6.2.4 Preliminary Design of Telecommunications Facilities

The telecommunications facilities required for effective and sure operation, maintenance and administration of this interconnecting transmission line and substation facilities are the following:

(1) Load dispatching telephones

(2) Maintenance and administration telephones

(3) Line maintenance telephones

(4) Carrier relays

(5) Cable faulted section detecting signal transmitting apparatus

(6) Fault locators

The telecommunications channels satisfying the above requirements, as indicated in Fig. 6-19 and Fig. 6-20, are to be constituted between Naga Power Plant and Sta. Barbara Substation using power line carrier terminal station equipment and UHF multi-channel radio apparatus. The telecommunications systems of Panay-Negros-Cebu are described below.

(1) Load Dispatching Telephone System

The load dispatching telephone system consists of telephone channels exclusively for load dispatching operations use for effective operation of the interconnected transmission line system and for coping rapidly during faults in the system, and channels will be comprised by a tone ringer telephone system allowing selective calling between any of the power generating plants and transforming stations of Naga, Amlan, Kabangkalan, Pulupandan and Sta. Barbara.

(2) Maintenance and Administration Telephone System

As maintenance and administration telephones for maintenance of power facilities and efficient administration, the automatic exchange system and cable terminal maintenance and administration telephone facilities described below will be provided.

i) Automatic Exchange System

Automatic exchanger units are to be installed at the power generating plants or transforming stations of Amlan, Kabangkalan and Pulupandan and these units and the automatic exchanger units at Naga Power Plant and Sta. Barbara Substation are to be mutually connected to comprise an automatic telephone channel network. The assumption was made here that automatic exchanger equipment would already exist at Naga Power Plant and Sta. Barbara Substation.

ii) Cable Terminal (CT) Maintenance and Administration Telephones

The telephone facilities for maintenance of the various cable terminal (CT) facilities are to be composed by speaker calling systems as shown below.

Fig. 6-19 Panay - Negros - Cebu Interconnected Transmission Lines Project Telecommunication System

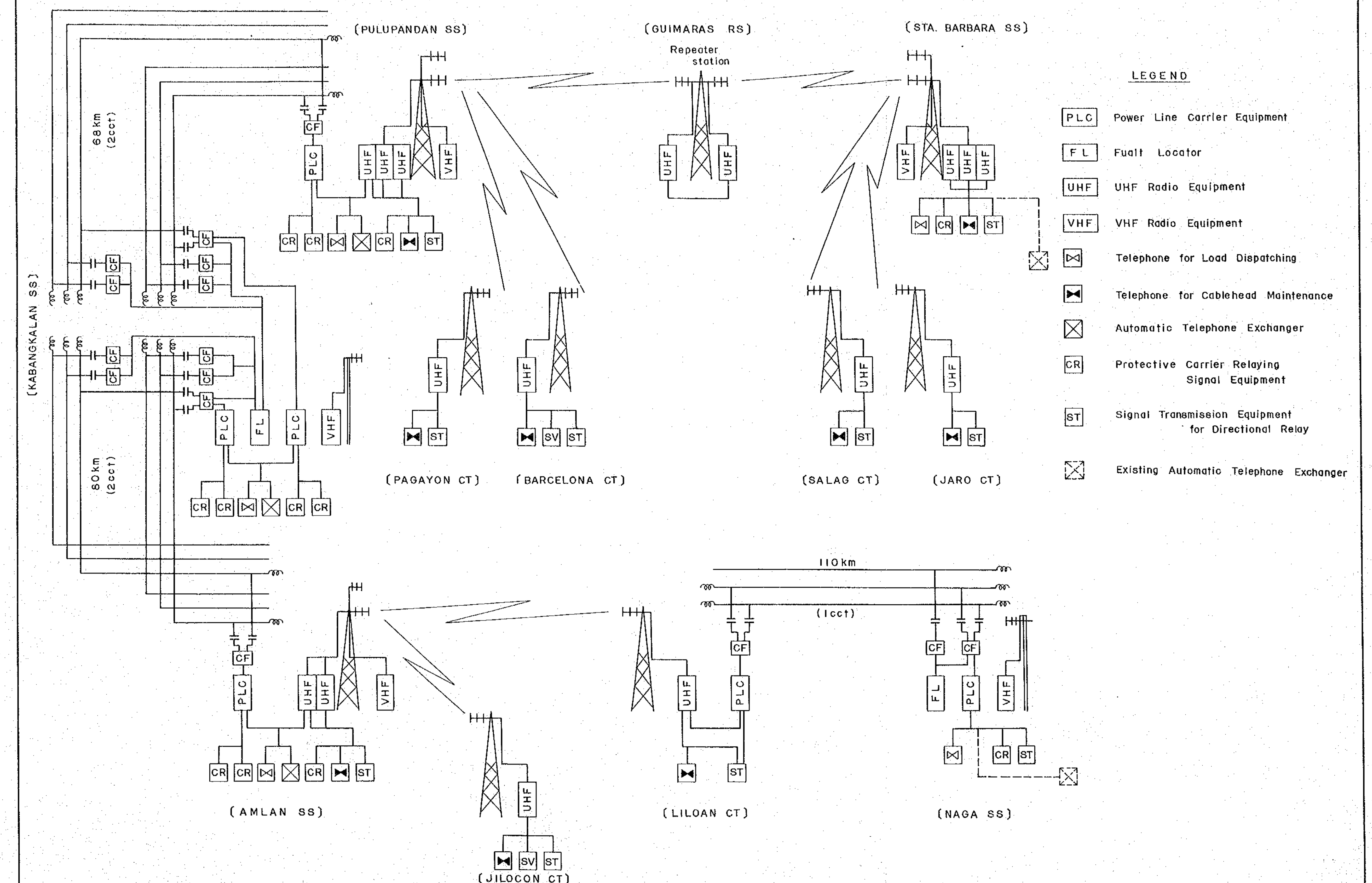
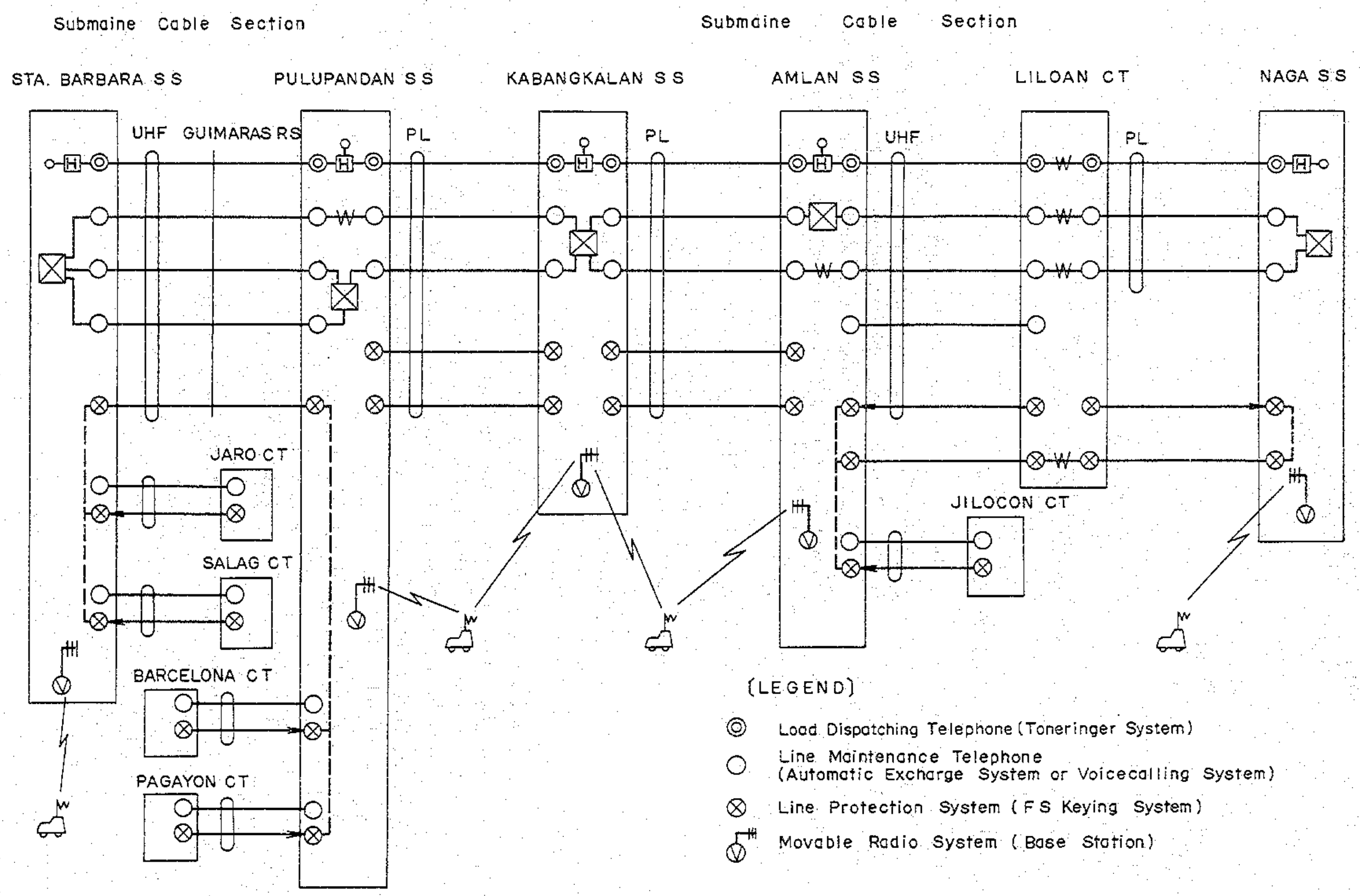


Fig. 6-20 Panay - Negros - Cebu Interconnected Transmission Lines Project. Telecommunication System Diagram



Amlan Power Plant → Jilocon CT
Amlan Power Plant → Liloan CT

Pulupandan Substation → Pagayon CT
Pulupandan Substation → Barcelona CT

Sta. Barbara Substation → Salag CT
Sta. Barbara Substation → Jaro CT

(3) Mobile Radio Telephone System

VHF radio stations are to be provided at Naga Power Plant, Amlan Power Plant, Kabangkalan Substation, Pulupandan Substation and Sta. Barbara Substation for transmission line maintenance telephones, and a mobile radio telephone system is to be structured. Vehicle-mounted mobile stations are to be deployed at these power generating plants and transforming stations.

(4) Carrier Relays

Carrier relays are to be provided at the sections below.

Naga PS - Amlan PS	:	1 cct
Amlan PS - Kabangkalan SS	:	2 cct
Kabangkalan SS - Pulupandan SS	:	2 cct
Pulupandan SS - Sta. Barbara SS	:	1 cct

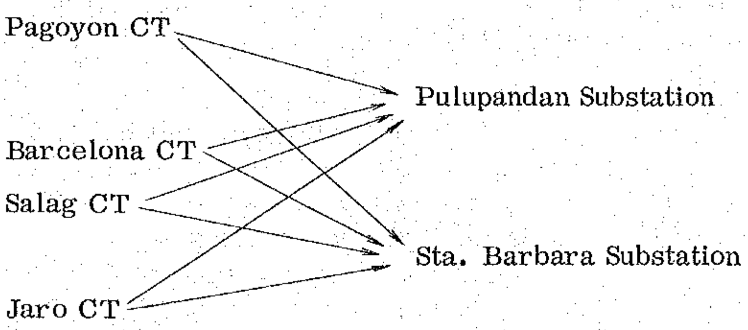
(5) Cable Faulted Section Detecting Signal Transmitting System

The transmission line between Naga and Amlan and between Pulupandan and Sta. Barbara include submarine cable parts, and in order to protect the cables during line faulting it is necessary to detect whether the fault is at a cable section or an overhead transmission line section. For this purpose, fault detection information at cable terminal points will be transmitted as indicated below.

i) Naga Power Plant - Amlan Power Plant

Liloan CT → Naga Power Plant
Liloan CT → Amlan Power Plant
Jilocon CT → Naga Power Plant
Jilocon CT → Amlan Power Plant

ii) Pulupandan Substation - Sta. Barbara Substation



(6) Fault Locator (FL)

Fault locators are to be provided at the locations below for long-distance transmission lines in order to pinpoint the locations during faulting of transmission lines.

i) Naga Power Plant Fault Locator

A fault locator is to be installed at Naga Power Plant to locate faulted points between Naga and Liloan.

ii) Kabangkalan Substation Fault Locators

Pulse radar system fault locators are to be installed at Kabangkalan Substation to locate faulted points between Kabangkalan and Amlan, 2 cct, and between Kabangkalan and Pulupandan, 2 cct.

(7) Telecommunications Power Supply System

Power supplies to telecommunications apparatus are all to be by a direct-current, no-outage power supply system based on floating battery charging. For this purpose, power supply is to be done by the following methods.

i) Power source for telecommunications apparatus installed at a sub-station are to be supplied by the station power supply of the substation.

ii) Power source for UHF and VHF telecommunications apparatus installed at a cable terminal are to be supplied from potential device (PD) for directional relays , connected at outgoing locations of overhead trans-mission lines at cable terminals.

iii) For the UHF repeater station on Guimaras Island, potential device for power supply are to be connected to the 138 kV transmission line, from which power supply is to be carried out.

6.3 Leyte-Samar Power System

6.3.1 Overhead Transmission Line

(1) Overhead Transmission Line Route

NAPOCOR has a projected route for the Leyte-Samar Interconnected

Transmission Line also, and has already started topographic surveying of a part of the section. The present Feasibility Study was carried out on this route planned by NAPOCOR. The route investigated is as indicated in Fig. 6-21.

The route starts from the Tongonan Geothermal Power Plant site, runs south for approximately 5 km, goes east along an existing forest road to cross the central mountain range of Leyte Island and reach the San Juanico Strait crossing point. Approximately 40% of this section is mountainland with the part crossing the mountain range virgin jungle, and it is thought considerable difficulty will be encountered in cutting out the right of way. The elevation reaches close to 1,100 m, with especially, one stretch of approximately 3 km having no nearby road at all, and it will be necessary to newly construct an access road. This portion will be the most difficult in construction of the transmission line route in the Project. The vicinity of the crossing with National Highway No. 2 is flat and coconut groves and rice paddies are spread out widely.

The route from the San Juanico Strait crossing point to Wright Substation is along National Highway No. 1 (Philippines-Japan Friendship Road) and generally traverses a hilly area.

The length of the transmission line from Tongonan Geothermal Power Plant to Wright Substation is as follows:

Leyte Island part	:	64 km
Samar Island part	:	49 km
Strait crossing part	:	2 km
Total	:	115 km

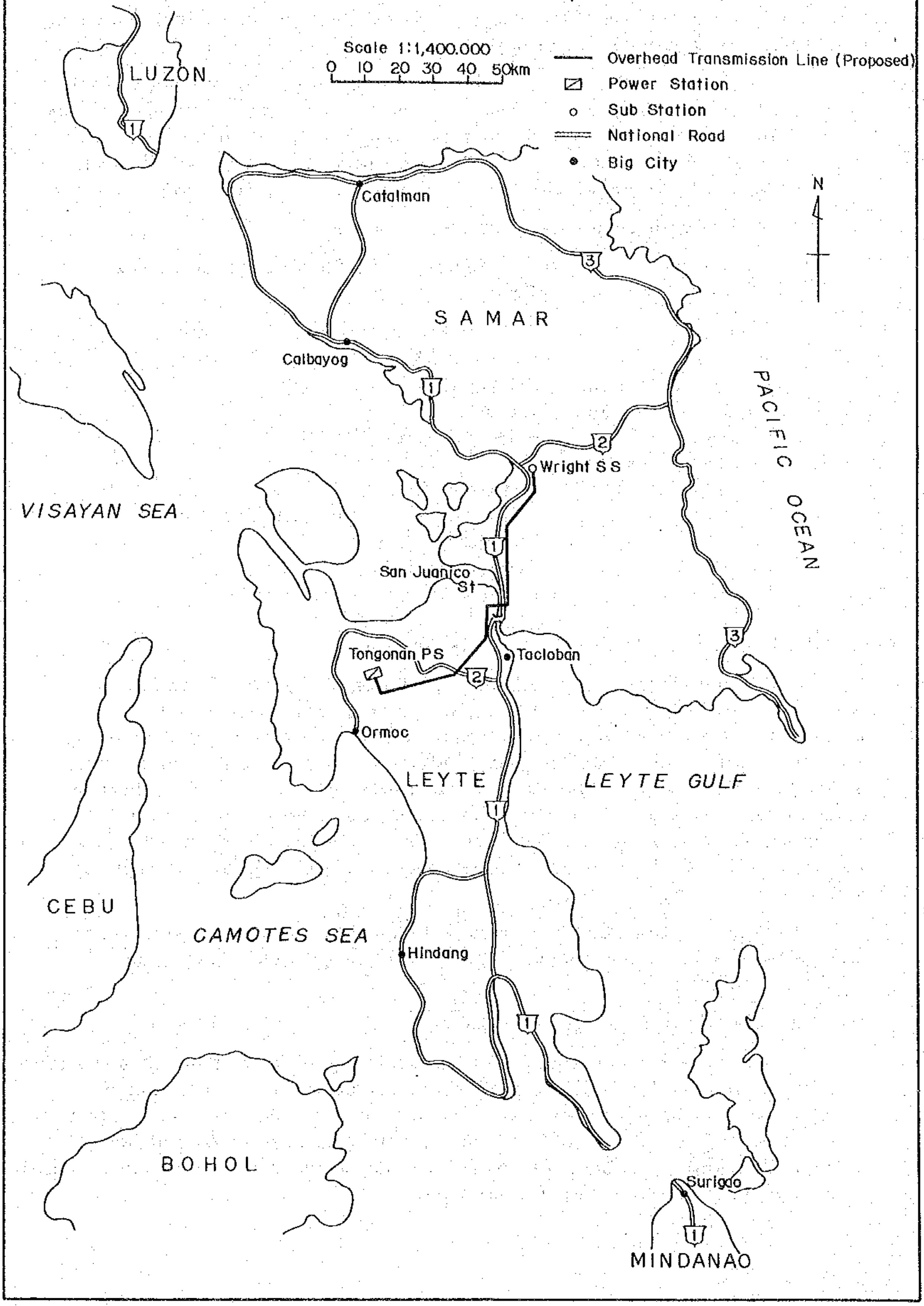
(2) Outline of Preliminary Design

i) Conductor

The power flow of this interconnecting transmission line, as described in 5.3.1, is forecast to be 15 MW at the cross section of 1990, and will be relatively small for the time being. Consequently, the conductor size is to be the minimum permitted from the aspect of corona noise, and 336.4 MCM ACSR is to be adopted as in the NAPOCOR plans. The conductor surface potential gradient in this case will be 14 kV/cm. On the other hand, the critical corona potential gradient when considering the minimum atmospheric pressure (at sea level) of 950 mb during typhoon and elevation of 1,100 m is approximately 15 kV/cm, and it will be possible for 336.4 MCM ACSR to be adopted from the aspect of corona noise.

