(3) Classification of Reliability Level in Supply Areas

In Japan, no uniform reliability standard (failure recovery time) is applied to the whole supply areas, but the supply areas are classified to 3 levels or so (for example, urban centers, urban peripheries, and suburban areas) according to the importance of loads, geographical conditions, etc., and this classification is reflected in the power facility planning.

In establishing the reliability level of the Project Area, it is not recommendable to set up a single standard for the whole area, because the geographical conditions and the importance of loads are different from Centro district and San Lorenzo district. Therefore, it is recommended to classify the whole area into two zones of different ranks, as illustrated in Figure 8-6, to assign separate failure recovery time to each zone, and have them reflected in future power facility planning.

Although the values of failure recovery time shall be determined after the current conditions are carefully studied by ANDE, the target values, as deduced from the Japanese current practice would be around 90 minutes in Area-A and 150 minutes in Area-B.

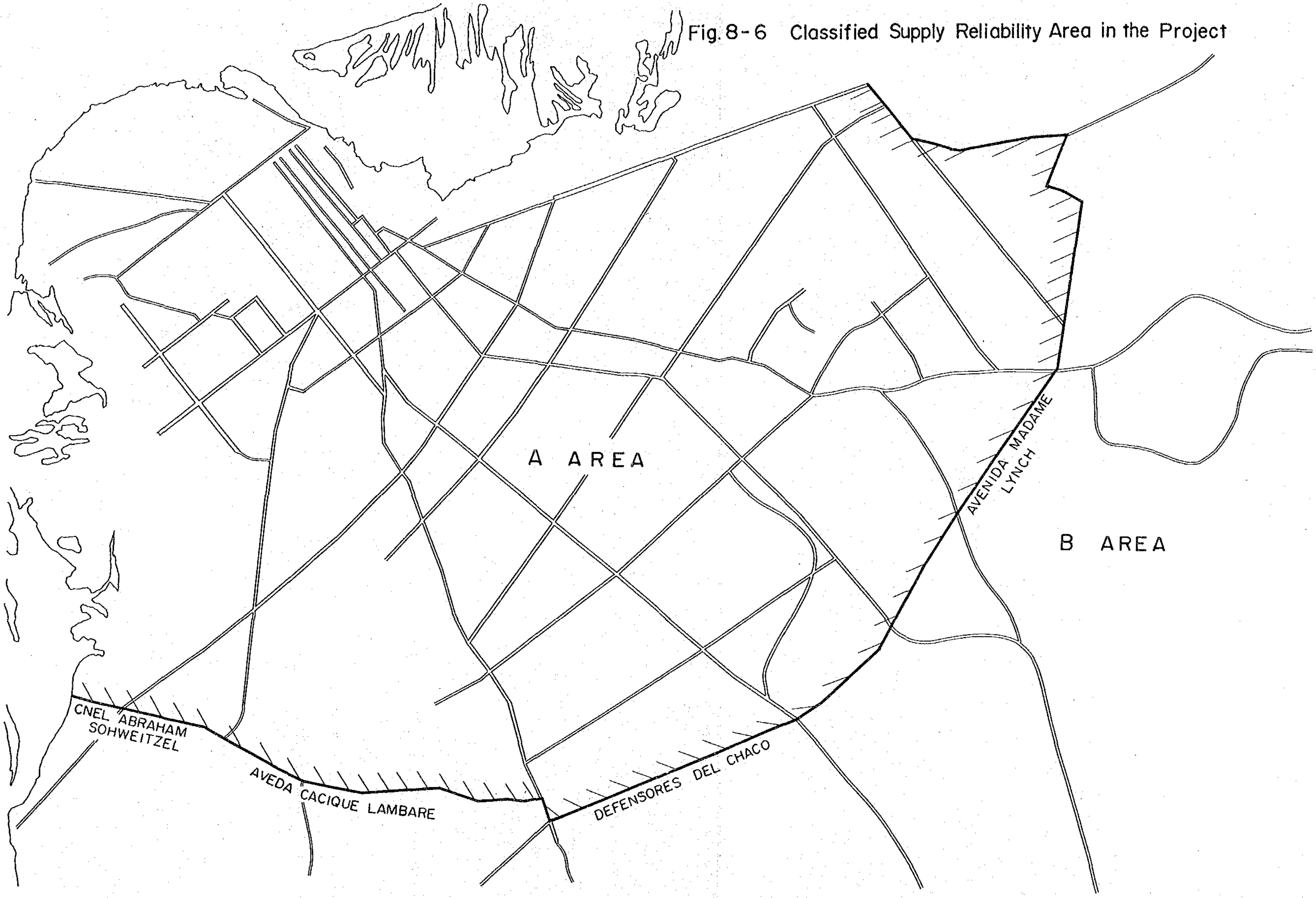
8.8 Distribution System Reliability Evaluation

The effect of reliability improvement measures such as introduction of automatic sectionalizing switches and computerization of the Distribution Dispatch Center, which are recommended in Chapter 8 and Chapter 9, have been evaluated by analyses for the distribution systems of 2000 when the Project is completed, for the two cases, on with reliability enhancement measures and another without these measures.

The analyses indicated the following benefits.

(1) Both the area affected by power supply failure, and the outage time of unfaulted section can be substantially reduced. These two effects bring about increase in energy sales revenue.

Fig. 8-6 Classified Supply Reliability Area in the Project



Considering the power demand growth in future, and the ensuing larger social effect of power supply failure, the benefit resulting from reduction of supply failure consists of various advantages that can not be evaluated only by the reduction of energy sales revenue. Therefore, we can assume that the actual benefit brought about should be even larger when we take into account such intagible advantages.

(2) The reduction of the area affected by the power failure will bring about reduction in working hours maintenance workers.

In addition, the quick identification of faulted section will have the effect of reducing the number of works required for restoration of power supply. Concerning these contributions, only the elements which can be quantified has been calculated. However, there are elements that can not be quantified, such as:

(a) Improved efficiency in normal distribution system operation.

(b) Reduction of the extent of distribution lines to be shut down for maintenance.

Therefore, the reliability enhancement measures proposed by JICA Study Team will have favorable effect in a large variety of aspects.

CHAPTER 9

SUPERVISORY AND CONTROL SYSTEM OF DISTRIBUTION CONTROL CENTER

CHAPTER 9 SUPERVISORY AND CONTROL SYSTEM OF DISTRIBUTION CONTROL CENTER

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List of Table and Figures

CHAPTER 9 SUPERVISORY AND CONTROL SYSTEM OF DISTRIBUTION CONTROL CENTER

9.1 Current Status of Dispatching and Control Systems

ANDE has the Central Load Dispatching Center under its Engineering Department, and the power generation, transmission and substation facilities all over the nation is controlled by this Central Load Dispatching Center. In the Metropolitan Area, the Distribution Dispatching Center is operated by ANDE under the Business Department to deal with monitoring, operation and maintenance works of distribution systems of 23 kV and lower voltage classes.

ANDE plans to move this Distribution Dispatching Center within a few years to a site at Boggiani which is currently used for its warehouse.

On of the tasks of JICA Study Team is to develop a conceptual design of the Supervisory Control and Data Aquisition system (SCADA System) which will be used in the new Distribution Control Center for enhancement of supply reliability of the distribution networks in the Project Area.

9.1.1 Central Load Dispatching Center

The Central Load Dispatching Center is located in a building which is adjacent to ANDE's headquarters, and the Center is in charge of the operation of power generation, transmission and substation facilities all over the nation.

This Center is equipped with a mimic power system board on which the transmission system from Itaipu and Acaray Power Plants, 220 kV transmission lines and 220 kV substations are represented, and the load dispatching control desks. The Center is operated by 3-shift, 2-men operators.

The Central Load Dispatching Center and each power facility are linked by UHF radio communication systems. The status of operation of each facility is directly reported to the Central Load Dispatching Center via UHF radio, and the shift operator manually operates the meters (indicating generator output, transmission line power flow, substation bus voltage, etc.) and circuit breaker positions to display the system status, and conducts monitoring and operation.

ANDE plans to renew this system with a monitoring and control system employing computer, and currently conducting a test operation on a test facility supplied by BBC.

This test facility consists of 1 CPU (64 kB main memory), auxiliary memory (2.5 MB), 2 CRTs, 2 typewriters and 1 operator's console. The functions of this system include monitoring of power facility status and remote operation of 220 kV circuit breakers, and the information required for this operation, such as circuit breaker positions, power generations at Acaray and Itaipu Power Plants, 220 kV transmission line power flow and 220 kV substation bus voltage, are transmitted from each station via power line carrier systems and UHF channels.

There are 24 UHF channels, and 3 of them will be allotted to SCADA System.

As this test facility has been operated with good performance, ANDE is contemplating to introduce a full scale SCADA System, equipped with a computer system, into its Central Load Dispatching Center in future. Therefore, the supervision and control system for the new Central Distribution Control Center to be studied here must be a system which is compatible to this SCADA system.

9.1.2 Distribution Dispatching Center

The Distribution Dispatching Center under the Business Department is located at Dr. Francia district near Centro, which is approximately 4 km away from ANDE's headquarters. The monitoring, operation, and recovery works of distribution systems having 23 kV or lower voltage in the Metropolitan Area, including the Project Area, are dispatched by this Center. The Distribution Dispatching Center is operated by 3-shift, 3-men crews, and patrol cars are assigned to this Center all the time and they are manned by 3-shift crews. When the new

Distribution Control Center is completed, it will become a larger organization staffed by 137 personnels. This new organization (Departamento Operacion de Redes Distribucion, to be termed D.O.R.D.) is illustrated in Fig. 9-1.

The Distribution Control Room is with mimic board representing the 23 kV distribution systems, command desks and a map indicating the city. The customer complaint dealing center, having 12 telephone sets, is provided adjacent to the above facilities, and 2 to 3 men answers these telephone sets under normal conditions. As troubles frequently occur on rainy days, the situation is such that that personnels keep answering all of these telephone sets all the time.

It was reported that the number of complaints placed by the telephone is 120 to 130 per day according to the 1988 record, and it is decreasing in recent years. When faults that must be dealt with by the distribution sector occurs, the fault locations are surmised based on reports send from the Central Load Dispatching Center, or in case of low voltage line failures, based on the complaint from customers. This information is supplied to the patrol vehicles or maintenance vehicles by VHF radio to deal with failures.

9.2 Basic Conditions

In enhancing the reliability of distribution systems, the most important factors are the reduction of failure through strengthening of facilities and the quick recovery from failure.

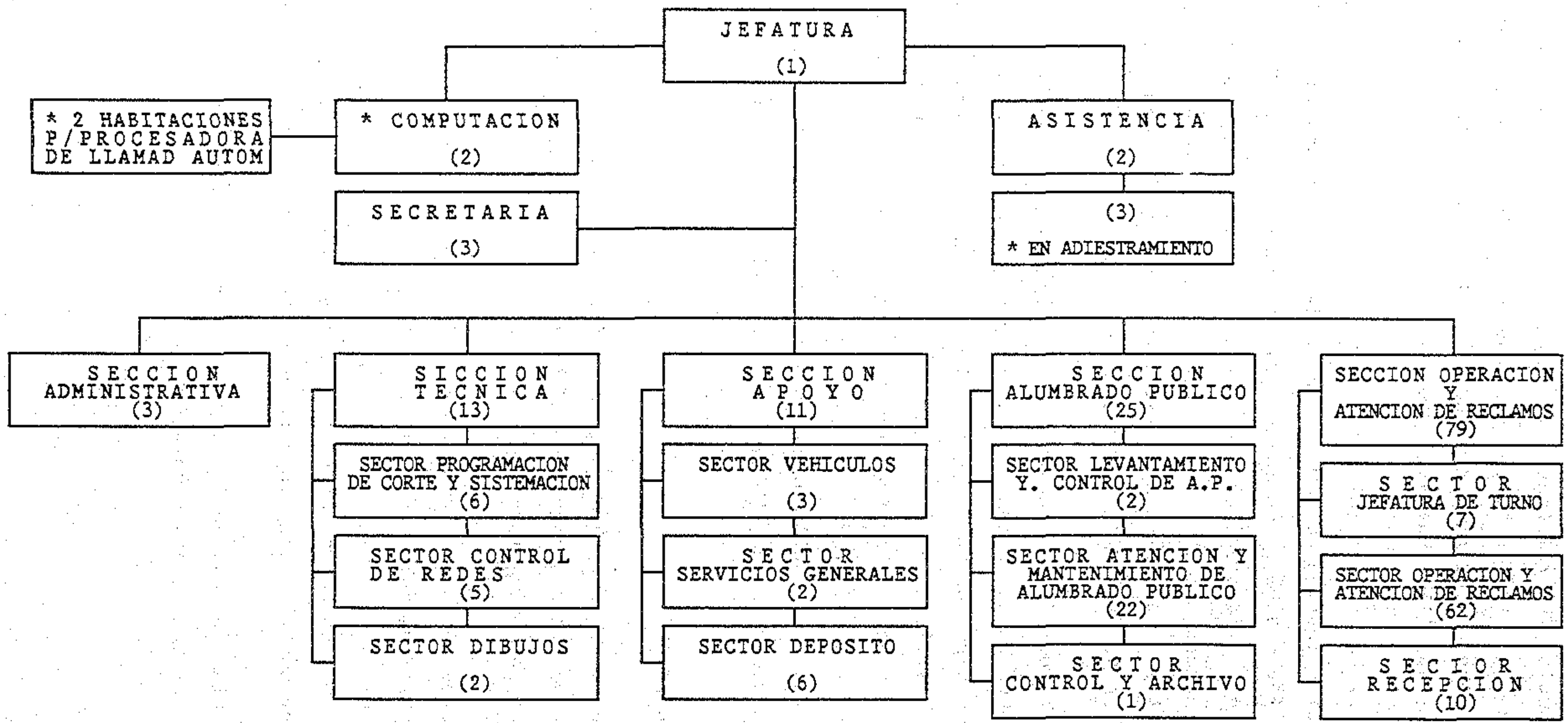
The measures for strengthening of facilities are discussed in Chapter 8. In realizing quick recovery from supply failure, a new supervision and control system, by which the current problems are overcome, and at the same time which is compatible to the SCADA System to be installed in the new Central Load Dispatching Center, must be introduced.

In developing the conceptual design of this system, the following factors must be taken into consideration.

Fig.9-1 Organization of New Distribution Control Center

DPTO. OPER. DE REDES DE DISTRIB

ORGANIGRAMA



TURNOS : SECCION OPERACION
06:00 a 14:00hs —— 28 personas(14vehiculos)
14:00 a 22:00hs —— 28 personas(14vehiculos)
22:00 a 06:00hs —— 6 personas(3vehiculos)

SECCION ALUMBRADO PUBLICO
07:00 a 15:00hs —— 11 personas(5vehiculos)
15:00 a 23:00hs —— 11 personas(5vehiculos)

OBSERVACIONES

Total de personal = 137
Total de vehiculos = 5 camiones
21 camiones

* Futuro crecimiento

(1) Quick Identification of Failure Information

At present, a report of failure on medium (23 kV) voltage class distribution systems is first transmitted from the distribution substation involved to the Central Load Dispatching Center, and then transmitted from the Central Load Dispatching Center to the Distribution Dispatching Center via UHF radio.

It is reported that the time required for a report to reach Distribution Dispatching Center from a distribution substation via Central Load Dispatching Center is approximately 15 minutes. This does not include the time required for an operator to confirm the nature of failure, and considering this, the time required for identification of a failure by a Distribution Dispatching Center operator may be longer, and this delays the time required for the Distribution Dispatching Center to deal with recovery of a failure.

It is necessary that the new Distribution Control Center can identify the failures which must be dealt with the Center, such as faults on 23 kV feeders, as soon as they occur.

(2) Constant Monitoring of Distribution Lines

It is required to constantly monitor the operation of distribution lines to promptly and accurately deal with the failures and line operations.

(3) The new supervision and control system for the Distribution Control Center must be such that it is compatible to the SCADA system to be introduced to the Central Load Dispatching Center and it can contribute to the overall reliability enhancement of the whole power system.

(4) The new system must be equipped with the function of processing and editing various data with appropriate software, so that the data base which can be used by the human operators can be developed and at the same time the statistics which are needed for automatic operation of substations and future distribution system planning can be developed.

9.3 Supervisory Control System of New Distribution Control Center

The conceptual design of this system shall be based on the following guidelines.

(1) Various information on operation and failure status on the secondary side of distribution substation transformers will be incorporated into the new system as much as possible so that quick and accurate recovery action on failures can be developed.

(2) The system will be equipped with the function of processing and editing various statistical data on distribution network so that such data can be utilized in future for distribution network planning.

(3) The system will be so designed that it is linked with the computer of the Central Load Dispatching Center to exchange information and share a common data base with it.

As the details of the system which will be introduced to the Central Load Dispatching Center has not been established yet, the detailed design of this system will be developed in coordination with SCADA System. In this stage, only the hardware conceptual design has been developed.

9.3.1 System Configuration and Basic Functions

This system will have the configuration which is basically compatible to SCADA System employing computer, and will be provided with a mimic monitoring board on which the operating status (circuit breaker positions) of the whole transmission and distribution systems of the Project Area are displayed. The status of the distribution systems, which is currently displayed on a manual mimic board, will be monitored on CRTs.

The operation status and of each feeder, as well as their statistical data, will be processed and edited, and output on CRT screens in order to rationalize the current logging works. The system will be equipped with the function of controlling the 23 kV circuit breakers on the secondary side of distribution substations.

