Cebu, Dec. 11, 1951) However, according to the wind speed of return period of 50 years obtained by extremum distribution analysis of strong-wind data (by Dr. Roman L. Kintarar, PAGASA), the three islands of Panay, Negros and Cebu are more or less covered with 90 kts (46.3 m/sec). Consequently, the design wind speed against this transmission line is to be in harmony with the existing transmission lines and the standard design wind speed of NAPOCOR of 46 m/sec will be used.

(3) Outline of Facilities of Overhead Transmission Line

The outline of the facilities of this overhead transmission line is as follows:

Length	:	302 km (lengths of individual sections as indicated in Table 6-1)
Voltage	:	AC 138 kV
Electricity System	:	3 phase, 3 wire, 60 Hz
Number of Circuits	:	1 cct and 2 cct
Conductor	:	240 mm^2 ACSR
Overhead Ground Wire	:	60 mm^2 GSC, 1 line
Insulator	:	250-mm suspension insulator, 8 and 10 insulator strings
Support	:	Angle steel tower
Foundation	:	Concrete slab foundation

6.2.2 Submarine Cables

(1) Selection of Submarine Cable Routes and Cable Terminals

i) Principles of Selection

In preparing a plan for a submarine cable line, there is no difference from other electric power facilities in that reliability must be emphasized along with the economics, and in particular, reliability must not be looked upon lightly. This is because if a fault were to occur with a submarine cable for some reason, several months may be required for restoration, and there will be a risk that power supply during this period will be disrupted.

Selection of the cable route is the most important factor governing the economics and reliability of the submarine cable line itself, and it is essential for the cable route to be selected based on multi-faceted and detailed investigations. The principal items among those to be investigated are described below.

(a) Cable Length

The construction cost of a submarine cable line is governed chiefly by the cable length, and moreover, since it will be as much as tenfold costlier than an overhead transmission line, the economics will be improved the shorter the cable length. Furthermore, if the cable length is too long, not only will the effective transmitting capacity of the cable be reduced because of capacitive charging currents required for the cable itself, but in case of OF cable, the feeding of oil for maintaining insulation properties will also be affected.

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

(b) Sea-bottom Topography and Bottom Material

The topography of the sea bottom and the bottom material are of greatest importance in securing reliability of a cable line. It will be most suitable for a cable route if the sea bottom is sandy, and in addition, as flat as possible.

If the underwater relief were to change on a small-scale (spacing: several to several tens of meters), the cable will bridge and be in a suspended state in the water, and subjected to the influences of waves and sea currents, it will become mechanically fatigued and damage will occur. Gentle and large-scale relief (spacing between ridges: several hundred meters) does not pose very great problems, but if there is a steep portion, the cable itself will move in the longitudinal direction over a long period of time accompanying thermal expansion and contraction of the cable, and the conditions will become undesirable with cable tension at such a portion being increased.

Generally speaking, when the sea-bottom topography is complex or is rocky, it may be expected that the previously-mentioned complex relief will exist, and such a site should be avoided as a cable route by all means. To overcome the drawbacks by submarine civil works will require tremendous expense. The same thing may be said when the sea bottom consists of coral, but submarine civil works will cost somewhat less depending on the type of coral.

If the sea-bottom geology consists of sandy material, there will generally be little relief so that damage will not be inflicted on the cable, while the cost of laying cable at the sea bottom will be relatively cheap. Consequently, it will be most desirable for the bottom material of a cable route to be sandy.

As for the case of muddy material, there will be no problem from the aspect of mechanical damage to the cable, but since the thermal conductivity of mud will be low, it would result in reducing the transmitting capacity of the cable, and it cannot necessarily be said to be a desirable geological condition.

(c) Depth of Water

The depth of water to the sea bottom is not necessarily a critical condition for a cable, but it is also an important matter since it will be related to the economics and ease or difficulty of cable-laying operations.

The range in which cable laid at the sea bottom is greatly affected by waves is a depth of 5 m and shallower, and in this range it is normal for the cable to be buried under the sea bottom for its own protection. The maximum depth at which a cable will be affected by waves will depend on the wave conditions at the specific sea area, and is said to be around 15 to 20 m.

Meanwhile, the depths at which underwater work is possible to be done by divers are down to about 30 m, and it is considered impossible for any work to be done below 60 m. Consequently, in case trouble occurs with a cable at deeper than 30 to 60 m, restoration work will be more difficult, the period required for the repairs will be longer, and the expense incurred higher.

The depth of the cable route will also be related to the design of the cable itself and the cable-laying work. In case the maximum depth of water along the cable route is very great, tension during cable laying will be very great and this will need to be taken into account in mechanical design of the cable itself, while the required performances of braking apparatus and other equipment used in cable laying will also be affected.

Based on the above, the depth of water desirable for a cable route may be said to be between 20 m and 30 m.

Next, if it is shallow for a great distance from the shore, the length of embedment of cable will be greater and the expense required for this will be increased. Furthermore, in relation to the draft of the cable-laying vessel, the mooring site at the time of cable landing will be far from the shore making operations difficult, or it may be impossible for the cable-laying vessel to be used. Therefore, a shore where water is shallow for a great distance is not desirable for a cable route.

(d) Tidal Current, Waves, Weather

Marine phenomena such as waves can be causes of mechanical damage occurring to a cable, but when a cable route of suitable topography and bottom materials as previously described is selected, and the cable is adequately protected at parts of shallow water, these phenomena will not greatly affect the reliability of the cable itself. However, the phenomena can greatly influence the case or difficulty of cable-laying works, or fault repairing works. Needless to say, severe conditions of tidal currents and waves are unsuitable from the standpoint of safety of vessels and workers, while it will be made difficult to navigate along the planned cable route, while also, the tonnages, required performances, and number of vessels used for cable-laying work will also be affected. Furthermore, there is a risk of cable performance being impaired during cable-laying work, while the problem that the actual locations of cable route will become blurred will also arise.

Therefore, the more that marine phenomena such as waves and tidal currents of a site are severe, the cable route should be selected that much more carefully, and moreover, the conditions of waves and tidal currents thoroughly investigated to establish the timing of the period for cable-laying works.

Firstly, the season suitable for such work is determined by weather and waves, and it is necessary for the work to done during a season in which more days of calm seas continue for longer periods, and this is related to the weather coefficient in computation of construction cost. Next, work-execution days are governed by variations in tidal currents, and referring to tide tables, days of neap tides, in effect, when tidal currents become relatively slow should be set for cable laying, while further, cable laying times should be set to coincide with tide reversal times.

Since it is necessary for cable laying periods to be selected according to the tidal currents, waves, and weather in this way, an adequate work period which will not restrict this freedom will be needed.

Next, the concentration of salt in the atmosphere is increased when high waves are produced and the surfaces of insulating tubes and insulators to be attached at cable terminals and overhead transmission lines in their vicinities will be soiled by salt, and there will be risk of electrical faulting to occur. Consequently, in case of laying submarine cables in waters where high waves frequently occur, it is necessary for site selections and design of cable terminals to be given consideration.

(e) Cable Terminal

At a cable terminal which is the connecting point between cable line and overhead line, there are installed:

- Cable-end box
- Cable protection lightning arrester
- Fault locator
- Overhead line outgoing steel structure
- Telecommunications apparatus
- Appurtenant facilities, and in case of OF cable, oil-feeding apparatus

and the space necessary for these facilities is about 35 m x 35 m (although the space required will differ depending on the size of the oil-feeding facility).

It is necessary for this required space to be at a flat area, and in addition, for the geological conditions to be suitable for providing the foundations of the various equipment units.

It is better for the location of the cable terminal to be as close to the cable landing point as possible to shorten the length of cable buried underground but if it is a location too close to the seashore, sprays of seawater will be caught with sea salt adhering to insulating tubes to cause insulation impairment, while there is a risk of line-to-ground faulting occurring, while corrosion of various equipment will progress comparatively rapidly.

It is desirable for the underground cable route to be at a gently sloped topography and where the geology allows embedment works to be performed easily, and places where cliffs or large height differences exist must be avoided. Cable laying is difficult at a cliff, while movement in the longitudinal direction will occur accompanying thermal expansion and contraction of the cable itself. However, in case of small height differences, it will be possible to cope with them by civil works or by attachment of cable-fixing devices.

Meanwhile, in selection of the location of the cable terminal, it is necessary for it to be selected where a steel tower can be erected in a suitable direction at a suitable site inland.

Further, it will naturally be necessary for considerations from many aspects to be given regarding conditions for hauling in equipment and materials, leading in of intrastation power supply distribution lines, provision of access roads so that in case faulting should occur maintenance personnel can arrive for repairs even during stormy weather at sea.

ii) Selection of Submarine Cable Route

For investigation of cable routes, sea-bottom topographies and bottom materials were estimated from hydrographic charts, and reconnaissances and observations from helicopter were made of vicinities of seashores. Cable routes were selected based on the principles of selection of the preceding section and the results of these investigations.

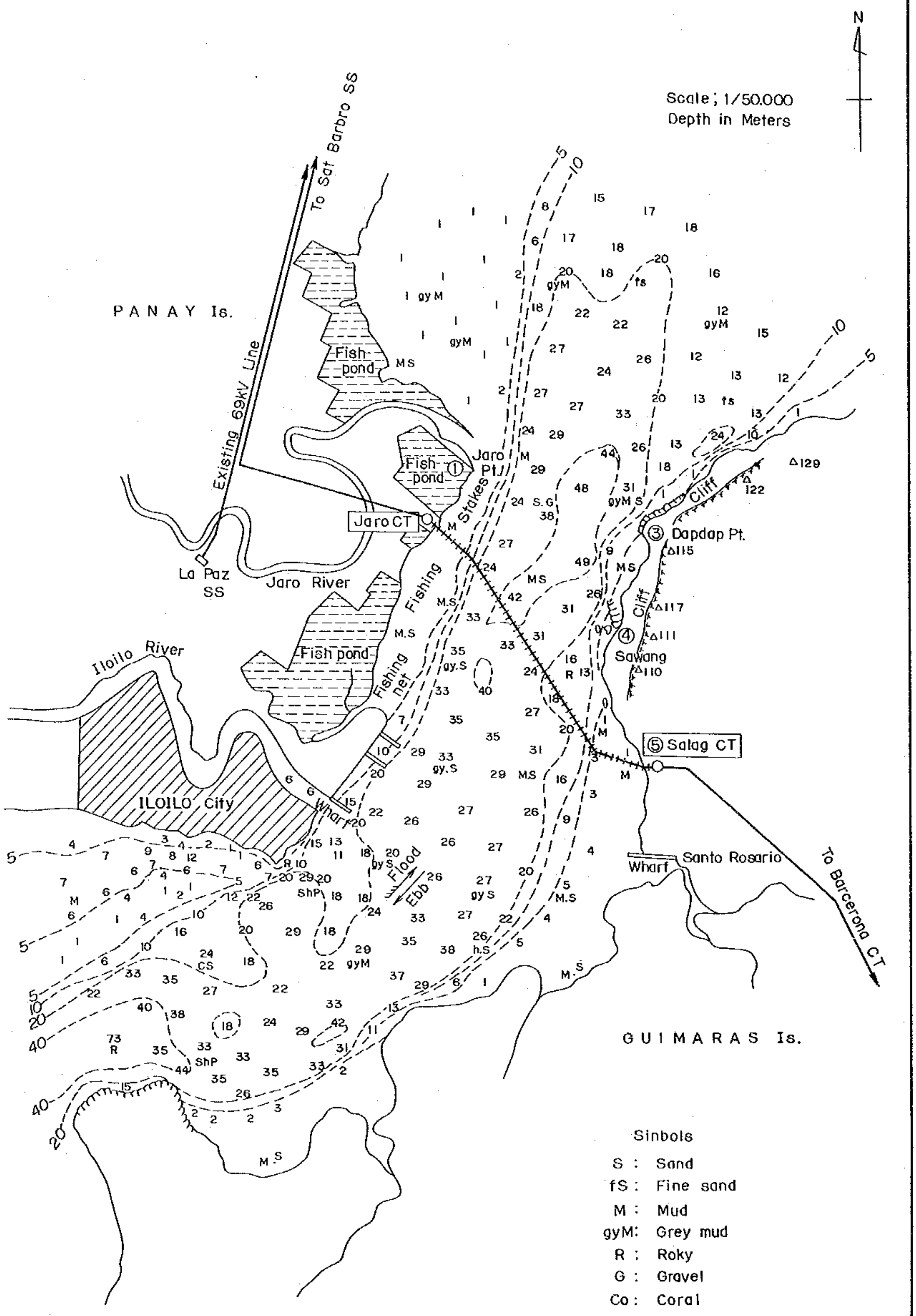
The routes investigated for the three straits of Iloilo, Guimaras and Tañon are shown in Fig. 6-3-(1), Fig. 6-3-(2) and Fig. 6-3-(3), respectively.

The cable route proposals across the respective straits should be determined ultimately on carrying out detailed investigations of the sea-bottom topographies and bottom materials.

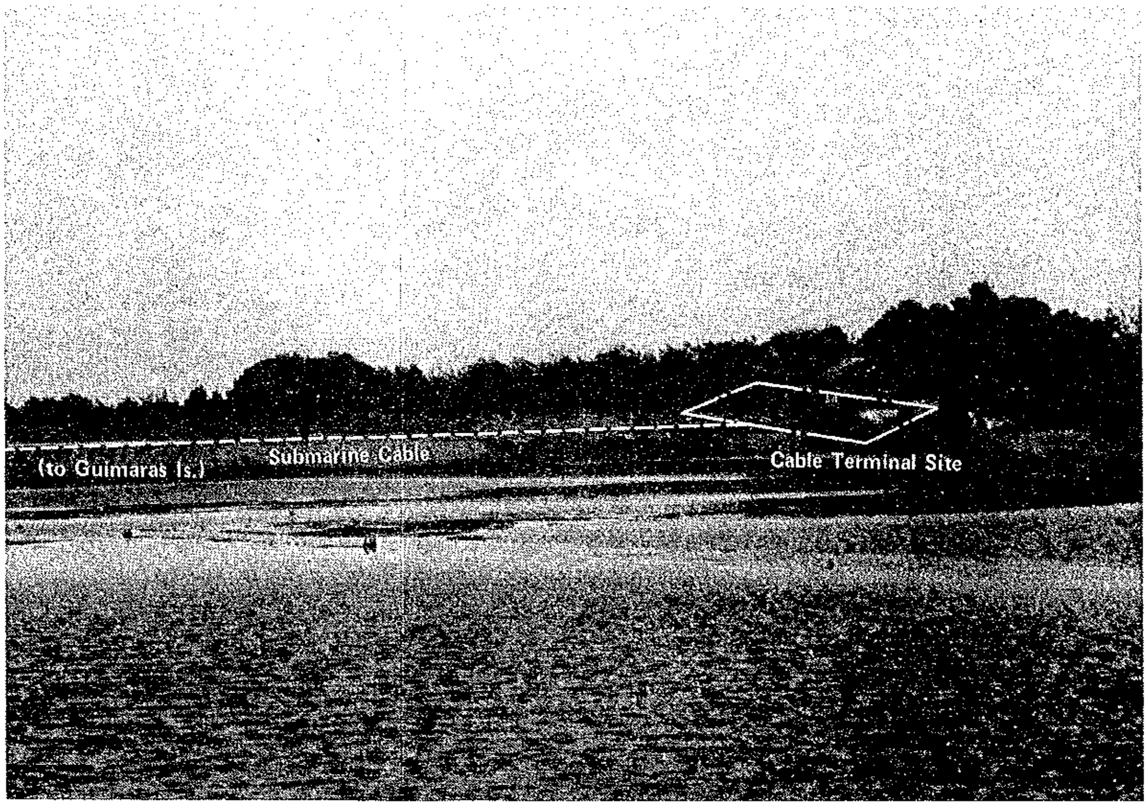
(a) Iloilo Strait

The shortest route between the two islands of Iloilo and Guimaras is the approximately 2 km between Pt. Jaro and Pt. Dapdap.

