REPUBLIC OF THE PHILIPPINES

REPORT
ON
FEASIBILITY STUDY
ON
LEYTE POWER TRANSMISSION PROJECT

(APPENDIX)

VOLUME II

FEBRUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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WEATHER CONDITIONS IN THE PROJECT AREA
AND
WIND VELOCITY FOR DESIGNING

A-1 WEATHER CONDITIONS IN THE PROJECT AREA AND WIND VELOCITY FOR DESIGNING

1. Weather Conditions of the Philippines

Philippine Islands are composed of over 7,000 islands located in the span of about 5°N.L. to 21°N.L., and these islands are roughly divided into Luzon area, Visayas area and Mindanao area.

Because of the fact that the Philippines is located in a low altitude area, characters of tropical climate are observed in this country except for high mountains, and accordingly, changes in temperature are small all the year round and humidity is high. The rainfall is large in general, and its distribution is affected by monsoon.

The factors which govern the climate of the Philippines can be mainly divided into the following four types.

a) Southwest monsoon

The southwest monsoon is caused by the Indian Ocean trade wind originated by high atmospheric pressure in Indian Ocean generated in winter of the southern hemisphere. In the area around the Philippines it becomes southwest air stream. This wind starts blowing at the beginning of June, becomes the strongest in August and continues up to the end of September. There are cases at occasions that it continues up to the end of October.

It brings heavy rain to the entire west coast of the Philippines in June through September. Therefore, this period is so-called rainy season.

In this period of June through September, the wind mainly blows in southwest direction on the north side of the Leyte Island, on the west side of the Samar Island and on the south side of the Luzon Island. The wind direction varies between south-southwest and west, and the wind velocity is around 3 to 6 kt in general.

b) Northwest monsoon

This is the cold air current caused by Asian winter high pressure, and it becomes northeast wind in the Philippines. It starts blowing toward the end of October, becomes the strongest in January and usually continues up to the end of April. Relative cold climate is continued because of influence of this air current, and heavy rain is observed along the east coast (Pacific Ocean side) in winter.

In the areas on the north side of the Leyte Island, west side of the Samar Island and the south side of the Luzon Island, the wind direction is northeast in general and the wind velocity is around 4 to 8 kt in general.

c) The North Pacific Trades

This is the air current from North Pacific high pressure. Wind direction is north or east in general in the Philippines. It becomes predominant in April, May and October, and it suppresses the air mass of northwest monsoon in the east area. It is most characteristic that it is the warmest air current that exerts influence over the Philippines. It brings fine weather, and thunder storms are occasionally produced out of a cumulus.

d) South Pacific Trades

This is the air current from South Pacific high atmospheric pressure produced in the southern hemisphere. The wind direction is southwest in June in the Philippines. This is a warm air current. Although its low layer is of high humidity, its upper layer is relatively dry, and its characteristic is similar to that of the southwest monsoon described earlier.

What characterize the climate of the Philippines besides four air currents described above are South Sea typhoons. In addition, the Philippines is also affected by fronts and the equatorial calm. It is also largely affected by sea currents as it is surrounded by seas.

The atmospheric temperature does not vary very much in the whole year. Zamboanga in Mindanao Island, for instance, the mean atmospheric temperature in warmest months (April, May) is 26.7°C, and the mean atmospheric temperature in coldest months (January, February) is 26.1°C. The difference is as minor as 0.6°C. It is around 3.6°C in Manila.

The average annual rainfall in the Philippines is about 2,400 mm. However, it is not equally distributed but largely affected by the topography, and is regularly distributed by the direction of the then seasonal wind. Although the difference between dry season and rainy season is clear on the South China Sea side including Manila, it is usual that rainfall is large throughout the year on the Pacific Ocean Side.

2. Weather Conditions in Northern Leyte, Western Samar and Southern Luzon

The weather data collected at weather observation stations in the project area, that is, Tacloban (Leyte Island), Catbalogan (Samar Island) and Legaspi (Luzon Island) are shown in Table A-1-1. The weather conditions in these areas can be summarized as follows from these data.

a) Air temperature

The mean annual temperature is about 27.3°C. The maximum and minimum temperature are 37.2°C and 16.7°C respectively at Legaspi, but when regional difference, altitude difference and so forth are considered, it can be considered that the air

Table. A-1-1 CLIMATIC DATA IN THE PROJECT AREA

Item		Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Observation Period
Temperature (°C)	Average	Tacloban	26.0	26.0	26.6	27.5	28.0	28.0	27.7	28.0	28.0	27.7	27.1	26.5	27.3	20
		Catbalogan	26.1	26.1	27.0	27.8	28.5	28.5	28.1	28.3	28.1	27.5	27.0	26.3	27.4	20
		Legaspi	25.5	25.6	26.3	27.3	28.1	28.1	27.7	27.7	27.3	27.1	26.6	26.0	27.0	20
	Highest	Tacloban	33.3	34.4	34.4	36.1	36.1	36.1	35.6	35.6	36.1	35.6	34.4	33.3	36.1	16
		Catbalogan	33.4	34.3	35.0	36.6	36.2	35.9	34.8	35.2	35.0	34.9	36.9	34.0	36.9	10
		Legaspi	32.8	33.9	33.9	35.6	37.2	37.2	36.7	35.6	36.1	35.0	34.4	33.3	37.2	27
	Lowest	Tacloban	18.9	17.8	17.8	20.0	22.2	22.2	21.7	21.1	21.7	21.7	20.0	17.8	17.8	16
		Catbalogan	16.4	18.3	18.1	17.9	21.4	22.1	21.7	21.1	21.1	21.1	18.9	18.3	16.4	18
		Legaspi	17.2	16.7	17.2	18.9	20.0	21.7	20.6	21.1	21.1	18.3	18.9	17.8	16.7	27
Sea level pressure (mb)		Tacloban	1012	1013	1013	1011	1010	1010	1009	1009	1009	1010	1011	1011	1011	20
		Catbalogan	1014	1013	1012	1011	1010	1011	1009	1009	1010	1010	1010	1009	1011	20
		Legaspi	1013	1013	1013	1012	1010	1010	1010	1008	1009	1010	1011	1012	1011	20
Relative humidity (%)		Tacloban	83	82	81	80	81	80	81	78	78	82	83	84	81	20
		Catbalogan	82	81	79	79	79	80	81	80	80	83	84	84	81	20
		Legaspi	84	82	82	82	82	82	84	85	85	85	85	85	84	20
Rainfall	Total (mm)	Tacloban	338	216	170	137	155	183	165	140	155	213	302	373	2541	34
		Catbalogan	298	191	157	135	165	207	254	204	258	308	366	383	2926	34
		Legaspi	391	292	196	150	163	201	259	201	259	348	465	516	3441	36
	Rainy days (day)	Tacloban	22	17	18	15	16	17	17	15	16	20	21	23	217	42
		Catbalogan	20	16	16	14	15	17	18	16	18	21	21	21	213	34
		Legaspi	23	16	17	14	14	15	19	17	19	21	22	24	221	47
	Greatest in one day (mm)	Tacloban	127	116	97	104	152	116	117	58	44	72	103	106	152	8
		Catbalogan	133	113	47	107	159	91	105	234	96	190	269	333	333	6
		Legaspi	236	41	72	74	84	237	133	134	83	92	485	128	485	5
	Nos. of days for each of classes of rainfall (day) — Each of class (mm) or more: 1	Tacloban	15	14	10	10	11	11	14	13	14	16	17	21	166	8
	10	Tacloban	5	4	3	2	4	4	5	4	5	5	7	8	56	
	25	Tacloban	2	2	2	1	1	2	1	1	1	2	3	3	21	
	50	Tacloban	1	1	—	—	—	—	1	—	—	1	1	2	7	
	1	Catbalogan	14	12	10	9	10	13	17	13	14	14	20	17	170	6
	10	Catbalogan	6	5	3	2	3	6	7	6	7	8	9	6	68	
	25	Catbalogan	3	1	1	1	2	3	3	3	2	4	4	2	29	
	50	Catbalogan	1	—	1	—	1	1	1	—	1	1	2	1	10	
	1	Legaspi	18	18	12	11	10	12	19	16	17	17	20	22	186	5
	10	Legaspi	10	5	5	4	4	4	6	5	9	3	11	13	84	
	25	Legaspi	5	1	2	1	1	3	3	3	3	4	7	8	41	
	50	Legaspi	2	—	—	—	—	1	—	2	—	1	3	4	13	
Thunderstorm (day)		Tacloban	0.9	1.0	2.2	4.5	10.5	11.4	10.2	7.6	8.7	8.0	2.9	1.6	69.5	10
		Legaspi	0.0	0.2	0.5	1.1	5.8	6.2	4.7	4.7	5.5	4.2	1.8	0.8	35.5	6

temperatures are around maximum 40°C and minimum 10°C in the project area.

b) Rainfall

There is no distinction in particular between dry season and rainy season. A lot of rain is brought in winter by northeast monsoon.

c) The number of days of thunderstorm is 69.5 days in Tacloban and 35.5 days in Legaspi. Both of these towns belong to a thunderstorm area.

3. Typhoon

The Philippines is the country that is most directly hit by typhoons. The middle part and the north part of the Philippine Islands in particular tend to be attacked by typhoons, but very minor at Palawan and Mindanao. Typhoons are usually generated on the east side of the Philippines and they advance toward the Philippine Islands and Indo-China. Attack by typhoons is frequent in July through December. The average course of these typhoons is toward the north in February through August, and it is usual that they go down south after August up to January.

20 typhoons at average per year enter the area that affects the Philippines; their 42% pass through the Philippine Islands. Southern part of Luzon Island and northern part of Samar Island are hit by 31 - 40% of these typhoons; northern part of Leyte Island by 21 - 30%;

and southern part of Samar Island by 11 - 20%. 4.7 typhoons at average per year cause damage to somewhere in the Philippines, and two of them, i.e., 43% of 4.7, cause loss of man power and economy in the northern part of Leyte Island and in the southern part of Samar Island and southern part of Luzon Island. (Table A-1-2)

Figures of maximum wind velocity, lowest atmospheric pressure and maximum rainfall in 24-hour period in the northern part of Leyte, Samar and southern part of Luzon summarized from the data related to typhoons are shown in Table A-1-3. The extreme values observed in this area are as follows.

Max. wind velocity : 275 kph (76.4 m/sec) (Virac, Catanduanes, 1970)

Min. atmospheric pressure: 950 mb (Virac, Catanduanes, 1959)

Max. rainfall in 24-hour period : 494 mm (Virac, Catanduanes, 1974)

The southern part of Luzon Island and the northern part of Samar Island are busy courses of typhoons as described earlier, and are particularly affected by typhoons.

Toble A-I-2 NUMBER OF TROPICAL CYCLONE

Month	Cyclone affected to the philippines	Disastrous cyclone Philippines	project area
Jon.	17	3	1
Fed.	9	1	1
Mor.	8	1	0
Apr.	12	5	2
Moy	25	7	5
June	48	11	5
July	100	21	4
Aug.	108	15	2
Sept.	97	16	1
Oct.	77	25	11
Nov.	74	29	20
Dec.	41	11	10
Total	616	145	62
Meon	19.9	4.7	2.0
Period	1948 - 1978	1948-1978	1948-1978

Reference : Tropical Cyclone Summories From 1948 to 1978
PAGASA (Dec. 1978)

Table A-I-3 HIGHEST MAGNITUDE OF TROPICAL CYCLONE DATA (1948 ~ 1978)

Name of place	Max. wind speed (KPH)	Mini pressure (mb)	Max. 24 hour rainfall (mm)
Taclobán (Leyte)	195 (1966)	986 (1971)	152 (1966)
Calbalógan (Samar)	218 (1959)	969 (1959)	388 (1959)
Gándara (Sámar)	—	—	484 (1951)
Catárman (Sámar)	261 (1957)	974 (1951)	347 (1953)
Borongán (Sámar)	121 (1951)	972 (1968)	377 (1968)
Sorsogón (Luzón)	—	—	336 (1949)
Legaspi (Luzon)	215 (1952)	970 (1972)	485 (1967)
Deat (Luzón)	185 (1967)	970 (1967)	391 (1949)
Masbate (Masbate)	185 (1966)	988 (1972)	285 (1952)
Virac (Catanduanes)	275 (1970)	950 (1959)	494 (1974)

4. Estimation of Wind Velocity for Designing

A overhead transmission line should be kept on running with high reliability over a long period of time, and large loads should be assumed for this purpose. On the other hand, however, the construction expenses increase and the economy is lost if excessively large loads are assumed. Accordingly, the wind velocity lelve used for the design is a very important factor.

