) Economic Justification

In order to meet the increase of power demand in short-term (1984/85 to 1988/89), the investments for transmission, distribution and substation facilities are not only from Indonesian Governmental own money, but from IBRD, ADB and OECF. Complication is due to the complex facilities from various financial sources, and makes it difficult to distinguish the benefits of respective projects.

In the above consideration, the economic evaluation in this report was made to all transmission, substation and distribution projects to be executed for the said short-term period in East Java, except to the power sources and EHV projects.

The project costs of all of the projects above-mentioned are the sums of the Economic cost (Direct cost + Consultant fee + Physical contingency) and Operation and Maintenance cost.

The benefit of all of the projects (except power sources and EHV projects) was obtained by deducting the increased 150 kV bus bar cost at the receiving end from the increased revenue of electric charge to be estimated by the commercial operation of the projects.

Based on the above results, the Internal Rate of Return (I.R.R.) was calculated, as shown in Table 1.2-3 and Fig.1.2-1. Namely, the calculated is approx. 10% I.R.R., which shows the economic justification as the public utility.

The main characteristics used for this economic evaluation are listed as below:

- Average revenue per kHW	: Rp. 98.3/kWH = 99.09 mills/kHW
- Univ cost of 150 kV bus bar at the receiving end	: Rp. 70.0/kHW = 70.56 mills/kWh
- Exchange rate	: US$1.0 = Rp.992
- Price level	: April 1984
- O & M ratio to economic cost	: 1.0% for Transmission Line 2.5% for Substation 3.0% for Distribution Line
- Transmission loss rate	: 3% at 150 kV bus bar
- Distribution loss rate	: 10% at 20 kV bus bar

The results of sensitivity test are tabulated as below:

Sensitivity Test

	Case		IRR in %
(1)	Base Case		10.0
(2)	Energy Sales	: +10%	11.5
(3)	- ditto -	: -10%	8.4
(4)	All Project Cost	: +10%	8.5
(5)	- ditto -	: -10%	11.7
(6)	Project Cost of this Expansion Program	: +10%	9.5
(7)	- ditto -	: -10%	10.5
(8)	Receiving cost (Bus bar cost at 150 kV)	: +10%	2.2
(9)	- ditto -	: -10%	16.5
(10)	Revenue including connecting charge		17.7

COST : BASE
BENEFIT : BASE

TABLE 1.2-3 INTERNAL RATE OF RETURN IN SHORT-TERM PROJECTS

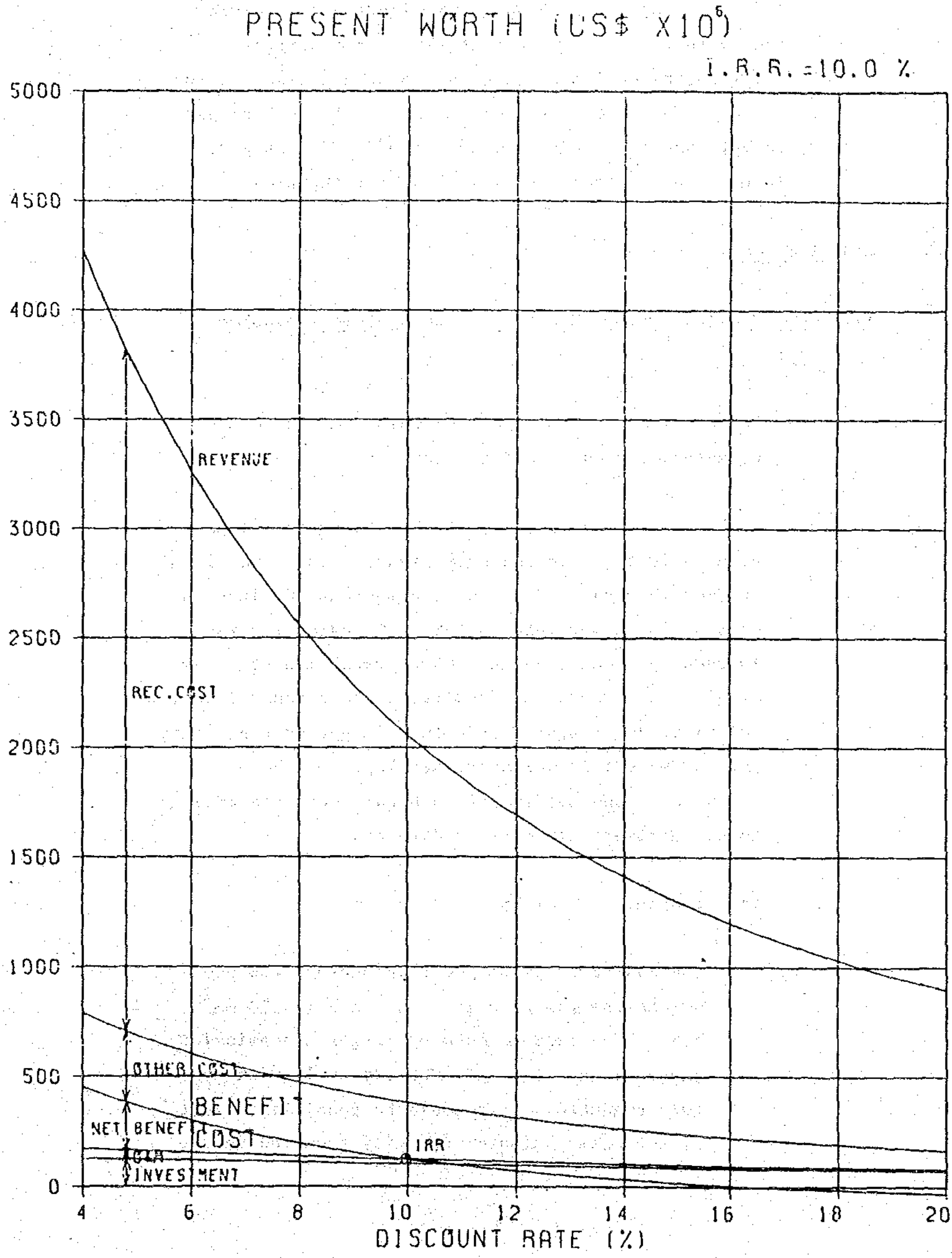
(USD X1000)

NO	YEAR	COST: EXP.PROG. INVESTMENT	COST: EXP.PROG. O&M	COST: TOTAL	BENEFIT: REVENUE	BENEFIT: REC.COST	BENEFIT: OTHER LOAN INVESTMENT	BENEFIT: OTHER LOAN O&M	BENEFIT: TOTAL	PRESENT WORTH: COST	PRESENT WORTH: BENEFIT	E.I.R.R. 9.98 % FACTOR
1	1982	0	0	0	0	0	-9859	0	-9859	0	-9859	1.0000
2	1983	0	0	0	41618	-33946	-54986	0	-47314	0	-43020	0.9093
3	1984	463	0	463	80263	-65468	-101523	-229	-86957	383	-71891	0.8267
4	1985	39028	0	39028	123169	-100465	-76525	-1655	-55476	29338	-41702	0.7517
5	1986	63471	806	64277	170930	-139423	-20551	-4103	6853	43934	4684	0.6835
6	1987	36432	2308	38740	223943	-182664	0	-5856	35423	24076	22015	0.6215
7	1988	7566	3198	10764	282704	-230593	0	-6358	45753	6083	25854	0.5651
8	1989	0	3368	3368	282704	-230593	0	-6358	45753	1730	23508	0.5138
9	1990	0	3368	3368	282704	-230593	0	-6358	45753	1573	21375	0.4672
10	1991	0	3368	3368	282704	-230593	0	-6358	45753	1431	19435	0.4248
11	1992	0	3368	3368	282704	-230593	0	-6358	45753	1301	17671	0.3862
12	1993	0	3368	3368	282704	-230593	0	-6358	45753	1183	16068	0.3512
13	1994	0	3368	3368	282704	-230593	0	-6358	45753	1075	14610	0.3193
14	1995	0	3368	3368	282704	-230593	0	-6358	45753	978	13284	0.2903
15	1996	0	3368	3368	282704	-230593	0	-6358	45753	889	12078	0.2640
16	1997	0	3368	3368	282704	-230593	0	-6358	45753	808	10982	0.2400
17	1998	0	3368	3368	282704	-230593	0	-6358	45753	735	9986	0.2183
18	1999	0	3368	3368	282704	-230593	0	-6358	45753	668	9080	0.1984
19	2000	0	3368	3368	282704	-230593	0	-6358	45753	608	8256	0.1804
20	2001	0	3368	3368	282704	-230593	0	-6358	45753	553	7507	0.1641
1982 - 2001		146960	50094	197056	4597779	-3750260	-263444	-100855	483212	117346	69919	
2002 - 2013		0	40416	40416	3392448	-2767116	0	-76296	549036	3769	51197	
1982 - 2013		146960	90512	237472	7990227	-6517384	-263444	-177151	1032248	121115	121116	

PRESENT WORTH

	DISCOUNT RATE (%)	(4.0)	(6.0)	(8.0)	(10.0)	(12.0)	(14.0)	(16.0)
COST	EXP.PROG. INVESTMENT	125303	116014	107595	99949	92991	86648	80853
	EXP.PROG. O&M	46696	34969	26835	21046	16825	13679	11285
	TOTAL	171999	150983	134429	120994	109816	100326	92138
BENEFIT	REVENUE	4267688	3263803	2563053	2060589	1691087	1412918	1198962
	REC.COST	-3481023	-2662185	-2090604	-1680760	-1379368	-1152474	-977957
	OTHER LOANINVESTMENT	-242191	-232618	-223665	-215281	-207417	-200031	-193085
	OTHER LOAN O&M	-93526	-70998	-55288	-44037	-35776	-29569	-24805
	TOTAL	450947	298003	193496	120512	68526	30844	3115
	B/C	2.622	1.974	1.439	0.996	0.624	0.307	0.034
	B-C	278948	147020	59067	-482	-41290	-69482	-89023

FIGURE 1.2-1 PRESENT WORTH OF BENEFIT AND COST IN SHORT-TERM PROJECTS



As seen in this Table, the economic condition is most influenced by the up-down of the increased receiving energy cost. This means that the most important to level up the economic efficiency of the project is to decrease the receiving energy cost. All above cases except case (8) "Receiving cost +10%" are considered to have the economic justification for the project.