The details of this concept are described in Section 9.4.

9.3.2 Scope of Supervision, Control and Metering

(1) Scope of Monitoring

As a general rule, the on/off status of circuit breaker or other switches on the distribution system are supervised.

The status of the whole power systems in the Project Area will be supervised by the positions of circuit breakers, on the mimic monitoring board.

This function will be provided because, in implementing the remote operation of 23 kV switches as described in the paragraph of scope of control, erroneous operations can be avoided if information on the upper power systems is available. In addition, this information will help the operators to understand that the 23 kV systems they are operating are not independent systems but they are related to the upper voltage systems.

(2) Scope of Control

Similarly to the current practice, the circuit breaker operations down to the secondary side of transformers will be controlled by the Central Load Dispatching Center, and the 23 kV feeder circuit breakers and the 23 kV bus circuit breakers will be controlled by the Distribution Control Center.

(3) Scope of Metering

Based on the same concept as Paragraph (2) above, the 23 kV voltage and current (power), below the transformer secondary circuit breakers, will be measured by this system.

9.4 Conceptual Design of Supervisory and Control System

9.4.1 Supervisory Function

The operating status and circuit breaker positions of 23 kV distribution systems will be constantly supervised on the mimic monitoring board and CRTs.

(1) Mimic Monitoring Board

The circuit breaker positions of 220 kV substations (those having 23 kV feeders), 66 kV transmission lines, 66 kV substations and 23 kV feeders are displayed. (Fig. 9-2)

(2) CRT

(a) Operation Monitoring Page

The simplified diagram of each substation and 23 kV power systems will be displayed and the following items will be indicated. (Fig. 9-3)

(i) 23 kV bus voltage
(ii) 23 kV feeder current (power)
(iii) Position of automatic switches
(iv) Loads on each section of 23 kV feeder that is separated by sectionalizing switches (manual input)

(b) Feeder Switch Position Monitoring Page

This function replaces the information displayed on the current monitoring board.

Each feeder is displayed on CRT, and the position of each sectionalizing switch will be monitored. The switch positions are input through CRT by the system operators according to the information reported by site workers. This information, including the time, switch number and type of operation, will be output on typewriters.

Fig.9-2 Arrangement of Mimic Board

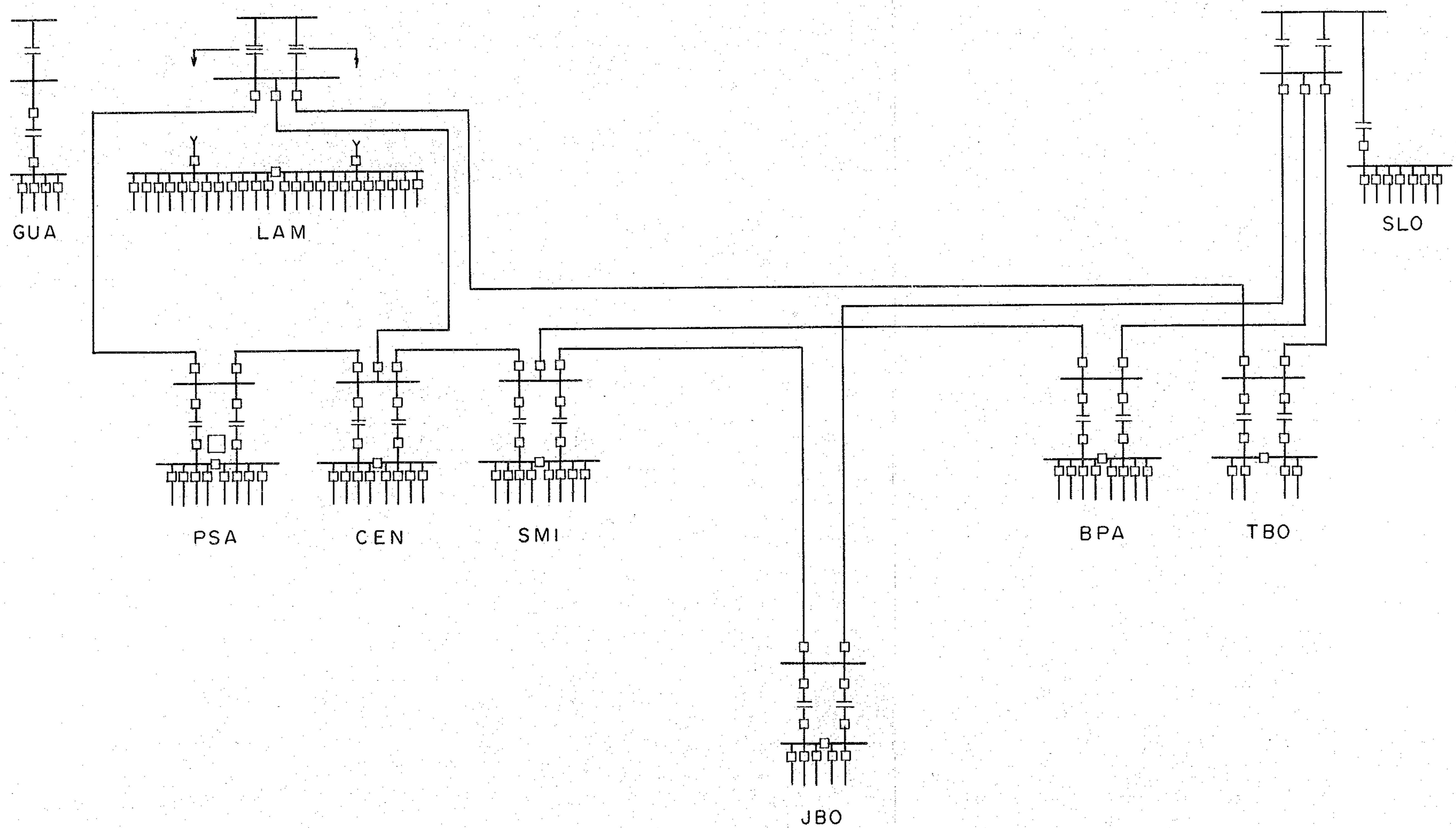
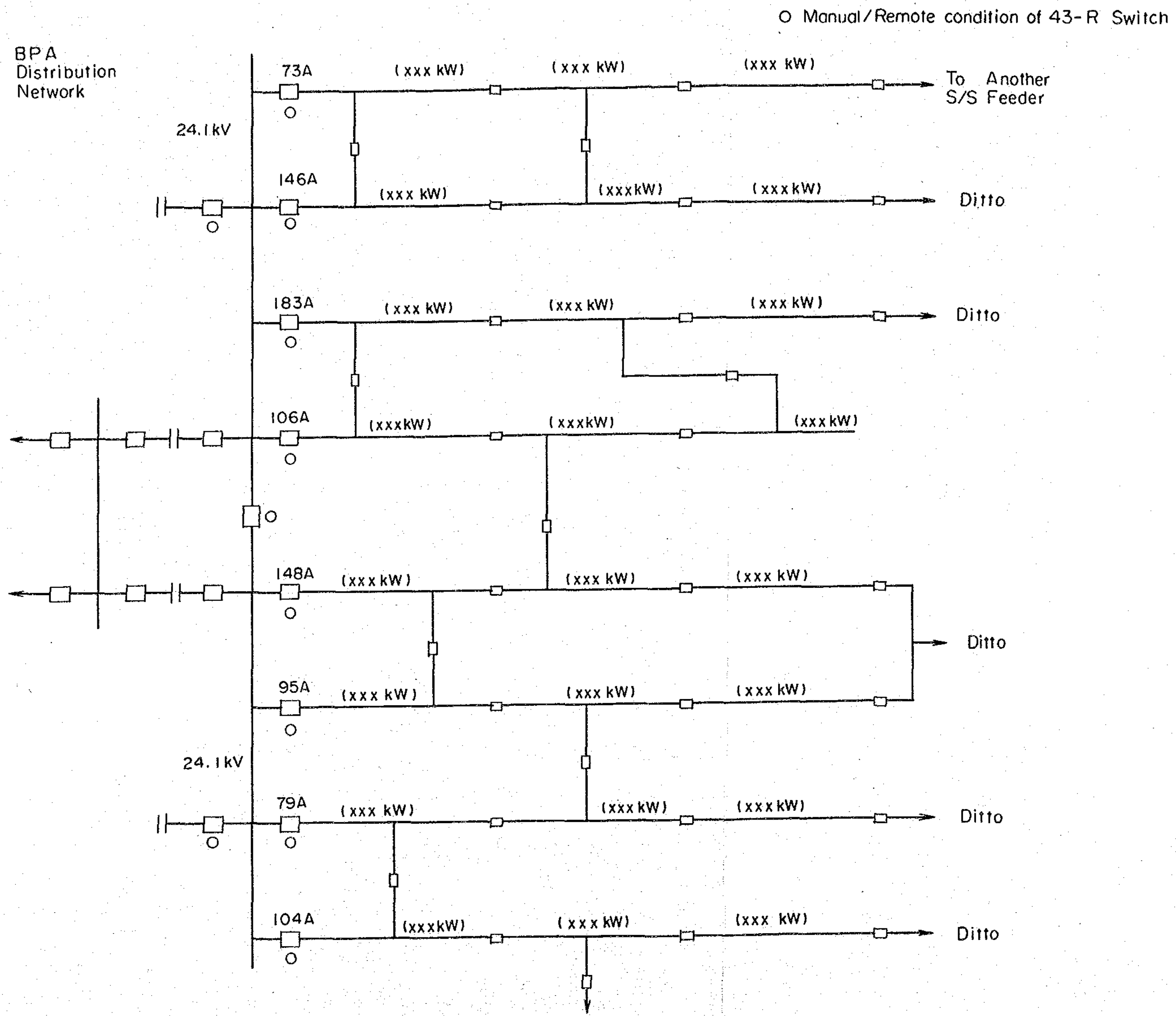


Fig. 9-3 CRT Display for Operating Condition of Distribution Lines



(3) Expandability

The configuration of distribution systems changes on daily and hourly basis, and new distribution lines are added as load increases. This system will have the function to deal with expansion and change of distribution systems. Such changes will be incorporated into the system by operators through simple operations on CRTs.

9.4.2 Control Functions

The system will be equipped with the function of remotely controlling the circuit breakers which are located on 23 kV busses and feeders below transformer secondary breakers. Each circuit breaker in substations will be equipped with the 43R switch (manual/remote). When the feeders are shut down for inspection, the related 43R switches will be turned to manual, to prevent unnecessary remote operation and facilitate work efficiency.

The circuit breakers can be remotely controlled only when 43R switch is set at "remote". The status of 43R switches will be displayed on the operation monitoring page of CRT. In actual operation, the operator will select a particular circuit breaker by pointing it with his light pen, and then execute ON/OFF operation.

When a circuit breaker is selected by an operator, that circuit breaker will be identified on the mimic monitoring board by flickering light, so that other operators can also confirm that the selection is correct.

9.4.3 Recording

The feeder operating conditions, which is currently logged by operators, will be recorded by computer operation. With this facility, the logging and editing of these records will be done in the Distribution Control Center. This will not only increase the efficiency of planning and operation of distribution networks, but also contribute to introduction of automatic operation to substations in future.

(1) Operation Records

(a) Daily Report

The hourly measurement of following data on 23 kV system of each substation will be output on typewriter at 24 hours every day.

(i) 23 kV bus voltage
(ii) Current (power) of each 23 kV feeder
(iii) Maximum current (power) of each feeder of each day

The measured values of Items i) and ii) will be displayed on CRT for each substation at every one hour. A facility to develop trend graphs of Item ii) for each feeder or substation will be added as required.

(b) Monthly Report

The following data of each substation will be output on typewriter at 24 hours on the last day of each month.

(i) Daily maximum current (power) of each feeder
(ii) Monthly maximum current (power) of each feeder

(c) Statistical Processing

As the trend of demands on each feeder is an important information in planning distribution networks, the system will be equipped with the function to display the monthly maximum current (power) of each feeder in the past two years on CRT as a trend graph.

As this information is a variable datum for the section in charge of distribution network planning in the Business Department, it is recommended to provide a facility by which this system is interlinked with the computer in ANDE's headquarters so that the data can be output at the headquarters whenever they are required.

(2) Fault Records

When the following faults occur, the system sounds buzzer and the fault messages are output on CRT screen and typewriter.

(a) Report of faults involving each substation, including substation faults (transformer fault, bus fault, etc.) and faults on connected transmission lines.

(b) All faults occurring on 23 kV systems are output on CRT and typewriter, including the time of occurrence, fault type, tripped circuit breakers.

(i) Short circuit and grounding faults on each feeder
(ii) Successful reclosing of each feeder (permanent fault)
(iii) Others (communication failure, etc.)

(c) Editing of fault records

All faults which occurred during a preceeding year are edited by each feeder.

(3) Operation Records

Each operation of 23 kV feeder and bus circuit breakers is output by message on typewriter.

(4) Status Records

Message is output on typewriter each time the status of a circuit breaker on 23 kV feeder or bus is changed.

(5) CRT Display Print

All messages displayed on CRTs are copiable through hard-copier.

9.4.4 Miscellaneous

(1) Overvoltage and Over Load Monitoring

A message is output on CRT and typewriter when feeder current or 23 kV bus voltage exceeds certain values (control values).

(2) Fault Section Identification in 23 kV Feeder Fault

With this function, the faulted section of a 23 kV feeder is identified by computer, to support the distribution system reliability improvement measures proposed in Chapter 8.

(a) Principle

The computer identifies the faulted section by analyzing the time difference in closing and tripping actions of the reclosing circuit breaker in a substation and the automatic switch on the feeder.

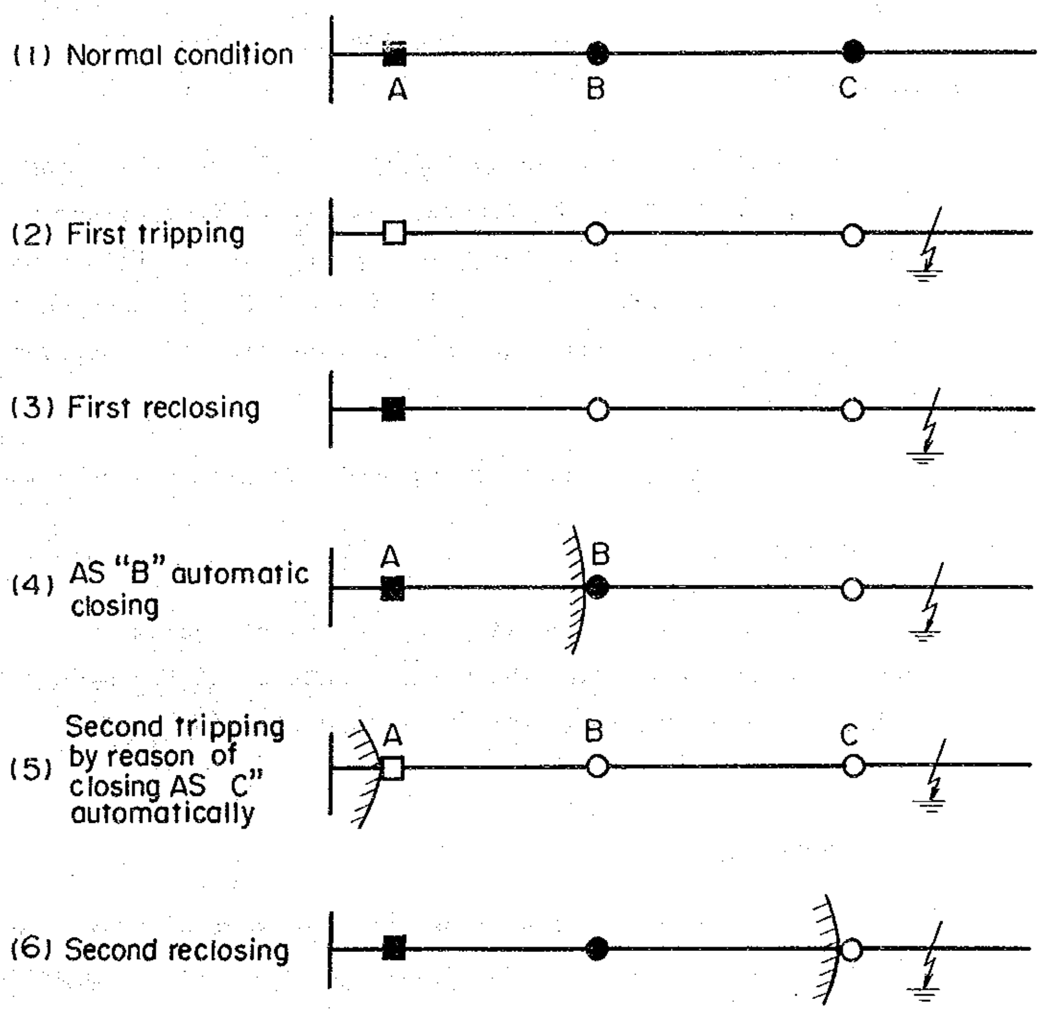
(b) Faulted Section Identification Method

In Figure 9-4, a series of operations to be performed by the 23 kV circuit breaker and automatic switch to separate the faulted section is indicated for the case that fault occurs at Section-C. In this case, the computer counts the time from the moment the 23 kV circuit breaker recloses and to the moment the automatic switch C recloses at time (2) and then the circuit breaker trips again. The computer identifies the particular automatic switch that aught to reclose at moment (2), and thereby detects the faulted section.

