The recommended countermeasures for the problems are as follows:

(a) Construction of connecting lines among the power stations;
(b) Unification of distribution voltage;
(c) Maintenance and reinforcement of the high and low voltage distribution lines;
(d) Installation of consumers' meters;
(e) Procurement of materials and parts for operation and maintenance; and
(f) Training of staff.

8.1.3 Load Dispatching Facilities

The current load dispatching system of EDP and its related problems were mentioned in Chapter 5. In this Section, countermeasures to solve the problems are discussed.

The current load dispatching method is presumed to be acceptable for small scale power systems and distribution networks. The countermeasures shall be based on EDP's familiar system.

8.2 Generating Facilities

8.2.1 Rehabilitation Plans

(1) No. 1 Power Station

The oldest generator in this plant was manufactured in 1926 and has been used for 67 years. The newest was built in 1966, and has been in use for 27 years. Of the 11 generators, only five appear currently operational. According to the EDP inspection, spare parts cannot be acquired for the older generators, and agreement to make spare parts could be obtained only from the manufacturer of the newest generator (built in 1966, with a rated capacity of 3,120 kW and current output of only 1,500 kW), who has offered only to provide parts for that specific generator. Even for this generator, however, an extended delivery period is required, and the cost for the parts is considerable. Purchasing new parts, therefore, does not appear to be a cost effective method of obtaining an increase of only 1,620 kW.

Thus, it appears almost impossible to rebuild the power station with the existing generators. In addition, with the exception of the newest generator, ten of the generators are 2 phase special generators, which supply power only to the 4.4 kV 2 phase power system operational within Phnom Penh. As this special system is to be changed to a 3-phase 15 kV system, restoration of these 10 generators would be a most inefficient and ineffective project. Owing to the impossibility of obtaining spare parts, one option would be to forgo any comprehensive rehabilitation of the 10 older generators, and to use them to adjust the voltage in the city's power system, for the remainder of their useful life-span.

The Study Team is in complete agreement with this option. However, the Study Team also believes that the 1966 generator should be used to its fullest capacity, and that improved operation and maintenance is required. In addition, as a designated oil and cooled water pipeline has been laid from the Tonle Sap to the No. 1 Power Station, we believe that this site should be a candidate for conversion to a new power station. Further, a 110 kV transmission line has been constructed connecting the former Kirirom Hydroelectric Power Station with the No. 1 Power Station. Therefore, the Study Team advised that, after restoration of the Kirirom Power Station the No. 1 Power Station site be used for a 110 kV receiving substation.

As of February 1993, no foreign countries or international institutions have presented any plans for rehabilitation of the No. 1 Power Station. We therefore feel there is no possibility that the output capacity will exceed the present capacity of 4,460 kW of the existing facilities at this station.

(2) No. 2 Power Station

The No. 2 Power Station is the largest power plant in Cambodia, possessing facilities with a 28,400 kW capacity. It also has the only steam power generators in Cambodia: three 6,000 kW units. These steam generators supply 45-50% of Phnom Penh's power at present, making them vital for the city's grid. Since November 1992, three engineers have been dispatched from the Czech manufacturer. They are presently supervising plant repair and overhaul using parts supplied from the manufacturer. Once this work is completed, these three steam generators can be expected to operate at their rated capacity of 6,000 kW each. As overhaul is scheduled for completion at the end of 1993, the No. 2 Power Station steam generators can be expected to increase output by 8,000 kW from the beginning of 1994, from the present 10,000 kW to 18,000 kW.

In addition to the steam generators, there were also 5 diesel generators with a unit capacity of 2,100 kW each. One of these was discarded in 1979, however, and of the 4 remaining generators, only two are actually operational, owing to breakdowns and a shortage of spare parts. In addition, neither of these two operate at rated capacity. These diesel generators are of 1973 USA manufacture, making it impossible to obtain spare parts. Thus, rehabilitation of these four generators is a problem requiring an urgent solution.

According to EDP and UNDP explanations, the Government of Ireland has decided to provide assistance for repair and overhaul of the four diesel generators, with completion scheduled for the end of 1993. This repair would make it possible to restore diesel generated electricity at the No. 2 Power Plant from the present 3,000 kW to 7,200-8,400 kW.

(3) No. 3 Power Station

Three generators at this plant are of the same model and year of manufacture as the diesel generators at the No. 2 plant. Two of the three generators installed are out of order, and output at the remaining No. 3 generator has fallen from its rated capacity of 2,100 kW to 1,500 kW. While these generators were produced 20 years ago, they are quite necessary for Phnom Penh's present power system, and should be restored quickly, so that their lifespan can be extended until such time as new facilities, which can supply sufficient power, are built.