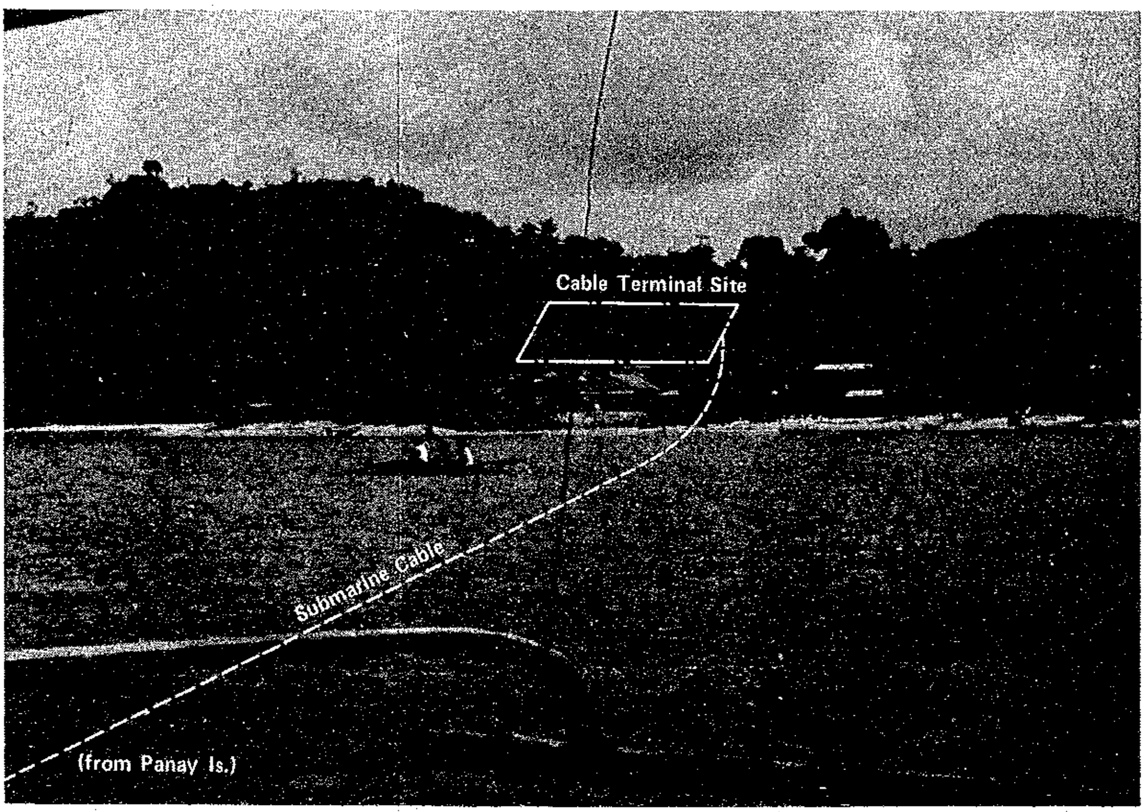
Fig. 6-3-(1) Submarine Cable Route in the Iloilo Strait



Iloilo Strait

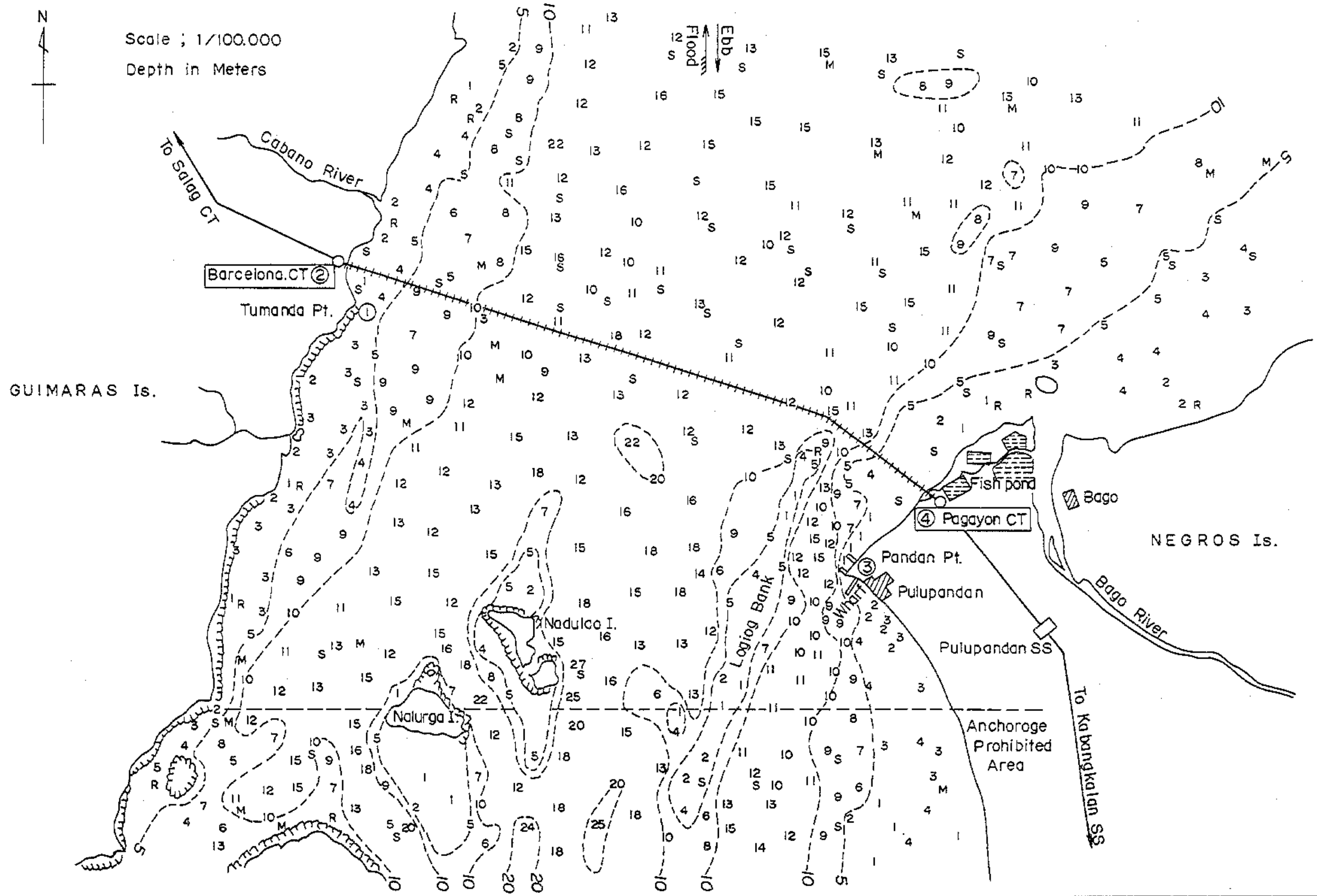


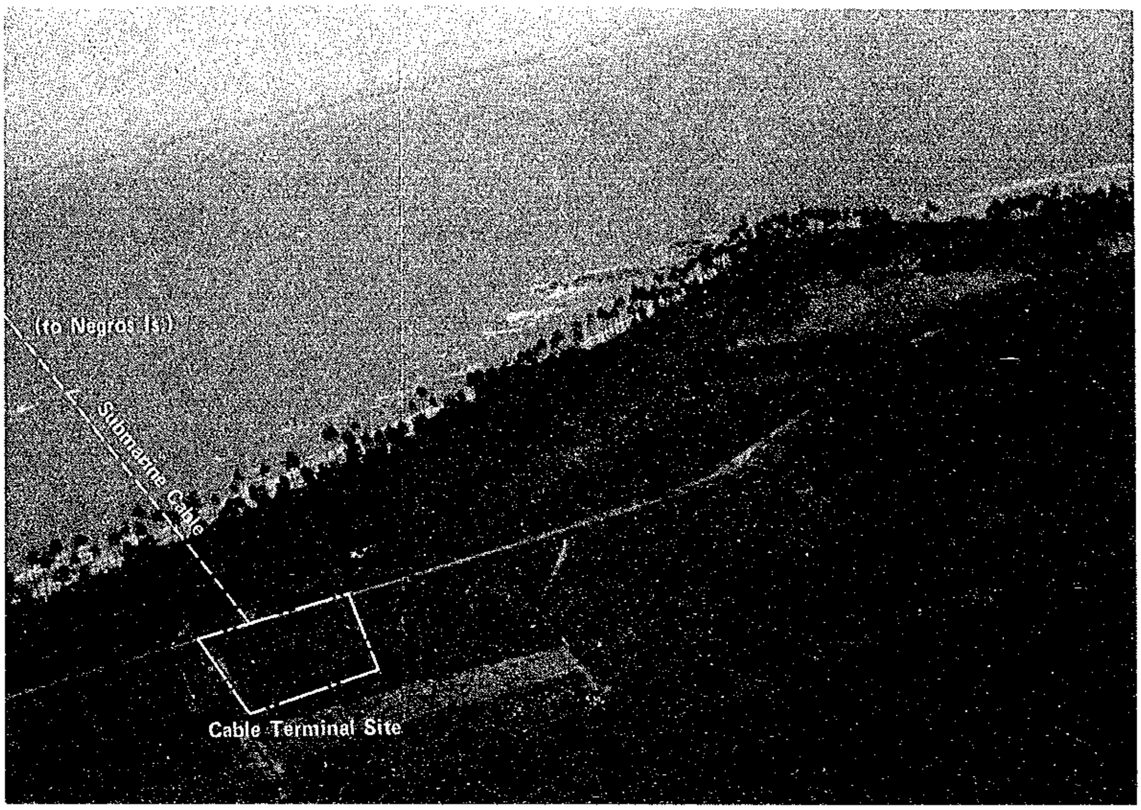
Jaro Cable Landing Site (Panay Is.)



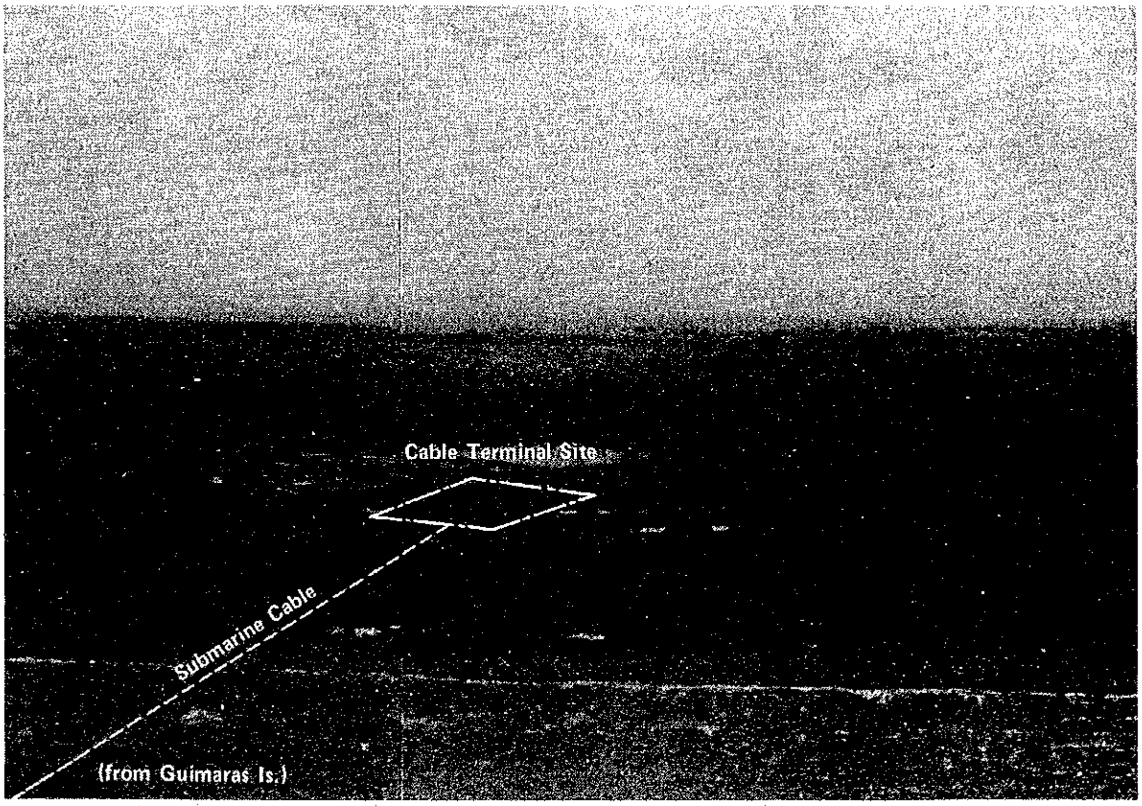
Salag Cable Landing Site (Guimaras Is.)