The result of computer identification is indicated on CRT by different color.

With this information, the maintenance vehicle can be dispatched more quickly, and it can go straight to a particular location to find the fault point on the distribution line instead of patrolling the whole line. This will reduce the time required for recovery, and substantially improve the supply reliability.

Fig. 9-4 Procedure for Detecting Faulty Section



□ CB in substation (open state)

■ CB in substation (closed state)

○ Automatic switch (open state)

● Automatic switch (closed state)

9.4.5 Hardware Configuration

The configuration of the hardware, which the JICA Study Team recommends based on consideration of the following three elements, is presented in Figure 9-5. The computer system layout is presented in Figure 9-6.

(1) Availability

As this SCADA System plays an important role in collecting data and controlling the 23 kV system, failure of this system would have a serious effect on operation of the distribution systems. Therefore, a redundant system (duplicate CPUs) is adopted so that the monitoring and control functions are not lost even if one CPU fails.

The system will be normally operated in on-line/stand-by mode.

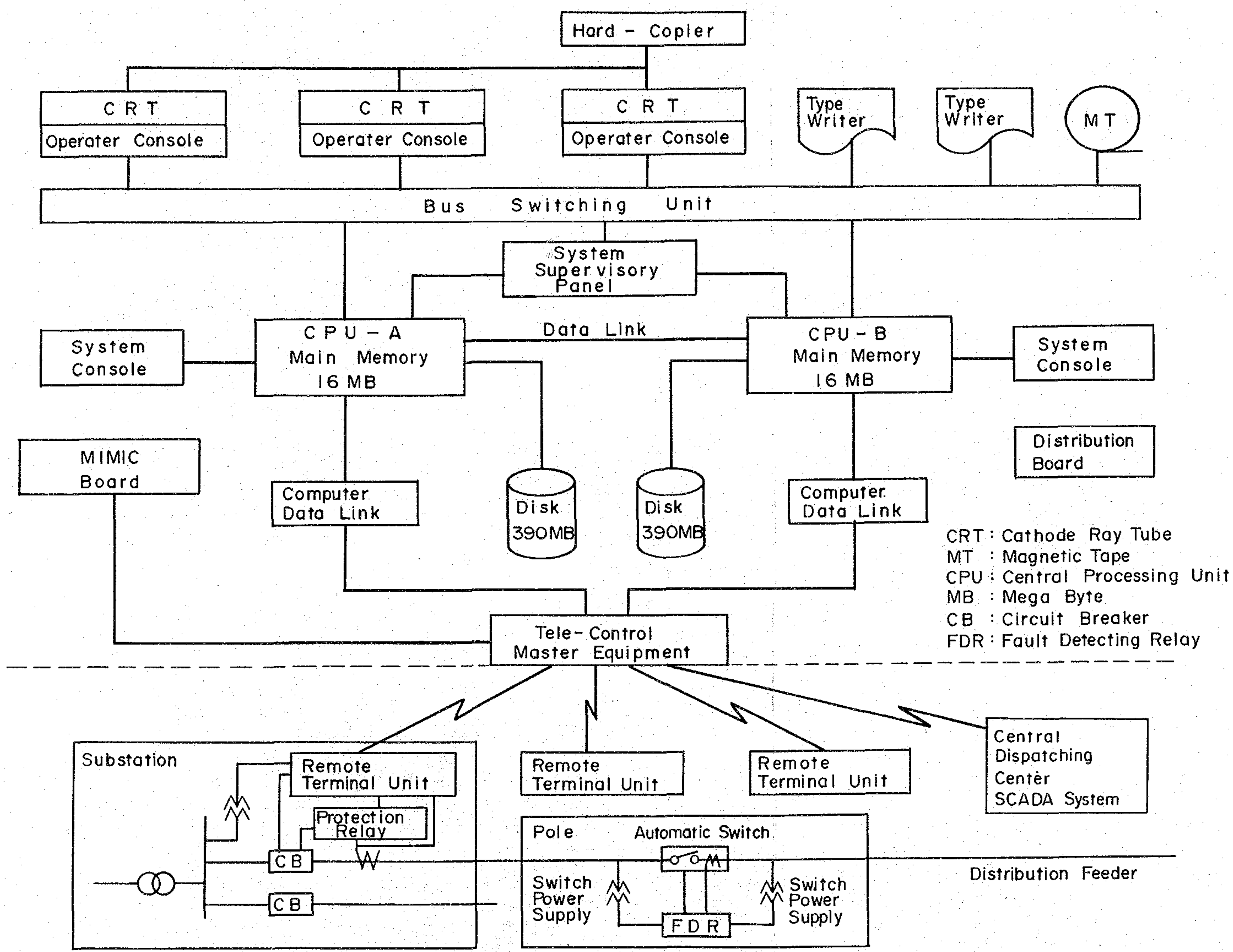
(2) Maintainability

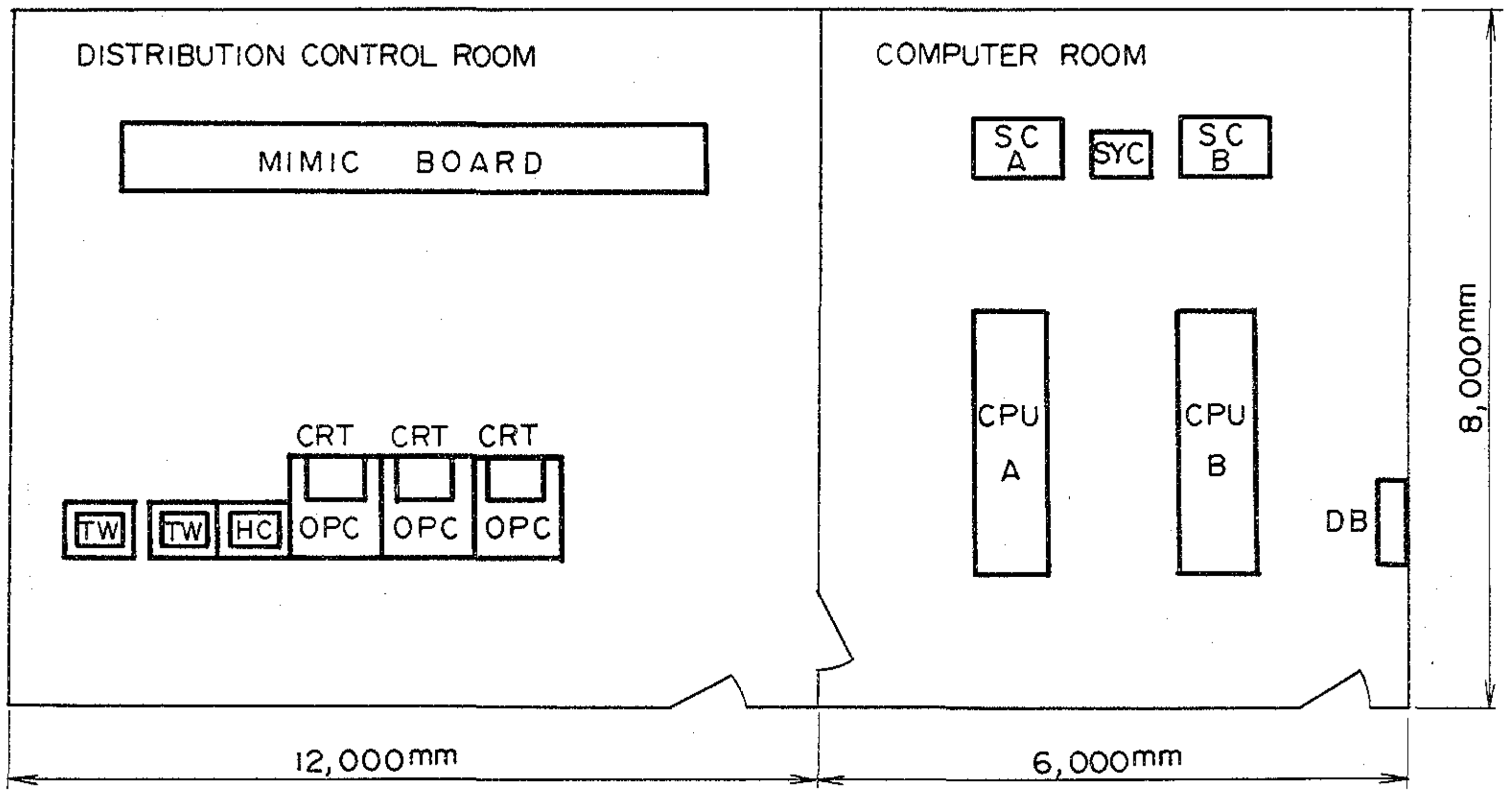
The system can be checked with one series of equipments separated and shutdown. The normal function of the system is maintained even when one series is separated for inspection or for other reasons.

(3) Expandability

The distribution systems will be expanded year after year as the power demand grows. This system has sufficient information processing capacity for the power system size which is expected in 2010 or so, and equipped with the following I/O capacity. In particular, the main and auxiliary memories will have sufficient capacity to deal with the final processing requirement from the beginning.

Fig.9-5 Configuration of Proposed SCADA System





TW : Type Writer
HC : Hard Copier
CRT : Catode Ray Tube
OPC : Operator Console
SYC : System Supervisory Panel
DB : Distribution Board
CPU : Central Processing Unit
SC : System Console

Fig. 9-6 Arrangement of Computer Equipment

(a) 23 kV feeders : 360
(b) Analogue data : 450 points
(c) Status data : 1,800 points
(d) Controls : 450 points
(e) Switches (manual control) : 3,600 points

(4) Man-Machine Interface

(a) CRT

One CRT will be provided for each operator. All CRT pages can be displayed by operation of function keys.

(b) Printer

The following 3 printers will be provided.

(i) Typewriter : 2
(ii) CRT hard copy : 1

(5) UPS (Uninterruptible Power Supply) System

The UPS system is important in assuring power supply to SCADA system.

The configuration of this system is illustrated in Figure 9-7. It is composed of two series in order to make it compatible to the computer system and keep high reliability.

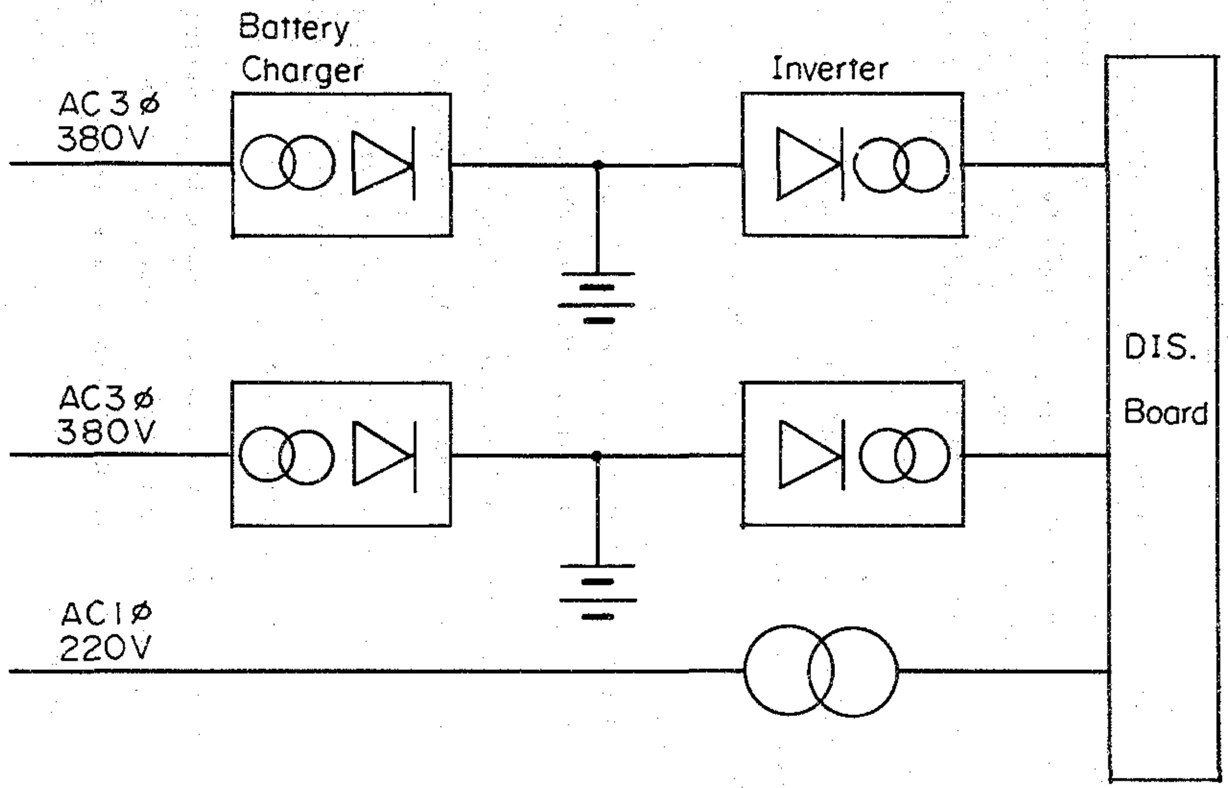
The capacity of UPS system will be around 15 kVA for each series.

9.5 Provisions to Existing Substations

It is required to provide the following facilities to the existing substations in order to collect data from these substations as described in Section 9-4.

(1) Auxiliary relay boards for remote control of 23 kV feeder circuit breakers.

Fig. 9-7 Uninterruptible Power Supply System



(2) Transducers for measurement of 23 kV voltage and feeder current.

As transducers will be powered by PT and CT circuits, it is necessary to check if the burdens of existing meters and the transducers do not exceed the PT and CT ratings.

9.6 Distribution Control Center Building

The Distribution Control Center building will be constructed with reinforced concrete structure, and the roof of the marshalling yard (Playa de Maniobras) will be supported by steel structure, as the beam span over this yard is long. As the ground of the proposed site has low bearing force, the building foundation will be supported by piles based on the soil survey.

The roof slabs of the Distribution Control Center building will be performed asphalt water proof, and provided with metal plate non-structural roof to protect the building from sunshine heat.

The windows exposed to sunshine shall be provided with movable vertical louvers or movable horizontal louvers, or other devices to evade the sunshine, as appropriate, fixed on the outside of windows.

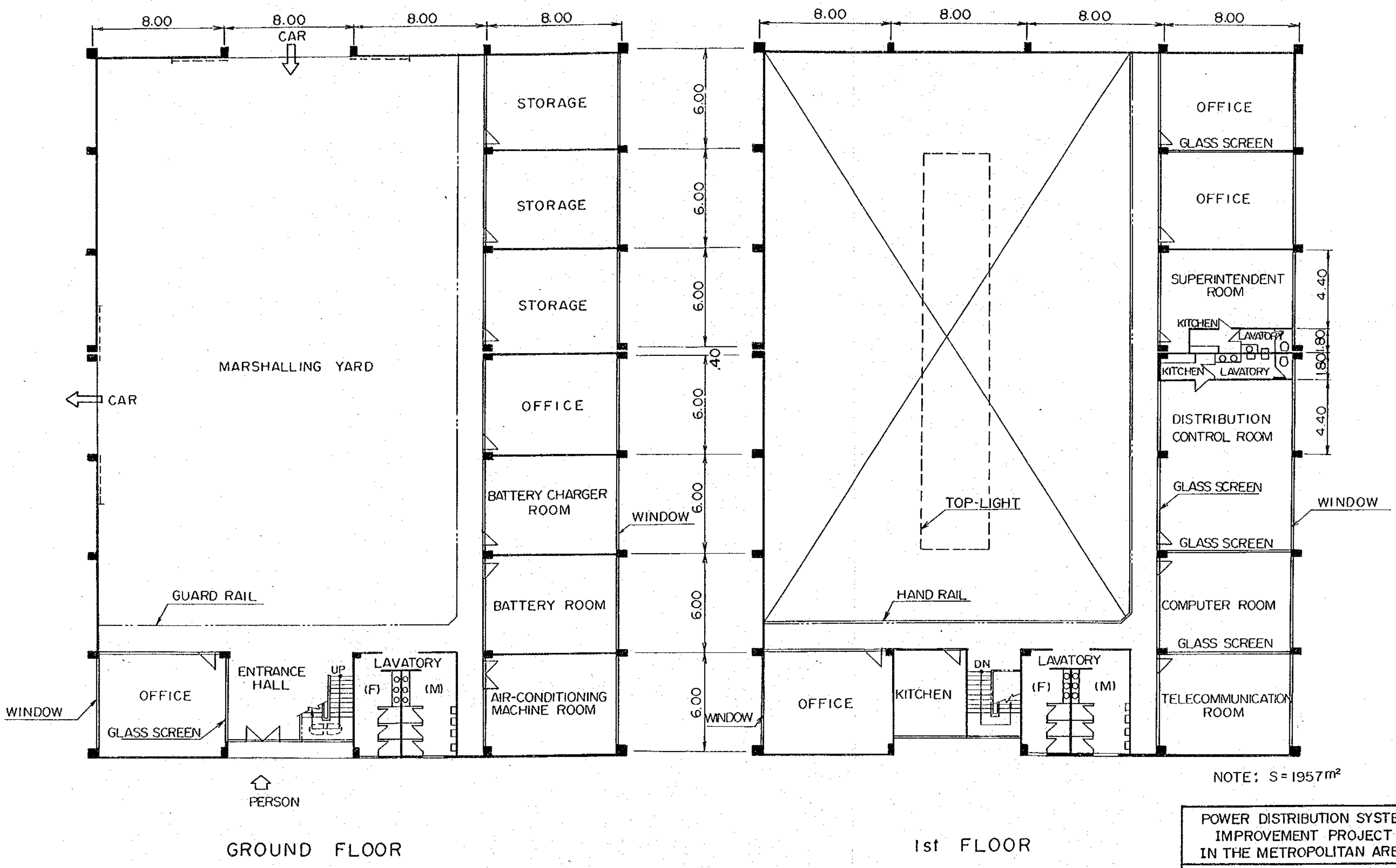
As the marshalling yard has high ceiling and wide cross distance, it is recommended to provide a top-light on a part of the roof.