The conditions for stringing conductors are to follow those in 6.2.1-(2)-i), and the maximum horizontal tension may be about 2,300 kg. As measures against vibration of conductors caused by breezes, dampers and armor rods are to be attached.

Fig. 6-21 138 kV Transmission Line Route
(Leyte - Samar Line)



ii) Other

Insulators, clearances, lightning protection design and supports are to conform to those of the Panay-Negros-Cebu interconnection, and these will be according to 6.2.1-(2)-ii) to v).

Regarding the type of support, in consideration of the fact that this transmission line, as the backbone of power supply for all of Samar Island in the future, will need to be of high reliability, angle steel towers are to be used similarly to the 3 island interconnecting transmission line, and the configuration of the single circuit steel tower of Fig. 6-2 can be followed.

(3) Outline of Overhead Transmission Line Design

The outline of the design of the Leyte-Samar Interconnected Transmission Line is as indicated below.

Length	:	115 km (including strait crossing)
Voltage	:	AC 138 kV
Electricity System	:	3 phase, 3 wire, 60-Hz
Number of Circuits	:	1 cct
Conductor	:	336.4 MCM ACSR
Overhead Ground Wire	:	70 mm^2 GSC, 1 line
Insulator	:	250 mm suspension insulator, 8 or 10 insulator strings
Support	:	Angle steel tower
Foundation	:	Concrete slab-type foundation

6.3.2 Strait-Crossing Overhead Transmission Line

San Juanico Strait lying between the islands of Leyte and Samar is a narrow strait of width of 1 to 3 km and length of approximately 20 km, and travel between the two islands can already be freely accomplished by crossing Marcos Bridge. This strait has shoals almost everywhere with tidal currents at Pt. Uban an average of about 1.5 kt and a maximum of 3 kt, while there are places in the strait where as much as 4 to 5 kt is reached. However, a navigation channel for draft of 5 m is secured, and this is being utilized as a route for relatively large inland-sea passenger ships plying between Tacloban and Manila.

To cross San Juanico Strait by aerial transmission line, since it will be a crossing of long span, a special design will be adopted considering the economics and reliability.

(1) Selection of Strait Crossing Route

The economics of a power transmission line crossing a strait is strongly influenced by the length of the span, and therefore, numerous candidate sites for crossing which would be of relatively short span were selected on a map and studied, and the 3 routes below which appeared to be of higher reliability were investigated through field reconnaissances and the topographies of steel tower locations were confirmed.

(a) Pangabaton Island Route
(b) Uban Route
(c) Marcos Bridge Route

The individual routes are as shown in Fig. 6-22.

The Pangabaton Island Route is a proposal for shortening span lengths by utilizing an island in the strait with a maximum span length of approximately 1,000 m, the shortest among the 3 routes, and the topographies of the sites for the steel towers are suitable. The total length of this route will be 2,100 m with 5 steel towers required. The NAPOCOR plan for this route was for a bend to be made at the middle steel tower on the island, but this would require an extremely tall dead-end tower resulting in increased weight of the steel tower, while line-stringing work would be accompanied by difficulties, so that it is thought a change should be made to a straight-line route.

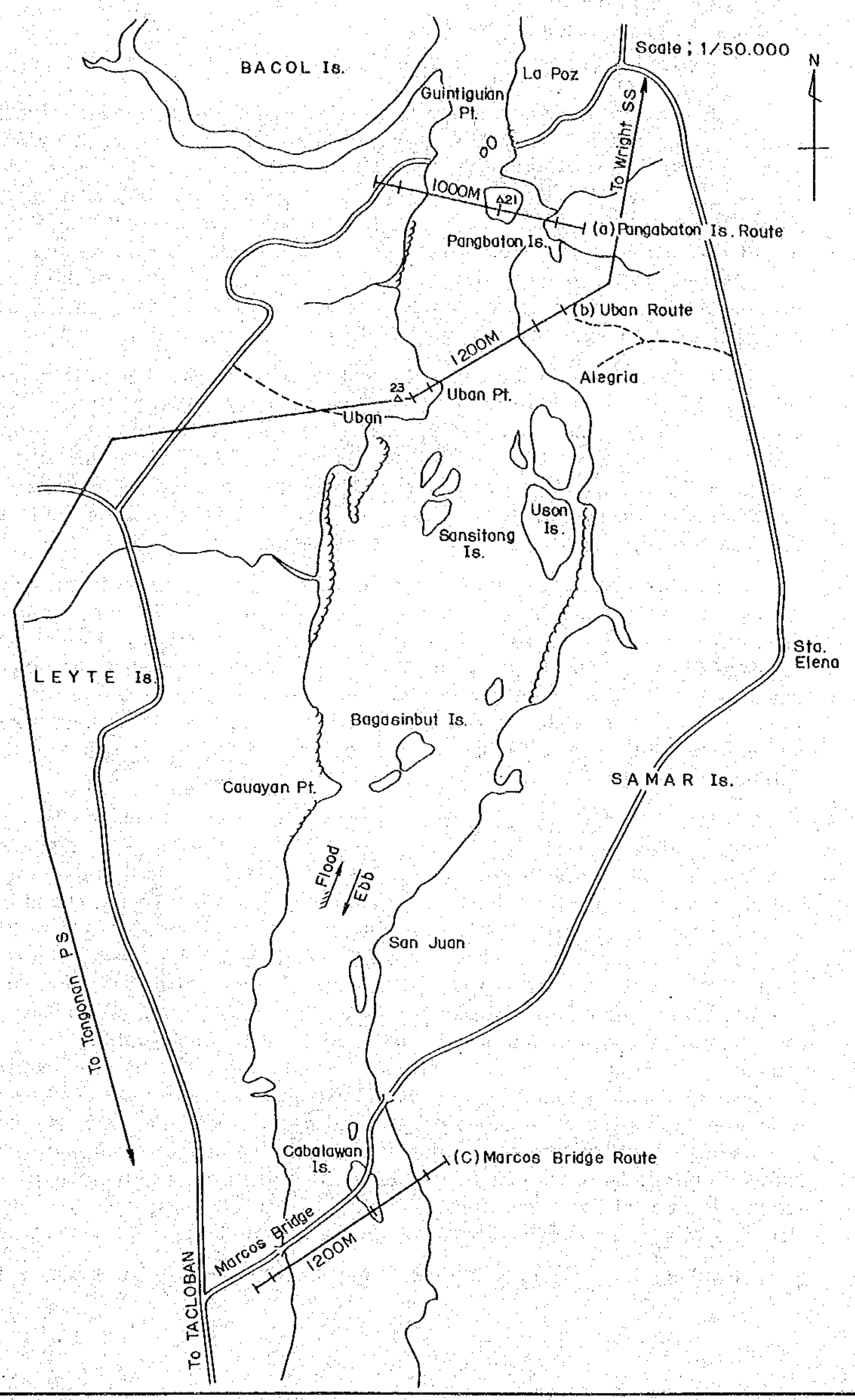
The Uban Route is for a direct crossing without utilizing an intermediate island, and the maximum span will be approximately 1,200 m, longer than for that of the Pangabaton Island Route. However, the total length will be 1,700 m, and the 4 steel towers required will be less than for the case of the Pangabaton Island Route. Furthermore, there are the advantages that construction materials for the steel towers at both sides can be hauled in from land, and that heavy equipment can be used for construction.

The Marcos Bridge Route would be a very symbolic transmission line route, but on the other hand, there is a risk of it involving an environmental problem. The maximum span length would be approximately 1,200 m, and the total length 2,400 m, while the number of steel towers would be large so that it would be economically disadvantageous compared with the other routes. Furthermore, the method of stringing a cable on Marcos Bridge was also examined, but with the total length being more than 2,700 m, it is thought to be extremely disadvantageous economically.

Next, in order to select the crossing route, economic comparisons were made upon rough designs concerning the two alternatives of the Pangabaton Island Route and the Uban Route. As a result, it was shown that the heights of the tallest steel towers on the Pangabaton Island and Uban routes would be approximately 90 m and 115 m, respectively, while the total weight of the steel tower foundations would be about 15% smaller for the Pangabaton Island Route. However, since there are 25% more conductor insulating materials, the materials cost for the Pangabaton Island Route will be only 8% cheaper. Meanwhile, on examination of the construction cost, since in the case of the Pangabaton Island Route, construction works on an intermediate island would be needed, not only would there be added expense for temporary works such as landing piers and landing equipment, transportation watercraft, stevedoring for loading and unloading, etc. for transportation of construction materials and equipment, but work efficiency will also be lowered, and there are many factors to increase the construction cost. Overall, it was judged that the Uban Route would be approximately 3% more economical.

As described above, it is thought reasonable for the Uban Route to be

Fig. 6-22 Overhead Transmission Line Route on the San. Juanico Strait



adopted for crossing San Juanico Strait in view of the economics and ease of maintenance after the facilities go into use.

It is necessary for precise surveying to be done by radio wave distance measurements, triangulation, etc. for final designs regarding this route. Also, careful investigations of the topographies and geologies of steel tower locations should be carried out.

(2) Outline of Preliminary Design

i) Conductor

Since the strait crossing will be of long span, while although a flat area, very tall steel towers must be used for the transmission line, and costs related to supports will make up a large part of the construction costs. That is, whereas they are 50 to 60% for ordinary transmission lines, they will be as much as 70 to 80% for a sea-strait-crossing transmission line. Consequently, in order to design a more economical sea-strait-crossing transmission line, it will be essential to use a conductor of high tensile strength to lower steel-tower height as much as practicable.

In view of the above, special high strength steel core aluminum alloy strands (AACSR) are to be adopted for the San Juanico Strait-crossing transmission line. This conductor is of a composite stranded construction of aluminum and steel strands similar to ACSR which uses a high-tension steel wire of tensile strength of 180 kg/mm^2 class as the core with aluminum alloy strands of 31 kg/mm^2 class at outer layers for an average tensile strength of about 54 kg/mm^2, 56% stronger than ordinary ACSR.

This crossing point is at a distance from the open ocean, with winds and waves at the surface comparatively calm, so that conditions for conductor corrosion are thought to be not too severe, but in view of the importance of this transmission line, a moderately corrosion-resistant conductor will be adopted. That is, a conductor with corrosion-resistant grease impregnated only at inner layers will be used.

Conductor size is to be determined based on current capacity, but there should be at least the equivalent of 445 A, the current capacity of 336.4 MCM ACSR used for orginary sections, and 200 mm^2 AACSR is to be used.

ii) Insulator

Reliability is to be thoroughly secured using double strings for both suspension and dead-end locations, while regarding the number of insulators per string, soilage of insulators by salt will be considered and 10 insulator strings of 250 mm suspension insulators are to be used conforming to 6.2.1-(2)-ii).

iii) Clearance

The standard insulation clearance and minimum insulation clearance are to be 100 cm and 75 cm, respectively, following 6.2.1-(2)-iii).

iv) Lightning Protection Design

This area belongs to a region of a high isokerautic level, while the steel towers will be tall, so that considering specially high impedance against lightning surges, an overhead ground line, 70 cm^2 GSC, one line, is to be strung.

v) Steel Tower

The overland transmission line is planned for only single-circuit for the time being, but for the strait crossing, double-circuit towers are to be constructed in consideration of economy including future expansion.

The steel towers must be of a height that marine navigation will not be hindered. It is considered that the height of conductor above sea level may be made 30 m to coincide with the clearance of Marcos Bridge. Based on the above, the minimum height of conductor support of the steel towers will be as follows:

Surface clearance	30 m*
Electrical safety distance	1 m
Conductor sag	88 m
Insulator string length	2 m
Tide level change	1 m
Steel tower location elevation	-20 m
Conductor support height	102 m

* The navigation clearance of Marcos Bridge is height of 23 m by width of 116 m, but the height above sea level is 30 m since the bridge is an arch structure.

The profile of this transmission line is shown in Fig. 6-23.

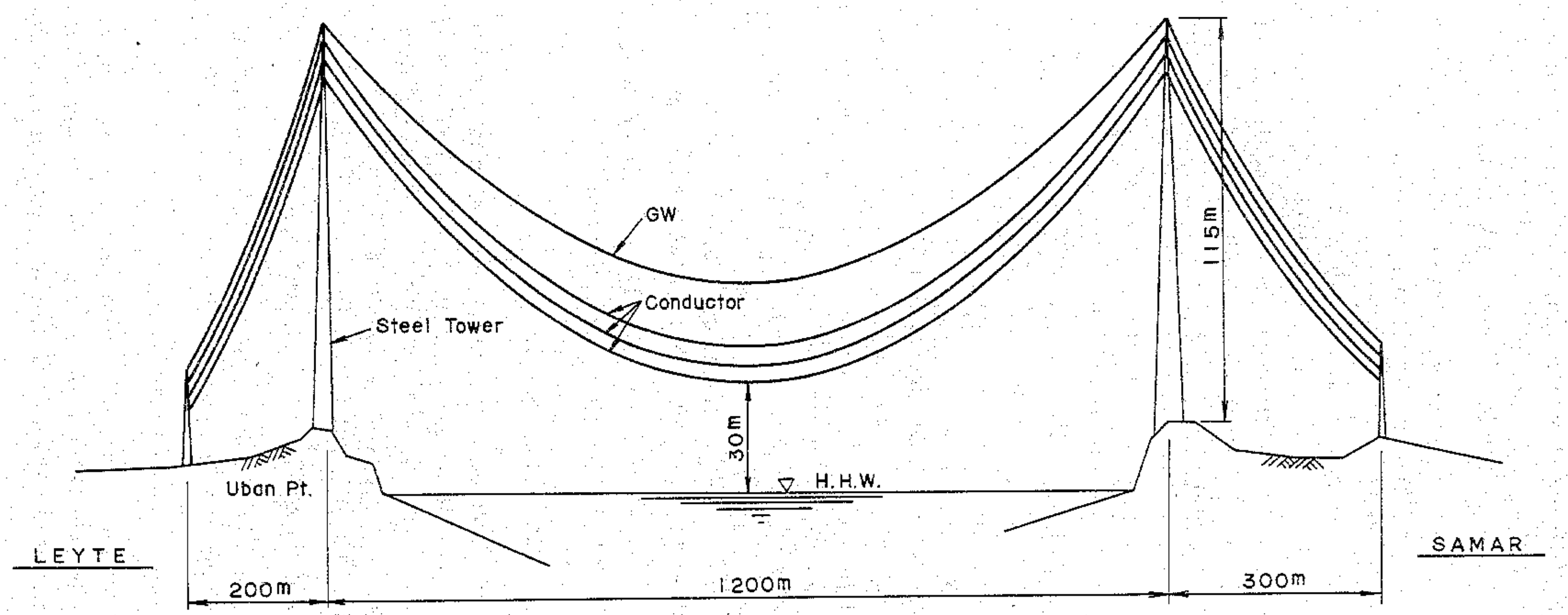
(3) Outline of Facilities of Strait-Crossing Transmission Line

Length	:	1,700 m (Uban Route)
Voltage	:	138 kV
Electricity System	:	3 phase, 3 wire, 60-Hz
Number of Circuits	:	2 cct
Maximum Span Length	:	1,200 m
Conductor Height above Sea	:	30 m (from highest tide level)
Conductor	:	200 mm^2 AACSR (high tension, moderate corrosion resistance)
Insulator	:	250 mm suspension insulator, 10 insulator string, double string
Overhead Ground Wire	:	70 mm^2 GSC, 1 line
Steel Tower	:	2 suspension, 2 strain, total 4 towers maximum tower height, approx. 115 m Total weight, approx. 120 ton

Fig. 6-23 138 kV Overhead Transmission Line of the San Janico Strait Crossing

(Uban Route)

Scale Horizontal ; 1/10.000
Virtical ; 1/ 2.000



6.3.3 Substation

(1) The Project (Leyte-Samar Interconnection) will have an interconnection as shown in Fig. 6-24 and the only substation concerned will be Wright Substation, the facilities of which are the following:

(a)	138 kV transmission line outgoing facilities	1 cct
(b)	138 kV facility for interconnection with 69 kV facilities	1 cct
(c)	Main transformer	1 bank
(d)	69 kV tranmission line outgoing facilities	3 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	3 units
	- Circuit breaker, 72.5 kV, 1,600 MVA, with CT	6 units
	- Disconnecting switch, 145 kV	6 units
	- Disconnecting switch, 72.5 kV	12 units

(2) Wright Substation is to be newly constructed at a point approximately 4 km outside of the small town of Wright in the central part of Samar Island. The projected site for the substation is a gently-sloped hill and a lot is to be cleared here and an outdoor switchyard and main substation building constructed. Wright Substation is to be connected with Tongonan Geothermal Power Plant on Leyte Island by a 138 kV transmission line to literally form the backbone of the Leyte-Samar Power System, and through supply of cheap power generated from geothermal energy, there are great expectations held for the development of Samar Island, and therefore, the substation may be said to be of extreme importance. In view of the above, the basic consideration in preliminary design with regard to the principal parts of the substation is to be the same as stated in 6.2.3 on the Panay-Negros-Cebu Power System.