Fig. 6-3-(2) Submarine Cable Route in the Guimaras Strait



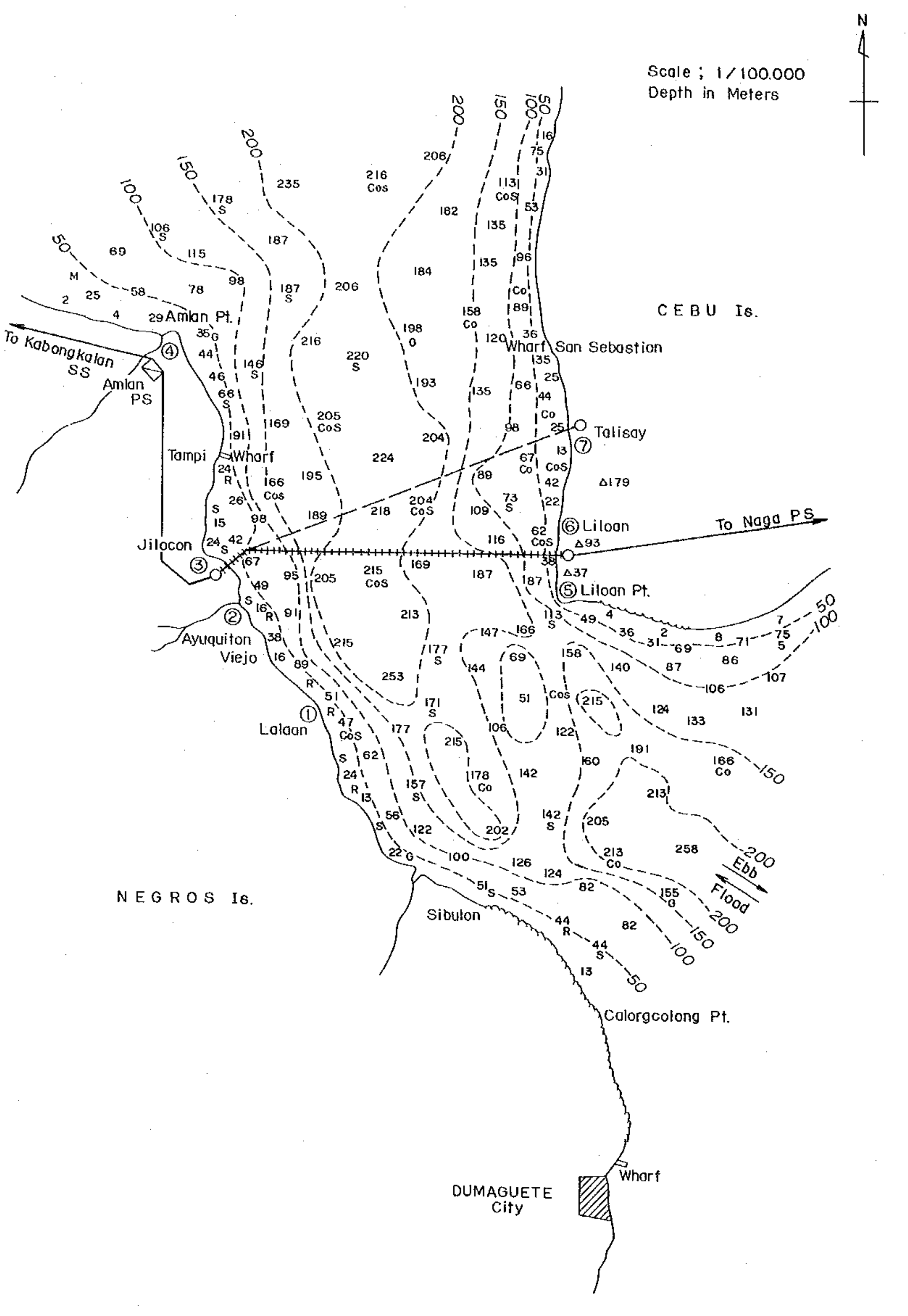


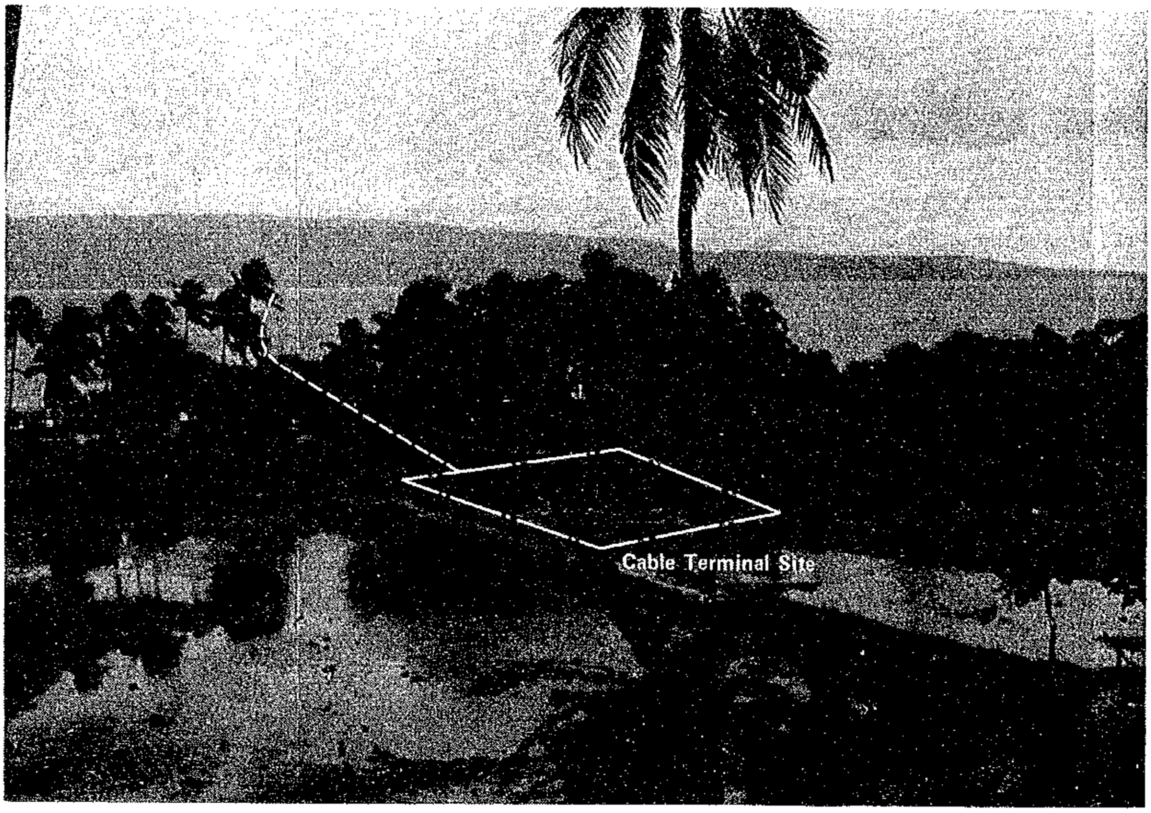
Barcelona Cable Landing Site (Guimaras Is.)



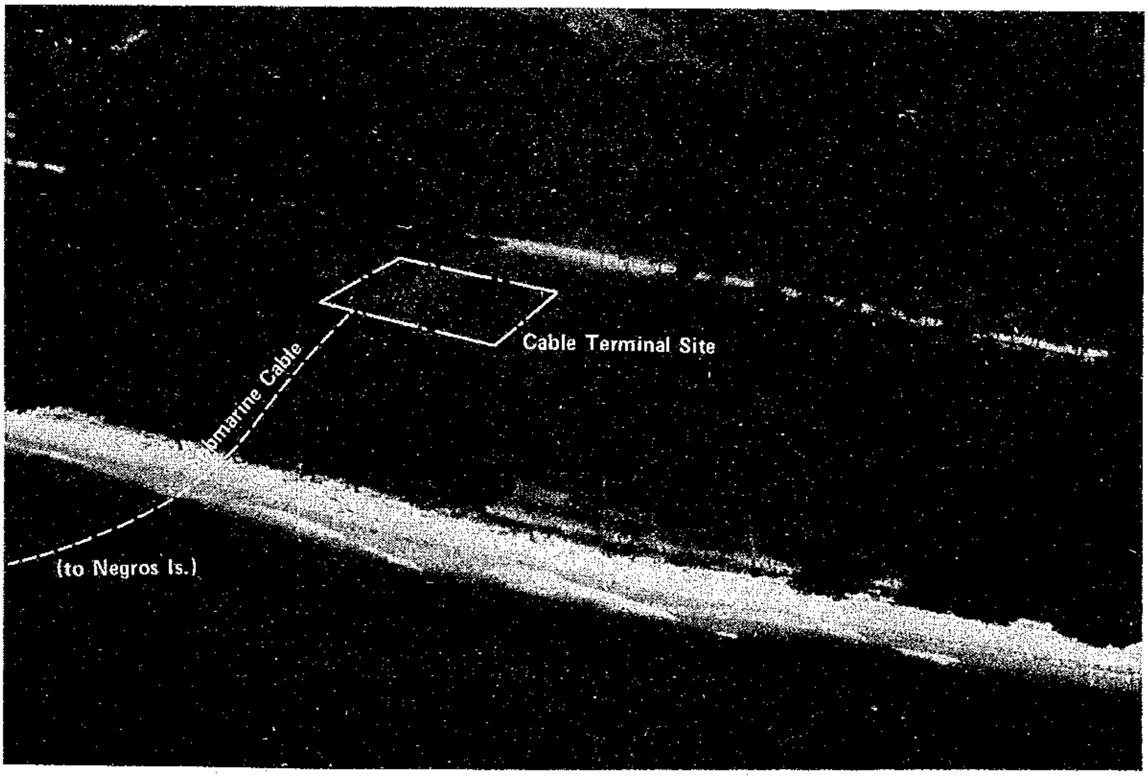
Pagayon Cable Landing Site (Negros Is.)

Fig. 6-3-(3) Submarine Cable Route in the Tañon Strait





Jilocon Cable Landing Site (Negros Is.)



Liloan Cable Landing Site (Cebu Is.)

However, the vicinity of Pt. Jaro ① on the Iloilo side has fish ponds over a wide area so that construction of cable terminal and connecting transmission line is difficult, and the site ② approximately 1 km south from Pt. Jaro was selected as the landing point.

On the other hand, Pt. Dapdap ③ on the Guimaras side is rocky, in addition to which the inland mountain slopes comprise cliffs, so that it would be extremely difficult for a connecting transmission line to be constructed, and it is unsuitable as a cable landing site. There is a small-sized sand beach at Sawang ④ approximately 1 km south of Pt. Dapdap, but it is similarly considered to be difficult for a connecting transmission line to be constructed. Approximately 1.5 km further south, the Salag site ⑤ is suitable both geologically and topographically for cable landing, while there are suitable sites for a cable terminal and a connecting transmission line, and therefore, the Salag site ⑤ is to be considered as the first candidate location for the landing site. As for the Sawang site, in case it is judged upon detailed investigations that it will be possible to construct a power transmission line, it will be permissible for this to be made the cable landing site.

The bottom material at the middle part of the strait is more or less sandy or muddy and there will be no special problem with regard to cable laying.

The length of the cable route between Jaro ② and Salag ⑤ is 3.7 km (3 km according to NAPOCOR plans), and the maximum depth of water is 42 m.

(b) Guimaras Strait

Regarding the cable landing site on the side of Guimaras Island, since Pt. Tumanda ① is a reef area, the sand beach of Barcelona ② to the north was selected. However, since it is thought the topography of the shallow part of this vicinity is complex, it is necessary for the cable route to be finally decided upon detailed investigations of the sea-bottom topography and the bottom material.

At the vicinity of Pt. Pandan ③ on the Negros side, since there are existing facilities such as sugar plants, and considering the connecting transmission line route, the Pagayon site ④ approximately 2 km to the north was selected as the cable landing site.

It is thought that the greater part of the bottom material at the middle portion of the strait consists of sand. However, the Negros side is the shallow shoals of the Logiog Bank for about 2 km to the offshore side, and since a rocky or hard sandy ground is anticipated, it will be appropriate for the cable route to detour around this shoal portion. However, if it should be confirmed by bottom material investigations that Logiog Bank has a sand layer of sufficient thickness, it will be possible for a straight line cable route to be taken.

The length of the cable route is 12.8 km (NAPOCOR plan: 13 km), while the maximum depth of water is 18 m.

(c) Tañon Strait

The shortest route between the islands of Negros and Cebu is the approximately 5.5 km between Lalaan and Pt. Liloan, but near the line connecting these two points and the waters south of this line the sea-bottom topography is estimated to vary in a complex manner, so that it is necessary for judgments to be made after careful sea-bottom investigations have been carried out, and for the present, this route should be considered as being unsuitable.

The general area of the Lalaan site ① on the Negros side is a reef area and is unsuitable as a cable landing site. It was thought to adopt the method of landing at a sand beach at the mouth of Ayuquitan Viejo ② approximately 2 km to the north, with the landing cable laid at the river bed, but since it was considered that flow conditions would be violent during floods and the stream flow conditions would vary easily, this site was also judged to be unsuitable. The cable landing site on the Negros side most suitable is the sand beach of the Jilocon site ③ , which is also suitable as a site for connection between cable terminal and connecting power transmission line.

The vicinity of Pt. Amlan ④ is a sandy beach, and it is possible for a cable to be landed, but the bottom from the shoreline is deposited with gravel and is shallow, while tidal currents are variable to make boat navigation difficult, so that it cannot be said to be suitable as a cable landing point.

On the other hand, the vicinity of Pt. Liloan ⑤ on the Cebu side is a broad sandy beach and suitable locations for a cable terminal are available inland, but there are coral reefs offshore with a possibility that their edges comprise topographies of steep slopes. Furthermore, these are waters where tidal current directions vary in a complicated manner, and Pt. Liloan is not necessarily suitable as a cable landing site. A site, ⑥, approximately 1 km north of Pt. Liloan has a sandy beach, while offshore coral reefs are not thought to be very wide-spread so that cable protection would be possible through underwater civil works. The height difference of approximately 3 m on the land side can also be coped with by civil works. Accordingly, the Liloan ⑥ site can be made the cable-landing point. Farther to the north by about 2.5 km, the vicinity of the Talisay ⑦ site is more suitable than Liloan ⑥ with regard to the onshore topography, but according to observations from helicopter, coral reefs appear to be spread out prominently. If it is judged upon detailed investigation of bottom materials that these coral reefs can be handled, it is possible that the Talisay ⑦ site will be advantageous as the cable-landing point.

It is estimated that the bottom material of this sea area is a mixture of sand and coral fragments, with coral reefs developed at

Table 6-2 General Condition of Submarine Cable Routes

Item	Iloilo Strait cable route	Guimaras Strait cable route	Tañon Strait cable route
Section	Jaro - Salag	Barcelona - Pagayon	Jilocon - Liloan
Length	3.7 km	12.8 km	7.1 km
Depth	Max. 42 m	Max. 18 m	Max. 220 m
Geographical condition	Almost plane	Almost plane partially shallow	Steep slope near the both side shore
Geographical condition	Sandy and mudy	Sandy	Sandy and coral partially coral reef
Tide current	Max. 3 - 4 kt Ave. 1.5 kt	Max. 2 kt Southwest monsoon season Max. 6 kt	Highest tide 5 - 6 kt Neap tide 2 - 3 kt
Fishing	Private fishing Fishing fence is seted near the shore Jaro side.	Private fishing	Private fishing
Cable terminal	Jaro : Land work is required	Barcelona : No problem	Jilocon : No problem
	Salag : No problem	Pagayan : Piling may be needed.	Liloan : Low cliff of coral. Civil work is required.

shallow parts, and investigations of the sea-bottom topography and bottom materials should be given special emphasis. It is thought appropriate for the selection of one of the above two routes to be made based on the results of sea-bottom investigations.

The length of the cable route from Jilocon ③ site to Liloan ⑥ site is approximately 7.1 km (NAPOCOR plan: 7 km) and the maximum depth is approximately 220 m.

iii) General Conditions of Submarine Cable Routes

The general conditions of the cable routes crossing Iloilo Strait, Guimaras Strait and Tañon Strait are as indicated in Table 6-2.

According to investigations at port and harbor offices at neighboring ports of the three straits, the information was obtained that none of the cable routes is especially an anchorage area for ships, while obstacles such as sunken vessels should not exist. As for wave conditions, it was suggested that waves were small in May-June, and this would be the most suitable period for marine operations.

With regard to the ports and harbors to be used as bases during cable-laying works, the situation will be as described below. During operations at Iloilo Strait it will be possible to use the nearby port of Iloilo. The cable route across Guimaras Strait is close to the port of Pulupandan, but this port has no breakwater, and during strong winds, waves from the Visayan Sea or the Sulu Sea are high, and the waters become considerably rough. At present, a port is being constructed at Bacolod and it is thought refuge may be taken there during strong winds. Next, regarding Tañon Strait, the port of Dumaguete is nearby, but since it faces directly out to the Bohol Sea, refuge during strong winds will be taken at the ports of either Tagbilaran or Cebu.

iv) Detailed Investigations of Submarine Cable Route

Investigations of sea-bottom topography and bottom materials are extremely important for the reliability and thus the economics of a submarine cable line is as already stated under 6.2.2-(1). However, because of limitations of time for the present Feasibility Study, data such as hydrographic charts and water channel journals, and enquiries made of agencies concerned in the field were relied on, with field investigations actually carried out being restricted to only the vicinities of seashores, and thus the investigations were inadequate for cable routes.

Prior to formulation of final plans for the submarine cables, detailed investigations of necessary items headed by sea-bottom conditions at cable route areas should be carried out as soon as possible. With respect to the actual method of carrying out the investigations, it is conceivable that NAPOCOR will obtain a general concept of the conditions concerning important items by undertaking a preliminary investigation itself, followed later by more detailed investigations caused to be made by contractors or suppliers.