The building dimensions shall be based on Fig. 9-8, and the interior layout shall be determined according to the site conditions. Main rooms shall be air-conditioned.

The equipment layout shall be determined by referring to Fig. 9-6, and the equipment technical data is shown on Table 9-1. The control room and the computer room shall have a free access floor with a separation of 300 mm height.

It is recommended for lighting system to be designed according to the illuminance standard presented in Table 7-10.

Furthermore, the building design shall be executed in accordance with the regulation for construction and the regulation for fire fighting and protection of Asuncion City.



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

DISTRIBUTION CONTROL CENTER

Fig.	9 - 8

SHEET NO.

Table 9-1 Technical Data for Design of New Distribution Dispatching Center Building

1 Heat radiation

Control room : 2,580 kcal

Computer room : 10,320 kcal

2 Weight

Control room	:	1,500 kg	Floor Design Load : 500 Kg/ m^2 (Maximum)
Computer room	:	4,000 kg	

CHAPTER 10

TELECOMMUNICATION SYSTEM PLANNING

CHAPTER 10 TELECOMMUNICATION SYSTEM PLANNING

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CHAPTER 10 TELECOMMUNICATION SYSTEM PLANNING

10.1 Current Status of Telecommunication System

The telecommunications system currently being operated by ANDE in the Project Area, covering the capital city Asuncion and its surrounding areas for load dispatching, maintenance of substation and transmission/distribution line, consists of 450 MHz UHF radio channels and 150 MHz VHF radio channels, as well as power line carrier telephone circuits used between some substations.

The communication channels used for load dispatching operations consists of 4 channels of UHF radio (3 multiplex channels and 1 simplex channel) which links the Central Load Dispatching Center to such substations as San Lorenzo, Guarambare, Barrio Parque, Puert Sajonia, Tres Bocas, Centro, Lambare, San Miguel and Jardin Botanico. These channels also connect Distribution Network Operation Center (D.O.R.D.), High Voltage Line Maintenance Department, Equipment Centrals Department, and Laboratory Department, and are used for maintenance or operation of these organizations. One of the channels (simplex) is also used as the mobile radio channel for operation of distribution substations by the above four departments. Of the four VHF radio channels, two channels are used between Technical Department and Commercial Department and another two channels are used only for Commercial Department. In general, the existing UHF and VHF radio communication systems in the Project Area are used for communication of multiple purposes such as load dispatching, maintenance of power plants and substations, and administration of the maintenance departments of the Head Office in spite of their small number of channels, and they constitute telephone circuits only, without facility of data transmission. This situation places certain limitation on efficient implementation of maintenance and operation works.

10.2 Improvement of Telecommunication Circuits

10.2.1 Basic Policy for Improvement of Telecommunication Circuits

A total of 10 distribution substations are being operated or constructed in the Project Area, where 7 more distribution substations such as A,B,E,F,G,K,L will be constructed by the year 2000. According to the Project, a distribution control center will be constructed in Boggiani, where the five Maintenance Departments are currently located. According to the plan of the Project, the 17 distribution substations mentioned above will be remotely supervised and controlled by the distribution control center, which will take over the operation tasks currently being conducted by D.O.R.D. for the distribution systems having 23 kV or lower voltages, so the operational efficiency of these systems will be improved by using new telecommunication system.

In the telecommunication system of distribution substation supervision and control, high reliability, quick response and high level of priority of data transmission are required. In the telecommunication system to improve distribution line operation works, a large amount of data must be transmitted and processed quickly and the results must be filed and edited appropriately. While fixed radio communication circuits are required for the former, the mobile radio communication circuit is required for the latter. For these reasons, the communication systems for the above two purposes must be created independently, and they will be utilized in common or connected together as circumstances such as business or location requires. As the distribution substations will be located within a radius of 25 km from the new distribution control center, construction of a radial radio circuits is more advantageous in terms of economy, reliability and other factors. In the central area of Asuncion, however, cable circuits must be introduced to some extent because many high buildings occupy this area.

The UHF frequency band shall be adopted for the new telecommunication system, because with UHF multiple access subscriber system, radial communication circuits can be easily constructed, and several tens of multiplex channels can be accommodated with higher economy. In comparison, the VHF frequency band can not provide sufficient communication channels, since 3 channels are usually accommodated in this band. SHF band (microwave radio) could provide sufficient channels, but the construction cost is too high.

10.2.2 Radio Wave Transmission Test

(1) Geography of Project Area

The Project Area covers a narrow and long basin along the Paraguay River where altitude is from 60 to 80 meters high. Most of the rest of the area are relatively flat land having altitude of 100 to 180 meters. However, buildings are concentrated in urban areas and high trees grow densely according to mild climate of this country. Therefore, in constructing a UHF network, it is necessary to take adequate measures to prevent these buildings and trees from creating large attenuation of radio waves. It may be difficult to constitute UHF radio circuits in central urban areas where high buildings are concentrated. Sufficient land areas are found in Boggiani where the distribution control center is to be constructed, so high guyed towers can be constructed for antennas in Boggiani. Sufficient care must be taken for distribution substations which are to be constructed in the central urban area, because the land areas available are small and there are nearby tall buildings.

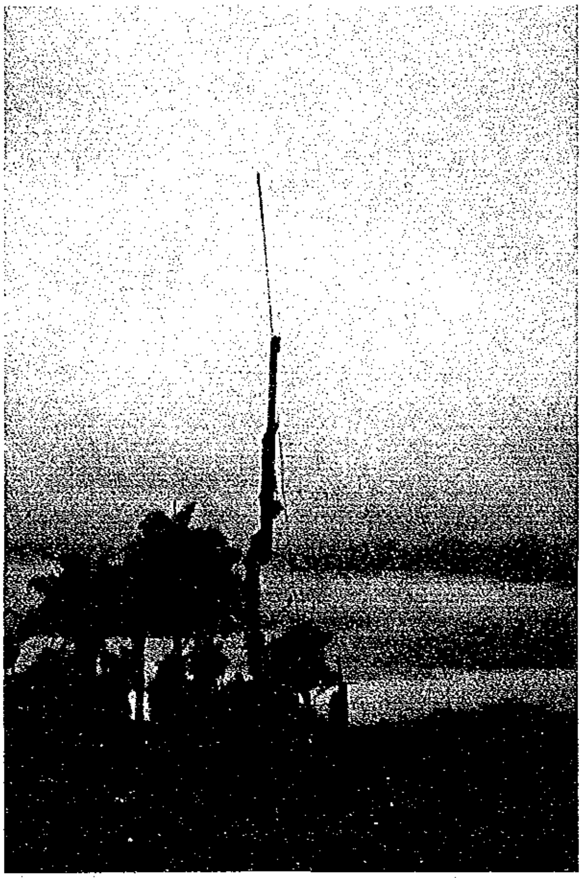
(2) Test Method

One handy radio set for amateur radio (Type IC-23, 144 - 146 MHz/430 - 440 MHz, 5 W output) and a mobile radio set for amateur radio (Type IC-2400, 144 - 146/430 - 440 MHz, 10 W output) were procured, and a field intensity measuring instrument (Manufactured by the Anritsu, Type 518) was rented to perform test measurements. It had been confirmed before procurement of these instruments that these radio sets can be operated by ANDE without securing permission. The field tests were conducted on 400 MHz only, because VHF channel can not satisfy the needs of ANDE, and VHF has better transmission performance as compared to UHF. It was desirable to perform the transmission performance tests on 800 MHz and 1500 MHz, because the transmission performance of these frequency bands is inferior to that of 400 MHz band outside the line of sight, but such tests were not possible this time since it would have taken more than 4 months to procure the radio sets. The tests were performed at Mojon, because; (1) the altitude of Boggiani is 140 m, which is substantially lower than Mojon where altitude is 180 m, (2) the antenna height was limited to 19 m, and (3) Mojon is only 4.2 km away from Boggiani, and the transmission test performed at Mojon can be effectively useful for Boggiani. The radio wave was transmitted as illustrated in Picture 10-1, that is, the antenna was raised to a height 19 m above ground by a line maintenance crane vehicle, and it was connected to the handy radio set on the ground by feeder. Since the output of the mobile radio set is reduced when the power supply voltage is reduced, the large capacity battery of the crane vehicle was used as power source. On the receiving side, the mobile radio set was loaded on a ANDE vehicle, which traveled for establishing communication with the sending side, while the field intensity measurement tests and speech tests were conducted at existing and planned distribution substation sites.

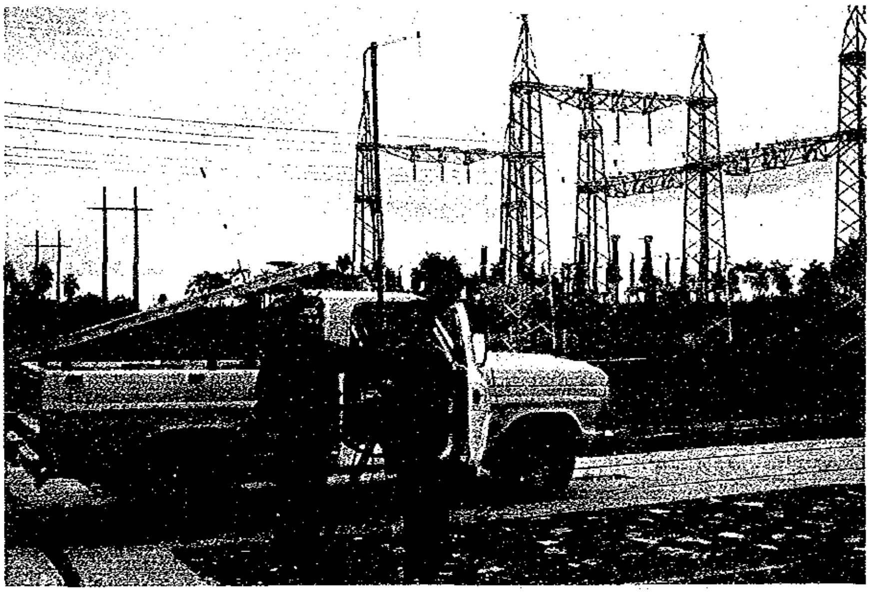
(3) Test Results

As the measurement had to be done with the antenna fixed at the standard height of 4 m, input field of sufficient strength was not obtained due to the nearby buildings and high trees. Also, as the reception sensitivity of the field intensity measuring instrument was +16 dB-microvolt/m, which was worse than the reception sensitivity of the mobile radio set of -16 dB-microvolt/m, only speech test was possible when the distance from Mojon is more than 6 km, although both field intensity test and speech test were possible within the radius of 6 km from Mojon, where the field intensity was from 18.5 to 38 dB-microvolt/m. The difference between the field intensity calculated from profile and the measured value, which was 1 to 19 dB, was estimated as the shield effect of buildings and trees. As the distance from Mojon exceeds 6 km, the incident angle of the radio wave was reduced, for which the attenuation by buildings and trees increased and was estimated to be from 15 to 20 dB. Subtracting this value from the calculated value, we can estimate the field intensity as 15.5 to 2.9 dB-microvolt/m. These values are less than +16 dB-microvolt/m which is reception sensitibity of field intensity meter.

The background noise, measured by the field intensity measuring instrument, was 14 dB-microvolt/m at 200 kHz reception band. When this value was converted to that at 15 kHz, we obtain the background noise of 2.5 dB-microvolt/m. This was a value that makes radio speech possible.



Picture 10-1 Transmission of Radio Wave in Field Tests



Picture 10-2 Reception of Radio Wave in Field Tests

Table 10-1 UHF Band (430 MHz) Radio Wave Transmission Test Result

Measurement Point		Distance from Mojon (km)	Measured Value (dBu/m)	Speech Test	Calculated Value (dBu/m)				Calculated - Measured
Name on Map	Name or New Site				Field Intensity	Topographical Loss	Diffraction Loss	Calculated Value	
DCC (E)	DORD	4.2	38	Good	59.0	11.0	0	48.0	10.0
BPA	Barrio Parque	6.15	19	"	52.3	11.0	9.0	32.3	13.3
D	New Site	5.8	30	"	53.4	11.0	10.4	31.0	1.0
L	"	6.15	19	"	52.3	11.0	6	35.3	16.3
SLO	San Lorenzo	6.5	21	"	51.1	11.0	0	40.1	19.1
I	New Site	5.5	25	"	54.3	11.0	0	43.3	17.7
I'	"	4.95	28	"	54.3	11.0	0	43.3	15.3
A	"	9.2	Can not measure	"	45.3	11.0	6.0	28.3	-
H	"	8.65	"	"	46.4	11.0	8.0	27.4	-
K	"	8.7	"	"	46.3	11.0	9.0	26.3	-
JBO	Jardin Batanico	10.5	"	"	43.0	11.0	7.5	24.5	-
LAM	Lambare	4.9	18.5	"	56.3	11.0	10.1	35.2	17.3
GRA	Guarambare	17.8	Can not measure	"	33.9	11.0	0	22.9	-
J	New Site	11.5	"	"	41.5	11.0	0	30.5	-
LIM	Limpio	26.1	Did not measure	Not measured	27.2	11.0			
SMI	San Miguel	8.0	"	"	47.8	11.0			
PSA	Puerto Sajonia	12.0	"	"	40.7	11.0			

10.2.3 Mobile Radio Circuits for Distribution Line Operation

As discussed in Section 10-1, the communication channels for operation of transmission and distribution systems in the Project Area are composed of one channel of UHF radio and four channels of VHF radio. These radio channels are currently the cause of reduced work efficiency and interference with other maintenance communication because; (1) they are used in common with other divisions, and (2) it takes much time to complete speech because of being simplex system, therefore they can not satisfy the needs of the large number of radio equipped vehicles, (3) they employ the general calling system, so the persons on vehicle have to keep attention whether a call is addressed to them or not. As the total number of repair works for distribution line amounts to 50,000 cases per year, the data required for restoration of failures can not be adequately edited, thereby impeding the restoration works.

In absorbing the DORD to the distribution control center, it is proposed to introduce new UHF mobile radio circuits and a new computer system for storage and display of information on distribution operation works through communication circuits. The features of the new UHF mobile radio circuits are described below.

(1) Radio Frequency and Number of Channels

As the antenna height of mobile radio set is limited to car height in a mobile radio system, the radio wave must be selected in such a frequency that the radio wave can propagate by diffraction even when there are obstructs such as buildings and trees. Such frequency is either 150 MHz band or 400 MHz band. Assuming that the number of radio-equipped vehicles is 50, and there are 50,000 repair works per year, the number of channels required is 8. (2 minutes/time/set x 2 times x 50 sets = 200 minutes, 200/60 = 3.33 Erlang. With loss probability of 2/100, 8 channels are required.) As a wide frequency bandwidth is required, it would be difficult to secure such a bandwidth if 150 MHz is adopted. The 400 MHz band should be selected, because this is also a more general practice.

(2) Circuit Designs

The wave propagation test was performed with the standard antenna height of 4 m. However, the antenna height of mobile radio sets is limited to 1.5 m, and it is necessary to adopt a high antenna on the transmission side in order to prevent the shield effect of buildings and trees. In view of the performance of the test at Mojon, where the test antenna elevation above sea level was 199 m (site elevation of 180 m plus antenna height of 19 m equals 199 m), it is necessary to construct a 80 meter high steel tower at Boggiani to make the antenna height to be 220 m, which is approximately 20 m higher than the antenna height during the propagation test (elevation of Boggiani of 140 m plus antenna height of 80 m equals 220 m). Antenna height of 100 m is recommended because some margin is required over the test results, and considering the performance of taxi radio in Tokyo.

The channel design, which has been developed for the 26.5 km distance from Boggiani Distribution Control Center to Limpio Substation, being the severest case, is presented in Table 10-2. The reception input is -102.2 dbm = 10.8 dB-microvolt, which is equivalent to 28.8 dB-microvolt/m in terms of input field intensity, and sufficient communication can be obtained with this field strength. Although shield factor of -20 dB is adopted in this channel design, the actual shield factor is less than this value in many locations. Considering the fact that the distance from Boggiani is less than 9 km in most case of substations, this design will have no problem.

Table 10-2 Circuit Design Example

Section	Boggiani to Limpio (26.5 km)
Output	+44 dBm (25W)
Transmission Feeder Loss	- 2.7 dB
Transmission Antenna Gain	+10.0 dB
Reception Antenna Gain	+ 4.0 dB
Reception Feeder Loss	- 0.5 dB
Propagation Loss	-126.0 dB
Land Coefficient	-11.0 dB
Shield Coefficient	-20.0 dB
Reception Level	-102.2 dBm

General specification of the equipment for distribution line operation mobile radio has been defined in Table 10-3 below based on the above data.