(3) With regard to the composition of Wright Substation, the single-line diagram of Fig. 6-25 should be referred to.

6.3.4 Telecommunications Facilities

The interconnecting transmission line and the substation are the most important facilities for transportation to Samar of the power of Tongonan Geothermal Power Plant on Leyte, and telecommunications facilities will be indispensable for effective and sure operation of these facilities. The telecommunications facilities will comprise the following:

(1) Load Dispatching Telephone System

Power line carrier tone ringer telephone channels are to be structured between Tongonan Geothermal Power Plant and Wright Substation.

(2) Mobile Radio Telephone System

VHF base stations are to be provided at Tongonan Geothermal Power Plant and Wright Substation, and telecommunications channels structured with vehicle-mounted mobile VHF stations for transmission line maintenance and protection.

Fig. 6-24 Leyte - Samar Interconnected Transmission Line Project Connection Diagram

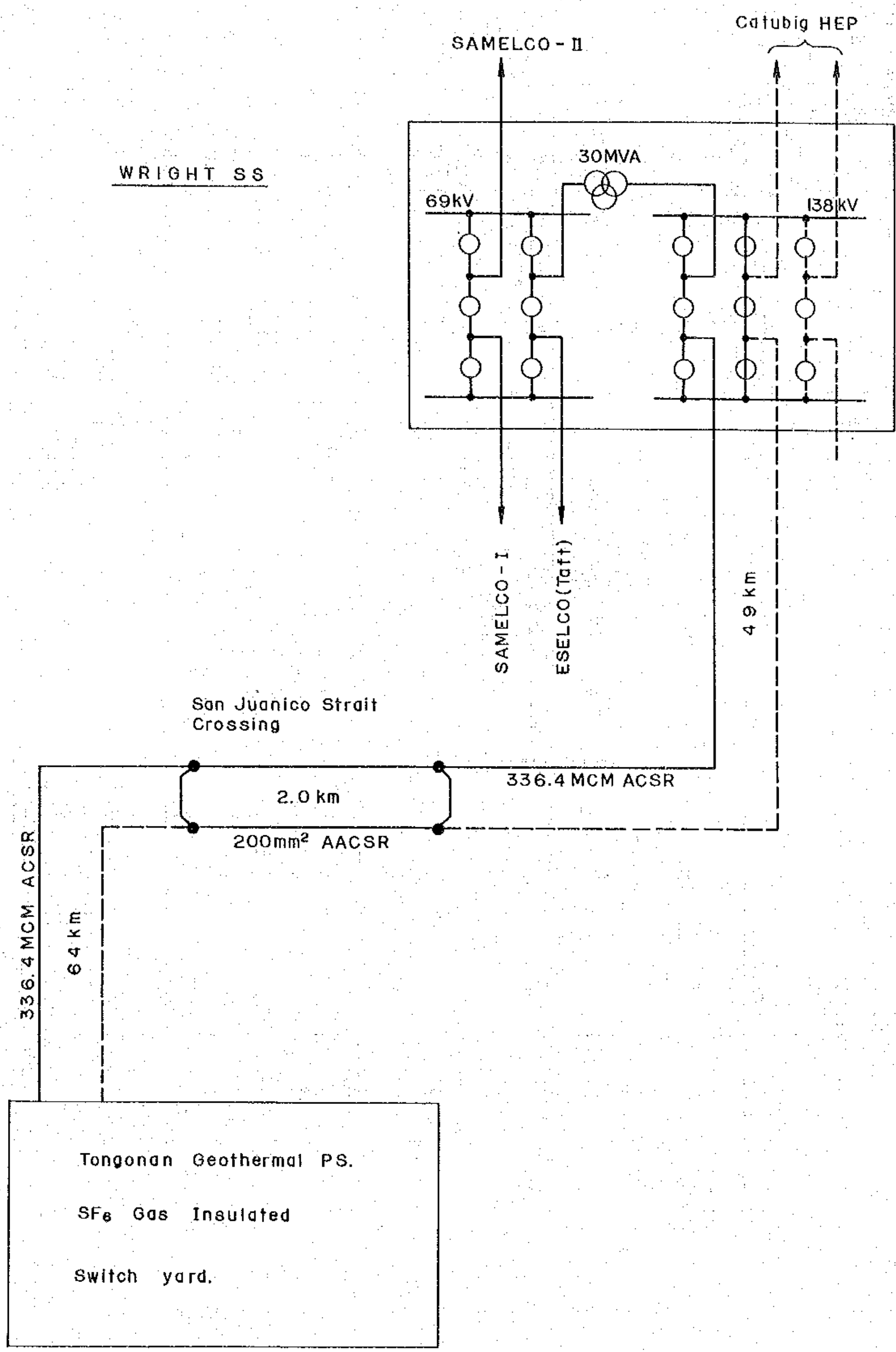
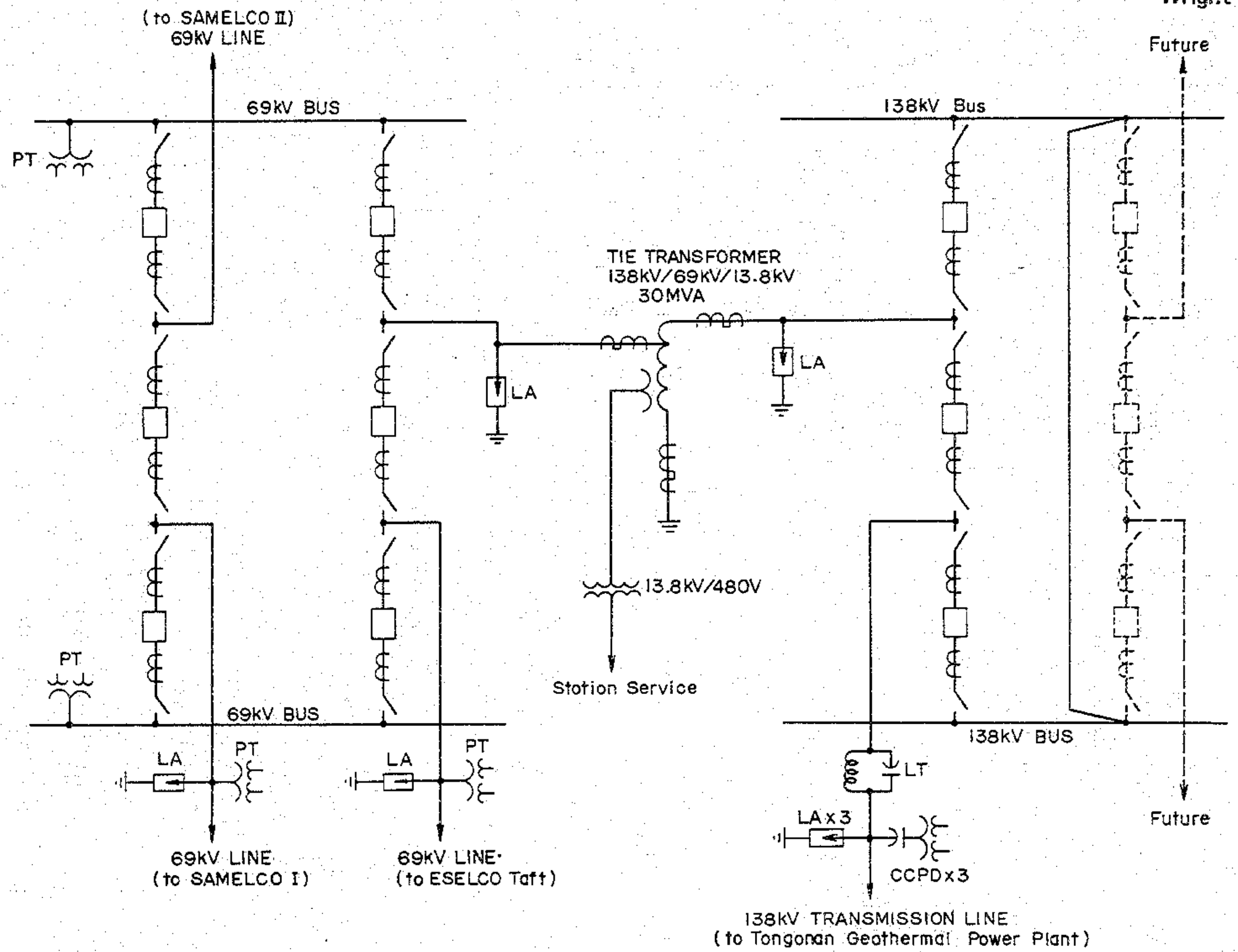


Fig. 6-25 Single Line Diagram
Wright Substation



(3) Carrier Relays

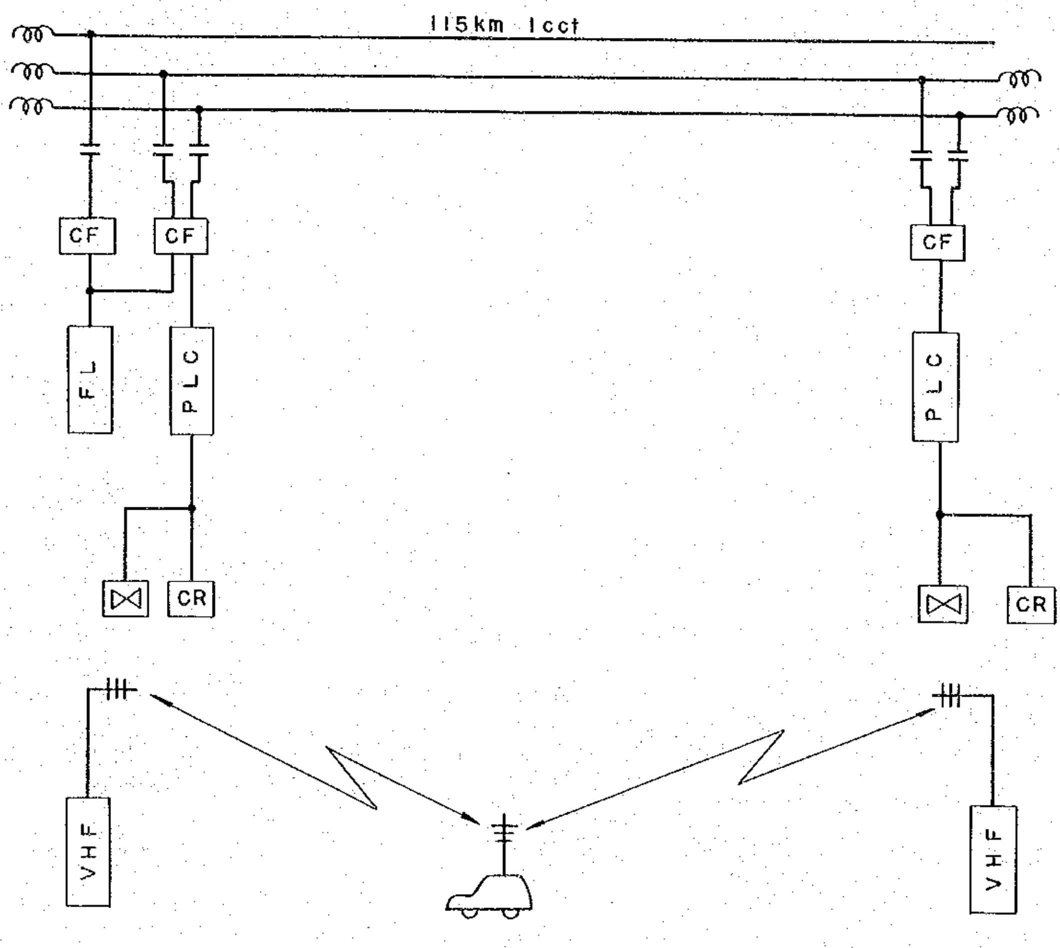
Transmission line protection by a single-phase reclosure system is to be provided for operation of the transmission line with a high degree of reliability. Signal transmitting apparatus for this purpose are to be installed at Tongonan Geothermal Power Plant and Wright Substation.

(4) Fault Locator

A fault locator of pulse radar type is to be installed at Tongonan Geothermal Power Plant for locating faults in the interconnecting transmission line.

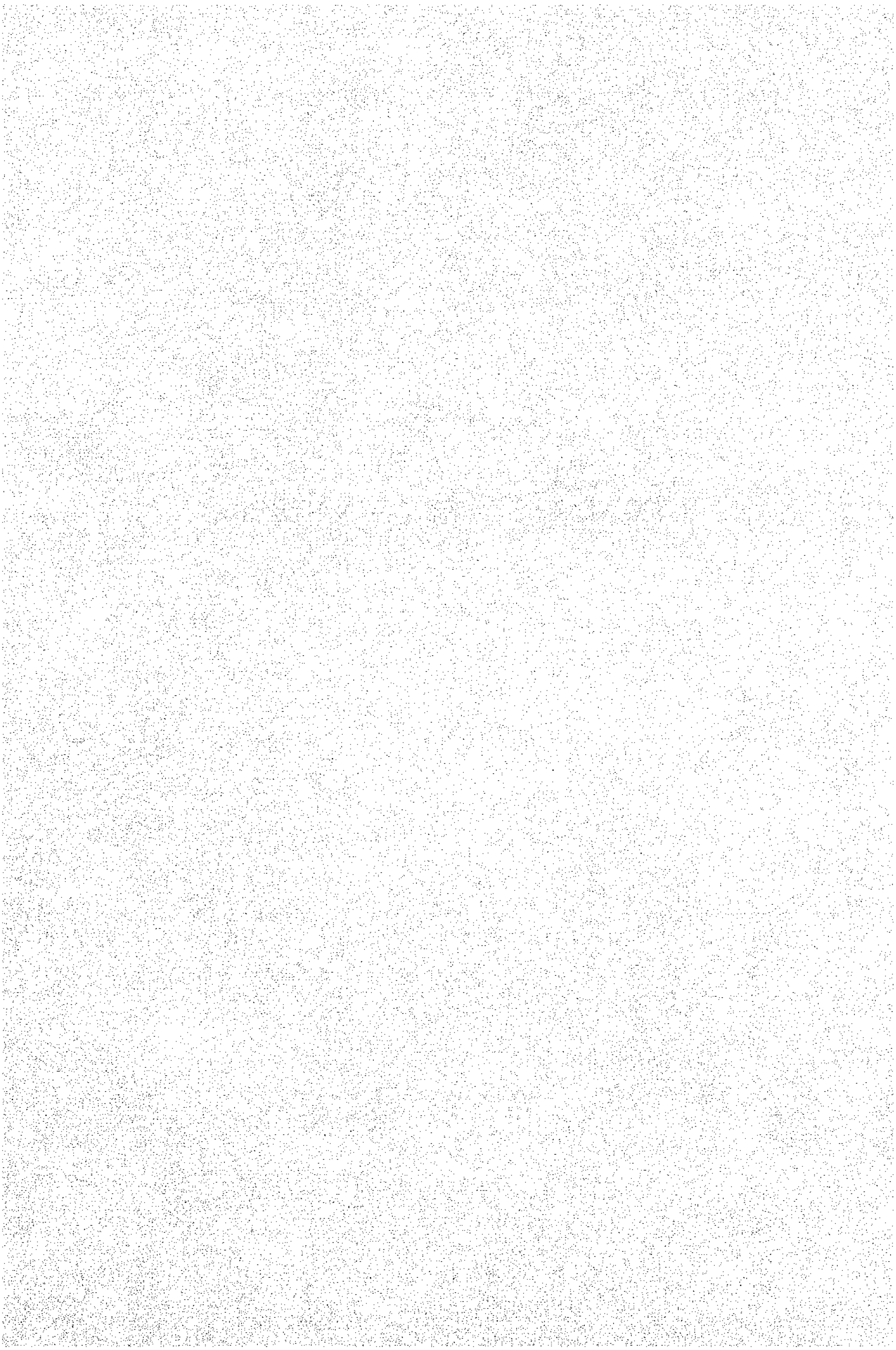
The system diagram for structuring the abovementioned telecommunications channels is shown in Fig. 6-26.