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

- Cable length
- Depth of water
- Sea-bottom topography, changes due to causes such as drift sand
- Bottom materials (particularly, boulders, reefs), thermal conductivity (particularly, mud)
- Tidal currents (bottom current and surface current), tide level, tide and turn of tidal current
- Water temperature, water quality, aquatic micro-organisms
- Meteorology (air temperature, wind speed, wind direction, fog, others)
- Waves (height, frequency of occurrence, period of occurrence)
- Sunken obstacles (existing cables, sunken vessels, fish grottoes, etc.)
- Ship navigation, anchorage
- Fishing (methods and equipment)
- Landing point and cable terminal
  Topography, space, geology, distance from shore, insulating tube soilage conditions, outgoing route of overland transmission line, leading-in of distribution line for station power supply
- Operations base port, investigation of watercraft for works
- Other construction projects (bulkheads, dredging)
- Related laws, ordinances and regulations on power cables, offshore works, etc.

(2) Outline of Preliminary Design

i) Selection of Cable Type

As types to be examined for adoption in the submarine cable lines oil-filled cable (OF cable) and cross-linked polyethylene cable (XLPE cable) will be considered.

Other than the above, there are oil-impregnated paper cable (PL cable) and gas-filled cable (GF cable) as cables for power transmission. PL cable was widely used for a long time as a low-voltage cable, but the durability is inferior and it is not used very much any more. Especially, in the case of a submarine cable, it will be unavoidable for there to be sloped portions in the cable route, and at sloped portions the impregnated oil will migrate down to lower levels over a period of many years to leave de-oiled parts. Various measures for preventing de-oiling have been provided, but it cannot be denied that it is a cable which inherently possesses a deteriorating nature, and therefore, this type is hardly ever adopted except for long-distance submarine cables for which it is not possible to design means of feeding oil. As for GF cable, transient mechanical stresses fluctuation is small so that it is suited to submarine cables of great depths, but since special manufacturing technology is required, there are very few cases of its use in the whole world.

The cable which electrically is the most reliable is the OF cable and it is adopted for practically all high-voltage power cables. This cable requires appurtenant facilities for oil feeding, and although trouble with the cable proper would be extremely rare, trouble is likely to occur with the oil-feeding system, which requires careful inspection and maintenance. Submarine cables are subjected to various manners of mechanical handling, whereas OF cable has the drawback of being susceptible to mechanical damage.

The XLPE cable came into use in the 1950s and much trouble of various kinds were experienced with early products, but after going through a stage of improvement, it has almost completely replaced the OF cable for 66 kV to 77 kV class and under, while recently, it is beginning to be adopted for 275 kV to 330 kV class. Research and development is still going on at present for XLPE and it is a cable which is in a continuing state of improvement. Even though in electrical reliability it is inferior to the OF cable, the XLPE has already been adopted even as an extra-high voltage cable, and it may be considered that its practicality has been established. Furthermore, the XLPE cable has many advantages such as being strong against mechanical stresses, and being easy to maintain as oil-feeding devices are unnecessary. This type has been used for submarine cable lines of relatively low voltages, but it appears not to have been used yet for 138 kV class. One of the reasons is concern about the effect of seawater on the insulation, but this problem can be completely eliminated by providing a lead sheath as a metal waterproofing layer. It is conceivable for the lead sheath to become fatigued by expansion and contraction accompanying temperature changes of the insulation, but regarding this point, it will be possible to lower the possibility of fatigue by restricting the conductor temperature.

With respect to the economics of the OF and XLPE cables, OF is slightly cheaper than XLPE in terms of cable price alone, but XLPE cable will not require oil-feeding apparatus, while laying work will be relatively simple, and in addition, maintenance is easy, so that overall, it is thought there will be little difference between the two. It is thought that economic evaluations will differ depending upon individual suppliers.

Based on the above, and considering that it has high mechanical strength and that maintenance is easy, and that progress will be made in research and development with regard to fatigue of the lead sheath, XLPE cable is to be adopted for these submarine cable lines. It might be added that even if the type of cable were to be changed at the stage of definite design, since the construction costs will not be very much different, the change will not affect the conclusions regarding the feasibility evaluation which is the purpose of the Study reported herein.

ii) Cable Size

The current capacity of a cable is governed by the thermal conductivity of the surrounding soil in the condition that 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 is similarly a problem.

In order to obtain the interconnected capacity stated in 5.2.2, it is possible to use cable size of 200 mm^2 if the specific thermal resistivity of the soil is about 40°C cm/W or under. However, since the specific thermal resistivities in the field for the coming project are unknown, a cable size of 300 mm^2 is to be adopted assuming cases of adverse conditions. The final selection of cable size should be done after the specific thermal resistivity value is grasped by detailed investigations of the sea bottom. In the case of using cable of 300 mm^2, since it is estimated that the bottom material will be sandy at Tañon Strait, if the specific thermal resistivity is 60°C cm/W, the current capacity will be 610 A and the interconnection capacity 130 MW. The conductor temperature will be about 65°C during transmission of 100 MW and the possibility of lead fatigue will be alleviated. Since the bottom material of Iloilo Strait is mostly mud, if the specific thermal resistivity is 140°C cm/W, the current capacity will be 500 A and the transmitting capacity 100 MW. As for the size required for the onshore cable from the shoreline to the cable terminal, it will be necessary for a study to be made at the time of final design.

When the structure of the 300 mm^2 XLPE cable is considered as a 3 core cable, the outside diameter of the cable will be approximately 180 mm ∅ which will exceed the limit to manufacturing capabilities, and as of necessity, single-core cables will be used. It may be said to be reasonable for single-core cables to be adopted from other engineering viewpoints also. Since the depth of Tañon Strait exceeds 200 m, the tension during cable laying will be more than 10 tons, and braking apparatus will be needed to safely lay a cable. And in order for a cable to be smoothly played out using the braking apparatus, it will be necessary for a coupling method to be used where the cable itself and the outside diameter will be of practically the same diameter, but at present, equal diameter coupling of high voltage, 3 core cable has not been developed. A single-core cable has a lighter weight per unit length, and cable-laying work will be relatively easier.

iii) Number of Cable Lines to be Laid

It is conceivable to lay 4 lines of submarine cables including one reserve line in order to improve the reliability, but 3 lines are to be laid this time for the reasons below.

Although the 3 straits for the cable routes are all major provincial navigation channels, passage of large-sized vessels is not so frequent, neither are these sea areas anchorages, while with regard to fishing which is apt to be a cause of submarine cable trouble, it consists mostly of private fishing by individuals and large-scale trawling is not being done. Regarding the cables themselves, since protection measures will be provided as much as practicable as will be described later, it is thought the possibility of cable trouble occurring will not be great, and considering reduction of the initial construction cost, it is judged reasonable for 3 lines of cable to be laid.

Further, in case a situation should arise in the future that cable troubles occur frequently in contrast to expectations, it will become necessary to lay an additional cable line as a reserve, and this again is one reason that single-core cables are to be adopted.

iv) Insulation Design

With rated voltage of cable as 138 kV, BIL as 650 kV, and considering performances of onshore cables, the thickness of insulation is to be 20 mm.

On the other hand, considering that this area is of high isokerautic level, lightning arresters are to be installed at cable terminals at both ends of a cable, and it is to be protected against lightning surge at the time of a stroke.

v) Armor and Protection Method for Cable

The cable is to be provided with one layer of 8 mm ø steel wire for the purposes of prevention of damage from anchors and mechanical reinforcement against cable laying tension.

The cross sectional composition of the submarine cable is given in Table 6-3 and Fig. 6-4.

The objective of protection of cables is firstly to avoid damage due to anchors and waves, and the concrete methods must be studied in accordance with the sea bottom topography and bottom material. The concrete methods of protection will be determined based on the results of detailed results of sea bottom conditions, but for the purposes of this Report, the following assumptions are to be made.

For all of the cables at the three straits, the lengths from the shores to depths of water of about 5 m are to be buried at the sea bottom mainly by the jet burying method. At these sections, lengths about one half on the seashore sides are to be provided with cast iron protection pipes. As for the shallow-water part at the Liloan side of Tañon Strait, since coral reefs are developed, it was considered that a trench would be excavated with underwater civil engineering equipment prior to cable laying, and after laying cables, they would be covered with sand bags or concrete.

vi) Cable Terminal

At each terminal, other than installation of cable-end coupling cubicles, frames, and a steel structure for outgoing transmission lines, lightning arresters and fault locators are to be provided as appurtenant facilities for cable protection. Also, it is necessary for introduction of telecommunications channels for signal transmissions of fault locators and maintenance communications, and as power supplies for these, distribution-line leading-in facilities and batteries for reserve power supply are to be installed. A plan for a cable terminal layout is indicated in Fig. 6-5.

vii) Cable-Laying Works

Cable is to be loaded on ship from a factory in a foreign country, transported to the site, and directly laid. The cable-laying vessel will need to be a ship of 5,000 ton to 6,000 ton class, and for navigation from overseas, it would be desirable for the vessel to be an ocean-going type, but since the depths of water of the cable routes are shallow, it may be that a flat barge of shallow draft will be used.

Table 6-3 Composition of 138 kv Submarine Cable

	Kind	XLPE	Cross linked polyethylene
	No. of core	Single	
Conductor	Section area	300 mm^2	
	Material	copper	
	Shape	Compressed circular	
	Diameter	20.65 mm	
Insulation	Conductor shielding layer	1.0 mm	Inner semi-conducting
	Insulation layer	20.0 mm	XLPE
	Insulation shielding layer	1.3 mm	Outer semi-conducting
Shielding tape		0.2 mm	Semi-conducting
Interrupt water layer		3.0 mm	Load sheath
Anticorrosive jacket		4.5 mm	Polyethylene jacket
Protection	Bedding tape	0.25 mm	Cotton tape
	Insect repellent	0.3 mm	Brass tape
	Bedding	1.5 mm	Jute
	Armour wire	8mmϕ x 33 wires	Galvanized steel wire
	Serving	4.5 mm	Jute
Outside/diameter		Approx. 110 mm	
Weight of unit length		Approx. 31.8 kg/m	in the open air

Fig. 6-4 Cross Section of 138 kV Submarine Cable

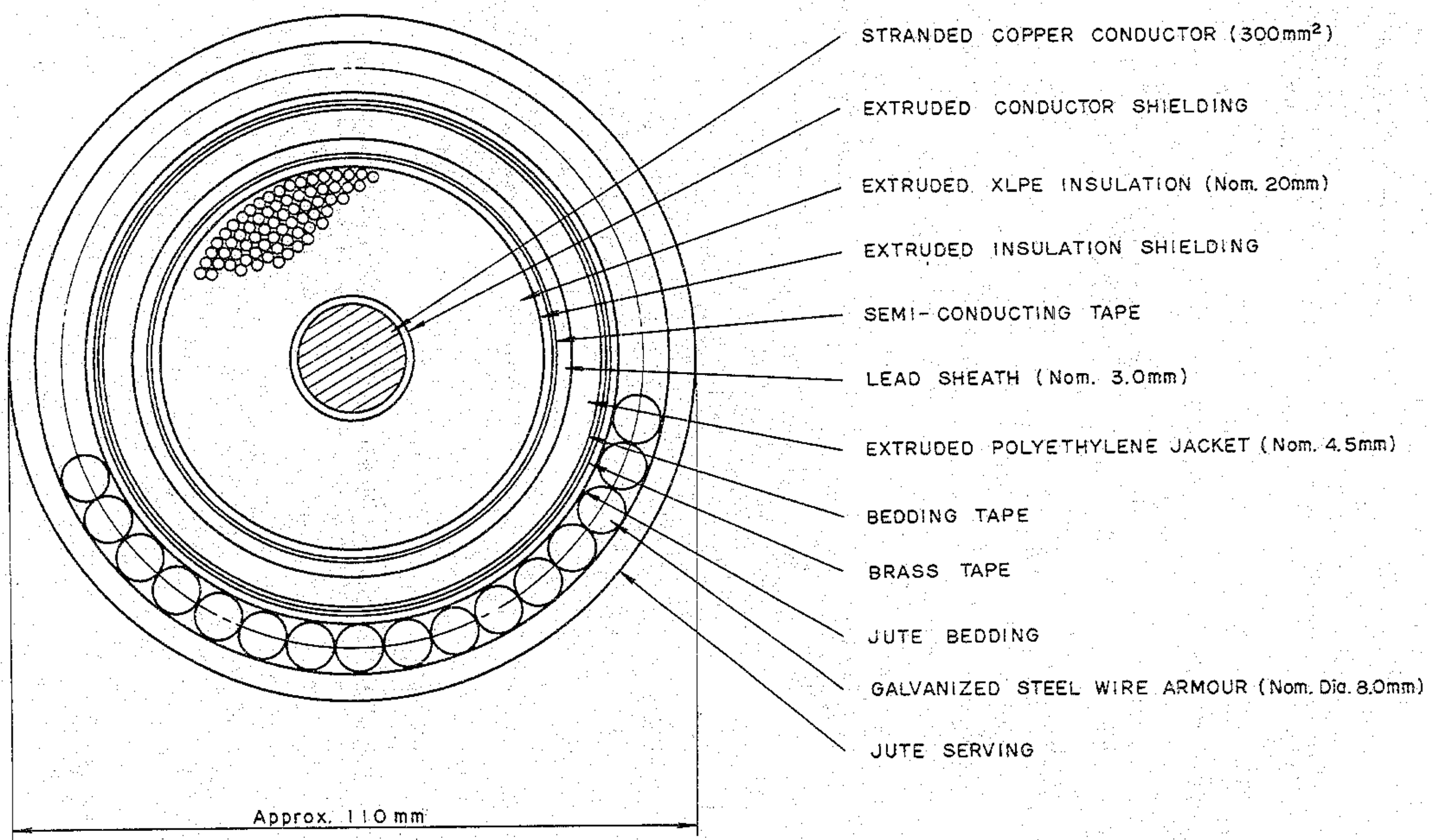
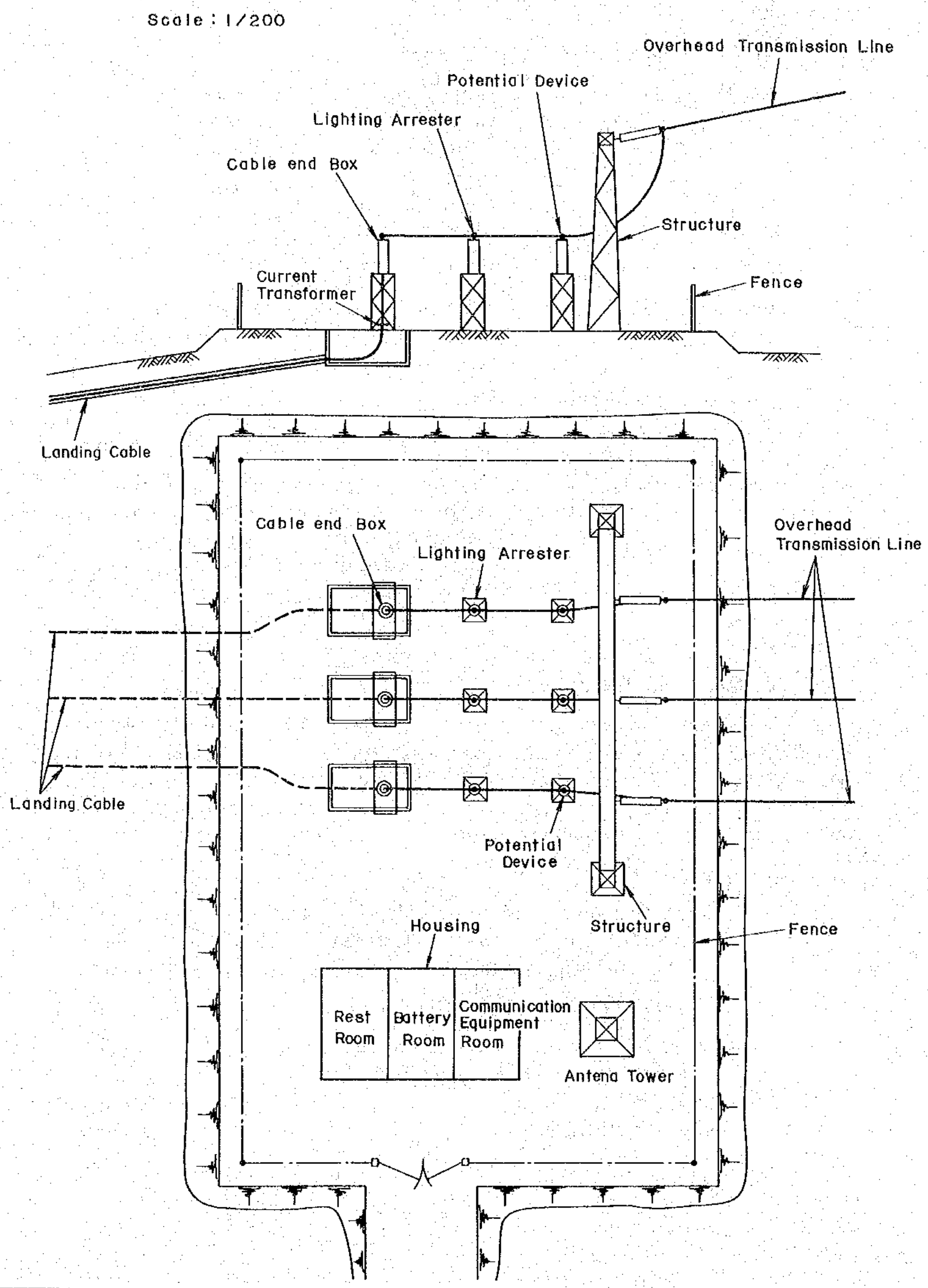