Table 10-3 General Specification of Distribution Line Operation Mobile Radio Equipment

System	FDMA
Number of Channels	8
Number of Subscribers	96
Radio Frequency	335 - 470 MHz
Transmission Power Output	25 W (44 dBm)
Antenna Tower	Guyed Type, 100 m

10.2.4 Fixed Radio Circuits for Distribution Substation Supervision/Control

As these circuits are used for remote supervision and control of distribution substations, the channels must have high quality and reliability, and have sufficient capacity so that circuits are seldom busy. The radio channels having the following performance should be selected.

(1) Radio Frequency

In UHF frequency (300 to 3000 MHz) radio communication, the 400 MHz band, 800 MHz band, 1500 MHz band and 2000 MHz band are generally used. In the 400 MHz band and 800 MHz band, it has been experienced that the urban radio noise such as those generated by automobiles sometimes cuts off communication, or produces code error in data transmission, so that it is recommended to use 1500 MHz band or 2000 MHz band in this case.

(2) Radio System

There are two systems of UHF band multiple access, multiplex communication, the FDMA (frequency division multiple access) and TDMA (time division multiple access). In the FDMA system, only one subscriber can be connected in the radio set of the subordinate station. Therefore, two radio sets are required when both telephone channel and supervision/control channel are necessary, and the host station must be expanded accordingly, thereby increasing the cost. In the TDMA system, as multiplex channels are prepared in both host and subordinate stations, both telephone circuits which are used as demand assign (in which the empty channel can be selected by the control channel for communication circuit every time a call occurs) and the data transmission circuits which are used as pre-assign (the radio channels are pre-assigned to subordinate stations) can be composed without increasing cost. And also, TDMA system is very preferable because one communication channel can be used for 4 to 5 subordinate stations, if the supervision/control system employs polling system (the host station calling subordinate stations one by one and subordinate station transmitting data in response to host station calling). In TDMA system, the subordinate station has 6 channels, which can be extended by 5 km by a communication cable, and the excess channels in one station can be used for supervisions/control of other substations and section switch for distribution line.

For these reasons, the TDMA system is proposed as the radio system. The general specification of the radio equipment used for the distribution substation supervision/control is illustrated in Table 10-4 below.

Table 10-4 Radio Equipment Specification

System	TDMA
Access System	Demand Assign/Pre Assign
Number of Access Channels	15
Number of Subscribers	128
Radio Frequency	1500 MHz band (1427 to 1535 MHz)
Transmission Output	1 W
Antenna Height	95 m with common use of tower for distribution line operation mobile radio

As the supervision/control circuits require high reliability, and the most advanced digital technology is used in the radio system, all radio sets shall be prepared by a set of two, one for normal use and another for standby.

10.2.5 Telecommunication Circuits for 220 kV Transmission Line Protective Relay

In the Project, a double circuit of 220 kV transmission line will be constructed between Puerto Botanico Substation and B Substation, and one circuit out of the two circuits of the transmission line between Guarambare Substation and Lambare Substation will be extended to A Substation, as well as a new single circuit of 220 kV transmission line will be constructed between Lambare Substation and A Substation. The communication line required for protection of these new transmission lines shall be provided by radio channels due to the following reasons.

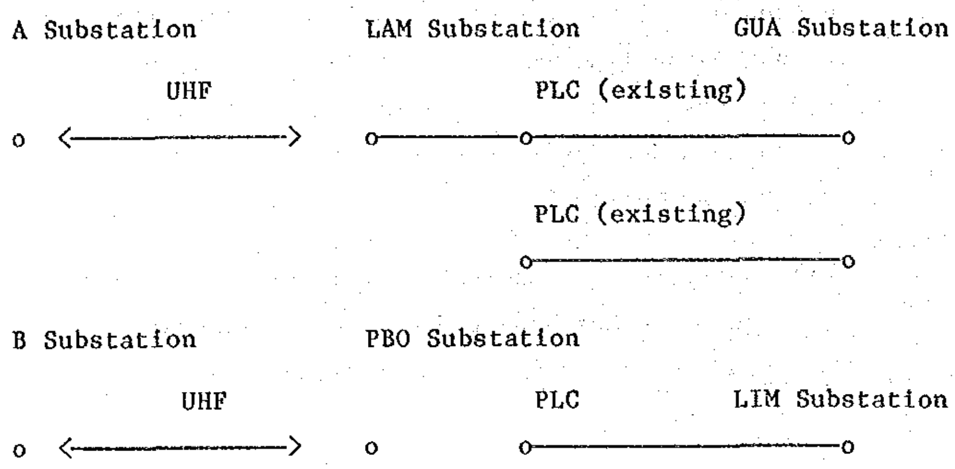
(1) Sufficient communication reliability can be assured when 1,500 to 2,000 MHz band radio circuits are used and the transmission and reception sets are provided with normal/standby redundancy.

(2) If the antenna for substation supervision/control is utilized in common, only one couple of radio sets are sufficient for the double circuits of transmission line between Puerto Botanico Substation and B Substation when the radio systems are used, a couple of transmission/ reception sets, and coupling devices such as coupling condenser and line traps are required for each circuit of transmission line when the power line carrier systems are used. Therefore, the radio system is more economical than the power line carrier system.

(3) As the transmission line between Lambare Substation and A Substation consists of overhead line sections and underground cable sections, the impedance matching bridge is required at the junction of overhead line and underground cable, in addition to the conventional equipment when the power line carrier system is used, thereby making the power line carrier system even less economical.

(4) The communication channel between Guarambare Substation and A Substation can be established by connecting one of the radio channels to be newly installed between Lambare Substation and A Substation to the existing power line carrier circuit between Guarambare Substation and Lambare Substation.

With this arrangement, the communication channel for the transmission line protective relay can be developed as illustrated in the figure below.



The specification of radio equipments to be used for protective relay of the 220 kV lines is presented in Table 10-5 below.

Table 10-5 Specification of Radio Equipments for Transmission Line Protective Relay

System	Digital (PCM-PSK)
Frequency	2,000 or 1,500 MHz
Number of Channel	6/30
Output Power	0.2 W
Standby System	Transmitter; Hot standby and switching without instantaneous stop. Receiver; Parallel reception
Antenna Tower	Common use of tower for supervision/ control of distribution substations

10.3 Establishment of Information Transmission System

10.3.1 Mobile Radio System for Operation of Distribution Line

In order to get more efficient works of distribution line operation, a mobile radio system for operation of distribution line will be newly established. The main characteristics of the system are described below.

The FDMA 400 MHz mobile radio circuits described in Section 10-2-3 will be used not only for telephone communication but also for data transmission.

(1) Telephone

The telephone system shall be such that individual calling between distribution control station and line operation vehicles as well as between individual line operation vehicles is performed by dialing.

(2) Data Transmission Circuit

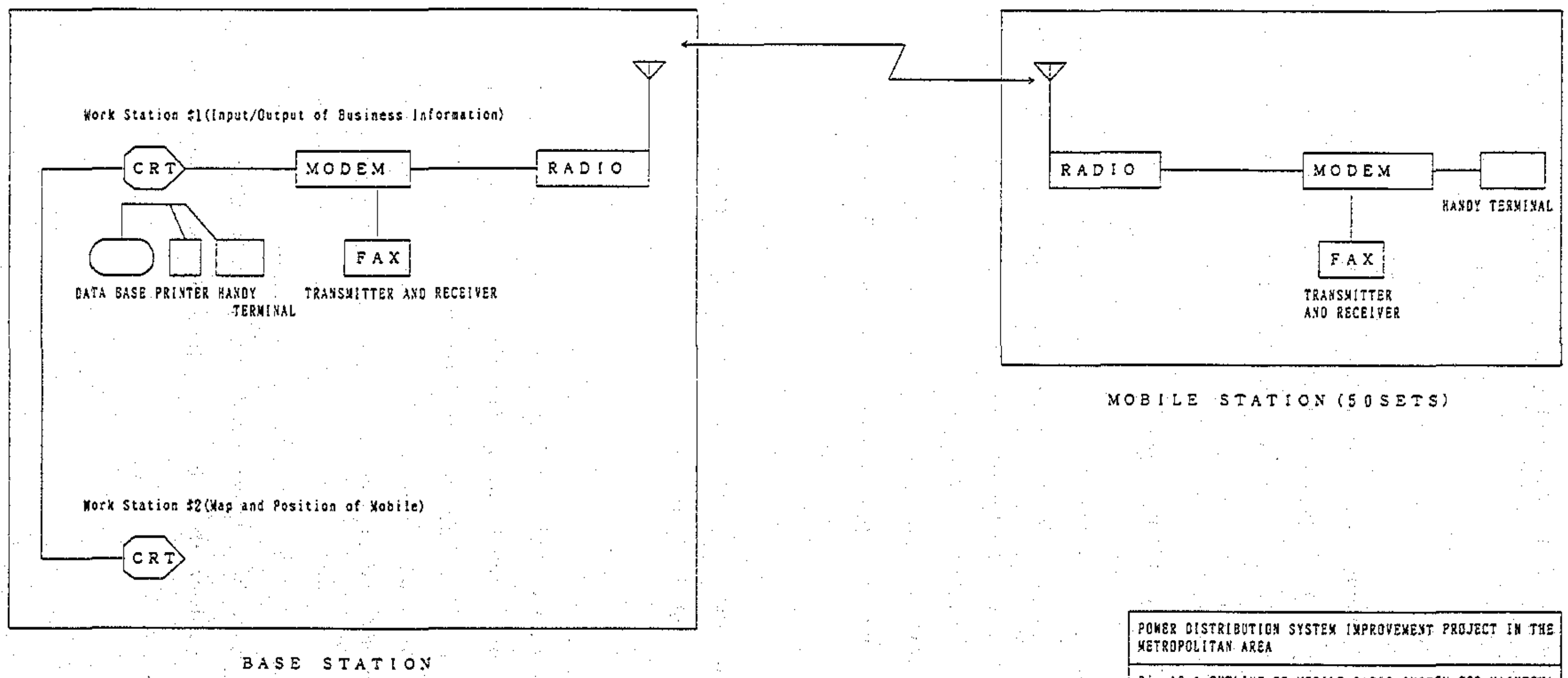
The data transmission shall be performed while there is no telephone call on the channels. The system shall be such that the remote display of vehicle positions, transmission of work plans, results, and other information by handy terminal and facsimile can be exchanged between distribution control stations and line operation vehicles. The outline of this system is as shown in Fig. 10-1.

10.3.2 Information Transmission and Control System for Supervision/Control of Distribution Substations

(1) Control System

The main functions of the supervision/control system to be introduced are display for monitoring and logging, and an adequate polling system for this purpose shall be adopted. It is impossible to adopt a system in which transmission can be initiated by the subordinate station for urgent message such as alarms, because such system requires complicated control system and many communication channels. As there are few data which must be transmitted urgently in this system, all data transmissions will be initiated by the request of host station.

Fig. 10-1 Outline of Mobile Radio System for Maintenance of Distribution Line



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA
Fig.10-1 OUTLINE OF MOBILE RADIO SYSTEM FOR MAINTENA-NCE OF DISTRIBUTION LINE

(2) Transmission Delay Time

It is necessary to make the delay time as short as possible for transmission of alarms from a subordinate station, as described in Paragraph (1), and the delay time is specified to be no more than 2 seconds for digital signals. For analogue signals, the allowable delay time is longer than for digital signals, and the load on the computer is increased when the data is renewed too frequently. For these reasons, the delay time will be specified to be no longer than 10 seconds. The delay time of control signal is selected at the same value with digital signal, or no more than 2 seconds.

(3) Number of Channels

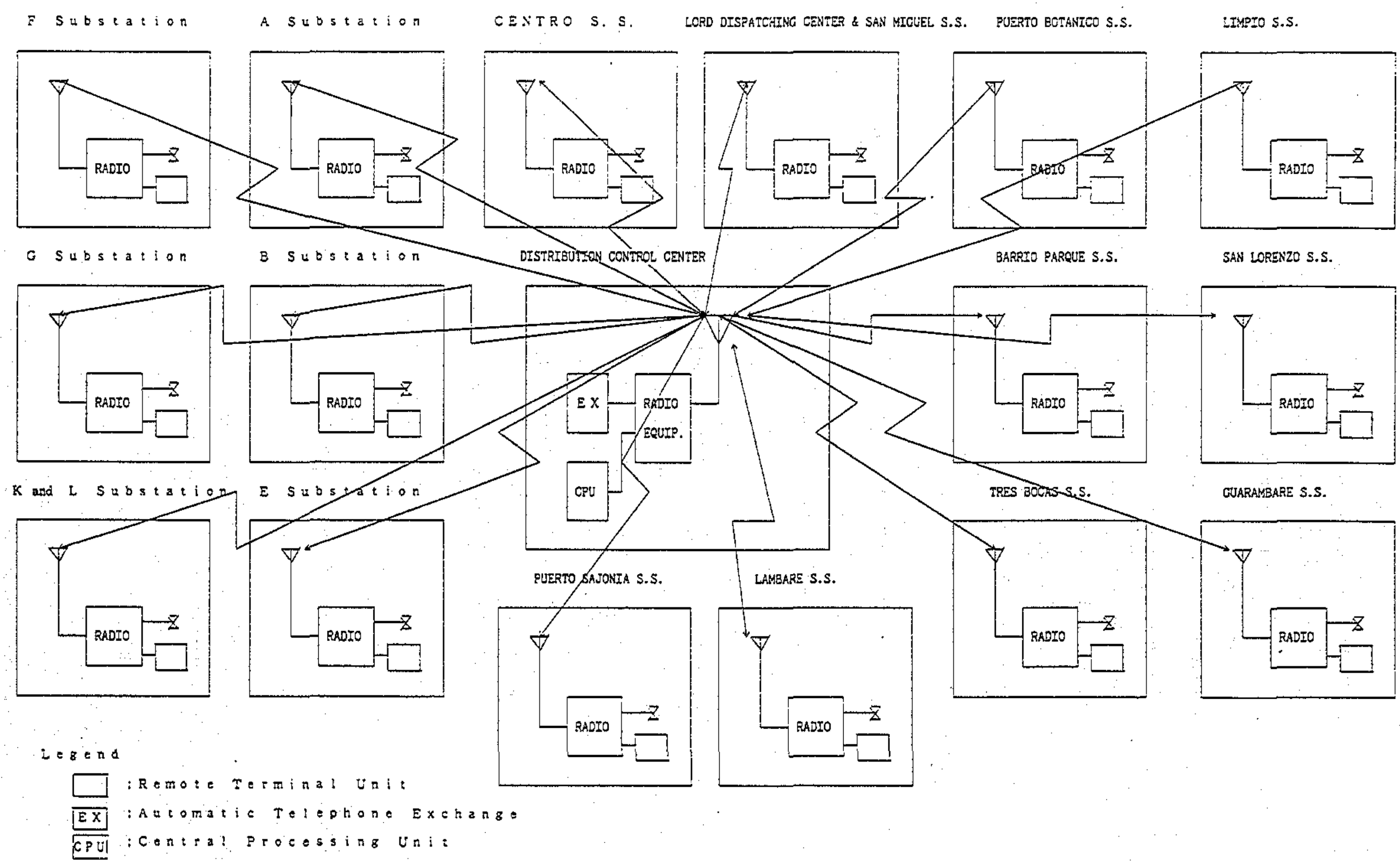
In a communication channel for supervision/control, the supervision/control functions must not be delayed by a busy circuit when the computer polls substations, so the dedicated communication channels must be pre-assigned. 5 substations can be processed by 1 channel when the system described in Paragraphs (1) and (2) is selected. Therefore, 5 channels are pre-assigned for supervision/control of up to 25 substations, and the remaining 10 channels are used for telephone communication as demand assign. As no busy is allowable in a telephone call for load dispatching, 1 to 2 channels of the 10 will be used as dedicated channels having tone ringer function (individual call using tone frequency).

The outline of this system is as shown in Fig. 10-2.