Fig. 6-26 Leyte - Samar Interconnected Transmission Line Project Telecommunication System Diagram



CHAPTER 7

POWER SYSTEM ANALYSIS



CHAPTER 7 POWER SYSTEM ANALYSIS

Since the Project is a power transmission and transformation project and will be a trunk transmission line to become the backbone in structuring the electric power system, it will have a close relationship with the electric power development program which is indispensable in carrying out power system analysis.

NAPOCOR made a review of the program for power generating, transmitting and transforming facilities in the Visayas in December 1979 and decided on a development program up to 1993. This power development program is indicated in Fig. 7-1. The feature of this power development plan is that the ratio of thermal generating plants is very high. The composition ratios by types of plants in 1985 and 1990 are as indicated below.

Table 7-1 Type of Power Plant

Unit: MW

Type of plant	Panay–Negros–Cebu		Leyte–Samar		Remarks
	1985	1990	1985	1990	
Thermal					
Coal	175.0	285.0	0	0	Breakdown shown Table 7-2.
Diesel	303.2	288.2	0	0	
Geothermal	115.5	190.5	153.0	228.0	
Sub-total	593.7	763.7	153.0	228.0	
Hydro	0.8	80.8	0	30.0	
Total	594.5	844.5	153.0	258.0	

The maximum unit capacity in the Panay-Negros-Cebu Power System will be 55 MW scheduled as a coal-fired thermal. The unit capacity for geothermal power plants will be 37.5 MW, while that for diesel power plants will be 18 MW. On the other hand, the generating facilities considered within the Leyte-Samar Power System are geothermal and hydro facilities with the unit capacity planned for geothermal a maximum of 37.5 MW.

7.1 Supply Reliability and Required Reserve Capacity

As already described, NAPOCOR has formulated and is moving ahead with a power development program predicated on interconnections of the three islands of Panay, Negros and Cebu, and the two islands of Leyte and Samar. The former three-island interconnection will connect the islands by 138 kV submarine cables, while the latter two-island interconnection will be by 138 kV aerial transmission line.

The study regarding supply reliability and required reserve capacity described herein will be limited to the system of the three islands of Panay, Negros and Cebu. Regarding the supply reliability and reserve capacity of the Leyte-Samar System, these will be omitted as object of study in view of the power source structure and number of units.

7.1.1 Supply Reliability

The supply reliabilities described here will be those of the three-island interconnected system at the points of time of 1985 and 1990, and the supply reliabilities in case NAPOCOR were to develop the three islands individually without interconnections with submarine cables*1.

In general, the concept of supply reliability is expressed by concrete measures such as duration of outage and number of times of outage. However, the supply reliabilities considered here are those which are to be calculated by the probability of supply hindrance seen from the forced outage factor by type of power supply source*2 and by individual unit capacities based on the total supply capabilities of power supply sources and power demands in 1985 and 1990. In calculation of the supply reliability, evaluations are generally made from the composite probability of the three items of probability of variation in river water flow for hydro, the probability of variation in power demand and the outage probability by type of equipment and by unit capacity, but since the ratio of hydro in the power supply structure of the three-island interconnected system is small, the probability of variation in river water flow, and the probability of variation in power demand — because it is difficult to estimate due to lack of data — were both omitted from supply reliability calculations.

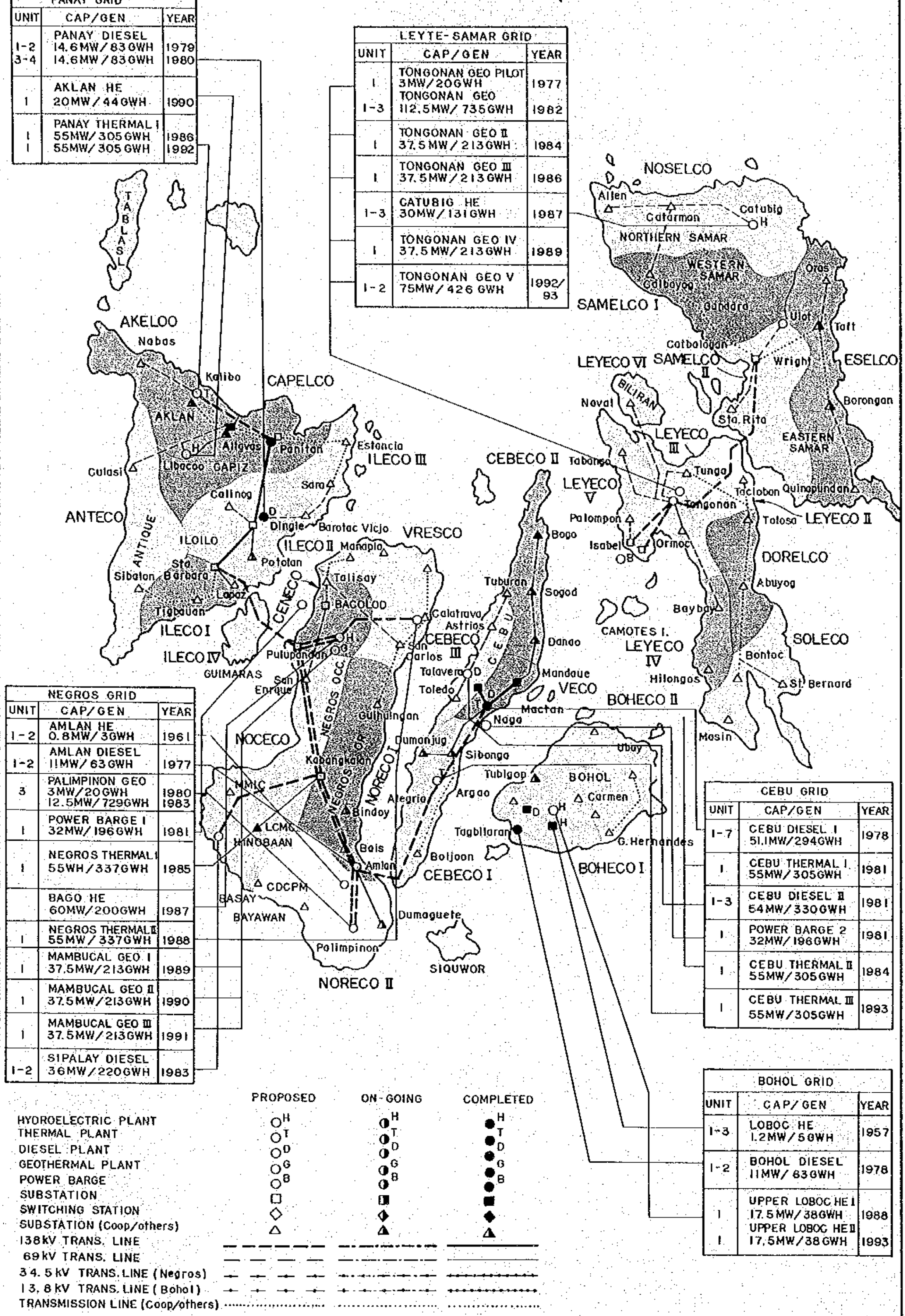
*1 The difference in the required reserve capacities for identical supply reliabilities is the benefit of the three-island interconnection. Furthermore, as will be described in Chapter 9, "Economic Analysis", there will be the benefit of transmitting electric power from non-petroleum-based energy sources on Negros to the other islands.

*2 The forced outage factor will differ due to differences in unit capacities even with the same types of equipment. However, the outage rates were determined by type of equipment only with regard to the power generating facilities comprising the Panay-Negros-Cebu Power System.

7.1.2 Required Reserve Supply Capacity

The reserve supply capacity brought up here is the reserve capacity for supplying power to be taken into account at the stage of implementing an electric power development plan for supplying stable electric power to meet random fluctuations in demand and supply, and in effect, indicates the degree of allowance of power supply facilities to cope with maximum demand. NAPOCOR, in establishing the power development program in the Visayas, has considered securing of reserve capacity of the maximum unit capacity in the power system or reserve capacity corresponding to 15 to 20% of the maximum power demand, whichever is larger.

Fig. 7-1 National Power Corporation Visayas Region General Development Plan



PANAY GRID

UNIT	CAP/GEN	YEAR
1-2 3-4	PANAY DIESEL 14.6MW/83GWH 14.6MW/83GWH	1979 1980
1	AKLAN HE 20MW/44GWH	1990
1 1	PANAY THERMAL I 55MW/305GWH 55MW/305GWH	1986 1992

LEYTE-SAMAR GRID

UNIT	CAP/GEN	YEAR
1	TONGONAN GEO PILOT 3MW/20GWH	1977
1-3	TONGONAN GEO 112.5MW/735GWH	1982
1	TONGONAN GEO II 37.5MW/213GWH	1984
1	TONGONAN GEO III 37.5MW/213GWH	1986
1-3	CATUBIG HE 30MW/131GWH	1987
1	TONGONAN GEO IV 37.5MW/213GWH	1989
1-2	TONGONAN GEO V 75MW/426GWH	1992/93

NEGROS GRID

UNIT	CAP/GEN	YEAR
1-2	AMLAN HE 0.8MW/3GWH	1961
1-2	AMLAN DIESEL 11MW/63GWH	1977
3	PALIMPINON GEO 3MW/20GWH 12.5MW/729GWH	1980 1983
1	POWER BARGE I 32MW/196GWH	1981
1	NEGROS THERMAL I 55WH/337GWH	1985
	BAGO HE 60MW/200GWH	1987
1	NEGROS THERMAL II 55MW/337GWH	1988
1	MAMBUCAL GEO I 37.5MW/213GWH	1989
1	MAMBUCAL GEO II 37.5MW/213GWH	1990
1	MAMBUCAL GEO III 37.5MW/213GWH	1991
1-2	SIPALAY DIESEL 36MW/220GWH	1983

CEBU GRID

UNIT	CAP/GEN	YEAR
1-7	CEBU DIESEL I 51.1MW/294GWH	1978
1	CEBU THERMAL I 55MW/305GWH	1981
1-3	CEBU DIESEL II 54MW/330GWH	1981
1	POWER BARGE 2 32MW/196GWH	1981
1	CEBU THERMAL II 55MW/305GWH	1984
1	CEBU THERMAL III 55MW/305GWH	1993

BOHOL GRID

UNIT	CAP/GEN	YEAR
1-3	LOBOC HE 1.2MW/5GWH	1957
1-2	BOHOL DIESEL 11MW/63GWH	1978
1 1	UPPER LOBOC HE I 17.5MW/38GWH UPPER LOBOC HE II 17.5MW/38GWH	1988 1993

Accordingly, it was decided that the relation between reserve supply capacity and supply reliability described here would be studied with the reserve capacity standard being considered by NAPOCOR as the tentative measure.

NOTE: The basis for determining the necessary reserve capacity is that abundant and good-quality electricity will be supplied, and this basis will directly determine the total capacity of power generating facilities. Although NAPOCOR has selected the reserve capacity standard as mentioned above, generally, it is normal for the measure of reliability of electric power supply to be set and the required reserve supply capacity to be determined in order that this standard will be maintained. In Japan, electric power development programs which should be secured as reserve capacity to maintain the number of days of supply hindrance (anticipated number of days of shortage) of 0.3 day (supply capability shortage probability 0.0125 = 0.3 day/24-day) during one month are being pushed forward. As will be described later in detail, with the reserve capacity standard of NAPOCOR, when converted to the supply reliability capability of Japan, the number of days of supply hindrance will be about 1.0 day. In effect, since it may be considered that there will be ample reserve capacity in months other than that of maximum demand, it may be considered that the supply capacity shortage will be 1 day/yr.

7.1.3 Concrete Calculation Procedures for Supply Reliability and Required Reserve Supply Capacity

In case of examining the power supply reliability inside an interconnected system, when there is surplus capacity in a system within the limits of the interconnected capacity of the interconnected transmission lines, supply is made to other systems, and in contrast, when there is surplus capacity in another system and there is a supply-capacity shortage in one's own system, the shortage in the power-supply capability will be eliminated if power is received within the limits of the capacity of the interconnected transmission lines. In effect, the electric power supply reliability will be improved by interconnection.

(1) Preconditions for Calculations

(a) Bases for Comparisons

The years considerd for calculations were 1985 and 1990, and the electric power development plans in the cases of three-island individual isolated development and three-island interconnected development were assumed as shown in Table 7-2. Regarding the power development program for the inter-island interconnection project, this was decided on in December 1979 upon reviews made by NAPOCOR, while with respect to the individual isolated development of the three islands, the Survey Team made the projection adding necessary power generating facilities (diesel) based on the above-mentioned three-island interconnected development program of NAPOCOR. As for the maximum demands of the power systems, the maximum demands in 1985 and 1990 of each island were used, and it was assumed that these maximum demands would be the same from June to December. (The months in which the maximum demands of the various islands arise differ, but differences are small from June to December.)

(b) Interconnected Capacity of Three Islands

The computation of reserve supply capacity is done using cases of various interconnected capacities, and considering the scales of the power systems of the three islands, the four cases below were compared. (Regarding the basic consideration in determining the interconnected capacity, 5.2.2, "Interconnection Capacity" of Chapter 5, "Interconnected Power Transmission and Transformation Project" should be referred to.)

	Island		Interconnected Capacity (MW)		Island		Interconnected Capacity (MW)		Island
Case 1	Panay	—	25	—	Negros	—	25	—	Cebu
Case 2	Panay	—	50	—	Negros	—	50	—	Cebu
Case 3	Panay	—	50	—	Negros	—	75	—	Cebu
Case 4	Panay	—	50	—	Negros	—	100	—	Cebu

(c) Forced Outage Rates of Units by Type

Generally, the forced outage rate P is calculated by the equation below.

$$P = \frac{O}{R + O}$$

where

O: forced outage time
R: operating time

The Survey Team attempted to make a study of forced outage rates during field investigations, but with the exception of Bataan Thermal Power Station, it was found difficult to collect proper data. However, NAPOCOR has indicated the figures below as operating indices, and these were adopted as the forced outage rates by types of plant.

Type of Plant	Forced Outage Rate in Percent
Thermal	6.0
Diesel	6.0
Hydro	1.5
Geothermal	3.0

Table 7-2-(1) Generating Units in 1985

Isolated island development plan						Inter-island interconnected development plan					
Type of unit	Unit capacity (MW)	No. of unit	Total capacity (MW)	Forced outage rate (%)	Remarks	Type of unit	Unit capacity (MW)	No. of unit	Total capacity (MW)	Forced outage rate (%)	Remarks
a) Cebu Island					Max. demand : 180 MW	a) Cebu Island					Max. demand : 180 MW
Coal-fired	5.0	2	10.0	6.0		Coal-fired	5.0	2	10.0	6.0	
Coal-fired	55.0	1	55.0	6.0	*except one (1) unit	Coal-fired	55.0	1	55.0	6.0	*except one (1) unit
Diesel	3.4	2	6.8	6.0		Diesel	3.4	2	6.8	6.0	
Diesel	5.0	4	20.0	6.0		Diesel	5.0	4	20.0	6.0	
Diesel	7.3	6	43.8	6.0	*except one (1) unit	Diesel	7.3	6	43.8	6.0	*except one (1) unit
Diesel	8.0	4	32.0	6.0		Diesel	8.0	4	32.0	6.0	
Diesel	18.0	3	54.0	6.0		Diesel	18.0	3	54.0	6.0	
Sub-total	-	22	221.6	-		Sub-total	-	22	221.6	-	
b) Negross Island					Max. demand : 215 MW	b) Negros Island					Max. demand : 215 MW
Hydro	0.4	2	0.8	1.5		Hydro	0.4	2	0.8	1.5	
Geothermal	1.5	2	3.0	3.0		Geothermal	1.5	2	3.0	3.0	
Geothermal	37.5	3	112.5	3.0		Geothermal	37.5	3	112.5	3.0	
Coal-fired	55.0	1	55.0	6.0		Coal-fired	55.0	1	55.0	6.0	
Diesel	3.6	1	3.6	6.0		Diesel	3.6	1	3.6	6.0	
Diesel	5.5	5	27.5	6.0		Diesel	5.5	5	27.5	6.0	
Diesel	8.0	3	24.0	6.0	*except one (1) unit	Diesel	8.0	3	24.0	6.0	*except one (1) unit
Diesel	18.0	2	36.0	6.0	*except one (1) unit	Diesel	18.0	1	18.0	6.0	*except one (1) unit
Sub-total	-	19	262.4	6.0		Sub-total	-	18	244.4	-	
c) Panay Island					Max. demand : 54 MW	c) Panay Island					Max. demand : 54 MW
Hydro		0				Hydro		0			
Coal-fired		0				Coal-fired		0			
Diesel	5.5	4	22.0	6.0	*except one (1) unit	Diesel	5.5	2	11.0	6.0	
Diesel	7.3	6	43.8	6.0		Diesel	7.3	3	21.9	6.0	*except one (1) unit
Sub-total	-	10	65.8	-		Sub-total	-	5	32.9	-	
Total	-	51	549.8	-	Max. demand : 449 MW Reserved cap.: 22.4%	Total	-	45	498.9	-	Diversity factor : 1.02 Max. demand : 440 MW Reserved cap.: 13.5%

Note : Asterisk * means scheduled outage of the unit for maintenance.