Fig. 6-5 Cable Terminal Arrangement



It will be suitable for submarine cables to be laid during May-June when marine phenomena are most stable, but there will be works to be carried out for several months, before and after, for preliminary civil works, cable terminal-related works, and after laying, cable protection works.

(3) Outline of Submarine Cable Facilities

Length	:	Iloilo Strait	3.7 km
		Guimaras Strait	12.8 km
		Tañon Strait	7.1 km
		Total	23.6 km
Voltage	:	AC 138 kV	
Number of Circuits	:	1 cct	
Submarine Cable	:	300 mm^2 single-core XLPE cable (lead sheath, 8 mm ϕ steel wire single-layer armor)	
Number of Lines Laid	:	3 lines	
Protection	:	Sea bottom embedment, protection boxes	
Cable Terminal	:	Terminal connecting cubicle, platform, outgoing steel structure, cable protection lightning arrester, fault locator, tele-communications apparatus, reserve power supply battery	

6.2.3 Substations

(1) Outline of Facilities

The composition of the 3 island interconnection of Panay-Negros-Cebu based on the Visayas Region Interconnected Power Transmission and Distribution Plan is as shown in Fig. 6-6. The related substation facilities, and additions to existing power generating and transforming stations and outdoor switchyeards will be as indicated below.

i) Naga Coal-Fired Thermal Power Station (Cebu Island)

- 138 kV transmission line outgoing facilities	1 cct
Circuit breaker, 145 kV, 3,140 MVA, with CT	3 units
Disconnecting switch	6 units

ii) Amlan Diesel Power Station (Negros Island)

- 138 kV transmission line outgoing facilities	5 cct
- 138 kV facility for interconnection with 69 kV facility	1 cct
- Main transformer	1 bank

	- 69 kV transmission line outgoing facilities	1 cct
	Main transformer, 138 kV/69 kV/13.8 kV, 30 MVA, single winding	1 unit
	Circuit breaker, 145 kV, 3,140 MVA, with CT	6 units
	Circuit breaker, 72.5 kV, 1,600 MVA, with CT	3 units
	Disconnecting switch, 145 kV	12 units
	Disconnecting switch, 72.5 kV	6 units

iii) Kabangkalan Substation (Negros Island)

- 138 kV transmission line outgoing facilities	6 cct
- 138 kV facility for interconnection with 69 kV facility	1 cct
- Main transformer	1 bank
- 69 kV transmission line outgoing facilities	2 cct
Main transformer, 138 kV/69 kV/13.8 kV, 10 MVA, single winding	1 unit
Circuit breaker, 145 kV, 3,140 MVA, with CT	11 units
Circuit breaker, 72.5 kV, 1,600 MVA, with CT	4 units
Disconnecting switch, 145 kV	22 units
Disconnecting switch, 72.5 kV	8 units

iv) Pulupandan Substaion (Negros Island)

- 138 kV transmission line outgoing facilities	5 cct
- 138 kV to 69 kV interconnection facilities	1 cct
- Main transformer	1 bank
- 69 kV transmission line outgoing facilities	1 cct
Main transformer, 138 kV/69 kV/13.8 kV, 30 MVA, single winding	1 unit
Circuit breaker, 145 kV, 3,140 MVA, with CT	6 units
Circuit breaker, 72.5 kV, 1,600 MVA, with CT	2 units
Disconnecting switch, 145 kV	12 units
Disconnecting switch, 72.5 kV	4 units

v) Sta. Barbara Substaion (Panay Island)

- 138 kV transmission line outgoing facilities	1 cct
Circuit breaker, 145 kV, 3,140 MVA, with CT	2 units
Disconnecting switch, 145 kV	4 units

Details of the above power generating stations and substations are as shown in the drawings listed below.

Fig. 6-6	Three-Island Interconnection
Fig. 6-7	Single Line Diagram (Naga Coal-Fired Thermal Power Plant)
Fig. 6-8	Ditto (Amlan Diesel Power Plant)
Fig. 6-9	Ditto (Kabangkalan Substation)
Fig. 6-10	Ditto (Pulupandan Substation)

(2) Locations and Compositions of Power Generating Plants and Transforming Stations

i) Naga Coal-Fired Thermal Power Plant

(a) The outgoing point on the Cebu side in the Project is to be Naga Coal-Fired Thermal Power Plant of NAPOCOR at Naga approximately 20 km distant from the city of Cebu, the center of Cebu Island. With this transmission line led into Naga Coal-Fired Thermal Power Plant, the 138 kV trunk transmission lines on Cebu Island, Naga Coal-Fired Thermal Power Plant - Banilad Substation, and Naga Coal-Fired Thermal Power Plant - Cebu Diesel II (Talavera) will become interconnected, and this will literally serve as the artery of the Cebu Power Grid.

(b) With regard to the outgoing facilities of the 138 kV interconnecting transmission line, ample space for expansion at the existing outdoor switchyard can be secured so that expansion will be done here, and in consideration of future power development projects, outgoing facilities for 2 circuits are to be installed.

ii) Amlan Diesel Power Plant

(a) According to the power development program of NAPOCOR, it had been planned for a new substation to be constructed at Lalaan approximately 12 km distant from Dumaguete City at the southern part of Negros Island as the primary substation to be connected to the 138 kV interconnecting transmission line, but as a result of the present field investigations, it was found to be topographically difficult to secure a lot for a substation in this vicinity as hilly land closes in on the sea at the projected site, and combined with the aspect of salt soilage of principal equipment, this site is not suitable, and it was decided to connect the 138 kV interconnecting transmission line to Amlan Diesel Power Plant of NAPOCOR 7 km to the north. And, in this relation, it was decided for the 138 kV transmission line, 2 cct, connecting with Palimpinon Geothermal Power Plant to be led in to this plant.

(b) The existing switchyard of Amlan Diesel Power Plant is composed for 69 kV. The 138 kV switchyard to be newly provided is to be added adjacent to the 69 kV switchyard, but since the land is sloped, the site is to be levelled in the form of two steps to reduce the amount of land levelling in developing land for the substation, and as the ultimate scale, incoming of a 138 kV transmission line of 7 circuits was considered.

(c) Main Transformers

The main transformer capacity to be added at Amlan Diesel Power Plant was set at 30 MVA considering standardization of unit capacities, based on the equipment installation plans of NAPOCOR and the results of load forecasting. Since the windings of main transformers, on both the 138 kV and 69 kV sides, are connected to directly-grounded systems, they are to be of economical single-winding structure, with tertiary windings for 13.8 kV to supply station service power of the plant from the grid in a stable manner. With regard to transformers, on comparison of banks of idential capacities — 3 phase, 1 unit, or single-phase, 3 units — a 3 phase unit would be of a price approximately 80% of that of the single-phase units, while the weight would be reduced so that less expense will be required for transformer foundation work. Examined from the aspect of reliability, transformers of recent have very low faulting rates, there is little necessity for installing a reserve transformer, therefore the 3 phase unit will be more advantageous.

(d) Bus Connection System

Amlan Diesel Power Plant, after interconnection of the three islands of Panay, Negros and Cebu, will become a very important substation of the system similarly to the other power plants and substations (Naga Coal-Fired Thermal Power Plant, Kabangkalan Substation, Pulupandan Substation, Sta. Barbara Substation) to be connected with this 138 kV interconnecting transmission line, and therefore, a 1.5 CB system already adopted by NAPOCOR for major power plants and substations was decided on, being advantageous for inspection of major equipment such as circuit breakers, convenience of system operation, and prevention of complete outage during bus faulting.

(e) It was decided that the insulation designs of the main buses of the power plants and substations would follow the design for the transmission line. The dielectric strengths of transforming equipment with regard to 138 kV direct-grounding systems are to satisfy BIL 650 kV, and abnormal voltages of the system exceeding this are to be protected against by lightning arresters and rod gaps. As for salt-damage protection design of equipment, differing from the case of a transmission line, there are economic limits to excessively insulating the various pieces of equipment, while in case of substations, since maintenance and supervision would be easier compared with transmission lines, measures against salt damage shall consist of periodic washing.

(f) With respect to a building for the substation, since there is no extra space for additionally installing distribution panels and 138 kV transmission line protection panels in the main building of the existing Amlan Diesel Power Plant, the main substation building is to be constructed at a part of the switchyard site, and equipment is to be accommodated in this building.

iii) Kabangkalan Substation

(a) Kabangkalan Substation will be located roughly at mid-point of the 138 kV interconnecting transmission line of the Project passing from Amlan Diesel Power Plant to Pulupandan Substation on Negros Island, and this may be said to be an important substation which will serve for connection of a 138 kV transmission line to Negros Coal-Fired Thermal Power Plant I for which plans are being made by NAPOCOR and the connection of the 138 kV transmission line to Sipalay, the major load center of Negros Island.

(b) Regarding the site for Kabangkalan Substation, since there is a flat grassland approximately 2 km south of Kabangkalan with adequate space, this site is to be developed and levelled for construction of the substation. The following were considered for the final scale of the substation, and it was assumed steps would be taken to secure the necessary land.

- 138 kV transmission line	:	7 cct
- Main transformer	:	1 bank
- 69 kV transmission line	:	3 cct

(c) The capacity of the main transformer is to be 10 MVA based on the results of load forecasting, with the composition of the transformer the same as at Amlan Diesel Power Plant, a three-phase unit with single winding. The basic thinking regarding insulation and salt-damage protection is also the same.

(d) The main building of the substation is to accommodate controlling and instrumentation circuits for the substation switchgear, distribution panel, main transformer and transmission line protection devices, power supply apparatus, telecommunications apparatus, etc., and is to be built at a corner of the switchyard.

iv) Pulupandan Substation

(a) A related substation on the Negros side of the route from Negros Island to Sta. Barbara Substation on Panay Island via Guimaras Island is to be provided at Pulupandan, close to the landing point of the submarine cable and adjacent to Bacolod City which can be said to be the center of Negros Occidental. Through construction of this Pulupandan Substation, future interconnection by 138 kV transmission lines can be made with Bago Hydroelectric Power Plant, Negros Coal-Fired Thermal II, and Mambucal Geothermal Power Plant projected in the power development plans prepared by NAPOCOR, and thus this substation may be said to be one which will become extremely important.

(b) The vicinity of Pulupandan is very flat and there are many large sugar cane fields. Consequently, the substation will be constructed opening up and levelling grassland about 5 km inland from the seashore. The land to be secured is that necessary considering the following ultimate scale of the substation:

138 kV transmission line	:	7 cct
Main transformer	:	1 bank
69 kV transmission line	:	3 cct

(c) Pulupandan Substation originally was projected as a switching station in the power development plans prepared by NAPOCOR, and a main transformer was not to be installed, but since this will become a most important substation as previously described, as a result of field investigations, the plans were changed to transfer the transformer intended for Bacold Substation to Pulupandan in order to secure a stable station service power supply, while the section between Pulupandan and Bacolod is to be connected by a 69 kV transmission line. The capacity of the main transformer is to be 30 MVA based on the results of load forecasting, and it is to be a 3 phase unit with single winding. Insulation and salt-damage protection is to be considered with the same basic consideration.

(d) The main building of the substation is to be constructed newly similarly to Kabangkalan Substation, and the necessary distribution panel, protective devices, telecommunications facilities, etc. are to be accommodated.

v) Sta. Barbara Substation

(a) The existing Sta. Barbara Substation of NAPOCOR was selected as the outgoing point on the Panay side for the Project. Sta. Barbara Substation is connected by 138 kV transmission line with Panay Diesel Power Plant (Dingle) and Panitan Substation on Panay Island, and also is to be connected in the future with Panay Coal-Fired Thermal Power Plant (Kalibo) planned to be constructed at the northern part of Panay Island.

(b) At the time of the field investigations for this Study, Sta. Barbara Substation was being constructed by NAPOCOR, and in development of the lot for the substation, space for the outgoing facilities of the 138 kV transmission line of the Project was taken into consideration and secured, and outgoing facilities for one circuit are to be added here.

The above describes the locations and compositions of the power generating and transforming stations related to the Project. As references, the methods of connecting instrument transformers (PD, CT) for transmission line protection, bus protection and main transformer protection under a 1.5 CB bus system are indicated in Fig. 6-17 and Fig. 6-18.

