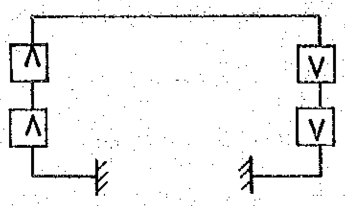
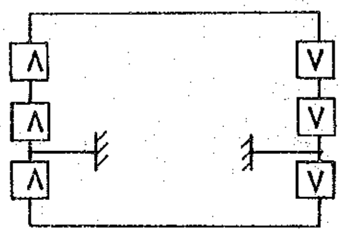
d) In case of failure in one pole or scheduled maintenance (12-pulse operation)



450 MW

e) In case of failure in one group (12-pulse + 6-pulse operation)



675 MW

Besides, the system can be operated in the pattern of either (a) or (b). In the event that the operation pattern is shifted from (c) to (a), (b) or (e), such changeover must be made after the faulty pole is once put into stoppage.

6.1.5 HVDC System Operation

(1) System Composition

One single system will be made up in each monopole unit and, wherever possible, independently so as to ensure improvement of reliability.

(2) Transmission Direction

The system will be so designed as to permit bidirectional transmission. For the time being, however, power will be transmitted in a one-way direction (Jaro C/S → Naga C/S). In case of the reverse way from Naga C/S to Jaro C/S, the required short-circuit capacity at the Jaro side will be about 3 to 5 times as much as required for DC transmission capacity.

(3) DC Rated Output

DC rated output will be defined on the line side of the direct-current reactor at the converter station of sending end.

(4) Minimum DC Continuous Output

Minimum DC continuous output aims at 10 percent of rated output; 22.5 MW at one-group operation and 45 MW at two-group operation. However, the system will be put into operation at zero power factor for a short time because of need to enter into coordinative operation with power output from Tongonan Power Plant.

(5) Fundamental Control System

a) Power will be controlled on the rectifier side (Jaro side) and DC voltage will be regulated on the inverter side (Naga side).

b) Setting value for power output should include additional output from frequency constant control on Jaro side so that the Power Setting Switch (PSS) can be well coordinated with generator output at Tongonan Power Plant.

c) Sett ng value for power output will be calculated on Jaro side and transmitted to Naga by means of high-speed CDT.

(6) Operation in the Event of DC Transmission Line Failure (ground fault)

In this case, the pole in trouble will be restarted after short time stoppage in its operation. During the time of such stoppage, the sound pole will be operated with overload within the permissible range of the valve so as to restrain possible speed increase of the generator at Tongonan Power Plant.

(7) Operation in the Event of the Connected AC Line Failure

Power conversion on both poles will be suspended for a while after detection of voltage drop and put back to the original state immediately after recovery from voltage drop. In any case of failure at sending end, operation must continue as long as possible without suspension.

(8) Operation in the Event of AC Filter Failure

a) 1st stage

i) In case of fault in #11, #13 and HP filter units, the converter will be taken out of operation.

ii) In case of fault in #5 and #7 filters, the converter will be taken out of operation only at the time of 6-pulse operation.

b) 2nd stage

i) In case of fault with a single unit out of six (6) units in #11, #13 and HP filters, operation can still continue at 50 percent load.

ii) In case of fault in #5 and #7 filters, the pole in 6-pulse operation will be put into stoppage.

(9) Transmission Line Failure between Jaro C/S and Tongonan S/Y

In case of failure on one circuit, the HVDC system can be operated at 100 percent load.

(10) Jaro Converter Station will be given the role as the main control station for the operation of the HVDC system.

6.2 Transmission Line

6.2.1 Climate Conditions

In the design of the overhead transmission line, it is a matter of importance to acquire full knowledge about the local climate conditions including wind velocity and air temperature etc. Especially, wind velocity is an extremely important factor of grave influence to economy and reliability of the overhead transmission line.

Since the Philippine Islands are located at a low latitude, the local climate is featured by a tropical weather pattern of very little temperature variation all the year round and much rainfall due to high temperature and moisture and seasonal wind below. Typhoon hits the Philippine Islands very frequently, say about 20 times a year at average in close proximity to or within the influential area of the Philippines.

Meteorological study has been made from the observation data locally available on such specific items as wind velocity, temperature and number of thunder-storm days which should be incorporated into the transmission line design. Study result are outlined hereunder.

a) Wind Velocity

The proposed transmission line route for this project will extend over a long distance of about 455 km, in which the overhead line is of 432 km, starting from Tongonan Switch Yard located at the northern part of Leyte Island and terminating at Naga Converter Station after passing through the western part of Samar Island. The area which the route will pass through is influenced most heavily by typhoon among many islands of the Philippines. In particular, in the northern part of Samar Island and in the southern part of Luzon Island strong wind blows very frequently and wind of high velocity is recorded.

Normally, in the case of the important transmission line which should require high reliability the design consideration must be given at least, on 50-year probability basis in the forecast of wind velocity. According to this normal design practice, therefore, the wind velocity has been estimated on the 50-year probability basis by due reference to the past recorded data on annual maximum wind velocity available from each local observation station near the proposed overhead transmission line route and the standard design criteria of NAPOCOR.

From the result of study, it is estimated that the extreme limit of wind velocity (gust) withstood by supporting towers of the overhead transmission line would be about 226 kPH at station of Catbalogan, Catarman and Legaspi and about 187 kPH at Tacloban.

Those values are considered acceptable to the design, not only in view of reliability for the overhead transmission line of the project and the local climatic condition with many incidences of typhoon in the proposed area, but also even by comparision with the designed (gust) velocity of 185 kPH for the AC 230 kV overhead transmission line proposed in Luzon by NAPOCOR.

After review of the result, it has been decided that the overhead line between Jaro and Naga (except the overhead line across San Juanico Strait) will be designed at the designed wind velocity (gust) of 220 kPH and the overhead lines across San Juanico Strait and AC 138 kV overhead line between Tongonan S/Y and Jaro C/S will be designed at a velocity (gust) of 185 kPH referring estimation from the result at the station of Tacloban.

b) Air Temperature

Air temperature in Legaspi is 37.2°C at maximum and 16.4°C at minimum. With due consideration to the regional and altitudinal difference temperature may be 40°C at maximum and 10°C at minimum for project.

Since the design criteria of NAPOCOR provides maximum temperature at 48.9°C and minimum temperature at 7.2°C, the design for the transmission line of the Project has adopted the same figures at both maximum and minimum temperature degrees, or 48.9°C and 7.2°C.

c) Number of Thunderstorm Days

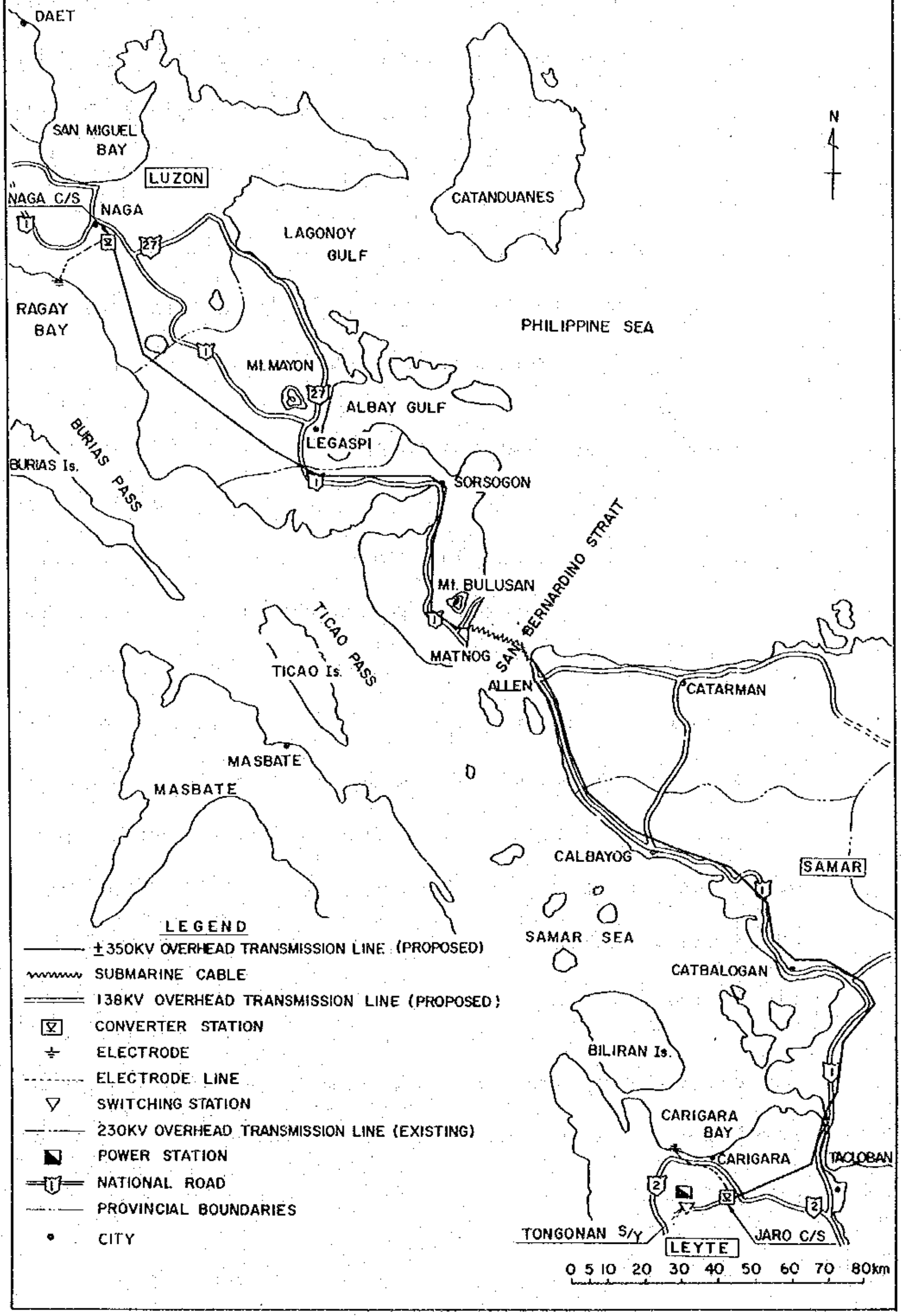
Number of thunderstorm days is registered at 69.5 days in Tacloban City and 35.5 days in Legaspi City. The design of the transmission line under this Project is based upon 55 days a year.

6.2.2 DC Overhead Transmission Line

(1) Overhead Transmission Line Route

The proposed route for the DC overhead transmission line of the Project extends over a distance of 429 km from Jaro C/S at the northern part of Leyte to Naga C/S at the southern part of Luzon by way of the western part of Samar Island. This transmission line between Jaro and Naga Converter

Fig.6-1 TRANSMISSION LINE ROUTE



Stations will cross San Juanico Strait (Leyte ∿ Samar) and San Bernardino Strait (Samar ∿ Luzon), in addition to three islands and they may be divided into three different categories such as overhead line section on land, overhead line section across strait and submarine cable section.

The proposed route for the overhead transmission line in Leyte, Samar and Luzon is summarized as described hereunder. The route of the transmission line is shown in Fig. 6-1.

The route proposed for the section from Jaro C/S is on the nearly flat area all the way to the starting point of the straits crossing at San Juanico strait, except the mountainous area on the border between the Leyte Province and Tacloban City. In order to facilitate construction and maintenance of the transmission line, the route would inevitably make a detour toward the south of this mountainous zone at a relatively low elevation. The flat area has a wide expansion of paddy field and coconut plantation and there exists no other way of detour to avoid the paddy field area.

The route across Samar Island, from the starting point of straits crossing to the submarine cable terminal point of San Bernardino strait, runs nearly in parallel with the

National Highway No. 1 and passes through the hilly zone almost all the way. Since the route runs in close approach to the coastal line in the most part of the whole section, it must be selected on as far inland side as possible or at a relatively high elevation zone with a view to preventing possible salt contamination on insulators of the transmission line.

There exist exposures of rock above the ground surface between Calbayog and Lipata as the submarine cable terminal point. In the judgement from the geological maps, it is estimated that the local geology in this section should consist mainly of andesite and basalt.

The route starting from the submarine cable terminal in Luzon Island runs nearly in parallel with the National Highway No. 1 making detour on the western side of Bulusan Volcano situated at the extreme south of Luzon Island. Then, it goes further in almost straight line from Putiao at the northern part of Sarsogon Prevince and reaches Naga converter station after making detour on the western side of Lake Bato. In this section the route passes through hilly or plain area in general.

In the section from the submarine cable terminal in Luzon at Sorsogon there are to be considered two alternative routes of making detour on the western side or the eastern side of Bulusan Volcano. The extreme southern area of Luzon is noted as the area heavily influenced by typhoon among all the Philippine islands. Furthermore, the route proposed on the eastern side of Bulusan Volcano looks out upon the Pacific Ocean and, therefore, salt contamination is expected to have a more severe effect on insulators from strong wind. Because of this contamination problem, this route is less advantageous than the other alternative. On the other hand, the other alternative proposed to take the western side of Bulusan Volcano is valued with more importance from high electrical reliability of the overhead transmission line, though it may be of less economic advantage because of additional 10 km for detour. After such comparison, the latter has been selected.

The proposed route for the DC overhead line from Jaro C/S to Naga is facing the sea, in many sections, being close to the coast. In selecting the route, therefore, consideration has been given to prevent line insulators from salt contamination as well as to facilitate both construction and maintenance. With these in mind, the route will pass through as far inland as possible or at high elevation area. It is anticipated, however, that insulation deterioration will be caused by salt contamination influenced by strong wind from the offshore. Since this problem must be considered most seriously in regard to electrical reliability of the transmission line, it will be necessary to carry out designing based on data obtained in the field.

Judging from the geological maps there would exist large or small fault lines in the proposed route. Suppose if steel towers are erected on top of such fault lines, bearing foundation might be displaced in the future. If such displacement should occur, it would affect reliability of the transmission line because the steel towers will be weakened by even minor displacement of the foundation, no matter how reliable the tower structure itself may be. Also, it would be impossible to stop any movement of the foundation once it should take place and relocation of the tower in trouble would be required. Therefore, it is very important to avoid fault lines in the proposed area for determination of tower location.

(2) Outline of Preliminary Design

i) Voltage and conductor

Voltage and conductor are designed, as stated in 5.4.2, at ±350 kV and ACSR 810 mm^2, double conductors.

The stringing conditions of conductors will be less than 22 percent in tensile strength of breaking strength at normal condition (15°C, no wind) and less than 40 percent at the worst condition in case of typhoon (7.2°C with wind (gust) velocity of 220 kPH, and a wind-pressure drop ratio of 0.6). It is recommended that the maximum horizontal tension should be designed at about 6,000 kg.

As a measure against conductor vibrations caused by light breezes, dampers and armar rods are to be provided at conductor supporting points.

ii) Insulators

As stated earlier, the proposed route for the overhead transmission line is close to the coast in many sections. Since it is anticipated that the insulation ability may be affected by salt accumulation on insulators by tidal wind, required number of insulators must be determined with due consideration of such influence.

In the case of the DC transmission line, the quantity of contamination may be higher than in the case of the AC transmission line, because of its dust collecting performance due to direct current charging, especially in the less polluting inland area with few salt contamination. On the other hand, in the heavy polluting area where the insulator will be affected directly by salt, the quantity of polluting adherence to insulators may be rather less influenced since adhesion will be dominated by rapid contamination due to strong wind.