Table 7-2-(2) Generating Units in 1990

Isolated island development plan

Type of unit	Unit capacity (MW)	No. of unit	Total capacity (MW)	Forced outage rate (%)	Remarks
a) Cebu Island					Max. demand : 255 MW
Coal-fired	5.0	2	10.0	6.0	
Coal-fired	55.0	2	110.0	6.0	*except one (1) unit
Diesel	3.4	2	6.8	6.0	
Diesel	5.0	4	20.0	6.0	
Diesel	7.3	6	43.8	6.0	*except one (1) unit
Diesel	8.0	5	40.0	6.0	
Diesel	18.0	4	72.0	6.0	*except one (1) unit
Sub-total	-	25	302.6	-	
b) Negros Island					Max. demand : 276 MW
Hydro	0.4	2	0.8	1.5	
Hydro	10.0	1	10.0	1.5	
Hydro	50.0	1	50.0	1.5	
Geothermal	1.5	2	3.0	3.0	
Geothermal	37.5	4	150.0	3.0	*except one (1) unit
Coal-fired	55.0	1	55.0	6.0	*except one (1) unit
Diesel	3.6	1	3.6	6.0	
Diesel	5.5	5	27.5	6.0	
Diesel	8.0	3	24.0	6.0	*except one (1) unit
Diesel	18.0	1	18.0	6.0	*except one (1) unit
Sub-total	-	21	341.9	-	
c) Panay Island					Max. demand : 67 MW
Hydro	10.0	2	20.0	1.5	
Coal-fired		0			
Diesel	5.5	7	38.5	6.0	*except one (1) unit
Diesel	7.3	6	43.8	6.0	*except one (1) unit
Sub-total	-	15	102.3	-	
Total	-	61	746.8	-	Max. demand : 598 MW Reserved cap.: 24.9%

Inter-island interconnected development plan

Type of unit	Unit capacity (MW)	No. of unit	Total capacity (MW)	Forced outage rate (%)	Remarks
a) Cebu Island					Max. demand : 255 MW
Coal-fired	5.0	2	10.0	6.0	
Coal-fired	55.0	2	110.0	6.0	
Diesel	3.4	2	6.8	6.0	
Diesel	5.0	4	20.0	6.0	
Diesel	7.3	6	43.8	6.0	*except one (1) unit
Diesel	8.0	4	32.0	6.0	
Diesel	18.0	2	36.0	6.0	*except one (1) unit
Sub-total	-	22	258.6	-	
b) Negros Island					Max. demand : 276 MW
Hydro	0.4	2	0.8	1.5	
Hydro	10.0	1	10.0	1.5	
Hydro	50.0	1	50.0	1.5	
Geothermal	1.5	2	3.0	3.0	
Geothermal	37.5	3	112.5	3.0	*except two (2) units
Coal-fired	55.0	1	55.0	6.0	*except one (1) unit
Diesel	3.6	1	3.6	6.0	
Diesel	5.5	5	27.5	6.0	
Diesel	8.0	3	24.0	6.0	*except one (1) unit
Diesel	18.0	1	18.0	6.0	*except one (1) unit
Sub-total	-	20	304.4	-	
c) Panay Island					Max. demand : 67 MW
Hydro	10.0	2	20.0	1.5	
Coal-fired	55.0	1	55.0	6.0	
Diesel	5.5	1	5.5	6.0	*except one (1) unit
Diesel	7.3	3	21.9	6.0	*except one (1) unit
Sub-total	-	7	102.4	-	
Total	-	49	665.4	-	Diversity factor : 1.02 Max. demand : 586 MW Reserved cap.: 13.5%

Note : Asterisk * means scheduled outage of the unit for maintenance.

The average forced outage rates of Unit No.1 (75 MW) and Unit No.2 (150 MW) of Bataan Thermal in the past were 8.4% and 9.6%, respectively, due to internal causes, and 0.6% and 0.4%, respectively, due to external causes.

(d) Power Interchange based on Differences in Load Curves of Three Islands

The diversity in loads of the three islands was obtained from the load curves of the days in 1971 and 1979 that demands were maximum for the power companies representing the islands, PECO (Panay Island), CENECO (Negros Island) and VECO (Cebu Island). As shown in Fig. 7-2, peaks appear at the same time for the Panay and Negros electric power systems and it will not be possible for power interchange to be done between the two. However, the power system of Cebu has 7% to 10% surplus capacity for supplying the other two islands. In contrast, at the time the peak appears in the Cebu power system, the Panay system will have 3% to 5% and the Negros system 10% to 15% surplus capacity to supply Cebu. Consequently, the differences in the loads of the islands were taken into consideration in calculating the required reserve capacity.

The supply capabilities of the islands based on diversity of loads were considered to be the following:

	Panay	Negros	Cebu
Panay		0	5%
Negros	0		5%
Cebu	5%	15%	

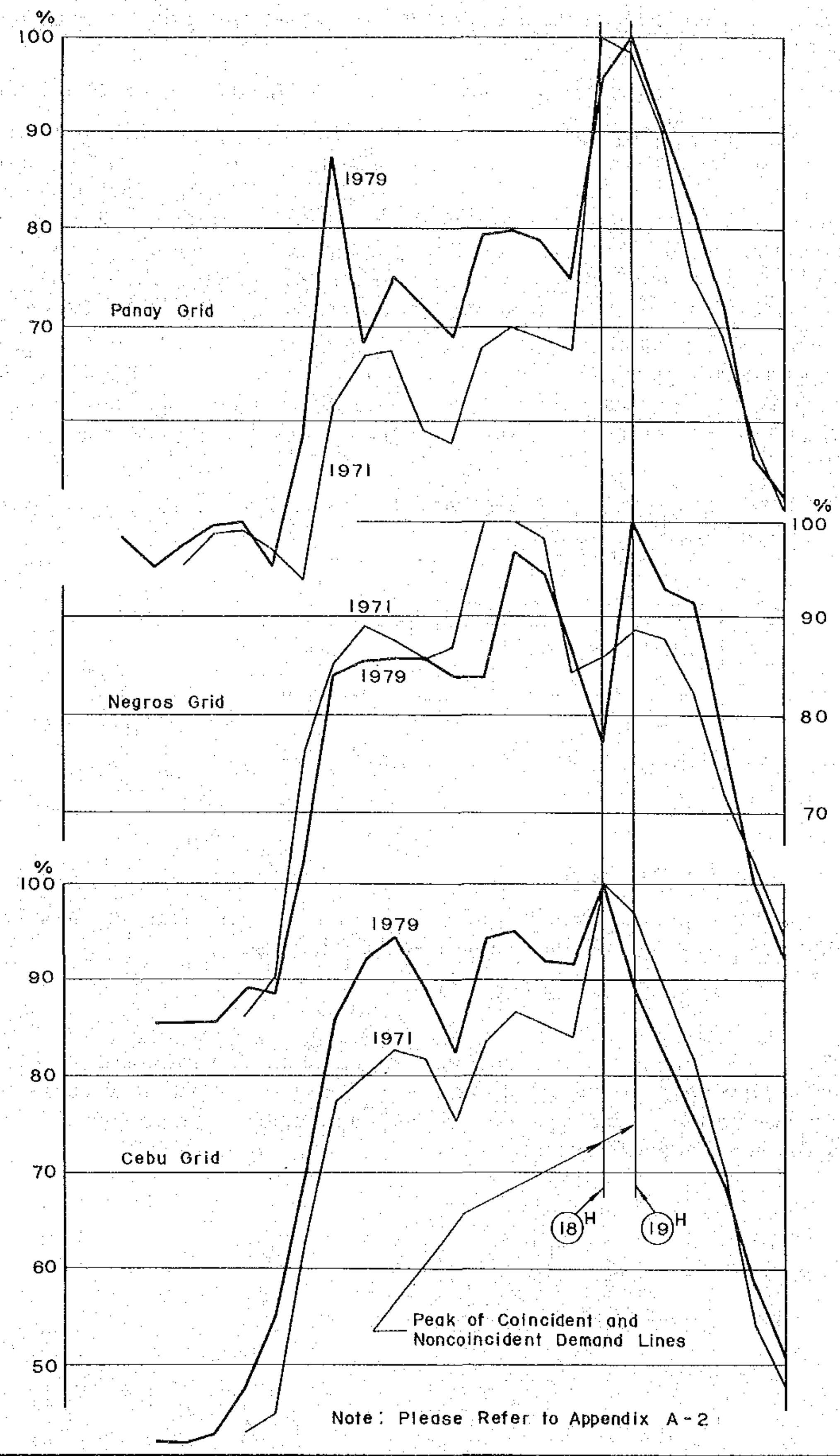
(2) Calculation Technique

In general, the probability $P_{(r)}$ of outage of r units from among n units divided into groups can be determined by the following:

$$P_{(r)} = {}_nC_r \cdot P_r \cdot (1 - P)^{n-r}$$

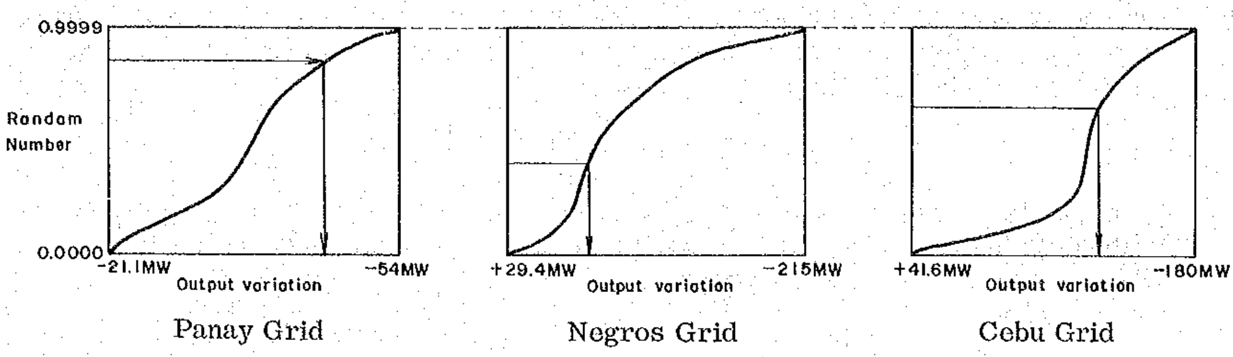
The outage probability and the output outage of each group are calculated in this way and the probability distribution is obtained for each output outage. By multiplying these outage probabilities together, the output variation probability distribution for the entire system of each island is obtained. (In general, the shape is close to being normal distribution.)

Fig. 7-2 Load Diversity



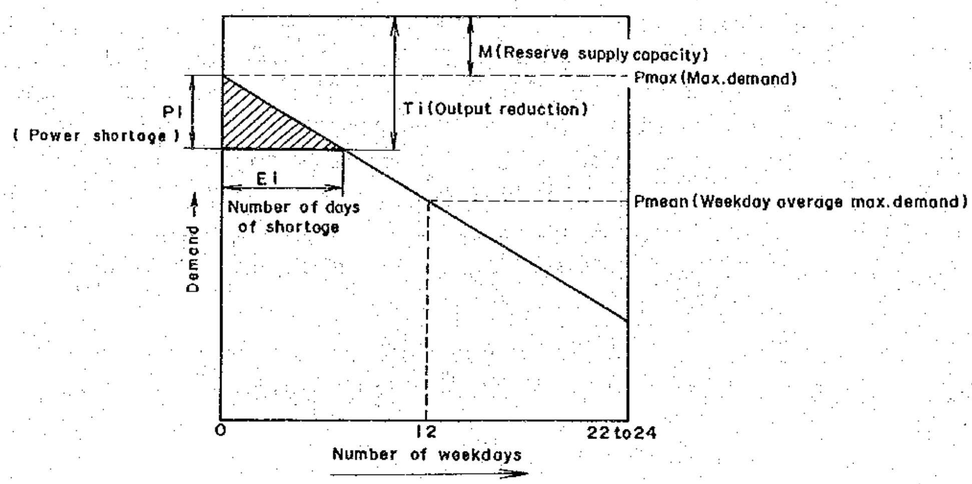
Note: Please Refer to Appendix A-2

Fig. 7-3 Cumulative Probability Distribution of Outage (1985)



Converting these output variation probability distributions into the cumulative probability distributions shown in Fig. 7-3, the output variations are sampled by random number calculations (Monte Carlo method), and the surplus or deficit in supply capacity of each island is calculated adding the reserve supply capacity. Further, after obtaining the power supplied from other islands (calculated by the flow method), the anticipated number of days of shortage for each island is obtained by the load duration curve shown in Fig. 7-4. The necessary reserve supply capacity (M) of each island is obtained as the given target value which is the sum of the anticipated number of days of shortage obtained by such calculations done a certain number of times (sampling of about 5,000 times) divided by the number of times of calculation.

Fig. 7-4 Load Duration Curve (by Island)



In Fig. 7-4, with output reduction as T_i, the probability thereof as P_i, and reserve supply capacity as M, the number of days in a month that a shortage in supply capacity will be seen is obtained from the power demand curve. Putting this number of days of shortage as E_i, the anticipated number of days of shortage is defined as the following:

$$\sum_i = E_i \cdot P_i = \text{Anticipated Number of Days of Shortage}$$

The number of days of shortage is related to the size of reserve supply capacity M, and the anticipated number of days of shortage is decreased as the reserve supply capacity is increased.

In calculation of the reserve capacity for the three-island interconnected system, the reserve capacity is hypothesized (initial value) from the development program in the case of inter-island interconnection in Table 7-2, and the respective anticipated number of days of shortage for each island is obtained. For an electric power system where the result of the above calculation is smaller than the given anticipated number of days of shortage, the reserve capacity is increased to obtain the rate of change in the anticipated number of days of shortage against the change in the reserve capacity, and converging calculations are made to arrive at the given anticipated number of days of shortage (identical criterion for all islands), and in the end the reserve capacity required for the three-island interconnected system is obtained.

7.1.4 Calculation Results and Conclusions

It is generally said that the reserve capacity of an interconnected power system consisting of two systems would be ample at about 10% if the two systems are of about the same size. This can be clearly seen in Table 7-3, where in the three-island interconnection, even if the interconnecting capacity (interconnecting capacity of submarine cable) were to become larger than 50 MW the reduction in the required reserve capacity will be small.

On considering the necessary reserve capacity for the three-island interconnection in relation to supply reliability, if the standard necessary reserve capacity of NAPOCOR is taken to be 15%, the number of days of shortage in supply capacity will be 0.30 day, and will be the same as for the supply reliability of Japan. However, considering that probability of variation in power demand is not taken into account in these calculations of required reserve capacity (it is estimated that the proportion of required reserve capacity to cope with fluctuations in power demand will be fairly large), in real terms, it is estimated to be a number of days of shortage in supply capacity of 1.0 day.

As is clear from the relation between interconnection capacity (transmission capacity of submarine cable) and the savings in the reserve supply capacity through three-island interconnection, the savings in reserve capacity are increased through expansion of the electric power system.

The reserve capacities necessary in case of isolated development of each island are given in Table 7-3, these being required for calculating the benefit of the inter-island interconnection in saving reserve supply capacity.

