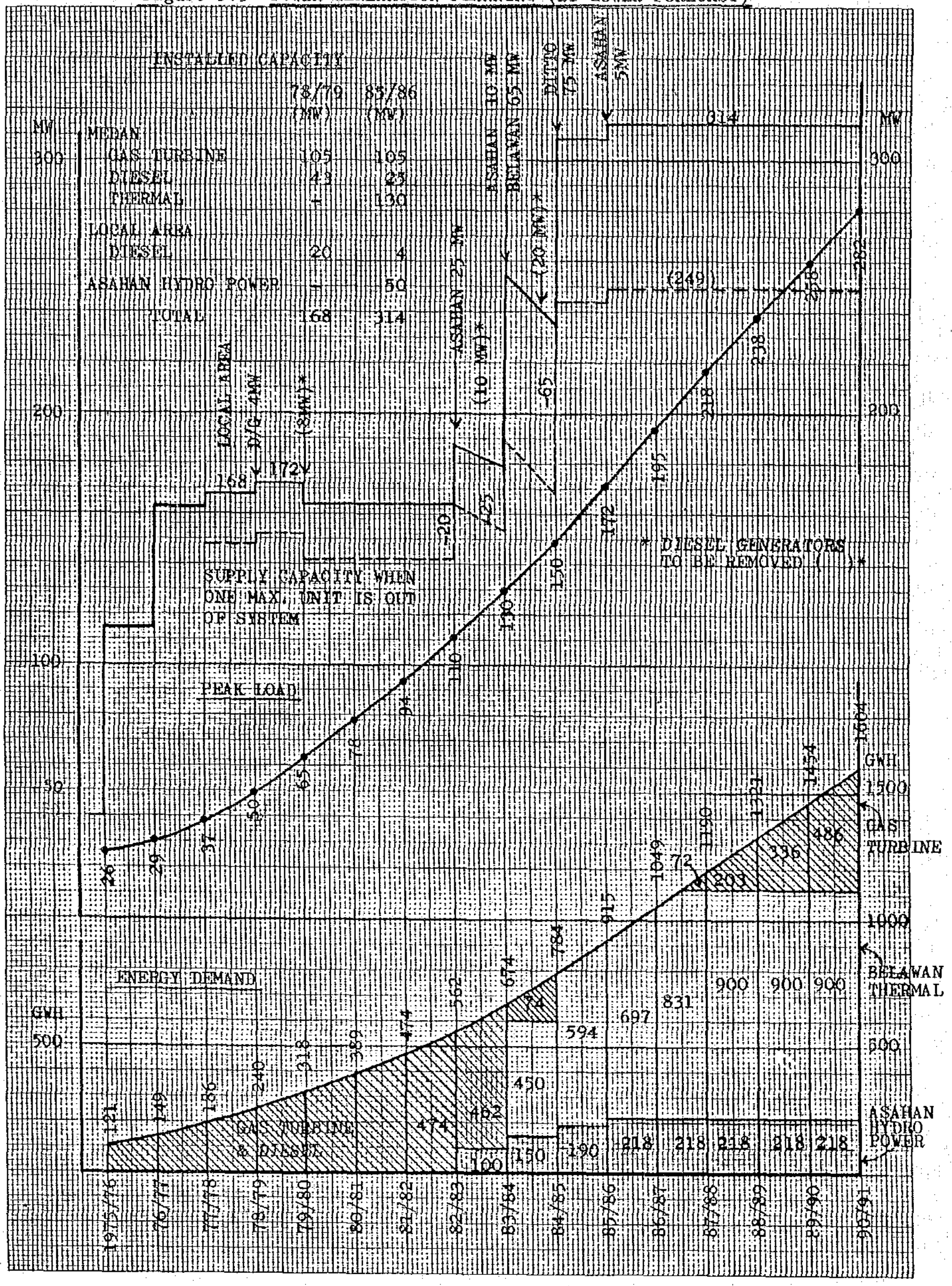
Figure 3.3 POWER GENERATION PLANNING (BY LOWER FORECAST)



CHAPTER 4

SYSTEM PLANNING

4.1 System Planning

In planning the transmission system, followings are the given conditions;

a) Medan is the biggest load center and the power production center as well. A 150 kV ring is planned and under construction around Medan.

b) Asahan hydroelectric power is supplied from INALUM at the 275 kV bus of his substation at Kuala Tanjung.

c) Load centers are at Tebing Tinggi, Pematang Siantar, Kisaran, Tanjung Balai and Brastagi, locating each other or from the above power sources with about 50 km distance.

From these conditions and the geographic locations of these centers, the transmission line network is automatically planned as follows;

i) To construct a main line from Kuala Tanjung to Medan via Tebing Tinggi.

ii) To branch a line from Tebing Tinggi to Pematang Siantar

iii) To extend a line from Kuala Tanjung to Kisaran and another from Medan to Brastagi.

As for the system voltage, 150 kV is selected according to the Indonesian standard. An economic comparison study on alternative 275 kV and 70 kV schemes has supported this selection as explained in succeeding clauses.

The main line between Kuala Tanjung and Medan is planned to have double circuits due to its role of a trunk line, while other branch lines are planned to have a single circuit only taking into account their transmission capacity and relatively small scale loads.

At Kuala Tanjung, therefore, step-down transformers of 275 kV/150 kV are planned to be installed. The main line to Medan and a branch line to Kisaran will be connected to 150 kV bus. On the other hand, the another end of the main line at Medan may be connected directly to the 150 kV bus of Medan Timur substation.

At Tebing Tinggi, one circuit of the main line will be paid-branched and connected to 150 kV bus, from which a branch line will be extended to Pematang Siantar.

The line to Brastagi will be branched from Titi Kuning, another substation of Medan 150 kV ring and the nearest site to Brastagi.

4.2 Substation Transformer Capacity

150 kV transformer capacity at each substation is decided so as meet the local demand expected by 1990/91, as follows;

	Load forecast in 1990/91	Transformer
P. Siantar	17.0 MW	2 x 10 MVA
T. Tinggi	8.7 MW	1 x 10 MVA
Kisaran	16.3 MW	2 x 10 MVA
Brastagi	2.2 MW	1 x 10 MVA
K. Tanjung	5.8 MW	1 x 10 MVA

(Remark)

1) For saving the cost and spare holding, the transformer capacity is made uniform.

2) The price of 150 kV transformers of less than about 10 MVA is not reduced proportionally, therefore a 10 MVA transformer is applied even the load is far less the capacity.

3) The load in 1990/91 is computed from the energy demand forecast given in Table 3.1 by assuming the load factor to be 65 %.

4) No transformer is planned at Medan as the power will be fed through the existing 150 kV/20 kV network.

The main transformers of 275 kV/150 kV at Kuala Tanjung should have the capacity of about 60 MVA to send the power of 50 MW. Two transformers of 40 MVA each are planned to be installed so that about two thirds of 50 MW may be sent even one transformer becomes out of operation due to a fault or maintenance.

4.3 Review on Alternative Schemes

As the high tension voltage at the INALUM substation is 275 kV, an alternative transmission scheme of 275 kV may be conceived for the main line. As for the branch lines to Pematang Siantar and Kisaran, 70 kV should be applied as the 275 kV lines and equipment are two expensive to send some tens MW for about 50 km distance.

Another alternative is to use the 70 kV system not only for the branch lines but also for the main line, as the demand scale is not so big and the transmission distance is not so far. Single line diagrams for comparison of alternative transmission scheme are given in Figure 4.1.

A comparative study on these alternative schemes is made for costs of constructing transmission lines and high tension equipment, but eliminating 20 kV side and indoor equipment and substation civil works, which are almost same in cost in any scheme.

The energy loss in each scheme is also roughly computed for the economic life of lines and equipment, 35 years, and evaluated at the rate of US¢ 3 kWh.

The computation is given in Table 4.1 and the result is as follows:

	150 kV Scheme	275 kV Scheme	70 kV Scheme
Cost of Construction	12.36 (100%)	15.06 (122%)	11.76 (95%)
Energy Loss Value	0.53	0.93	2.41
Total	12.89 (100%)	15.99 (124%)	14.17 (110%)

(US$$10^6$)

As seen, the 150 kV scheme is the most economical scheme.

As for the Titi Kuning - Brastagi section, it seems needless to compare the 150 kV scheme with an alternative 70 kV one, because in case of the alternative 70 kV scheme a step-down transformer, 150 kV/ 70 kV, is additionally needed at Titi Kuning. This additional cost compensates the cost difference between 150 kV line and 70 kV one as shown in Table 4.2. Then, a preferrence is given to the 150 kV scheme owing to better voltage regulation, less energy loss and future needs for more transmission capacity.

4.4 Power Flow Analysis

Power flow analysis is made with a digital computer (1) to review the voltage regulation and the necessity of any capacitors for voltage control and (2) to estimate the transmission capacity.

4.4.1 Voltage Regulation Study

The analysis is made for the following case.

System load

Medan	180 MW
Local area	32 MW
Total	212 MW

Power output

Belawan Thermal	122 MW
Gas Turbine	40 MW
Asahan Hydro	50 MW
Total	212 MW

(This represents the expected conditions in 1986)

The results are given in Figure 4.2. The voltage drop in 150 kV system is only 1.7 % without any capacitor for voltage control. Therefore, no special consideration may be needed for voltage control except employing the conventional on-load tap changer for 150 kV/20 kV transformers to keep constant voltage at 20 kV bus of each substation.

4.4.2 Transmission Capacity Study

To assess the transmission capacity in future, following case is analized for reference only.

System load	
Medan	409 MW
Local area	56 MW
Total	465 MW
Power output	
Belawan Thermal	166 MW
Gas turbine	60 MW
Asahan Hydro	100 MW
New Power /1	157 MW
Total	483 MW

The results are given in Figure 4.3. The power flow through the main line amounts to 220 MW, yet the voltage drop between Kuala Tanjung and Medan is 2.7 % only. Meanwhile, the thermal capacity of the main line is about 300 MW as given below;

$$\sqrt{3} \times 150 \text{ kV} \times 600 \text{ A}^{/2} \times 0.85 \times 2\text{-cct} = 265 \text{ MW}$$

The voltage regulation for the maximum allowable power flow, 265 MW, would be still less than 4 % (2.7 % x 300/220); therefore the transmission capacity of the main line is limited not by the voltage regulation but by the thermal capacity of conductors, namely about 265 MW.

4.5 20 kV Lines

Besides the above mentioned load centers, where the 150 kV/20 kV substation are planned, following towns are deemed as sub-centers of loads, to which secondary transmission lines of 20 kV were planned to be extended;

/1 For the purpose of assessing the transmission capacity of the main line, this new power source was assumed at Kuala Tanjung.

/2 Current carrying capacity of ACSR 240 mm^2

Tanjung Balai, about 22 km from Kisaran
Pulau Radja, about 50 km from Kisaran
Parapat, about 43 km from Pematang Siantar
Tanah Djawa, about 15 km from Pematang Siantar
Kabanjahe, about 11 km from Brastagi

150 kV/20 kV substations are generally located about 5 to 8 km apart from the town center and accordingly 20 kV feeders between them are also needed.

As for Parapat-Porsea-Balige area, the power will be supplied directly from the Siguragura hydroelectric power station with a 20 kV line.

These 20 kV lines connect to the existing 6 kV distribution system through 20 kV/6 kV transformers or directly to the new 20 kV distribution network. In the area to be electrified newly, like Parapat-Porsea section, pole mounting transformers will connect the 20 kV line directly to low tension distribution lines. However, these connection including 20 kV transformers are not included in this project, as most of them are under implementation in accordance with the construction or extension of local diesel power plants.

4.6 Future Extension

PLN prepared a future extension plan of 150 kV network to cover such major towns as Sidikalang, Tarutung, Sibolga, Rantau Parapat in several stages, as shown in Figure 4.4.

Although not reviewed in detail, the 150 kV network would satisfy the requirement for this wide range power transmission. (In this meaning, 70 kV scheme should not be employed for the current system under study).

The complete plan of this extension should be reviewed in due time including consideration for future power sources, industrial development, etc. No further comment may be given as the matter is beyond the scope of work for the current study.

√ Table 4.1 COMPARISON OF ALTERNATIVE TRANSMISSION SCHEME

(Main System)

		Original	Alternative A	Alternative B
		(See Figure 4.1 as for details)		
(A)	Transmission Lines Cost			
	K. Tanjung-Medan	(150kV, 2-cct)	(275kV, 1-cct)	(70kV, 2-cct)
		US$5.13x10^6	US$7.61x10^6	US$4.73x10^6
	T.Tinggi-P.Siantar	(150kV, 1-cct)	(70kV, 1-cct)	(70kV, 1-cct)
		1.77	1.61	1.61
	K.Tanjung-Kisaran	(150kV, 1-cct)	(70kV, 1-cct)	(70kV, 1-cct)
		2.16	1.97	1.97
	Total	US$9.06x10^6	US$11.19x10^6	US$8.31x10^6
(B)	Substation, High Tension Equipment Cost/1			
	K.Tanjung S/S	US$1.74x10^6	US$1.08x10^6	US$1.59x10^6
	T.Tinggi S/S	0.57	1.28	0.45
	Medan Timur S/S	0.23	0.83	0.73
	P.Siantar S/S	0.38	0.34	0.34
	Kisaran S/S	0.38	0.34	0.34
	Total	US$3.30x10^6	US$3.87x10^6	US$3.45x10^6
(C)	Total of Transmission Lines and Substations			
		US$12.36x10^6 (100%)	US$15.06x10^6 (122%)	US$11.76x10^6 (95%)
(D)	Present Worth of Loss Energy for 35 years/2			
	Total energy loss	17.6 GWh	31.1GWh/3	80.4GWh
	Loss in monetary term at US¢3/kWh	US$0.53x10^6	US$0.93x10^6	US$2.41x10^6
(E)	Sum of Costs and Present Worth of Loss Energy			
		US$12.89x10^6 (100%)	US$15.99x10^6 (124%)	US$14.17x10^6 (110%)

/1 20kV and indoor equipment, erection cost and miscellaneous materials, civil and building works are common or almost same in costs, therefore they are eliminated from the comparison.

/2 See the attached calculation sheet in the next page

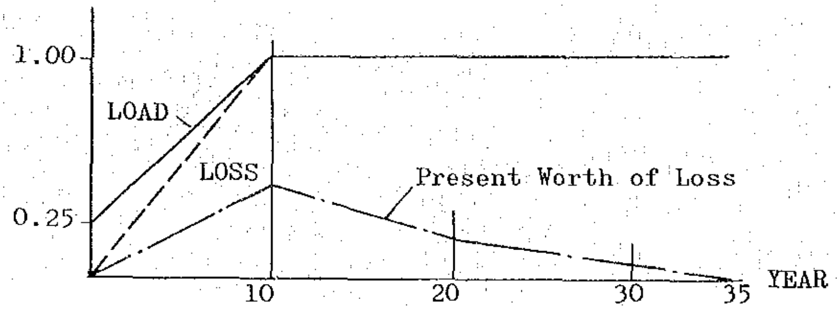
/3 Energy loss in 275 kV line was neglected.