10.3.3 Signal Transmission System for 220 kV Transmission Line Protective Relay

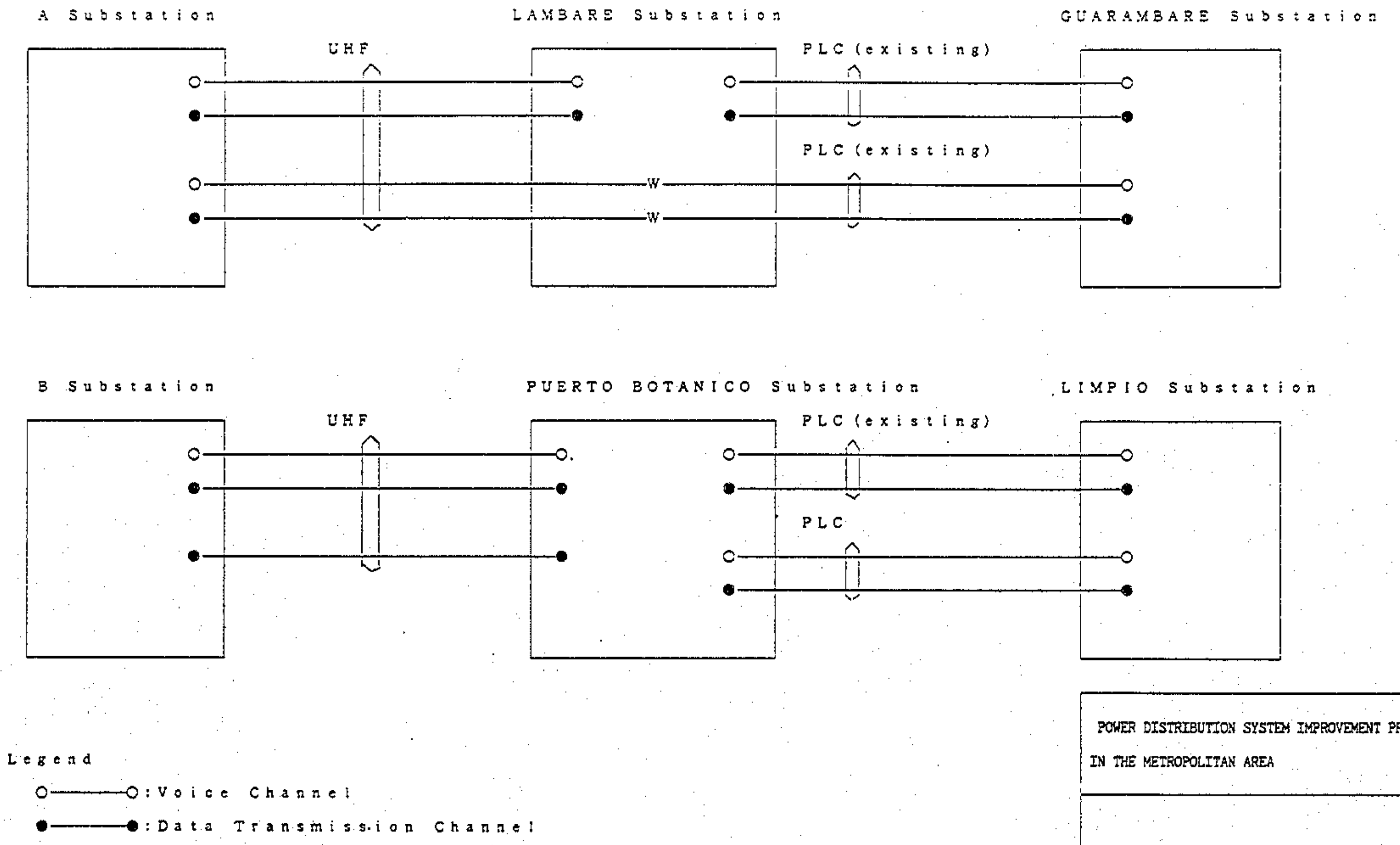
One of the signal transmission sets for line protective relay at Lambare Substation for Guarambare Substation shall be moved to the A Substation, and all signal transmission sets for protective relays of the line between Lambare Substation and A Substation, and the double circuit transmission line between Puerto Botanico Substation and the B Substation, shall be newly installed with specification compatible to the existing sets.

Fig. 10-2 Outline of Distribution Supervisory Control Radio Circuit



The outline of this system is as shown in Fig. 10-3.

Fig. 10-3 Outline of 220 kV Transmission Line Protective Relay Communication Circuit



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

CHAPTER 11

CONSTRUCTION WORK SCHEDULE AND CONSTRUCTION COST

CHAPTER 11 CONSTRUCTION WORK SCHEDULE AND CONSTRUCTION COST

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CHAPTER 11 CONSTRUCTION WORK SCHEDULE AND CONSTRUCTION COST

11.1 Construction Work Schedule

11.1.1 Scope of Construction Work

The refurbishment and expansion of transmission and distribution systems in the Project Area must be implemented immediately. The start of construction work has been set at 1993, considering the time required to develop detailed designs and bid invitation document, to award contract, and to close agreement with the contractors. Therefore, the first step of this Project will be completed by the end of 1994.

At the end of 1994, the 220 kV transmission lines to be introduced to the Metropolitan Area, the primary substations, the Distribution Control Center, and the monitoring/control systems and communication systems will be completed. Following this, the 66 kV transmission lines, the secondary substations and the distribution systems will be completed in succession by keeping pace with the growth of power demand in the Project Area.

11.1.2 Construction Method

The construction works of transmission lines, substations, communication systems and Distribution Control Center will be awarded to contractors in full turn key basis including architectural and civil engineering works, purchase, shipment and installation, and test of equipments.

The construction works for the distribution facilities will be implemented by ANDE by dividing the Project Area into a number of areas based on the refurbishment and expansion plans are developed for each supply area.

11.1.3 Construction Work Schedule

The construction work schedule, which has been developed according to the scope of construction and construction method described above is presented in Table 11-1.

11.2 Construction Cost

The construction cost added up for each item of transmission lines, substations, distribution lines, architectural works, and communication systems is presented in Table 11-2. These costs were calculated by foreign currency (US$) and local currency (guarani).

11.2.1 Basic Conditions for Cost Calculation

The construction costs have been calculated based on the following conditions.

(1) The FOB price is based on 1989 price level, and escalation is not taken into account.

(2) Freight and Insurance Premium

CIF price is applied for construction cost, which is to be calculated by adding freight (marine and land) and insurance premium to the FOB prices by the following rates.

- Freight : 10% of FOB price.
- Insurance premium : 1% of FOB price.

As it is expected that the import tax exemption is applied to the commodities imported for this project, the import tax is not taken into account in the calculation.

(3) Foreign Currency Exchange Rate

1 US$ = 1,200 guarani

(4) Labor Cost

The labor costs (for decommissioning of old facilities and installation of new facilities) have been estimated based on the following rates. The labor costs in distribution sector, however, are based on the values indicated by ANDE.

Substation Sector	:	20%
Transmission Sector	:	30%
Distribution Sector	:	(To be determined on discussion with ANDE)
Telecommunication Sector	:	20%

(5) Engineering Fee and Construction Management Fee

A 7% portion of construction cost has been added to the construction cost in foreign currency.

(6) Contingency Cost

10% each of the sums of foreign currency prices and local currency prices of construction costs have been assumed as contingency.

11.2.2 Division of Foreign Currency and Local Currency

The construction costs have been divided into the foreign currency portion and the local currency portion by the following rules.

(1) *Foreign Currency Portion*

(i) Materials and equipments used in transmission, substation, distribution and telecommunication facilities.

(ii) Freight and insurance premium.

(iii) Cost incurred by having manufacturers' technicians for installation and adjustment of equipments used in substations, distribution control facilities and telecommunication systems.

(iv) Engineering fees.

(2) Local Currency Portion

(i) Contracted construction costs in Paraguay of transmission, substation, distribution and telecommunication facilities.

(ii) Gravels, sand, cement and other materials to be procured in Paraguay for construction works.

(iii) Architectural construction costs of Distribution Control Center and new substations.

Table 11-1 Construction Schedule

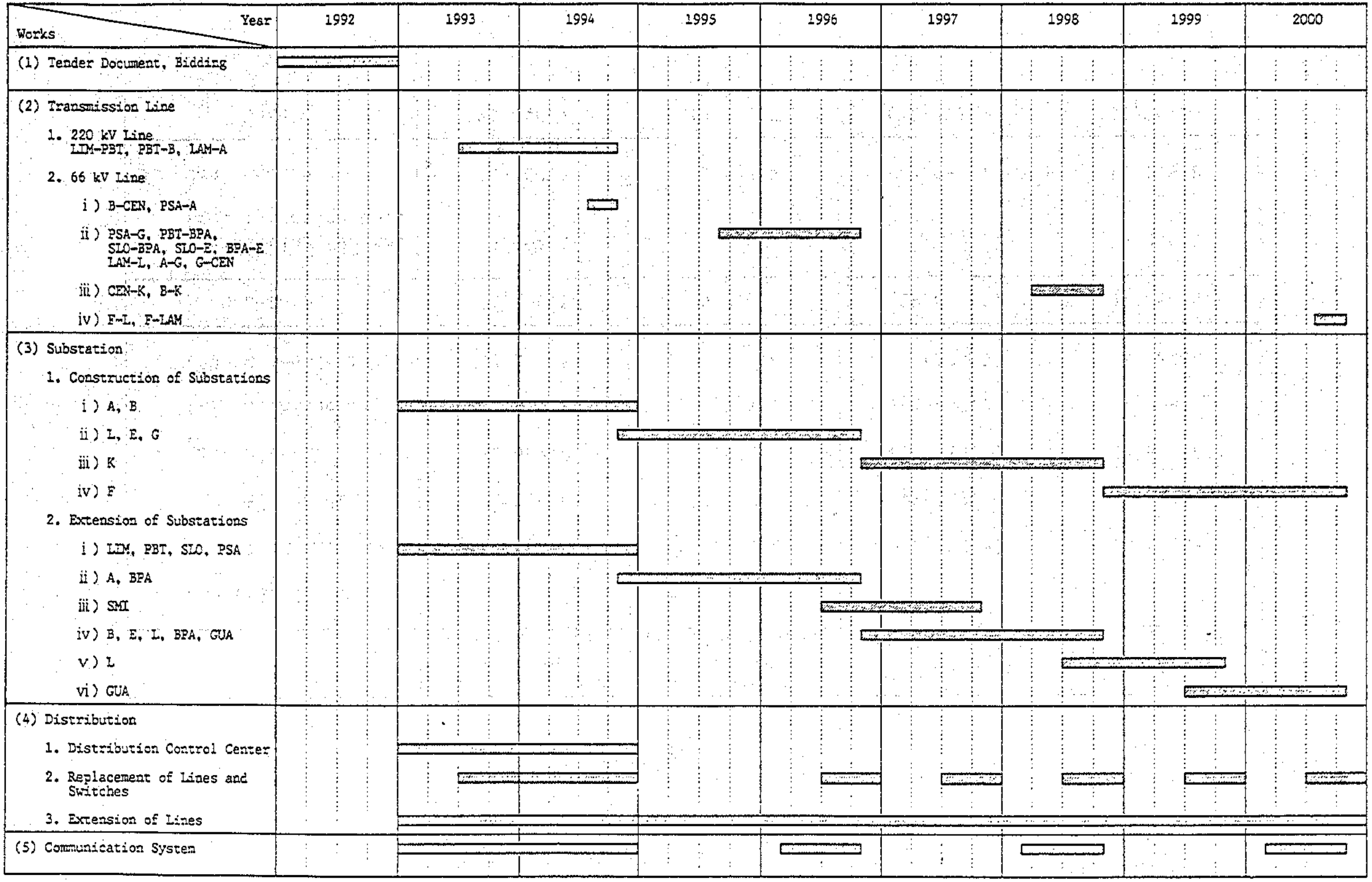

Table 11-2 Construction Cost

	Foreign Currency Portion (Thousand US$)	Local Currency Portion (Million Guarani)	(US$ Equivalent) (Thousand US$)	Total (Thousand US$)
1. Construction Cost				
(1) Transmission	11,416.0	3,721.0	(3,100.8)	14,516.8
(2) Substation	44,289.0	11,187.0	(9,322.5)	53,611.5
(3) Distribution	42,662.0	18,018.0	(15,015.0)	57,677.0
(4) Architecture	0	2,519.0	(2,099.2)	2,099.2
(5) Communication	3,309.5	329.4	(274.5)	3,584.0
Sub-Total	101,676.5	35,774.4	(29,812.0)	131,488.5
2. Engineering Fee and Administration Cost	9,204.2	0	(0)	9,204.2
3. Contingency	10,167.7	3,577.4	(2,981.1)	13,148.8
Total	121,048.4	39,351.8	(32,793.1)	153,841.5

CHAPTER 12

ECONOMIC EVALUATION

CHAPTER 12 ECONOMIC EVALUATION

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CHAPTER 12 ECONOMIC EVALUATION

12.1 Methodology of Evaluation

The following cost and benefit elements have been estimated in evaluating the economy of this power distribution system improvement project.

In the evaluation, the economic internal rate of return (EIRR) by which the total cost [C] and the total benefit [B] become equal has been calculated, and at the same time the surplus benefit (B-C) and the benefit to cost ratio (B/C) have also been calculated as the bases of overall judgment.

Cost: a) Total project investment.

b) Operating and maintenance costs of completed facilities.

Benefit: a) The incremental electric energy which is made available to the customers by this Project.

b) The reduction in the electric energy lost by power supply failures which is expected to be brought about by this Project.

c) The reduction of operating/maintenance costs which is expected to be brought about by this Project.

In addition to the above elements, it is expected that benefits will be brought about by this Project such as reduction in failures and damages in electrical equipments of customers due to improvement of voltage and frequency fluctuations, reduction of inconveniences of the customers due to reduced supply failures, and the improvement of supply reliability in broader sense. However, as these factors are difficult to quantify, they have not been included in the economic evaluation.

Benefit could have been also evaluated by comparing the cost of this Project with the cost of alternative supply provided by hypothetical diesel power plants. However, this method is not suitable in this case for the following reasons.

(a) A large power supply sources are already developed and available.

(b) Transmission lines having sufficient capacity exist to supply power to the Project Area.

(c) As the power supply requirement is expected to grow by more than 450 MW until 2000, it is not logical to assume alternative diesel plants which unit capacity is only around 15 MW.

12.2 Basic Assumptions/Conditions

The calculations in the economic evaluation were performed based on the following assumptions and conditions.

(1) Total Project Investment

The total project investment was calculated as the construction cost of the Project excluding the interests during construction and import taxes. The total construction cost has been added up on the 1989 price base.

(2) Foreign Currency Exchange Rate

It was assumed that 1 US$ = 1,200 guarani.

(3) Operation and Maintenance Costs

The operation and maintenance costs were assumed to be 4% of the total investment after 2001 when all facilities are completed. They were assumed to be 4% of the total cumulative investment committed until the preceding year for the period from 1995 to 2000 when some facilities are under construction.

(4) Period of Calculation

The amortization period of major power facilities is set forth by the financial standard of ANDE as below.

Transmission line	:	30 years
Substation equipment	:	30 years
Distribution transformer	:	25 years

The amortization period for this Project was calculated by averaging the above values using weighing factors for transmission, substation and distribution facilities which are proportional to the relative weight of each sector in the total investment. The calculated amortization period was 27 years.

Considering that the facilities to be constructed under this Project will be completed one by one from 1994 to 2000, the period of calculation for the economic evaluation was set from the middle point of the construction period (from 1993 to 2000), that is, 1997, for 27 years, or until 2023.

(5) Discount Rate

The discount rate was selected at 12% per annum based on a discussion with ANDE.

12.3 Cost

12.3.1 Total Project Investment

The total construction cost, which was added up in Chapter 11, was regarded as the total investment of this Project. The yearly investment is presented in Table 12-1.

12.3.2 Operation/Maintenance Costs

The annual values of operation/maintenance costs of this Project, as calculated by the assumption in Paragraph 12.2(3), are presented in Table 12-1.

Table 12-1 Investment Cost and Operation Maintenance Cost

(Unit: 1,000 US$)

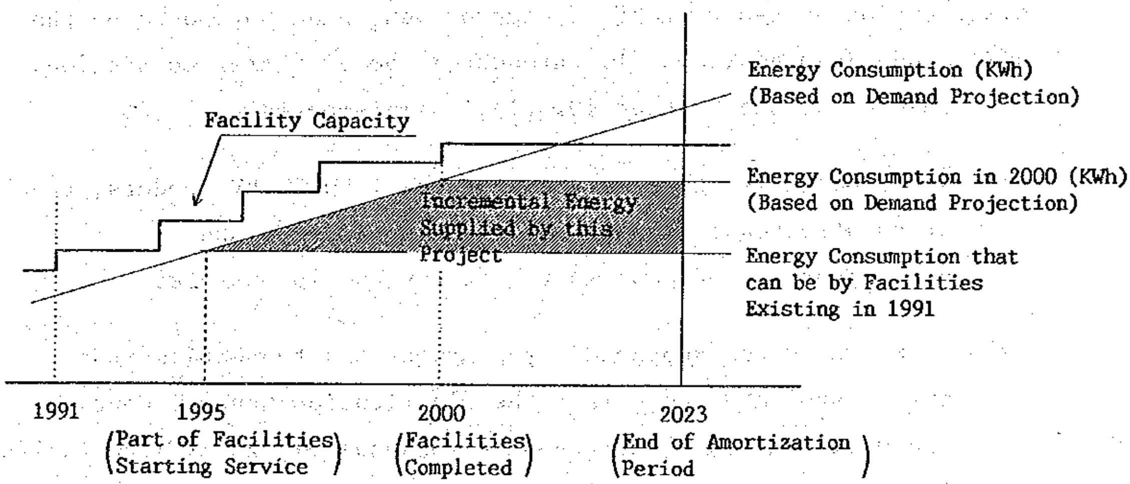
	1993	1994	1995	1996	1997	1998	1999	2000	2001 - 2023	Total
Construction Cost (Foreign and Local)	31,029.8	39,538.0	7,361.1	9,998.4	7,115.7	9,021.7	6,213.6	21,210.2		131,488.5
Administration Cost and Engineering Fee	2,172.1	2,767.7	515.3	699.9	498.1	631.5	434.9	1,484.7		9,204.2
Contingency	3,103.0	3,953.8	736.1	999.8	711.6	902.2	621.3	2,121.0		13,148.8
Total Investment Cost	36,304.9	46,259.5	8,612.5	11,698.1	8,325.4	10,555.4	7,269.8	24,815.9		153,841.5
Operation Maintenance Cost	-	-	3,302.6	3,647.1	4,115.0	4,448.0	4,870.2	5,161.0	6,153.7	167,079.0

12.4 Benefit

12.4.1 Value of Incremental Electric Energy Made Available to Customers by This Project

The existing distribution network facilities in the Project Area will not be able to meet the power demand in the area in 1992 and thereafter if the marginal supply capacity required to deal with large system failures are taken into account. (The existing facilities can supply the demand in 1991 and thereafter only if there is no emergency situation such as equipment failure.)