1.2.3. Long-term Master Plan

(1) Construction Cost of Mid-term and Long-term Expansion Program

(a) Introduction of New Technique into the Mid-term and Long-term System Expansion Plan

The power load in the mid-term and long-term expansion plan is forecast to increase greatly; the power load in 2003 is projected to reach more than 10 times as much as the power load in 1983. To cater for the increasing power load, extensive expansion of transmission and substation facilities was planned involving introduction of equipment with a larger unit capacity and new materials which are developed by the new technique. The outline of such equipment and materials to be introduced is mentioned below.

i) Transmission Lines

The maximum size of power conductors now used by PLN for the transmission lines is 330 mm^2 ACSR. The requirements of larger transmission capacity than 330 mm^2 ACSR are dealt with by twin conductors. It would be possible to meet even the transmission capacity required in the long-term expansion plan by means of double capacity of 330 mm^2 ACSR. For 150 kV system ground wires, 100 mm^2 alumoweld wires are proposed to be used to endure the maximum system capacity (short circuit of 25 kA), considering the ground fault current at the time of grounding under the system with solidly earthed neutral.

ii) Substations

In the long-term plan, 500 kV substations will be constructed in the City of Surabaya. In order to keep space requirements to a minimum for 500 kV substations in the city, Full GIS equipment is proposed for installation at the substations. Further review should be done of the introduction of Full GIS in relation to the problem of land acquisition of substation sites. Up to now, unit capacity of 50 MVA has been used for 150 kV/20 kV transformers in the City of Surabaya, but future expansion of transformers was planned with an unit capacity of 100 MVA, on the basis of comparative analysis of necessary additional capacity and cost of transformers. The present breaking capacity will be used continuously for 150 kV circuit breakers, because the system was configurated so as to keep the maximum short circuit capacity at 25 kA.

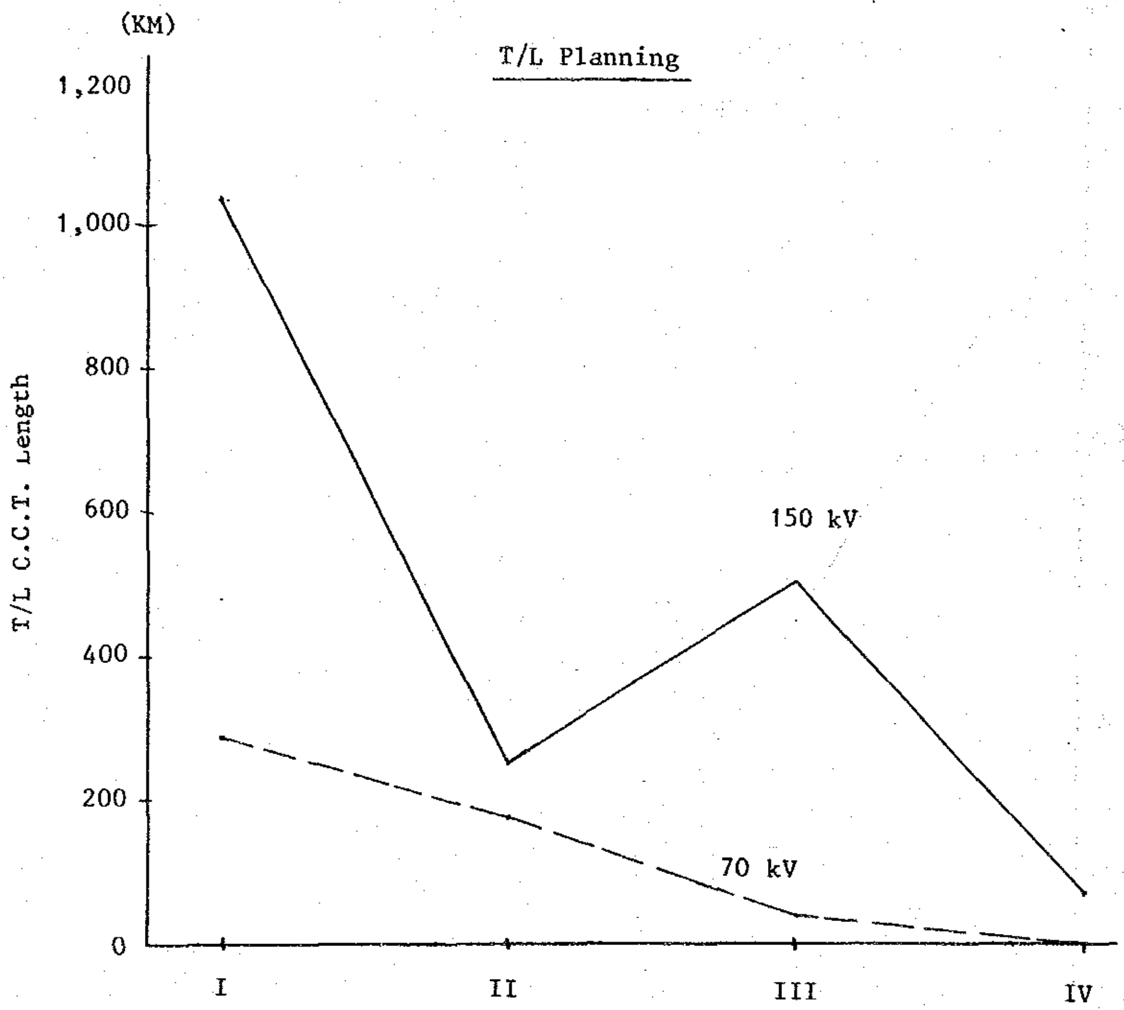
(b) Quantities of Expansion Work

The summary of quantities of expansion work for the mid-term and the long-term is tabulated below.

Summary of Quantities

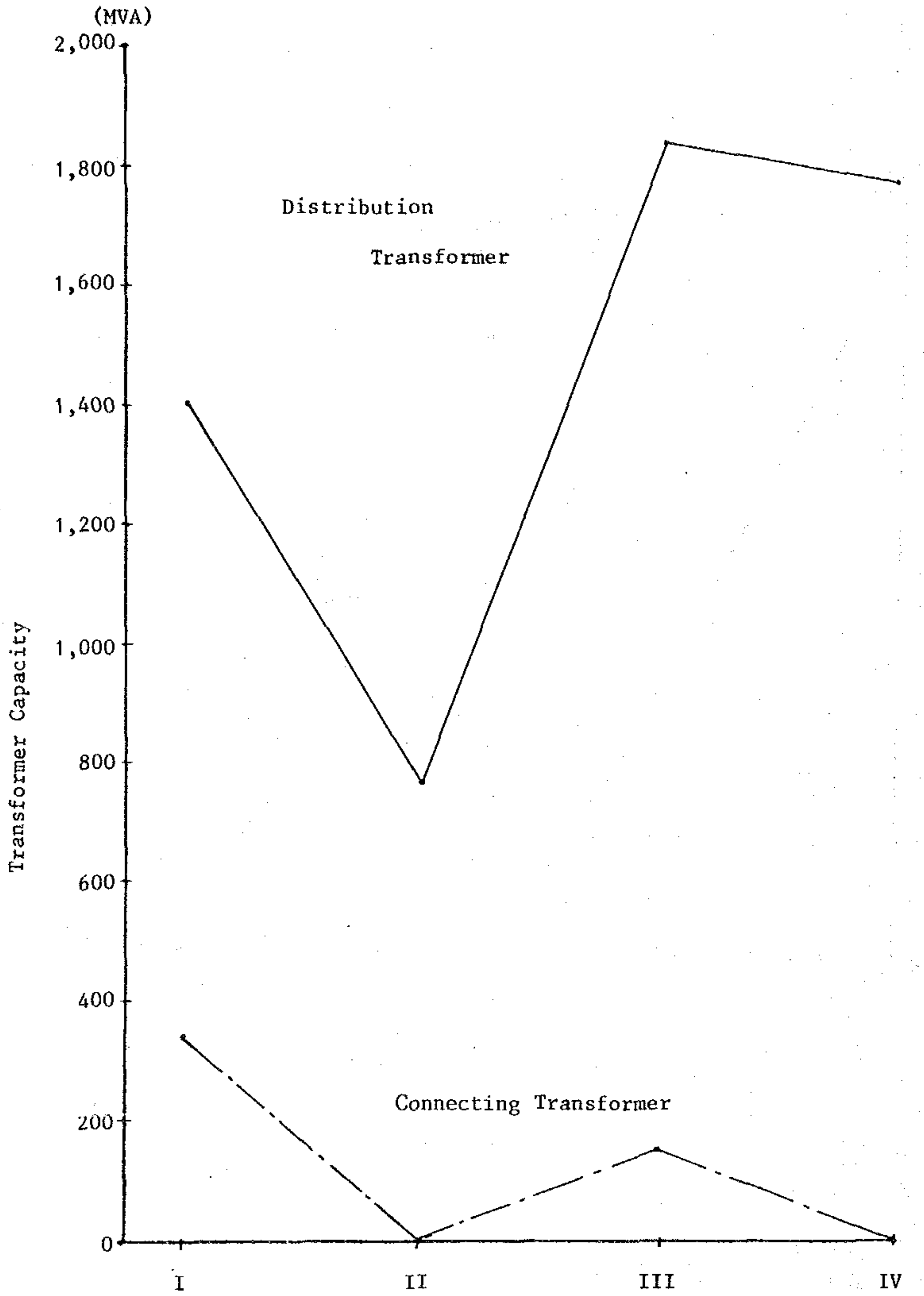
Item	Description		Quantities		Total
			Mid-term	Long-term	
Transmission Line	150kV circuit length (km)		245	581	826
	70kV circuit length (km)		173	40	213
Substation	Distribution transformer(MVA)		760	3,630	4,390
	Connecting transformer(MVA)		0	150	150
Distribution Line	Pole transformer	Unit	5,986	11,917	17,903
		MVA	958	1,907	2,865
	M.V. Line (km)		3,173	6,640	9,813
	L.V. Line (km)		7,782	15,492	23,274