SIMPLIFIED ENERGY LOSS CALCULATION

	70 kV	150 kV
(Branch Lines)		
I for 20MVA = 20,000kVA/$\sqrt{3}$V	165A	77A
r = 0.12 ohm/km x 1.1 = 0.132 ($240mm^2$ACSR, 50^oC)		
P = $3I^2r$ per km	10.78kW/km	2.35kW/km
K.Tanjung-Kisaran, 55km	592.9 kW	129.3 kW
T.Tinggi-P.Siantar, 48km	517.4 kW	112.8 kW
P = Total peak loss	1,110.3 kW	242.1 kW
Annual loss, P x 8,760hr x 0.4	$3.89x10^6$kWh	$0.85x10^6$kWh
Present worth of loss for 35 years (PW Factor = 8.0)/1	$31.12x10^6$kWh	$6.80x10^6$kWh
Loss in monetary term, US¢3/kWh	US$0.93x10^6$	US$0.20x10^6$
(Main Lines)		
30MVA/2cct = 15MVA		
I for 15MVA = 15,000kVA/$\sqrt{3}$V	124A	58A
r = 0.132 ohm/km		
P = 2 x $3I^2r$	12.18kW/km	2.66kW/km
K.Tanjung-Medan, 91km	1,108.4 kW	242.1 kW
Annual loss, P x 8,760hr x 0.4	$3.88x10^6$kWh	$0.85x10^6$kWh
Present worth of loss for 35 years (PW factor = 12.7)/1	$49.28x10^6$kWh	$10.80x10^6$kWh
Loss in monetary term, US¢3/kWh	US$1.48x10^6$	US$0.33x10^6$
(Total)		
Peak loss	2,219 kW	484 kW
Annual loss	$7.77x10^6$kWh	$1.70x10^6$kWh
Present worth of loss for 35 years	$80.4x10^6$kWh	$17.6x10^6$kWh
Loss in monetary term	US$2.41x10^6$	US$0.53x10^6$

/1 See the attached "SIMPLIFIED CALCULATION OF PRESENT WORTH FACTOR", in the next page.

SIMPLIFIED CALCULATION OF PRESENT WORTH FACTOR



1) Assumption

a) The demand reaches the saturated level limited by the capacity of substations and transmission lines in 10 years, with an annual growth rate of 15%.

b) The discount rate is 8% per annum.

2) Calculation

	Load	Loss	Present Worth	Sum of Present Worth
1st year	0.25	0.0625	0.0625	
				2.6285
10th year	1.00	1.00	0.4632	
				3.3885
20th year	1.00	1.00	0.2145	
				1.5695
30th year	1.00	1.00	0.0994	
				0.4175
35th year	1.00	1.00	0.0676	
			Total	8.004
			Say	8.0

3) In case the load is constant from the initial year, the present worth of loss in the 1st year becomes 1.0; therefore the sum of present worth becomes 12.6915 (say 12.7) by a similar calculation.

Table 4.2 COMPARISON OF ALTERNATIVE TRANSMISSION SCHEME

(Titi Kuning - Brastagi System)

		Original (150kV, 1-cct)	Alternative (70kV, 1-cct)
(A)	Transmission Line	US$1.92x$10^6$	US$ 1.74x10^6
(B)	Substations, High Tension Equipment		
	Titi Kuning S/S	US$ 0.11x10^6	US$ 0.33x10^6
	Brastagi S/S	0.26	0.22
	Total	US$ 0.37x10^6	US$ 0.55x10^6
(C)	Total of Transmission Line and Substation	US$ 2.29x10^6	US$ 2.29x10^6

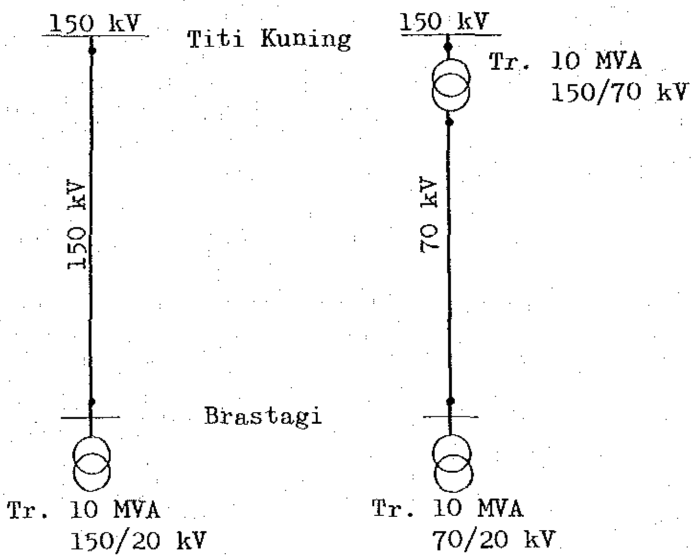


Figure 4.1 SINGLE LINE DIAGRAM FOR COMPARISON OF ALTERNATIVE TRANSMISSION SCHEME

Transformer

Switchgear

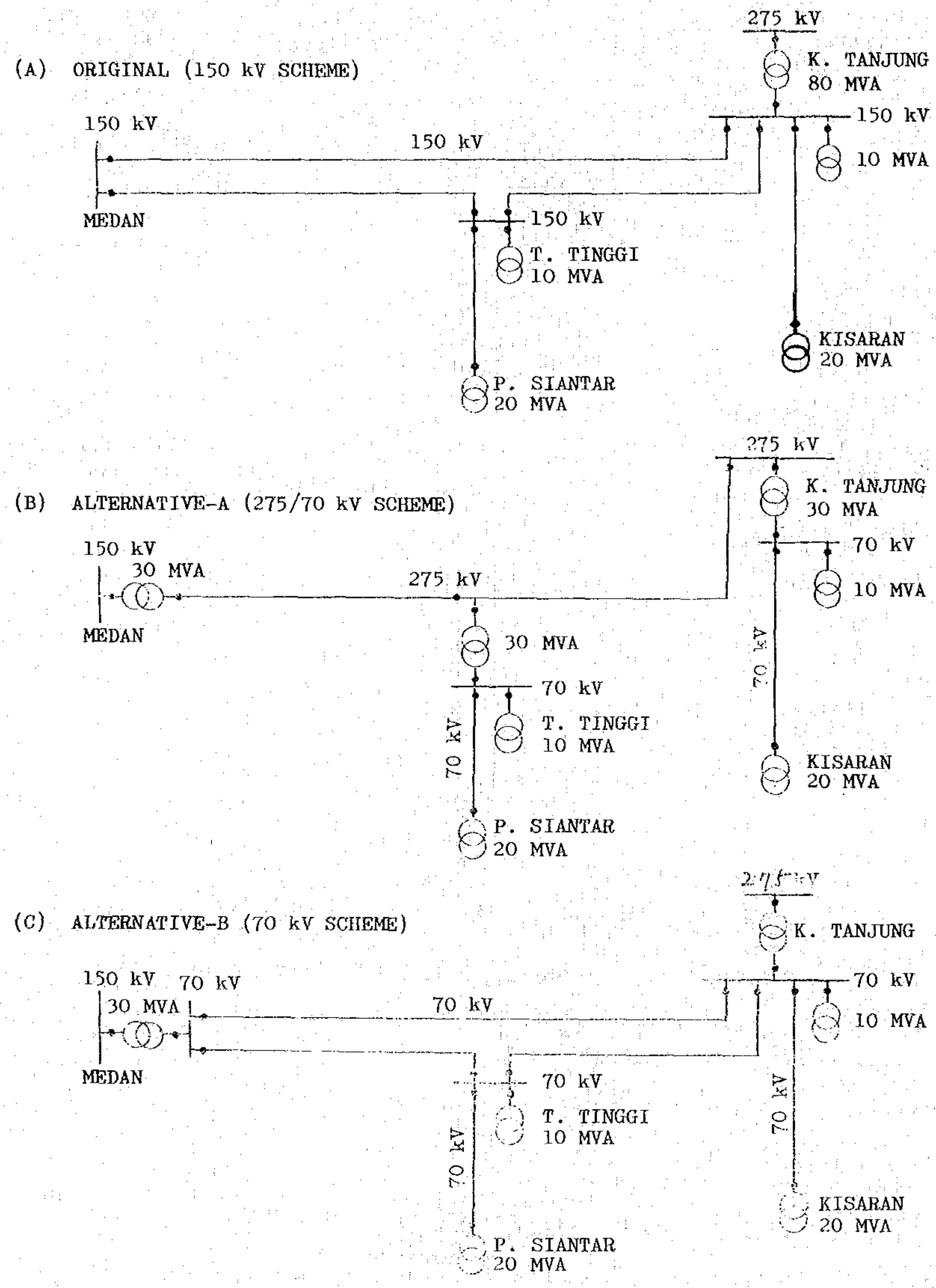


FIG. 4.2 POWER FLOW DIAGRAM (1)

LOAD:		POWER OUTPUT:	
SYSTEM MEDAN	180 MW	BELAWAN THERMAL	122 MW
OTHER AREA	32 MW	GAS TURBINE	40 MW
TOTAL	212 MW	ASAHAN HYDRO	50 MW

(POWER FLOWS ARE IN MW AND MVA)

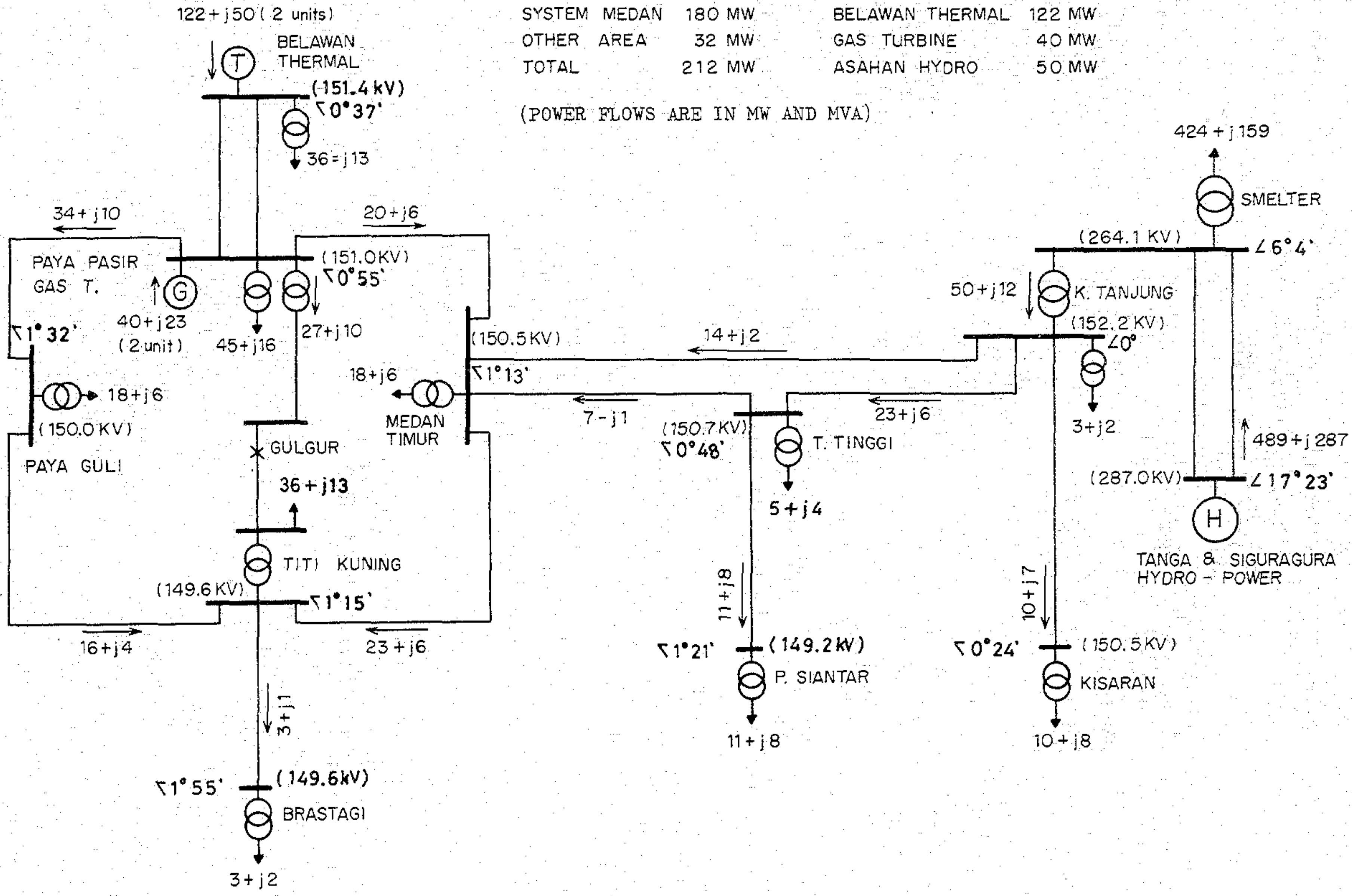


FIG. 4.3 POWER FLOW DIAGRAM (2)

LOAD:

SYSTEM MEDAN	409 MW
OTHER AREA	56 MW
TOTAL	465 MW

POWER OUTPUT :

BELAWAN THERMAL	166 MW
GAS TURBINE	60 MW
ASAHAN HYDRO	100 MW
NEW POWER	157 MW

(POWER FLOWS ARE IN MW AND MVA)