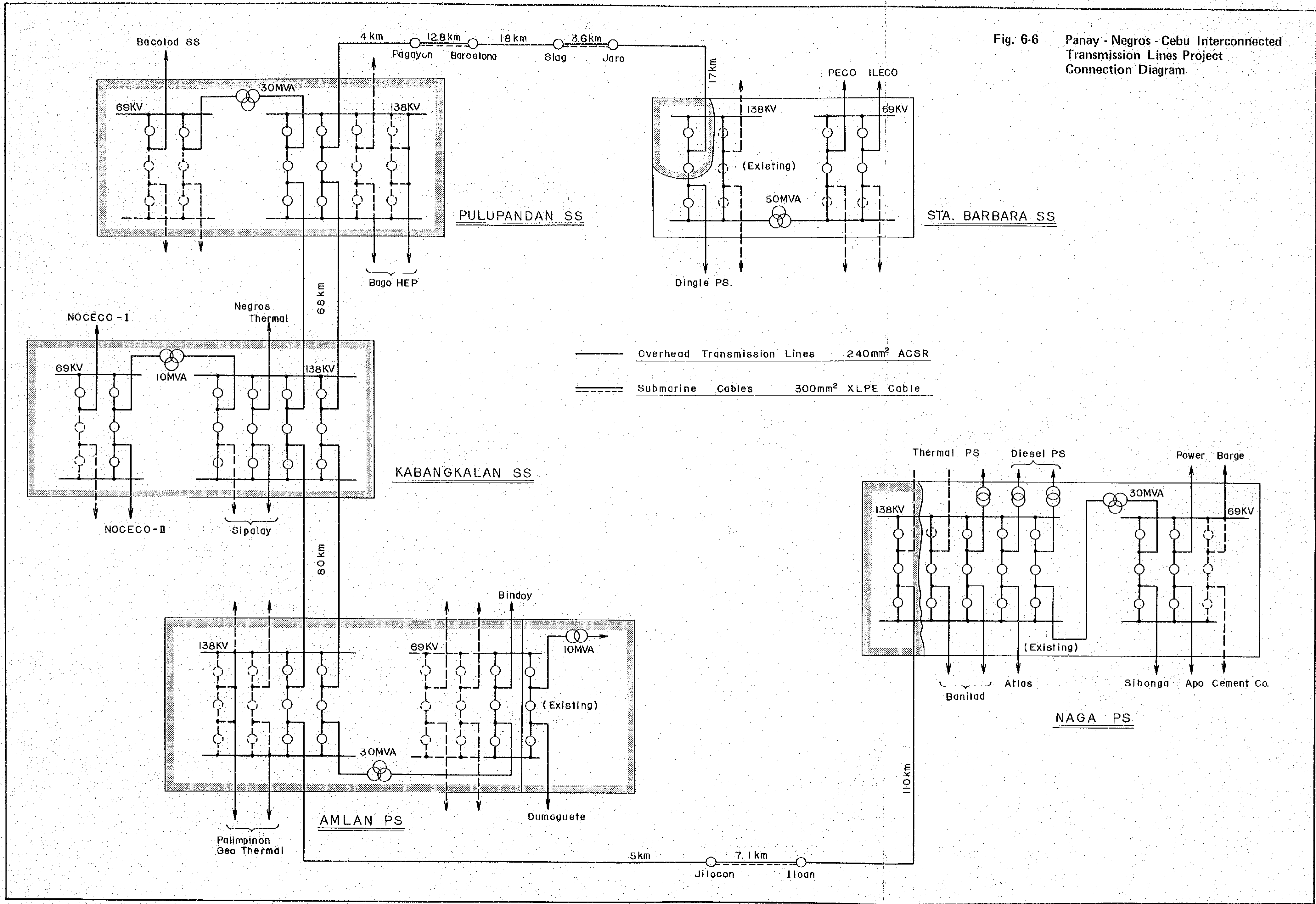


Fig. 6-6 Panay - Negros - Cebu Interconnected Transmission Lines Project Connection Diagram
Bacolod SS
4 km
12.8 km
18 km
3.6 km
Pagayon
Barcelona
Slag
Jaro
17 km
30MVA
69KV
138KV
PULUPANDAN SS
Bago HEP
PECO
ILECO
(Existing)
50MVA
STA. BARBARA SS
Dingle PS.
68 km
NOCECO - I
Negros Thermal
10MVA
KABANGKALAN SS
NOCECO - II
Sipalay
Overhead Transmission Lines 240mm² ACSR
Submarine Cables 300mm² XLPE Cable
Thermal PS
Diesel PS
Power Barge
NAGA PS
Banilad
Atlas
Sibonga
Apo Cement Co.
80 km
Bindoy
AMLAN PS
Dumaguete
Palimpinon Geo Thermal
110 km
5 km
7.1 km
Jilocon
Iloan