The above quantities are broken down into 5 year periods, the result of which is shown in the following figures. This shows that the circuit length of transmission lines to be constructed will decrease as years go on, while the capacity of distribution transformers will increase with increase in 20 kV power load. The expansion of distribution facilities will come to a peak in the mid-term and the beginning of the long-term and will tend to decrease from the latter half of the long-term, because of saturation of the low voltage load.

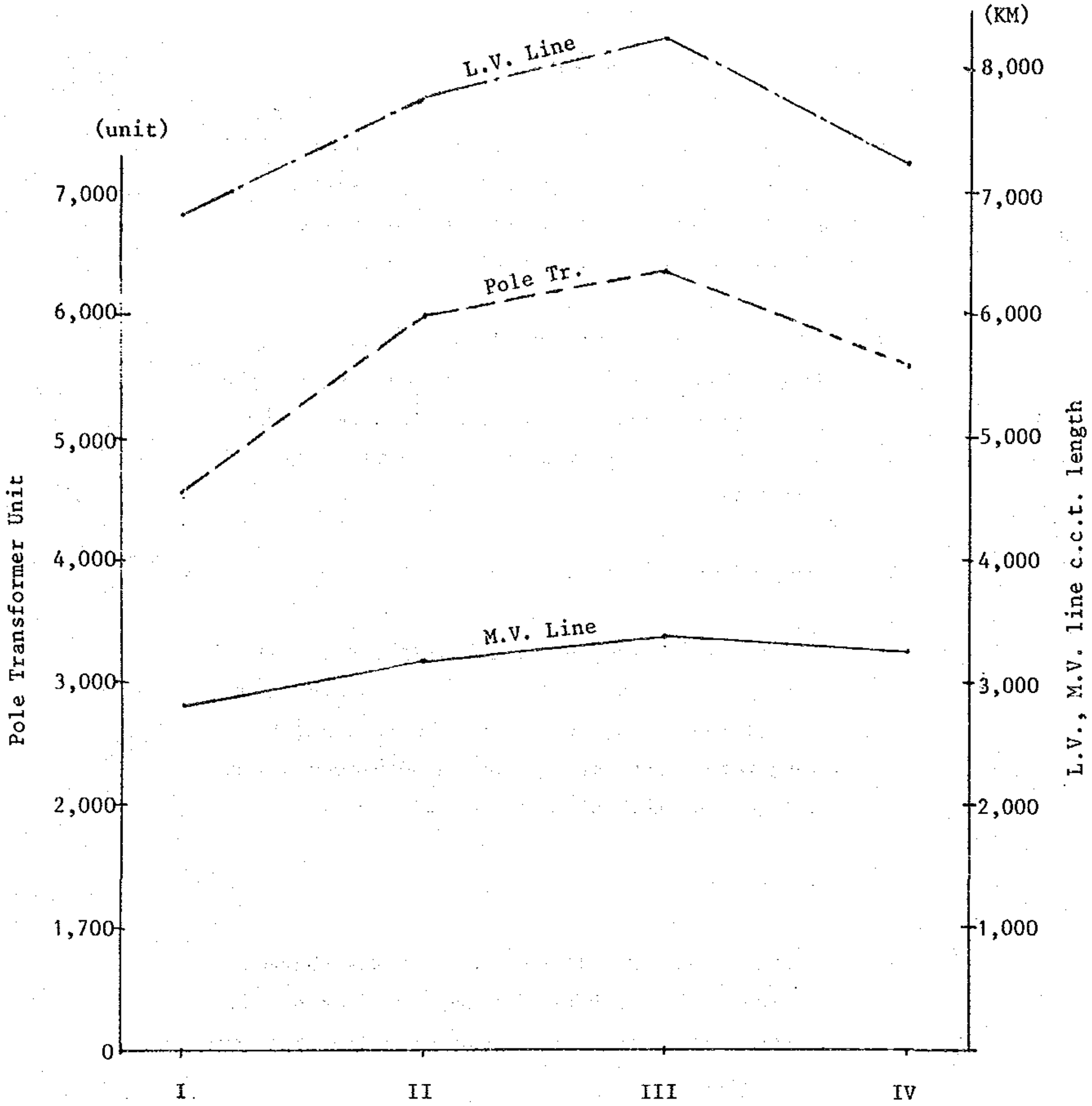


T/L Planning
(KM)
1,200
1,000
800
600
400
200
0
T/L C.C.T. Length
150 kV
70 kV
I
II
III
IV

S/S Planning


(MVA)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Transformer Capacity
Distribution
Transformer
Connecting Transformer
I
II
III
IV

D/L Planning



(unit)
(KM)
L.V. Line
Pole Tr.
M.V. Line
Pole Transformer Unit
L.V., M.V. line c.c.t. length
7,000
6,000
5,000
4,000
3,000
2,000
1,700
0
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
I
II
III
IV

(c) Approximate Cost Estimates

The cost estimates for expansion of 150 kV and 70 kV facilities were made on the basis of the following assumptions. For reference, the cost of construction of EHV transmission line was estimated.

i) The division of foreign components and local components is assumed to be the same as for the short-term planning. For the estimate of the local cost, an exchange rate of US$1 to Rp.1,000 was used.

ii) Base of Unit Cost Estimates

In principle, the unit costs used for the short-term plan were used also for the cost estimates of the expansion work in the mid-term and the long-term. However, following adjustments were adopted for the estimates of unit costs.

- Steel towers

The estimated unit cost per ton was changed from US$900 to US$1,000, bearing in mind the tendency of the total annual construction cost to decrease.

- Conductors

The costs of the newly installed 100 mm^2 AW to be used for 150 kV transmission lines were estimated at US$1,600/km.

- Transformers

Due to a worldwide general reductions in unit prices, the present cost of transformers is reduced by about 20%, and for the newly introduced of 150 kV/20 kV transformers with a capacity of 100 MVA, the cost per unit is estimated at US$982,000/unit.

- Substation Buildings

The construction cost was increased by about 10% over the estimates for the short-term plan, referring to the latest contract prices.

iii) Summary of Approximate Cost Estimates for Expansion Work of 150 kV and 70 kV systems.

The estimated direct costs are summarized as follows:

Total Amount of Estimated Costs (US$ x 10^3)

Term / Item	Mid-term		Long-term		Total	
	Foreign currency	Local currency	Foreign currency	Local currency	Foreign currency	Local currency
Transmission Line	9,597	4,120	23,686	10,885	33,283	14,902
Substation	30,888	15,459	87,293	29,092	118,181	44,551
Distribution Line	194,429	153,391	464,406	121,269	658,835	174,660

The following figures indicate the breakdown of the above costs every 5 years. They show that the construction cost of the substation expansion will decrease in the mid-term but will increase a little in the long-term, while the cost of the distribution expansion will tend toward gradual increase commensurate with the increase in installation of service equipment and underground cables for middle voltage lines in the long-term.