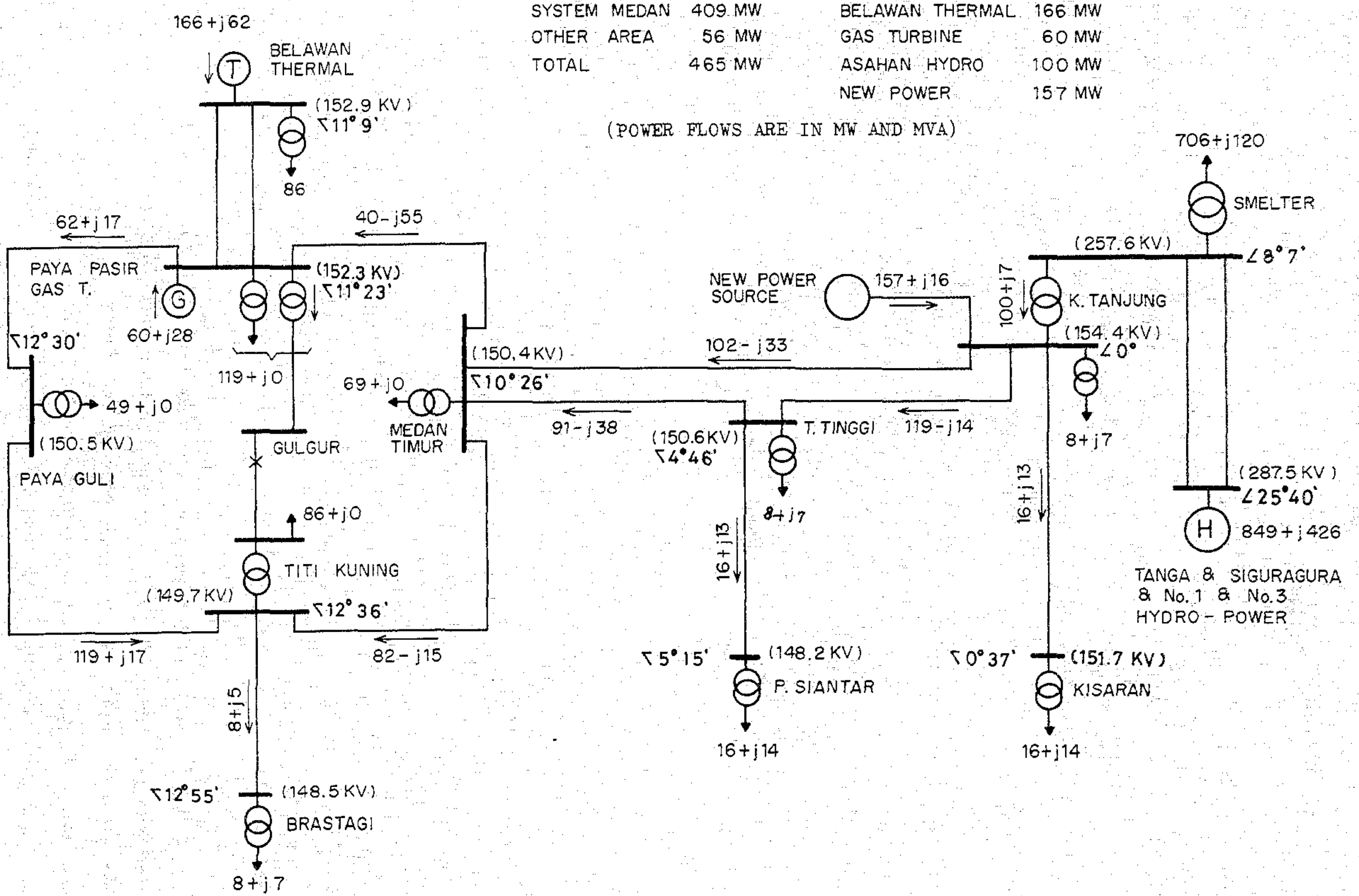
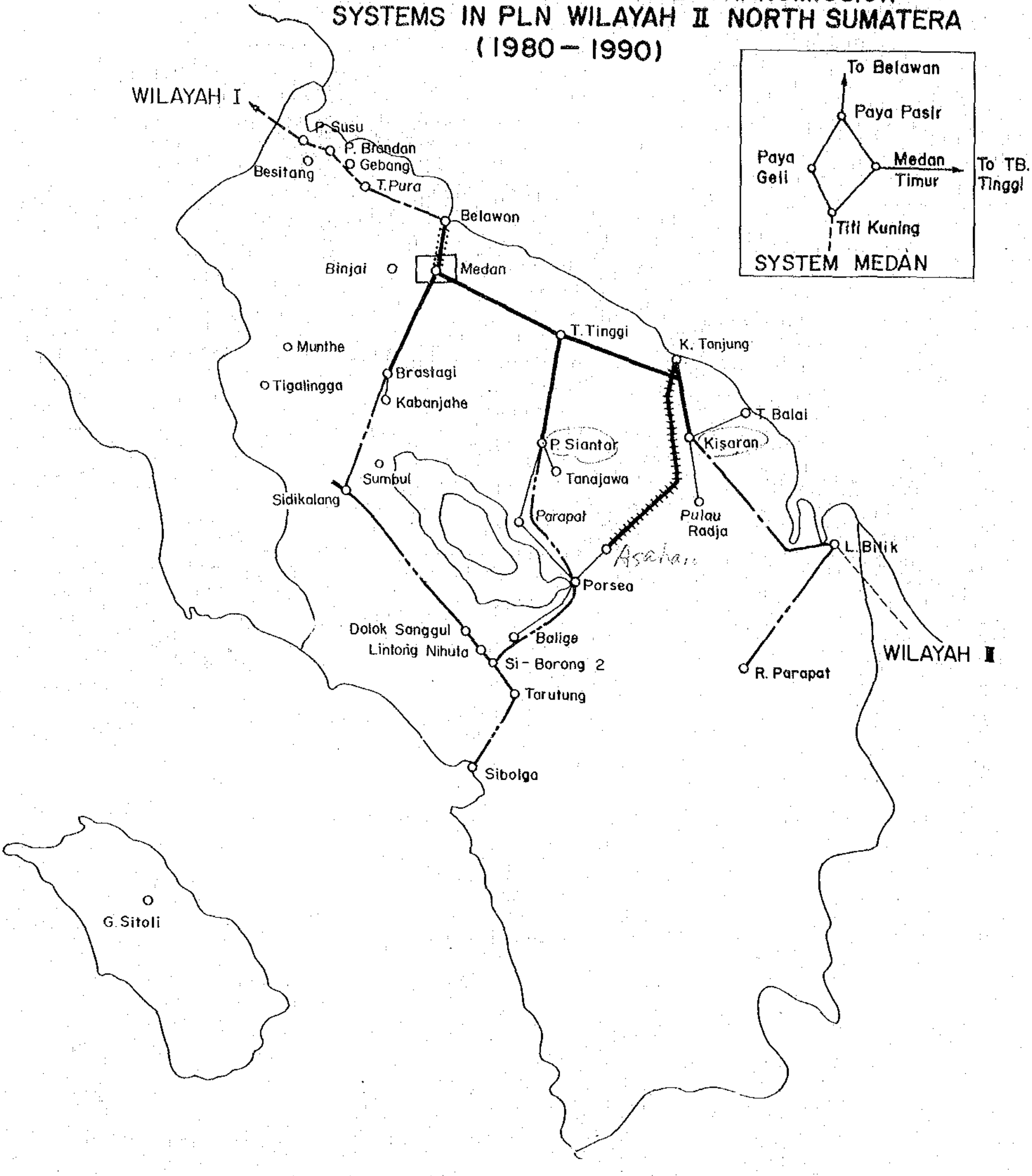


Figure 4.4 CONCEPTUAL HIGH VOLTAGE TRANSMISSION SYSTEMS IN PLN WILAYAH II NORTH SUMATERA (1980 – 1990)



1979 150KV existing transmission (Medan System)

1982 275KV transmission (Asahan – Kuala Tanjung)

1983 150KV transmission in this Study

1983 20KV transmission in this Study

1985 150KV transmission (Pangkalan – Port Brandan – Tanjang Pura)

1987 150KV transmission (Belawan – Tanjang Pura, Kisaran – Lb. Bilik)

1990 150KV transmission (Berastagi – Sidikalang – Rantang Parapet – Lb. Bilik)

CHAPTER 5

PRELIMINARY DESIGN

5.1 Meteorological Condition

The meteorological data for Medan, T. Tinggi, P. Siantar, Kisaran and K. Tanjung were collected. The records of maximum, minimum and average temperature, maximum surface wind, annual and monthly rainfall, and number of thunderstorm days are shown in Appendix I, Data 2, Meteorological Data.

Average temperature in each town is almost constant through the year. In general the highest temperature is recorded from April through May during the year and the lowest temperature from January to February. The highest temperature during 1975 to 1979 is 35.6°C in Medan, 32.0°C in P. Siantar and 33.4°C in Kisaran, and 28.5°C in Pintu Pohan, Sigura-gura in 1975. The lowest temperature is 18.7°C in Medan, 19.2°C in P. Siantar and 20.1°C in Kisaran, and 10.2°C in Pintu Pohan in 1975. The average temperature is 26.3°C in Medan, 24.5°C in P. Siantar and 26.4°C in Kisaran, and 20.4°C in Pintu Pohan in 1975.

Gust wind exceeding 20 m/sec (28.9 knots) is not recorded during the period 1975 through 1979 in Medan. The direction of the strongest wind is predominately west ward, and it is also noted that such strong wind usually accompanies shower.

Monthly rainfall is little in January to March and much in September to December in Medan. And it is almost same patterns in T. Tinggi, P. Siantar, Kisaran and K. Tanjung. Average annual rainfall is 2,007 mm in Medan, 1,455 mm in T. Tinggi, 2,646 mm in P. Siantar, 1,675 mm in Kisaran and 1,300 mm in K. Tanjung.

The number of thunderstorm days in Medan, is recorded as 34 to 85, and it occured every month of the year. In August to October it is higher level in the year. Due consideration is to be given in the design of transmission lines against such higher isokeraunic level.

5.2 Outline of Transmission Line Route

150 kV and 20 kV transmission line routes were selected on 1/50,000 and/or 1/100,000 maps and field reconnaissance along the selected route was made. The outlines of the routes are given in Drawing No. NSTL-001 and are as follows.

Kuala Tanjung - Tebing Tinggi 150 kV line

The length is 38 km. Its outgoing part from Kuala Tanjung substation is in swamp area. Then turning to West, along the access road to the INALUM smelter, the route runs over gently sloped low hills, rubber plantations and palm oil estates, spread over flat lands, and reaches Tebing Tinggi substation selected at a corner of a rubber plantation.

Tebing Tinggi - Medan Timur 150 kV line

The length is 53 km. The route runs towards North-west over paddy field for the first part, then enters into rubber plantations spread over some ten meters high hills. At the part approaching to Medan, it crosses over paddy fields.

An alternative route, along the main road connecting Medan and Tebing Tinggi, was not employed because it lies on poorer soil lands and gives no merit in the route length. Acquiring the right of way is more difficult due to populated area.

Kuala Tanjung - Kisaran 150 kV line

The length is 55 km. Near Kuala Tanjung substation, the route was selected in parallel to the 275 kV INALUM line over swamp area and palm oil estates, towards South. Then, it turns to South-east and runs through rubber plantations in flat lands and reaches Kisaran substation, along the main road from Tebing Tinggi to Kisaran.

Titi Kuning - Brastagi 150 kV line

The length is 53 km. The first few km of the route was obliged to run over cultivated lands in populated suberb of Medan, due to the location of existing Titi Kuning substation. Then the route turns to South-west until approaching to the main road to Brastagi, through wild fields. It climbs up steep mountains from EL. 300 m to EL. 1600 m at the third quarter part of the length, after which it runs over wild field over gently sloped hills until reaching Brastagi substation.

Tebing Tinggi - Pematang Siantar 150 kV line

The length is 48 km, most of which lies on sloped hills covered with palm oil and rubber trees. The route is stretched almost straightly southwards from Tebing Tinggi along the main road and railway, and gradually climbs up to EL. 600 m.

Pematang Siantar - Parapat 20 kV line

The length is 43 km. Two thirds of the route crosses over gradually elevating cultivated lands and the remaining one third at Parapat side runs over ridges of mountains which elevation vary from EL. 800 m to EL. 1000 m.

Parapat - Porsea - Balige 20 kV line

The length is 34 km for Parapat-Porsea, 22 km for Porsea-Balige and 19 km for Siguragura-Porsea. The sections of Parapat-Porsea and Siguragura-Porsea are mostly on mountains and hills and partly over cultivated lands and paddy fields among hills. The Porsea-Balige section runs over mostly paddy fields along the road.

Pematang Siantar - Tanah Djawa 20 kV line

The length is 15 km. The circumstance is quite same as the first part of 20 kV line to Parapat.

Kisaran - Pulau Radja - Tanjung Balai 20 kV line

The length is 50 km for Kisaran-Pulau Radja and 22 km for Kisaran-Tanjung Balai. The route for Kisaran-Pulau Radja runs over mostly flat land covered with palm oil and rubber trees and partly swamps in low land along the Asahan river. The Kisaran-Tanjung Balai section is to be constructed along the road between them on the road shoulder as the area is swampy.

Generally speaking, all part of the line routes are along the existing public roads or estates roads within one to two km and accessible without difficulties. Therefore no special consideration may be given for access preparation.

A few km part near Kuala Tanjung substation lies within one to ten km from the sea coast. However, no special consideration will be needed for salt contamination or errosion problems as the long-term salt contamination test performed by INALUM at Kuala Tanjung demonstrated it not to be necessary.

5.3 Geology

The line route runs over volcanic plateau, the foot plane of Toba Volcano and coast plane along Malacca Strait, as shown in Drawing No. NSTL-001. The ground soil is mainly consisted of alluvial and marine plain deposits consisting of volcanic ash including sand produced by Toba Volcano in late Mesozoic Era. The volcanic ash is generally divided into the following three layers:-

(1) Volcanic sandy ash layer (Tfs): Tfs-layer, mainly consisting of sand fraction of volcanic ash, is distributed in the whole Project Area. This layer has a sufficient bearing capacity, but it is located at more than 10 m deep except mountain slopes, and therefore to be expected as bearing layer of the pile foundation.

(2) Volcanic silty ash layer (Tfm): Tfm-layer, consisting of silty volcanic ash, is generally overlying Tfs-layer. Its N-value is 3 to 4 in general, hence pile foundations are to be applied to heavy angle towers, although conventional foundations may be adopted for light angle and suspension towers. Where ground water level is high, N-value of less than 1 is also observed.

(3) Loamy soil layer (Lm): Lm-layer, consisting of lateritized volcanic ash, is located in hilly land area. This layer has relatively large bearing capacity and is suitable for tower foundations with an adequate thickness. Its thickness, however, is less than 4 m from ground surface, and not enough to bear foundation loads. Therefore, most of tower foundation will be supported by Tfm-layer underlying Lm-layer.

The geological and topographical features of the route are shown in Figure 5.1 and outlined below:-

Kuala Tanjung - Tebing Tinggi

In 5 km section from Kuala Tanjung S/S and at a few points crossing over rivers, the route lies on swamp and paddy field, where the soil is consisting of silty soft soils of 10 m thick overlying loose sand layer and 10 - 20 m pile foundations are needed. T. Tinggi S/S is located on the about 20 m thick Tfm-layer of poor bearing capacity, therefore pile foundations are needed for heavy structures.