In view of the fact that salt contamination to the insulator is varied largely in its quantity depending upon the local climate condition and the point of measurement, the survey by actual measurement of contamination should continue for a period of 2 to 3 years at as many points as possible in one specific area if it is intended to clarify the real state of insulator contamination in the designated area. Therefore, in determining required number of insulators, the possibility of contamination must be investigated thoroughly along the proposed area of the Project.

According to rough estimation of probable salt quantity from number of insulators in NAPOCOR's practice for the 230 kV transmission line as well as from the local climate condition that the washable effect of insulators is higher in the project area by frequent rain, as evidenced by the recorded annual rainfall, it may be reasonable to assume that such salt deposit on insulators would be about 0.12 mg/cm^2 in the seaside area and about 0.03 mg/cm^2 in the general inland area off the seaside.

On this basis, required number of insulators to withstand normal working voltage of 350 kV would be estimated at 46 fog-type insulators of 250 mm (5.65 cm/kV in surface leakage distance) in the seaside zone and 29 fog-type insulators of same size (3.56 cm/kV in surface leakage distance) in off-seaside zone. This preliminary design is based upon the number of insulators thus estimated.

In the case of the DC transmission line, the insulator pin may be deformed by influence of electrolytic·corrosion due to leaking current at plus direct current charging, thus probably affecting mechanical strength of the insulators. As a countermeasure, the normal practice is to adopt the pin with a zinc sleeve.

Therefore, in order to preserve mechanical reliability of insulators for the transmission line under the Project it is recommended that insulator pins with a zinc sleeve should be used for insulators.

iii) Clearance

Clearance designing for the DC transmission line must be determined from required insulation strength against internal abnormal voltage, allowing for occurrence of lightning surge to a certain extent. This principle is same as applicable to the AC transmission line.

Required clearance has been reviewed on the following assumed conditions:

- Internal abnormal voltage would be 1.7 pu mainly from overvoltage in the sound pole at the time of one pole fault.
- No arcing horn would be provided for each string of insulators since grounding current would be much less than that in the AC transmission system and could be fully compensated by arc-resisting performance of insulators.

- Each string of insulators would be of considerable length to meet design requirement against possible salt contamination. Since it would have very high insulating strength in normal operation, any insulating coordination between air gap to the tower and the insulators' string would be difficult. For this reason, the design should allow for possible flashover, to some extent, to the tower and the standard insulation clearance would be determined from the lightning protection design.

Maximum allowable voltage for the transmission line is predetermined at 350 kV herein to determine required clearance with due consideration to all the foregoing conditions. Required insulation clearance would be 320 cm at standard and 185 cm at minimum.

iv) Lightning protection design

Thunderstorm days a year amounts to 55 or so in the project area, and lightning strikes to the transmission line may probably occur 120 times a year per 100 km length of the line. Therefore, the lightning protection measures are to be provided.

As a step for this purpose, the conductor will be shielded from probable lightning strike estimated at

97 percent by overhead ground-wire of 70 mm^2 GSC in two wires with the shielding angle designed to be less than 25° against the conductor.

In order to restrain possibility of causing back-flash over into the conductor to possible minimum, in case of lightning strike to either tower or overhead ground wire, the volue for grounding resistance of the tower will be reduced toward the target value of 20Ω.

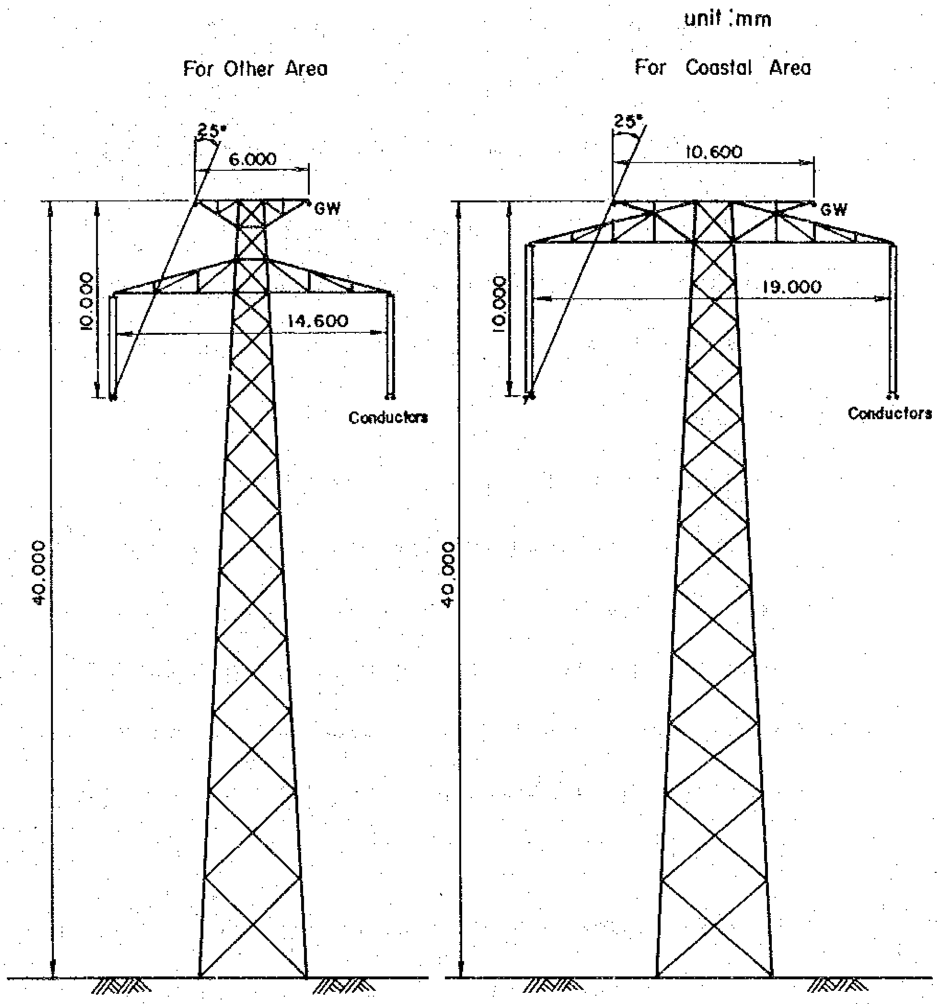
According to estimating the lightning fault rate from the lightning protection design as specified above, it is expected there will be 1.4 fault per 100 km annualy.

v) Supports

In view of the fact that reliability at a high level should be required for the overhead transmission line as connected with the major generating sources and the project area is exposed to frequent attacks of typhoon, angle steel towers will be used for supports, the typical configuration of steel towers are shown in Fig. 6-2.

In view of equal importance in the security of high reliability, the tower foundation is designed for concrete base with normal slab. Tower foundation in the rice

Fig.6-2 DC± 350KV TRANSMISSION LINE STANDARD TYPE SUSPENSION TOWER



field or in swampy areas may require extra reinforcement by piles according to the result from the geological investigation.

Designed wind (gust) velocity for towers will conform to the value of 220 KPH (61.1 m/s) as described in the foregoing item 6.2.1.

(3) Outline of DC Overhead Transmission Line

The following is the outline of preliminary design for the DC overhead transmission line in the islands of Leyte, Samar and Luzon.

Total length:	Leyte	32 km
	Samar	188 km
	Luzon	186 km
	Total	406 km (Including San Juanico strait crossing section)
Voltage:	DC ± 350 kV	
Electrical system:	Bipolar transmission, grounding at both ends of neutral point.	
No. of circuit:	Single circuit	
Conductor:	Two (2) conductors, each of 810 mm^2 ACSR	
Overhead ground-wire:	70 mm^2 GSC, 2 line	

Insulator:	250 mm fog type suspension insulator with zinc sleeve, 29 and 46 units a string
Supporting structure:	Angle steel tower
Foundation:	Concrete slab foundation

6.2.3 Overhead Transmission Line Across the San Juanico Strait

San Juanico strait between Leyte and Samar Islands is a narrow strait of 1 to 3 km in width and about 20 km in length, making free traffic possible between the two islands by way of Marcos Bridge. This straits is featured by many shallows everywhere in the water, with current velocity of 1.5 kt at average and 3 kt at maximum in the offshore of Uban pt; 4 to 5 kt somewhere within the straights. The water course is secured to draft of 5 m for vessels and is navigable by domestic passenger ships of relatively large size between Tacloban and Manila.

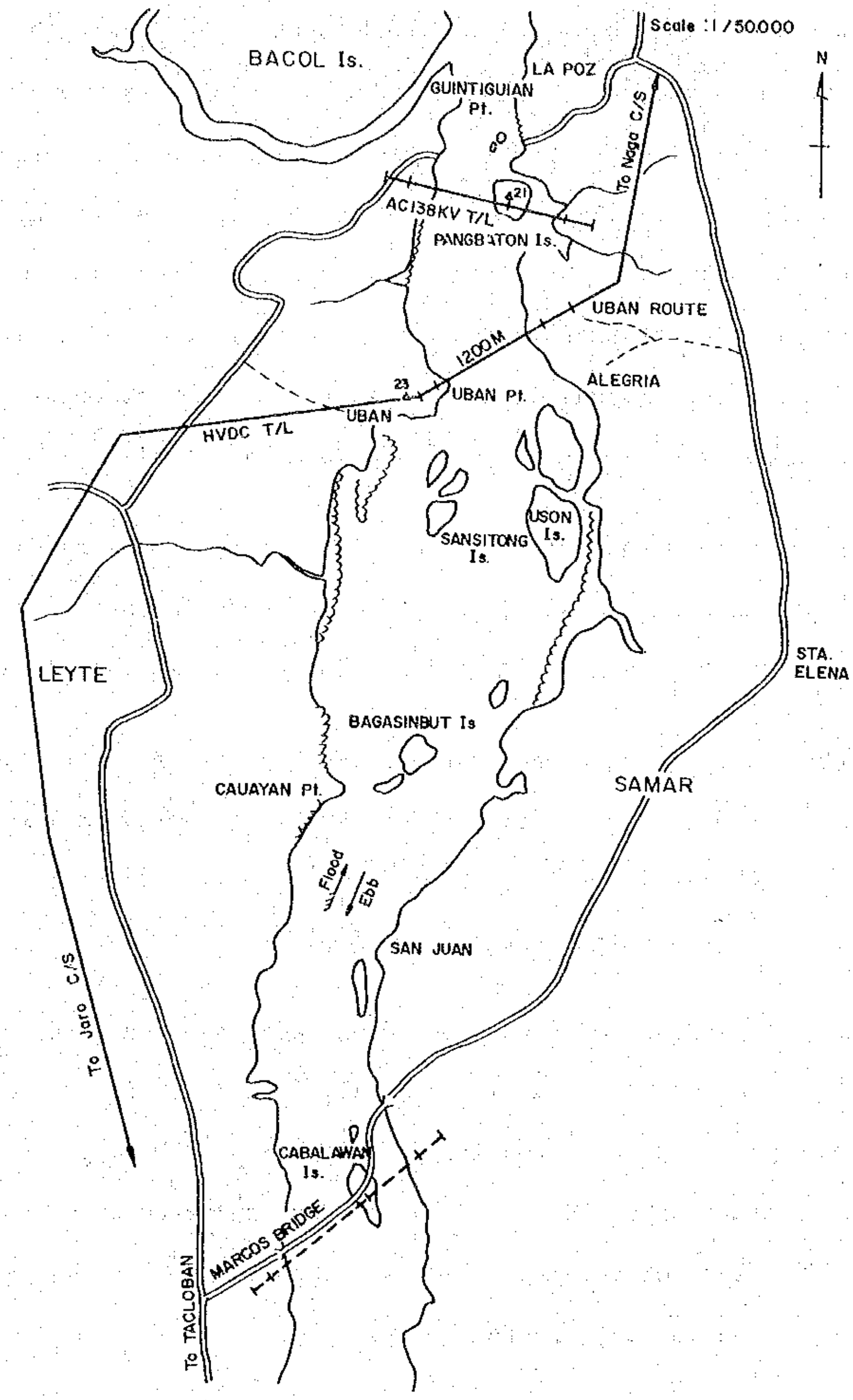
Since the overhead transmission line should require long span crossing over the San Juanico Strait, special design will be adopted with due consideration to both economy and reliability.

(1) Route of Overhead Transmission Line Crossing the Strait

A route for crossing on the strait directly to the Samar Island side from Uban Pt. on the Leyte Island was selected. The route is shown in Fig. 6-3.

This Uban route has such advantages that carry-in of equipment for construction and materials to both tower sites are easy and it is possible to use heavy machinery for construction works. Besides, the economy and ease of maintenance after commencement are taken into account and it is considered suitable route.

Fig. 6-3 DC±350kV OVERHEAD TRANSMISSION LINE ROUTE ON THE SAN JUANICO STRAIT



Besides the Uban route, Pangbaton Island route and Marcos Bridge route can be considered for crossing the strait. However, all of these other routes make use of isolated islands, and therefore, cost for transportation of construction equipment and materials is high and working efficiency will drop. Therefore, they involve many factors which cause increase of construction expenses. In addition, the Pangbaton Island route is being investigated and surveyed as the route for the Leyte-Samar interconnected AC 138 kV transmission lines. Construction of overhead transmission lines of two in parallel along this route involves technical problems such as space of Pangbaton Island. Marcos Bridge route might involve environment problem. The Uban route was selected under these circumstances.

Besides the fact that high reliability is required for the this power transmission lines, selection of places for construction of steel towers exerts major influence over the economy. It is therefore necessary to carry out precision surveying through radio distance measurement, triangulation and so forth for final design of this route. Furthermore, it is necessary to carefully execute topographical and geological investigations of steel tower locations.

(2) Outline of Preliminary Design

i) Conductor

Since the strait crossing will be of long span, inspite of a flat area, very tall steel towers must be used for the transmission line, and the tower construction cost takes a greater share in the total construction cost. Consequently, the most important thing in design consideration for construction of the transmission line at less cost is to reduce the tower height to possible minimum by use of a conductor of high strength.

For the reason stated above, special high strength steel core aluminum alloy strands (AACSR) will be used for the strait crossing transmission line.

Seeing that the proposed crossing route is far inside from the open ocean, it appears that there would not be so crucial corrosion problems to be anticipated on the conductor from little influence of wind and wave over the sea surface. However, in view of importance of the transmission line, the conductor to be used will be of moderate corrosion-proof type with anti-corrosive grease only on the inner layer of the conductor.

The conductor will be 520 mm^2 AACSR of two (2) conductors, determined from current capacity and potential gradient of conductors. The line for the ordinary section will constitute two (2) conductors, size of 810 mm^2 ACSR, from the result of economic evaluation even allowing for possible power loss. In this crossing section, however, two (2) conductors, size of 520 mm^2 AACSR, will be used instead for reasons that such power loss may be insignificant in the economic evaluation because of short line and, furthermore, that economic disadvantage may be brought about by increased scale of related facilities if the conductor of equivalent capacity to two (2) conductors of 810 mm^2 ACSR.

ii) Insulators

Insulators will be of 320mm fog type well matched with required mechanical strength of the conductor and will be assured doubly of reliability by use of the double string for both at suspension and tension string. Required number of insulators is determined correspondingly from the design criteria specified in the foregoing Section 6.2.2 (2) ii); 36 fog-type insulators of 320 mm size for each (5.66 kV/cm in surface leakage distance) to be coupled in strings with special precaution against salt contamination.

iii) Clearance

Standard and minimum clearance will be 320 cm and 185 cm respectively same as in Section 6.2.2 (2) iii).

iv) Lighting protection design

Considering high equivalent impedance to lightning surge caused by so high tower, a ground wire of single 70 mm^2, aluminum clad steel wire, was selected to install.

v) Steel towers

Required tower height must be determined from the requirement that the conductor would not give disturbance to navigation in the strait. The optimum height of conductor above the sea level may be 30 m in conformity with the established clearance for Marcos Bridge from the sea level. In this instance, the required conductors support height is estimated at about 130 m.