Therefore, the portion of the energy demand exceeding the limit which can be met by the facilities existing in 1991 will not be met after 1995, if the new facilities under this Project do not start service in 1994. This is illustrated in the figure below.



Therefore, the sum of the energy consumption (as estimated by the demand projection) that exceeds the amount of 1991 (as estimated by the demand projection), for the period starting from 1995, when a part of facilities under this project is completed, to 2023, when the amortization of facilities under this Project ends, can be regarded as the incremental electric energy that is made available to the customers by this Project (the hatched area in the above figure).

The benefit of this project was calculated by multiplying this incremental energy supply with the electricity tariff, which will be discussed later.

This incremental energy supply of each year is given in Table 12-2.

12.4.2 Value of Electric Energy Made Available by This Project Through Reduction in Supply Failures

The energy being lost by supply failures can be reduced when the distribution system reliability improvement plan, proposed by the JICA Study Team as Items (1) through (3) below (Refer to Section 8.6, Chapter 9, and Section 10.3.1) is implemented.

(1) As automatic switches are introduced into 23 kV feeders, the areas affected by supply failure are reduced, and corresponding increase in tariff revenue is expected.

(2) As SCADA System supported by computer and the mobile radio system are introduced into the Distribution Control Center, the mobilization or maintenance personnel in 23 kV line faults is speeded up and the time required for recovery is reduced, with corresponding increase in tariff revenue.

(3) As insulated conductors are introduced into medium and low voltage lines, supply failures caused by tree contacts are reduced, with corresponding increase in tariff revenue.

However, as the magnitude of benefits brought about by these factors is very small as compared with the incremental energy supply discussed in the previous section, these benefits are not counted in this economic evaluation.

Table 12-2 Increased Energy which will be Available by this Project

Year	GWh (Forecast)	1991 GWh (Forecast)	Increased Energy (GWh)
1995	1,867.6	1,299.0	568.6
1996	2,031.7	1,299.0	732.7
1997	2,204.7	1,299.0	905.7
1998	2,386.4	1,299.0	1,087.4
1999	2,576.9	1,299.0	1,277.9
2000	2,776.3	1,299.0	1,477.3
2001 - 2023			1,477.3
Total			40,027.5

12.4.3 Reduction of Distribution System Operation/Maintenance Costs to be Brought About by Project

The operation/maintenance costs will be reduced by the reliability improvement measures discussed in Section 12.4.2, as described below.

(1) As faulted sections of 23 kV feeders can be identified in supply failures, the recovery time can be reduced, with corresponding reduction in the number of maintenance workers.

(2) The number of operating personnels can be reduced as new Central Dispatching Center and the Distribution Dispatching Center are completed.

As the benefit related to these factors are very small as compared to incremental energy supply, these factors are also neglected in economic evaluation.

12.4.4 Unit Price for Electric Energy Benefit

Unlike a power generation project, no alternative plan can be defined in evaluating a distribution facility plan.

Therefore, we judged it is appropriate to use the electricity tariff rate as the reference of benefit in evaluating this Project, because the tariff of an electric company is calculated on cost basis as an utility company should, and this can be regarded to reflect the "willingness to pay" on the side of the customers.

As of the end of 1989, the average energy tariff of ANDE is 47.13 guarani (refer to Section 3.4, Electric Tariff). The tariff rate used in calculation of benefit was selected at 25.54 guarani based on the following reasoning.

The electric tariff is calculated by adding the interest of borrowed money and appropriate return of capital to the supply cost. The supply cost is the business cost itself, and it includes operation/maintenance cost, capital depreciation and overhead expenses in generation, transmission/substation, and distribution sections.

In setting the unit price for evaluation of benefit in this economic evaluation, it would be appropriate to assess the percentage of business cost being incurred in transmission, substation and distribution sections, which are involved in this Project, to the total business cost of ANDE, and then multiply the average tariff rate of ANDE with this percentage to obtain the unit price of benefit.

The business expenses of each section was calculated based on the 1988 Annual Report of ANDE. Then the total depreciation of ANDE was allotted to each section in proportion to the amount of fixed assets in each section. The percentage of business cost of each section was obtained by adding these two.

(Unit: Million ₲)

	Business Expense	Fixed Assets	Allotted Depreciation	Total
Power Generation	6,631	99,199(42%)	3,912	10,543(46%)
Transmission/ Substation	2,435	83,546(35%)	3,260	5,695(24%)
Distribution	4,811	55,877(23%)	2,142	6,953(30%)
Total	13,877	238,542(100%)	9,314	23,191(100%)

The above calculation indicates that transmission/substation and distribution sections of ANDE accounts for 54% of the total business cost.

Based on this, the value of 25.54 guarani/kWh to be used for this economic evaluation has been calculated as below.

47.31 guarani x 54% = 25.54 guarani

12.4.5 Benefit in Each Year

The benefit gained by this Project, as obtained by multiplying the incremental energy gained with the unit electricity price calculated above, is presented in Table 12-3.

Table 12-3 Benefit of the Project

Year	Increased Energy (GWh)	Energy Price (₵/kWh)	Benefit	
			Million ₵	Thousand US$
1995	568.6	25.54	14,522	12,101.7
1996	732.7	25.54	18,713	15,594.3
1997	905.7	25.54	23,132	19,276.3
1998	1,087.4	25.54	27,772	23,143.5
1999	1,277.9	25.54	32,638	27,198.0
2000	1,477.3	25.54	37,730	31,441.9
2001 - 2023	1,477.3	25.54	37,730	31,441.9
Total	40,027.5		1,022,297	851,919.4

12.5 Results of Economic Evaluation

The flow of benefit and cost of this Project is illustrated in Table 12-4.

The economic internal rate of return (EIRR), the excess benefit (B-C) and the benefit to cost ratio (B/C) as obtained by these benefit and cost are as below.

EIRR	:	14.9%
B - C	:	25,236.3 thousand US$
B/C	:	1.18

In judging the economic soundness of this Project, the JICA Study Team notes that all of EIRR, B-C, and B/C values are good, and this Project is economically feasible. The true economic value of this Project should be even higher if the social benefits to be brought about by this project, which are discussed in Section 12.1 but can not be quantified, are taken into account. Therefore, it is judged that this Project should be implemented.

12.6 Sensitivity Analysis

The sensitivity analysis of this Project has been studied for the following two cases.

(1) When the total investment increases by 10% (Table 12-5).

(2) When the discount rate is 14% (Table 12-6).

B - C and B/C still exhibit favorable values and the Project is economically feasible even when the construction unit cost escalates and the total investment on this Project rises by 10%.

The discount rate for this evaluation has been set at 12% based on a discussion with ANDE. The above indices exhibits favorable values even when this is assumed to be 14%. This indicate that the Project has sufficient margin in terms of discount rate which reflect the opportunity cost of capital.

Table 12-4 Benefit Flow and Cost Flow of the Adopted Improvement Plan

(Unit: Thousand US$)

Serial No.	No. after Completion	Cost: Inves. Cost	Cost: O&M Cost	Cost: Total	Cost: N.P.V.	Benefit: Total	Benefit: N.P.V.	B - C
0		0.0		0.0	0.0		0.0	0.0
1		36304.9		36304.9	32415.1		0.0	-36304.9
2		46259.5		46259.5	36877.8		0.0	-46259.5
3		8612.5	3302.6	11915.1	8480.9	12101.7	8613.8	186.6
4		11698.1	3647.1	15345.2	9752.2	15594.3	9910.5	249.1
5		8325.4	4115.0	12440.4	7059.0	19276.3	10937.9	6835.9
6		10555.4	4448.0	15003.4	7601.2	23143.5	11725.2	8140.1
7		7269.8	4870.2	12140.0	5491.5	27198.0	12303.0	15058.0
8		24815.9	5161.0	29976.9	12107.2	31441.9	12698.9	1465.0
9	1		6153.7	6153.7	2219.1	31441.9	11338.3	25288.2
10	2		6153.7	6153.7	1981.3	31441.9	10123.5	25288.2
11	3		6153.7	6153.7	1769.0	31441.9	9038.8	25288.2
12	4		6153.7	6153.7	1579.5	31441.9	8070.4	25288.2
13	5		6153.7	6153.7	1410.3	31441.9	7205.7	25288.2
14	6		6153.7	6153.7	1259.2	31441.9	6433.6	25288.2
15	7		6153.7	6153.7	1124.3	31441.9	5744.3	25288.2
16	8		6153.7	6153.7	1003.8	31441.9	5128.9	25288.2
17	9		6153.7	6153.7	896.3	31441.9	4579.3	25288.2
18	10		6153.7	6153.7	800.2	31441.9	4088.7	25288.2
19	11		6153.7	6153.7	714.5	31441.9	3650.6	25288.2
20	12		6153.7	6153.7	637.9	31441.9	3259.5	25288.2
21	13		6153.7	6153.7	569.6	31441.9	2910.3	25288.2
22	14		6153.7	6153.7	508.6	31441.9	2598.4	25288.2
23	15		6153.7	6153.7	454.1	31441.9	2320.0	25288.2
24	16		6153.7	6153.7	405.4	31441.9	2071.5	25288.2
25	17		6153.7	6153.7	362.0	31441.9	1849.5	25288.2
26	18		6153.7	6153.7	323.2	31441.9	1651.4	25288.2
27	19		6153.7	6153.7	288.6	31441.9	1474.4	25288.2
28	20		6153.7	6153.7	257.7	31441.9	1316.4	25288.2
29	21		6153.7	6153.7	230.0	31441.9	1175.4	25288.2
30	22		6153.7	6153.7	205.4	31441.9	1049.5	25288.2
31	23		6153.7	6153.7	183.4	31441.9	937.0	25288.2
Total		153841.5	167079	320920.5	138968.1	851919.4	164204.4	530998.9

I R R	0.1495049
B - C	25236.377
B / C	1.1815983

Table 12-5 Benefit Flow and Cost Flow of Sensitivity Analysis (Investment Cost 10% up)

(Unit: Thousand US$)

Serial No.	No. after Completion	Cost				Benefit		B - C
		Inves. Cost	O&M Cost	Total	N.P.V.	Total	N.P.V.	
0		0.0		0.0	0.0		0.0	0.0
1		39935.4		39935.4	35656.6		0.0	-39935.4
2		50885.5		50885.5	40565.6		0.0	-50885.5
3		9473.8	3632.9	13106.6	9329.0	12101.7	8613.8	-1004.9
4		12867.9	4011.8	16879.7	10727.4	15594.3	9910.5	-1285.4
5		9157.9	4526.5	13684.4	7764.9	19276.3	10937.9	5591.9
6		11610.9	4892.8	16503.7	8361.3	23143.5	11725.2	6639.8
7		7996.8	5357.2	13354.0	6040.7	27198.0	12303.0	13844.0
8		27297.5	5677.1	32974.6	13317.9	31441.9	12698.9	-1532.7
9	1		6769.1	6769.1	2441.0	31441.9	11338.3	24672.8
10	2		6769.1	6769.1	2179.5	31441.9	10123.5	24672.8
11	3		6769.1	6769.1	1945.9	31441.9	9038.8	24672.8
12	4		6769.1	6769.1	1737.5	31441.9	8070.4	24672.8
13	5		6769.1	6769.1	1551.3	31441.9	7205.7	24672.8
14	6		6769.1	6769.1	1385.1	31441.9	6433.6	24672.8
15	7		6769.1	6769.1	1236.7	31441.9	5744.3	24672.8
16	8		6769.1	6769.1	1104.2	31441.9	5128.9	24672.8
17	9		6769.1	6769.1	985.9	31441.9	4579.3	24672.8
18	10		6769.1	6769.1	880.2	31441.9	4088.7	24672.8
19	11		6769.1	6769.1	785.9	31441.9	3650.6	24672.8
20	12		6769.1	6769.1	701.7	31441.9	3259.5	24672.8
21	13		6769.1	6769.1	626.5	31441.9	2910.3	24672.8
22	14		6769.1	6769.1	559.4	31441.9	2598.4	24672.8
23	15		6769.1	6769.1	499.5	31441.9	2320.0	24672.8
24	16		6769.1	6769.1	446.0	31441.9	2071.5	24672.8
25	17		6769.1	6769.1	398.2	31441.9	1849.5	24672.8
26	18		6769.1	6769.1	355.5	31441.9	1651.4	24672.8
27	19		6769.1	6769.1	317.4	31441.9	1474.4	24672.8
28	20		6769.1	6769.1	283.4	31441.9	1316.4	24672.8
29	21		6769.1	6769.1	253.1	31441.9	1175.4	24672.8
30	22		6769.1	6769.1	225.9	31441.9	1049.5	24672.8
31	23		6769.1	6769.1	201.7	31441.9	937.0	24672.8
Total		169225.65	183786.9	353012.55	152864.9	851919.4	164204.4	498906.9

I R R	0.1323167
B - C	11339.571
B / C	1.0741803

Table 12-6 Benefit Flow and Cost Flow of Sensitivity Analysis (Discount Rate 14%)

(Unit: Thousand US$)

Serial No.	No. after Completion	Cost				Benefit		B - C
		Inves. Cost	O&M Cost	Total	N.P.V.	Total	N.P.V.	
0		0.0		0.0	0.0		0.0	0.0
1		36304.9		36304.9	31846.4		0.0	-36304.9
2		46259.5		46259.5	35595.2		0.0	-46259.5
3		8612.5	3302.6	11915.1	8042.4	12101.7	8168.3	186.6
4		11698.1	3647.1	15345.2	9085.6	15594.3	9233.1	249.1
5		8325.4	4115.0	12440.4	6461.2	19276.3	10011.5	6835.9
6		10555.4	4448.0	15003.4	6835.3	23143.5	10543.9	8140.1
7		7269.8	4870.2	12140.0	4851.6	27198.0	10869.3	15058.0
8		24815.9	5161.0	29976.9	10508.7	31441.9	11022.2	1465.0
9	1		6153.7	6153.7	1892.3	31441.9	9668.6	25288.2
10	2		6153.7	6153.7	1659.9	31441.9	8481.3	25288.2
11	3		6153.7	6153.7	1456.1	31441.9	7439.7	25288.2
12	4		6153.7	6153.7	1277.3	31441.9	6526.1	25288.2
13	5		6153.7	6153.7	1120.4	31441.9	5724.6	25288.2
14	6		6153.7	6153.7	982.8	31441.9	5021.6	25288.2
15	7		6153.7	6153.7	862.1	31441.9	4404.9	25288.2
16	8		6153.7	6153.7	756.2	31441.9	3863.9	25288.2
17	9		6153.7	6153.7	663.4	31441.9	3389.4	25288.2
18	10		6153.7	6153.7	581.9	31441.9	2973.2	25288.2
19	11		6153.7	6153.7	510.4	31441.9	2608.1	25288.2
20	12		6153.7	6153.7	447.8	31441.9	2287.8	25288.2
21	13		6153.7	6153.7	392.8	31441.9	2006.8	25288.2
22	14		6153.7	6153.7	344.5	31441.9	1760.4	25288.2
23	15		6153.7	6153.7	302.2	31441.9	1544.2	25288.2
24	16		6153.7	6153.7	265.1	31441.9	1354.5	25288.2
25	17		6153.7	6153.7	232.5	31441.9	1188.2	25288.2
26	18		6153.7	6153.7	204.0	31441.9	1042.3	25288.2
27	19		6153.7	6153.7	178.9	31441.9	914.3	25288.2
28	20		6153.7	6153.7	157.0	31441.9	802.0	25288.2
29	21		6153.7	6153.7	137.7	31441.9	703.5	25288.2
30	22		6153.7	6153.7	120.8	31441.9	617.1	25288.2
31	23		6153.7	6153.7	105.9	31441.9	541.3	25288.2
Total		153841.5	167079	320920.5	127878.4	851919.4	134712.0	530998.9

I R R	0.1495049
B - C	6833.6620
B / C	1.0534387

CHAPTER 13

FINANCIAL ANALYSIS

CHAPTER 13 FINANCIAL ANALYSIS

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CHAPTER 13 FINANCIAL ANALYSIS

13.1 Analytical Methodology

The financial analysis of this Project has been conducted by the methodology described below.

(1) Calculation of Debt Service Ratio

Generally speaking, the following two indices are used to evaluate the financial value of a Project that to be implemented by a corporation.

- Rate of Return

This is the ratio of the business revenue to the net operating assets. The interests on borrowed money is paid by out of this revenue, and the remaining money is the net profit.

- Debt Service Ratio

The ratio of the cooperate internal financing, which is business profit plus depreciation, to the reimbursement plus interest of borrowed money.

In our analysis, the debt service ratio among the two indices above has been adopted. To calculate this value, the following three works were required.

(a) Development of reimbursement plan
(b) Development of profit and loss statement
(c) Cash flow analysis

(2) Calculation of Financial Internal Rate of Return (FIRR)

The financial internal rate of return, by which the yearly sums of costs and revenues are equal (the financial internal rate of return), has been calculated, and this value has been compared with the opportunity cost of capital.

13.2 Premises

This financial analysis has been conducted by the following basic conditions.

(1) Capital Procurement Cost

(a) *Foreign Currency*

An interest rate of 7% per annum. The principal and interest to be uniformly reimbursed for 20 years.

(7% interest rate was adopted here reflecting the current interest rate level for financing by international financial institutions for development such as World Bank, IDB and ADB.)