In other sections than mentioned above, conventional foundations may by applied as better Tfm-layer and Tfs-layer are observed.

Tebing Tinggi - Medan Timur

The first 40 % section lies on volcanic silty ash and sand with high ground water level but with preferable bearing capacity in general. The next 40 % section is on gently low hill of lateritized brown-coloured volcanic ash deposits and/or thick Tfm-layer. The remaining 20 % section neighbouring to Medan Timur S/S is in paddy field of soft silty clay layer and loose sand layer, where pile foundations are needed.

Tebing Tinggi - Pematang Siantar

The first part of about 20 % of the route from Tebing Tinggi S/S lies on volcanic ash with high ground water, hence pile or special foundations will be necessary for angle towers. The remaining section lies on sloped hill covered with lateritized volcanic ash deposit with low water level. This layer is relatively stable and suitable for conventional foundations. In the vicinity of

Pematang Siantar S/S, as relative soft volcanic ashy silt and sand layer are observed under the lateritized volcanic ash deposit, due consideration should be given for heavy structures at the time of detailed design.

Kuala Tanjung - Kisaran

The first 8 km section from Kuala Tanjung is almost same as that for Kuala Tanjung - Tebing Tinggi. In the following 20 km section, the route runs partly over sloped low hills of reddish laterite with low ground water and high bearing capacity and partly low land where pile foundations are needed. The remaining section is on low land of volcanic silty ash and sand but with good bearing capacities in general.

Kisaran S/S, located near Silau river, needs pile foundations as the supporting layer exists at about 10 m depth, because sand sand layer which was observed at 3 - 6 m depth has not enough bearing capacities.

Titi Kuning - Brastagi

This line runs over mainly mountainous area, the elevation of which varies from 10 m to 1500 m. In the vicinity of Titi Kuning S/S, bearing layer for foundations exists in relatively shallow portion, except some locations where soft clay layer reached to deep level. Then, the route goes on sloped low hills covered with slightly lateritized surface with low ground water level, and further climbs up steep mountains consisting with semi-solidifying tuff, andestic tuff breccia and volcanic breccia. Pile foundations are expected at only such limited areas as river crossings and deep soft clay layer. Brastagi substation is located on the ground of unsolidifying tuff, which has enough bearing capacity for foundations, covered with 1 m thick coarse-gained pumice.

20 kV Line Sections

Most of 20 kV lines run over plateau, hills and mountains of stiff clay with graval, volcanic sand, and talus, and no special consideration is needed for foundations.

Only at the section of Kisaran - Tanjung Balai, low land paddy field of extremely poor soil is observed for about 7 km near Tanjung Balai. The N-value is almost zero. In this section, however, a pole line is planned along the public road on its shoulder.

(Remark)

The above explanation gives the outline of geology in the Project Area. In executing the construction, a detailed investigation should be made especially on angle tower locations and in low land area. From the preliminary survey during this study, pile foundations are tentatively expected for the following:-

i)	Kuala Tanjung - Tebing Tinggi line:	35% of total length
	Tebing Tinggi - Medan Timur line:	25% "
	Tebing Tinggi - Pematang Siantar line:	10% "
	Kuala Tanjung - Kisaran line:	25% "
	Titi Kuning - Brastagi line:	5% "

ii) Heavy structures such as building, transformers and switch-gear at Kuala Tanjung, Tebing Tinggi, Medan Timur and Kisaran.

The results of soil investigation with a Swedish sounding tester and a cone penetrometer are attached in the Appendix II DATA.

5.4 Design of 150 kV Transmission Line

Preliminary design of 150 kV transmission lines are as follows:

Main Line (Kuala Tanjung - Medan Timur)

Rate voltage:	150 kV
No. of circuit:	2
Conductor:	ACSR, 240 mm^2
Overhead groundwire:	2 Nos. of galvanized steel wire, 55 mm^2
Insulation:	Unbalanced insulation practice to be employed. (Higher insulated circuit will be pai-branched at Tebing Tinggi substation.)

Insulator:	Ball and socket type porcelain insulator, 254 mmø x 146 mm
Suspension set:	Single or double strings of 9 discs (low insulation) Single or double strings of 11 discs (high insulation)
Tension set:	Single or double strings of 10 discs (low insulation) Single or double strings of 12 discs (high insulation)
Support:	Galvanized steel towers of double circuit construction with vettical conductor arrangement
Foundation:	Concrete footing with concrete pile where needed

<u>Branch Line</u> (Kuala Tanjung - Kisaran, Tebing Tinggi - Pematang Siantar, & Titi Kuning - Brastagi)

Rated voltage:	150 kV
No. of circuit:	1
Conductor:	ACSR 240 mm^2
Overhead groundwire:	1 No. of galvanized steel wire, 55 mm^2
Insulation:	Standard insulation
Insulator:	Same as main line
Suspension set	Single or double strings of 9 discs
Tension set	Single or double strings of 10 discs
Support:	Galvanized steel towers of single circuit construction with triangle conductor arrangement
Foundation:	Same as main line

(Remark)

The less size of conductor may be applied from the viewpoint of expected load, especially for the branch lines. However, the replacement of conductors in future is practically impossible and land acquiring for additional new lines would become difficult in year by year. Therefore, the size of conductor should be as practically large as possible so far it does not harm the economic feasibility. In this sense and with the consideration for future expansion of 150 kV system, the PLN standard size, 240 mm^2, was employed not only for the main line but also for the branch lines.

The design criteria for the line will be as follows referring to the regional meteorological conditions, results of geological investigation and Indonesian standards for design;

Wind pressure	Based on 25 m/s wind velocity
on conductor and groundwire:	40 kg/m^2
on insulator set:	60 kg/m^2
on tower:	120 kg/m^2
Temperature range	
Maximum conductor temperature:	60 °C
Maximum ambient temperature:	40 °C
Average ambient temperature:	25 °C
Minimum ambient temperature:	5 °C
Relative humidity	80 %
Isokeraunic level	more than 100
Bearing force of soil	
Hill and high land	50 t/m^2 (ultimate)
Low land	20 t/m^2 (ultimate)
Swamp and poor land	to be supported with piles

Typical skeleton diagrams for steel towers are shown on the attached Drawing No. NSTL-003.

5.5 Design of 20 kV Transmission Lines

Three kinds of design were employed; steel tower lines, concrete pole lines and steel pole lines.

Most of the 20 kV lines under this project will be constructed across the field and hills for a relatively long distance and act as the secondary transmission lines but not as distribution lines. For these parts, steel tower line design was applied due to rigid construction and less maintenance, with spans over 300 m so that the supports may be located at the top of hills or ridges.

The feeder lines from these substations to town centers will be erected along the roads and longer spans may not be applied due to the curve of roads and existence of many obstacles. Therefore, conventional pole line design with short spans are to be employed. Local made concrete poles were planned to be used for most of these pole lines but imported galvanized steel poles will be used for the part in town centers.

Length of each line is about 135 km for steel tower lines, 70 km for concrete pole lines and 20 km for steel pole lines.

The outline of design is as follows:-

	Tower line	Pole line
Rated voltage	20 kV	20 kV
No. of circuit	1	1
Conductor	ACSR 120 mm^2	HAl 120 mm^2
O/H groundwire	Galvd.steel wire 38 mm^2	Galvd.steel wire 38 mm^2
Insulator	Standard porcelain disc insulator	Pin type insulator & porcelain disc insulator
Support	Galvd.steel tower	Concrete or steel pole

The design creteria for the line will be mostly same as 150 kV transmission lines.

Preliminary design of towers and pole supports is shown on the attached Drawing No. NSTL-004.

Preliminary design of towers and pole supports is shown on the attached Drawing No. NSTL-004.

5.6 Substations

Selection of sites for substations was made during the site survey in December 1979, jointly by JICA experts and PLN counterparts, with consideration for availability of the land wide enough for future extension, distance from the load center, easy access from the public road, non-difficulty for the right of way for outgoing and incoming lines, etc.

Kuala Tanjung Substation is located neighbouring to INALUM 275 kV substation. Pile foundations are needed for all structures and equipment. As the site is surrounded by swamps, no difficulty is encountered as for the substation land acquiring and the right of way for 150 kV lines.

Tebing Tinggi Substation is located about 7 km North-west from the town along the main road to Medan. The site is in a rubber plantation. Pile foundations are needed for heavy equipment and buildings.

Pematang Siantar Substation is located on wild field about 5 km South from the town center. The site is on a gently sloped hill and the soil conditions seem satisfactory for ordinary foundation.

Kisaran Substation is located about 5 km South-east from the town, along the main road to Tanjung Balai, in a rubber estate. The circumstance seems almost similar to Tebin Tinggi site.

Brastagi Substation is located on a flat wild field at the midpoint between Brastagi and Kabanjahe. The conditions are similar to Pematang Siantar.

Medan Timur Substation, located in the paddy field at the outskirts of Medan, is under construction as a part of System Medan. Erection of 150 kV switchgear only is needed in this Project for interconnecting the main line to System Medan.

Titi Kuning Substation was already completed and a set of 150 kV switchgear is installed in this Project for the line to Brastagi.

Substations were designed as simple as possible so as to save the cost and give easy operation and maintenance, but due consideration was given to easy extension in future. Transformers and 150 kV equipment are installed in outdoor, while 20 kV switchgears are housed in metal cubicles. All equipment will be controlled from the indoor control boards.

The substations connected to the main line will have a double bus in future although a single bus only will be constructed in this project.

At Tebing Tinggi, a 10 MVA transformer is installed with 4 circuits of 20 kV metal-clad switchgear. Due consideration is given for such future extension as the double-bus system, pai-branch connection to both circuits of the main line between Medan and Kuala Tanjung and the extension of transformers and feeders.

At Kuala Tanjung, two transformers of 275 kV/150 kV are installed with only one set of circuit breakers to save the cost of expensive switchgear. But, disconnecting switches will be installed independently for each transformer so that any one may be separated from the system and the remaining way continue the service. Similar design was applied for Pematang Siantar and Kisaran, where two transformers of 150 kV/20 kV are planned. It is noted that a set of 275 kV circuit breaker is installed by INALUM for public supply and this circuit breaker is used as the high tension side switchgear for 275 kV/150 kV transformer.

All transformers are oil immersed natural cooled type with on-load tap changers. 150 kV circuit breakers are SF6 gas filled or other appropriate type. 20 kV switchgears are out-door metal-clad type. These will give the easiest operation even by unskilled operators and the minimum level maintenance.

Preliminary design of connection diagram and equipment layout for each substation are given in Drawings Nos. NSTL-005 to 012, although these are subject to further review in the detailed design stage.

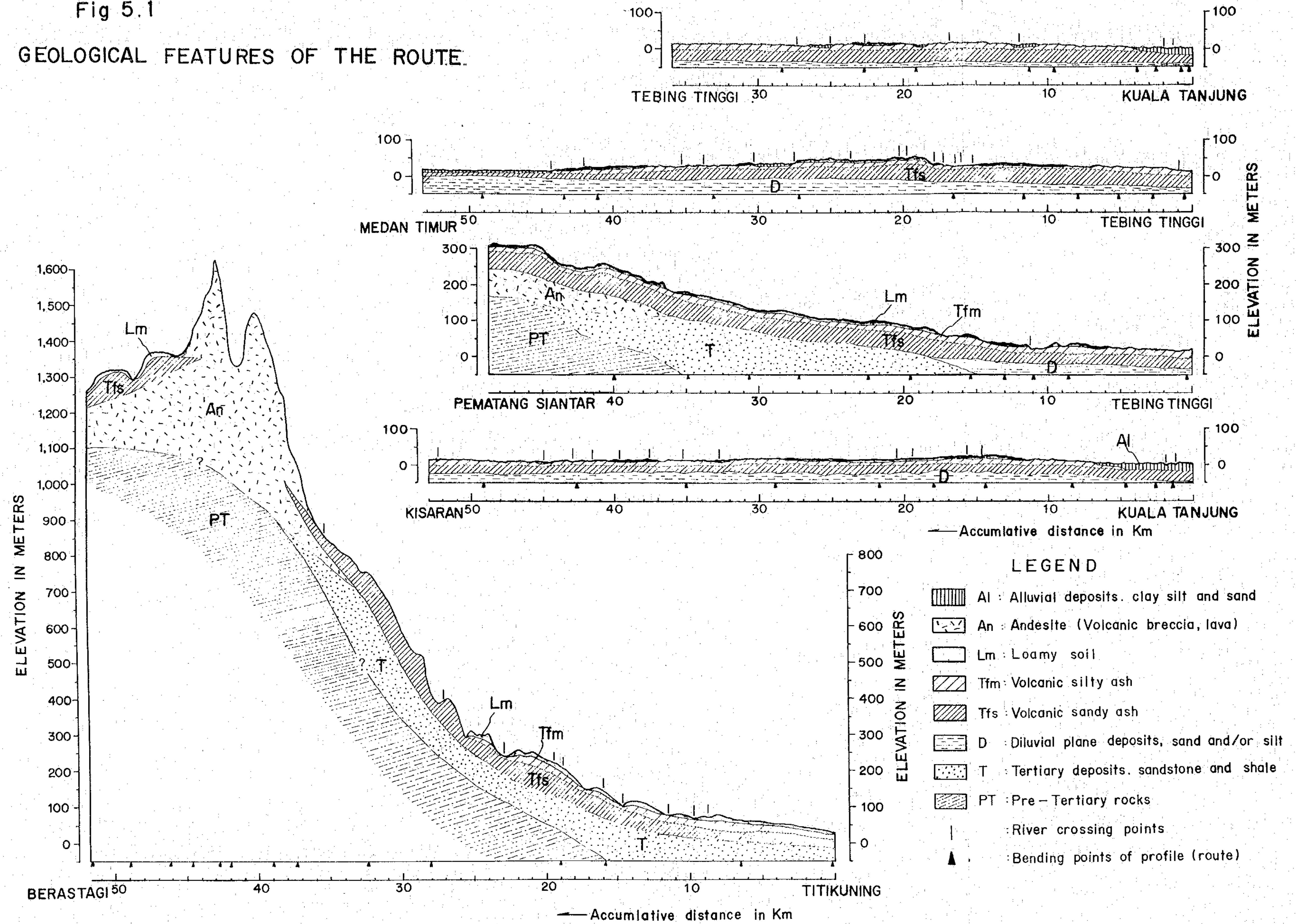
Communication between each station will be prepared with power line carrier telephone equipments, as shown in Drawing No. NSTL-014.