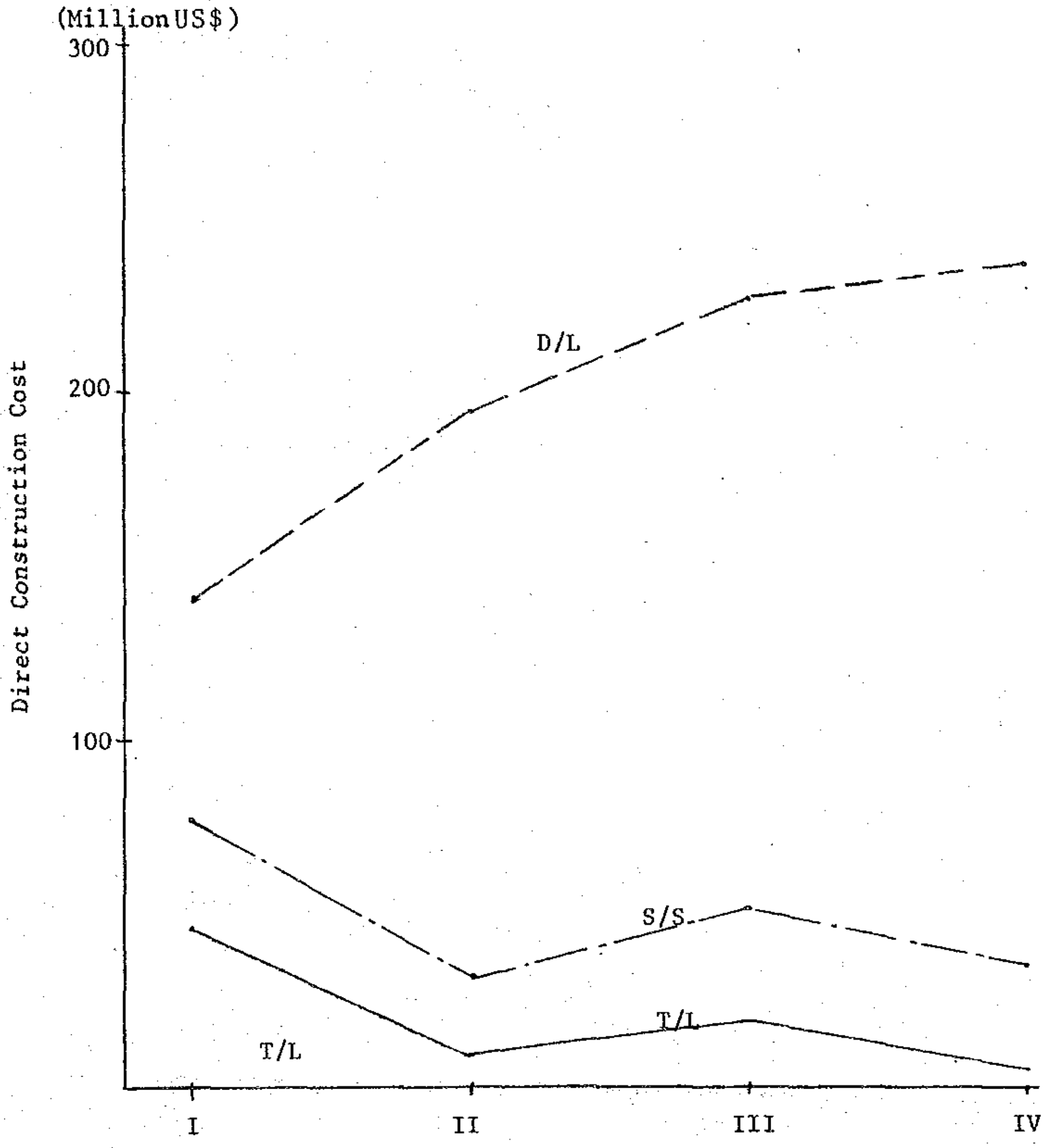
iv) Estimated Costs of EHV Transmission Lines

The estimated costs of 500 kV construction work associated with the expansion of the Sukolilo Substation and of 500 kV/150 kV transformers at Krian and Paiton are shown below.

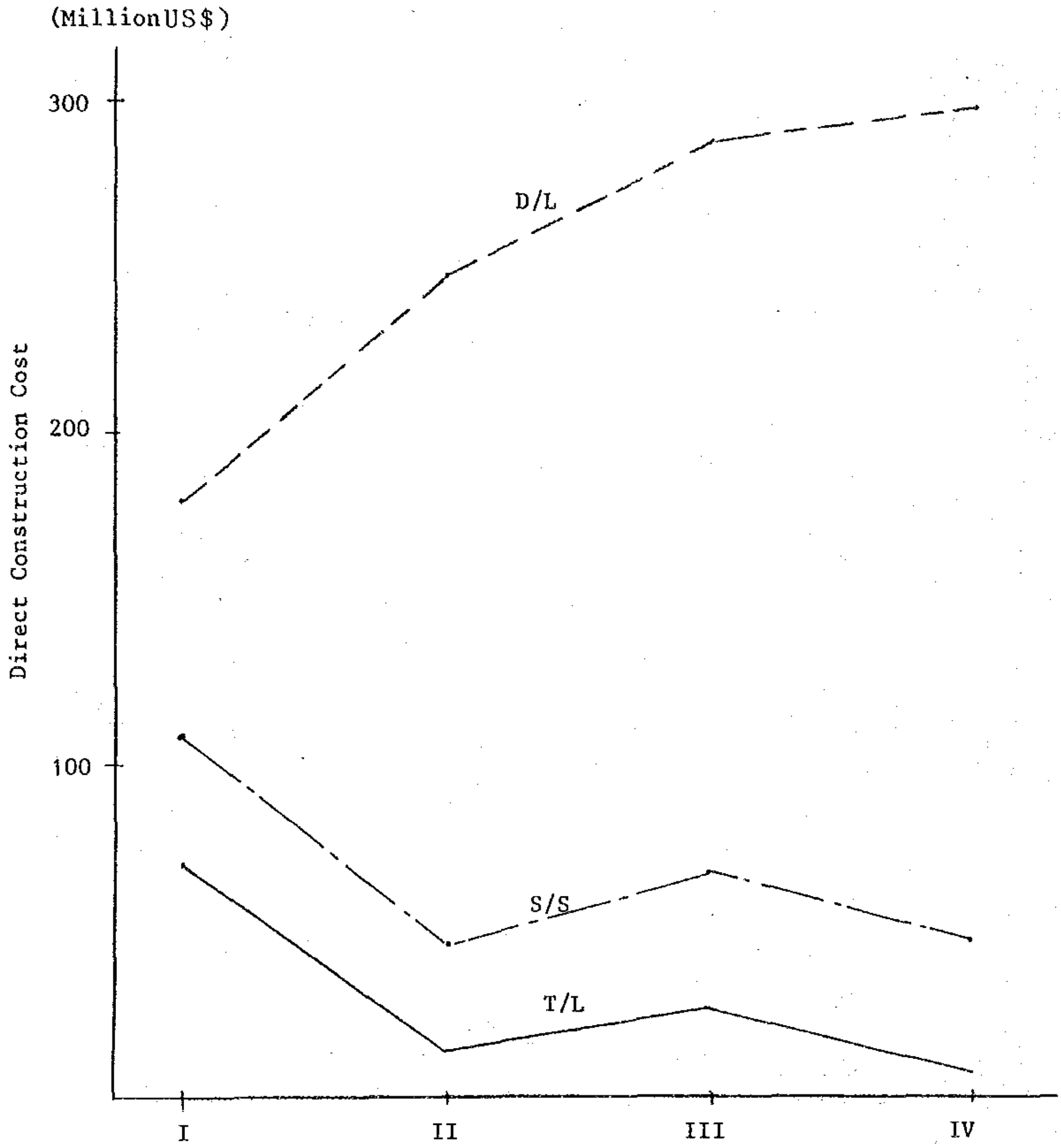
Total Amount of Estimated Costs (US$ x 10^3)

Term / Item	Mid-term		Long-term		Total	
	Foreign currency	Local currency	Foreign currency	Local currency	Foreign currency	Local currency
Transmission Line	-	-	6,830	2,747	6,830	2,747
Substation	15,080	3,284	28,940	6,342	44,020	9,626

Gross Amount of Direct Construction Cost (F.C.)



Gross Amount of Direct Construction Cost (F.C. + L.C.)



(2) Economic Evaluation of Mid/Long-Term Plan

The mid-term plan was developed on a yearly basis. However, the long-term plan was made at intervals of 5 years. Accordingly, different methods of economic analysis were used for each plan. The internal rate of return was calculated by the present worth method for the economic analysis of the mid-term plan. The economics of the long-term plan was evaluated by comparison of the annual cost calculated from the levelized capital cost with the annual benefit.

(a) Economic Evaluation of Mid-term Plan

i) Project Cost

The project cost was derived from the total of investment amount and O/M cost. The investment cost is the economic cost which is the total of direct cost, physical contingencies and engineering cost. The O/M cost was obtained by multiplying the estimated investment cost by the following O/M ratios.

	O/M Ratio
Transmission Lines	1.0 %
Substation	2.5 %
Distribution Lines	3.0 %

ii) Benefit

The benefit for the mid-term plan was obtained by reducing the increment cost of energy receiving on 150 kV bus bar from the increased revenue of energy sales from the revenue in 1988/89 which is the preceding year of the mid-term plan. It was assumed that the same amount of benefit on the last year of the mid-term plan will be repeated every year after the same year. The period of calculation was made for 30 years. The following revenue per kWh and unit cost of energy receiving which were estimated by PLN were used for the calculation.

Unit revenue = Rp.98.3 kWh = 98.3 mills/kWh
Unit cost of energy receiving =
Rp.70.0/kWh = 70.0 mills/kWh
Exchange rate 1US$ = Rp.1,000

The received energy is the total of the sold energy estimated in Section 1.2.1. and power losses calculated by the following rates.

	Sectional Loss Rate	Total Loss Rate at 150 kV Bus bar
Transmission Loss	3% at 150 kV bus bar	3.0 %
Distribution Loss	10% at 20 kV bus bar	9.7%
Total		12.7 %

iii) Result of Economic Analysis of the Mid-term plan

The internal rate of return calculated with the above parameters was 15.7% as shown in Table 1.2.4. Figure 1.2-2 indicates the internal rate of return thus calculated. Sensitibity tests were made in respect of variations in parameters. The result of the test is summarized below.

Result of Sensitivity Tests

Case		IRR (%)
(1)	Base case	15.7
(2)	10% increase of sold energy	17.8
(3)	10% decrease of sold energy	13.5
(4)	10% increase of construction cost	13.7
(5)	10% decrease of construction cost	18.0
(6)	10% increase of power receiving cost	4.1
(7)	10% decrease of received power cost	24.3
(8)	Revenue including connecting charge	25.6

This table shows that the economics of the mid-term plan will be higher than that of the short-term plan. This advantage is caused by the fact that main transmission lines and substations, especially transmission lines, will have been completed during the period of the short-term plan.