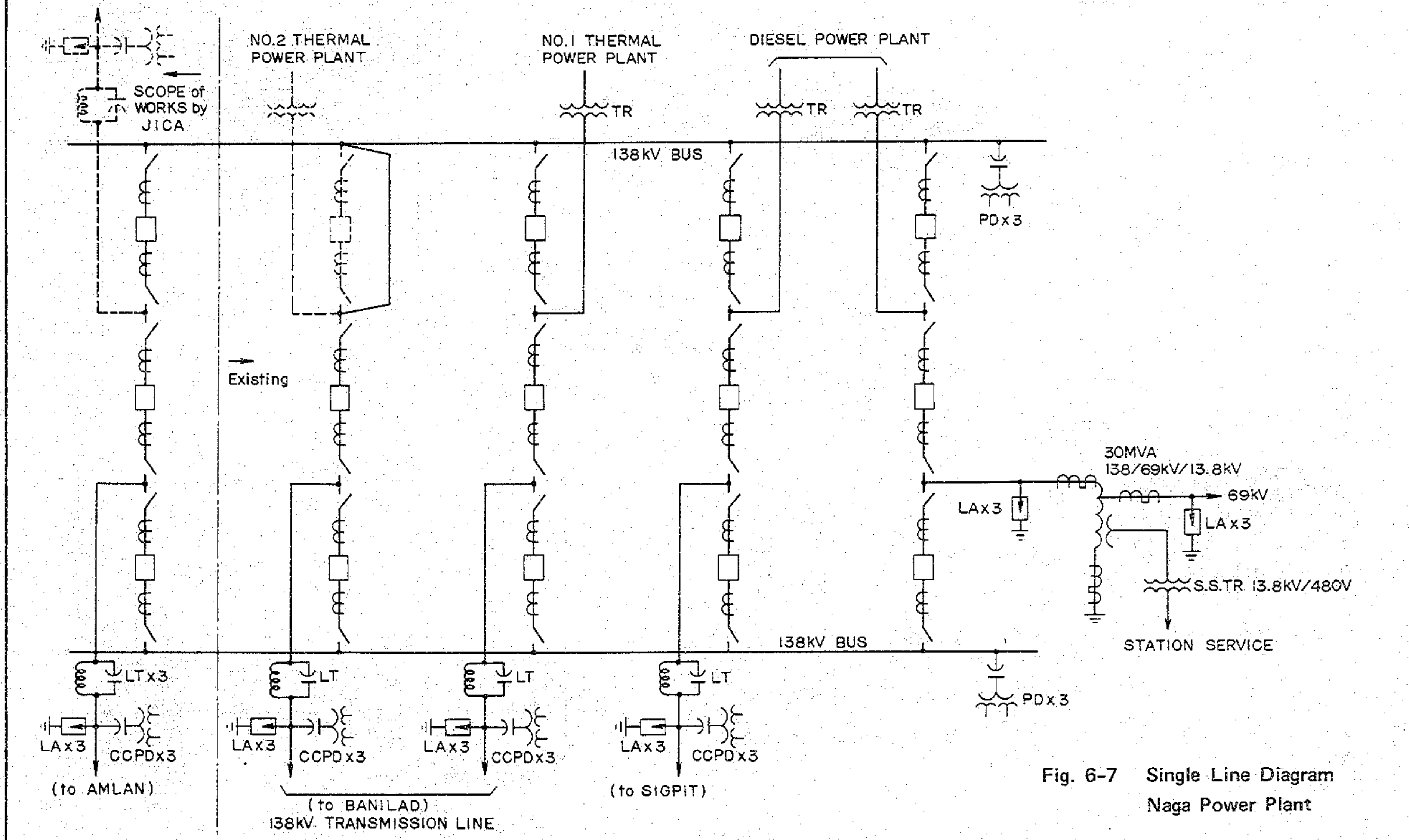


Fig. 6-7 Single Line Diagram
Naga Power Plant

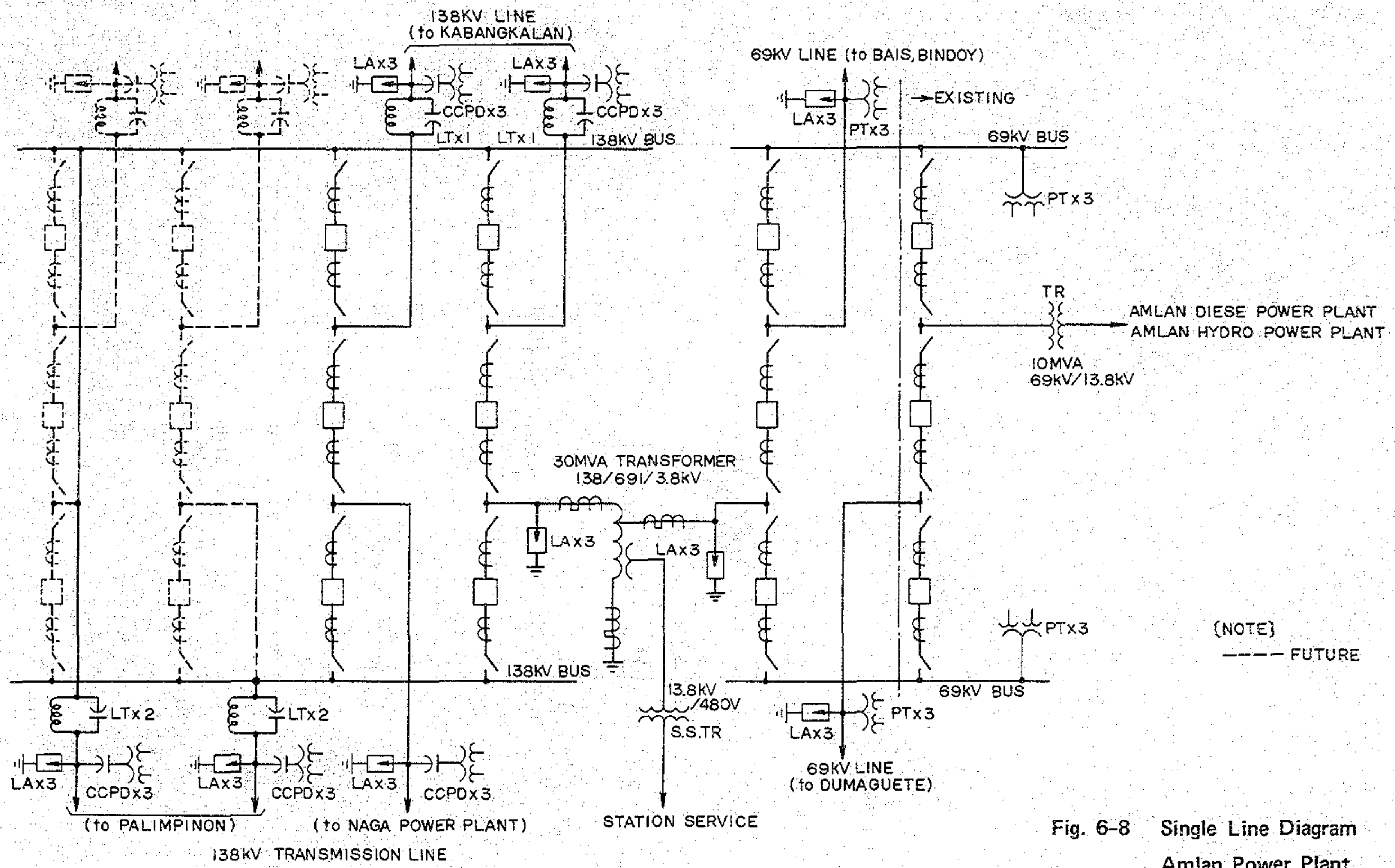


Fig. 6-8 Single Line Diagram
Amlan Power Plant

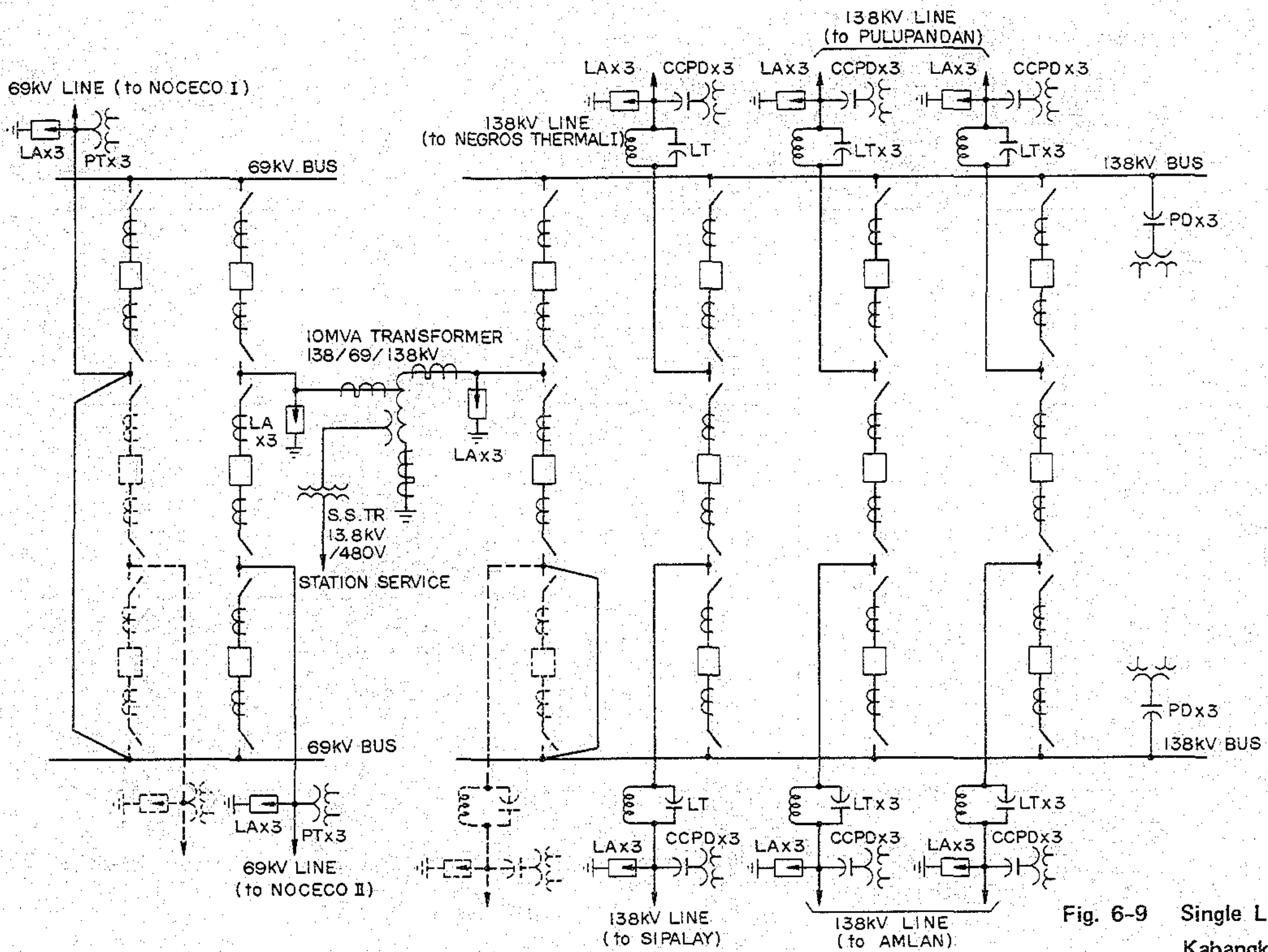


Fig. 6-9 Single Line Diagram
Kabangkaran Substation

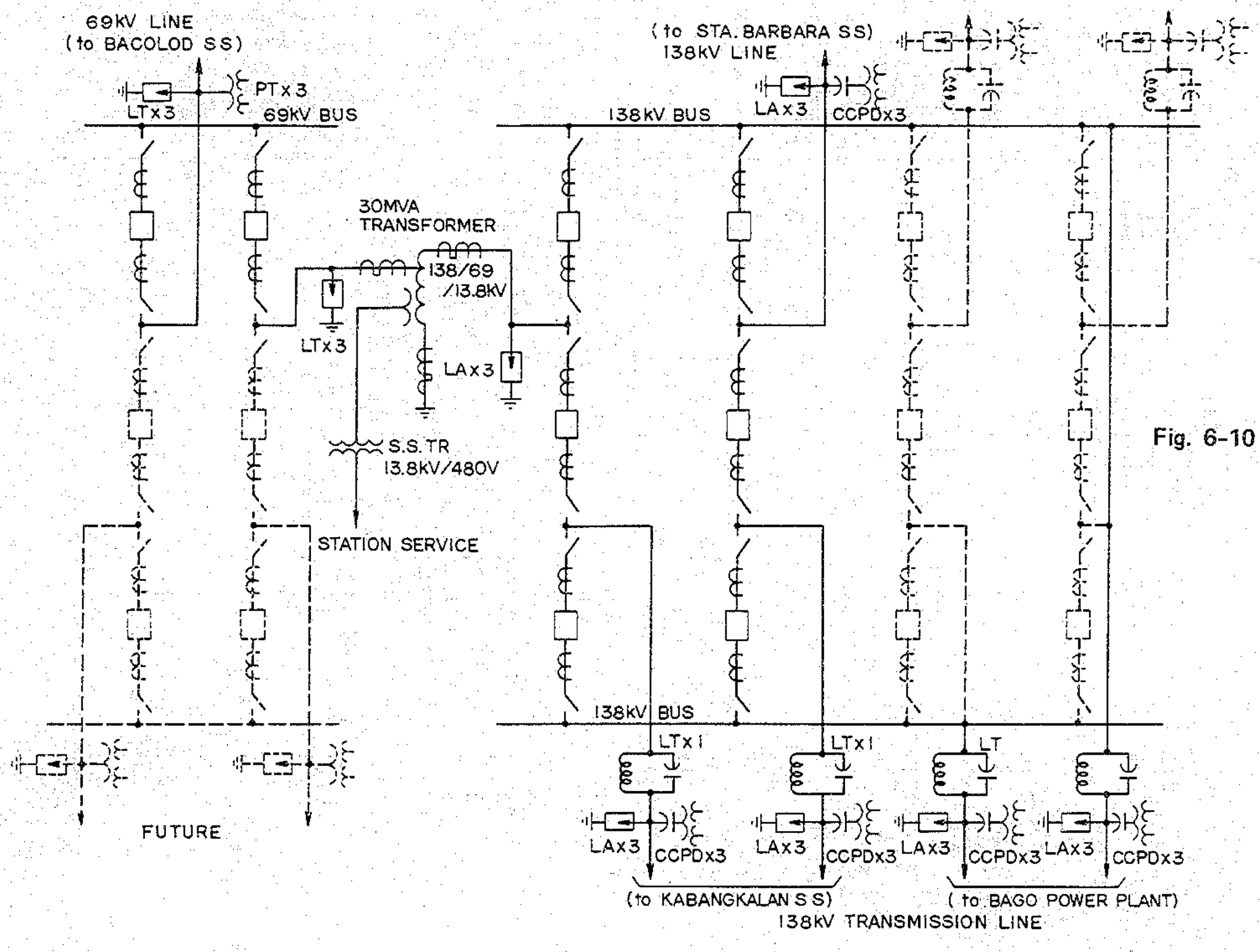


Fig. 6-10 Single Line Diagram
Pulupandan Substation

(NOTE)
---- FUTURE

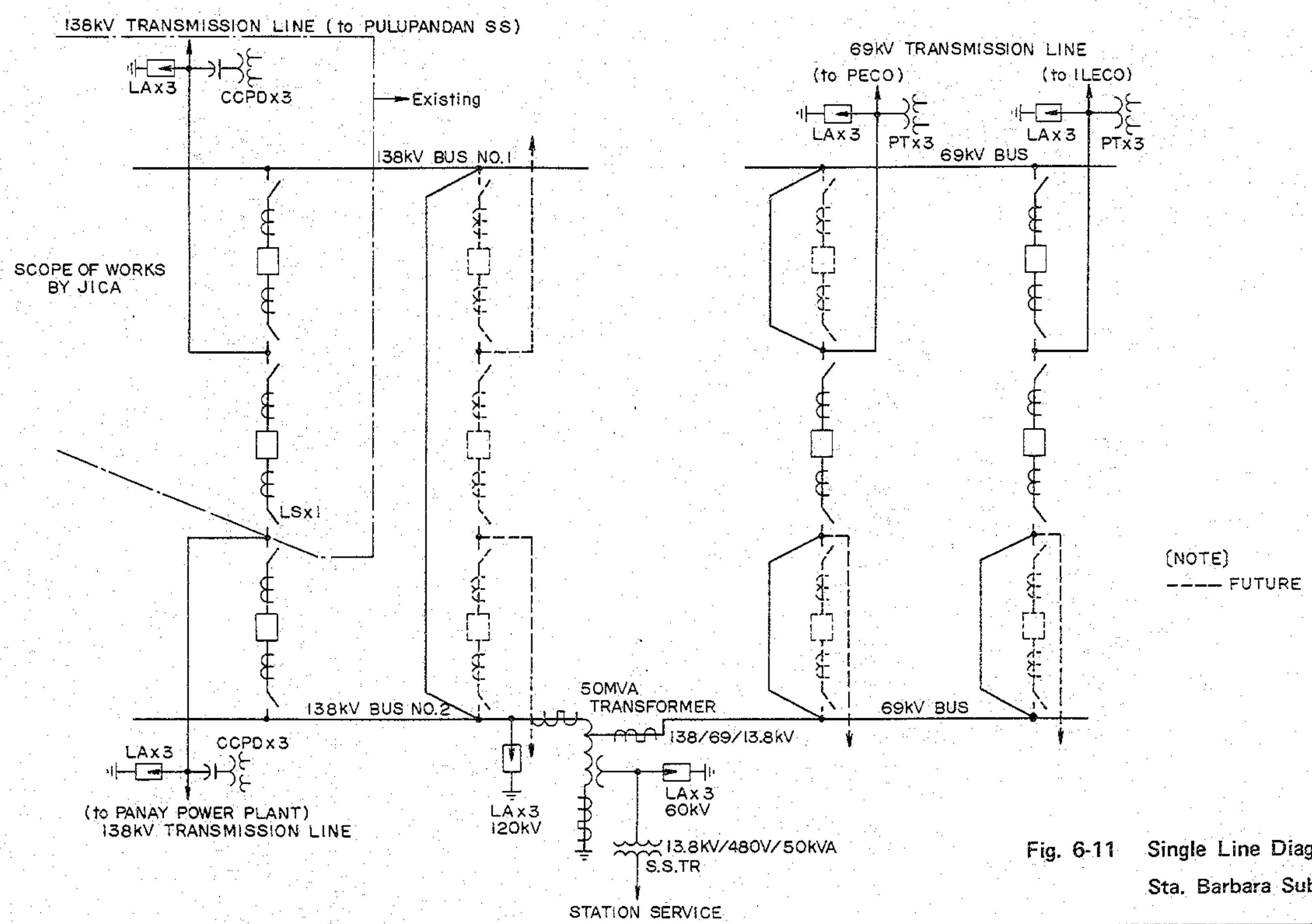


Fig. 6-11 Single Line Diagram
Sta. Barbara Substation

Fig. 6-12 Naga Power Plant Switchyard Enlargement Plan

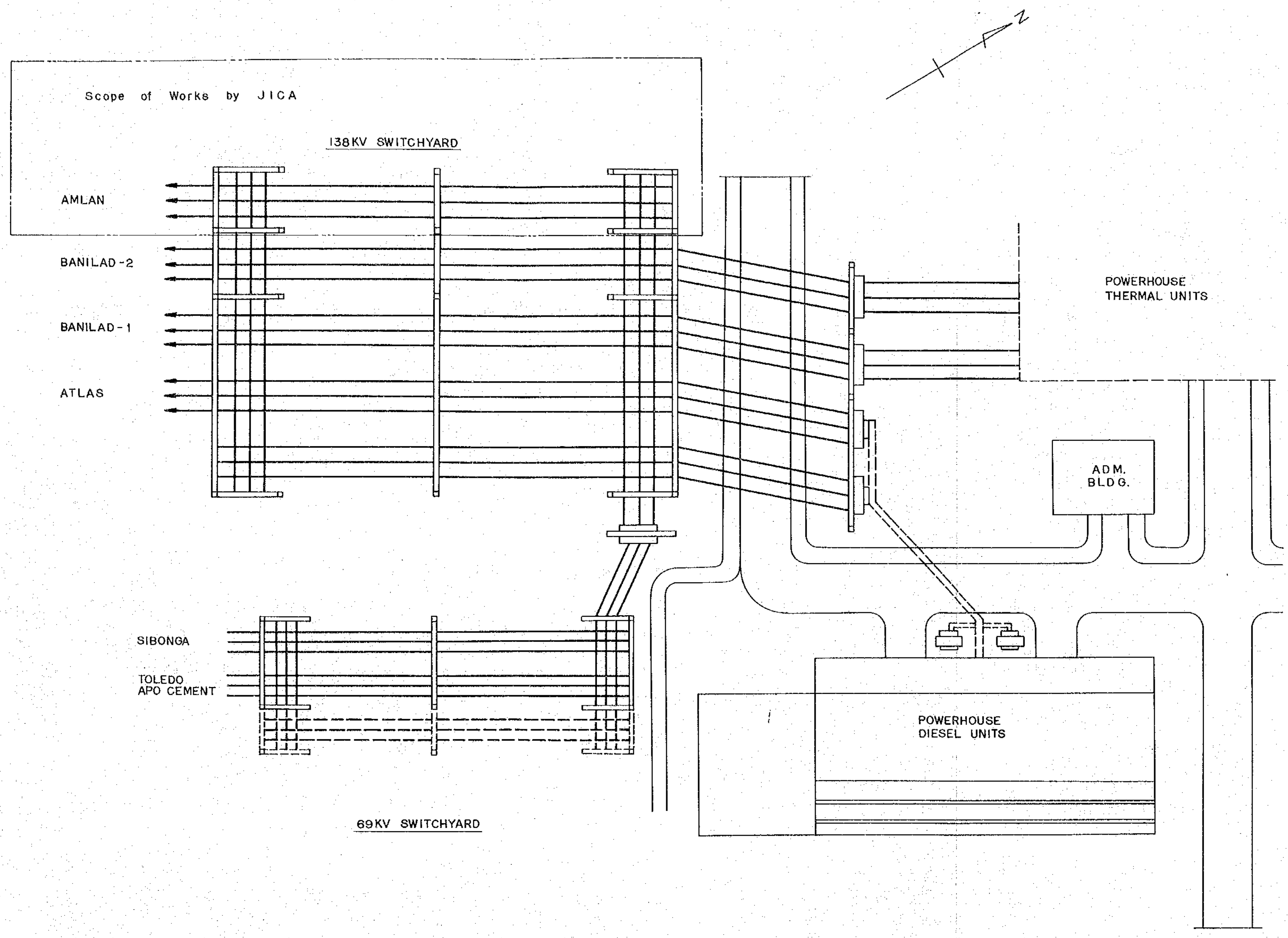


Fig. 6-13 Amlan Power Plant Switchyard Enlargement Plan for 138 kV Structure (Refer to NAPOCOR Original Drawing)