The designing wind velocity for the tower in this area may be at a level of 185 kPH, as specified in the foregoing Section 6.2.1, most probably as may be required to ensure transmission line reliability. However, since the tower height will reach as high as about 140 m, the designed wind velocity has been determined at 240 kPH in anticipation of gradual velocity increase.

(3) Outline of Straits-Crossing Transmission Line

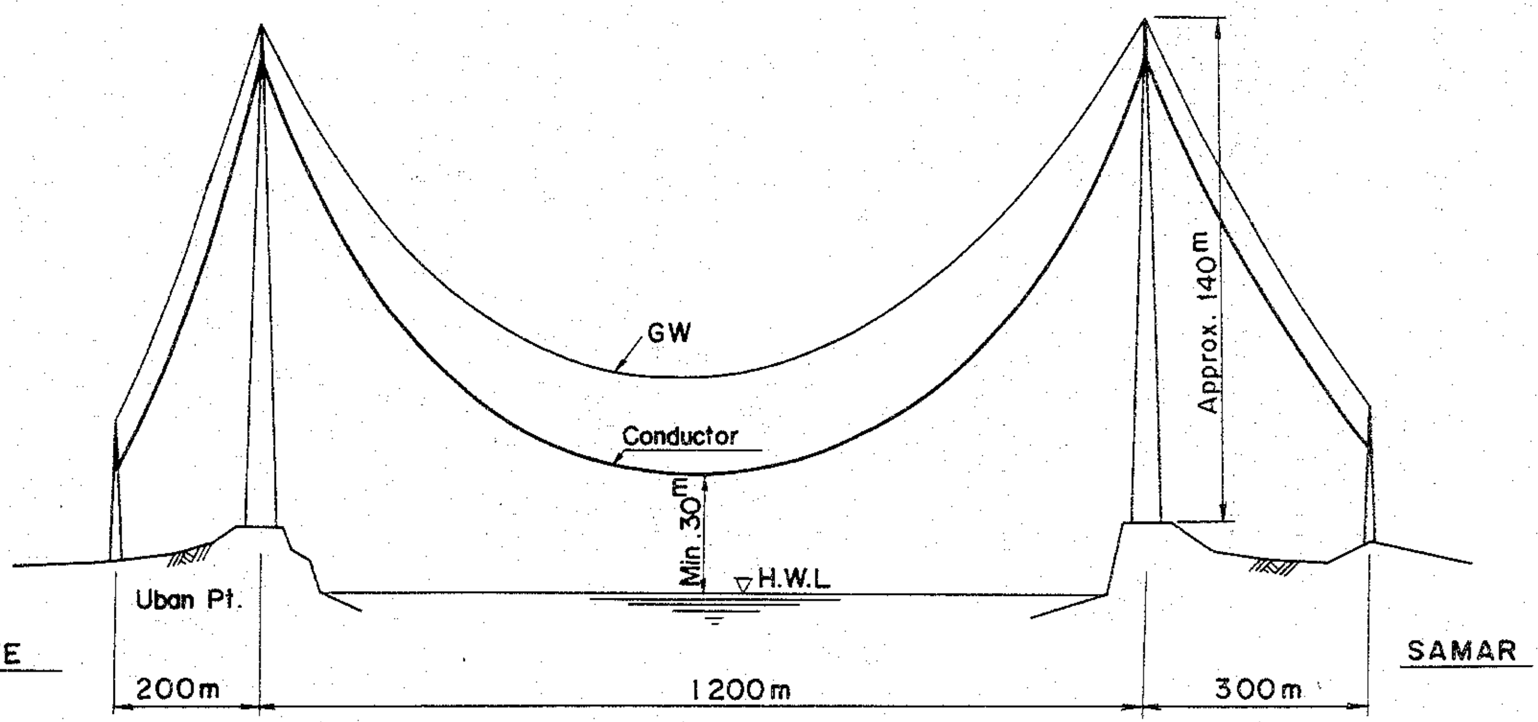
Length:	1,700 m (Uban route)
Voltage:	DC ± 350 kV
Electrical system:	Bipolar, both-end grounding at neutral point
No. of circuit:	Single circuit
Max. span:	1,200 m
Conductor height from sea level:	30 m (from highest tide)
Conductor:	2 conductors of AACSR 520 mm^2 (High-strength conductor of light corrosion proof)
Insulator:	320 mm Fog type suspension insulator with zinc sleev, 36 units a string
Overhead ground wire:	70 mm^2 aluminum clad wire, 1 wire
Steel tower:	Two (2) of suspension type and two (2) of strain type 4 towers in total

The outline of crossing the straits is shown in Fig. 6-4.

Fig. 6-4 DC±350kV HVDC Transmission Line of the San Juanico Strait Crossing

(Uban Route)

Scale Horizontal : 1 / 10.000
Vertical : 1 / 2.000



6.2.4 DC Submarine Cable

(1) Selection of Submarine Cable Route and Cable Terminal

i) Principles of Selection

In preparing the plan for submarine cable route, particular importance must be attached to reliability though the plan should reflect equal importance to economy as well as reliability, same as in the case of planning and designing for any other facilities of this Project. If any fault should occur in the submarine cable for some reason, it may often require a long period of several months until the line has been recovered and may affect the power service for the whole period of stoppage.

Since selection of the optimum cable route is the must important factor to economy and reliability of the submarine cable line, the route must be determined from the result of survey. Main survey items are stated hereunder.

a) Cable length

Construction cost for the submarine cable line is normally subjected to the cable length, being equivalent nearly to ten fold as much as required for the overhead transmission line. Therefore, its economy can be improved as the cable line length becomes shorter. If the cable length is too long in the case of OF cable, the feeding of oil for maintaining insulation properties will also be affected.

Therefore, a cable route should first be selected so that cable length will be as short as practicable.

b) Sea-bottom topography and bottom material

Sea-bottom topography and bottom material are important factors in order to ensure reliability of the submarine cable line. The optimum condition for the cable route is that the sea-bottom is flat with sandy layers.

If the sea-bottom for the cable route is undulated up or down (at a span of several meters to several ten meters) on a small scale, the cable line would be laid in bridge to cross over such a span and would thereby get into mechanical fatigue and become susceptible to any damage by influence of waves and tidal current. If the line has any portion of acute gradient, the cable will move in its longitudinal direction, by action of its heat expansion, in a long run and may be into the unfavorable condition because of extra increase in the tensile strength at the gradient.

In the meantime, if the sea-bottom is of sand, it would not provide any opportunity to cause hurt or damage to the cable because of far less undulation and, besides that, construction cost required for burying of the cable could be reduced to relatively less.

If the sea-bottom is muddy materials, it would cause no mechanical stress or damage to the cable in the least. However, it would not be favorable to the submarine cable line because low thermal conductivity of muddy materials would reduce transmitting capacity of the submarine cable line.

c) Water depth

Although water depth is not necessarily decisive factor for selection of the cable route, it is still an important factor to the project economy and difficulty of cable laying work.

The preferrable depth of water for the cable route is said to range from 20 m to 30 m when viewed from the cable design and the submarine cable laying work. If the sea is shallow to a great distance from the shore, it is not favorable for cable line because of extra cost of burying work and difficulty in landing of the cable.

d) Tidal current, waves and weather

All such marine phenomena as tidal current and wave would not be the dominant factor to reliability of the cable if the submarine cable route is selected on the suitable sea-bottom condition and the cable line is protected sufficiently at the shallow depth under the water, though mechanical stress or damage may be caused to the cable by such factors. However, those factors are, in fact, largely influence difficulty of the cable laying work or recovery work from failure. If the marine phenomena, such as tide and wave, is more crucial, the cable route should be selected more carefully. Besides that, the timing for cable laying work must be determined after comprehensive study on wave, tidal current and weather conditions at the construction site.

e) Cable terminal

The cable terminal at the point of contact between cable line and overhead lines is provided with ① cable end box, ② arrester for cable protection, ③ steel structure for autgoing overhead line and ④ telecommunication facility, including oil feeding apparatus if OF cable is applied.

Necessary space for accommodation of those components will be sized about at 50 m × 60 m (depending on the probable size of the oil feeding apparatus).

The site to be selected for this space should be on the flat ground and of suitable geological condition for establishment of the foundation on which all such equipment can be installed.

The terminal should be located preferrably close to the landing point of submarine cable so as to shorten the underground cable length. However, if it is too close to the sea shore, it would be caught by sprays of seawater, which may cause insulation deterioration of insulating tube from salt deposit or corrosion to various equipment.

The underground cable route should preferrably be selected on the flat terrain with the soil condition to permit easy laying of the cable line underground and should avoid passage through the unfavorable zone with cliffs and terraces.

Furthermore, determination of location for the cable terminal should be carefully studied by considering various aspects such as the overhead transmission line in connection, transportation of construction equipment and materials and incoming of service line for power generating source.

ii) Survey results of San Bernardino strait

Submarine cables should be used for the power transmission lines across the straits in this project, and the possibility of laying of submarine cables is an extremely important subject that affects the possibility of implementation of the project itself. Furthermore, investigations of the submarine topography, sea-bottom materials and other bottom conditions are extremely important for securing the reliability and economy of submarine cables, as already described in 6.2.4 (1) i).

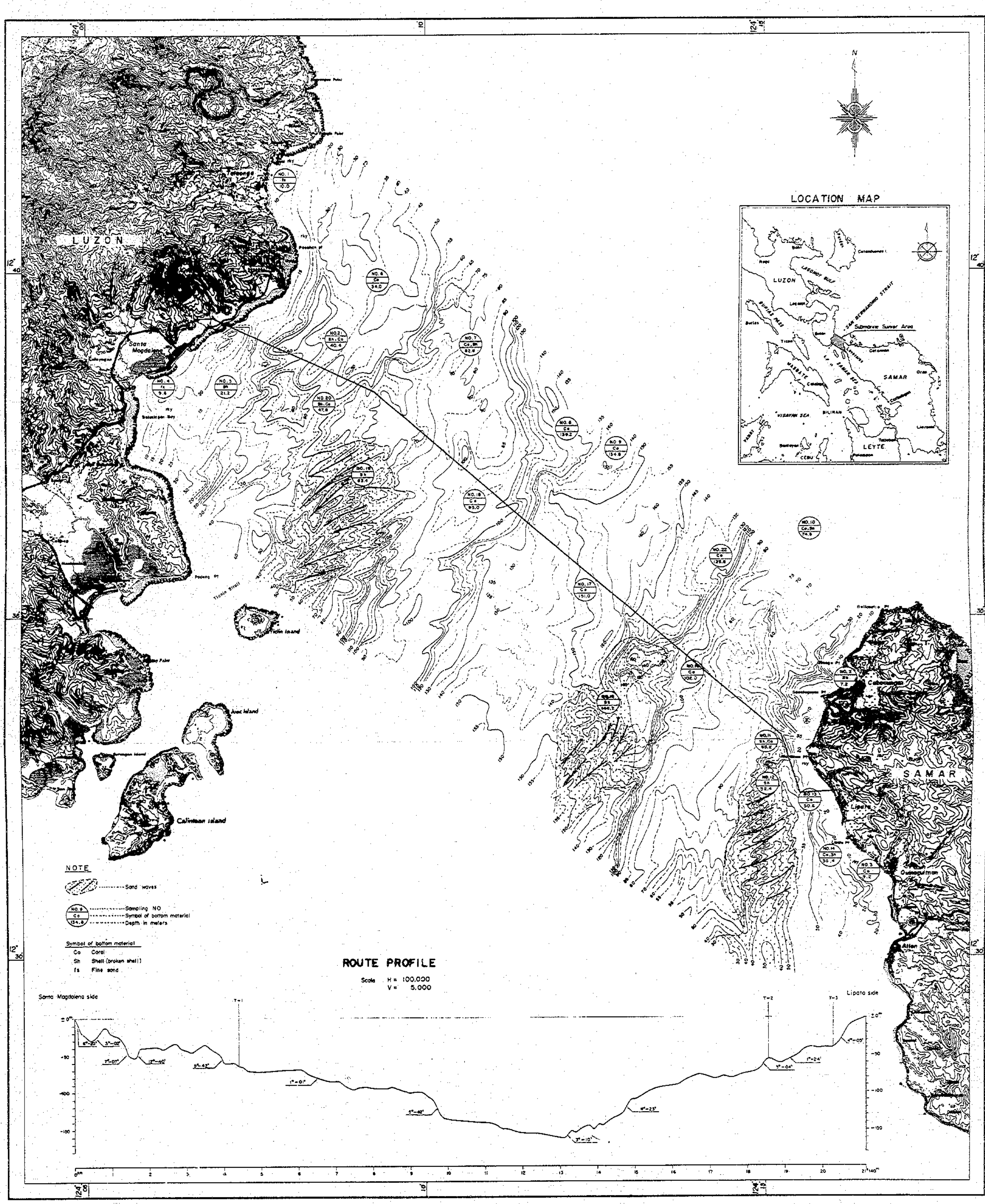
During this feasibility study, therefore, a field survey was carried out by using surveying equipment and so forth besides examinations on marine charts. The outline of the results of these investigation is described below.

a) Submarine topography

For investigation of the submarine topography, water depth, sea-bottom undulation and so forth were analyzed in detail from the records obtained with sounders, and a submarine topographical map was drawn up. The map is shown in Fig. 6-5.

The strait is of such a topography that slopes and flats alternately appear toward the center of the

Fig. 6-5 PLAN AND PROFILE OF SUBMARINE CABLE ROUTE IN THE SAN BERNARDINO STRAIT
(LUZON - SAMAR)



strait from the areas around shorelines of both islands, and an almost flat basin of a width of about 5 km and depth of 120 to 160 m is located in SW-NE direction at a point of about 1/3 from Samar Island. The maximum depth in the surveyed area is about 160 m measured in this area.

Although a steep inclination (maximum inclination 22°) was observed at a point of about 0.5 km off Calarayan of Samar Island. But inclination of slopes is relatively gentle in general.

Sand waves were observed in the surveyed area. (Fig. 6-5) The properties of sound waves were not checked in detail because the period of this study was limited, but it is noted that in general they will move. If submarine cables are laid through these zones, the possibility of mechanical fatigue may occur to cables due to bridging and hurt and damage may also occur to cables due to gravel or sand. Therefore, they are not suitable areas from the aspect of reliability of cables.

From the submarine topography of the surveyed area, it can be estimated that it is possible to lay cables on areas where slopes and undulation which cause troubles to cables are minor except for areas with sand waves and some areas of steep inclination.

b) Sea-bottom materials

Collected sea-bottom materials in the surveyed area are shown in Fig. 6-5. Besides collection of fine sand (fs) near the coastlines of Santa Magdalena and Talaonga of Luzon Island, coral (Co), pieces of shells (sh) and their mixture (Co, sh) were collected at the majority of sampling points. Boulders were not collected.

The sea bottom materials of the strait are generally composed of coral and shells and boulders are minor. When estimation is made from these facts, it is considered that the situations will not cause obstruction to the laying of submarine cables.

c) Tidal current

The tidal current velocity in the strait is as fast as 6 to 7 kt at maximum at the occasions of spring tide according to local tidal current forecast values and the strait has a relatively fast current.

These forecast values are said to be applicable to the center of the strait, and they are affected by the form of the land, situations of submarine topography and so forth near the coastlines of both islands, particularly at bay entrances and channels.