Fig. 7-5 Relation between Saving Reserve Capacity and Interconnection Capacity

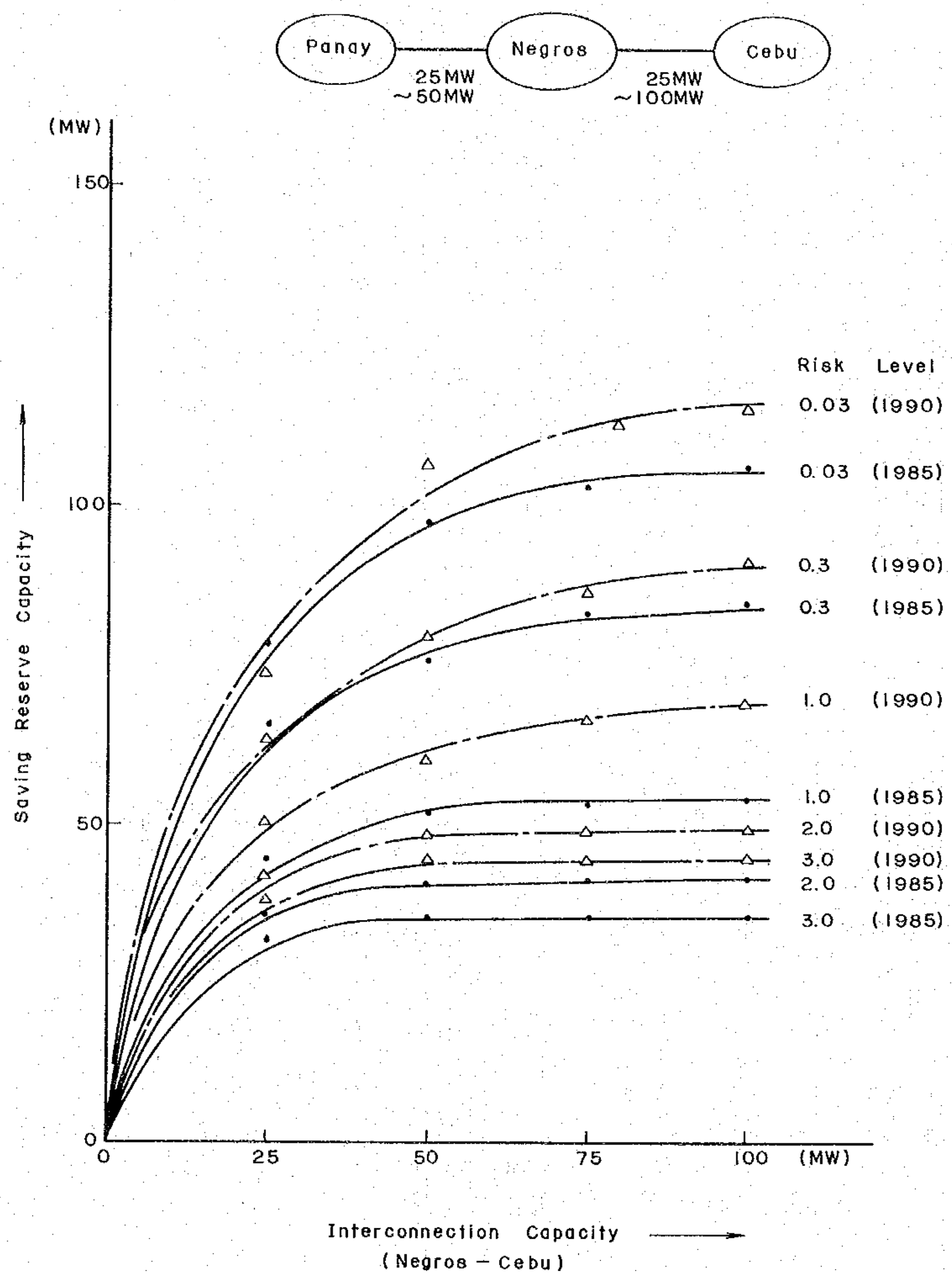


Table 7-3 Required Reserve Generating Capacity

Unit : MW

Risk Level*	Development without interconnection				Development with interconnection				Merit of interconnection			
	Panay	Negros	Cebu	Total	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
In 1985												
1.00	8.70	31.96	29.17	69.83	25.04	18.16	16.66	16.33	44.79	51.67	53.17	53.50
0.30	13.67	53.95	54.50	122.12	55.18	47.72	38.67	37.52	66.94	74.40	83.45	84.60
0.03	21.04	85.92	77.92	184.88	105.75	87.01	81.47	78.94	79.13	97.87	103.41	105.94
In 1990												
1.00	10.43	32.73	39.35	82.51	30.62	23.03	15.20	13.17	51.89	59.48	67.31	69.34
0.30	15.56	55.01	64.06	134.63	70.22	54.85	48.71	42.96	64.41	79.78	85.92	91.67
0.03	24.12	92.05	98.06	214.23	141.28	107.18	102.31	98.17	72.95	107.05	111.92	116.06

Note :
Case 1 : Panay —(25 MW)— Negros —(25 MW)— Cebu
Case 2 : Panay —(50 MW)— Negros —(50 MW)— Cebu
Case 3 : Panay —(50 MW)— Negros —(75 MW)— Cebu
Case 4 : Panay —(50 MW)— Negros —(100 MW)— Cebu

* Expected number of days that peak load is not served.
Figures in parenthesis mean an interconnection capacity of submarine cable.

7.2 Power System Analysis

Based on the interconnected power transmission and transformation project described in Chapter 5, examinations were made of power flow, stability and short-circuit capacity as described in detail below.

To begin with the conclusions, with the power transmission and transformation project presently planned by NAPOCOR, there will be no transmission line exceeding its transmission capacity from the standpoint of power flow, while there will be no special problem about stability and short-circuit capacity.

However, the 138 kV transmission lines of the Project will compose a part of a typical long-distance series grid, and 69 kV transmission lines connected to this power system will extend radially for fairly long distances along the coastlines of the various islands. With such a system composition, there will be a problem about maintaining proper voltages within the system. That is, in order to maintain 69 kV systems within a certain standard range (100 % ± 5 %), it is difficult to meet the reactive power consumption of the load with only the reactive power supply from generators, and in these calculations, it was assumed that voltages would be maintained by installing voltage adjusting equipment such as tap-equipped transformers or static power condensers at 69 kV substations directly connected to major loads.

These examinations of power system voltages are for the points in time of 1985 and 1990, and in case of contemplating installation of static power condenser in the future, the studies should be made considering in more detail the actual electric power system.

The interconnected operation of the three islands of Panay, Negros and Cebu will have various advantages, but on the other hand, generally speaking, with a long-distance series grid, there will be a risk that a disturbance occurring in one portion of the grid will be propagated to the entire system, resulting in cases in total outage of the power system. In order to verify this, stability calculations were made in the present Study assuming heavy power flows. The result was that there would be stability, and it may be said that the power system of the Project is electrically an adequately strong one.

7.2.1 Preconditions for Power System Analysis

The basic particulars necessary for power system analysis were those listed below.

- Years Considered: 1985, 1990
- Compositions of Power Systems Considered
  - i) Panay-Negros-Cebu Power System: See Fig. 7-6
  - ii) Leyte-Samar Power System: See Fig. 7-7

  In making the power system analysis, the 138 kV and 69 kV power generating, transmitting and transforming facilities were determined as shown in Fig. 7-6 and Fig. 7-7.
- Power Demand at Substation End
  - i) Peak Load: See Fig. 7-6, Fig. 7-7

    These diagrams indicate only kW loads.

ii) Off-peak Load (Midnight)
Off-peak loads were considered to be the same as peak load for mining demand, while for non-mining demands calculations were made assuming them to be 30% of peak load.

- Load Power Factor: 0.9
- Order of Priority in Operating Generating Facilities
  - i) During Maximum Demand
    (1) Hydro, (2) Geothermal, (3) Coal-Fired Thermal, (4) Diesel Thermal and Power Barge
  - ii) During Midnight Demand
    (1) Geothermal, (2) Coal-Fired Thermal, (3) Diesel Thermal and Power Barge
- Station Service Ratios at Thermal Power Plants
  - Diesel Thermal: 5%
  - Power Barge: 3%
  - Geothermal: 5%
  - Coal-Fired Thermal: 7.5%
- Generator Power Factor
  - Diesel Thermal: 0.8
  - Power Barge: 0.8
  - Geothermal: 0.8
  - Coal-Fired Thermal: 0.85
- Equipment Constants: See Appendix Table A-3-(2)
- Line Constants
  - i) 138 kV
    - (a) 2 cct:
      $Z_1 = 0.0962 + j\,0.256$ %/km/cct
      $Z_{00} = 0.443 + j\,1.472$ %/km/cct
      $Y_1 = 0.0642$ %/km/cct
      $Y_{00} = 0.1218$ %/km/cct
    - (b) 1 cct:
      $Z_1 = 0.1 + j\,0.265$ %/km/cct
      $Z_0 = 0.212 + j\,1.465$ %/km/cct
      $Y_1 = 0.0632$ %/km/cct
  - ii) 69 kV
    - (a) 1 cct:
      $Z_1 = 0.4038 + j\,0.9855$ %/km/cct
      $Z_0 = 0.987 + j\,3.15$ %/km/cct
      $Y_1 = 0.0176$ %/km/cct

    Impedance percentages based on 100 MVA.
- Allowable Voltage Fluctuation Range
  To be within 100% ± 5% at 69 kV bus end.

In power flow calculations of the Panay-Negros-Cebu Power System, it was assumed static power condenser for load power factor of 100% would be installed at 69 kV substations for major loads.

7.2.2 Results of Power Flow Calculations

Power flow calculations were made for peak hours and midnight off-peak hours based on the load forecasts for 1985 and 1990. The results are shown in Figs. 7-8, 7-9, 7-10 and 7-11.

As for the Leyte-Samar Power System, studies were made only for 1990 when the load will become heavy. The results are indicated in Figs. 7-12 and 7-13.

[Panay-Negros-Cebu Power System]

(1) Power Flow

i) 1985 (See Figs. 7-8, 7-9)

The power flows of the main trunk line (Naga Power Plant - Sta. Barbara Substation) will be 17 to 100 MW from Naga to Sta. Barbara during both peak and off-peak hours, with the heaviest power flow being about 100 MW between Kabangkalan and Amlan.

ii) 1990 (See Figs. 7-10, 7-11)

About 20 to 75 MW will flow from Sta. Barbara to Kabangkalan, with the flow light at about 2 MW from Amlan to Kabangkalan during peak hours, but during midnight off-peak hours, there will be a flow of about 50 MW. From Amlan to Naga, there will be a flow of about 40 to 70 MW

(2) Power Flow Bottlenecks

i) Transmission Lines

Since the Panay-Negros-Cebu Power System will not have any part comprising a looped system in 1985 and 1990, a study was made assuming outage of 1 cct of the 2 cct transmission line portion.

As a result, it was shown that none of the transmission lines would become overloaded in 1985 and 1990.

The continuous single-circuit transmission capacities were based on the figures below.

138 kV, 240 mm^2 ACSR: 135 MVA
69 kV, 336.4 MCM ACSR: 57 MVA

ii) Transformers

For transformers, a study was made to see of there would be overloading at the various substations in a state of normal power flow.

As a result, it was shown that at all of the substations there would be no transformer which would become overloaded in 1985 and 1990.

(3) Voltage Regulation

Voltage regulation consists of the problem of how the balance of reactive power is to be adjusted, and is performed by means of static power condensers and transformer taps.

However, as the reactive power balance in 1990 of the Panay-Negros-Cebu Power System indicates (see Appendix Table A-3-(3)), there will be some amount of reactive power (5 MVar) produced from 138 kV transmission lines, but at 69 kV transmission lines there will inversely be shortages of about 35 MVar, and as a whole, the shortage will be about 170 MVar.

Since in the case of the Panay-Negros-Cebu Power System there are no sources of reactive power sufficient to maintain voltages located near substations, some of which have heavy loads, while the 69 kV transmission lines are long and voltage drops are large, it is unavoidable to depend on adjustments to be made with generators and transformer taps connected with 138 kV buses.

However, although there is about 230 MVar of reactive power supply capacity of generators, if reactive power is supplied from generators in order to maintain voltages on the low-voltage sides of 69 kV substations at 95% or higher, it will not be possible to maintain voltages at generator ends, and as a result it will not be possible to effectively utilize reactive power of generators.

Thus, the problem will be where to install the sources of the reactive power lacking, and in general, installation at 138 kV substations having heavy loads, or installation of static power condenser at 69 kV substations for voltage improvement are conceivable.

When static power condensers are installed at 138 kV substations, facilities of large capacities to compensate for reactive power losses to the loaded substations will be required, and controls will become necessary during peak and off-peak hours. Voltage calculations were therefore made assuming that static power condenser corresponding to load power factor of 100% would be installed at 69 kV substations.

The results of the study are described below.

i) Cebu Power System

(a) Peak Hours in 1985 and 1990

During peak hours in 1985 and 1990, regulation is to be done at Naga Power Plant so that the Naga 138 kV bus voltage will be about 100 to 103%, and if the transformer taps used at Banilad Substation are 135 kV/69 kV, it will be possible to maintain the secondary-side voltages of 69 kV substations at 95% to 105%.

(b) Off-peak Hours in 1985 and 1990

Since loads are light during off-peak hours, voltages will be slightly on the high side, and if the 138 kV bus voltage at Naga is held to a maximum of 103%, the voltage can be maintained at no more than 105% even if the taps at Banilad Substation are not changed.

ii) Negros Power System

(a) Peak Hours in 1985

During peak hours in 1985, in order to regulate voltage at CDCP Substation, it will be necessary for the taps at Sipalay Substation to be made 131 kV/69 kV and make the 69 kV bus voltage of Sipalay about 103%. Also, the 138 kV bus voltage of Amlan Diesel Power Plant should be adjusted to about 101% at Palimpinon Geothermal Power Plant, the taps at Pulupandan Substation set at 131 kV/69 kV, and in addition, if the transformer taps of Talisay Diesel Power Plant are adjusted in a manner that the 69 kV bus voltage of Talisay will be 98% or higher, voltages at all 69 kV substations can be maintained within 95 to 105%.

(b) Peak Hours in 1990

During peak hours in 1990, since loads will be heavier compared with the peak hours during 1985, voltages at the substations of CDCP, Bayawan, Cadiz and Victorias will drop. In order to increase the voltages at these substations to 95% or higher, if a static power condenser of about 10 MVA is installed at Talisay Diesel Power Plant so that the 138 kV bus voltage at Amlan would be maintained at around 103 to 104%, the 138 kV bus voltage at Sipalay at 97% or higher, and the Talisay 69 kV bus voltage 100% or higher, it will be possible to maintain voltages within ±5% without changing the transformer tap positions at peak hours in 1985.

(c) Off-peak Hours in 1985

Compared with peak hours in the same year of 1985, voltages will be slightly higher as a whole, but at the 69 kV substations interconnected with Sipalay Substation, since there will be few voltage regulation locations nearby, the voltages will conversely be lowered. Because of this, it will be necessary to maintain the 138 kV bus voltages at Amlan at 101 to 103%. Also, if the 138 kV bus voltage at Pulupandan is made to be about 100%, it will be possible to maintain the voltages of all 69 kV substations within ±5% without changing peak-hour transformer taps.

(d) Off-peak Hours in 1990

The off-peak hours in 1990 will be similar in trend to the off-peak hours of 1985, but the voltages of the substations connected with Sipalay Substation will be lowered more than in 1985. On the other hand, since the voltages of substations interconnected with Pulupandan Substation are slightly high, by making the Pulupandan 138 kV bus voltage about 100%, adjusting the Pulupandan transformer taps, and making the Pulupandan 69 kV bus voltage about 100%, it will be possible for the voltages of 69 kV substations to be maintained within ±5%.

iii) Panay Power System

(a) Peak Hours in 1985 and 1990

For peak hours in 1985, if voltage regulation is done with the Dingle diesel generator so that the Dingle 138 kV bus will be 97 to 105%, it will be possible to maintain the voltages of 69 kV substations within ±5%.

During peak hours in 1990, it will be necessary for voltage regulation to be done at Panay Thermal Power Plant to hold the Panitan Substation 138 kV bus voltage at about 100 to 103% in order to maintain the voltage at Calinog Substation.

(b) Off-peak Hours in 1985 and 1990

For off-peak hours in 1985, if it were to be possible to maintain voltage at Pulupandan Substation on Negros at about 100%, there will be no problem of voltage regulation even if all generators on Panay Island were to be shut down.

During off-peak hours in 1990, if adjustments were to be made at Panay Thermal Power Plant so that the 138 kV bus voltage at Panitan will be about 101 to 103 %, it will be possible to maintain the voltages of 69 kV substations within ±5 %.

[Leyte-Samar Power System]

(1) Power Flow

The results of power flow calculations are as shown in Figs. 7-12 and 7-13, and the power flow of the principal trunk line (Tongonan Geothermal Power Plant - Wright Substation) will be about 5 to 10 MW. In 1990, there will be no facility — transmission line, transformer — in the entire system which would become overloaded.

The continuous transmission capacities of the 1-cct transmission line were based on the following values:

138 kV	336.4 MCM, ACSR	106.2 MVA
69 kV	336.4 MCM, ACSR	56.8 MVA

(2) Voltage Regulation

The section between Wright and Quinapundan comprising a part of the Leyte-Samar Power System will be a 69 kV transmission line of approximately 240 km, while the 69 kV transmission line from Tongonan to Maasin will be approximately 210 km to constitute a long-distance transmission line, and voltage drop will be increased. In operation of the power system for this purpose, it is thought the voltage regulation measures described below will be necessary.

i) Peak Hours in 1990

During peak hours, by adjusting transformer taps at Wright Substation to be 131 kV/69 kV, and the 138 kV bus voltage at Tongonan Substation to be between 104 to 105 % through adjustments at Tongonan Geothermal Power Plant, it will be possible to maintain the voltages of 69 kV substations within ±5 %.

ii) Off-peak Hours in 1990

During off-peak hours, because the loads will be lighter than during peak hours, and because of Ferranti effects, the voltages of 69 kV substations on Samar Island will be on the high side. Because of the above situation, the transformer taps of Wright Substation are to be 142 kV/69 kV during off-peak hours, and if the Tongonan 138 kV bus voltage is adjusted to about 100 %, it will be possible to maintain all 69 kV substations at voltages within ±5 %.