Ireland has agreed to repair and overhaul all three generators at this plant, in addition to repairing the No. 2 Power Station diesel generators. This assistance will increase capacity at the No. 3 Power Station from the present 1,500 kW to 5,400 kW-6,300 kW.

(4) No. 4 Power Station

This station boasts the most modern generators in Phnom Penh with a total installed capacity of 15,000 kW (manufactured in 1984 and 1987). However, as of February 1993, three of the five existing generators were not operational, and total output from this station had fallen to 5,200 kW. Complete restoration of this generator would result in an increased capacity of 40% of Phnom Penh's present total capacity of 24,160 kW. This would be a major contribution to restoration of the city's power stations, making such restoration one of the most important and urgent projects in the entire master plan.

The facilities at the No. 4 Power Station are precisely the same as those for the No. 5 Power Station which is on adjoining land, and was never completed. The EDP has decided not to complete the No. 5 Power Station, and to cannibalize the facilities and equipment at the No. 5 Station to provide parts for the No. 4 Station. In fact, parts have already been taken from generators 1 through 4 at the No. 5 Station, and used for the No. 4 Station. The UNDP also supports quick restoration of the No. 4 Power Station, and plans to provide technical support based on the EDP plan to use the equipment at the No. 5 Station for repair of the No. 4 Station. The UNDP reconstruction plan involves guidance on repair, operation and maintenance of the No. 4 power station to be provided by specialists from the former Soviet Union.

The UNDP intends to restore all five generators by the end of 1995, and to increase the present output of 5,200 kW to the rated capacity of 15,000 kW.

(5) No. 5 Power Station

With the collapse of the former Soviet Union, it has become difficult to obtain spare parts for this facility. In addition, operating cost is higher than for other stations, and the quality of equipment already installed has deteriorated. It is therefore inadvisable to complete this plant. EDP and UNDP reached the proper decision by concluding not to re-commence construction, and to cannibalize this station for spare parts for the No. 4 Power Plant. In addition, the station site, buildings, overhead traveling cranes, and machine foundations can also be put to effective use for an expanded power station. Thus, the Study Team does not recommend restoration of the No. 5 Power Station, and advises that the equipment on-site be used for a new plant.

(6) Summary of Rehabilitation Plans

The preceding was a summary of the Study Team's recommendation concerning rehabilitation projects for existing power facilities, as well as the trends for aid from various countries. As shown in the following chart, power outputs after rehabilitation of the various power stations in 1995 will have increased greatly over the present.

Increase of Possible Power Output

Unit: kW

Power Station	Assisting Country & Institution	Feb. 1993	End 1993	End 1994	End 1995
No. 1	-	4,650	4,650	4,650	4,650
No. 2 Steam	Czech	10,000	12,000	18,000	18,000
No. 2 Diesel	Ireland	3,000	8,400	8,400	8,400
No. 3	"	1,500	1,500	6,300	6,300
No. 4	UNDP	5,200	5,200	5,200	15,000
No. 5	-	-	-	-	-
Total		24,350	31,750	42,550	52,350

As stated in section 8.2.1, the wisest decision for Power Station No. 1 is not to restore the station. Rehabilitation of other stations is either being planned or is actually being performed by the Czech Republic, Ireland, or UNDP. At present, therefore, there is no need for Japan's participation.

As seen in Tables I.5.1 to I.5.4, the diesel engine-generators presently running in the No. 1 power station are of low speed, while diesel type generating sets in the No. 2 and No. 3 power stations are of medium speed and that in the No. 4 power station is of high speed. Operation of those generating sets after rehabilitation is expected to be as follows taking account their functions and remaining service lives. The No. 1 power station is desirable to be operated for the system peak demand or standby of the system for prolonging its life. Steam turbine-generator sets in the No. 2 power station will be used for the system base demand, while diesel type generating sets in the No. 2 and No. 3 power stations will be used for the system peak demand in consideration of the past long service period. The No. 4 power station will be operated for the system peak demand because of high speed machines and unreliable supply of spare parts.

From such operation system, generating capacity of the rehabilitated facilities will be 18,000 kW for the base demand and 34,350 kW for the peak demand.