Areas of fast tidal current are unsuitable from the aspects of safety during cable laying work and ship operation along the scheduled cable route. Therefore, it is necessary to avoid places of fast tidal current to the most possible extent from the cable route and to carry out laying work at the occasion of neap tide or direction change at which the tidal current is relatively slow, by using the tide chart.

iii) Selection of submarine cable route

The cable route was selected based on the principles of selection described in 6.2.4 (1) i) from the results of field surveys for sea-bottom topography and bottom material of the strait and also from the results of exploration of areas around coasts of both islands.

The selected cable route is shown in Fig. 6-5.

From the results of field survey, areas of sand waves and areas near the coastline where the velocity of tidal current is fast, as well as anchorages are avoided for selection of the cable route. That is, according to the sailing directions, inside of a small bay off Quinaguitman located in a distance of about 1.6 km southeast of Lipata of Samar Island is a good anchorage during the period of northeast monsoon and about 0.8 - 1.1 km from the shore of Balusingan Bay on Luzon Island is an anchorage, and otherefore, these areas were avoid-ed as much as possible.

The selected cable landing point on Samar Island side is the point about 300 m north side of Lipata, and on Luzon Island side is the point about 1.4 km north-east of Santa Magdalena. The beach of these landing points is of sand containing pieces of coral, and both geology and topography are suitable for landing of cables. Suitable ground spaces for cable terminals and connecting overhead transmission lines are also available. Roads for access to these points are also provided. These places are shown in Fig. 6-6.

The outline of the cable route across this strait is as shown in Table 6-3.

Table 6-3 General Condition of Submarine Cable Route

Section	Lipata - Santa Magdalena
Length	23.0 km
Depth	Max. 161 m
Geographical condition	Almost plane
Geological condition	Coral partially coral reef
Current velocity	6 - 7 kt
Fishery	Private fishing
Cable terminal sites	Land works is required at both sites

The survey made this time is only a part of the feasibility study, and it is insufficient as a submarine cable route survey. Therefore, it is essential to carry out a detailed survey along the planned submarine cable route including observation of the sea bottom conditions as early as possible prior to the final plan for the submarine cable route.

Fig.6-6 CABLE LANDING SITE AND CABLE TERMINAL SITE

The items of investigation necessary for submarine cable route are as follows:

- Cable length
- Water depth
- Sea-bottom topography including changes due to drift sand, etc.
- Sea-bottom geology (boulder and reef in particular) and thermal conductivity (mud in particular)
- Tidal current (bottom current and surface current), tide level, tide and turn of tidal current
- Water temperature, water quality and aquatic micro-organisms
- Meteorology (air temperature, wind velocity, wind direction, fog, etc.)
- Wave height, occurring frequency, occurring time
- Sunken obstacles (existing cables, sunken boats, fishing grottoes, etc.)
- Passage and anchoring of ships
- Fishing (methods and equipment)
- Landing points and cable terminals

  Topography, space, geology, distance from the shor

  Porcelain tube contaminating conditions, outgoing route of transmission line

  Leading-in of distribution line as power supply for station

Operations base port, investigation of watercraft for works

Plans for other construction project (bulkheads, dredging)

Relevant laws, ordinance and regulations related to power cables and works on sea, etc.

(2) Outline of Preliminary Design

i) Selection of cable type

Solid cables and OF cables were examined for selection of cable type to be used for the submarine cable line. GF cable, XLPE cable and so forth are available besides the above as power cables. Although GF cable is inferior to OF cable in the aspect of reliability, GF cable is superior to solid cable and pressure changes accompanying temperature changes are minor, and therefore, GF cable is suitable for a long distance submarine line. However, the number of actual use is small in the world because of special manufacturing technology. As for XLPE cable, although it may be considered that its performance for use for up to AC 138 kV has almost been accomplished, no data which corroborate its use for DC has yet been obtained. Its accomplishments as existing DC cables is also none.

Solid cable involves the problem of extraction of oil from the insulation layer and its reliability is inferior compared to OF cable and GF cable. However, because of the fact that no oil feeding equipment or gas feed equipment is required, it is frequently used for voltages of DC ±250 kV class or less in general. Solid cable is affected by the external pressure of the seawater in a deep sea and such consideration in design to employ oval structure for conductors. Under these circumstances it is the real situation that this cable is not adopted in many cases except for submarine cables of extremely long distances for which lubrication design is difficult.

OF cable is of the highest reliability, as insulation characteristics are improved by feeding oil under pressure, and accordingly, is used for the majority of high voltage power cable line. However, OF cable require oil feeding equipment and this equipment requires maintenance.

The length of the submarine cable for crossing San Bernardino Strait is about 23 km and the maximum depth is about 160 m. Therefore, there are no large problems in the aspect of oil feed design. In addition, it is considered possible to use stationary type oil feeding equipment, and therefore, maintenance is not so great.

The transmission lines of the Project are large capacity power supply lines and the economical loss is great if service is interrupted due to a trouble with the submarine cable. Accordingly, it is necessary to maintain high reliability for the cable itself.

As the cable type largely affects the reliability of the HVDC system of this project, it was determined to adopt OF cable which is the most superior in the aspect of reliability, with these circumstances taking into account the above consideration.

ii) Cable size and number of cables to be laid

The current capacity of a cable is affected by the thermal conductivity of the surrounding soil in the condition where the cable is laid. In the case of a submarine cable, the current capacity is limited at buried parts near the seashore, and the thermal conductivity of the soil becomes a problem.

As the cable size to match the power to be transmitted of 900 MW (final stage), 1,000 mm^2 may be used if the specific thermal resistivity of the soil is 100°C cm/W or less. However, because the specific thermal resistivity of the field is not yet known, final selection of the cable size should be made after the value of the specific resistivity is found through detailed survey of the sea bottom. It is also necessary to study the required size of the onshore cable between the seashore and the cable terminal to match the final design like the submarine cable.

Though laying of three cables including one spare cable to be used on occurrence of a trouble may be considered for improving the reliability of the submarine cable, it was decided to lay two cables in this study because of the reasons stated below.

Passage of large ships is relatively frequent through the strait and there are some anchoring areas in the vicinity of bay of both islands. But it is possible to designate the cable route as prohibited area for anchoring. Regarding fishing which frequently causes troubles to submarine cables, private fishing only is made in many cases, and almost no large size trawl fishing is performed. Under these circumstances it is estimated that the possibility of occurrence of cable troubles is minor, as protective measures of the most possible extent will be taken for the cable itself (to be described in the next section). As bipolar single circuit, both neutral points grounding system is adopted as the main circuit composition of the HVDC system, so, it is possible to transmit half of the transmission capacity by one pole even on occurrence of a trouble to the other pole of the HVDC transmission lines. Besides, reduction of construction cost was also taken into account, and it is judged reasonable for 2 cables to be laid.

iii) Insulation design

The basic thought on insulation design of DC cables is not different from that for AC cables. That is, considering the characteristics of insulation materials including aging and temperature dependability, the composition of the insulator is designed based on the potential and electric field distribution generated in the insulator when operating voltage, test voltage and abnormal voltage are applied to the insulator.

With AC cables, distribution of potential gradient in the insulator is determined by the electrostatic capacity, and its value is always fixed when the rated voltage and structure of a cable are selected, and is not changed at all by temperature or other factors. On the contrary, with DC cables, distribution of potential gradient is determined by insulation resistance. As this insulation resistance changes in accordance with temperature and by potential gradient itself, distribution of potential gradient changes in complexity in accordance with load conditions, and phenomenon of changing the polarity which is specific to DC cables, is also involved. These points are what are largely different from those of AC cables in the insulation design of DC cables.

Improvement of insulation characteristics can be expected with DC cable as it is possible to use insulation paper of high density because the problem of dielectric loss tangent does not exist in DC cables. With OF cables, the maximum allowable potential gradient of insulation paper is approximately of the following values from records of existing cables.

AC cable : 10 - 15 kV/mm

DC cable : 25 - 35 kV/mm

The thickness of the insulation paper is designed based on the above indicated value with allowance in production and laying taken into account.

The insulation thickness was determined as 21.0 mm with the rated voltage of the submarine cable of the project assumed as DC 350 kV and BIL assumed as 1,050 kV and with the experience with DC cables taken into account.

As locations of cable terminals are close to the sea-shore, insulation deterioration of pot head for cable end box due to salt will have to be considered. Therefore, it is necessary to consider contamination proof design for pot head and to consider cleaning of pot head in dry seasons.

On the other hand, with the fact that the project area is frequently hit by lightning taken into account, lightning arresters will be set up at cable terminals for protection of cables from the surge entering at the occurrence of lightning.

iv) Oil feed design and oil feeding equipment

As the inside of OF cables is filled with insulation oil, it is necessary to compensate changes of oil level and oil pressure caused by changes of temperature accompanying ON and OFF of loads, etc. so that the oil pressure is always kept at a certain positive value. The oil duct is provided at the center of conductors in a single core OF cable. It is necessary that the diameter of the oil duct is as large as possible and that insulation oil of as low viscosity as possible is used in order to minimize changes in pressure caused by movement of insulation oil.

Because of these reasons, oil duct diameter of 25.0 mm is used in the OF cables and low viscosity alkyl benzene synthetic oil is used as the insulation oil. If oil feed is made from both ends of cables, it is estimated that the working oil pressure range will be about 7 to 12 kg/cm^2 based on the examination made with cable length of 23 km, maximum depth 161 m and ON-OFF of loads taken into account.

External gas type pressure oil tanks (OPT), which do not require driving power and easy maintenance are adopted as the feed oil tanks, and oil pressure supervisory equipment will be attached to them.

The places of installation of external gas type pressure oil tanks are indoors.

v) Method for steel armoring and protection of cables

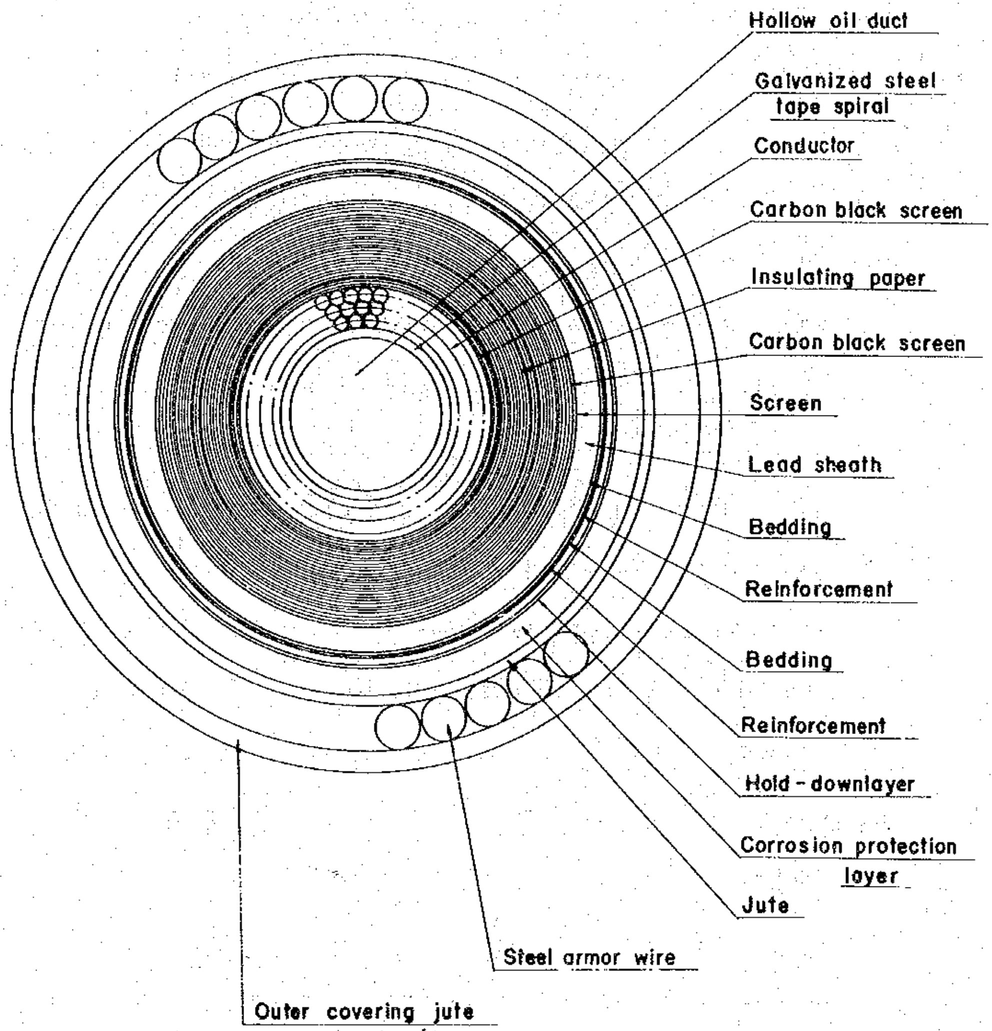
The cables will be armored with a layer of steel wire of 8 mm diameter for preventing damage caused by anchors and also for mechanical reinforcement against the laying tension.

The construction of OF submarine cable is shown in Table 6-4 and Fig. 6-7.

Table 6-4 Construction of OF Submarine Cable

Conductor	Nominal cross-sectional area	mm^2	1,000
	Outer diameter	mm	49.8
Hollow oil duct	Inner diameter	mm	25
	Steel tape thickness	mm	1.5
Inner-carbon black screen layer		mm	0.3
Insulation layer		mm	21.0
Outer-carbon black screen layer		mm	0.15
Lead sheath thickness		mm	4.6
Reinforcement layer		mm	1.0
Corrosion protection layer		mm	4.5
Outer-bedding layer		mm	1.5
Steel armor wire		mm	8.0
Outer covering jute		mm	4.75
Finished outer diameter		mm	150
Approximate weight		kg/m	65

Fig.6-7 Cross Section of Submarine Cable



The purpose of protection of a submarine cable is to prevent damage to cable due to anchoring and waves, and the concrete method of protection should be considered in accordance with the sea bottom topography and geology. Therefore, concrete method of protection will be determined based on the result of detailed investigation of the sea bottom conditions, but the following is assumed in the report.

The cables in the water depth to about 50 m from the sea level will be buried under the sea bottom mainly by jet burying process. Of this section at each end of the cables, protective tubes made of cast iron will be attached to the cables to the section of water depth up to about 20 m from the sea level. As the shallow sections near both islands have developed coral reefs, trenches will be excavated in advance by using a machine, cables will be laid in these trenches and then cables will be covered up by using sand bags or concrete.

vi) Cable terminals

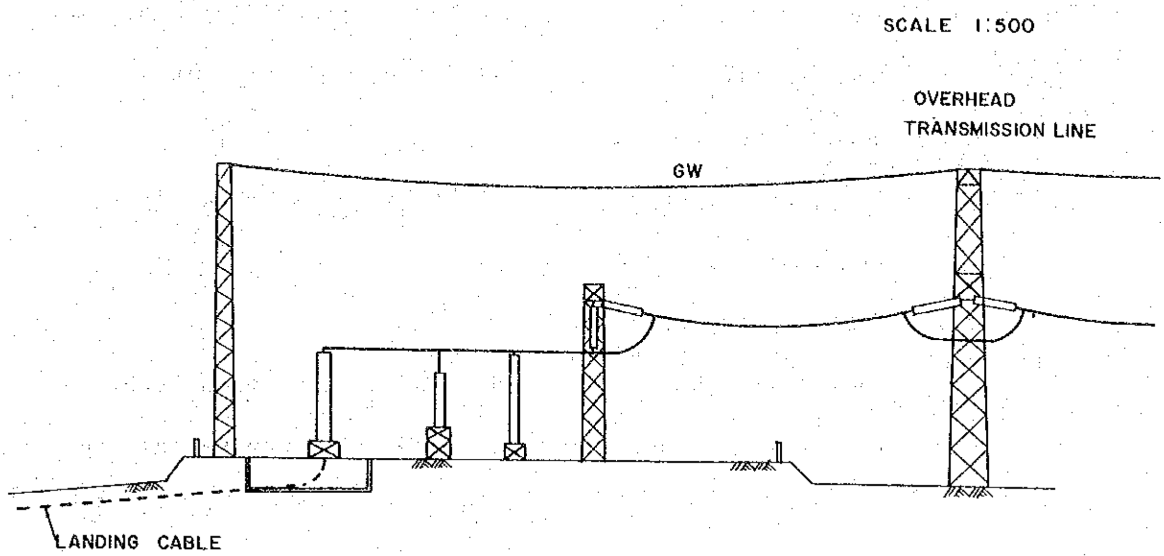
A cable end box and its stand, oil feeding equipment and a tower for outgoing overhead transmission lines will be installed at each cable terminal. In addition, a lightning arrester for protection of cables will also be installed. Telecommunication lies are also required, and solar cells and storage batteries will be installed, and distribution lines will put up for supplying power.