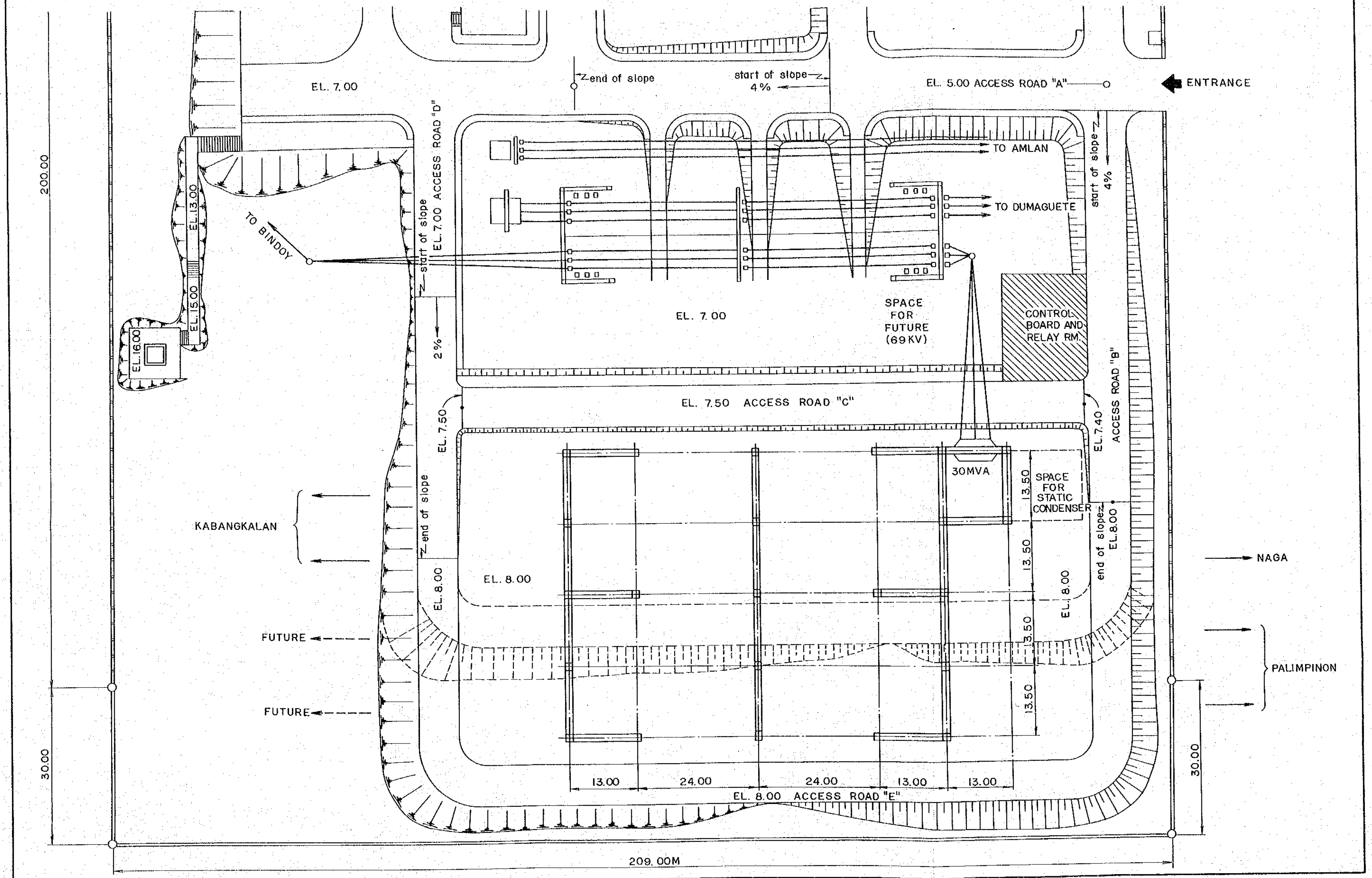


Fig. 6-14 Kabangkaran Substation Steel Structure Arrangement

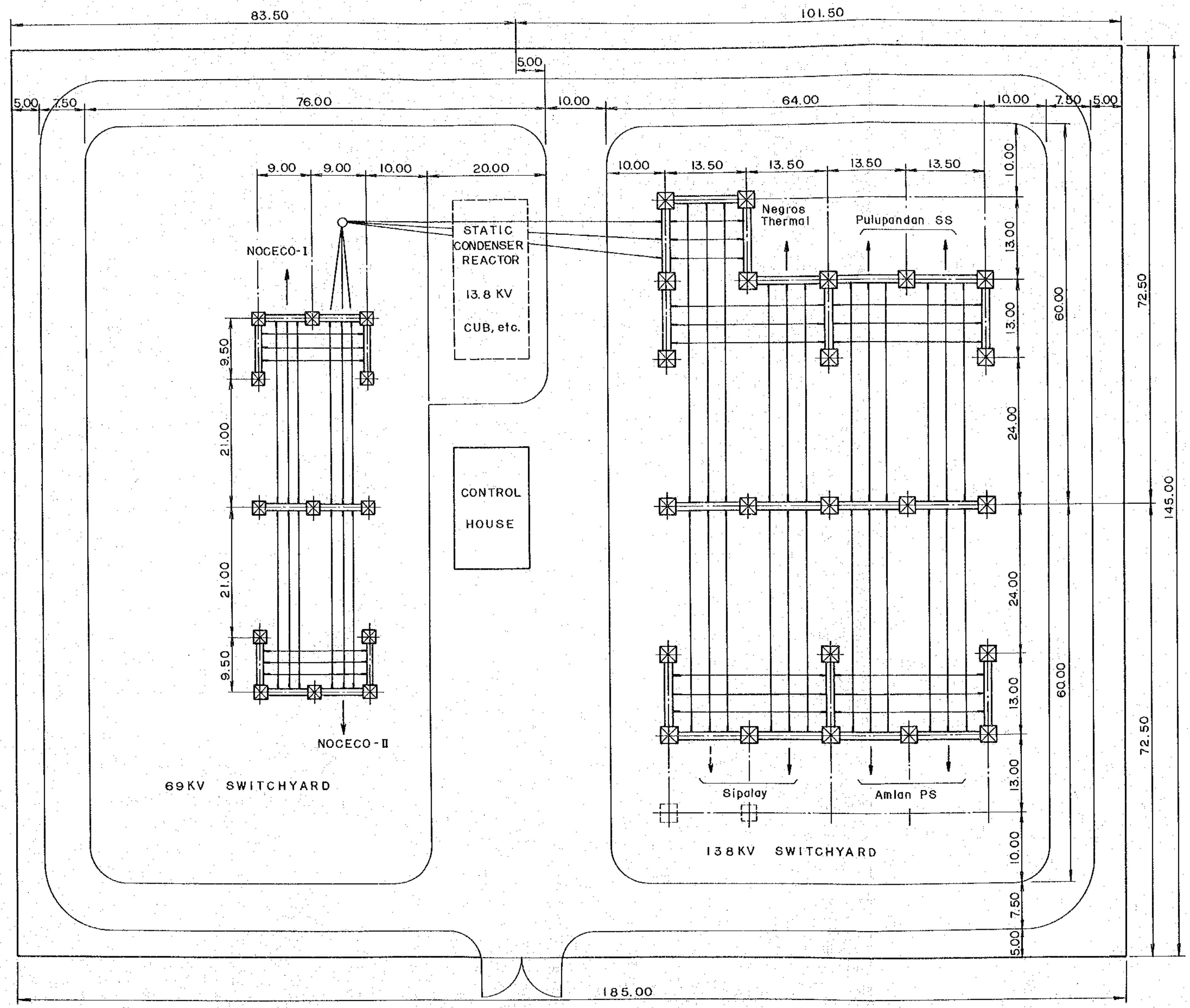


Fig. 6-15 Pulupandan Substation Steel Structure Arrangement

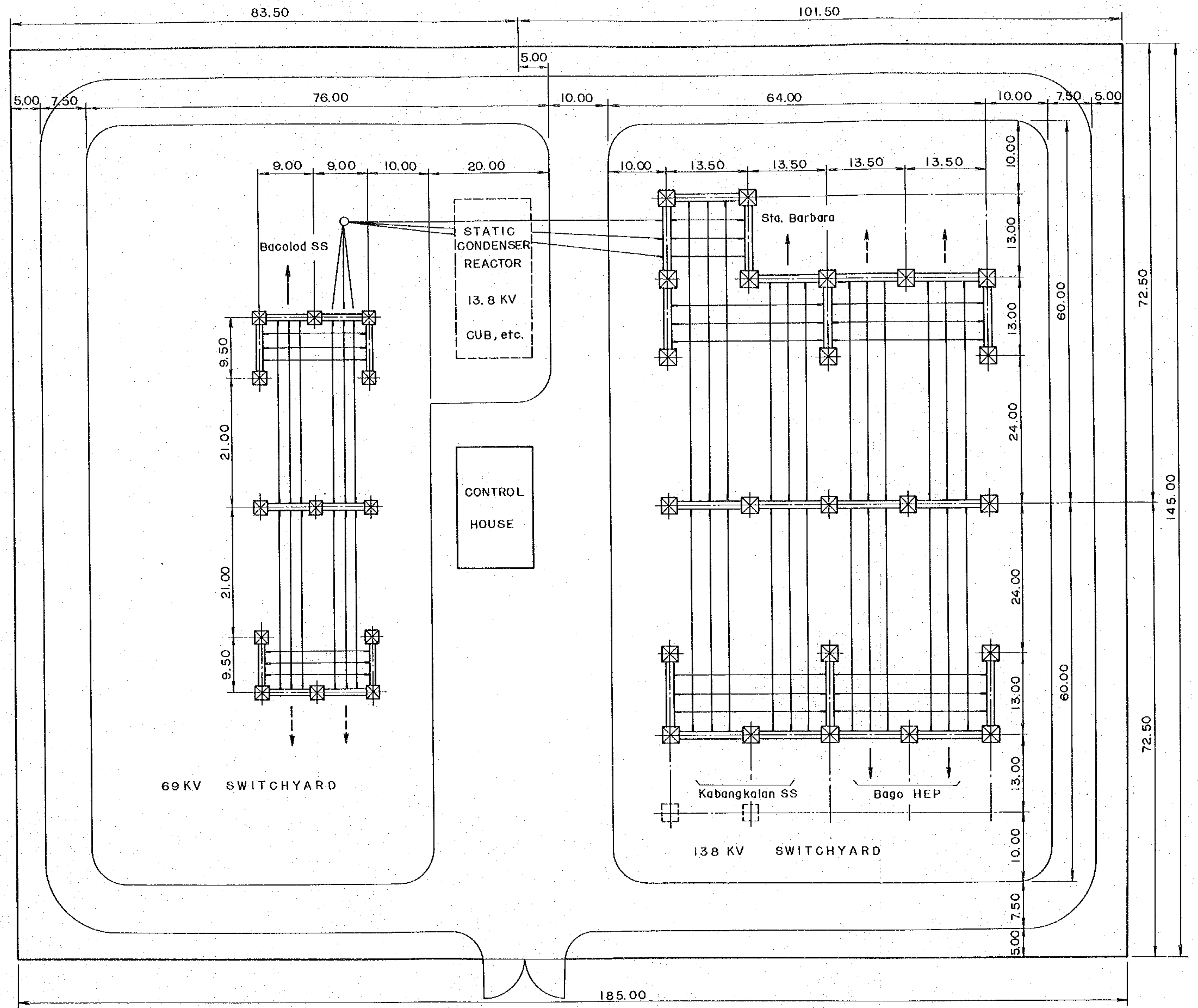
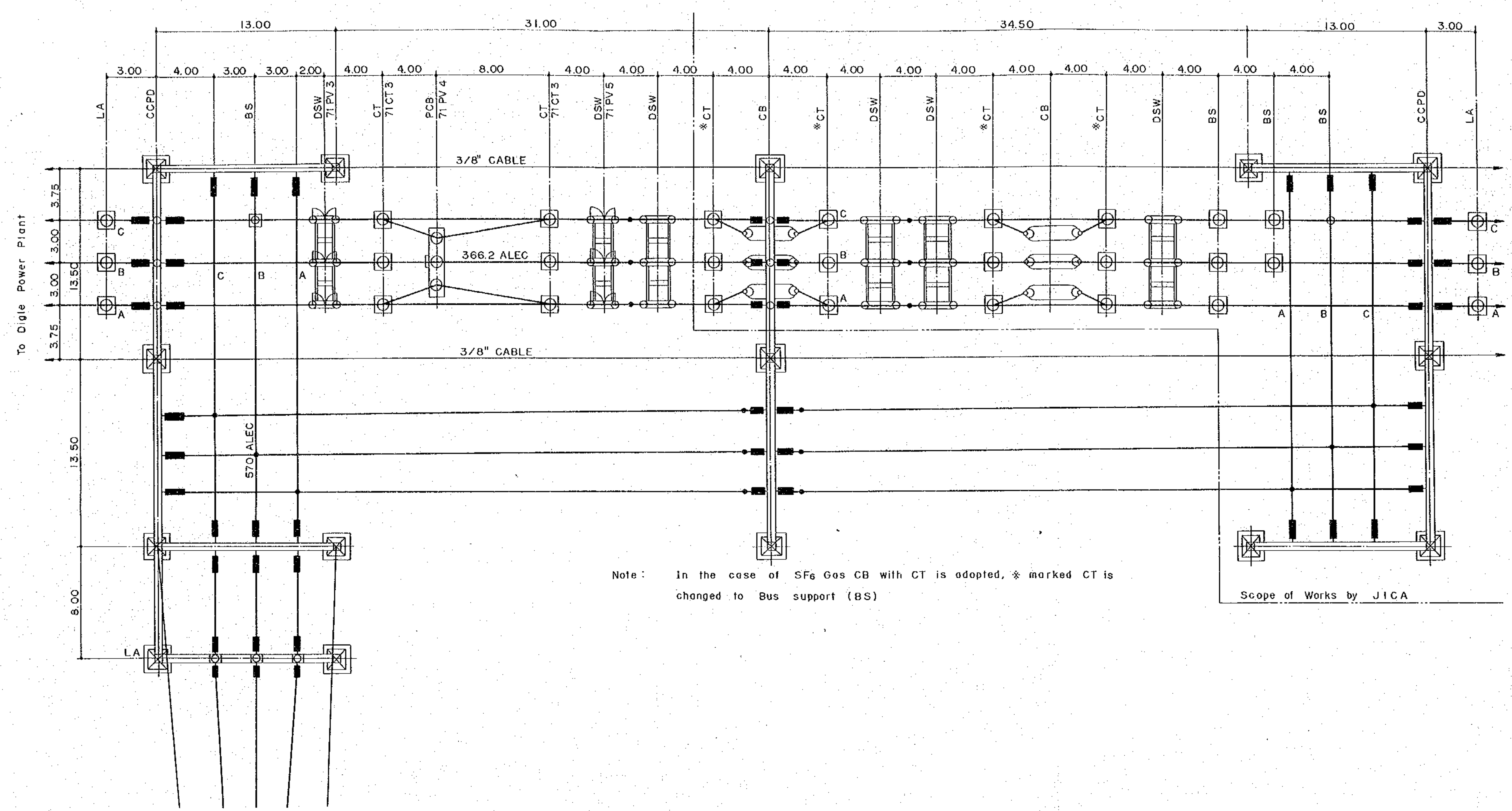


Fig. 6-16 Sta. Barbara Substation Enlargement Plan (Refer to NAPOCOR Original Drawing)



Note : In the case of SF_6 Gas CB with CT is adopted, ※ marked CT is changed to Bus support (BS)

Fig. 6-17 Ref. Drawing for CT Connection on 1.5 CB Bus System (I)

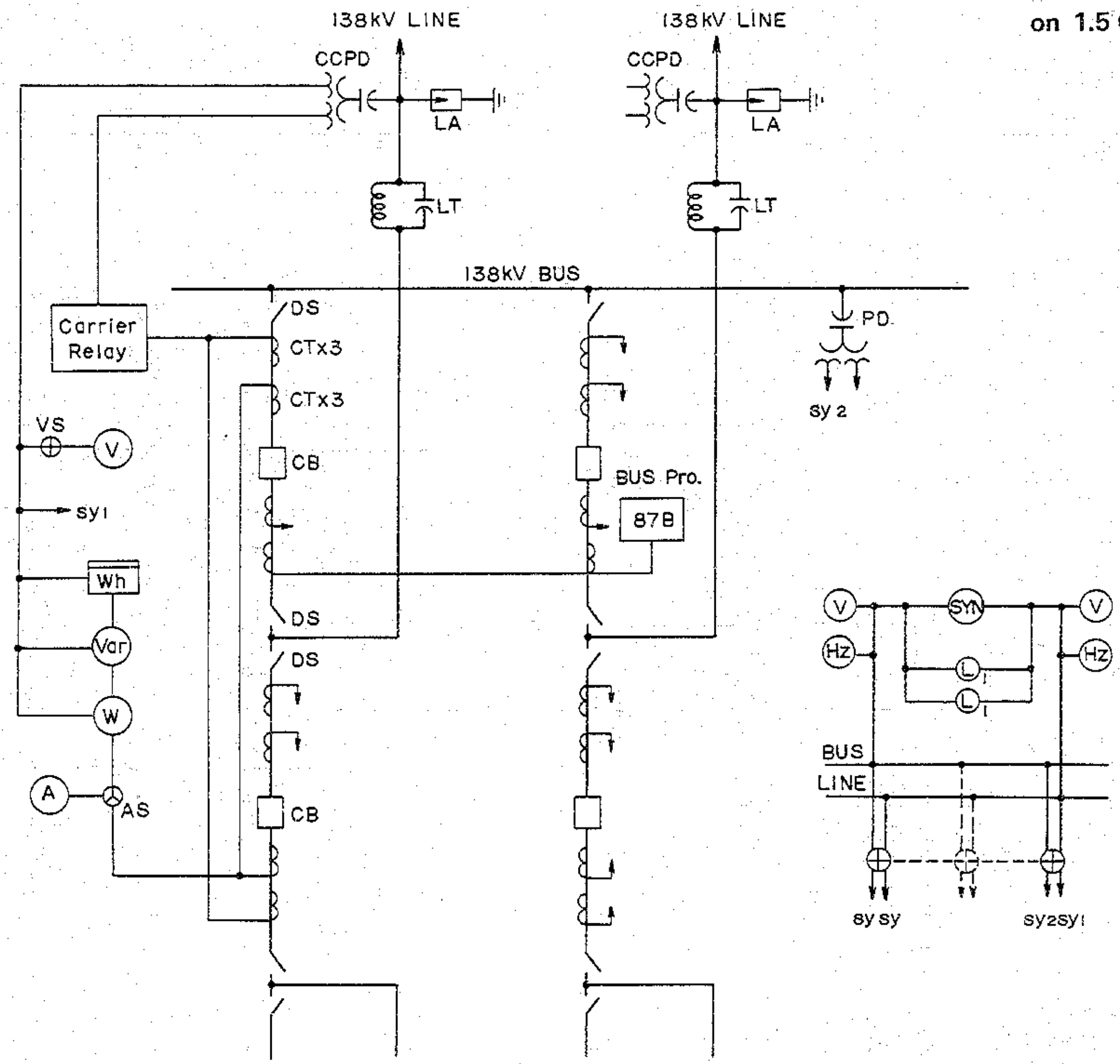


Fig. 6-18 Ref. Drawing for CT Connection on 1.5 CB Bus System (II)