(b) Economic Evaluation of Long-term Plan

The economics of the long-term plan made at intervals of 5 years were analyzed by comparison of the annual levelized cost with the annual benefit.

i) Levelized cost

The levelized cost was obtained by summing up the levelized capital cost, O/M cost and other costs. The levelized capital cost was calculated by multiplying the capital recovery factor by the construction cost including IDC. The other costs were estimated equivalent to 40% of the O/M cost.

ii) Benefit

The benefit for the long-term plan was obtained by reducing the increment cost of energy receiving from the increment revenue of energy sales. The energy sales were estimated at 9,003 GWh in 1993/94, 15,275 GWh in 1989/90 and 24,849 GWh in 2003/04. Accordingly, the benefit computed with an assumed total energy loss rate of 12.7% is shown below.

	Increment Energy (GWh)	Amount (1 million US$)
Former half of the Long-term		
Revenue of energy sales	6,272	616.5
Cost of received power	7,184	502.9
Benefit		113.6
Latter half of the Long-term		
Revenue of energy sales	9,574	941.1
Cost of received power	10,967	767.7
Benefit		173.4

iii) Result of Economic Analysis of the Long-term Plan

Table 1.2-5 shows the net benefit and B/C ratio calculated with interest taken as a parameter. We can draw the following conclusion from this table.

- The B/C ratio for the long-term former half period plan was 1.2 at 12 percent interest rate and 1.0 at 15 percent interest rate.

From this result, the internal rate of return was presumed to be around 15%. This shows that the former half period plan is economically justified. However, it is more economical than the mid-term plan, because the former half period plan involves infrastructure components where benefits can also be gained in the later years, but in this evaluation such benefits are neglected.

- The B/C ratio for the latter half period plan was calculated to be 1.0 at 25 percent interest rate. This implies that the internal rate of return would be more than 25%. This demonstrates now the higher economies of the latter half period plan. This may be attributable to less the inflastructure components of the projects involved in the half period plan.

The result of the calculation throughout the long-term gives the mean value between the former and the latter half period. The B/C ratio indicates 1.0 at 20% interest rate.

COST : BASE
BENEFIT : BASE

TABLE 3.2-1 INTERNAL RATE OF RETURN IN MID-TERM PROJECTS

(USD X1000)

NO	YEAR	COST: INVESTMENT T/L	COST: INVESTMENT S/S	COST: INVESTMENT D/L	COST: INVESTMENT E.S.	COST: O&M	COST: TOTAL	BENEFIT: REVENUE	BENEFIT: REC.COST	BENEFIT: TOTAL	PRESENT WORTH: COST	PRESENT WORTH: BENEFIT	I.R.R 15.68 FACTO
1	1986	0	0	0	556	0	556	0	0	0	744	0	1.338
2	1987	5228	11627	20759	1969	0	39583	0	0	0	45791	0	1.156
3	1988	5784	15506	41831	2921	0	66042	0	0	0	66042	0	1.000
4	1989	2169	8176	50550	4405	966	66266	70678	-57652	13026	57282	11260	0.864
5	1990	762	5580	56153	4296	2666	69457	151087	-123242	27845	51901	20807	0.747
6	1991	716	6178	62305	3952	4409	77560	238672	-194685	43987	50099	28413	0.645
7	1992	363	3309	34383	2817	6240	47112	326587	-264765	59822	26306	33403	0.558
8	1993	66	606	6621	1694	8271	17258	418463	-341340	77123	8330	37225	0.482
9	1994	0	0	0	0	9389	9389	418463	-341340	77123	3917	32179	0.417
10	1995	0	0	0	0	9603	9603	418463	-341340	77123	3464	27816	0.360
11	1996	0	0	0	0	9603	9603	418463	-341340	77123	2994	24065	0.311
12	1997	0	0	0	0	9603	9603	418463	-341340	77123	2588	20786	0.269
13	1998	0	0	0	0	9603	9603	418463	-341340	77123	2237	17968	0.233
14	1999	0	0	0	0	9603	9603	418463	-341340	77123	1934	15532	0.201
15	2000	0	0	0	0	9603	9603	418463	-341340	77123	1672	13426	0.174
16	2001	0	0	0	0	9603	9603	418463	-341340	77123	1445	11606	0.150
17	2002	0	0	20759	0	9603	30362	418463	-341340	77123	3950	10033	0.130
18	2003	0	0	41831	0	9603	51434	418463	-341340	77123	5784	8673	0.112
19	2004	0	0	50550	0	9603	60153	418463	-341340	77123	5847	7497	0.097
20	2005	0	0	56153	0	9603	65756	418463	-341340	77123	5525	6481	0.084
986 - 2005		15088	50982	441895	22610	137574	668149	6225043	-5077764	1147279	347853	327149	
006 - 2015		0	0	103309	0	96030	199339	4184630	-3413400	771230	10990	31695	
986 - 2015		15088	50982	545204	22610	233604	867488	10409673	-8491164	1918509	358844	358844	

PRESENT WORTH

	DISCOUNT RATE (%)		(6.0)	(8.0)	(10.0)	(12.0)	(15.0)	(20.0)	(25.0)
COST	INVESTMENT	T/L	14988	14972	14963	14961	14970	15010	15079
	INVESTMENT	S/S	48771	48166	47618	47121	46461	45561	44869
	INVESTMENT	D/L	348640	313602	286837	266030	242587	216346	199077
	INVESTMENT	E.S.	20427	19819	19260	18746	18051	17065	16257
	O&M		104368	83429	67973	56332	43701	30416	22440
	TOTAL		537194	479988	436651	403190	365769	324399	297722
BENEFIT	REVENUE		4736743	3812982	3129098	2612361	2049188	1452268	1089952
	REC.COST		-3863758	-3110247	-2552404	-2130901	-1671521	-1184614	-889073
	TOTAL		872984	702735	576694	481459	377666	267654	200879
	B/C		1.625	1.464	1.321	1.194	1.033	0.825	0.675
	B-C		335790	222746	140063	78269	11897	-56745	-96843

Table. 1.2-5 Benefits and Costs in Long-term Projects

unit in Million US Dollers

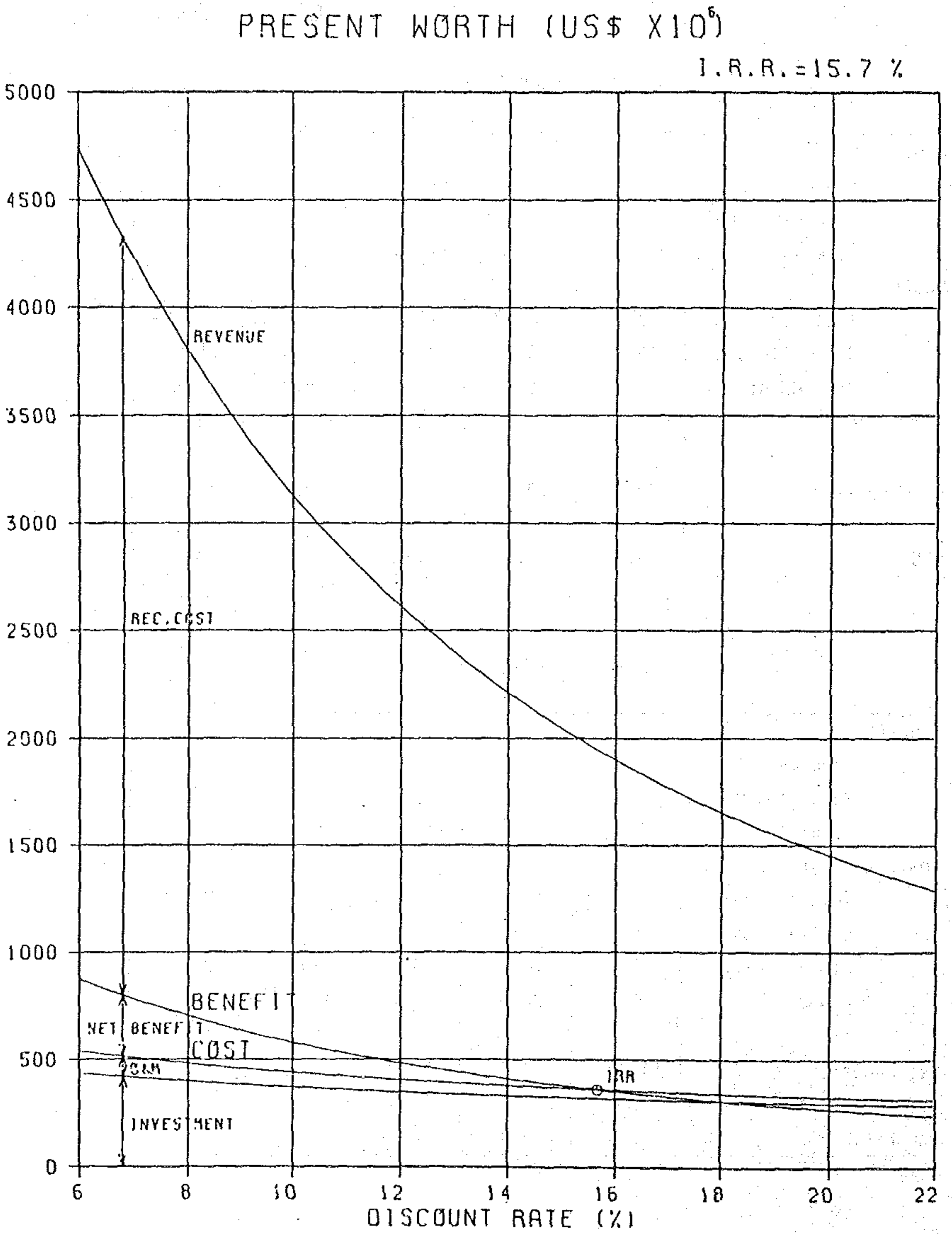
Former Long-term

Benefit					
Revenue			616.5		
Receiving costs			502.9		
Benefit			113.6		
Costs					
Interest rate	8 %	10 %	12 %	15 %	20 %
Capital costs	55.5	65.1	75.4	92.6	125.0
O&M and others	18.4	18.9	19.5	20.2	21.6
Costs	73.9	84.0	94.9	112.8	146.6
Net benefit	39.7	29.6	18.7	0.8	-33.0
B/C ratio	1.5	1.4	1.2	1.0	0.8