For determining the design wind velocity, the method to use the maximum wind velocity recorded in the past in the subject area and the method to estimate the wind velocity value through analysis of probability of occurrence of strong winds are available. The former has such a defect of being affected by the difference in the number of years of records in the subject area. The latter method is adopted generally in these days, and there are many cases where a return period is determined depending on the reliability of transmission lines, and the estimated wind velocity in this period is adopted as the design wind velocity.

It has been confirmed through analysis of weather data that the distribution of maximum wind velocity in every year confirms to I type of Gumbel. According to Gumbel, probability P (V) of excess of wind velocity beyond a certain wind velocity level V is expressed by the following equation.

$$P(V) = 1 - \exp\{-\exp\{-\frac{\pi}{\sqrt{6}\sigma_V}(V-\bar{V}+0.45\,\sigma_V)\}\}$$

where; $P(V)$: Probability of excess of wind velocity beyond V ($= \frac{1}{T}$; T : return period)

$\bar{V}$: Mean value of annual maximum wind velocity

σ_V : Standard deviation of annual maximum wind velocity

The relationship between return period (RP) and wind velocity (V) was obtained based on the annual maximum wind velocity data (1 minute evaluation) at observation stations located in the project area shown in Table A-1-4 in accordance with the above equation. The result is shown in Fig. A-1-1.

In the design of overhead transmission lines, the share of the wind load in the entire load is large if the design wind velocity is large, and therefore, there is such a trend that transmission line construction expenses increase exponentially when the design wind velocity is increased.

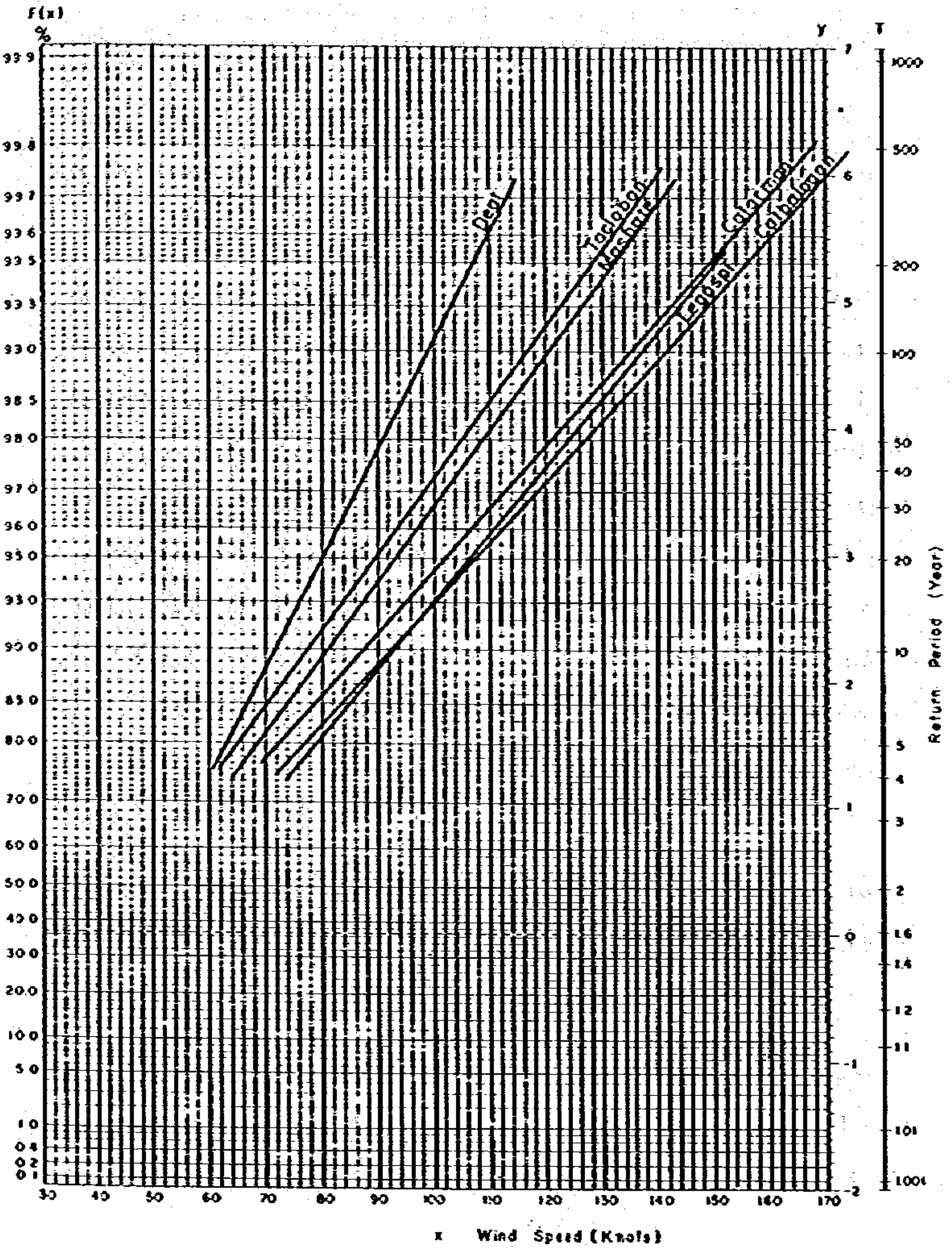
The design wind velocity is a factor that exerts direct influence over the economy and reliability of transmission lines. The transmission lines of the project are of a large scale with the total distance of about 432 km, and when the design wind velocity is overestimated, the economy of the transmission lines is largely affected.

Table A-I-4 RANKS OF ANNUAL MAX WIND SPEED

(Speed in Knots)

Station / Ranks	Leyte Is.	Samar Is.		Luzon Is.		Masbate
	Tacloban	Catbalogan	Catarman	Legaspi	Daet	Masbate
1	25	22	36	21	26	30
2	26	28	38	30	33	30
3	30	30	39	38	44	36
4	30	30	40	40	46	36
5	32	40	40	40	46	38
6	34	40	40	40	49	40
7	36	42	40	44	50	46
8	36	46	40	48	50	48
9	37	50	40	51	52	50
10	37	52	46	52	55	52
11	38	65	46	55	56	60
12	38	70	48	55	56	62
13	40	79	50	56	66	68
14	42	80	55	56	72	100
15	43	95	60	60	90	100
16	44	98	61	60		
17	47	114	104	69		
18	50		140	70		
19	52			80		
20	52			80		
21	55			94		
22	56			100		
23	56			110		
24	61			116		
25	72					
26	84					
27	90					
28	102					
29	105					

Fig. A-1-1 WIND SPEED AND RETURN PERIOD



F(x)=exp{-exp(-y)}, y=a(x-u), T=1/{1-F(x)}

Because of reasons stated above, it is suitable that the design wind velocity to be adopted for the transmission lines of the project is determined based on the design criteria of existing overhead transmission line in the Philippines, result of analysis of wind velocity data and so forth.

According to NAPOCOR's design criteria steel towers are designed so that the member strength using the yield strength as the reference is beyond the stress applied to members when a load that is obtained by multiplying the overload factor to the assumed maximum load. When an extreme value is used as the design wind velocity, it is sufficient if a value of around 1.1 is considered as the overload factor. If the extreme value is not available, a value of around 1.5 is considered as the overload factor in general, and the value obtained by multiplying this overload factor to the assumed maximum load is regarded as the extreme value, and this stress is caused to correspond to the yield strength.

NAPOCOR's steel tower design adopts the latter method. When the extreme value is estimated from the design wind velocity of 185 RPH (Gust), 216 KPH (Gust) (185 KPH x $\sqrt{1.5/1.1}$) is obtained.

The value obtained by multiplying two times of projection area to the steel tower wind pressure on one windward side is adopted as the steel tower wind pressure value. But this value is applicable to a case where the fill-up ratio of the steel tower is very small and it is considered that the influence of shield of the windward side to the leeward side is almost none. In practice, however, the influence of shield is present, and it is sufficient if a value of around 1.5 times of the projection area is considered. When this factor is discharged, the value that a steel tower is considered to withstand in practice is 249 KPH (Gust) (216 KPH (Gust) $x\sqrt{2/1.5}$).

The design wind velocity for NAPOCOR's existing overhead transmission lines was 165 KPH (Gust) (mean wind velocity per minute 127 KPH, gust ratio 1.3). However, because of a fact that steel towers designed based on this standard fell down due to a typhoon, the design wind velocity was revised and changed to 185 KPH (Gust) (mean wind velocity per one minute 142 KPH, gust ratio 1.3) for recent by planned power transmission lines.

At the present situation steel towers are used for supporting 230 KV overhead transmission lines and wooden pole are mostly used for overhead transmission lines of a voltage level less than 230 KV. 230 KV overhead transmission lines are presently existing only in Luzon Island, and none of them are existing on Leyte Island or Samar Island.

The following factors taken into account;

a) The area of the project is often directly hit by typhoons and has high frequency of occurrence of strong winds compared to other areas of the Philippine Islands.

b) Being large capacity overhead transmission lines, high reliability is required.

It is necessary that a value that is higher than 185 KPH (Gust) which is the value currently adopted by NAPOCOR, is adopted.

Steel towers designed with design wind velocity of 185 KPH (Gust) withstand in practice, with occurrence of permanent strain to their members, wind velocity of 249 KPH (Gust), which is the extreme wind velocity.

When the return period is calculated from this wind velocity of 249 KPH (Gust) with gust ratio 1.3 taken into account, from the relationship between the wind velocity (1 minute evaluation) at observation station at Catbalogan at which the extreme wind velocity value is the highest among observation stations shown in Fig. A-1-1 and return period, around 15 years was obtained. If the design wind velocity of 185 KPH (Gust) is used in this area, it is considered that accidents to steel towers for overhead transmission lines occur about once every 15 years due to strong winds.

It is usual that the return period of 50 years is adopted and steel towers are designed with the wind velocity (extreme value) in this period for overhead transmission lines requiring high reliability, and it is desirable that the return period of 50 years be considered for the steel towers for the overhead transmission lines of the project.

When the extreme wind velocity value in the return period of 50 years is calculated with gust ratio of 1.3 taken into account from the relationship between the wind velocity (1 minute evaluation) at observation station in Catbalogan and return period, 305 KPH (Gust) is obtained. According to the design wind velocity level adopted by NAPOCOR, this value is 226 KPH (Gust).

If a design wind velocity value that is larger by 20% than the design wind velocity adopted for recent planned overhead transmission lines (185 KPH Gust) is adopted, it can be estimated as an almost appropriate design wind velocity that does not extremely spoil the economy even when the occurrence of frequency of strong winds due to typhoons in the project area, reliability of overhead transmission lines of the project and economy are taken into account. Therefore, it is recommended that the value of 220 KPH (Gust) be used as the design wind velocity and that design practices specified in NAPOCOR's standards are adopted.

The extreme wind velocity value at observation station in Tacloban is less compared to that at observation station in Catbalogan. When a calculation identical to the above is made this wind velocity value, 187 KPH (Gust) can be estimated. Therefore, the value of 185 KPH is adopted as the design wind velocity (gust) for overhead transmission lines across San Juanico Straight and AC 138 kV overhead transmission lines according to the result of estimation based on the value measured at Tacloban.

A — 2

SURVEY
FOR
SALT DEPOSIT DENSITY OF INSULATOR

A-2 SURVEY FOR SALT DEPOSIT DENSITY OF INSULATORS

1. Purpose

When the surface of insulators used to transmission lines is contaminated with electrolytic materials and the materials become humidified, the insulation performance of the insulator is extremely lowered and sometimes, the insulation performance drops as low as one fifth or sixth of that of clean state. Salt contained in the air coming from the oceanic surface creates this problem most seriously, and when installing transmission lines along coast lines, the number of insulators must be determined in thorough consideration of the insulation deterioration for adequate insulation designing.

Accordingly, salt deposit density to insulators in the proposed route of transmission lines must be investigated beforehand. Since salt adhesion to insulators greatly varies by weather conditions and measurement sites, it is recommended that the surveys and measurement are conducted in as many places and for as long a time as possible to find out the exact situation.