As for the civil and building works of each substation, due consideration is given in employing the Indonesian local standard practice for the work so that local contractors may perform the work. In this sense, the substation buildings are designed as simple as possible with inclined tile roofs supported by wooden frames, mortar finished brick walls and plastic tile finished concrete floors. Each substation, having a control room, a battery room and a store room, will be erected to house the control gear, telephone equipment and other indoor equipment. Tebin Tinggi will be the center of this power system, therefore office rooms will be added to this substation building.

Preliminary design of control building for each substation is shown in Drawing No. NSTL-013.

Fig 5.1

GEOLOGICAL FEATURES OF THE ROUTE



CHAPTER 6

CONSTRUCTION & OPERATION PLANNING

6.1 Construction Management

The project implementation is divided into following three stages:-

1) Detailed survey and design, including preparation of tender documents.
2) Tender call and contract awarding.
3) Manufacturing equipment and materials and field construction.

Detailed topographic and geological surveys are normally to be made before commencement of detailed design. However, in the case of transmission line, detailed surveys may be made in parallel to the detailed design and tender call if the approximate quantities of work is known, like this project case. Therefore, in planning the construction time schedule, this practice was applied as will be explained in the succeeding clause.

Then, throughout all stages abovementioned, a project execution team should be organized at the site to execute or supervise the survey work at the initial stages and then to supervise the construction later. A recommended organization of the project team is as given in Figure 6.1.

Basic Strategy of Project Implementation

Taking into account the local contractor's capability, requirement for earlier completion of the project, necessity of training and transfer of technology not only to PLN staff but also to local contractors, the execution of the project was planned as follows:

a) 150kV Transmission Line

   i) Towers, conductors, insulators and other fitting will be procured by international tender, on CIF basis.

   ii) Custom clearing and transport from the port to central stores will be carried out with force account.

iii) Local transport from the central stores to sites and all erection works will be done by local contractors, with technical guidance given by the guidance team of the Consultant.

iv) Special tools for tower erection and conductor stringing will be procured by an international tender and supplied to local contractors.

b) 20 kW Transmission Line

i) Procurement and transport to central stores of towers, steel poles, conductors, insulators and other fittings will be made similarly to 150 kV line materials.

ii) Concrete poles, however, will be procured locally at site delivery basis.

iii) Local transport and erection will be done entirely by local contractors. Stringing work in tower line section will be done by local contractors who were well trained in stringing work of 150 kV lines.

c) Substations

i) All civil and building works will be done by local contractors.

ii) Supply and erection of electrical equipment will be tendered internationally.

d) Engineering

i) An experienced foreign consultant (the Consultant) will be hired for detailed design, supervision of field survey and assisting the project team during construction. Local consultants will also be used to assist the Consultant.

ii) Topographic and geological surveys will be made partly by force accounts and partly by local consultants or survey contractors under the supervision of the Consultant.

As the project involves the construction of seven substations, 247 km of 150 kV lines and 225 km of 20 kV lines over four years, a powerful team of full-time staffs is essentially needed for smooth implementation of the project. Besides, followings are to be noticed;

(1) Land acquisition and topographic and geological survey for substation sites are to be made before commencement of design work.

(2) Topographic (profile) survey is to be commenced immediately after commencement of design work, and profile design and tower locating design with cross sectional survey and geological investigation are to be completed before awarding the contract.

(3) Land and right of way acquiring for transmission lines are to be immediately made following to the selection of tower locations. Delay in this activity frequently causes troubles with inhabitants and contractors and serious delay in completion of the project.

(4) Sufficient mobility of the project team is essential in this project, which covers the area stretching over 250 km.

(5) Local contracts are to be split up into reasonable and adequate sizes considering the local contractor's capabilities, otherwise the overburden to them will cause serious delay in progress or in extreme cases the frustration of contracts.

(6) International tenders are preferably split up into following two contracts considering the contract size, processing of contracts in time, future spare parts procurement, supplier's responsibility for completion, etc.

a) Supply of transmission line materials

b) Supply and erection of substation equipment

6.2 Construction Time Schedule

In planning the time schedule of the project implementation, the priority was given for earlier completion of the main system, Kuala Tanjung - Tebing Tinggi - Medan section, so as to make possible to receive the cheap Asahan hydro-electric energy as early as possible. This section involves the new construction of two substations at Kuala Tanjung and Tebing Tinggi, and 91 km of a double circuit 150 kV line, 30% of which needs pile foundations. The connection to Medan Timur substation is so simple work as to install two sets of switchgear only.

All construction forces, local and foreign, will therefore be concentrated into this section; yet it takes about two years from awarding the contracts. Before that, detailed design and tender documentation, tender call and evaluation, and contract processing require at least one year. As a result, the earliest completion time is expected at the end of third year from the commencement of design work.

150 kV branch line sections, Kuala Tanjung to Kisaran, Tebing Tinggi to Pematang Siantar and Titi Kuning to Brastagi, were planned to be worked out in parallel immediately after completion of various sector work of the main section and may be completed with a delay of a half year, because most of civil works may be started from the end of second year and electrical works from the middle of third year. Thus, the completion of all 150 kV system is at the middle of fourth year.

20 kV lines may be independently carried out by other groups of contractors than those employed for 150 kV lines, except the conductor stringing in tower line section, which needs the mechanized stringing with special tools due to long spans similar to 150 kV lines and accordingly to be done after 150 kV line completion. Thus, the total completion of 20 kV line is expected at the end of fourth year.

The bar chart construction time schedule is as given in Figure 6.2.

6.3 Construction Cost

PLN has executed many contracts for 150 kV lines and substations as well as for 20 kV pole lines. The construction cost estimate of the Project was made in the light of the price and costs adopted in the newest contracts executed in Sumatra i.e., Maninjau hydroelectric project in Central Sumatra the contracts of which were concluded in October to November 1979.

The contracts for this Project would be executed at the end of 1980 on the assumption that this Project will be implemented following the proposed schedule. The base cost of the Project, therefore, was calculated using the prices at the end of 1980, which was estimated on the basis of "Maninjau prices" paying due consideration for the expected price escalation by the end of 1980.

In December 1979, the oil price was sharply hiked to US$30/barrel level, about 40% up. This certainly gives a higher escalation rate than normally expected. The remarkable effect was already observed in aluminium price, from ¥350,000/ton in mid-1979 to ¥520,000/ton in January 1980. The aluminium price may also be affected by the soaring price of copper, from ¥450,000/ton in mid-1979 to ¥730,000/ton in January 1980, probably due to unstable circumstances in the Middle East. The prices of conductors have been, and will greatly be affected by the price hike of relevant raw materials.

Under these circumstances, the estimate of accurate price escalation by the end of 1980 is quite difficult. The escalation rate of 15% to 20% for all costs other than aluminium conductors, however, is assumed taking into consideration the manufacturers' forecasts for general electrical equipments which lie in the range of 15% to 20%. For aluminium conductors, current price in January 1980 is applied.

Other basic assumptions made for cost estimate of the Project are as follows:-

- 150 kV T/L materials will be procured by international tender;

- Piling and erection of 150 kV line will be executed by local contractors with technical guidance by consultants;
- 20 kV line erection will be executed by local contractors;
- Supply and erection of substation equipments will be executed through international tenders;
- Civil and building works of substations will be executed by local contractors;
- Foreign costs for imported equipments and materials are estimated on the basis of CIF price at Port Belawan;
- Local cost includes inland transportation cost between the landing port for imported inputs of the Project and the Project site;
- Conversion rates of currencies are assumed as US$1.00 = ¥230 and US$1.00 = Rp. 625.

The detailed breakdown of the base cost estimate of the construction cost is given in Table 6.1 and summarized below.

Base Cost of the Project

	Foreign Currency		Local Currency		Total
	(¥10^6)	(US$$10^3$)	(Rp.10^6)	(US$$10^3$)	(US$$10^3$)
Transmission Line	2,516.2	10,940	5,049.2	8,079	19,019
Substations	2,027.0	8,813	2,100.0	3,360	12,173
Land, Administration & Engineering	500.0	2,174	1,240.0	1,984	4,158
Total	5,043.2	21,927	8,389.2	13,423	35,350

Physical contingency is determined at 5% of the total base cost paying due attention to the characteristics of the Project and to the uncertainty of work quantity due to the precision of the survey works. Economic construction cost of the Project is obtained by adding the physical contingency to the base cost of the Project.

Price contingency is determined at 6% p.a. both for foreign and local components considering the recent trends of price escalation for project inputs. Financial construction cost of the Project is obtained by adding price contingency to the economic construction cost./1 Economic and financial costs of the Project is shown in Table 6.1 and summarized below.

Economic and Financial Costs of the Project

	Cost Item	Foreign Component (¥10^6)	Foreign Component (US$$10^3$)	Local Component (Rp.10^6)	Local Component (US$$10^3$)	Total (US$$10^3$)
(A)	Base Cost	5,043.2	21,927	8,389.2	13,423	35,350
(B)	Physical Contingency (5% of A)	252.3	1,097	419.5	672	1,769
(C)	Economic Cost: (A) + (B)	5,295.5	23,024	8,808.7	14,095	37,119
(D)	Price Contingency (10% of C)	504.5	2,193	790.6	1,265	3,458
(E)	Financial Cost: (C) + (D)	5,800.0	25,217	9,600.0	15,360	40,577

The annual disbursement schedule of the financial construction cost of the Project is shown in Table 6.3 and summarized below.

Disbursement Schedule of the Financial Construction Cost of the Project (US$$10^3$)

	1st Year	2nd Year	3rd Year	4th Year	Total
Foreign Component	685	10,717	13,019	796	25,217
Local Component	1,925	5,346	5,502	2,587	15,360
Total	2,610	16,063	18,521	3,383	40,577

/1: Custom duties for imported inputs and taxes for all the inputs of the Project are assumed to be exempted because PLN will be the executing agency for the Project.

6.4 Operation and Maintenance

Upon completion of the project, the system will be handed over to Wilayah II for neceesary operation and maintenance.

Daily operation will be made under the control of the load dispatching center to be installed in Medan, which is under planning and will be completed before the completion of this project. The control instruction will be issued from the load dispatcher in time to time through the power line carrier telephones to be installed under this project.

Each substation should have four-shift operation teams, consisting of following staffs, and auxiliary servicemen.

	Kuala Tanjung Tebing Tinggi Pematan Siantar	Kisaran Brastagi
Operator-in-charge	1 x 4	1 x 4
Assistant operator	2 x 4	1 x 4
Guardman	3	3
Day time labourer	4	2
Total	19/station	13/station

As for the maintenance, a maintenance office is recommended to be established at Tebing Tinggi (or Pematang Siantar) to make periodical inspection and tests of substation equipment, line patrol and maintenance or repair work with following team.

1 - Maintenance engineer-in-charge

1 - Substation equipment engineer (electrical)

1 - Transmission line engineer (civil)

4 - Electrician (technical high school graduate)

4 - Linesmen (recruited from linesmen engaged in the construction)

10 - Labourers

The normal operation and maintenance costs a year are estimated based on the following figures.

Staff salary	104 persons x Rp.0.8 x 10^6/person year	Rp.83.2 x 10^6
General office expense	about 50% of the above	Rp.41.6 x 10^6
Painting and other routine maintenance	about 0.5% of the construction cost	Rp.116.0 x 10^6
	Total	Rp.240.8 x 10^6 (US$0.385 x 10^6)

Considering the above, the operation and maintenance costs of the Project are determined at 1 % of the construction cost of the Project.

Table 6.1 ECONOMIC AND FINANCIAL COST ESTIMATE OF THE CONSTRUCTION COST OF THE PROJECT

		Foreign Component		Local Component		Total
		(¥10^6)	(US$$10^3$)	(Rp.10^6)	(US$$10^3$)	(US$$10^3$)
(A) TRANSMISSION LINES						
A-1) 150 kV Transmission Lines						
a) Kuala Tanjung-Medan, 2-cct	91 km	673.4	2,928	1,380.2	2,208	5,136
b) Tebing Tinggi-P. Siantar, 1-cct	48 km	230.4	1,002	482.0	771	1,773
c) Titi Kuning-Brastagi, 1-cct	53 km	254.4	1,106	507.0	811	1,917
d) Kuala Tanjung-Kisaran, 1-cct	55 km	264.0	1,148	635.0	1,016	2,164
Sub-total	247 km	1,422.2	6,183	3,004.2	4,807	10,990
A-2) 20 kV Transmission Lines						
a) Steel tower line	135 km	405.0	1,761	1,053.0	1,685	3,446
b) Concrete pole line /1	70 km	147.0	639	546.0	874	1,513
c) Steel pole line	20 km	142.0	617	86.0	138	755
Sub-total	225 km	694.0	3,017	1,685.0	2,696	5,713
A-3) Tools for Erection & Maintenance		100.0	435	300.0 /2	480	915
A-4) Erection Guidance	150 m/m	300.0	1,304	60.0	96	1,400
Total for Transmission Lines		2,516.2	10,940	5,049.2	8,079	19,019
(B) SUBSTATIONS						
B-1) Substations						
a) Kuala Tanjung, 272/150/20 kV	80 MVA	561.0	2,439	610.0	976	3,415
b) Tebing Tinggi, 150/20 kV	10 MVA	285.0	1,239	460.0	736	1,975
c) Pematang Siantar, 150/20 kV	20 MVA	174.0	757	270.0	432	1,189
d) Kisaran, 150/20 kV	20 MVA	174.0	757	270.0	432	1,189
e) Brastagi, 150/20 kV	10 MVA	119.0	517	210.0	336	853
f) Medan Timur & Titi Kuning		139.0	604	30.0	48	652
g) Carrier Telephone set	5 pairs	125.0	543	-	-	543
h) Spare parts & tools		100.0	435	-	-	435
Sub-total		1,677.0	7,291	1,850.0	2,960	10,251

	Foreign Component (¥10^6)	Foreign Component (US$$10^3$)	Local Component (Rp.10^6)	Local Component (US$$10^3$)	Total (US$$10^3$)
B-2) Equipment Erection	350.0	1,522	250.0	400	1,922
Total for Substations	2,027.0	8,813	2,100.0	3,360	12,173
(C) ENGINEERING & ADMINISTRATION	500.0	2,174	440.0	704	2,878
(D) LAND & RIGHT OF WAY	-	-	800.0	1,280	1,280
(E) CONTINGENCIES:					
Physical	252.3	1,097	419.5	672	1,769
Price	504.5	2,193	790.6	1,265	3,458
GRAND TOTAL	5,800.0	25,217	9,600.0	15,360	40,577

/1: Local-made poles are assumed to be used.