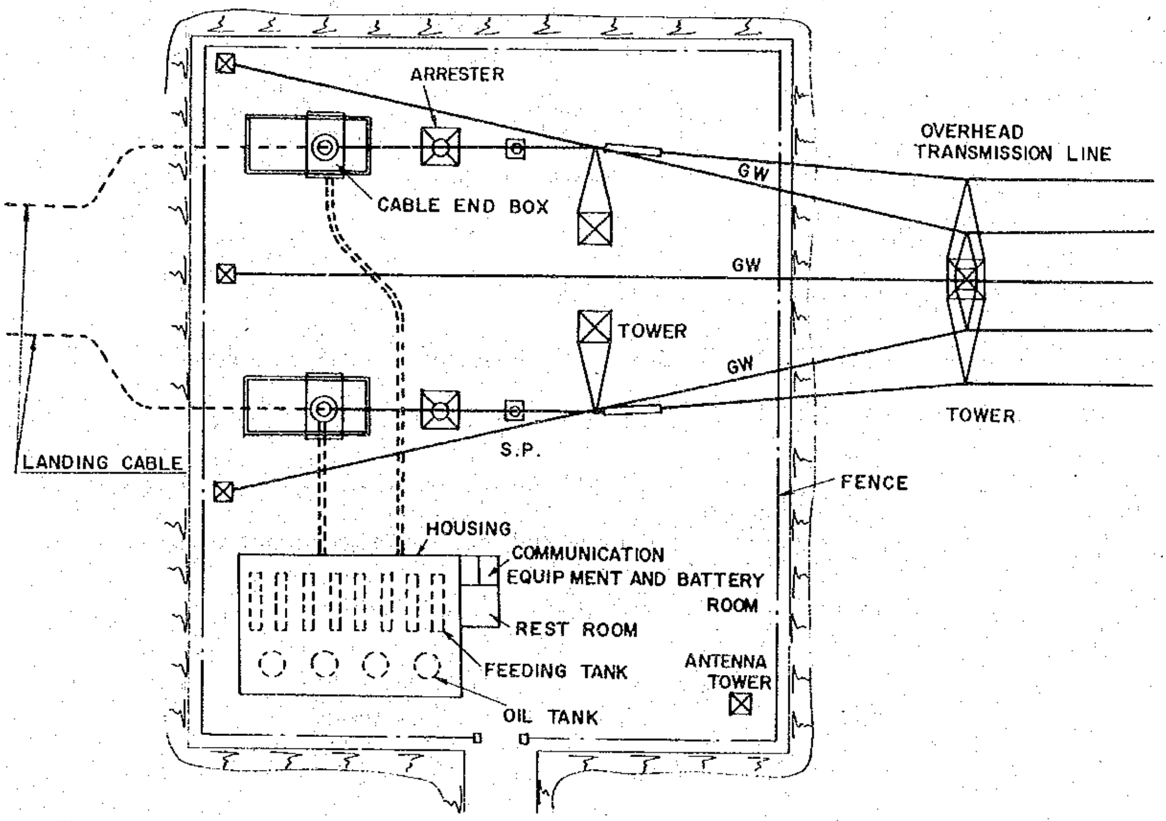
A proposed layout of a cable terminal is shown in Fig. 6-8.

vii) Cable laying work

Cables will be loaded in a ship at an overseas cable factory, shipped to the site and will then be laid by using the same ship. A ship of about 6,000 to 8,000 ton class is required for laying cables, and an ocean type ship is desirable from outside of the Philippines. It is desirable that laying of submarine cables is executed in April - June in which oceanic conditions are most stable. According to the time schedule for the project, the laying work will be executed in November - December in which oceanic conditions are likewise relatively stable, and preparatory civil works and works for cable terminal will be executed in advance for several months. After completion of cable laying work, cable protection work and other related activities will be executed in the succeeding months.

Fig. 6 - 8 CABLE TERMINAL ARRANGEMENT





(3) Outline of facilities of submarine cables

Length	23.0 km
Voltage	DC ±350 kV
Submarine cables	1,000 mm^2 single core OF cable (lead sheathed; 8 mm dia. steel wire single layer armored)
Number of cables to be laid	2 cables
Protection	Burial under sea bottom, mounting of protection tube
Cable terminals	Cable end boxes, its stands, steel towers for outgoing transmission line lightning arresters, solar cells, storage batteries.

6.2.5 138 KV AC Overhead Transmission

(1) Overhead Transmission Line Route

NAPOCOR is planning to construct a switchyard in the Tongonan area, with intention to centralize generated power from geothermal power plants to be constructed in dispersion throughout the area. This transmission line will be led to Jaro Converter Station beyond the mountain ranges in the central part of Leyte after starting from the Tongonan switch yard about 8 km to the south and then proceeding to the east alongside the forest path. When completed, this will run in parallel with the AC 138 kV Leyte-Samar interconnecting transmission line which NAPOCOR proposes to construct. The route surveyed for the transmission line is as shown in Fig. 6-1. Since the greater part of this section is situated in the forest, it is anticipated that much difficulty would be involved in clearing the forest in the right-of-way. The route is about 1,000 m in altitude and, in particular, a portion for about 3 km length has no access roads. Therefore, the roads for construction work must be newly opened in this section. Furthermore, as the geological map suggests existence of the fault line alongside the mountain range, full care must be taken, as stated 6.2.2 (1), in selecting the tower location.

(2) Outline of Preliminary Design

i) Conductor

Power flow for the transmission line is estimated at 440 MW to be well matched with power to be generated from Unit No. 4 thru Unit No. 11 of Tongonan Geothermal Power Plant.

Applicable conductor size will be equivalent to ACSR 610 mm^2 with two (2) conductors as estimated from current capacity of the conductor to be matched with estimated power flow, according to the design standard of NAPOCOR. In this instance, since the transmitting section is shortly limited to about 26 km, transmission loss is estimated at a small figure of about 1.2 percent. The conductor will have no bearing on the corona problem in the least, as its potential gradient of conductors is kept at such a low figure as 5 kV/cm.

If two (2) conductors of ACSR 610 mm^2 are used, this could ensure reliability of the transmission line connected to the power generating sources, because even if one of these two circuits should fail the other sound circuit could carry about 400 MW.

For this reason above, the transmission system has been designed for two (2) conductors of ACSR 610 mm^2.

The stringing conditions of the conductor are such that tensile strength at normal condition (15°C, no wind) should be designed below 22 percent of breaking strength and the same at the worst condition in case of typhoon (7.2°C, 185 kPH wind velocity) (Gust) and a wind-pressure drop ratio of 0.6) should be designed below 40 percent of breaking strength. It is recommended that maximum horizontal tension should then be designed at about 6,000 kg.
As a measure against breeze vibration, damper and armor rods are to be provided at the conductor supporting points.

ii) Insulation design

It is anticipated that no salt contamination would affect the transmission line since it will pass through the inland area. In this case, surge voltage is the only decisive factor for determination of required number of insulators and insulating clearance.
With maximum allowable voltage of the line designed at 154 kV and its effective grounding done at the electricity stations, the magnitude of the switching surge voltage is assumed as 2.8 pu.

Furthermore, it is assumed that probable insulation reduction would be 25 percent of the assumed minimum atmospheric pressure during typhoon of 950 millibars (at sea level) and maximum elevation of 1000 m.

As the result, required number of insulators against the switching surge voltage can be estimated at 7. The NAPOCOR's design standard provides that eight (8) insulators should be installed at a suspension string set and nine (9) should be at a tension string set. The number such specified will be sufficient to withstand against normal 80 kV voltage to groun (= 138 kV/$\sqrt{3}$), even if considering salt adherence of about 0.05 mg/cm^2. This preliminary design is based on the assumption that nine (9) insulators would be installed at both suspension string set and tension string set alike with conformity to the specified number of insulators for the daad end in the design standard by NAPOCOR.

Required insulation clearance is determined at 100 cm at standard and 75 cm at minimum.

iii) Lightning protection design

Annual total number of thunder storm days amounts to 69.5 days in Tacloban, from which it can be said that this area is struck frequently by lightning. In anticipation, therefore, that lightning strike to the transmission line may occur probably as many as 150 times a year per 100 km unit length, protective measures against lightning are considered.

For this purpose, one 70 mm^2 GSC will be installed as the overhead ground wire at the shielding angle of less than 30° to the conductors, so that the conductor can be shielded from lightning at a probable rate of 95 percent. Grounding resistance of the tower will be reduced toward the target value of 20Ω, so that frequency of inverse flashover failure which might arise from lightning strike to either tower or overhead ground wire can be reduced to possible minimum.

Arcing horns will be provided on each insulator string set so as to protect insulators from damage at occurrence of inverse flashover. The horn gap is taken at 90 cm.

On the basis of lightning protection design as above, the rate of line fault from lightning strike is estimated at about 12 times a 100 km annualy.

iv) Supports

In view of the fact that the overhead transmission line should require high reliability as the trunk line to be connected with the power generating sources and the greater part of its route will pass through the mountainous zone, steel angle towers will be used as supports. The typical type of tower is as shown in Fig. 6-9.

The tower foundation is designed for slab concrete with usual base mat so that equal relaibility as the supports can be secured.

Design wind speed of 185 KPH (Gust) will be used, as stated in the foregoing item 6.2.1.

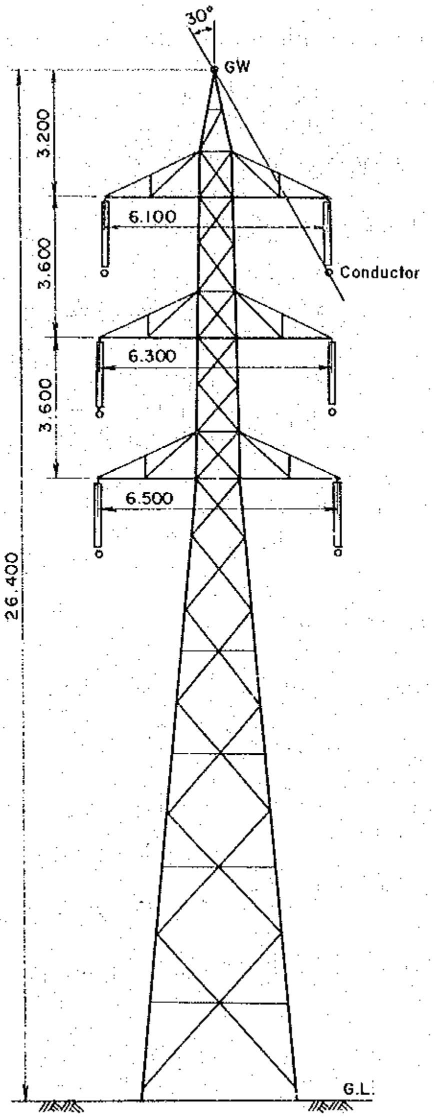
(3) Outline of Facilities for Overhead Transmission Line

The outline of facilities for the AC overhead transmission line from Tongonan Switch Yard to Jaro Converter Station.

Length:	26 km
Voltage:	AC 138 kV
Electrical system:	3-phase, 3-wire, 60 Hz
Conductor:	AC 610 mm^2, 2 conductors
Overhead ground wire:	70 mm^2 GSC, 1 wire
Insulator:	250 mm suspension-type, 9 insulators per string
Support:	Steel angle tower
Foundation:	Concrete slab foundation

Fig. 6-9 138KV TRANSMISSION LINE STANDARD TYPE SUSPENSION TOWER

Unit : mm



6.3 Grounding Electrodes and Electrode Lines

6.3.1 Power Transmission by Earth Return Circuit Operation

The DC power transmission lines of this project constitute the trunk line of large capacity power transmission. From the standpoint of reliability, therefore, it was decided to employ bipolar single circuit power transmission and neutral point both ends grounding system, as already described in 5.3.2.

This system is such that grounding is made by electrodes installed near the converter stations located at both ends of power transmission lines, and normally, only unbalance current of a few percent or less flows to the earth because of unbalance off impedance of converter transformers on plus and minus polarity and also control angle.

On occurrence of a fault with one pole, it is possible to transmit half electric power through the earth return circuit by making use of the other pole. In this case, however, it is necessary to thoroughly examine electrolytic corrosion to buried metal articles, and the influence over magnetic compass, telecommunication lines and so forth due to current that flows to the earth or seawater.

Electrolytic corrosion to buried metal articles, and influence over telecommunication circuits and so forth is what should be thoroughly considered in the stage of selection of points for grounding electrodes.

On the other hand, submarine cables will be laid across the San Bernardino Straight between Samar Island and Luzon Island. Accordingly, there is a fear of occurrence of compass error on the ships which use magnetic compass.

The extent of influence over the magnetic compass depends on whether the going circuit is provided or not, magnitude of DC current, depth of cables in the water, cable laying direction, cable laying interval, ship sailing direction and horizontal component of force of earth magnetism and so forth, and it is maximum when cables are laid in north-south direction and ships sail just above the cables in the direction parallel with cables.

The magnetic compass error caused by DC current (1,290 A) of submarine cables to be laid across the San Bernardino Straight is, accordingly a rough estimate, about 2 degrees on the sea surface during bipolar operation and about 4 degrees on the sea surface during single pole earth return circuit operation in the case where cable laying interval is 100 m, depth of cables in the water is 100 m and horizontal component of force of earth magnetism is 0.38 Qe.

Regulated values of errors to the magnetic compass are not observed internationally, but these errors cannot be ignored in general. As the San Bernardino Strait is an international course and also as an island course, thorough care should be taken in the selection of the submarine cable route and in the decision of laying interval. In addition, it is necessary to investigate the situation of use of magnetic compasses by ships, adjustment with relevant governmental organizations and so forth.

6.3.2 Grounding Electrodes and Electrode Lines

(1) Selection of Sites of Installation of Grounding Electrodes and of Route of Electrode Lines

i) Principle for selection

The roles grounding electrodes play in the availability of HVDC power transmission system are important. At the same time, influence such as electrolytic corrosion caused by the return circuit current that flow into the earth or seawater from grounding electrodes is large. Accordingly, design of grounding electrodes as well as selection of sites of installation of grounding electrodes are the most important subjects, and it is required to determine the points of installation through detailed investigations. The main items to be investigated are indicated below and these items are described.

a) Earth resistivity

To know earth resistivity is important for design as well as for selection of points of installation of grounding electrodes. It is possible to reduce the size of the grounding electrode in the place where resistivity is low. The ground space required is smaller and higher economy is obtained in this case.