Since there is not much time left before starting construction of the Leyte transmission line, survey of salt adhesion to insulators must be started immediately.

The following describes the survey method of salt deposit density to insulators.

2. Measuring Points

It is desirable to conduct the measurement at many points proposed for installation of the transmission lines facing with coast lines and the following six points are the minimum necessities.

ⓐ Alegria (or Uban Pt.)

ⓑ A point that is closest to the coast between Calbayog and Viriato

ⓒ A point in neighborhood of the Lipata cable terminal

ⓓ A point in neighborhood of the Santa Magdalena cable terminal

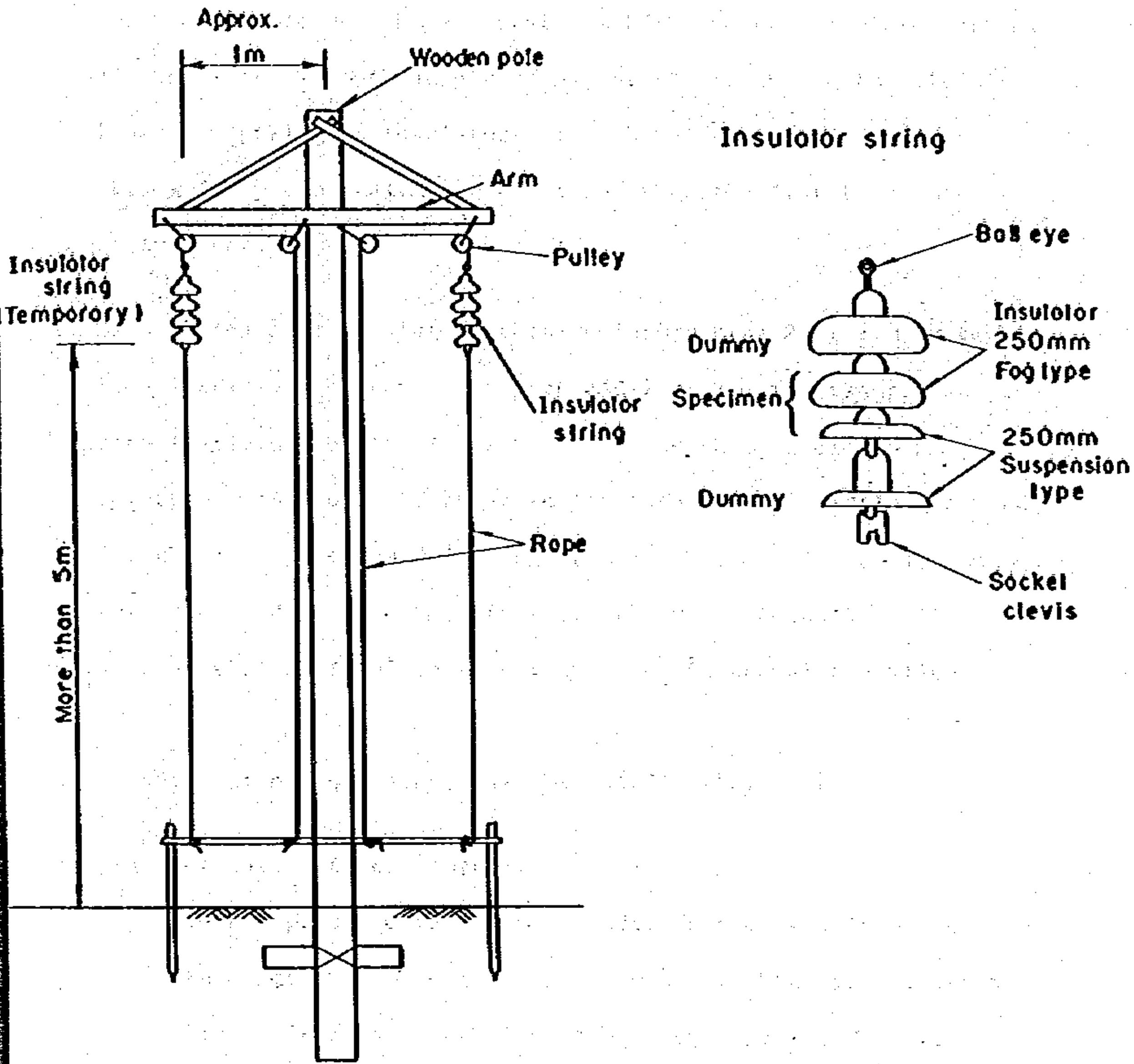
ⓔ A point in neighborhood of Botan (a point that is closest to the Sorsogon bay)

ⓕ Pasacao

Select a place to install test equipment in each point while paying attention to the following items.

- The place must be at a top or close to top of a hill or right that is close to sea and its side toward the sea is open.
- There should be no sheltering objects like trees that block wind from the sea.
- The place must be exposed to strong wind at the time of typhoon and seasonal wind.
- The place must be convenient enough to conduct the measurement.

Fig.A-2-1 Exposuring Stand & Specimen



3. Test Equipment

Install the test equipment as shown in Fig. A-2-1 at each measurement point.

The wooden pole must be at least 6 m high and the insulator string for the specimen must be placed higher than trees in the vicinity. Install 2 string of insulators at each wooden pole and use one string for periodical measurement and the other for temporary measurement.

Each string must consist of total 4 insulators; 2 of 250 mm fog-type insulators at the upper part and 2 of 250 mm standard suspension insulators at the lower part. Among them, 1 of 250 mm fog-type insulators and standard insulator in the middle are used for the measurement and 2 at the top and bottom are dummies that are used to make the air flow around the insulators the same as that of insulators that are used in actual condition.

4. Measurement of Equivalent Salt Deposit Density

i) Insulators to be measured

Use 2 types; one is 250 mm standard suspension insulator and the other is 250 mm fog-type insulator. Measure the equivalent salt deposit density on both the upper and lower surface of the insulators.

ii) Measurement timing

Conduct the measurement in the following two patterns.

- Periodical measurement

... Once a month on a predetermined day at predetermined time of the day.

- Temporary measurement

... After strong wind like typhoon or seasonal wind, and after a certain number of fine days in the dry season.

Avoid measuring immediately after rainfall as much as possible. Particular care must be considered in the dry season so that the measurement is conducted on a day before rainfall.

iii) Measurement instruments and tools

Conductivity meter (for liquid measurement)

Thermometer

Measuring cylinder (about 300 cc capacity)

Beaker (about 500 cc capacity)

Funnel (small size)

Vat (30 cm × 30 cm)

Tweezers

Scissors

Gauzes (one at a time)

Distilled water (300 cc at a time)

iv) Measurement method

Conduct the measurement in the following procedures.

a) Thoroughly clean all measurement instruments and tools with the distilled water.

b) Prepare a predetermined amount (100 cc) of distilled water with the measuring cylinder and pour it into the beaker.

c) Measure the conductivity of the distilled water using the conductivity meter. (This measurement may be omitted when it is known that the conductivity of the distilled water is low enough, but it must be often checked.)

d) Thoroughly rinse the materials adhering to the insulator with the distilled water contained in the beaker using the tweezers and gauze into the vat. Collecting of the materials from the upper and lower surface must be separated as precisely as possible. In the case of the lower surface, do not collect the materials adhering around the pin in the inside of the innermost pleats. Also, care must be taken not to let materials adhering to other than the porcelain surface being mixed in the liquid.

e) Squeeze out the material contained in the gauze. Stir the solution in the vat to obtain uniform concentration. Use a new gauze for each collection work.

f) Pour the liquid into the beaker and measure the conductivity of the solution. Measure the temperature of the solution at the same time.

g) Record the conductivities and temperatures of the solution and distilled water and the amount of water used in the table as shown in Table A-2-1.

5. Data Processing

Calculate the equivalent salt deposit density on the test insulators from the measurement data. First, convert the conductivities and temperatures of the solution and distilled water into salt concentrations using a graph. Then calculate the equivalent salt deposit density using the following formulae:

Solution concentration × Water amount used (100 cc)
= Salt contents in the solution

Distilled Water concentration × Water amount used (100 cc)
= Salt contents in the distilled water

$$\frac{\begin{bmatrix}\text{Salt contents in}\\\text{the solution}\end{bmatrix} - \begin{bmatrix}\text{Salt contents in}\\\text{distilled water}\end{bmatrix}}{\text{Area of upper or lower surface of insulators}} = \text{Equivalent salt deposit density } (mg/cm^2)$$

The term of "Equivalent salt deposit density" means appraisal of the soluble materials adhering to the insulator as the amount of salt (NaCl) that is equivalent in the conductivity.

Table A-2-1 Measured Data of Equivalent Salt Deposit Density

Site

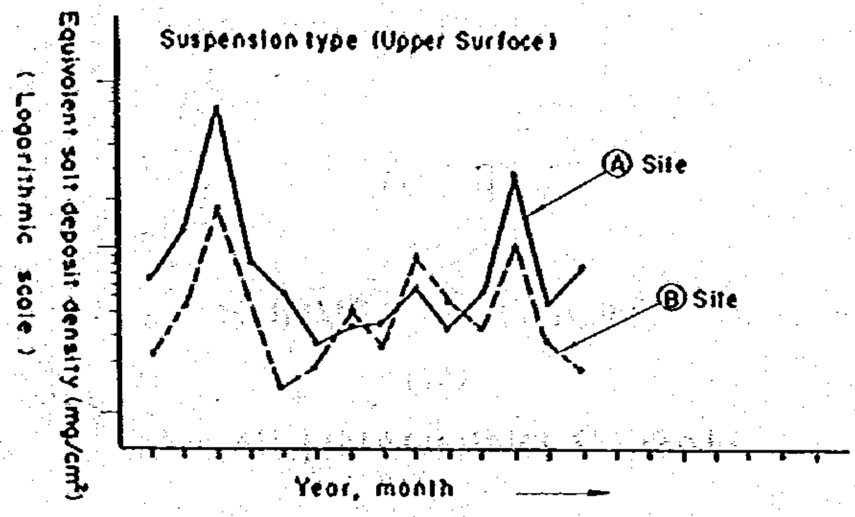
Date of Measuring	Kind of Insulator / Item	Fog type				Suspension type			
		Upper surface		Under surface		Upper surface		Under surface	
		Collected Solution	Distiled Water	Collected Solution	Distiled Water	Collected Solution	Distiled Water	Collected Solution	Distiled Water
(Month Day Year)	Volume of Water								
	Conductivity								
	Salt Concentration								
	Salt Content								
	E.S.D.D								
	Volume of Water								
	Conductivity								
	Salt Concentration								
	Salt Content								
	E.S.D.D								
	Volume of Water								
	Conductivity								
	Salt Concentration								
	Salt Content								
	E.S.D.D								
	Volume of Water								
	Conductivity								
	Salt Concentration								
	Salt Content								
	E.S.D.D								

Collect the individual data of the equivalent salt deposit density throughout the measurement period and summarize them in the time series graph or distribution graph as shown in Fig. A-2-2.

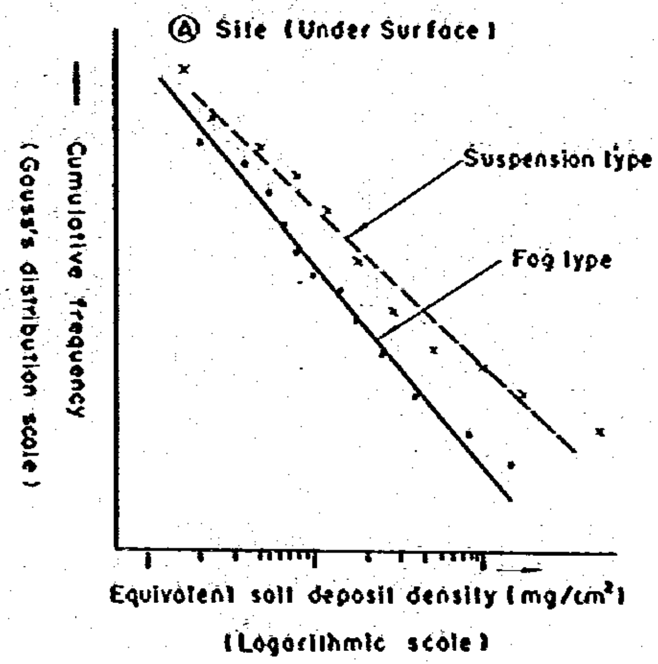
Also, the daily meteorological data (weather, wind speed, rainfall, etc.) during the measurement period must be recorded and put together.