7.3 Stability Study

7.3.1 System Disturbance Conditions

(1) Panay-Negros-Cebu Power System

In the Panay-Negros-Cebu Power System, since Pulupandan - Kabangkalan, Kabangkalan - Sipalay, Kabangkalan - Amlan, and Naga - Banilad are 2 cct sections, assuming 1 cct, 3 phase, short-circuit faults of these sections with the faults cleared after 5 cycles from occurrence, and on calculations of 2 second transient stability, it was judged that stable operation would be possible if all power generators do not step out.

Since the stretch between Amlan and Naga is single circuit, assuming a single phase-to-ground fault in this section, calculations were made of transient stability. As for the reclosing system, single phase reclosing was adopted, with the duration of no voltage 25 cycles.

In order to confirm the stability under a normal state, a small external disturbance was applied to the generator of Naga Thermal and steady-state stability calculations were made, and it was judged that steady operation would be possible if the phase-angle difference disturbance of the generator is not monotonous divergence or oscillating divergence.

(2) Leyte-Samar Power System

Regarding the Leyte-Samar Power System, since in 1985 only Tongonan Geothermal Power Plant will be in operation, while in 1990 Catubig Hydroelectric Power Plant will be in operation in addition to Tongonan Geothermal, only 1990 will be of concern stability-wise.

For this power system in 1990, a 3 phase, short-circuit fault at a point extremely close to the Tongonan Geothermal Power Plant was assumed, with the fault cleared after 5 cycles, and the transient stability at 2 seconds after occurrence of the fault was calculated and it was judged that stable operation would be possible if all of the generators do not step out.

7.3.2 Results of Stability Calculations

(1) Panay-Negros-Cebu Power System

The results of stability calculations are indicated in Table 7-2 with swing curves shown in Appendix Fig. A-3-(1) through Fig. A-3-(14).

According to the above, the system is stable in both 1985 and 1990, and steady operation will be possible. To further study the strength of the power system with respect to stability, transient stability and steady-state stability calculations were made for a case of heavy power flow in a main trunk line assuming addition of a 100 MW generating station at Bago Substation as an increment to the power flow at peak hours in 1990 with 100 MW received at Naga Substation, and both were found to be stable. The swing curves are shown in Appendix Fig. A-3-(3) and Fig. A-3-(14).

Table 7-4 Result of Transient Stability

Item / Year	Fault line or generator	Kind of fault	Fault clearing time (sec)	Judgment
1985 Peak	Pulupamdan-Kaban-gkalan S/S	3LG-O	0.08	Stable
"	Kabangkalan - Sipalay S/S	3LG-O	0.08	"
"	Kabangkalan - Amlan S/S	3LG-O	0.08	"
"	Naga-Bamilad S/S	3LG-O	0.08	"
"	Naga (T) Generator	$\Delta\theta G$	—	" *
1990 Peak	Pulupandan-Kaban gkalan S/S	3LG-O	0.08	"
"	Kabangkalan -Amlan S/S	3LG-O	0.08	"
"	Naga-Banilad S/S	3LG-O	0.08	"
"	Naga (T) Generator	$\Delta\theta G$	—	" *
"	Amlan - Naga P/P	1LG-O-C	0.08-0.42	"

Note *1: Inherent steady state stability

(2) Leyte-Samar Power System

The results are shown in Table 7-5. The swing curve is shown in Appendix Fig. A-3-(14).

Table 7-5 Result of Transient Stability

Year		Kind of Fault	Fault clearing time (sec)	Judgment
1990 Peak	Tongonan -Pasar S/S	3LG-O	0.08	Stable

Although steady-state stability calculations were not made, it is surmised from Appendix Fig. A-3-(9) that since the phase angle difference of the Tongonan generator terminal and the Catubig generator terminal is 22 deg and smaller than the generator terminal phase angle difference at 1990 peak hours of the Panay-Negros-Cebu Power System, stable operation will be possible.

7.4 Short Circuit Study

7.4.1 Preconditions

The three-phase short-circuit capacities at peak hours in 1990 are shown in Table 7-6. Further, the calculations were made using Xd'' as generator reactance, with all generators stepped in.

7.4.2 Results of Short-Circuit Capacity Calculations

As a result of the study, the short-circuit capacity at the 138 kV side bus of a 138 kV substation will be approximately 6 kA (1,500 MVA), while that at the 69 kV side bus of a 69 kV substation will be not more than 5 kA (600 MVA). Therefore, there will be ample allowance if the following are used as circuit breaker capacities:

138 kV CB : 3,140 MVA (IEC Standard: 145 kV, 12.5 kA)
69 kV CB : 1,600 MVA (IEC Standard: 72 kV, 12.5 kA)

Table 7-6 Fault Current in 1990

(1) Panay-Negros-Cebu Grid

Fault Position		3øS (kA)	1øG (kA)
Banilad	138 kV bus	3.6	3.9
VECO	138 kV bus	3.3	3.7
Naga	138 kV bus	4.8	5.6
Naga	69 kV bus	3.8	4.7
Talavera	138 kV bus	3.3	3.6
Amlan	138 kV bus	4.4	4.0
Amlan	69 kV bus	2.8	3.5
Kabangkalan	138 kV bus	4.5	4.0
Sipalay	138 kV bus	3.4	3.8
Pulupandan	138 kV bus	5.0	4.9
Bago	138 kV bus	4.9	5.2
Sta. Barbara	138 kV bus	2.8	2.8
Dingle	138 kV bus	2.5	2.8
Panitan	138 kV bus	2.1	1.9

(2) Leyte-Samar Grid

Substation		3øS (kA)
Wright	138 kV bus	1.2
Tongonan	138 kV bus	3.4
Isabel	138 kV bus	2.5

7.5 Summary and Suggestions

7.5.1 Panay-Negros-Cebu Power System

(1) There is no transmission line or transformer which will be overloaded by power flows in either 1985 or 1990. Neither will there be any problem of steady-state or transient stability.

(2) The section between Amlan and Naga will be 138 kV, 1 cct, but since it was shown there would be ample stability with a single-phase reclosing system, it will be possible to adopt a single-circuit transmission line from the standpoint of supply reliability.

(3) Regarding the aspect of voltage regulation, it will be necessary to maintain voltage by installing on-load voltage regulators or static power condensers at principal 69 kV loaded substations.

(4) Breaking capacities of about 3,140 MVA should be adopted for 138 kV and about 1,600 MVA for 69 kV.

7.5.2 Leyte-Samar Power System

(1) Although only the power system in 1990 was the object of study, there will be no problem with respect to both power flow and stability.

(2) Regarding the aspect of voltage regulation, it will be possible for voltage regulation to be done in 1990 if the transformers at Wright Substation and Tongonan Power Plant are equipped with on-load tap-changing devices.

(3) Breaking capacities of the same specifications as for the Panay-Negros-Cebu Power System should be adopted.

Fig. 7-6 Inter Island Power System (Panay-Negros and Cebu) in 1985 and 1990

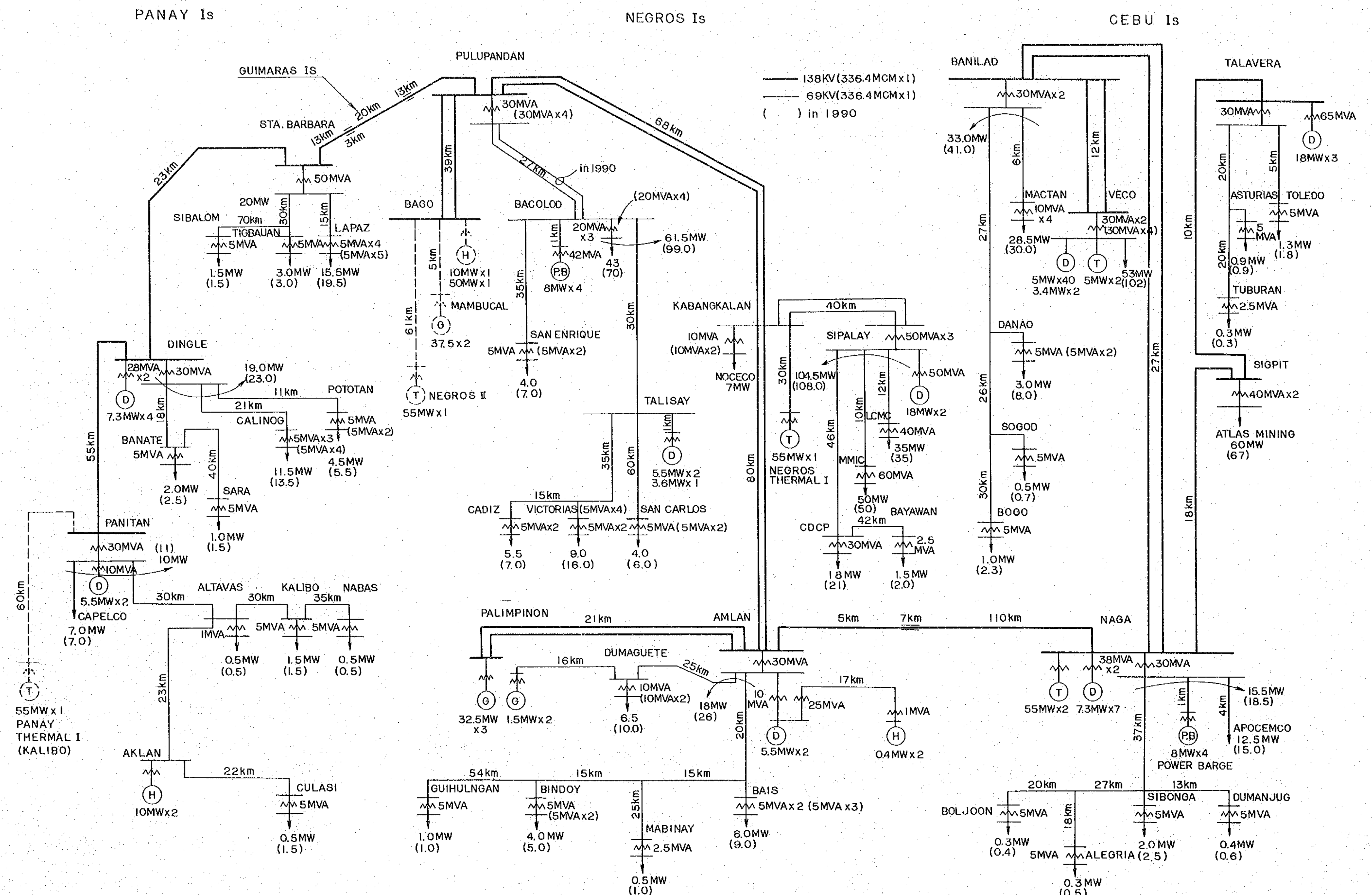


Fig. 7-7 Inter Island Power System (Leyte and Samar) in 1990

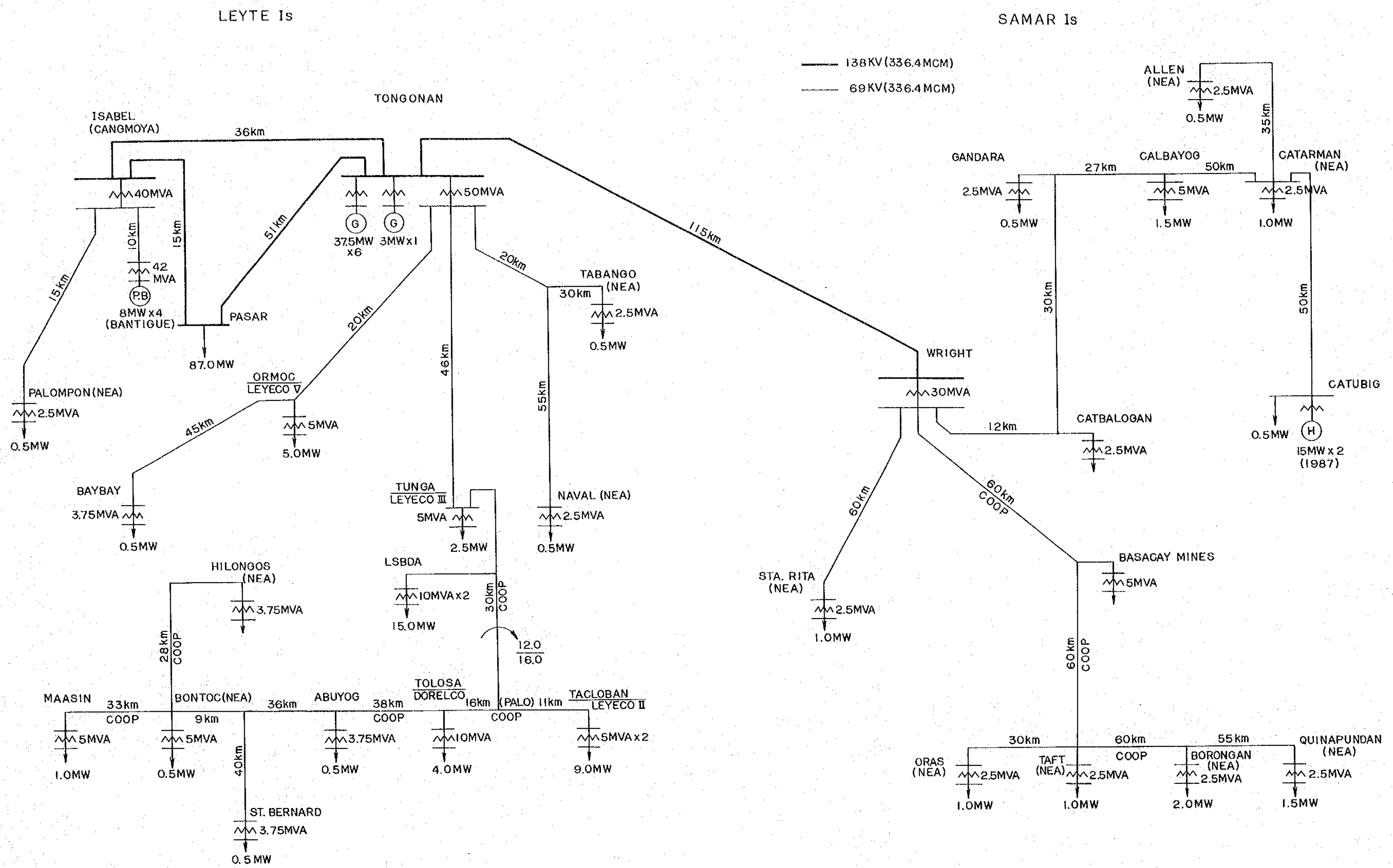


Fig. 7-8 Power Flow and Voltage Regulation at Peak Time in 1985
(Panay - Negros - Cebu Grid)