For electrodes on the land, it is desirable that earth resistivity is uniform over a broad area and that it is free from seasonal changes and changes for years.

For electrodes installed at beach, it is desirable that the resistivity of the ground located on the land side and of the sea bottom is large.

b) Moisture content of soil

The earth resistivity is large affected by the moisture content of the soil. Therefore, the reliability and economy of electrodes are largely affected by the moisture content of the soil particularly with grounding electrodes on land. It is desirable that the moisture content of the soil is free from seasonal changes and changes for years like earth resistivity.

c) Buried metal articles, telephone lines and others
Electrolytic corrosion to buried metal articles, influence to single wire type telephone lines and railroad signals as well as turn around current to AC system and transfer voltage are largely affected by the return circuit current. It is therefore necessary to investigate the situations (locations, outline of equipment, importance, etc.) of these facilities and equipments over a broad range.
The influence becomes less if the distance to grounding electrodes is increased. When installed on the beach or in the sea, the majority of the return circuit current flows to the sea, and consequently, its influence is minor compared to grounding electrodes on the land.

d) Possibility of access of men and animals
Influence over men and animals caused by potential rise and potential gradient in the vicinity of electrodes should be considered. Accordingly, places which are relatively spaced apart from houses and which have no possibility of access of men or animals are desirable as the places for installation of grounding electrodes. Broad sites are required particularly for grounding electrodes on the land.

e) Distance to converter station and transportation of materials

Grounding electrode lines are required between a converter station and grounding electrodes. It is desirable from the view point of economy that the distance between them is as short as possible.

It is necessary to transport equipment and materials of a large volume for installation of grounding electrodes. Conditions for transportation of these equipment and materials, provision of an access road for recovery and so forth on occurrence of a fault besides regular maintenance and management and replacement of electrodes should be taken into account.

ii) Selection of sites of installation of grounding electrodes and of routes of grounding electrode lines

The places of installation of grounding electrodes were at first roughly determined through topographical maps and marine charts and then proposed sites were investigated through exploration and observation from helicopters.

Grounding electrodes may be installed on the land, at the beach or in the sea, but places of installation should be determined upon synthetic examination of economy, ease of execution of installation work, management and maintenance of equipment and so forth. If a grounding electrode is installed at the beach or in the sea, influence exerted over other facilities and equipment is minor and it is possible to install it compactly in a small space. In the case of a converter station located near the sea, therefore, the grounding electrode is usually installed at the beach or in the sea.

As both of Jaro and Naga at which construction of converter stations is planned in this project are relatively close to the sea, investigations were made with the point laid on the beach because of the reasons stated above. Points at which investigations were made in Carigara Bay and Ragay Bay are shown in Fig. 6-10.

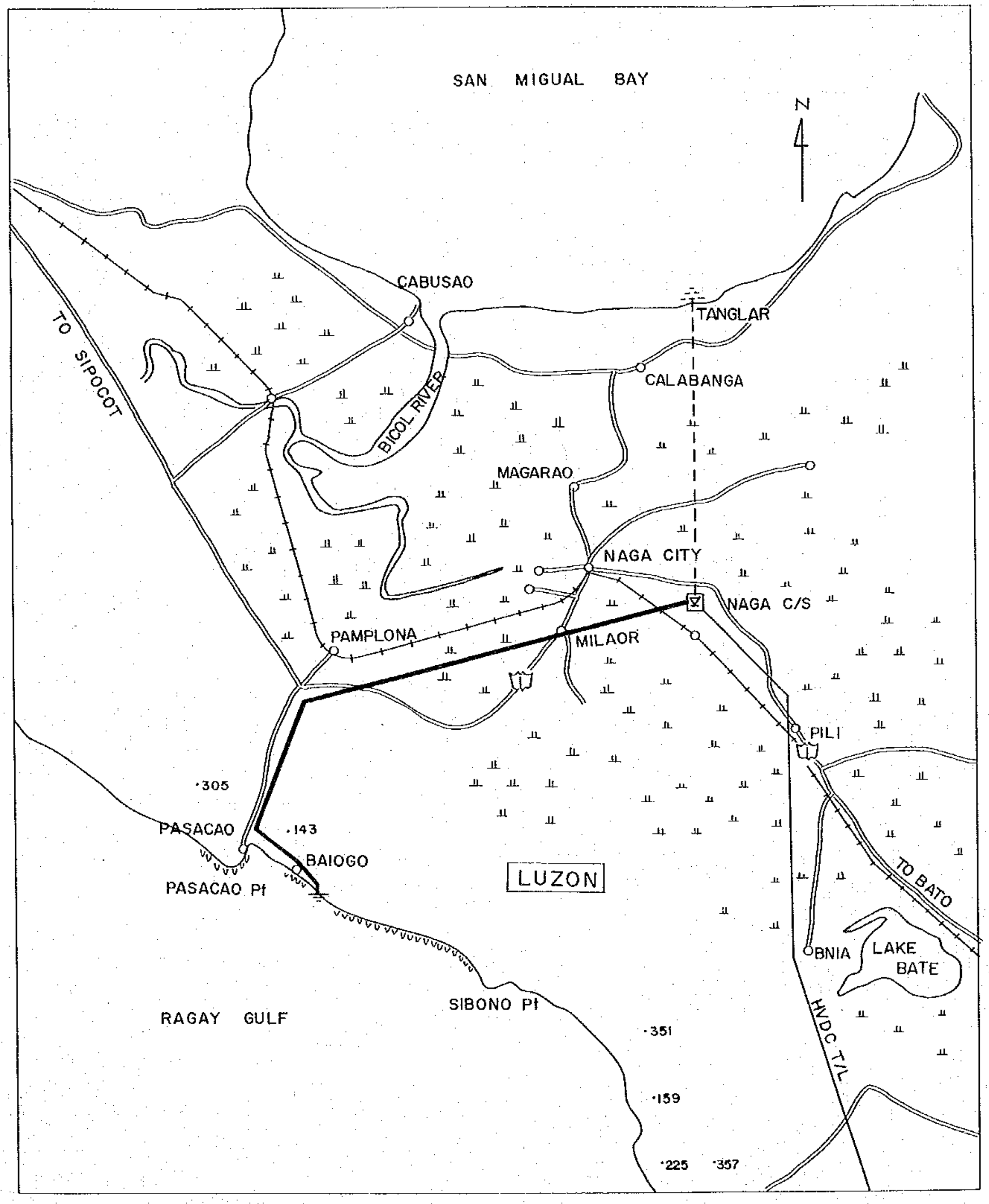
a) Managasnas electrodes (Jaro C/S side)

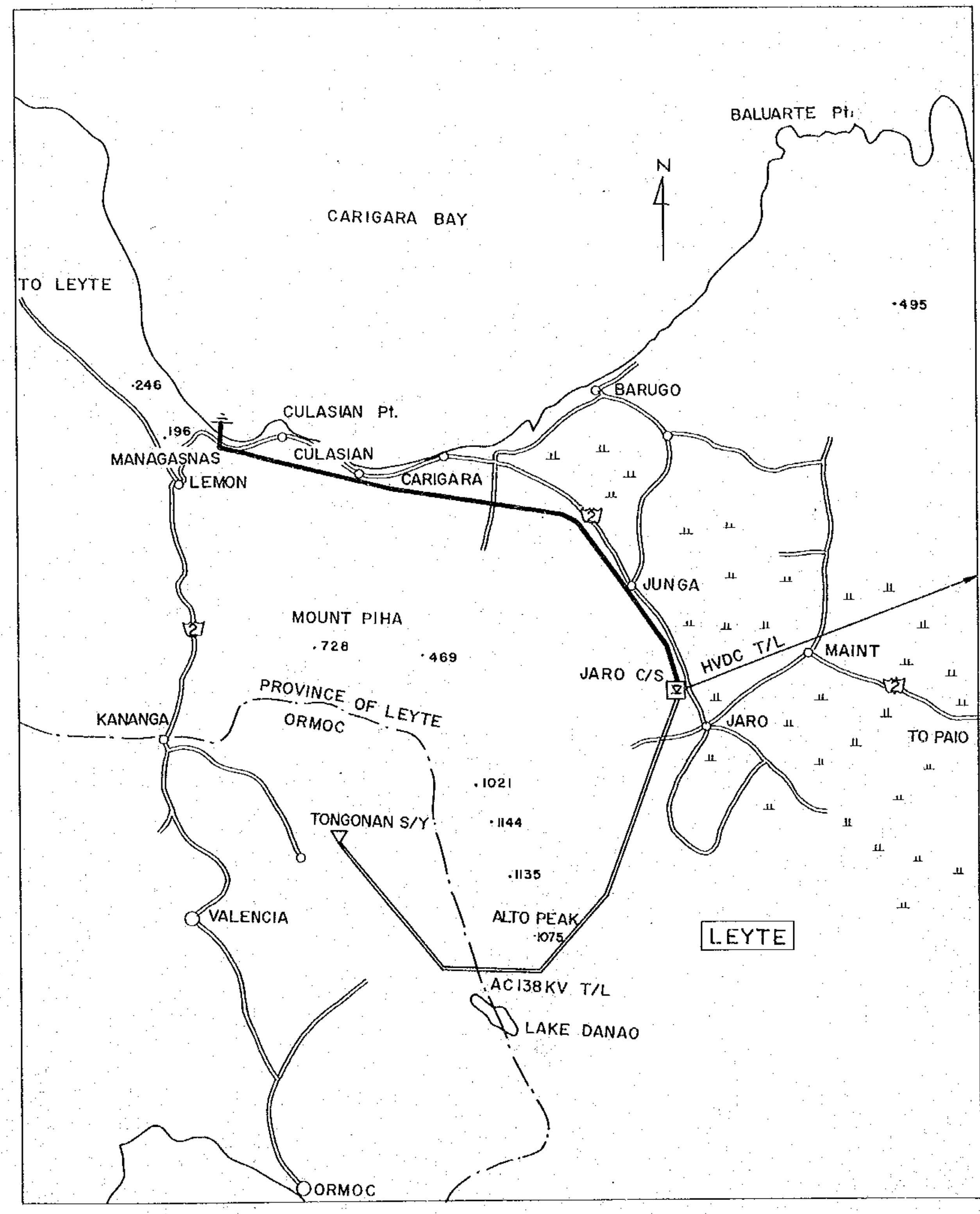
   Managasnas area located along the west coast of Cariga Bay was selected as the proposed site for the installation of grounding electrodes. As this place is shallow and the coastline is used as a passage for local residents, which are situations unsuitable for a place for installation of grounding electrodes, it is necessary to design the electrode with these situations taken into account.

Fig. 6-10 ELECTRODES AND ELECTRODE LINES

LEGEND
- ELECTRODE (PROPOSED)
- ELECTRODE LINE (PROPOSED)
- HVDC TRANSMISSION LINE
- AC138KV TRANSMISSION LINE

SCALE 1:250,000
0 5 10 15 20





b) Pasacao electrodes (Naga C/S side)

A place that is located in a distance of about 4 km on the southeast side of Pasacao of Regay Bay and a place in Tanglar in San Migual Bay were selected as proposed sites for installation of the grounding electrodes on Naga converter station side. The former place in Pasacao has no problem in the environment, but it has such disadvantages that a long electrode line is required and it is necessary to construct an access road about 1 km long.

The latter place in Tanglar has such advantages that the length of the electrode line required is relatively short and an existing road can be used. However, because of the fact that the sea bottom is shallow, the current density is high and off-limit a broad area is required. In addition, it is a good fishing area for local residents. Therefore, this place involves problems of environment.

With importance attached to environmental conditions, said place in Pasacao is selected as the site for installation of the grounding electrodes on the Naga converter station side in this feasibility study. However, further examination will be made in the stage of detailed design, and grounding electrodes may be installed in Tanglar if it is possible to enforce shore line off-limit measures.

The routes of electrode lines should be between these places of installation of grounding electrodes and converter stations along the road as much as possible. Although the places stated above were selected in the present stage for installation of grounding electrodes, detailed investigations regarding earth resistivity, coastline topography and so forth should be done and then places of installation of grounding electrodes should be decided finally. It is also necessary to investigate places on the land and check the possibility of installation.

Grounding electrodes are very important in the aspect of reliability of HVDC power transmission system, and at the same time, their influence exerted over other facilities and equipment are large including electrolytic corrosion caused by the return circuit current that makes inflow to the ground or the sea for a short or long length of time as already described in 6.3.2 (1). However, selection of location of grounding electrodes made during this feasibility study was dependent on topographical maps and marine charts partly

because of the limit in time and enforced field studies were limited to the vicinity of coastlines only. Therefore, they are insufficient as studies for selection of sites of installation of grounding electrodes. It is necessary to implement detailed investigations regarding necessary items such as distribution of earth resistivity and situations of other facilities or equipment as early as possible prior to establishment of the final plan for grounding electrodes.
As a method for implementing investigations in practice, NAPOCOR carries out preliminary investigations on important items and general situations and then contractors are hired for executing detailed investigations.
Items requiring investigation for decision of places of installation of grounding electrodes are as follows.

- Distribution and changes (seasonal changes and secular changes) in resistivity.
- Temperature, thermal conductivity and moisture content of the ground
- Topography, geology and submarine geology
- Buried metal articles
- Telecommunication lines, AC system, railroads and their signalling system

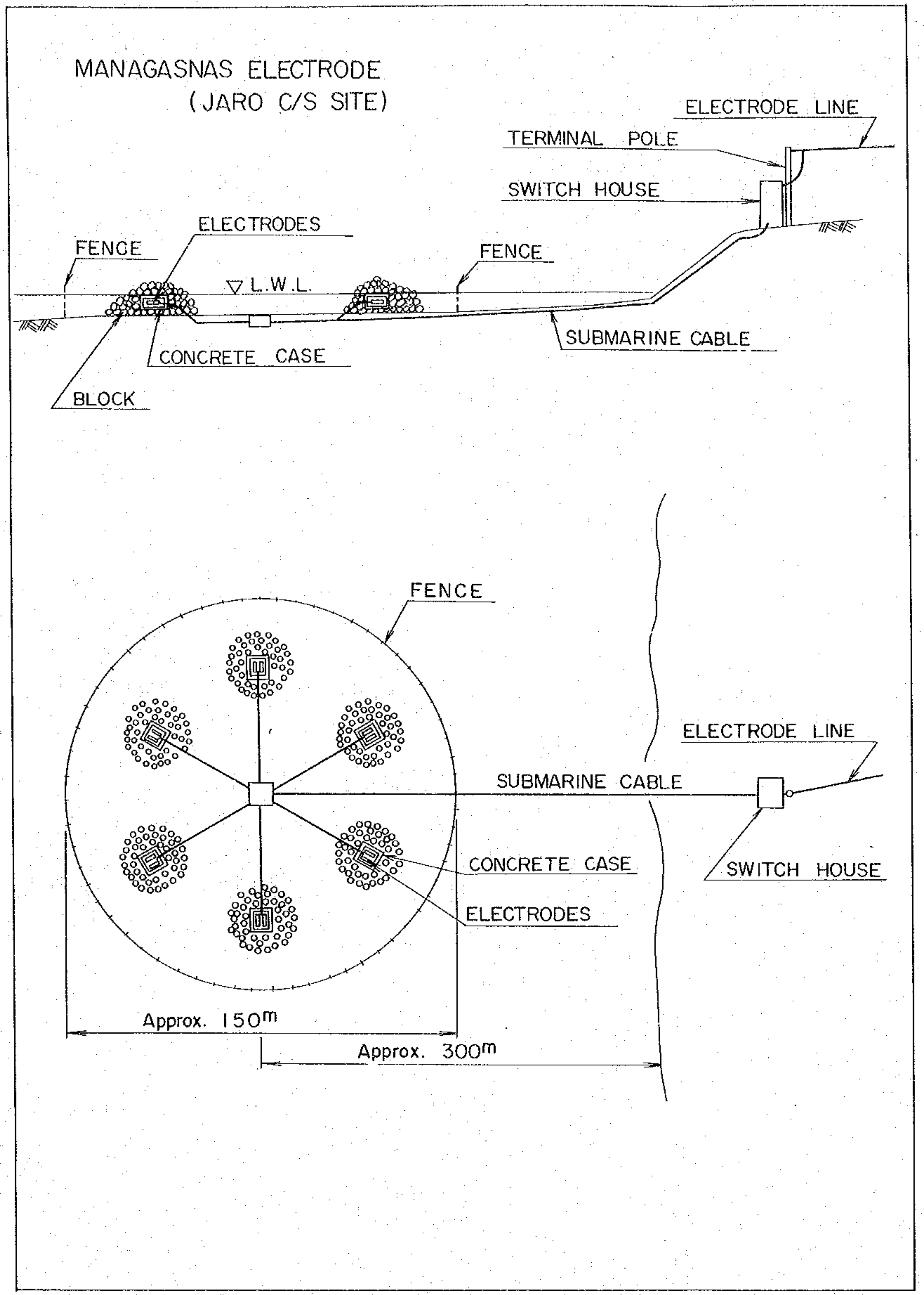
influence over fishing (there is such a nature that fishes in the sea gather in the area near the electrode) are rather important items.