Latter Long-term

Benefit					
Revenue			941.1		
Receiving costs			767.7		
Benefit			173.4		
Costs					
Interest rate	8 %	10 %	12 %	15 %	25 %
Capital costs	51.9	60.5	69.9	85.4	148.6
O&M and others	17.5	18.0	18.5	19.3	21.9
Costs	69.4	78.5	88.4	104.7	170.5
Net benefit	104.0	94.9	85.0	68.7	2.9
B/C ratio	2.5	2.2	2.0	1.7	1.0

FIGURE 1.2-2 PRESENT WORTH OF BENEFIT AND COST IN MID-TERM PROJECTS



1.2.4. Technical Studies

(1) Study of System Planning

(a) Load Dispatching System after Interconnection between Java and Bali Island

At present, there exists no interconnection line between East Java and Bali Island. The interconnection project by submarine cable is planned for completion by 1988.

(i) Load Dispatching System before Interconnection

Load dispatching control of main power sources and trunk line in Java system has been made by J.C.C. (Java Control Center).

However, the load dispatching from 150 kV system to distribution line has been controlled by A.C.C. (Areal Control Center). Load dispatching control at load side in whole East Java area has been made by Waru A.C.C.

Bali Island has no general load dispatching system, but some individual systems, operating independently.

(ii) Load Dispatching System immediately after Interconnection

System conditions in East Java immediately after interconnection by submarine cable are expected to be such that a part of 150 kV line system is added to the existing system in East Java. Therefore, as with the interconnection between Java and Madura Island, the load dispatching to

Bali Island should be controlled by Waru A.C.C. However, on occasions in the past, not only Japan but European countries have had bitter experiences in submarine cable accidents. It is absolutely essential to take the necessary measures to prevent submarine cable accidents and communication system troubles in dispatching.

(b) Countermeasures against Flicker Caused by Arc Furnace

At present, East Java power system has a big demand of arc furnace using scrap materials. Since this load is a cause of flicker, the flicker must be limited within allowable level. The load of this flicker consumer is a contracted 32 MVA near Waru Substation, at present with the total installed transformer capacity of 70 MVA. In this Report, the study has been made on the voltage fluctuation and the countermeasures to limit the flicker within allowable levels, in the cases of arc furnace capacity of 20 MVA and 70 MVA.

(i) Limitation of Flicker

So far no international standard has been settled for the calculation method of flicker and its limitation. Therefore, this report adopted the standard calculation method and standard limitation usually used in Japan. Namely, the limitation of flicker is expressed as follows:

$$\Delta V\ 10\ \max \leqq 0.45\ (100V\ \text{base})$$

Where, ΔV 10 max is the maximum effective value obtained by converting the generated voltage fluctuation to 10 Hz.

(ii) Countermeasures in case of arc furnace capacity of 20 MVA

In case that the flicker consumer is supplied with 70 kV exclusive circuit, the installation of Thyristor Controlled Reactive Power Compensating System (TQC System) having approx. 12 MVA capacity, is required to limit the flicker within allowable levels.

(iii) Countermeasures in case of arc furnace capacity of 70 MVA

In this case, the installation of TQC System also is not sufficient as a countermeasure. New installation of 70 kV exclusive transmission line for this consumer is necessary. Also the installation of 150 kV/70 kV exclusive transformer bank is needed for 150 kV bus bar load. Furthermore, the installation of TQC System with the capacity of approx. 34 MVA is also required to keep ΔV 10 max less than 0..45 V at 150 kV bus bar.

(c) Study of D.C.C. System

The increase of power demand brings with it the need for more complex but more reliable power facilities.

To meet this tendency, the automatic control system for distribution line is actively developed in this country. Furthermore, the D.C.C. system is also continuing, as a suitable plan. However, close attention to implementation of D.C.C. system is recommended as follows.

(i) To investigate and study the necessary Organization staff for operation & maintenance for Distribution line in D.C.C. system.

(ii) To study duplication of transferring facilities to the main substation, and to add the transferring to D.C.C. system of the information such as accident, trouble, etc.

(iii) To study the design and procurement method of interface to be installed in each substation for conjunction with the existing Substation facilities and Communications facilities.

(iv) To plan the implementation of D.C.C. system in other regions, based on the actual effect from the execution of D.C.C. system in the Surabaya area.

(d) Load Shedding for Prevention of Total Blackout

In general, according to the development of power system or increase in system capacity, the power variation required for the generation or the load variation to restore the frequency of electric system increases roughly in proportion to the system capacity, although the normal frequency itself tends to become more stable.

However, the unbalance of supply and demand caused by the breaks of trunk transmission lines or generators increases with the installation of large capacity power plants connected to extra high voltage transmission lines.

Therefore, a kind of data process and instruction system which is composed of automatic information transmission system accompanied with a computer, will become necessary for some specified large power sources respectively, in order that frequency drops will not cause system collapses and to avoid local overloads. Generally, in addition to the above system, various system protection devices which immediately detect any noticeable unbalance of demand and supply by means of measuring the system frequency and the power flows of interconnection lines will also become necessary.

These processes correspond to automatization of emergency load sheddings executed by operators in a load dispatching office, and hereafter these will be called "load shedding".

(i) B.S.S. (Block System Stabilizer)

This is a kind of wide area integrated system protection scheme which has the following features, and we provisionally call it B.S.S. (Block System Stabilizer).

- Judgement standards and operation procedures of possible accidents on major power plants are put into a computer program.

- Various actual operating conditions of the system are always automatically transmitted to the computer.

- The computer always processes these data immediately and some necessary outputs are updated and stored.

- When any major signal meeting the conditions specified on the program is put in the computer, the output of the optimum operations for each stations can be obtained automatically.

- The information obtained is immediately transmitted to respective stations.

- Eventually, all the stations given this instruction automatically execute necessary operations respectively.

(ii) U.F.R. (Under Frequency Relay)

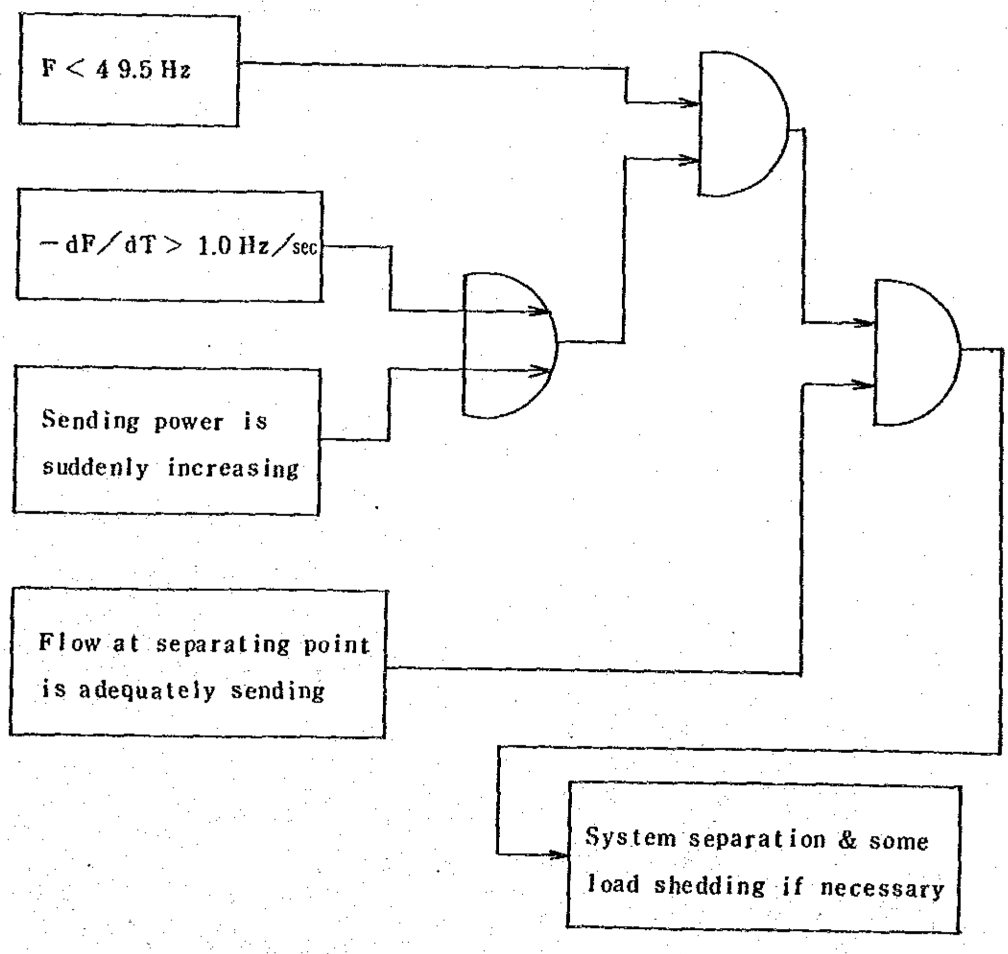
The system protection devices are needed for the back-up protection of B.S.S. and for limiting the collapsed range of the system and restoring the system as quick as possible at the time of frequency drop or sudden change of currents of interconnection lines. The devices are sensitive to the occurrence of any sudden unbalance of demand and supply, as soon as a frequency drop or sudden change of currents is detected on the interconnection lines. The devices are divided into following two (2) kinds according to their function.