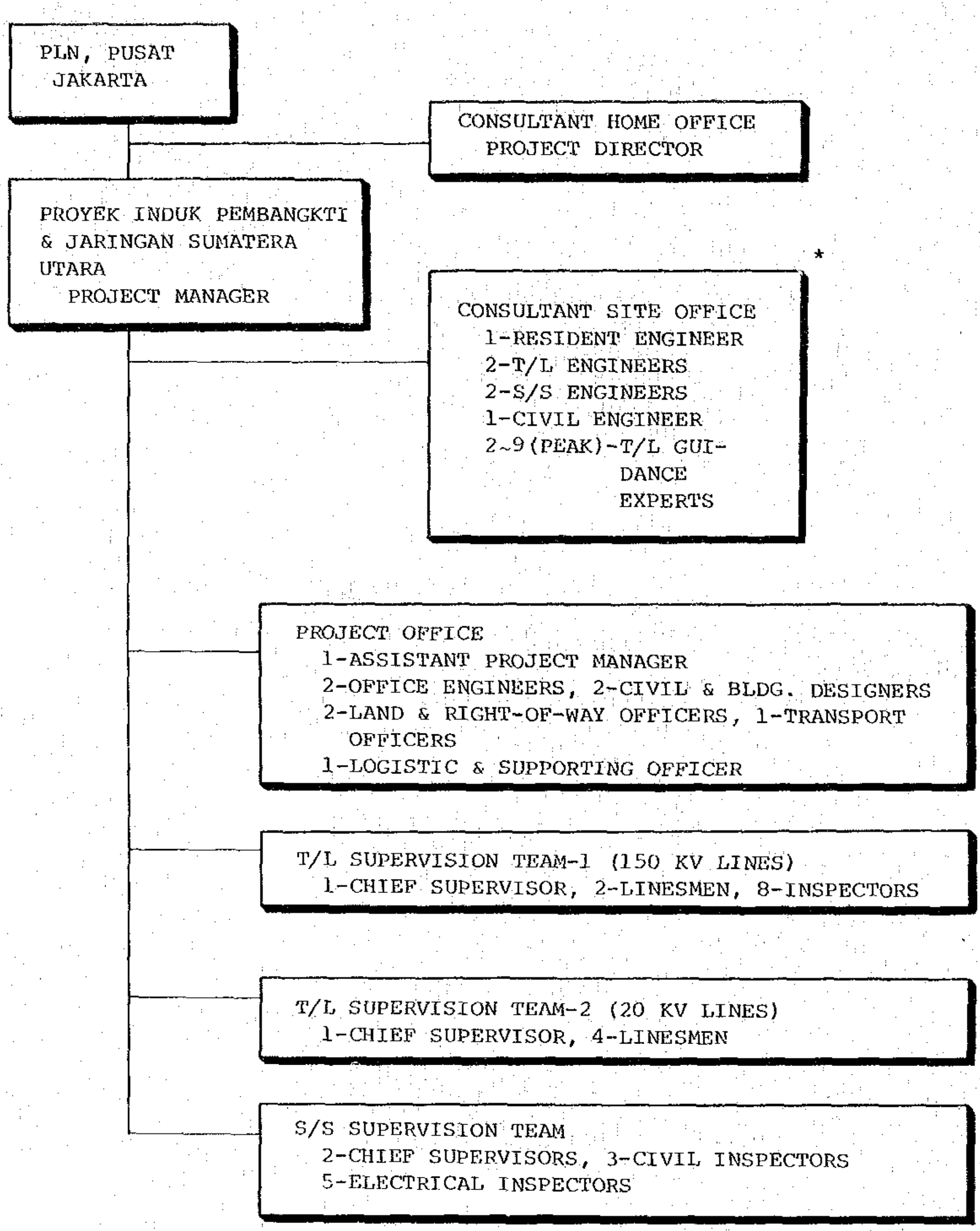
/2: Vehicle for supervision and guidance.

Table 6.2 ANNUAL DISBURSEMENT SCHEDULE OF THE FINANCIAL CONSTRUCTION COST OF THE PROJECT

($US\$10^3$)

Cost Items	1st Year	2nd Year	3rd Year	4th Year
Foreign Component				
150 kV Line		3,710	2,473	
20 kV Line		1,810	1,207	
Tools		435		
Erection Guidance		522	522	260
(Sub-total)		6,477	4,202	260
S/S Equipment CIF		2,187	5,104	
Equipment & Erection		304	1,065	153
(Sub-total)		2,491	6,169	153
Engineering	652	652	652	219
Contingency				
Physical	33	481	551	32
Price		616	1,445	132
Total	685	10,717	13,019	796
Local Component				
150 kV Line	481	1,923	1,923	481
20 kV Line		539	1,078	1,078
Tools	240	240		
Erection Guidance		38	38	19
(Sub-total)	721	2,741	3,039	1,578
S/S Civil Work	296	1,184	1,184	296
Equipment & Erection		80	280	40
(Sub-total)	296	1,264	1,464	336
Administration	176	176	176	176
Land & Right	640	640		
Contingency				
Physical	92	241	234	105
Price		284	589	392
Total	1,925	5,346	5,502	2,587
Grand Total	2,610	16,063	18,521	3,383

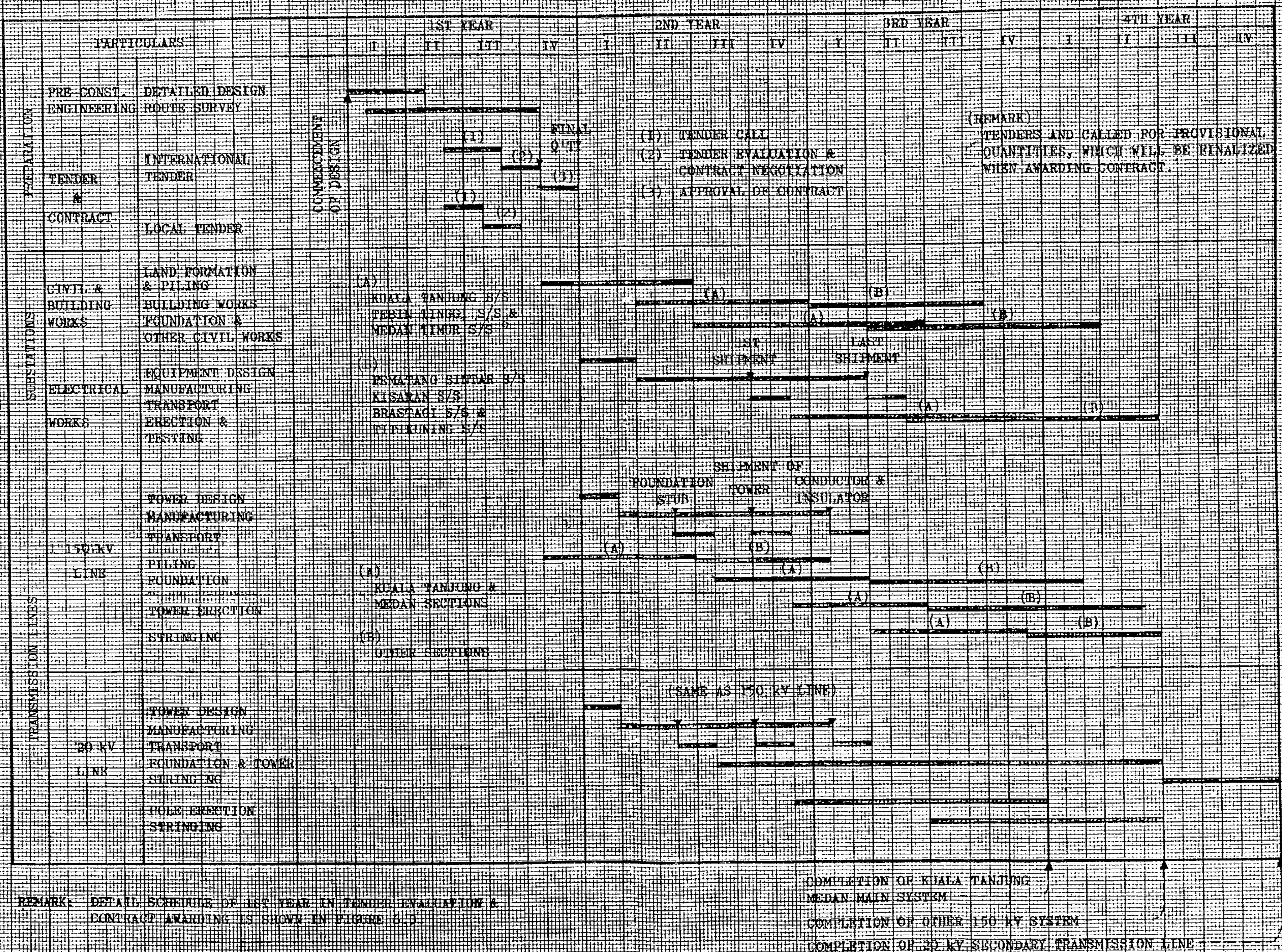
Figure 6.1 PROPOSED ORAGINIZATION CHART FOR PROJECT INPLEMENTATION



(Remarks) 1) T/L .... Transmission Line
S/S .... Substation
2) Staffs in asterisked blocks are to be full-time staffs.

Figure 6.2 NORTH SUMATRA TRANSMISSION LINE PROJECT

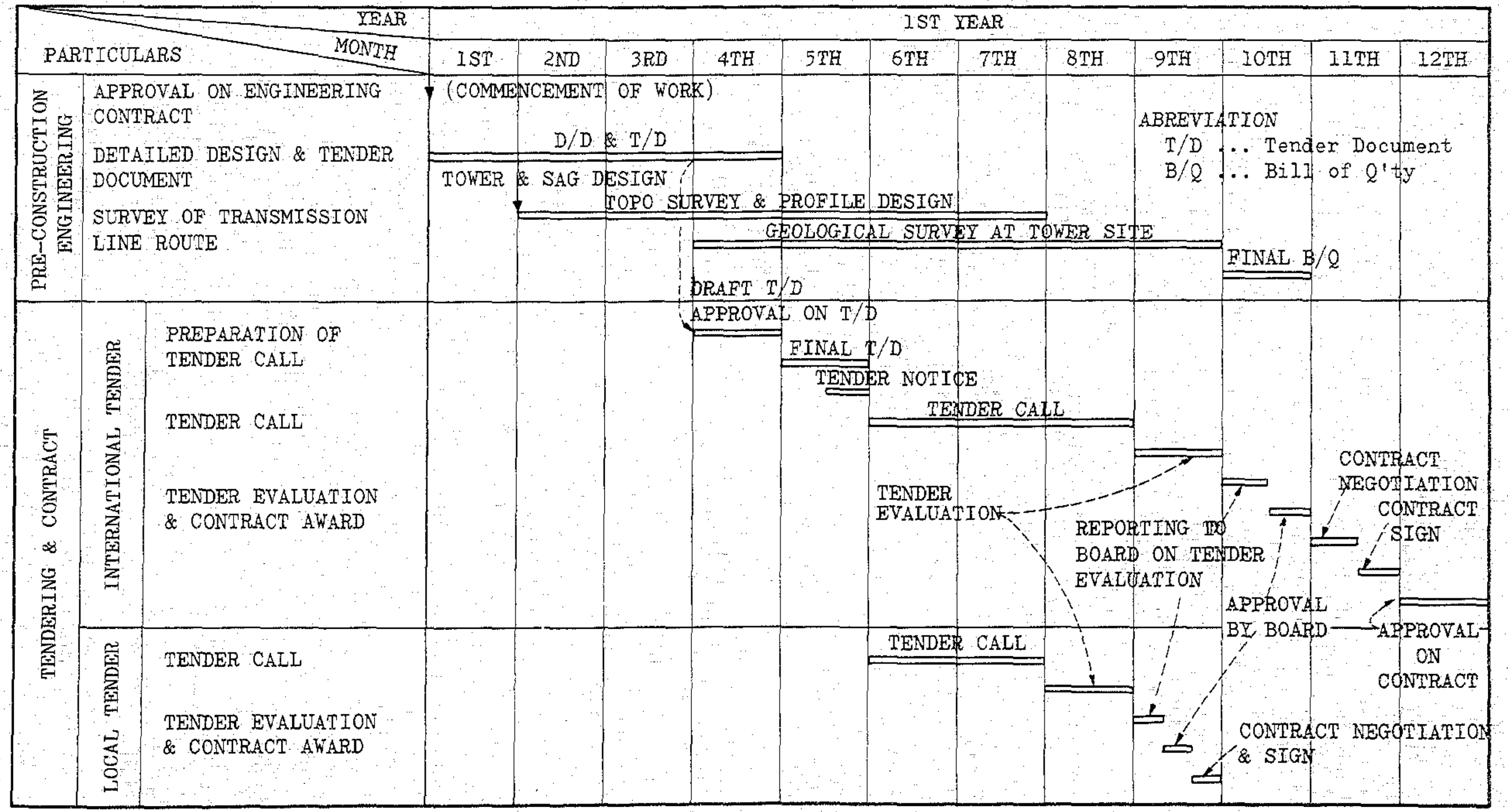
CONSTRUCTION TIME SCHEDULE



REMARK: DETAIL SCHEDULE OF 1ST YEAR IN TENDER EVALUATION & CONTRACT AWARDING IS SHOWN IN FIGURE 6.3

FIGURE 6.3 NORTH SUMATERA TRANSMISSION LINE PROJECT

DETAILED SCHEDULE FOR PRE-CONSTRUCTION ENGINEERING, TENDERING & CONTRACTING



(Remark)
1) Tender for transmission lines is called for provisional quantities. The B/Q is finalized at contract awarding.
2) Tender evaluation to contract awarding is tightly scheduled and the best efforts by every concerned are assumed.

CHAPTER 7

ECONOMIC ANALYSIS

7.1 General

A transmission project should be treated as one unified project with a power generation project because power supply benefits can only be produced through the execution of both. It is not, therefore, quite appropriate to evaluate the economic feasibility of a transmission project independently. The economic analysis in this chapter is, therefore, made with a view to giving a rough indication of the economic feasibility of the Project.

The economic feasibility of the Project is evaluated by benefit cost ratio and economic internal rate of return, of the Project on the basis of the economic costs and net benefits of the Project.

As given in Chapter 6, economic costs consist of the construction cost and operation and maintenance cost of the Project. Net benefits of the Project is obtained by subtracting the cost of energy supplied by INALUM from the gross benefits of the Project which is computed on the basis of the equivalent cost of the least cost alternatives.