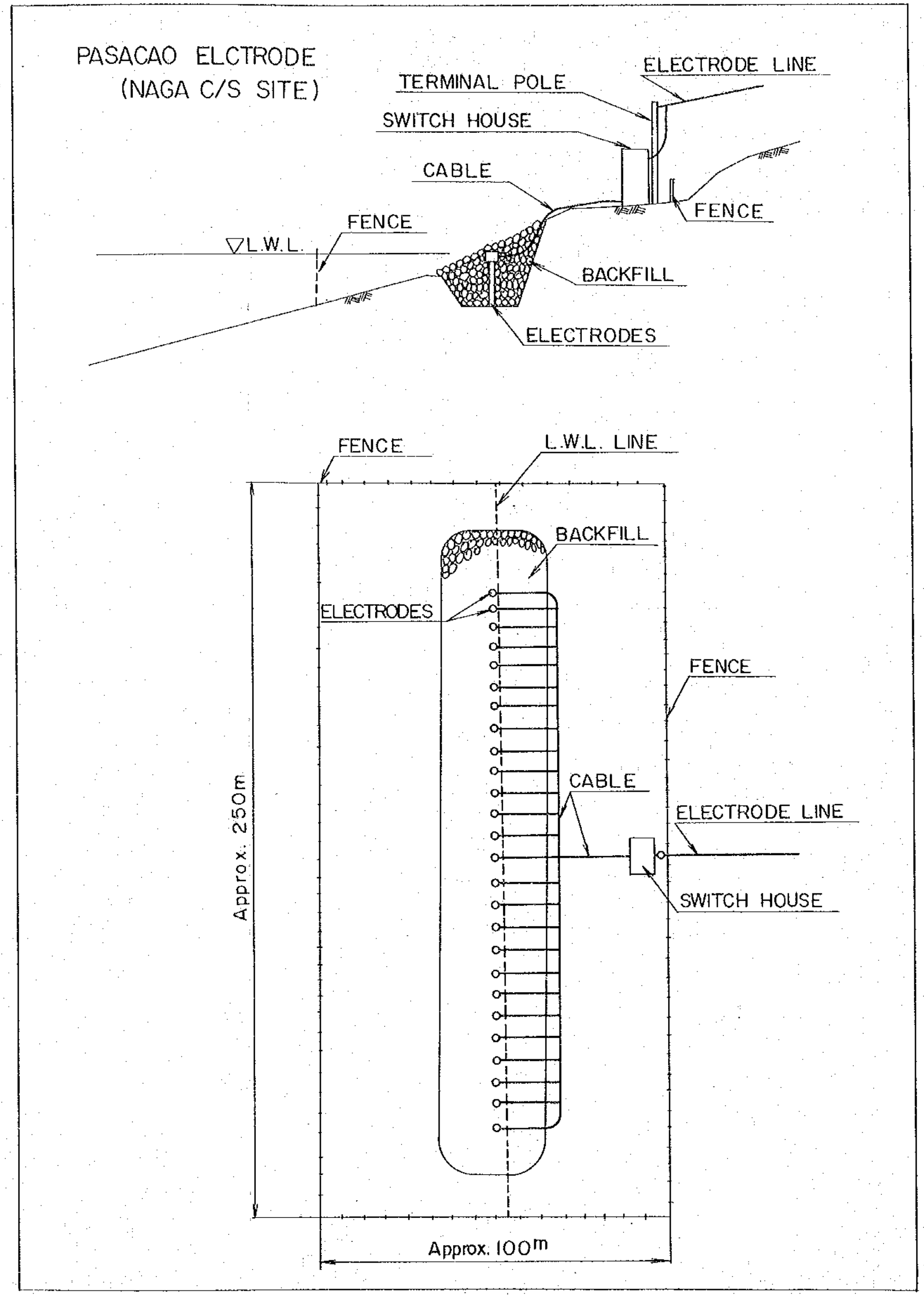
When an electrode is used as an anode, it is unavoidable that the electrode material is consumed accompanying outflow of current, and the rate of its consumption is governed by the electrode material and current density on the electrode surface. Therefore, it is necessary to examine these factors with economy, frequency of replacement of electrode and so forth taken into consideration. Although various materials are available for electrodes, graphite which is of relatively good corrosion resistance and is of relatively low cost was selected. Configuration of the electrode will be of bar structure of about 10 cm (diameter) x about 2 m (length) with the surface current density taken into account. It is assumed that a current of 50 A is fed to each electrode, and 26 electrodes (load current 1,290 A) will be used at one place. The configuration of these electrodes is shown in Fig. 6-11.

a) Managanas electrodes (Jaro C/S side)

The shoreline of this area is used as the passageway for traffic of local residents and it is of shoaling topography as already described, electrodes will be

Fig.6-11 ELECTRODES ARRANGEMENT





installed at a place of the water depth of about 3 m that is located off the waterfront by about 300 m.

Cases made of concrete and containing several electrodes will be arranged in a circular form so that the current distribution will become uniform. Connection between these electrodes and the electrode line terminal on the land will be made by means of submarine cables.

These concrete cases will be buried by using concrete block and/or tetra pods to avoid damage due to the strong wave. But it is necessary that they are of a structure that makes free entry of seawater. Fences will be installed around the entire area in which electrodes are installed, for protection of men and fishes.

b) Pasacao electrodes (Naga C/S side)

This place is of relatively ideal topography as a place for installation of coastal electrodes. Electrodes will be buried in a single row along the coastline in such a position that they are located in the seawater even at the time of low tide. Cobble stones and rough gravel will be used for backfilling in order to permit free entry of seawater.

Fences will be installed on both land side and sea side for protection of men and fishes.

It is assumed in this feasibility study that electrodes described above are used. However, it is necessary to design more suitable electrodes with field conditions investigated in more details in the stage of detailed design.

ii) Outline of preliminary design of grounding electrode line

ACSR 410 mm^2 2-conductors will be used for matching DC current of 1,290 A and with power loss taken into account.

As for the number of insulators to be used, two 250 mm fog-type insulators (with zinc sleeve) are used from the aspect of lightning protection design, with the fact those area are a heavy lightning area taken into account.

The supports are steel post and wooden pole, and wooden pole will be used from the standpoint of electrolytic corrosion in the section of several kilometers from grounding electrodes.

iii) Outline of facilities of grounding electrodes and grounding electrode lines

Site of grounding electrodes

Jaro C/S side : Managasnas (Carigara Bay)

Naga C/S side : Pasacao (Ragay Bay)

Length

Jaro C/S - Managasnas electrode : 28 km

Naga C/S - Pasacao electrode : 32 km

Conductor

410 mm^2 ACSR, 2 conductors

Insulators

250 mm fog-type insulator (with zinc sleeve) two pieces

6.4 Converter Station

6.4.1 Applicable Standards

Alternating current equipment : ANSI

Direct current equipment (thyrister valve) : IEC

6.4.2 Climatic Conditions

		Jaro	Naga
(1)	Elevation above sea level (m)	Less than 1,000 m	Less than 1,000 m
(2)	Max. temperature	40°C	40°C
(3)	Cleanliness of atmosphere	Clean	Clean
(4)	Max. wind velocity	40 m/sec	40 m/sec
(5)	Salt contamination	0.01 mg/cm^2	0.01 mg/cm^2
(6)	Valve cooling water supply	To be supplied by NAPOCOR	
(7)	Earthquake		
	Acceleration (G)	0.2 G	0.2 G (Static horizontal)
		(Dynamic design to be applied to thyrister valve)	
(8)	Transport limitation	As instructed by authorities	
(9)	Grounding resistance	Below 1 Ω	Below 1 Ω

6.4.3 Target Value of Availability

Availability of the converter station aims at its target at and above 97 percent.

Availability (%)

$$= \frac{8760 - (\text{Forced and scheduled outage time})}{8760} \times 100$$

6.4.4 Operating Condition of Related AC System

(1) Related AC system

Fig. 6-12 shows the related AC system at the time the DC system has started its operation at the 1st stage. In this total system, the DC system would be capable of operating at rated output of 450 MW.

(2) System frequency fluctuation (Target values for both Jaro and Naga Converter Stations)

60 Hz ± 0.3 Hz	Continuous
- 1.5 Hz	For one minute

Jaro Converter Station should be operated in coordination with geothermal generating units.

(3) System voltage fluctuation (target values)

Jaro	:	138 KV ± 5%	Continuous
Naga	:	230 kV ± 5%	Continuous

The transient voltage fluctuation within operable range shall be plus 20% to minus 40% as against rated voltage.

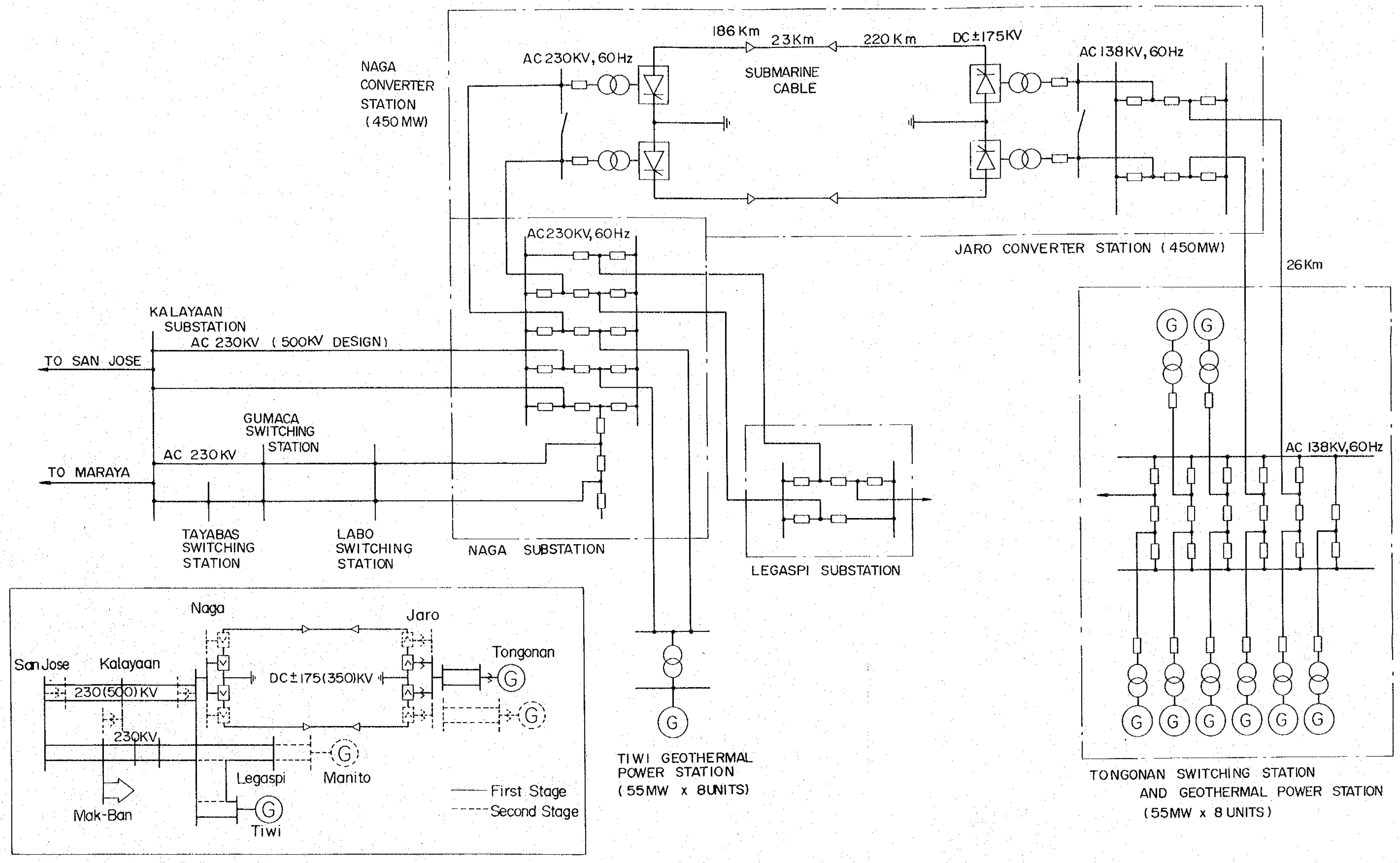
(4) Protection system for transmission line between Jaro and Tongonan

As per operating practice of NAPOCOR :

Protection relay : Directional relay

Fault breaking system : 3-phase breaking on fault circuit (No automatic reclosure)

Fig. 6-12 SINGLE LINE DIAGRAM OF THE NEIGHBOURING A.C SYSTEM (FIRST STAGE) (PRELIMINARY)



6.4.5 Preliminary Design of Converter Station (Fig. 6-13)

(1) Fundamental matters

i) DC main circuit is designated as bipole composition at the 1st stage.

ii) DC system constitutes a single system per monopole.

iii) Converters will be increased in the following steps:

1st stage : 6-pulse converter x 2 units/each end
1 unit per pole

2nd stage : 6-pulse converter x 4 units/each terminal (series connection of 1 unit per one pole)
2 units per pole

iv) Converter capacity is determined at 225 MW per each unit.