. System Separation Relay

System separation relay is recommended as one of the system protection devices, for the following reasons.

The effect of most of the frequent total blackouts recorded in Java Power System, could be limited in their extent by successful separate operation of power plants. But the system must be separated without delay at suitable system separation points.

Therefore, it is recommended that simpler system configurations should be considered so that the separation can be easily made at the time of blackout, and that system separation relays as illustrated below should be installed at suitable system separation points. If possible, it is desirable to keep the power flow at those points slightly out of the line in such a case.



. Automatic Load Restricting Relay

As a back-up to the various load sheddings above-mentioned, the automatic load restricting schemes detecting a frequency drop and acting by classified frequency have been recently introduced. These execute urgent load restrictions automatically and specifically prior to the instructions given by a dispatching office.

This measure is effective against comparatively slow frequency drops, so it is recommended for introduction in stages throughout the system.

The various load shedding methods are collectively tabulated on the following table together with the ordinary frequency control methods.

	Operation Method	Subjected Disturbance to Control	Target Range of Frequency	Objects of Control
Ordinary time	Governor free operation of generator	Random fringy fluctuation	50 ± 0.1 Hz	Specified principal power plants
	AFC			
	ELD	Random fringy fluctuation & hourly fluctuation of daily load curve		
	Manual		50 ± 0.3 Hz	General power plants
On accidents	B.S.S. (Block system stabilizer)	Falling off of a large capacity (e.g. more than 100 MW) generation	Over 49.5 Hz	. Paiton and other substations for Paiton P/S . Segoromadu line others for Gresik P/S
	System Separation Relay			. 500 kV bus tie at Paiton S/S . Krian line at Gresik P/S . etc.
	Automatic Load Restricting Relay	Back-up protection	Over 49.0 Hz	Specified feeder of distribution substations, etc.
	Manual		Over some 48.0 Hz	Specified transmission line, etc.

(2) Study of Transmission Line Facilities

(a) Study of Design Criteria and Recommendation for Standardization of Facilities

Comparative study was made between the design criteria by French Loan obtained at our first field investigation and those by NEWJEC settled at the East Java Transmission/ Distribution Project (I to III stage). As a result of this study, no difference was found in the electrical design criteria, but a difference was revealed in the mechanical ones, such as standards of wind pressure. For instance, the mean wind velocity is supposed at 25 m/s by both consultants, but the wind pressure is not same at this velocity, as firmly tabulated below:

Wind Pressure \ Consultant	French Loan	NEWJEC (E.J.P. I - III stage)
On tower (kg/m^2)	120	110
On wire (kg/m^2)	45	40
On 150 kV insulator string (kg/st x 2)	60	60

The result of the respective study is as follows:

(i) Wind Pressure on Tower

Wind pressure on an object is expressed in the following formula.

$$P = \frac{1}{2} \rho C x V^2 \qquad (kg/m^2)$$

where, P : Wind pressure (kg/m^2)
ρ : Air density ($kg\ S^2/m^4$)
Cx : Drag coefficient
V : Wind velocity (m/s)

ρ is fixed by climatic conditions. Based on the investigations of the temperature and atmospheric pressure records in Surabaya area, the air density of 0.1208 $kg.S^2/m^4$ at the wind velocity of 25 m/s was applied to the above calculation.

Cx is influenced by the panel of tower. For this calculation the drag coefficient was fixed at 2.876, which is also obtained at 150 kV standard tower.

From the above, the wind pressure on tower is computed as follows:

$$P = \frac{1}{2} \times 0.1208 \times 2.876 \times 25^2 = 108.6 < 110$$

The result shows the sufficiency of the wind pressure on tower used in East Java Project First to Third Stages.

(ii) Wind Pressure on Wire

In this case, the air density (ρ) of 0.1208 is also applied for the wind pressure calculation.

The drag coefficient (Cx) is much changed with wind velocity, because wire section is almost circular. Therefore, the drag coefficient was obtained from its actual measurement record for past years, using the wind velocity of 25 m/s for standard wire in Indonesia.

From the above, the wind pressure on wire is computed as below

Kind of Wire / Item	Cu	A.C.S.R.				G.S.W.
	$50\ mm^2$	Pigeon	Ostrich	Hawk	$330\ mm^2$	$55\ mm^2$
Wind Pressure or Wire (kg/m)	46.4	43.0	39.6	36.6	35.1	44.9

It is confirmed in this Table that in case of T/L Installation with the thicker wire than Ostrich type, the wind pressure of 40 kg/m^2 is applicable for the calculation.

(iii) Wind Pressure on Insulator

According to the experiment of wind pressure against the insulator string, the maximum drag coefficient (Cx) of insulator is determined at 1.4. The wind pressure for string of 11 units, is calculated based on this maximum drag coefficient. The calculation results in the wind pressure of 19.5 kg/m^2. Therefore, 40 kg/m^2 is deemed sufficient for the wind pressure of insulator at supporting point, and the design criteria for East Java Project has enough allowance for wind pressure on insulator.

In the above consideration, the design criteria used for East Java Project was confirmed practicable for the Surabaya area. However, in the future T/L project, considrable study should be made about the local regional conditions of the line route, before determination of the design criteria.

Regarding the standarization of facilities, there is such a problem that the facilities are not always standardized, even if the design criteria is standardized. Because the standards of materials, dimension and standards are differ from country to country, increased difficulty in standardization is anticipated in future. The increase in internationalization of bank loans, consultants and contractors dispatched in Indonesia is also a factor.

(b) Study of Power Loss Reduction of Transmission Facilities

Comparison of power loss rate in power system between Japan and Indonesia (East Java), is tabulated as below:

IN%

Item \ Country	Indn. (E.J.)	Japan	Indn./Jap.
Power Station Loss	3.95	3.4	1.2
Transmission Line and Substation Loss	4.71	2.7	1.7
Distribution Loss	12.35	3.3	3.7
Total	21.0	9.4	2.2

As seen in the above Table the power loss rates in transmission, and substation, distribution in Indonesia are considerably higher than those in Japan.

Since the substation loss is almost negligible in comparison with transmission line loss, the transmission loss in Indonesia is regarded as 1.7 times of that in Japan. This is due to the delay in reinforcemet and rehabilitation of transmission facilities in comparison with the urgent increase of power demand.

In this Report, the additional installation of a 2nd circuit on double circuit towers with a single circuit transmission line was considered as a possible measures against loss reduction. The time of additional 2nd c.c.t. installation was estimated from the relation between the investment for additional installation and the profit by loss reduction.

(i) In case of Implementing only the Additional 2nd c.c.t.

In this case, the transmission line is made with twin conductors by connecting the existing two circuit conductors at the T/L bay in substation.

Conditions of calculation are as follows:

- Voltage and kind of conductor	:	150 kV, 330 mm^2 A.C.S.R. 70 kV, 300 MCM A.C.S.R.
- Annual power growth rate	:	13% to 20%
- Load factor	:	67%
- Power unit cost (Rp/kWh)	:	71.44 at 150 kV Bus 74.28 at 70 kV Bus
- Investment	:	Standard construction cost
- Depreciation period	:	25 years

(ii) In case of Concurrently Implementing the Additional 2nd c.c.t. of T/L and T/L bay in Substation

In this case, transmission line loss is reduced, and the reliability of the power system is increased, without interruption by single circuit trouble.

Conditions of calculation are same as those in case (a) above, except the growth rate which in this case has little influence. Growth rate of 16.5% is given for calculation.

The results of calculations in cases above (a) and (b) are shown in Figures as below:

The results and Figures lead the following conclusion:

- In case of (a), when annual average electric current reaches to 13% at 150 kV and 8% at 70 kV of current carrying capacity, the line is more economical, with very little influence by growth rate.

- In case of (b), economic borderline is influenced by T/L route length. A very heavy load is required in the short distance T/L route to cover the early time investment.

By means of the above method, the selection of suitable conductors and rehabilitation of deteriorated facilities are to be performed in order reduce power loss in Indonesia.

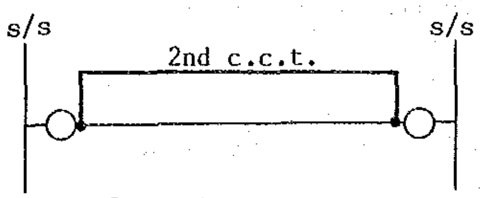
(c) Investigation and Study of Insulation Level

Investigation of the insulation method for the 70 kV and 150 kV transmission lines in East Java indicates that the unbalanced insulation method was used over the system.

In order to examine whether the method was effective against tripouts caused by lightning, the statistics of tripouts of transmission lines in East Java were gathered.