In this analysis, following assumptions are adopted:-

- Due to the rapid growth of the energy demand in the Project Area, energy to be supplied by the Project will be used up from the very year when the Project starts its operation, i.e., 1983. For the convenience of the benefit estimation, demand is assumed to remain constant after 1990;
- For the purpose of the economic analysis of the Project, Lower Forecast, is adopted, which gives conservative values of benefits.
- Economic life of the Project is assumed at 35 years;
- Price levels are as of the end of 1980 and fixed throughout the economic life of the Study;
- Price of C heavy oil (export price, taking inland transportation cost into account) is assumed at US$30/barrel;

- Price of energy supplied by INALUM is assumed at ¥3.7/kWh (US$0.0161/kWh), based on a preliminary information from Nippon Asahan Aluminium Company;
- First priority is placed on the Local Area for the electricity supply from Asahan. The remainder is provided for Medan Area;
- All the benefits are estimated on the basis of the equivalent costs of the alternative energy sources;
- Diesel plants of 2,000 kW class with the economic life of 20 years are selected as alternatives in the Local Area;
- After 1987, energy supply from Asahan will fall short of the demand in the Local Area and the shortage is assumed to be filled by the reinforcement of the System Medan which is more economical because of scale economy than the installation of local diesel plants. For the purpose of the economic analysis, this reinforcement is assumed to be made with new diesel plants in Medan. The cost and benefit for the Project attributable to the energy supply from the Medan System to the Local Area are almost equal disregarding the transmission loss. Both the cost and benefit are, therefore, counted out from consideration in this analysis.

7.2 Project Benefits

The benefits are estimated by the power and energy value of the electricity supplied from the Asahan Hydropower System and transmitted by the Project to the Project Area. The supply schedule of the electricity is shown in Table 7.1.

7.2.1 Benefits in Medan Area

The benefits to be produced by the Project in Medan Area are estimated by the avoided cost increase of the existing Medan Thermal Plant required for producing the same amount of energy to be provided by the Project/1.

/1: The energy from Asahan will be supplied to Medan Area only until 1987. Afterwards, Medan Area will have to meet its demand fully by its own power facilities. Only fuel cost, therefore, is taken into account in the benefit estimation, disregarding the kW value of the energy supply from Asahan.

The unit energy cost (fuel cost)/1 of the existing Medan Thermal Plant is estimated on the following assumptions.

Price of fuel/2	US$30/barrel
Fuel consumption/3	0.28 liter/kWh

The unit energy cost per kWh is thus estimated at US$0.0528/kWh.

For the calculation of the kWh value, advantageous factor of the Project to the Medan Thermal Plant is to be considered. In due consideration for the energy loss of both the Project and the Medan Thermal Plant, the compensation factor for the Project is estimated as follows:-

	Energy Loss (%)	
	Project	Medan Thermal Plant
Transmission	0/4	0/4
Station Service	0/4	5

$$\text{Compensation Factor} = \frac{1 - 0}{1 - 0} \times \frac{1 - 0}{1 - 0.05} = 1.053$$

The kWh value by the Project is obtained by multiplying the unit energy cost per kWh by the compensation factor, i.e., US$0.0528 x 1.053 = US$0.0556.

/1: Only fuel cost is taken into account in this Study, neglecting other variable costs. The benefits are, therefore, underestimated.

/2: C heavy oil

/3: According to the data obtained from PLN during the field survey, fuel consumption of the gas turbine plant in System Medan was 0.462 liter/kWh in 1979. This figure, however, is considered to be relatively high compared with other cases. Therefore, fuel consumption rate of 0.28 liter/kWh is assumed in this analysis.

/4: Transmission loss and station service have nothing to do with this estimate because power supply is evaluated at the secondary bus of the substations.

Benefits to be produced in Medan Area by the Project in each year are obtained by multiplying the kWh value of the Project by the amount of energy to be supplied by the Project in each year as summarized below.

Benefits in Medan Area

Year	Energy Supplied by the Project (GWh)	Benefits (US$$10^3$)
1983	61.94	3,444
1984	60.46	3,362
1985	76.32	4,243
1986	76.77	4,268
1987	42.92	2,386
1988 and after	– /1	–

7.2.2 Benefits in Local Area

Benefits to be produced by the Project in Local Area are estimated by the least cost alternative power plants. Diesel power plants of 2,000 kW class capacity are selected as alternative power plants, taking into consideration the scale of demand in each load center of the Local Area and economic efficiency of the alternatives.

For the convenience in calculating the power benefit, kW and kWh values are estimated on the basis of the equivalent costs of the diesel plants. The kW and kWh values of the Project are calculated hereunder.

kW Value

For the provision of the forced outage, overhaul and periodic inspection, 1 reserve unit for each 3 diesel units is assumed. The average construction cost of the 2,000 kW class diesel plants including reserve unit is assumed at US$500/kW. Annual equivalent cost required for meeting the expected power demand is estimated for the discount rate of 20 % by using the following ratio:

/1 : Energy from Asahan will be used up in the Local Area in 1987 and afterwards no remainder will be available for Medan Area.

	Percentage to Investment Cost(%)
Annual Capital Recovery of the Investment (economic life 20 years)	20.54
Overhaul and Replacement	2.00
Operation and Maintenance	3.00
Other Expenses (power cost for general use, insurance, etc.)	1.00
Total	26.54

Annual equivalent cost per kW for the discount rate of 20 % is equal to US$132.7 (US$500 x 0.2654).

For the calculation of the kW value, advantageous factor of the Project to the diesel plants is to be considered. In due consideration for the expected power loss and time loss of both the Project and diesel plants, the compensation factor for the Project is estimated as follows:-

	Power Loss and Time Loss (%) Project	Diesel Plants
Transmission Loss	0 /1	0
Forced Outage	0 /2	0 /3
Overhaul and Inspection	0 /2	0 /3
Consumption for Station Services	0	3

$$\text{Compensation factor} = \frac{1-0}{1-0} \times \frac{1-0}{1-0} \times \frac{1-0}{1-0} \times \frac{1-0}{1-0.03} = 1.031$$

The kW value of the Project is obtained by multiplying annual equivalent cost per kW by the compensation factor, i.e., US$132.7 x 1.031 = US$136.8.

/1: *Transmission loss has nothing to do with this estimate because* power supply is evaluated at the secondary bus of the sub-stations.

/2: Forced outage and overhaul and inspection of the Project are negligibly small and omitted in the calculation.

/3: Forced outage and overhaul and inspection of the diesel plants are neglected because of the provision of the reserve units.

kWh Value

The kWh value of the Project is estimated on the basis of the equivalent fuel cost of the diesel plants/1 and is calculated on the following assumptions:

Price of Fuel/2	US$30/barrel
Fuel Consumption	0.28 liter/kWh

Required fuel cost per kWh is estimated at US$0.0528.

For the calculation of the kWh value, advantageous factor of the Project to the diesel plants is to be considered. In due consideration for the energy loss of both the Project and the diesel plants, the compensation factor for the Project is estimated as follows:-

	Energy Loss (%)	
	Project	Diesel Plants
Transmission	0/3	0
Station Service	0/3	3

$$\text{Compensation factor} = \frac{1-0}{1-0} \times \frac{1-0}{1-0.03} = 1.031$$

The kWh value of the Project is obtained by multiplying annual equivalent cost per kWh by the compensation factor i.e., US$0.0528 x 1.031 = US$0.0544.

/1: To be exact, variable cost of which fuel cost is a major portion should be taken as annual equivalent cost per kWh. The kWh value is, therefore, underestimated.

/2: C heavy oil.

/3: Transmission loss has nothing to do with this estimate because power supply is evaluated at the secondary bus of the sub-stations.

The benefits to be produced in Local Area by the Project in each year are obtained as the sum of the benefits of power and energy supplied by the Project as shown below under the discount rate of 20 % for kW value estimation.

Benefits in Local Area

Year	Power Supply by the Project (MW)	Energy Supplied by the Project (GWh)	Power Benefits (US$$10^3$)	Energy Benefits (US$$10^3$)	Total Benefits (US$$10^3$)
1983	14.4	37.31	1,970	2,030	4,000
1984	16.7	87.34	2,285	4,751	7,036
1985	20.5	109.06	2,804	5,933	8,737
1986	25.0	134.69	3,420	7,327	10,747
1987	30.8	168.54	4,213	9,169	13,382
1988	38.1	211.46	5,212	11,503	16,715
1989	37.5	211.46	5,130	11,503	16,633
1990-2017	37.1	211.46	5,075	11,503	16,578

7.3 Cost of Energy Supplied by INALUM

The power to the project power system will be supplied from the power system owned by INALUM at Kuala Tanjung substation. The power supply schedule from INALUM is determined under Master Agreements as stated in CHAPTER 3 and restated hereunder.

Year	Power (MW)	Energy (GWh)
1983	25	100
1984	35	150
1985	45	190
1986-2017	50	218

The power price per kWh delivered at Kuala Tanjung is tentatively determined at ¥3.7/kWh (US$0.0161/kW equivalent) and will be determined after the Asahan Hydroelectric and Aluminium Project is finally completed. Assuming the power price at ¥3.7/kWh (US$0.0161/kW), the annual cost of energy imposed on the Project is estimated as follows:-

Year	Annual Cost of Energy	
	(¥10^6/kWh)	(US$$10^6$ [illegible])
1983	370.0	1,610
1984	555.0	2,415
1985	703.0	3,059
1986-2017	806.6	3,510

7.4 Net Project Benefits/1

The gross project benefits produced by the Project is obtained by summing up the benefits in Local Area and Medan Area. The net project benefits attributable to the Project is obtained by deducting the cost of energy from the gross project benefits as shown below.

Year	Net Project Benefits (US$$10^3$)
1983	5,834
1984	7,983
1985	9,921
1986	11,505
1987	12,258
1988	13,205
1989	13,123
1990-2017	13,068

/1 : In case of 20 % discount rate.

7.5 Project Feasibility

7.5.1 Feasibility

The economic feasibility is evaluated by benefit cost ratio (B/C) estimated at various discount rates and internal rate of return (IRR) of the Project on the basis of the net benefits and construction and operation and maintenance costs of the Project as shown in Table 7.2. B/C at the discount rates of 20 %, 25 % and 30 % are as follows:-

Discount Rates (%)	B/C
20	1.238
25	0.999
30	0.836

IRR of the Project is estimated at 24.9 % as illustrated in Figure 7.1.

B/C ratios and IRR obtained clearly shows the strong economic viability of the Project.

At present, energy supply of the Project Area is fully depending on fossil fuel, mainly on petroleum which is deemed to be exhausted. Besides, price of petroleum has been skyrocketing these years. The use of hydropower energy will conserve the precious resources and save economic cost by big margin as well.

The Project is technically feasible and economically viable. It is strongly recommended that, therefore, the Project will be implemented as early as possible.

The Project comprises the construction of transmission lines and substations and does not encompass the construction of distribution lines. In order to supply the customers with electricity at their houses or factories, additional costs would be required for distribution. It is not appropriate, therefore, to use the existing tariff of PLN in computing the revenue attributable to the Project.

Financial analysis is made, therefore, just for reference using assumed power rate for the electricity to be supplied at the secondary bus of substations by the Project.

7.5.2 Sensitivity Analysis

Cost of the energy to be supplied by INALUM is calculated based on the assumed price of ¥3.7/kWh (US$0.0161/kWh). The sensitivity of the Project to the change of the price is examined for the increase rate of 15 %.

As shown in Figure 7.1, IRR of the Project is reduced to 24.0 %. The Project still shows strong economic viability with high IRR value even under this condition.

Table 7.1 ENERGY & POWER DEMAND AND SUPPLY OF ASAHAN HYDROPOWER ELECTRICITY

		1983	1984	1985	1986	1987	1988	1989	1990-2017
1.	Energy & Power Demand (Customer Demand)								
1.1	Total Energy Demand (GWh)	625.62	725.34	847.06	961.69	1,083.54	1,199.67	1,313.68	1,443.94
1.2	Energy Demand in Local Areas (GWh)	74.62	87.34	109.06	134.69	168.54	217.67	253.68	292.94
1.3	Power Demand in Local Areas (~~GWh~~) MW	14.4	16.7	20.5	25.0	30.8	39.3	45.1	51.4
1.4	Energy Demand in Medan System (GWh)	551.00	638.00	738.00	827.00	915.00	982.00	1,060.00	1,151.00
2.	Energy & Power Supply								
2.1	Energy Supply from Asahan Hydropower less T/L Loss (GWh)/1	99.25	147.80	185.38	211.46	211.46	211.46	211.46	211.46
2.2	Power Supply from Asahan Hydropower (MW)	25.0	35.0	45.0	50.0	50.0	50.0	50.0	50.0
2.3	Energy Supply to Local Areas from Asahan Hydropower (GWh)	37.31/2	87.34	109.06	134.69	168.54	211.46	211.46	211.46
2.4	Power Supply to Local Area from Asahan Hydropower (MW)	14.4	16.7	20.5	25.0	30.8	38.1	37.5	37.1
2.5	Energy Supply to Medan System from Asahan Hydropower (GWh)	61.94	60.46	76.32	76.77	42.92	-6.21/3	-42.22/3	-81.48/3

Remarks: /1 Energy Supply from Asahan Hydropower (GWh) x (100 - Transmission Loss (%))

	1983	1984	1985	1986-1990
Energy Supply from Asahan Hydropower (GWh)	100	150	190	218
Transmission Loss (%)	0.75	1.45	2.43	3.00
Energy Supply from Asahan Hydropower less T/L Loss	99.25	147.80	185.38	211.46

/2 Electricity of Asahan Hydropower will be supplied to Local Areas from middle of the year.

/3 From 1988, it is assumed that energy will be supplied from System Medan to Local Area in order to make up the expected energy shortage in Local Area.