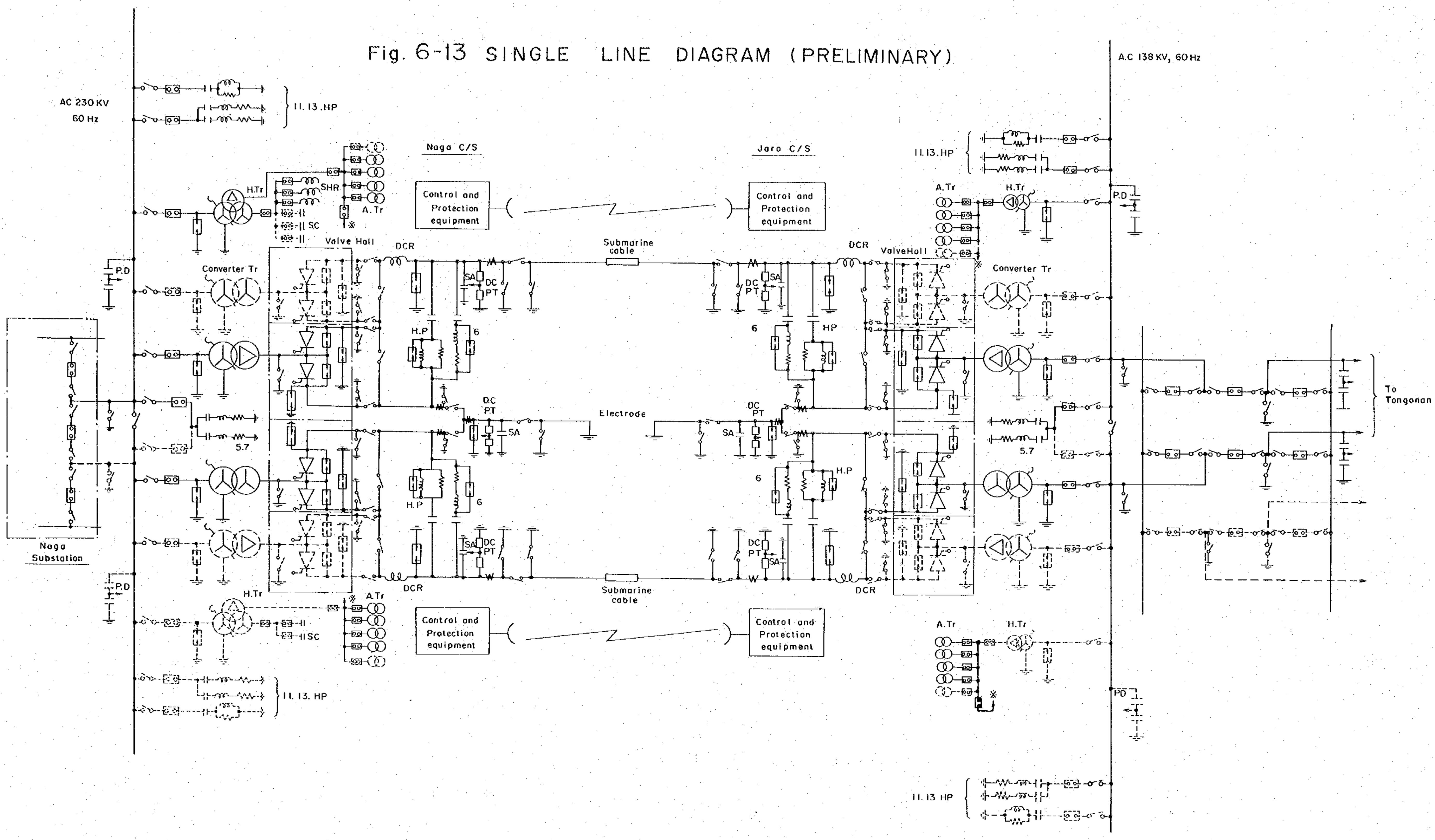
v) 12-pulse operation normally at the 1st stage
However, 6-pulse operation will be done at one pole failure and during maintenance work.
Transmitting capacity in this case will be 225 MW.

(2) AC main circuit

i) Connection of incoming line to the converter stations

Jaro : 138 kV 2-circuit incoming line from Tongonan Switch Yard will be connected to a single bus of the converter station through 1 1/2 CB bus.

Fig. 6-13 SINGLE LINE DIAGRAM (PRELIMINARY)



Naga : 230 kV feeder from Naga Substation will be connected directly to a single bus of the converter station.

ii) Bus at each converter station will be installed at a rate of one (1) bus per each pole.

iii) AC filter constitutes 5th, 7th, 11th 13th and high pass (HP) filters.

iv) 5th and 7th filters are of joint use for 2 poles while 11th, 13th and HP filters are installed at a rate of one unit per pole.

v) At the 2nd stage, only 11th, 13th and HP filters will be installed additionally as AC filter.

vi) Station power will be supplied from the secondary side (Jaro) and the tertiary side (Naga) of the station service transformers connected to the bus.

vii) Reactive power supply system will be connected to the secondary side of the station service transformer as referred to above.

(3) DC main circuit

i) Valve and its protection arrester

ii) Transformer for converter

Connections of 人- Δ and 人 -人 are adopted to meet requirement of 12-pulse operation from the initial stage.

iii) Following equipment will be provided per each pole on the DC high voltage side:

a) DC reactor for direct current smoothing

b) DC filter --- 6th and HP

c) Arrester and surge capacitor

Protection against surging from direct current side

d) DC current transformer, DC potential transformer for control and protection

iv) Electrode line will be equipped with the following items:

a) Arrester and capacitor

for control against overvoltage and surging

b) DC current transformer, DC potential transformer for control and protection

(4) Necessity of short-circuit capacity

Generally, when following points are considered, it is desirable that the short-circuit capacity at receiving end of AC system should be nearly five (5) times as much as the DC rated output, but it is possible also to reduce these figures to about 3 times if adequate control is applied.

- System voltage rise due to momentary voltage fluctuation
- Voltage stability of HVDC system
- Distortion of AC system voltage

(5) Necessity of reactive power supply

i) Reason for necessitating reactive power

a) Because voltage and current are regulated by control angle, AC current phase lagged by force when viewed from the AC side. Therefore, reactive power supply is required for such phase difference.

b) The overlapping period in the commutation is equal to the short circuit of line when viewed from the AC side and reactive power must be supplied to cover this overlapping period.

Since they are all lagging reactive power in all instances above, the converter station must be provided with leading reactive power.

ii) Reactive power requirement

Since required reactive power is equivalent to about 60 percent of rated direct current, the capacity is estimated at 270 MVA at the 1st stage and 540 MVA at the 2nd stage.

iii) Reactive power supply system

a) AC filter

b) Power condenser

c) Generator

These equipment can supply reactive power. Required reactive power will be supplied by operation of AC filter and generator at Tongonan in Jaro side and by AC filter and static capacitor in Naga side.

(6) Fundamental control of HVDC system (Fig. 6-14, Fig. 6-15)

i) Bidirectional power transmission should be possible for the converter. It should be noted, however, that the short circuit capacity at receiving end in large enough as stated earlier.

ii) The fundamental control are constant power control by the power setting switch and constant frequency control on AC side at sending end (Jaro Converter Station).

iii) Setting of the above PSS can be done through the following route:
Central dispatching station → Tangonan Power Plant
→ Jaro Converter Station

iv) The power setting value combined both power setting switch and frequency control will be transmitted to Naga Converter Station by communication circuit.

v) Jaro Converter Station will serve as the master control station for control of the DC system.

vi) The control system referred to below should be reviewed at the stage of detailed designing. Frequency control on sending end by controling direct current in coordination with generator in case of large frequency fluctuation at receiving end (Naga Converter Station).

Fig.6-14 OUTLINE OF HVDC CONTROL & PROTECTION SYSTEM DIAGRAM (PRELIMINARY)

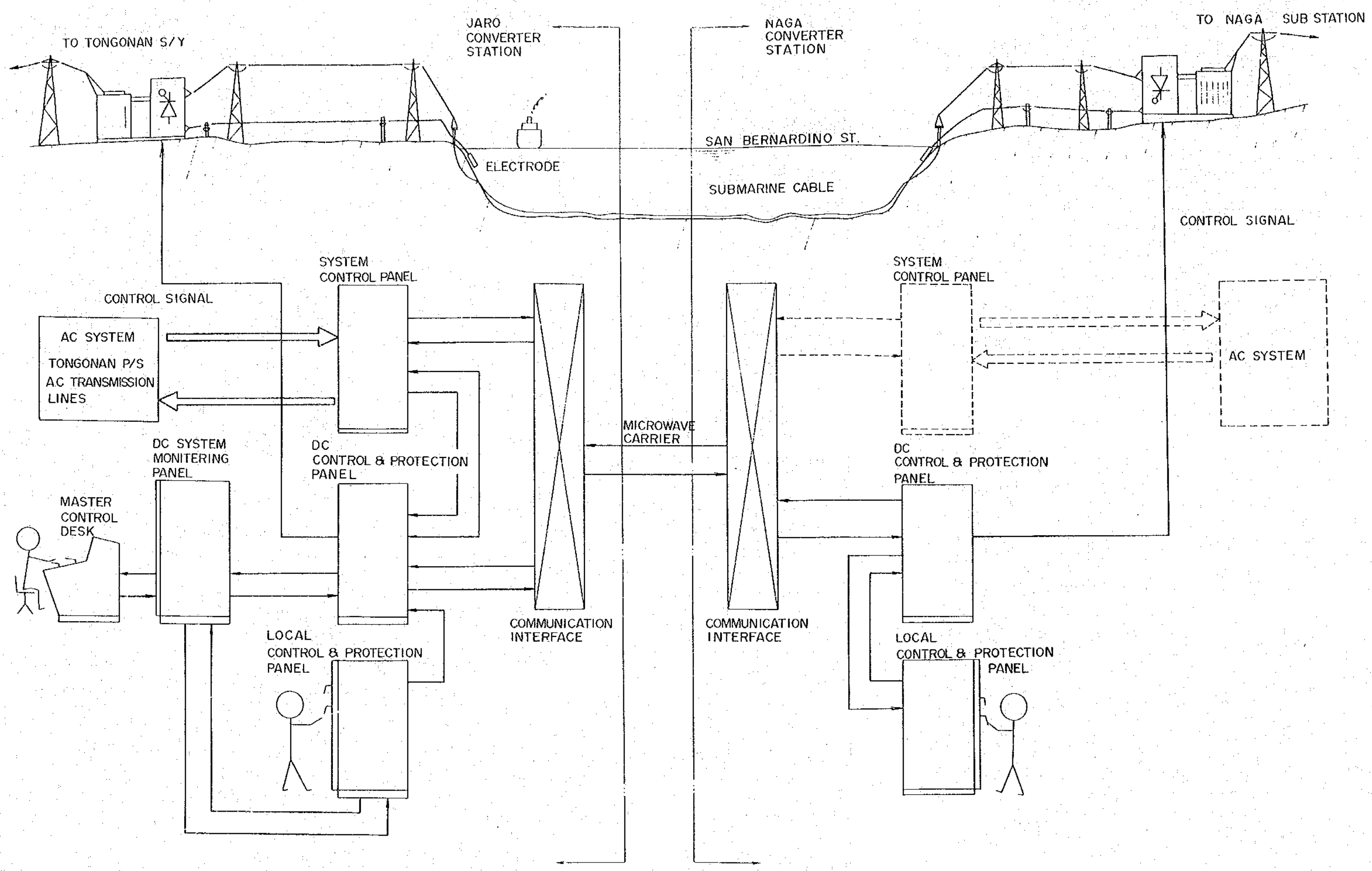
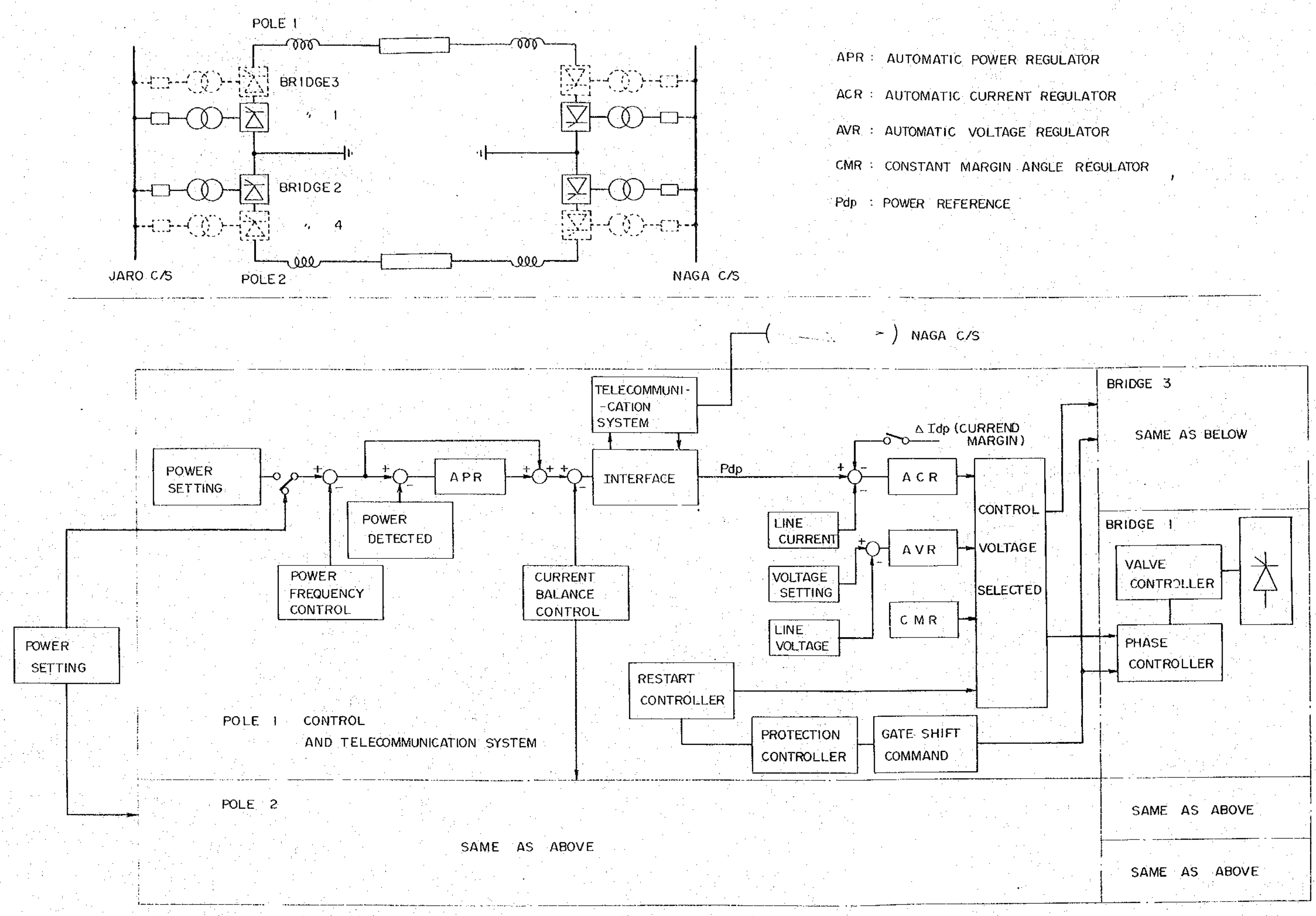


Fig.6-15 HVDC SYSTEM CONTROL BLOCK DIAGRAM (PRELIMINARY)



vii) These fundamental control functions (APR, ACR, AVR, CMR and AFC) should be divided into individual pole unit, if possible, so as to improve reliability and maintenance-ability of the system.

viii) In case of one pole grounding fault of the DC transmission line, the converter in the faulty pole goes into stoppage temporary until restarting of operation after recovery of insulation. During this period, overload operation should continue within the allowable extent by the other sound converter transmission line so that speed increase of the generator can be restrained.

ix) To be provided with function to correct unbalance of current between poles during their operation.

x) Coordinative control and protection between two converter stations can be ensured by the communication line of high reliability installed between Jaro and Naga Converter Stations.

xi) The function of voltage regulation on the AC system should be performed by generators connected to Tongonan and Naga and HVDC system will not perform.