Economic Border Line

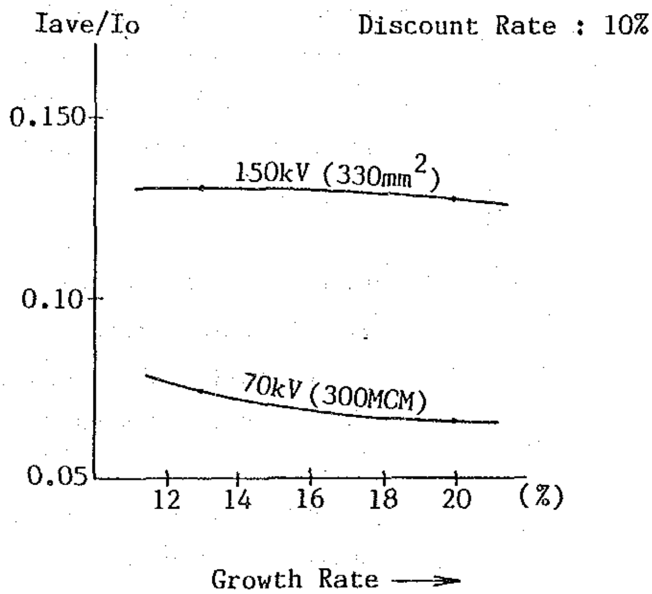
Case (1)



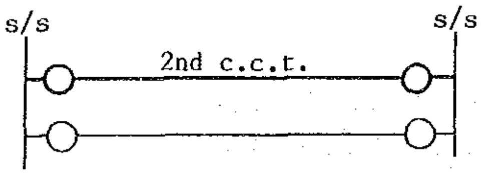
○ Line Bay

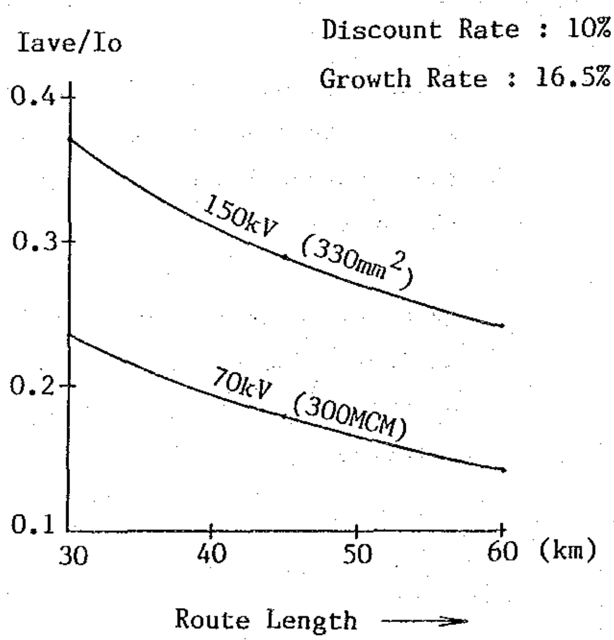
Iave - Annual average Current

Io - Current Carrying Capacity



Case (2)





Tripout Rate of 2 cct. Transmission Line
for 100 km per* year

Location	Voltage	Climate			Human work	Unknown cause	Total
		Bad weather	Ice load	Lightning			
East Java	150 kV	1.45	0	0.40	0.66	1.72	4.23
	70 kV	4.03	0	1.45	4.51	2.42	12.41
Japan	66 75kV	0.55	0.83	4.25	0.83	1.18	7.64

* East Java - rainy season (Nov. - June) only.

The records are shown in the above table. This table shows that the tripout rate of 70 kV lines in East Java is higher than that in Japan but their rate of tripout due to lightning is very low. This conflicts with the fact that IKL in East Java is as high as about 3 times of IKL in Japan. This contradiction may be caused by the method of classifying causes of tripouts. If the cause of tripouts reported as bad weather are all considered as lightning, the rate of tripouts due to lightning in East Java becomes almost equal to that in Japan. The forecasted rate of tripouts due to lightning was estimated at IKL 30, assuming all tripouts by bad weather were those by lightning. Actual tripout records and forecast tripout rate are shown in the following table of comparison.

Past Record and Forecast of Tripout Rate
per 100 km per Year

Item	Kind of Insulation		150 kV 1cct	150 kV 2cct	150 kV Total	70 kV 1cct	70 kV 2cct	70 kV Total
Past Record	Unbalanced Insulation		1.45	0.40	1.85	4.51	0.97	5.48
Forecast	Unbalanced Insulation		1.51	0.15	1.66	3.28	0.13	3.41
	Balance Insulation	Standard	0.93	0.79	1.72	1.29	2.08	3.37
		High	0.73	0.31	1.04	1.33	1.21	2.54

This table shows that past records of 150 kV and 70 kV 2 circuits tripouts are higher than the forecast rates of 2 circuits tripouts, but they are about half of the forecast rates of standard insulation, and the effect of unbalanced insulation is recognized. The small number of tripouts caused by lightning and the high number of tripouts due to unknown causes do not enable us to draw any conclusions on the effect of unbalanced insulation. It is recommended that the effect of unbalanced insulation should be reviewed when precise data of tripouts by causes are made available. For the unbalanced insulation, as tripouts will take place more frequently on lower circuits, there is the possibility that tripouts will occur at an intermediate substation incoming from the lower circuits. It is recommended that data on lightning in the tropical zone should be gathered and an adequate method of lightning-proof design should be established to review the insulation system.

(d) Determination of the Characteristics of Conductor

In East Java, various kinds of conductors are used for the existing transmission lines. It is recommended that the types of conductors should be unified to reduce the cost and promote the interchangability of conductors.

Existing and Recommended Kinds of Conductors

Voltage / Kind	70 kV		150 kV	
	Existing	Recommendation	Existing	Recommendation
HDCC	50 mm^2			
ACSR	Pigeon (85 mm^2)	Ostrich (152 mm^2)	JIS-160 mm^2	JIS-330 mm^2
	Piper (152 mm^2)		Hawk-240 mm^2	
	Ostrich (152 mm^2)		JIS-330 mm^2	

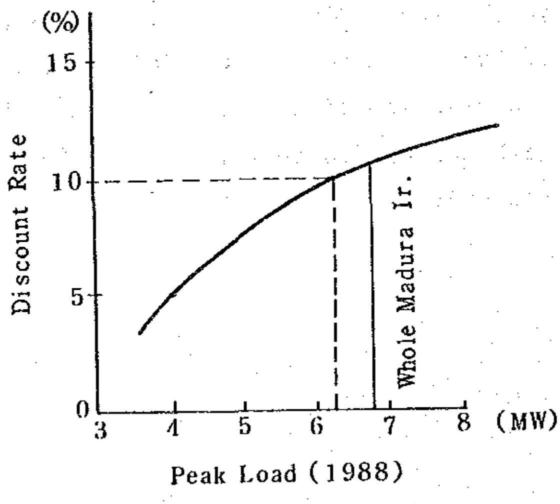
240 mm^2 ACSR are used for the 150 kV system in East Java. The economic evaluation of 330 mm^2 with 240 mm^2 was made by comparison of the difference in the construction cost (US$3,748/km) and the difference in annual loss derived from the difference in resistance (0.0335 /km). The discount rate of the difference in the annual loss will be over 10%, if the peak load in 1988 is more than 6,200 kW. And in the event the transmission line over the Island of Madura is planned with uniform conductors, 330 mm^2 conductors will be more economical.

Unit Cost of 150 kV Transmission Line
(1/2 circuit) (US$)

	Item	330 mm²	240 mm²
F.C.	Tower (2 circuits)	15,296	14,225
	Conductor (1 circuit)	9,595	8,167
	Earth wire (1)	1,298	1,298
	Insulator (1 circuit)	3,645	3,645
	Total	29,834	27,335
L.C.	Construction cost of Tower	17,850	16,601
	Total of F.C. + L.C.	47,684	43,936
	Difference	0	-3,748

The figure below is an example of the economic calculation. The size of conductors for transmission lines should be selected bearing in mind economic considerations, future system planning and problems related to right-of-acquisition.

Discount Rate



(e) Designing of Tower Foundations

In this study, various problems relating to tower foundations in East Java were reviewed.

(i) Square Pad and Chimney Type Foundation

In East Java, the square pad and chimney type foundations were used as standard foundation. However, recently circular pad and chimney type foundations started to be used in order to reduce the cost of foundation forms. The cost of both types of foundations was compared to each other on the assumption that the depths of both types are the same. The result of comparison shows that in soft ground the costs of both types of foundations (M type and N type) are almost equal to each other but the excavation volume and concrete volume of the circular pad and chimney type foundation for normal ground (L type) are increased by 10% to 20% over those of the square pad and chimney type foundation. It is recommended that adoption of either the square type or the circular type should be determined by comparison of the difference in forms and the difference in construction quantities.

(ii) Pile Foundation

Most of the transmission line routes in East Java are flat. There are some routes for which the use of pile foundations reaches 20% of the total quantities of foundations. Normally, steel pipes of large diameter are used as pile foundation. But they are imported into Indonesia. Therefore, the field construction works are influenced by the delivery time and quantities of imported pipes. In order to overcome this constraint, micro piles are being developed for domestic manufacture. They are a kind of in situ piles and are considered an effective method, if they are driven properly. It is recommended that the shape of points of steel piles should be changed from the square type to the circular type. Therefore, it is proposed to study whether the micro piles with round points can be manufactured in East Java.

(iii) Floating Type Foundation

In Japan, floating type foundations are used for tower sites at very deep position. The floating type foundations are placed at a shallow depth with a single concrete slab supporting all 4 steel tower legs. The volume of concrete in this type of foundation is about 8 times that of independent pile type foundations. However, the foundation work of this type can be carried out more efficiently with large capacity machinery, because the method of construction is simple. The cost of this type of foundation depends on the depth of bearing soil and load applied by each tower leg. It is recommended that application of this type of foundation should be studied for the East Java system.