Fig. A-2-2 Graph of Equivalent Salt Deposit Density Data

Trend of E.S.P.D.



Frequency of E.S.P.D.



A—3

SURVEY RESULTS ON SAN BERNARDINO STRAIT

A-3 SURVEY RESULTS ON SAN BERNARDINO STRAIT

1. Preface

San Bernardino Straits between Samar and Luzon is the channel of 17 - 23 km width and about 150 m at maximum depth. National Highway No. 1 running in each of those two islands is connected by ferry boats between Allen in Samar Island and Matnog in Luzon Island.

This Strait is an 'open sea' which guarantees free navigation on an international basis and is being utilized as the navigable water area for those liners cruising into the Pacific Ocean or the seas alongside the eastern side of Philippine islands and also as the main route from the Pacific Ocean to Manila, Cebu and Iloilo.

The Project proposes construction of the submarine cable across the Strait as the only possible means of interconnection. Indeed, the possibility of whether or not the submarine cable line can be laid across the strait is the decisive factor on success or failure of the whole Project. Also, it is of equal importance, as stated in the main report, to make survey of sea-bottom conditions including terrain and geology in order to ensure both economy and technical reliability of the submarine cable line.

With the above in mind, feasibility study recently conducted included the submarine survey to clarify sea-bottom conditions by means of various measuring instruments as well as by reference to marine charts, etc. The following is the outline of survey results.

2. Site Survey Period

March 10, 1981 ∿ March 23, 1981

3. Survey Items and Methods

a) Control point survey

This survey is made to determine the point of the slave station for the ratio-wave range finder to be used for spotting of the surveying boat. The back-crossing method was used for this survey at each point of slave stations.

b) Sea bottom survey

The sounder was provided on the surveying boat cruising the survey water area to fathom the sea depth and the seabed chart was drafted by detailed analysis of both depth to the bottom and its surface undulation from the recorded data.

The radio range finder was used for spotting of the surveying boat. The echo-sounder devised to enable continuous recording was used to fathom the water depth.

c) Bottom soil survey

Soil at top surface of the sea bottom was collected by use of the cylindrical sampler (of 20 cm diameter) of throwing type from boat.

d) Tidal current survey

The method used for this survey to measure tidal current velocity was simple with a boat floating over the water area from one preset point to another.

Besides all the survey items mentioned above, the navigation survey was conducted and necessary data was collected during the full period of all such surveys.

4. Survey Results on San Bernardino Strait

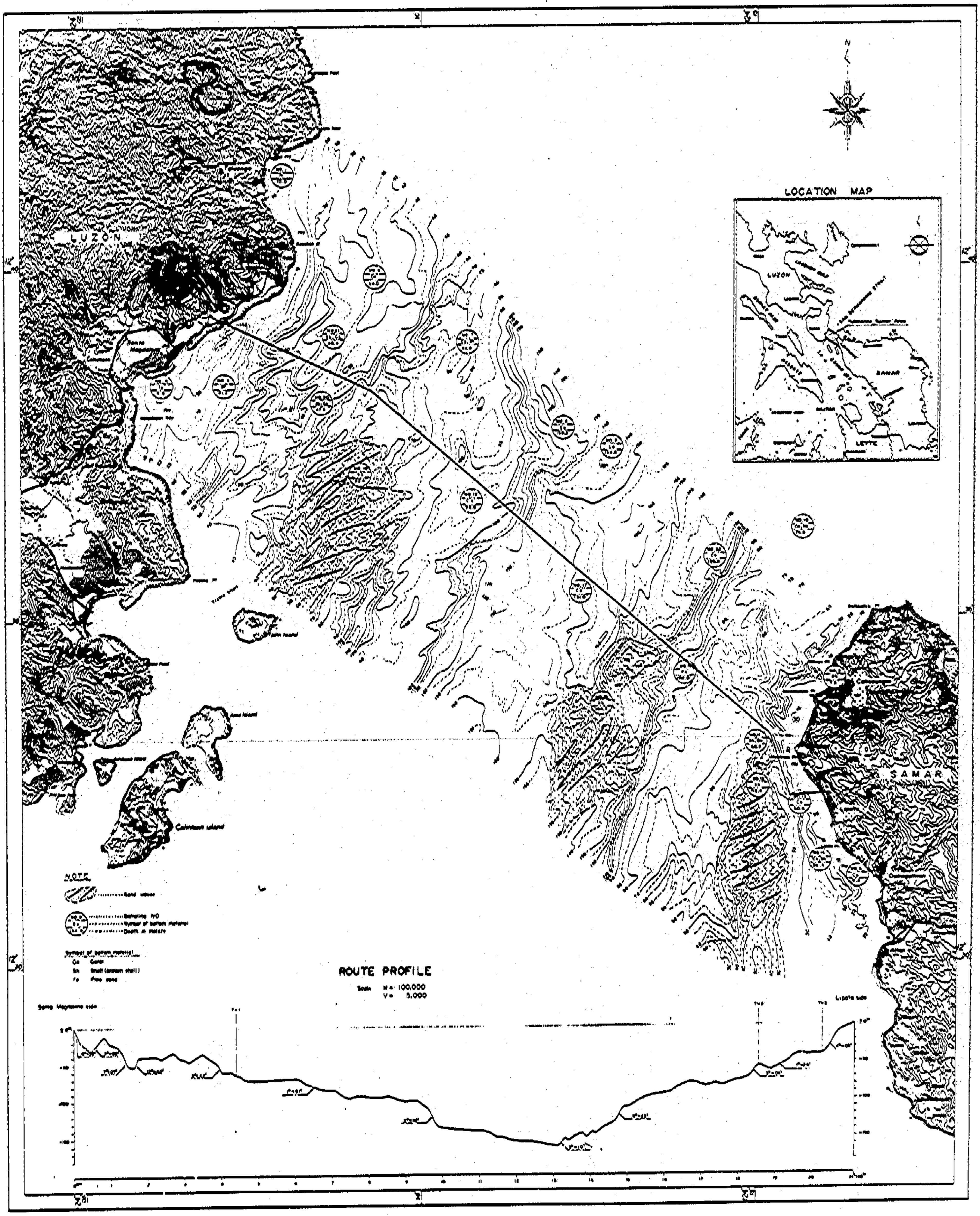
a) Sea-bottom terrain

The survey in search of sea-bottom terrain was conducted with the sounder on board the surveying boat and took records during cruising in the water area. Then, the topographic map of sea-bottom was prepared by detailed analysis of recorded data to seek water depth and sea-bottom undulation, as shown in Fig. A-3-1. The surveying work was conducted by use of the radio-wave range finder for position of the survey boat. To measure water depth the echo sounder was used so as to enable continuous recording of the measured data.

The sea bottom of the Strait is varied alternately with slope and flat bed surfaces from the water-front line of both islands toward middle of the strait. At about one-third point off from the Samar Island, the seabed forms nearly flat basin of 5 km width, at a depth of 120 to 160 m, in the SW-NE direction. Maximum depth in the water area under survey reaches about 160 m at this flat basin.

On the Samar Island side, water depth about 0.5 to 1 km offshore from the water-front is about 50 m, forming a relatively steep slope of 6° to 22°. The sea bottom up to about 4 to 6 km off-shore from the water-front line is nearly flat with a depth of about 50 m to 100 m, then leading to the deepest sea bottom of

Fig. A-3-1 PLAN AND PROFILE OF SUBMARINE CABLE ROUTE IN THE SAN BERNARDINO STRAIT
(LUZON - SAMAR)



the Strait. The seabed of 100 to 120 m depth forms a gentle slope about 7° to 15°.

As compared with the existing seabed slope on the Samar Island side, the non-slope zone on the Luzon Island side is undulated relatively in various ways though the slope surface is not so steep. Within reach of 0.4 to 1.5 km off from the water front, the sea bottom forms gentle slope with a depth of about 20 m, where coral reef appears everywhere. Toward about 3 to 5 km offshore from the water-front line, the sea bottom is nearly flat with a depth of about 20 to 50 m though there exist large or small up-heavals here and there. At 3 km offshore on the eastern side of Santa Magdalena there exists a basin with a depth of about 66 m, forming a gentle slope of about 5 to 8°. The zone of about 0.1 to 2 km width extending from this flat basin is inclined at 2 to 11 to a depth of 50 to 70 m. The sea bottom of 2 to 4 km width in a range of depth from 70 to 100 m is nearly flat. This zone leads to the deepest bottom after slope of about 5° to 12°.

In the water area under survey, another terrain feature was sand waves as observed at three areas, as shown in Fig. A-3-1; on the flat bottom and at the deepest bottom on the Samar Island side and on the flat bottom on the Luzon Island side.

Sand waves on the flat bottom closer to Samar Island are developed at a depth of 50 to 70 m. Each wave has crest in the SW-NE direction at a wave length of 50 to 70 m and at a height of 4 to 14 m. Sand waves at the deepest sea bottom are developed at a depth of 130 to 150 m. Each crest is in the SSW-NNE direction with wave length of 30 to 90 m and height of 5 to 16 m. Sand waves on the flat bottom on the Luzon side are developed at around 40 to 80 m depth. Each crest is in the SW-NE direction with wave length of 50 m and height of 15 m or so.

Sand waves are of swelled waves by influence of tidal current against bottom sand layers underwater and are generally said to be transferrable from one place to another. Transfer of such sand waves may be caused by undercurrent of seawater or by piston motion of seawater from action of surface wave.

Suppose if the submarine cable is laid upon such sand waves, it would form a bridge over the crest of wave, even though sand waves remain unmoved, and would be affected by wave or tidal current as time will go on, as the result of which the cable itself may go into mechanical fatigue and become susceptibe to hurt or damage. Otherwise, if sand waves are moved, the cable may be worn out or hurted by rolling or sliding motion of sand or gravel and the sand wave zone is not favorable to the serviceability of the submarine cable.

The movable pattern of sand waves is complicated; some are moved entirely as a whole, some are varied only in wave length and wave height within the same range or combined pattern of those two preceding cases. Whichever the pattern may be, each of those different patterns is considered to have close relation with the local bottom conditions such as terrain, tidal current and geology.

Because of the shortly limited survey period, sand wave characteristic could not be observed in detail. It is recommended, therefore, that considerable time should be provided for continuous survey on the characteristics of sand waves in future.

With regard to the sea bottom terrain, the survey result reveals that the bottom surface is relatively flat with gentle inclination except sand wave zone and steep slope (22° at max.) about 0.5 km offshore of Calarayan on Samar Island and that there may exist relatively a few slopes or rises affecting the cable line unfavorably.

b) Sea-bottom geology

The sample (of 20 cm diameter) were thrown from the boat into 22 spots in the water area under survey. Those sampling spots are shown in Fig. A-3-1.

Except where fine sand (fs) was collected near the water front of Santa Magdalena and Talaonga in Luzon Island, sampling of corral (Co) or shell (sh) or their mixture (Co, sh) was collected from all the spots. Sampling collected from sand waves at 3 spots consisted mostly of shell fragments, though mixed up party with corral or sand. Each fragmental size is very small and uniform.

Since the sampler size is 20 cm in diameter, any stone of size within that diameter should have been collected. Actually, none of those stones could be collected.

As shown in Fig. A-3-1, alongside the coastal zone of Samar and Luzon there exist stretches of rock everywhere together with corral reef near the water front.

From the survey result as above, general bottom geology all over the strait area consists of corral and shell with far less mixture of stones, except near the water front in the inner bay where there is less tidal influence. From those facts it can be said that the sea bottom geology would not affect availability of the submarine cable to be laid upon it.

c) Tidal current

According to the pailing direction it is noted that tidal current in the strait is influenced by the declination of the moon; that is, the double day tide while the moon is near the equator and change into the single day tide as the moon comes closer to maximum of north or south the declination. The flood tide flows in the southwest direction and the ebb tide flows in the northeast direction. Maximum flow velocity of the flood tide is 5.5 kt at the time of the spring tides and of the ebb tide is 5.5 kt - 8 kt at the time of the spring tides.