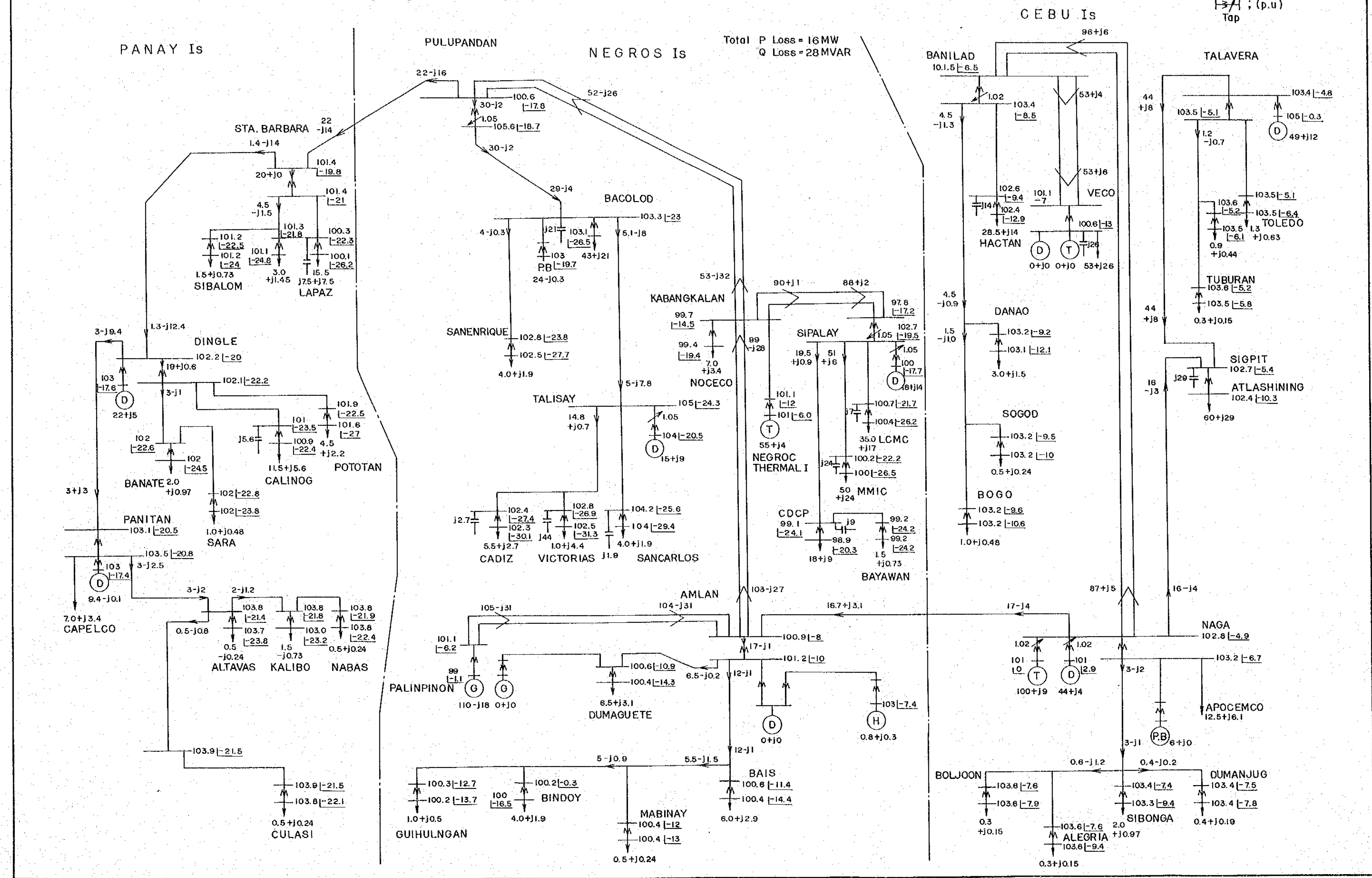
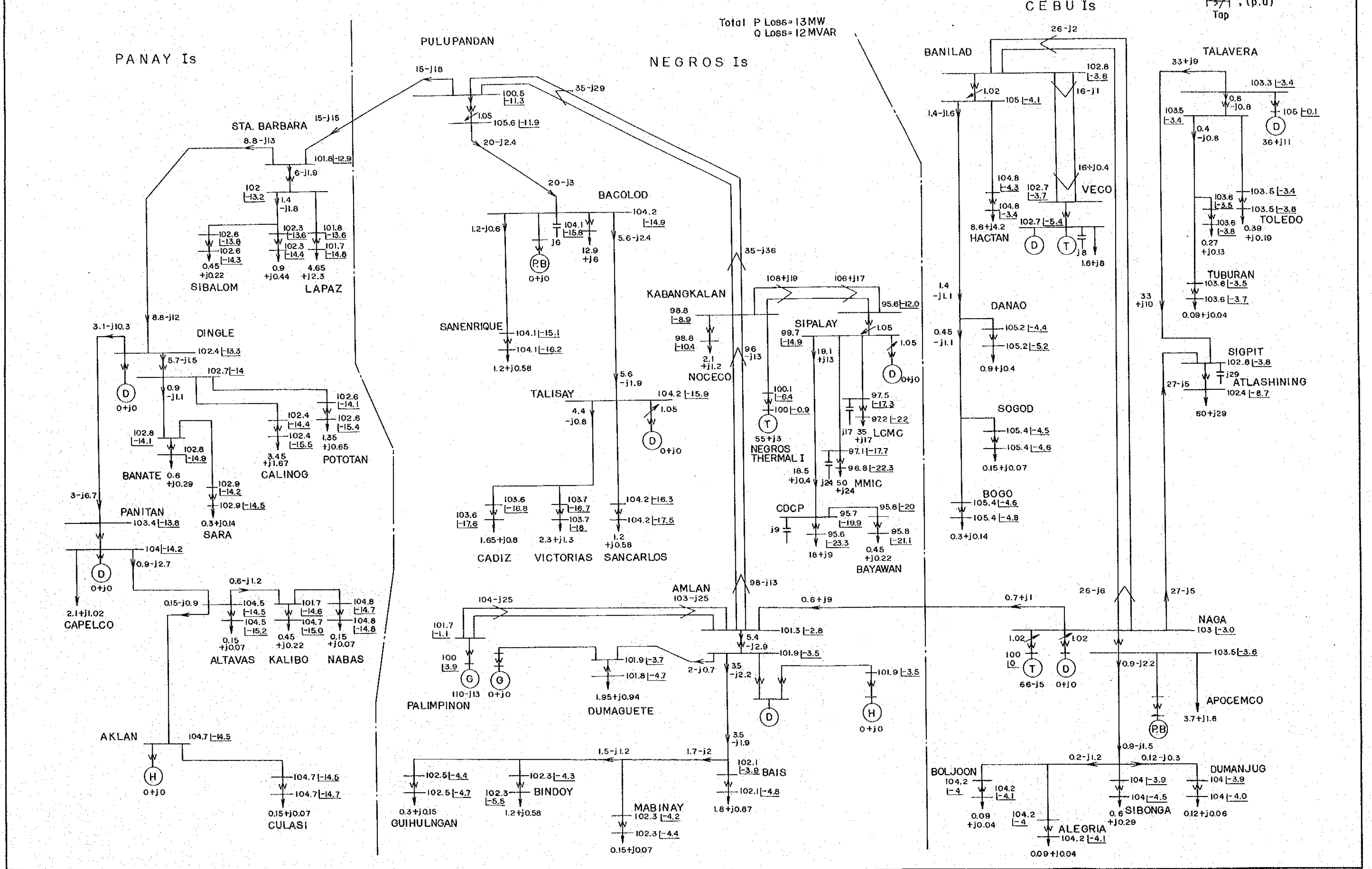


Fig. 7-9 Power Flow and Voltage Regulation at Off Peak Time in 1985
(Panay - Negros - Cebu Grid)



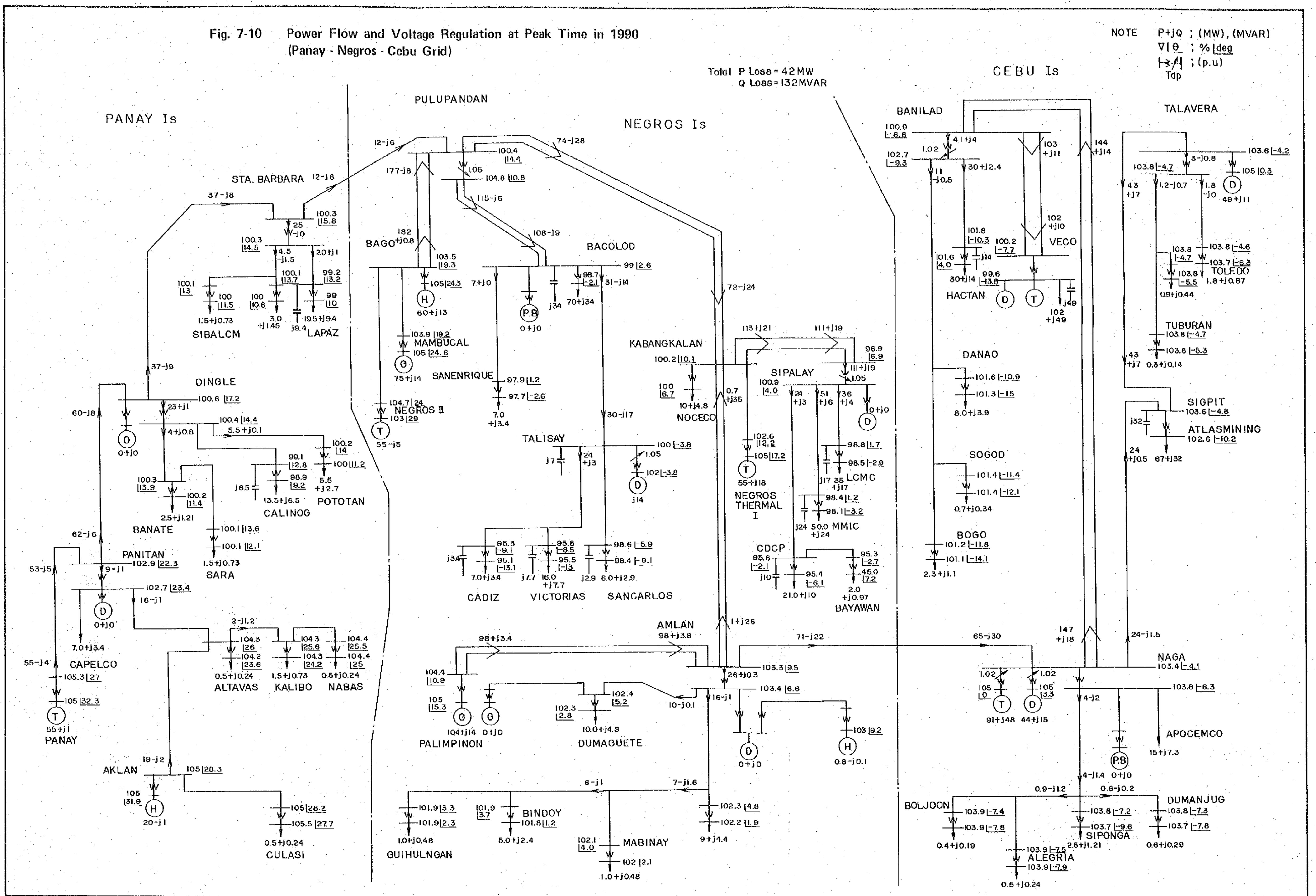


Fig. 7-10 Power Flow and Voltage Regulation at Peak Time in 1990 (Panay - Negros - Cebu Grid)

Fig. 7-11 Power Flow and Voltage Regulation at Off Peak Time in 1990
(Panay - Negros - Cebu Grid)

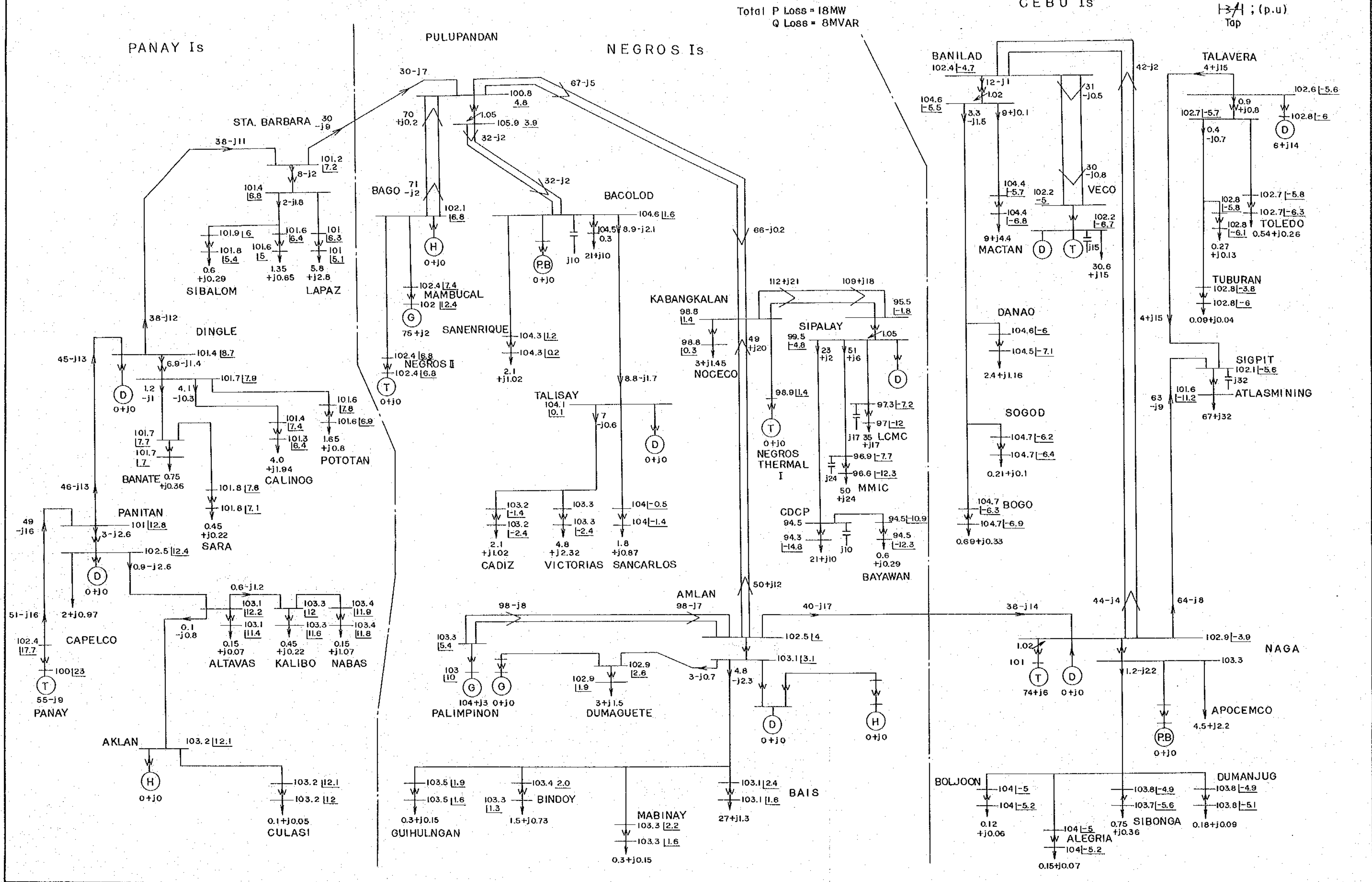


Fig. 7-12 Power Flow and Voltage Regulation at Peak Time in 1990
(Leyte - Samar Grid)

NOTE P+jQ ; (MW), (MVAR)
∇|θ ; %|deg
⊢3⊣ ; (p.u)
Tap

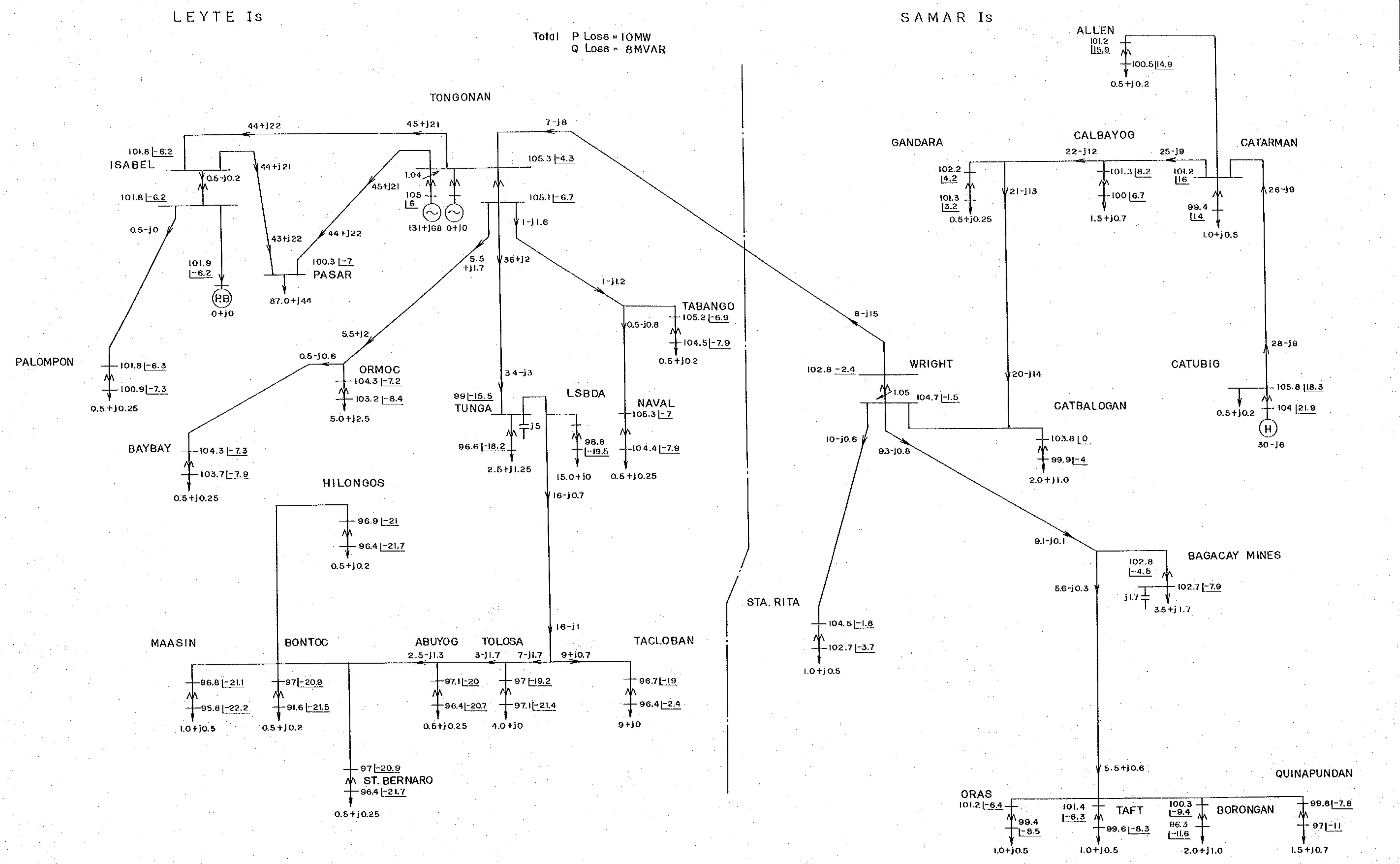


Fig. 7-13 Power Flow and Voltage Regulation at Off Peak Time in 1990
(Leyte - Samar Grid)

NOTE P+jQ ; (MW), (MVAR)
V|θ ; % |deg
Tap ; (p.u)