(b) Local Currency

An interest rate of 35% per annum on 50% of the construction cost to be provided by local currency. The principal and interest to be uniformly reimbursed for 10 years.

13.3 Construction Costs

The construction cost of this Project as counted on foreign currency and local currency for each year of the Project, as well as the interests during construction, are presented in Table 13-1.

13.4 Depreciation

The depreciation has been calculated on the fixed percentage diminishing value plan applied for 27 years on the total investment plus interest during construction of 222,485.8 thousand US$ with the residual value rate of 10%.

Table 13-1 Construction Cost and Interest During Construction

Year	Construction Cost		Interest During Construction		Total		Grand Total
	Foreign (Thousand US$)	Local (Million ¢) (Thousand US$)	Foreign (Thousand US$)	Local (Million ¢) (Thousand US$)	Foreign (Thousand US$)	Local (Million ¢) (Thousand US$)	(Thousand US$)
1993	29,218.2	8,504.1 (7,086.7)	1,022.6	744.1 (620.1)	30,240.8	9,248.2 (7,706.8)	37,947.6
1994	38,655.3	9,125.1 (7,604.2)	3,398.2	2,286.7 (1,905.6)	42,053.5	11,411.8 (9,509.8)	51,563.3
1995	6,157.7	2,945.8 (2,454.8)	4,966.7	3,342.9 (2,785.8)	11,124.4	6,288.7 (5,240.6)	16,365.0
1996	8,231.6	4,159.8 (3,466.5)	5,470.3	3,964.6 (3,303.8)	13,701.9	8,124.4 (6,770.3)	20,472.2
1997	5,961.3	2,836.9 (2,364.1)	5,967.0	4,576.8 (3,814.0)	11,928.3	7,413.7 (6,178.1)	18,106.4
1998	7,695.8	3,431.5 (2,859.6)	6,445.1	5,125.3 (4,271.1)	14,140.9	8,556.8 (7,130.7)	21,271.6
1999	5,311.8	2,349.6 (1,958.0)	6,900.3	5,631.1 (4,692.6)	12,212.1	7,980.7 (6,650.6)	18,862.7
2000	19,816.7	5,999.0 (4,999.2)	7,779.8	6,361.6 (5,301.3)	27,596.5	12,360.6 (10,300.5)	37,897.0
Total	121,048.4	39,351.8 (32,793.1)	41,950.0	32,033.1 (26,694.3)	162,998.4	71,384.9 (59,487.4)	222,485.8

13.5 Electricity Sales Revenue

An incremental sales revenue has been estimated for the whole incremental kWh that has been calculated in the economic evaluation.

13.6 Financial Analysis

13.6.1 Debt Service Ratio

(1) The reimbursement plan, the profit and loss statement and the cash flow are presented in Table 13-2, 13-3 and 13-4 respectively. It has been assumed that the interest during construction presented in Table 13-1 is included in the construction cost which is the basis of the borrowed money, and this account is recovered as a part of depreciation.

(2) Debt Service Ratio

The calculated debt service ratio is presented in Table 13-5.

The debt service ratio of the 20 years is 1.31, which is not very high as the index to represent the profitability of a project, but this can be regarded as an acceptable value for a project of low profitability such as improvement of power distribution systems.

In this analysis, an interest rate of 35% per annum, which is a value representing the current financial circumstance in Paraguay, has been assumed. This high interest rate substantially reduces the profitability of this Project.

Therefore, it is very important in maintaining a high profitability of this project to procure the local currency capital, as well as the foreign currency capital, at low costs.

13.6.2 Financial Internal Rate of Return (FIRR)

The flows of expenditures and revenues of this Project is as presented in Table 13-6, and the FIRR is estimated at 10.7%.

Based on this estimation, it can be concluded that this project is financially sound.

Table 13-2 Repayment Schedule of Debt

(Unit: Thousand US$)

No.	Year	Financing for Construction			Repayment of Foreign Currency				Repayment of Local Currency			
		F.C.	L.C.	Total	Interest	Principal	Total	Balance	Interest	Principal	Total	Balance
	1993	30240.8	4163.5	34404.3								
	1994	42053.5	5707.7	47761.2								
	1995	11124.4	4013.2	15137.6								
	1996	13701.9	5037.1	18739.0								
	1997	11928.3	4996.1	16924.4								
	1998	14140.9	5700.9	19841.8								
	1999	12212.1	5671.6	17883.7								
	2000	27596.5	7800.9	35397.4				162998.4				43091.0
1	2001				11409.9	3976.0	15385.9	159022.4	15081.9	789.4	15871.2	42301.6
2	2002				11131.6	4254.3	15385.9	154768.1	14805.6	1065.6	15871.2	41236.0
3	2003				10833.8	4552.1	15385.9	150215.9	14432.6	1438.6	15871.2	39797.4
4	2004				10515.1	4870.8	15385.9	145345.2	13929.1	1942.1	15871.2	37855.3
5	2005				10174.2	5211.7	15385.9	140133.4	13249.4	2621.8	15871.2	35233.5
6	2006				9809.3	5576.6	15385.9	134556.9	12331.7	3539.5	15871.2	31694.0
7	2007				9419.0	5966.9	15385.9	128589.9	11092.9	4778.3	15871.2	26915.7
8	2008				9001.3	6384.6	15385.9	122205.3	9420.5	6450.7	15871.2	20464.9
9	2009				8554.4	6831.5	15385.9	115373.8	7162.7	8708.5	15871.2	11756.4
10	2010				8076.2	7309.7	15385.9	108064.1	4114.8	11756.4	15871.2	0.0
11	2011				7564.5	7821.4	15385.9	100242.7				
12	2012				7017.0	8368.9	15385.9	91873.8				
13	2013				6431.2	8954.7	15385.9	82919.0				
14	2014				5804.3	9581.6	15385.9	73337.5				
15	2015				5133.6	10252.3	15385.9	63085.2				
16	2016				4416.0	10969.9	15385.9	52115.3				
17	2017				3648.1	11737.8	15385.9	40377.5				
18	2018				2826.4	12559.5	15385.9	27818.0				
19	2019				1947.3	13438.6	15385.9	14379.3				
20	2020				1006.6	14379.3	15385.9	0.0				
	Total	162998.4	43091.0	206089.4	144719.5	162998.4	307717.9		115621.0	43091.0	158712.0	

Table 13-3 Statement of Profit and Loss

(Unit: Thousand US$)

No.	Year	Revenue	Business Expenses			Business Profit	Financial Cost		Net Profit
			O&M Cost	Depreciation	Total		Interest Dur.Const.	Interest	
	1993						1642.7		-1642.7
	1994						5303.8		-5303.8
	1995	12101.7	3302.6		3302.6	8799.1	7752.5		1046.6
	1996	15594.3	3647.1		3647.1	11947.2	8774.1		3173.1
	1997	19276.3	4115.0		4115.0	15161.3	9781.0		5380.3
	1998	23143.5	4448.0		4448.0	18695.5	10716.2		7979.3
	1999	27198.0	4870.2		4870.2	22327.8	11592.9		10734.9
	2000	31441.9	5161.0		5161.0	26280.9	13081.1		13199.8
1	2001	31441.9	6153.7	18187.3	24341.0	7100.9		26491.7	-19390.8
2	2002	31441.9	6153.7	16700.5	22854.2	8587.7		25937.1	-17349.5
3	2003	31441.9	6153.7	15335.3	21489.0	9952.9		25266.4	-15313.5
4	2004	31441.9	6153.7	14081.7	20235.4	11206.5		24444.2	-13237.7
5	2005	31441.9	6153.7	12930.6	19084.3	12357.6		23423.5	-11065.9
6	2006	31441.9	6153.7	11873.6	18027.3	13414.6		22141.1	-8726.4
7	2007	31441.9	6153.7	10903.0	17056.7	14385.2		20511.9	-6126.6
8	2008	31441.9	6153.7	10011.7	16165.4	15276.5		18421.8	-3145.3
9	2009	31441.9	6153.7	9193.3	15347.0	16094.9		15717.1	377.8
10	2010	31441.9	6153.7	8441.8	14595.5	16846.4		12190.9	4655.5
11	2011	31441.9	6153.7	7751.7	13905.4	17536.5		7564.5	9972.0
12	2012	31441.9	6153.7	7118.0	13271.7	18170.2		7017.0	11153.2
13	2013	31441.9	6153.7	6536.2	12689.9	18752.0		6431.2	12320.9
14	2014	31441.9	6153.7	6001.9	12155.6	19286.3		5804.3	13482.0
15	2015	31441.9	6153.7	5511.2	11664.9	19777.0		5133.6	14643.3
16	2016	31441.9	6153.7	5060.7	11214.4	20227.5		4416.0	15811.5
17	2017	31441.9	6153.7	4647.0	10800.7	20641.2		3648.1	16993.1
18	2018	31441.9	6153.7	4267.1	10420.8	21021.1		2826.4	18194.6
19	2019	31441.9	6153.7	3918.3	10072.0	21369.9		1947.3	19422.6
20	2020	31441.9	6153.7	3598.0	9751.7	21690.2		1006.6	20683.6
	Total	757593.7	148617.9	182069.0	330686.9	426906.8	68644.3	260340.6	97921.9

Table 13-4 Cash Flow

(Unit: Thousand US$)

No.	Year	Cash Inflow				Cash Outflow			Balance	
		Financing	Net Profit	Depreci-ation	Total	Investment	Repayment of Princi.	Total	Year	Accumlated
	1993	34404.3	-1642.7		32761.6	34404.3		34404.3	-1642.7	-1642.7
	1994	47761.2	-5303.8		42457.4	47761.2		47761.2	-5303.8	-6946.5
	1995	15137.6	1046.6		16184.2	15137.6		15137.6	1046.6	-5899.9
	1996	18739.0	3173.1		21912.1	18739.0		18739.0	3173.1	-2726.8
	1997	16924.4	5380.3		22304.7	16924.4		16924.4	5380.3	2653.5
	1998	19841.8	7979.3		27821.1	19841.8		19841.8	7979.3	10632.8
	1999	17883.7	10734.9		28618.6	17883.7		17883.7	10734.9	21367.7
	2000	35397.4	13199.8		48597.2	35397.4		35397.4	13199.8	34567.5
1	2001		-19390.8	18187.3	-1203.5		4765.4	4765.4	-5968.9	28598.6
2	2002		-17349.5	16700.5	-648.9		5320.0	5320.0	-5968.9	22629.7
3	2003		-15313.5	15335.3	21.8		5990.7	5990.7	-5968.9	16660.8
4	2004		-13237.7	14081.7	844.0		6812.9	6812.9	-5968.9	10691.9
5	2005		-11065.9	12930.6	1864.7		7833.6	7833.6	-5968.9	4723.0
6	2006		-8726.4	11873.6	3147.1		9116.0	9116.0	-5968.9	-1245.9
7	2007		-6126.6	10903.0	4776.3		10745.2	10745.2	-5968.9	-7214.8
8	2008		-3145.3	10011.7	6866.4		12835.3	12835.3	-5968.9	-13183.7
9	2009		377.8	9193.3	9571.1		15540.0	15540.0	-5968.9	-19152.6
10	2010		4655.5	8441.8	13097.3		19066.2	19066.2	-5968.9	-25121.5
11	2011		9972.0	7751.7	17723.7		7821.4	7821.4	9902.3	-15219.2
12	2012		11153.2	7118.0	18271.2		8368.9	8368.9	9902.3	-5316.9
13	2013		12320.9	6536.2	18857.0		8954.7	8954.7	9902.3	4585.4
14	2014		13482.0	6001.9	19483.9		9581.6	9581.6	9902.3	14487.7
15	2015		14643.3	5511.2	20154.6		10252.3	10252.3	9902.3	24390.0
16	2016		15811.5	5060.7	20872.2		10969.9	10969.9	9902.3	34292.3
17	2017		16993.1	4647.0	21640.1		11737.8	11737.8	9902.3	44194.6
18	2018		18194.6	4267.1	22461.8		12559.5	12559.5	9902.3	54096.9
19	2019		19422.6	3918.3	23340.9		13438.6	13438.6	9902.3	63999.2
20	2020		20683.6	3598.0	24281.6		14379.3	14379.3	9902.3	73901.5
	Total	206089.4	97921.9	182069.0	486080.3	206089.4	206089.4	412178.8	73901.5	

Table 13-5 Calculation of Debt Service Ratio

(Unit: Thousand US$)

No.	Year	Internal Fund Procured				Repayment of Debt				Debt Service Ratio
		Business Profit	Depreciation	Total	Accumlated	Interest	Principal	Total	Accumlated	
					(A)				(B)	(A)/(B)
	1993									
	1994									
	1995	8799.1		8799.1	8799.1					
	1996	11947.2		11947.2	20746.3					
	1997	15161.3		15161.3	35907.6					
	1998	18695.5		18695.5	54603.1					
	1999	22327.8		22327.8	76930.9					
	2000	26280.9		26280.9	103211.8					
1	2001	7100.9	18187.3	25288.2	128500.0	26491.7	4765.4	31257.1	31257.1	
2	2002	8587.7	16700.5	25288.2	153788.2	25937.1	5320.0	31257.1	62514.2	
3	2003	9952.9	15335.3	25288.2	179076.4	25266.4	5990.7	31257.1	93771.3	
4	2004	11206.5	14081.7	25288.2	204364.6	24444.2	6812.9	31257.1	125028.4	
5	2005	12357.6	12930.6	25288.2	229652.8	23423.5	7833.6	31257.1	156285.5	1.47
6	2006	13414.6	11873.6	25288.2	254941.0	22141.1	9116.0	31257.1	187542.6	
7	2007	14385.2	10903.0	25288.2	280229.2	20511.9	10745.2	31257.1	218799.7	
8	2008	15276.5	10011.7	25288.2	305517.4	18421.8	12835.3	31257.1	250056.8	
9	2009	16094.9	9193.3	25288.2	330805.6	15717.1	15540.0	31257.1	281313.9	
10	2010	16846.4	8441.8	25288.2	356093.8	12190.9	19066.2	31257.1	312571.0	1.14
11	2011	17536.5	7751.7	25288.2	381382.0	7564.5	7821.4	15385.9	327956.9	
12	2012	18170.2	7118.0	25288.2	406670.2	7017.0	8368.9	15385.9	343342.8	
13	2013	18752.0	6536.2	25288.2	431958.4	6431.2	8954.7	15385.9	358728.7	
14	2014	19286.3	6001.9	25288.2	457246.6	5804.3	9581.6	15385.9	374114.6	
15	2015	19777.0	5511.2	25288.2	482534.8	5133.6	10252.3	15385.9	389500.5	1.24
16	2016	20227.5	5060.7	25288.2	507823.0	4416.0	10969.9	15385.9	404886.4	
17	2017	20641.2	4647.0	25288.2	533111.2	3648.1	11737.8	15385.9	420272.3	
18	2018	21021.1	4267.1	25288.2	558399.4	2826.4	12559.5	15385.9	435658.2	
19	2019	21369.9	3918.3	25288.2	583687.6	1947.3	13438.6	15385.9	451044.1	
20	2020	21690.2	3598.0	25288.2	608975.8	1006.6	14379.3	15385.9	466430.0	1.31
	Total	426906.8	182069.0	608975.8		260340.6	206089.4	466430.0		

Table 13-6 Cost Flow and Revenue Flow of Adopted Improvement Plan

(Unit: Thousand US$)

Serial Number	Year	Cost			Revenue	B - C
		Investment Cost	O&M Cost	Total		
0	1992			0.0		0.0
1	1993	37947.6		37947.6		-37947.6
2	1994	51563.3		51563.3		-51563.3
3	1995	16365.0	3302.6	19667.6	12101.7	-7565.9
4	1996	20472.2	3647.1	24119.3	15594.3	-8525.0
5	1997	18106.4	4115.0	22221.4	19276.3	-2945.1
6	1998	21271.6	4448.0	25719.6	23143.5	-2576.1
7	1999	18862.7	4870.2	23732.9	27198.0	3465.1
8	2000	37897.0	5161.0	43058.0	31441.9	-11616.1
9	2001		6153.7	6153.7	31441.9	25288.2
10	2002		6153.7	6153.7	31441.9	25288.2
11	2003		6153.7	6153.7	31441.9	25288.2
12	2004		6153.7	6153.7	31441.9	25288.2
13	2005		6153.7	6153.7	31441.9	25288.2
14	2006		6153.7	6153.7	31441.9	25288.2
15	2007		6153.7	6153.7	31441.9	25288.2
16	2008		6153.7	6153.7	31441.9	25288.2
17	2009		6153.7	6153.7	31441.9	25288.2
18	2010		6153.7	6153.7	31441.9	25288.2
19	2011		6153.7	6153.7	31441.9	25288.2
20	2012		6153.7	6153.7	31441.9	25288.2
21	2013		6153.7	6153.7	31441.9	25288.2
22	2014		6153.7	6153.7	31441.9	25288.2
23	2015		6153.7	6153.7	31441.9	25288.2
24	2016		6153.7	6153.7	31441.9	25288.2
25	2017		6153.7	6153.7	31441.9	25288.2
26	2018		6153.7	6153.7	31441.9	25288.2
27	2019		6153.7	6153.7	31441.9	25288.2
28	2020		6153.7	6153.7	31441.9	25288.2
29	2021		6153.7	6153.7	31441.9	25288.2
30	2022		6153.7	6153.7	31441.9	25288.2
31	2023		6153.7	6153.7	31441.9	25288.2
		222485.8	167079.0	389564.8		462354.6

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