Measurement of tidal flow was made by a simplest way with the boat floating on the sea at the predetermined position. The result of measurement reveals that the maximum flow velocity was measured at 3.5 kt (Date and time: March 31, 1981, 12:48 - 13:18) at the point 1.5 km off from Simaga Pt. on Samar Island. During the time of water depth sounding, the tidal current velocity of most probably 4 to 5 kt was sensible in the direction of southwest or northeast at about 3 km offshore between Malalimon Pt. and Balicuatre Pt. of Samar Island. Also, counter or eddy current was observed near this coastal line. Same as on the Samar Island side, rapid current flow was also sensible at about 3 km offshore from Luzon Island between Talagio Pt. and Pacahan Pt.

The local current flow forecast gives the value of 6 - 7 kt at maximum flood. In reality, this official value is said to be applicable to the middle of the Strait. Current velocity near both coastal sides is rather variable by influence of land sharp and sea bed topography in many instances; especially, the flow in estuaries and channels is much more influenced by these conditions.

Needless to mention, any water area of rapid current flow would be suitable in no way for safety of vessels and workers.

Moreover, it would become difficult to handle the boat for cable laying correctly alongside the proposed submarine cable route and this would result in decline of cable availability during its laying work. For this reason, it is advisable that the cable route should be selected, in so far as it is possible, by avoidance of any rapid current area and, besides, that the timing of such laying work should coincide with low tidal current or turning current at slowdown of its velocity.

The normal practice of current monitoring is to continue such monitoring more than one cycling period by use of the current meter. Since this Straits is featured by relatively rapid tidal current, it is necessary to clarify the real circumstance of tidal flow on the proposed route and its water area by current monitoring.

A — 4

CHARACTERISTICS
OF
HIGH VOLTAGE DIRECT CURRENT TRANSMISSION
(HVDC)

A-4 CHARACTERISTICS OF HIGH VOLTAGE DIRECT CURRENT TRANSMISSION (HVDC)

HVDC Transmission has the under-mentioned characteristics, comparing with AC transmission.

1. Facilities for DC Power Transmission are less in Size and Cost

(1) In the case of overhead transmission lines

(a) Required steel tower size is small

o Structure is simple.

Steel tower for DC bipolar power transmission (equivalent to two circuit of AC lines)

Steel tower for power transmission by two circuit of AC lines

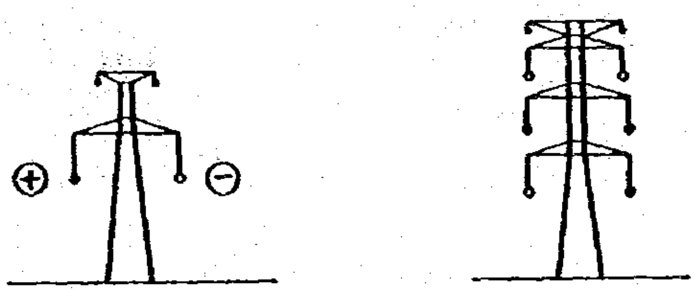


Fig. A-4-1 Typical Steel Towers for DC and AC Power Transmission

Example : The Hokkaido-Honshu HVDC line (DC ±250 kV, 600 MW) is of AC 154 kV class.

Standard steel tower height	: 35 m	
Mean steel tower weight	: approx. 10 tons per tower	= AC 154 kV class

- If DC power transmission is made, it is possible to transmit the power of 6,000 MW with steel towers of the height that is about the same as that of Hokkaido-Honshu HVDC link described above.
  (When ±250 kV, 12 kA [TACSR 810 mm^2 x 6] is used)

(b) Required number of conductors is small

- 1/3 or less of that of AC will do.

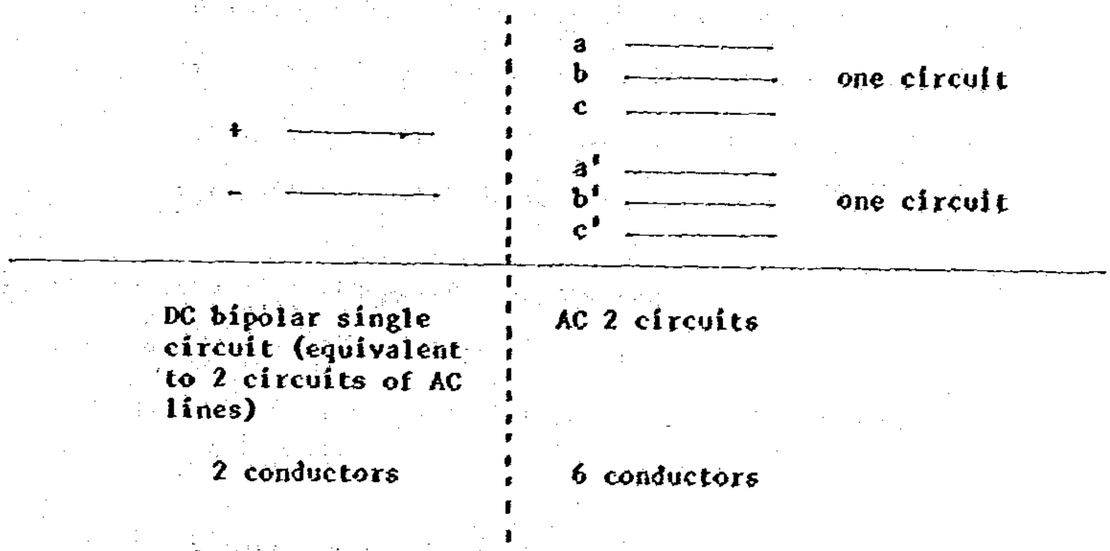


Fig. A-4-2 Comparison of Basic Configuration of DC and AC Lines

(c) There is no problem in stability, and it is not necessary to provide many circuits.

- With AC power transmission, there is a limit in the quantity of electric power that can be stably transmitted when the distance is long. For bulk power transmission, therefore, it is necessary to increase the number of circuits.

- o With DC transmission, such a problem is not involved, and it is possible to transmit electric power up to permissible thermal current of conductors.

(d) Economy is better for long distance power transmission

- o The cost of DC power transmission lines is only very small amount of that of AC power transmission.
- o When a comparison is made with AC transmission lines including substations at both ends and DC transmission lines including converter stations at both ends, the economy of DC system becomes conspicuous when the transmitting distance is long.

(2) In the case of cable power transmission

(a) Less cable size of less cost will do

- o Cable insulation is far stronger for DC compared with that of AC.

  Example : The cables of Hokkaido-Honshu HVDC link (±250 kV) is equivalent to AC 187 kV (conductor to earth voltage 110 kV) from the standpoint of insulation.

(b) No restrictions due to charging current

- o With AC cables, charging current flows through the interior, and the transmission capacity decreases. (It is particularly conspicuous with submarine cables. The transmission capacity decreases to a half in distance of 60 - 70 km.)

(c) Economy is better with long distance cables

- The result of examinations regarding submarine cables indicates that the economy balancing distance between AC and DC is 30 to 60 km.

2. Merits are Large in the Aspect of System Operation

(1) When DC linkage is made between AC systems, short-circuit current and ground fault current will not increase.
When AC linkage is made, on the other hand, short-circuit current and ground fault current increase, a lot of expenses are required for taking countermeasures against electromagnetic induction of telecommunication lines. In addition, technical development for increasing the breaking capacity of circuit breakers and replacement of existing circuit breakers are required. Such problems do not occur when DC linkage is made.

(2) Power flow control can be made quickly as desired
If AC linkage is made, a period of several to several ten seconds is required for changing the power flow because of inertia of generators. When DC linkage is made, on the other hand, power flow can be changed momentarily, and it is also possible to freely determine the extent of change in the power flow.

(3) It is possible to increase the transmission capacity of existing AC power transmission lines

The transmission capacity of existing long distance AC power transmission lines is not determined by the permissible thermal current of conductors but is determined by the limit of stable operation in many cases, and it is wasteful.

It is possible to largely increase the transmission capacity of AC power transmission lines by providing DC power transmission lines in parallel with AC power tra'smission lines or dividing both AC power systems.

(4) Frequency improvement at normal occasions and on occurrence of faults can be quickly and suitably made

If drop-off of a power source occurs in one system and the frequency largely drops, for instance, it is possible to make a backup with necessary electric power from healthy systems momentarily and without exerting application of excessive loads to the healthy systems, by making DC linkage. If AC linkage is made, there are cases where backup is excessive and it becomes necessary to discontinue the linkage.

(5) Voltage fluctuation of AC system can be suppressed

AC long distance power transmission involves the problems of rise of voltage on receiving side during light loads (Ferranti effect). However, such a problem will not occur with DC power transmission.

3. Disadvantages of DC Power Transmission

(1) Expenses for construction of converter stations required at both ends are high.

Converter equipment for DC power transmission are of high construction expenses compared to expenses for construction of substations for AC power transmission, and the economy balancing distance with AC power transmission is relatively long. However, it is considered that the economy balancing distance will become considerably short for stations of large capacity in the future.

(2) Flexibility of system configuration is small

The DC power transmission executed at the present time is only for two terminal transmission, that is, one terminal on sending side and one terminal on receiving side. Because of the fact that multi-terminal DC power transmission technology has not yet been established, it is not possible to make transmission to any place with a network formed among a number of power source points and demand areas, unlike AC transmission. In addition, there is small flexibility in the measures taken on occurrence of system faults, because practical use of DC circuit breakers has not yet finished.

The fact that it is not possible to easily transform the voltage like AC is also a restrictive factor for system configuration. However, it is expected that multi-terminal transmission technology and DC circuit breakers will be put into practical use within several years, and many problems described above will be solved at such an occasion.

(3) Operational experiences is minor and data for evaluation of reliability is not sufficient

The period of time elapsed since DC power transmission equipment using the most updated thyristor converters commenced their operation is short, and it is the present situation that data of operational experiences, which is most important for evaluation of reliability, is not sufficient.

From the viewpoint of reliability, there is no fundamental difference between AC and DC power transmission lines. Converter stations have such a disadvantage from the standpoint of reliability that the number of equipment is large compared with substations for AC power transmission. However, the present time is of such a stage that availability of 97% or higher can be aimed with the existing technology. If additional measures are taken in the aspects of equipment composition, main circuit composition and system configuration, it is considered that the reliability of converter stations can become equal to that of AC substations in practical use.

4. Applicable Fields of DC Power Transmission

The trend of application of DC power transmission in the world is described below.

(1) Long distance bulk power transmission

It is considered that the trend of increase of one power source capacity, increase of distance up to demand areas and uneven distribution of power sources will become more conspicuous in the future because of the hardship in the positioning of power sources. Accordingly, long distance bulk power transmission becomes necessary. In such a case, DC power transmission is more advantageous compared with AC power transmission in the aspects of economy, stability of operation, land space and environment.

(2) Measures related to short-circuit capacity

The short-circuit capacity of the system increase unavoidably when a power system is expanded. Accordingly, increase of breaking capacity of circuit breakers, influence over series equipment, induction hazard to telecommunication lines and so forth become problems. Introduction of DC power transmission systems and division of lower systems may be considered as the measures.

(3) Cable transmission to overcrowded demand areas

It is considered that concentration of population and industries to cities will continue in the future, and it is also considered that urban development and urban redevelopment to cope with such a situation will progress.

Accordingly, it becomes necessary to consider direct introduction into urban area of large capacity power sources located in rural areas or a form of supply of large capacity power transmission from power systems forming an external circle.

Large capacity underground cable transmission will be selected as the method of power transmission from the aspect of land and environment, and DC power transmission which does not involve problems of charging current or short-circuit current is more advantageous in this case.

(4) Submarine cable transmission from isolated islands

Because of hardship of positioning of power sources, there is a possibility where large scale power sources are constructed on isolated islands located in offings where positioning of power sources is relatively easy and power is transmitted through DC power transmission to main lands from these isolated islands by means of submarine cables in the future.

(5) Inter-system linkage

It is considered that the trend of increase in scale and concentration of power sources and increase of scale of power transmission will become more conspicuous in the future. Accordingly, increase of the scale of power source drop-off can be anticipated. Therefore, it will also become necessary to increase the inter-system linkage capacity.

(6) Coupling with new power generation and transmission technology

There is a possibility where the electric energy generated by MHD generation or oceanic differential temperature generation is transmitted by DC power transmission which does not involve the problems of charging current or short-circuit current by using ultra-low temperature or superconductive cables.