Table 7.2.a PW OF BENEFITS & COSTS

(DISCOUNT RATE: 20%)

Year in Order	Year	(1) Energy Supply to Local (GWh p.a.)	(2) Power Supply to Local (MW)	(3) Energy Supply to Medan (GWh p.a.)	(4) Energy Benefit in Local: (1)xUS$0.0544/ kWh x 10^3 (US$$10^3$ p.a.)	(5) Power Benefit in Local: (2)xUS$136.8/ kW (US$$10^3$ p.a.)	(6) Energy Benefit in Medan: (3)xUS$0.0556/ kWh x 10^3 (US$$10^3$ p.a.)	(7) Total Gross Benefits (4)+(5)+(6) (US$$10^3$ p.a.)	(8) Energy Cost of the Project (US$$10^3$ p.a.)	(9) Net Benefits (7)-(8) (US$$10^3$ p.a.)	(10) PW of Net Benefits (US$$10^3$)	(11) Construction cost & O & M Cost (US$$10^3$ p.a.)	(12) PW of Costs (US$$10^3$)
0	1979										30,573		24,696
1	1980											2,610	
2	1981											15,163	
3	1982											16,487	
4	1983	37.31	14.4	61.94	2,030	1,970	3,444	7,444	1,610	5,834		3,230	
5	1984	87.34	16.7	60.46	4,751	2,285	3,362	10,398	2,415	7,983		371	
6	1985	109.06	20.5	76.32	5,933	2,804	4,243	12,980	3,059	9,921		371	
7	1986	134.69	25.0	76.77	7,327	3,420	4,268	15,015	3,510	11,505		371	
8	1987	168.54	30.8	42.92	9,169	4,213	2,386	15,768	3,510	12,258		371	
9	1988	211.46	38.1	-	11,503	5,212	-	16,715	3,510	13,205		371	
10	1989	211.46	37.5	--	11,503	5,130	-	16,633	3,510	13,123		371	
11-38	1990-2017	211.46	37.1	-	11,503	5,075	-	16,578	3,510	13,068		371	

B/C = 30,573/24,696 = 1.238

Table 7.2.b PW OF BENEFITS & COSTS

(DISCONT RATE: 25%)

Year in Order	Year	(1) Energy Supply to Local (GWh p.a.)	(2) Power Supply to Local (MW)	(3) Energy Supply to Medan (GWh p.a.)	(4) Energy Benefit in Local: (1)xUS$0.0544/kWh x 10^3 (US$$10^3$ p.a.)	(5) Power Benefit in Local: (2)xUS$161.4 kW (US$$10^3$ p.a.)	(6) Energy Benefit in Medan: (3)xUS$0.0556/kWh x 10^3 (US$$10^3$ p.a.)	(7) Total Gross Benefits: (4)+(5)+(6) (US$$10^3$ p.a.)	(8) Energy Cost of the Project (US$$10^3$ p.a.)	(9) Net Benefits (7)-(8) (US$$10^3$ p.a.)	(10) PW of Net Benefits (US$$10^3$)	(11) Construction Cost & O & M Cost (US$$10^3$ p.a.)	(12) PW of Cost (US$$10^3$)
0	1979										22,143		22,164
1	1980											2,610	
2	1981											15,163	
3	1982											16,487	
4	1983	37.31	14.4	61.94	2,030	2,324	3,444	7,798	1,610	6,188		3,230	
5	1984	87.34	16.7	60.46	4,751	2,695	3,362	10,808	2,415	8,393		371	
6	1985	109.06	20.5	76.32	5,933	3,309	4,243	13,485	3,059	10,426		371	
7	1986	134.69	25.0	76.77	7,327	4,035	4,268	15,630	3,510	12,120		371	
8	1987	168.54	30.8	42.92	9,169	4,971	2,386	16,526	3,510	13,016		371	
9	1988	211.46	38.1	-	11,503	6,149	-	17,652	3,510	14,142		371	
10	1989	211.46	37.5	-	11,503	6,053	-	17,556	3,510	14,046		371	
11-38	1990-2017	211.46	37.1	-	11,503	5,988	-	17,491	3,510	13,981		371	

B/C = 22,143/22,164 = 0.999

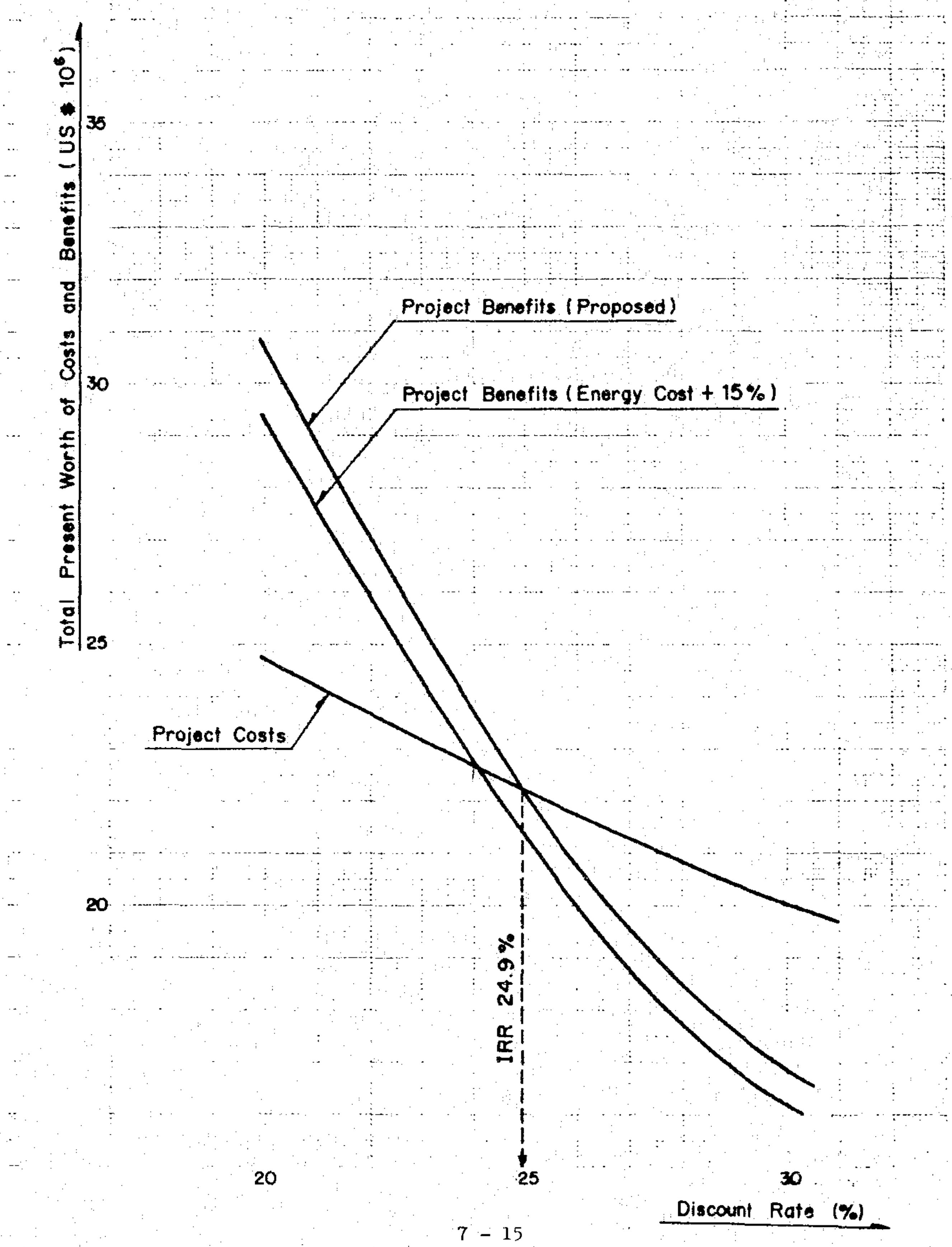
Table 7.2.c PW OF BENEFITS & COSTS

(DISCOUNT RATE: 30%)

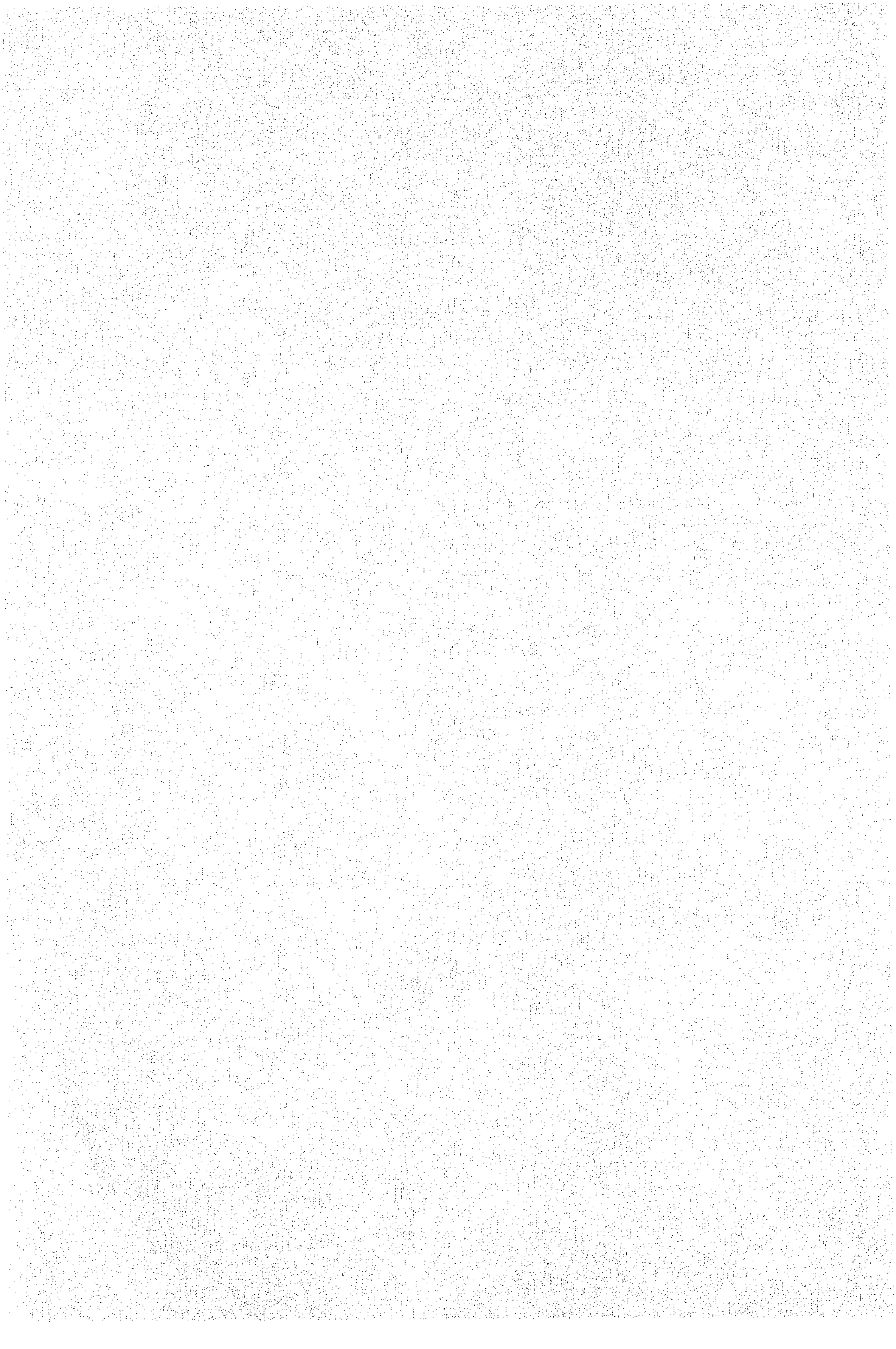
Year in Order	Year	(1) Energy Supply to Local (GWh p.a.)	(2) Power Supply to Local (MW)	(3) Energy Supply to Medan (GWh p.a.)	(4) Energy Benefit in Local: (1)xUS\$0.0544/kWh x 10^3 (US\$$10^3$ p.a.)	(5) Power Benefit in Local: (2)xUS\$186.4/kW x 10^3 (US\$$10^3$ p.a.)	(6) Energy Benefit in Local: (3)xUS\$0.0556/kWh x 10^3 (US\$$10^3$ p.a.)	(7) Total Gross Benefit (4)+(5)+(6) (US\$$10^3$ p.a.)	(8) Energy Cost of the Project (US\$$10^3$ p.a.)	(9) Net Benefit (7)-(8) (US\$$10^3$ p.a.)	(10) PW of Net Benefit (US\$$10^3$)	(11) Construction Cost & O & M Cost (US\$$10^3$ p.a.)	(12) PW of Cost (US\$$10^3$)
0	1979										16,766		20,048
1	1980											2,610	
2	1981											15,163	
3	1982											16,487	
4	1983	37.31	14.4	61.94	2,030	2,684	3,444	8,158	1,610	6,543		3,230	
5	1984	87.34	16.7	60.46	4,751	3,113	3,362	11,226	2,415	8,811		371	
6	1985	109.06	20.5	76.32	5,933	3,821	4,243	13,997	3,059	10,938		371	
7	1986	134.69	25.0	76.77	7,327	3,660	4,268	16,255	3,510	12,745		371	
8	1987	168.54	30.8	42.92	9,169	5,741	2,386	17,296	3,510	13,786		371	
9	1988	211.46	38.1	–	11,503	7,102	–	18,605	3,510	15,095		371	
10	1989	211.46	37.5	–	11,503	6,990	–	18,493	3,510	14,983		371	
11-38	1990-2017	211.46	37.1	–	11,503	6,915	–	18,418	3,510	14,908		371	

B/C = 16,766/20,048 = 0.836

√ Figure 7.1 ESTIMATION OF IRR OF THE PROJECT



A P P E N D I X



APPENDIX - I

EXPERTS AND COUNTERPART PERSONNELS

Experts

1)	T. Mori	Project Director
2)	N. Nozawa	Team Leader
3)	J. Tomisaka	Transmission Engineer
4)	T. Sakuma	Transmission Engineer
5)	M. Nakanishi	Geologist
6)	T. Kohjima	Economist
7)	K. Kawai /1	Power System Engineer
8)	Y. Watanabe /1	Substation Engineer
9)	H. Jyo /1	Communication System Engineer
10)	S. Osumi /1	Building Engineer
11)	M. Kiyoura /1	Civil Engineer

Counterpart Personnels

1)	Ir. Sjofjan Saibir	Project Manager
2)	Ir. Z.A. Dalimunthe	Chief Counterpart
3)	Ir. Kasian Tanjung	Assistant to Project Manager
4)	Ir. Aman Subagio	Transmission Engineer
5)	Ir. E. Parapat	Transmission Engineer
6)	Zainuddin B.A.	Transmission Engineer
7)	Ir. Usman Hidayat	Transmission Engineer
8)	Ir. Edward Sirait	Transmission Engineer
9)	S. Silaban	Transmission Engineer
10)	Ir. Udibowo	Geologist
11)	Samto	Geologist
12)	Drs. H.K. Hutagalung	Economist
13)	Ir. Usman Hidayat	Economist
14)	Ir. Budi Haryanto	Economist
15)	Rustam Achmad Bc. K	Office Manager
16)	Aida Mahmun	Typist

/1 *Home Work only*

Advisory Members (PLN, Pusat)

1)	Ir. Soejadi	Deputy Director of Construction
2)	Drs. Hutasoit	Head of Survey Division
3)	Ir. Hartojo Notodipuro	Deputy Director of General Planning
4)	Ir. Muljadi Utji	Head of Network Division
5)	Ir. Sabarto	Head of Exploitation Budget Division
6)	Ir. Ontowirjo	Head of Design Division
7)	Ir. Sihombing	Directorate of Planning

APPENDIX - II DATA

APPENDIX - II.1

POWER STATISTICS