5. DC Power Transmission Projects in the World

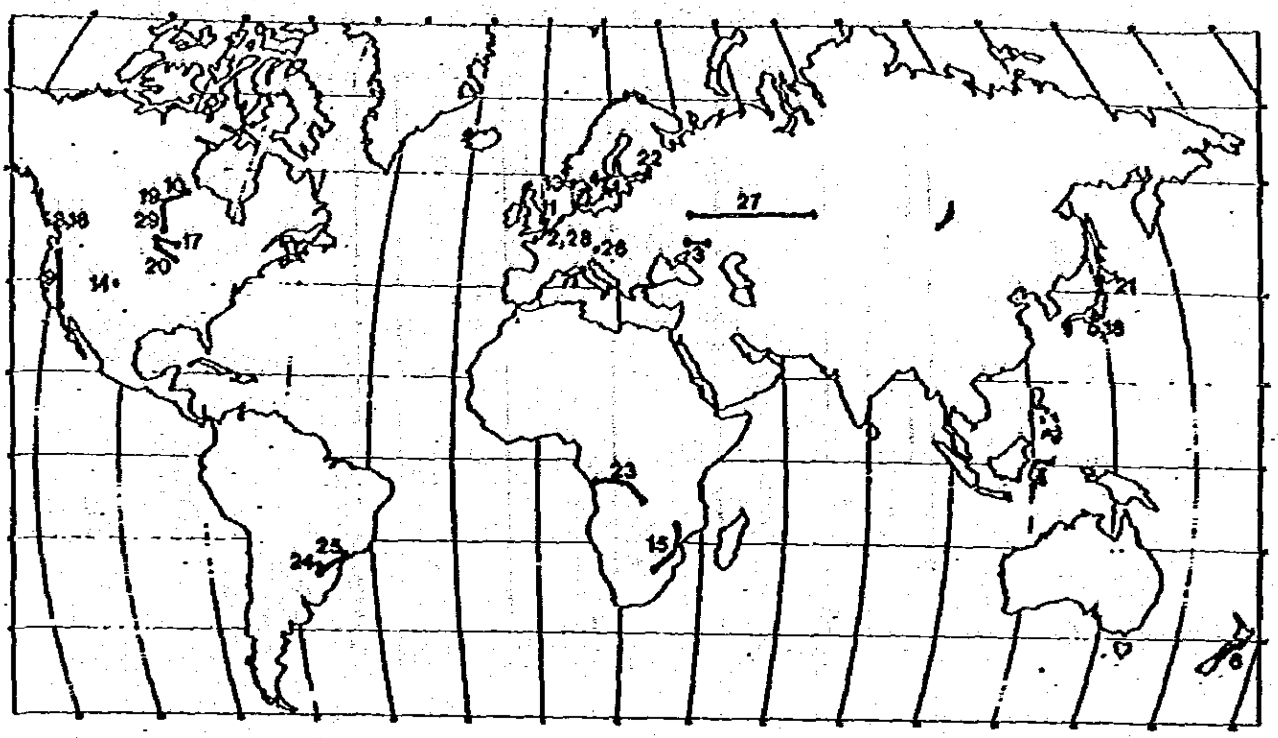
DC power transmission projects in the world (as of 1979) are shown in Fig. A-4-3. It indicates that DC power transmission has been positively used in the past two or three decades.

Based on the achievements of these projects, it is anticipated that penetration of DC power transmission will rapidly increase in the future. The total equipment value as of the end of 1979 is as much as 12,000 MW as shown in Fig. A-4-4.

What calls the attention of the world at the present time is Itaipu Project in Brazil. It is a huge project of transmission power of

6,300 MW, transmission voltage ±600 kV and transmission distance about 800 km. Construction works are in progress in a good order, and it is scheduled that the entire facilities will be completed in 1985.

Fig.A-4-3 HVDC systems in service, under construction or active consideration (situation as of October 1979)



No	HVDC system	Transmission Distance km: Overhead line	Cable	Total	Rated voltage kV x No. of circuits	Nominal capacity MW	Max. continuous capacity MW	Commissioning date	Comment
a)	Mercury-arc valve systems in operation								
1	Gotland - Swedish Mainland	0	96	96	150	30	30	1954/70	Thyristor bridge extension 1970
2	Cross Channel 1 (GB-F)	0	2x32-0	65	± 100	160	160	1961	
3	Volgograd - Donbass (SU)	470	0	470	± 400	720	720	1962-65	
4	Konti-Skan (DK-S)	95+85	25+60	180	250	250	250	1965	
5	Sakuma (J)	-	-	-	125x2	300	300	1965	50/60 Hz tie
6	New Zealand (NZ)	535+35	39	609	± 250	600	600	1965	
7	Sardinia - Italian Mainland	86+156+50	16+105	413	200	200	200	1967	Corsica tapping 1984/85
8	Vancouver Pole 1 (CDN)	total 41	total 33	74	+ 260	312	312	1968/69	
9	Pacific Intertie (US)	1362	0	1362	± 400	1440	1440	1970	Extension 1984 to ± 500 kV, 2000 MW
10	Nelson River Bipole 1 (CDN)	890	0	890	± 450	1620	1620	1973-77	
11	Kingsnorth (GB)	0	59+23	82	± 266	640	640	1975	Conurbation in-feed
b)	Thyristor valve systems in operation								
12	Eel River (CDN)	-	-	-	80 x 2	320	350	1972	Asynchronous tie
13	Skagerrak (DK-N)	113+??	127	240	± 250	500	500	1976/77	Extension to 1000 MW possible
14	David A. Hamil (US)	-	-	-	50	100	110	1977	Asynchronous tie
15	Cabora Bassa - Apollo (MOC-ZA)	1414	0	1414	± 533	1920	1920	1977-79	
16	Vancouver Pole 2 (CDN)	total 41	total 33	74	- 280	370	476	1977/79	
17	Square Butte (US)	749	0	749	± 250	500	550	1977	
18	Shin-Shinano (J)	-	-	-	125x2	300	300	1977	50/60 Hz tie
19	Nelson River Bipole 2 (CDN)	930	0	930	± 250	900	1000	1978	Final stage 1985: ± 500 kV, 1800 MW
20	CU (Underwood-Minneapolis, US)	710	0	710	± 400	1000	1100	1979	
c)	Thyristor valve systems under construction or active consideration								
21	Hokkaido - Honshu (J)	[illegible]	44	168	125	150		1979	Final stage: ± 250 kV, 600 MW
22	USSR-Finland	-	-	-	± 85x3	1070		1981	Asynchronous tie
23	Inga - Shaba (Zaire)	1700	0	1700	± 500	560		1981	Final stage: ± 500 kV, 1120 MW
24	Acaray (PY-BA)	-	-	-	26	50		1981	50/60 Hz tie
25	Itaipu (BR)	783/806	0	783/806	± 600x2	6300		1983-85	
26	Dürnrohr (A)	-	-	-	NA	550		1983	Asynchronous tie
27	Ekibastuz - Centre (SU)	2400	0	2400	± 750	6000		1984	
28	Cross Channel 2 (GB-F)	0	17+45+3	64	± 270x2	2000		1984	
29	Nelson River Bipole 3 (CDN)	930	0	930	± 500	2000		1990	

NA No data available

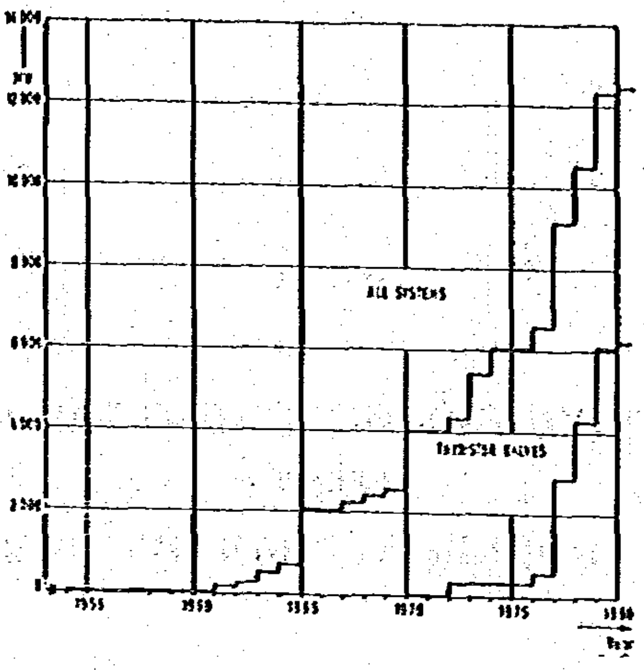


Fig.A-4-4 Development of the total installed capacity of HVDC systems until 1980

A — 5

ULTRA-RAPID RESPONDING EXCITATION
WITH
POWER SYSTEM STABILIZER (PSS)

A-5 ULTRA-RAPID RESPONDING EXCITATION WITH POWER SYSTEM STABILIZER (PSS)

The ultra-rapid responding excitation system is designed to help improvement of both transient and dynamic stability of the generator through its quick and proper control over the exciter by catching up with voltage fluctuation at generator terminal under system disturbance.

In order to improve transient stability by exciter, it is necessary to lift up quick respondability and ceiling voltage of the excitation system including AVR since the field circuit of the generator has large time constant. For this reason, the ultra-rapid responding excitation system makes use of either thyrister exciter or high-speed responding brushless exciter which is featured by much higher performance characteristic than the conventional type, so that quick respondability of the excitation system has been enhanced and ceiling voltage on the excitation system has been boosted up close to the allowable insulating limit for the generator field circuit.

Whilst respondability of the excitation system in quickened, the initial wave of Generator Swing-curve becomes small after occurrence of the system failure and, as a result, its transient stability can be improved, it may cause, on the other hand, the dynamic stability to decline and the damping degree of swing by and after the subsequent second wave to be deteriorated. To prevent this, the ultra-rapid responding excitation system is equipped with the power system stabilizer to improve the dynamic stability.

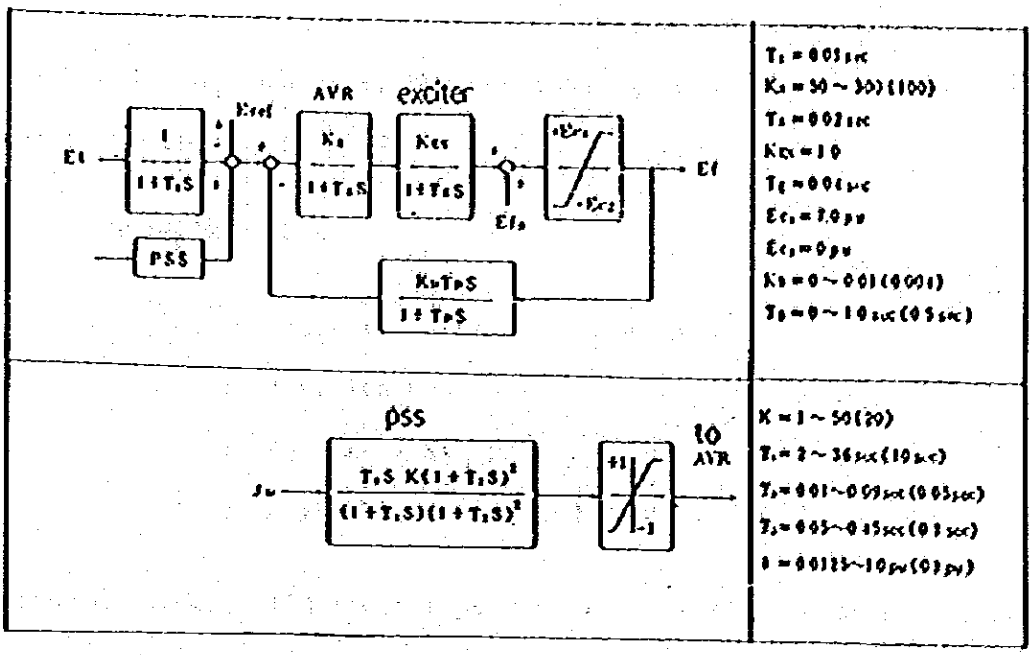
Power System Stabilizer

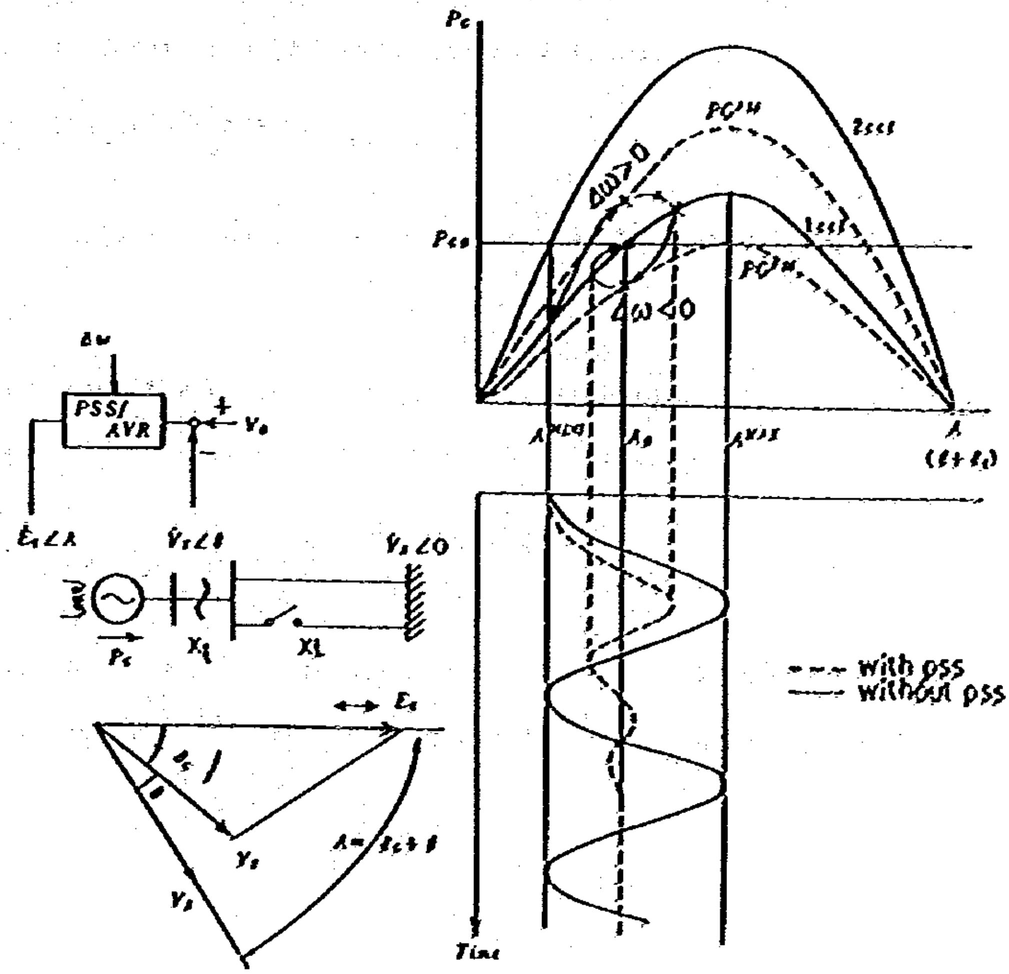
Since the power system stabilizer can be expected, as compared with any other conventional type of stabilizers, to perform its greater improving effect at less capital investment, it has become of wide acceptance to hydro power, thermal power and nuclear power generating units. By classification of its detecting method, the power system stabilizer may be divided into three different types, such as Δf (frequency deviation detection type), Δp (power deviation type) and Δw (phase angle speed deviation type). Their actions are based commonly upon the same principle. If the detected value is 'plus' (which means that a generator is accelerating on account of line fault), the stabilizer is designed to act upon the AVR circuit to urge boosting-up of generator terminal voltage and sweep out accelerating energy of the generator rotor into the Power system. It goes into the reversed action if the generator is decelerating, so that damping of the generator can be intensified.

(Theoretical Principle of Power System Stabilizer)

Assuming that one circuit would be opened in the model of single-unit infinite bus system as shown in the Fig. A-5-1, the phase angle of generator would continue its swing between A^{MIN} and A^{MAX} at Ao as the center point, if impedance variation and damping of the generator could

Fig.A-5-1 Principle of PSS





be ignored. In such case, the generator output PG can be attained from the following formula:

$$PG = \frac{Eq \cdot V_B}{X} \text{ SIN } A$$

Where, Eq : Internal voltage of generator

V_B : Infinite bus voltage

X : Xq + Xt + Xℓ

A : Angle between Eq and V_B

In the drawing, solid lines represent F_G as against A in the above formula in the case of power transmission by way of single circuit or double circuit. If the power system stabilizer is installed, the preceding formula should be changed as follows:

$$F_G^{PSS} = \frac{(Eq + \Delta E) \cdot V_B}{X} \text{ SIN } A$$

This is equivalent to the curve represented by dotted lines in the drawing.

In this case, the generator internal voltage Eq can be controlled by the stabilizer as expressed by the following formula:

$$\frac{\Delta E}{\Delta A} > 0 \quad , \quad \Delta w = \frac{\Delta A}{\Delta t}$$

Namely, $PG^{PSS} > PG$ is attained if the generator is accelerating ($\Delta W > 0$) and $PG^{PSS} < P_G$ if the generator is decelerating ($\Delta w < 0$).

Even if one circuit is opened, the angle A can reach the stable equilibrium point Ao promptly in whirl, after passing near before A^{MAX} from A^{MIN} as traced by arrow marks.

At this time, timing for control upon internal voltage Eq as against change of the angle A becomes a matter of importance. This is because time lag in the excitation system and the field circuit must be properly compensated against frequency in swing.

A—6

LIST OF DATA AND INFORMATION COLLECTED

A-6 List of Data and Information Collected

No.	Data and Information Collected		Remarks
1	Mak-Ban Geothermal Power Plant	1 book	Submitted by NAPOCOR
2	Implementation Schedule for various projects for Leyte-Samar Development	1	"
3	Daraga 50 MVA Substation Relaying and Metering single line diagram	1	"
4	Location map (Legaspi sub-area)	1	"
5	Tongonan Geothermal Power Plant & Central Switching Station	1	"
6	High Voltage Substation Equipment Technical Provisions	1 book	"
7	Tongonan Geothermal Power Station Preliminary Design Report Draft Part 1 and Part 2	1	"
8	VHF/FM Existing Visayas Communication Network	1	"
9	Proposed Luzon Regional Communication Network	1	"
10	" Visayas "	1	"
11	" Mindanao "	1	"
12	Allocation of P.L.C Equipment	1	"
13	Toropical Cyclon Summeries '48-'78	1 book	Submitted by PAGASA
14	Significant Philippine Earthquakes	1 book	Submitted by NAPOCOR
15	Potential Geothermal Areas	1	"
16	Bulk Substations Forcasted Load	1 set	"

No.	Data and Information Collected		Remarks
17	Generation Expansion Program Leyte-Samar Grid	1	Submitted by NAPOCOR
18	Projected Construction Schedule Luzon Power Grid	1	"
19	Power System Development Map	1	"
20	Luzon Grid. Historical and Projected Energy Generation and Peak Demand	1	"
21	Leyte-Samar Grid "	1	"
22	Historical and Projected Energy Generation and Peak Demand. 3-19-81	1	"
23	Historical Energy Sales & Forecast	1	"
24	NPC Generating Plants Luzon Grid	1	"
25	Single Line Diagram Southern Luzon 1981 - 1986	1 set	"
26	Generation Expansion Program Luzon Grid Updated Accelerated Program (Revised 27/Mar. '81)	1	"
27	Tongonan Geo. Construction Schedule	1	"
28	1979 Philippine Development Report	1 book	"
29	Philippine Economic Indicators Dec. 1979	1 book	"
30	" Dec. 1980	1 book	"
31	Annual Report, National Power Corporation 1977	1 book	Submitted by NAPOCOR
32	" 1978	1 book	"
33	" 1979	1 book	"
34	Power Expansion Program Agu. 1980	1 book	"

No.	Data and Information Collected		Remarks
35	Energy Generation & Sales Statistics	1 book	Submitted by NAPOCOR
36	PLC Frequency Allocation	1 book	"
37	Rating and Characteristics of Existing and Proposed Transmission Lines	1 set	"
38	" Substations	1 set	"
39	" Power Stations	1 set	"
40	Sailing Directions	1 set	
41	Nautical Charts	1 set	
42	Geographical Map of the Philippines	1 set	
43	Topographical Maps (Scale : 1 to 50,000, 1 to 250,000)	1 set	

A—7

ACTUAL FIELD INVESTIGATION SCHEDULE

A-7 Actual Field Investigation Schedule

1. 1st Field Investigation (March 2-31, 1981)

a) Group A : Transmission Line & Converter Stations Survey Team

Date/Day	Description	Member	Lodging
Mar. 2 (Mon.)	Arriving at Manila	H. Kitazawa K. Kamikawaji	Manila "
3 (Tue.)	Courtesy call at the Embassy of Japan, JICA Office and NAPOCOR Office.	M. Sakai Y. Inoue M. Sato	" " "
4 (Wed.)	Discussion about scope of work of the Project and field survey schedule of the Survey Team		Manila
5 (Thu.)	Data collection at NAPOCOR office		Manila
6 (Fri.)	Manila-Legaspi Allen-Legaspi by Helicopter — Legaspi — H.Kitazawa M. Sato	Data collection at NAPOCOR office	Manila
	[Legaspi C.S. site, T.L. Route, Electrode sites]	K. Kamikawaji M. Sakai Y. Inoue	
7 (Sat.)	Cable landing sites (Luzon side) — Sorsogon	Arrangement of Data	Manila
8 (Sun.)	Ditto (Samar side) — Legaspi	Ditto	Manila
9 (Mon.)	Legaspi-Tongonan Cebu by Helicopter — Cebu [T.L. Route, Jaro C.S. site]	HELALCO dispatching center and MAK-BAN G.T.P.S.	Cebu

Date/Day			Description	Member	Lodging
Mar.	10	(Tue.)	Visiting the Cebu Regional Office Cebu City S.S. and Cebu G.T.P.S.		Cebu
	11	(Wed.)	Cebu-Tacloban by Plane		Tacloban
	12	(Thu.)	Jaro C.S. site, Electrode site T.L. Route and Tongonan P.S.		Ormoc
	13	(Fri.)	San Juanico Strait		Tacloban
	14	(Sat.)	Tacloban-Catbalogan (Samar)		ditto
	15	(Sun.)	Tacloban-Allen-Sorsogon		Sorsogon
	16	(Mon.)	Submarine Cable route by ship (Matnog-Allen)		ditto
	17	(Tue.)	Submarine Cable landing site (Samar side)		ditto
	18	(Wed.)	ditto (Luzon side)		Legaspi
	19	(Thu.)	Visiting Daraga S.S. and Tiwi G.T.P.S. (Legaspi C.S. site)	H. Kitazawa K. Kamikawaji M. Sakai	ditto
	20	(Fri.)	Visiting Daraga S.S. and Electrode Site (Donsol)	Y. Inoue M. Sato	ditto
	21	(Sat.)	Electrode site (Paliqui Bay) by ship		ditto
	22	(Sun.)	Legaspi-Manila by Plane		Manila
	23	(Mon.)	Data collection at NAPOCOR office		Manila
	24	(Tue.)	ditto		ditto
	25	(Wed.)	Arrangement of data and Survey result		
	26	(Thu.)	ditto		ditto

Date/Day		Description	Member	Lodging
Mar. 27	(Fri.)	Explanation of results of survey and discussion with NAPOCOR		Manila
28	(Sat.)	Checked & reviews of survey report		Manila
29	(Sun.)	ditto		ditto
30	(Mon.)	Explanation to NAPOCOR and JICA		ditto
31	(Tue.)	Courtesy call to the Embassy of Japan, JICA office Leaving for Tokyo		

b) Group B : Submarine Cable Survey Team

Member : Y. Yamaguchi
Y. Watanabe
T. Ohmura
K. Shimo

Date/Day			Description	Lodging
Mar.	2	(Mon.)	Arrival of 1st Group (Y.Yamaguchi & Y. Watanabe)	Manila
	3	(Tue.)	Curtesy call to Embassy, JICA & NAPOCOR	Manila
	4	(Wed.)	Meeting with NAPOCOR	Manila
	5	(Thu.)	Meeting with NAPOCOR, Arrival of 2nd Group (T. Ohmura & K. Shimo) at Manila	Manila
	6	(Fri.)	Movement to Legaspi Hiring negotiation of survey boat	Legaspi
	7	(Sat.)	Movement to Sorsogon Preparation of survey materials Field survey of cable landing sites in Luzon	Sorsogon
	8	(Sun.)	Measurement of base points Field survey of cable landing sites in Samar	Sorsogon
	9	(Mon.)	Equipment of the survey boat Measurement of the base points	Sorsogon
	10	(Tue.)	Submarine cable route survey (No work due to heavy waves)	Sorsogon
	11	(Wed.)	-do-	Sorsogon
	12	(Thu.)	Submarine cable route survey (No. 1 to No. 3)	Sorsogon
	13	(Fri.)	-do- (No. 4 to No. 6)	Sorsogon
	14	(Sat.)	-do- (No. 7 to No. 12)	Sorsogon

Date/Day		Description	Lodging
Mar. 15	(Sun.)	Submarine cable route survey (No. 13 to No. 19)	Sorsogon
16	(Mon.)	-do- (No. 20 to No. 21)	Sorsogon
17	(Tue.)	-do- (No. 22 to No. 26)	Sorsogon
18	(Wed.)	Submarine cable route survey (No. A & B) Sampling of seabed sand/soil	Sorsogon
19	(Thu.)	Sampling of seabed sand/soil	Sorsogon
20	(Fri.)	-do-	Sorsogon
21	(Sat.)	Sampling of seabed sand/soil Observation of tide way	Sorsogon
22	(Sun.)	Measurement of base points	Sorsogon
23	(Mon.)	Submarine cable route survey (No. 27 to No. 28) Removal of the survey equipment from the boat	Sorsogon
24	(Tue.)	Packing of the survey equipment Arrangement of collected data (Y. Yamaguchi) Movement to Legaspi Cancellation of base contract of the boat	Sorsogon/ Legaspi
25	(Wed.)	Cancellation of base contract of the boat Movement to Manila	Manila
26	(Thu.)	Arrangement of collected data	Manila
27	(Fri.)	Arrangement of collected data Meeting with NPC	Manila
28	(Sat.)	Arrangement of collected data	Manila
29	(Sun.)	Arrangement of collected data	Manila
30	(Mon.)	Courtesy call to Embassy, JICA & NAPOCOR	Manila
31	(Tue.)	Leaving for Tokyo	

c) Group C : Economic Study Team

Member : K. Yanagisawa

Date/Day			Description	Lodging
Mar.	5	(Thu.)	Arriving at Manila	Manila
	6	(Fri.)	Courtesy call to Embassy, JICA & NAPOCOR	Manila
	7 to 13		Data collection	Manila
	14	(Sat.)	Manila-Legaspi-Sorsogon	Sorsogon
	15	(Sun.)	Inspection of seabed survey	Legaspi
	16	(Mon.)	Legaspi-Manila	Manila
	17	(Tue.)	Data collection	Manila
	18	(Wed.)	Manila-Tacloban-Tongonan-Ormoc Visiting Tongonan Geothermal Site	Ormoc
	19	(Thu.)	Ormoc-Isabel-Tacloban visiting PASAR & PHILPHOS sites	Tacloban
	20	(Fri.)	Tacloban-Manila	Manila
	21 to 25		Data collection	Manila
	26	(Thu.)	Arrangement of collected data	Manila
	27	(Fri.)	Meeting with NPC	Manila
	30	(Mon.)	Courtesy call to EOJ, JICA & NAPOCOR	Manila
	31	(Tue.)	Leaving for Tokyo	

2. 2nd Field Investigation (July 5-25, 1981)

Member : H. Kitazawa
T. Iso
M. Sakai

Date/Day			Description	Lodging
July	5	(Sun.)	Tokyo - Manila	Manila
	6	(Mon.)	JICA, Embassy, NAPOCOR	"
	7	(Tue.)	NAPOCOR	"
	8	(Wed.)	NAPOCOR	"
	9	(Thu.)	Manila - Tacloban, San Juanico Straigt	Tacloban
	10	(Fri.)	Jaro - Carigara	"
	11	(Sat.)	Tacloban - Manila	Manila
	12	(Sun.)	Manila	"
	13	(Mon.)	Manila - Naga - Legaspi	Legaspi
	14	(Tue.)	Legaspi - Sorsogon	Sorsogon
	15	(Wed.)	Sorsogon - Matnog	"
	16	(Thu.)	Sorsogon - Allen - Legaspi	"
	17	(Fri.)	Legaspi - Manila	Manila
	18	(Sat.)	NAPOCOR	"
	19 - 24		NAPOCOR	"
	25	(Sat.)	Manila - Tokyo	

3. 3rd Field Investigation (Oct. 7-21, 1981)

Member : K. Ozawa
H. Kitazawa
T. Iso
A. Tanaka

Date/Day			Description	Lodging
Oct.	7	(Wed.)	Tokyo - Manila (PR431)	Manila
	8	(Thu.)	Japan Embassy, JICA, NPC I/A Amendement	"
	9	(Fri.)	NAPOCOR, Preparation of site investigation	"
	10	(Sat.)	Mak-Ban Geothermal Power Plant	"
	11	(Sun.)		"
	12	(Mon.)	Manila - Naga for Naga C/S by RP Domestic Airline	Naga
	13	(Tue.)	Naga Electrode site in Pasacao by Cars	Naga
	14	(Wed.)	Electrode site in Santa Rosa-Bonat and Naga Legaspi by Cars	Legaspi
	15	(Thu.)	Legaspi - Matnog - Legaspi by cars for Cable Site	"
	16	(Fri.)	Legaspi - Manila by PR Domestic Airline	Manila
	17	(Sat.)	Making Report for Site Investigation	"
	18	(Sun.)	Making Report for Site Investigation	"
	19	(Mon.)	Report on the Investigation, Discussion on the Basic Design with NAPOCOR Report to JICA	"
	20	(Tue.)	Discussion with NAPOCOR, Report to JICA	"
	21	(Wed.)	Manila - Tokyo	

A – 8

ECONOMIC EVALUATION

A-8 ECONOMIC EVALUATION

The economic viability of the project has been assessed using annual oil savings as the economic benefit. The oil savings is realized from the non operation of existing oil thermal plants located in the Greater Manila Area.

1. Calculation of Equivalent Available Supply Energy

GWH Generation of Tongonan- Station Service and Transmission line Losses
= Energy Sales in Luzon

Generation of Oil fired thermal plant in Luzon =
Energy Sales (Tongonan) + Station Service Loss

e.g. 3338 x 0.93 = 3,104.34 energy sales in Luzon
3104.34 x 1.05 = 3,259.56

2. Calculation of Oil Savings Unit Cost

<u>Data</u>

$34/barrel
600 KWH/barrel
$34 ÷ 600 KWH/barrel = 0.0567 $/KWH

3. Calculation of EIRR

Linear Interpolation between 10% and 13%

DISCOUNTED COST AND BENEFIT STREAMS

YEAR		8 % D.R. COST OF HVDC/ PLANT	8 % D.R. BENEFIT	10 % D.R. COST OF HVDC/ PLANT	10 % D.R. BENEFIT	13 % D.R. COST OF HVDC/ PLANT	13 % D.R. BENEFIT
1982	3	2.9	-	3.1	-	3.3	-
1983	2	38.3	-	39.7	-	41.9	-
1984	1	173.9	-	177.1	-	181.9	-
1985	0	43.3	-	43.3	-	43.3	-
1986	1	140.7	171.1	138.2	168.0	134.5	163.6
1987	2	130.4	153.0	125.7	147.5	119.1	139.8
1988	3	150.0	145.3	142.0	137.5	131.0	126.8
1989	4	179.5	133.7	166.8	124.3	149.8	111.6
1990	5	141.1	123.0	128.7	112.2	112.5	98.1
1991	6	136.5	168.6	122.3	151.0	104.0	128.5
1992	7	167.8	206.5	147.6	181.6	122.2	150.4
1993	8	175.4	214.3	151.5	185.1	122.1	149.2
1994	9	161.9	197.7	137.3	167.6	107.8	131.5
1995	10	149.2	182.1	124.2	151.6	94.9	115.8
1996	11	138.1	168.6	112.9	137.8	84.0	102.5
1997	12	127.9	156.1	102.6	125.3	74.3	90.7
1998	13	118.4	144.5	93.3	113.9	65.8	80.3
1999	14	109.7	133.8	84.8	103.5	58.2	71.0
2000	15	101.5	123.9	77.1	94.1	51.5	62.9
2001	16	94.0	114.7	70.1	85.6	45.6	55.6
2002	17	87.1	106.2	63.7	77.8	40.3	49.2
2003	18	80.6	98.4	57.9	70.7	35.7	43.6
2004	19	74.6	91.1	52.7	64.3	31.6	38.5
2005	20	69.1	84.3	47.9	58.4	28.0	34.1
2006	21	64.0	78.1	43.5	53.1	24.7	30.2
2007	22	59.2	72.3	39.6	48.1	21.9	26.7
2008	23	58.0	67.0	38.0	43.9	20.5	23.6
2009	24	58.1	62.0	37.4	39.9	19.6	20.9
2010	25	51.1	57.4	32.3	36.3	16.5	18.5
2011	26	43.5	53.1	27.0	33.0	13.4	16.4
2012	27	40.3	49.2	24.6	30.0	11.9	14.5
2013	28	39.0	45.6	23.3	27.3	11.0	12.8
2014	29	38.4	42.2	22.5	24.8	10.3	11.4
2015	30	34.1	39.1	19.7	22.5	8.8	10.0
		3277.6	3482.9	2718.4	2816.7	2141.9	2128.7

EIRR = 12.64%

	COST OF HVDC						COST OF TONGONAN GEOTHERMAL PLANT				BENEFIT COST	
YEAR	AVAILABLE SUPPLY ENERGY (GWH)	LOSS FACTOR (%)	LOSS ENERGY (GWH)	CAPITAL INVESTMENT (10^6 US $)	O & M COST (10^6 US $)	LOSS COST (10^6 US $)	GEN. CAPACITY (MW)	O & M COST (10^6 US $)	STEAM COST (10^6 US $)	TOTAL COST (10^6 US $)	EQUIVALENT AVAILABLE SUPPLY ENG. (GWH)	OIL SAVING COST (10^6 US $)
1982				2.3						2.3		
1983				32.8						32.8		
1984				161.0						161.0		
1985				43.3						43.3		
1986	3,338	11.6	387	0	5.4	19.3	440	10.5	116.0	152.0	3259.56	184.82
1987	3,223	11.6	385	0	5.4	19.2		11.2	116.3	152.1	3147.26	178.45
1988	3,305	11.6	383	36.8	5.4	19.1		12.0	115.7	189.0	3227.33	182.99
1989	3,286	11.6	381	92.0	5.4	19.0		12.8	115.0	244.2	3208.78	181.94
1990	3,263	11.6	378	55.1	5.4	18.9		13.7	114.2	207.3	3186.32	180.66
1991	4,832	7.7	371	0	7.8	18.5	220	21.5	168.8	216.6	4718.45	267.54
1992	6,392	8.4	936	0	7.8	26.8	220	29.3	223.7	287.6	6241.79	353.91
1993	7,165	9.2	659	0	7.8	32.9	110	33.2	250.8	324.7	6996.62	396.71
1994	7,137	9.2	656	0	7.8	32.8		33.2	249.9	323.7	6969.28	395.16
1995	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
1996	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
1997	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
1998	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
1999	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2000	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2001	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2002	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2003	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2004	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2005	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2006	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2007	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2008	7,100	9.2	653	18.6	7.8	32.6		33.2	248.5	340.7	6933.15	393.11
2009	7,100	9.2	653	46.6	7.8	32.6		33.2	248.5	368.7	6933.15	393.11
2010	7,100	9.2	653	27.9	7.8	32.6		33.2	248.5	350.0	6933.15	393.11
2011	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2012	7,100	9.2	653	0	7.8	32.6		33.2	248.5	322.1	6933.15	393.11
2013	7,100	9.2	653	14.1	7.8	32.6		33.2	248.5	336.2	6933.15	393.11
2014	7,100	9.2	653	35.3	7.8	32.6		33.2	248.5	357.4	6933.15	393.11
2015	7,100	9.2	653	21.1	7.8	32.6		33.2	248.5	343.2	6933.15	393.11

JICA