8.2.2 Plan for Expansion

Whilst restoration of existing facilities will increase by more than double present output, this will not be sufficient to meet continuously growing needs. As Cambodia is not a petroleum producer, development should ideally emphasize her abundant hydraulic resources as much as possible. However, owing to the long period required for development of a hydropower plant and the required experience in maintenance and operation required by Cambodian technicians, expansion in the short term should center around installation of diesel engine or steam turbine generators.

Hydroelectric power development takes seven to eight years from the time of initial feasibility study through initial power generation. Even restoration of a destroyed plant would take six years. Thus, assuming Cambodia were stable enough, a new plant would not be completed until the year 2000 or 2001, while restoration of a destroyed plant would take until 1999. For this reason, Cambodia must rely completely on combustion generators at least until 1999. It seems to be optimistic that MOI expects the completion of restoration to the destructed Kirirom hydropower system to be around the end of 1997.

Once potential demand and distribution loss are taken into consideration, Phnom Penh's power requirements will reach 58,000 kW by the end of 1995, and 83,000 kW by 1999. Possible output in 1995, including planned restoration of existing facilities, yields only 52,350 kW, a shortage of 5,650 kW, which will balloon to 30,650 kW by 1999.

(1) Assistance of Foreign Countries and International Institutions

To remedy this situation, expansion projects are being promoted. Research with the Ministry of Industry, EDP, and UNDP in Phnom Penh has confirmed that the following plans are under consideration as of January 1993.

(a) Aid from France

Installation of a 1,800 kW diesel generator in the existing No. 1 Power Station. This generator was in transit as of January 1993, and operation is scheduled to begin in August of 1993. As stated above, since there are diesel generators in the No. 1 Power Station which should be discarded, the new generator can make use of existing buildings, machine foundations, and the overhead crane.

(b) Aid from Italy

Installation of a 4,200 kW diesel generator in the No. 3 Power Station. Italy is also to supply the transformer and switchgears accompanying this generator. While the details of this project have not been revealed, there is a site available for these facilities, and the scheduled date for completion is within 1994.

(c) Financing from the Asia Development Bank (ADB)

EDP plans to install diesel generators totaling 12,000 kW with financing from ADB. These will be installed in the No. 1 or No. 4 Power Station. Unit capacity and number of generators have yet to be determined. According to EDP and UNDP, installation is to be completed before 1995.

(d) Financing from the World Bank

According to EDP and UNDP, four diesel generators with unit capacities of 2,100 kW each are to be installed in the No. 2 or No. 3 Power Station, for a total of 8,400 kW. Installation is scheduled to be completed before 1995.

The following table presents the additional output from expansion plans presently undertaken by other countries as well as international organizations.

Additional Power Output

(Unit: kW)

Power Station	Assisting Country & Institution	Feb. 1993	End 1993	End 1994	End 1995
No. 1	France	-	1,800	1,800	1,800
No. 3	Italy	-	-	4,200	4,200
No. 1 or No. 4	ADB	-	-	-	12,000
No. 2 or No. 3	World Bank	-	-	-	8,400
Total		-	1,800	6,000	26,400

The following table presents the balance between total generating capacity and demand as of year end 1993 through 1999 including rehabilitation and expansion of the generating facilities.

Power Demand/Supply Schedule

(Unit: kW)

Year	1993	1994	1995	1996	1997	1998	1999
Output from restoration	24,350	31,750	42,550	52,350	52,350	52,350	52,350
Output from expansion	1,800	1,800	6,000	26,400	26,400	26,400	26,400
Total output	26,150	33,550	48,550	78,750	78,750	78,750	78,750
Demand required	47,000	53,000	58,000	62,000	69,000	76,000	83,000
Allowance for inspection of the largest unit	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Total output required	53,000	59,000	64,000	68,000	75,000	82,000	89,000
Demand/supply balance	-26,850	-25,450	-15,450	10,750	3,750	-3,250	-10,250

(2) Recommendation to Assistance from Japan

Despite timely efforts by various countries and international organizations, demand will continue to outstrip supply through the end of 1995, making planned load shedding unavoidable.

Although demand can be expected to meet supply after 1995, this balance will only be temporary, and Cambodia will once again have a capacity shortage from mid-1998. Since hydroelectric power contributions can only be expected from 2000 at the earliest, as stated previously, Cambodia will depend completely on combustion generators at least until the end of 1999. Therefore, as the Study Team has determined that no plans for expanded combustion generation exist, other than those discussed above, Japan should provide assistance for at least 10,000 kW in consideration of maintenance interruption for one of the largest units (6,000 kW).

Except for 1 unit x 1,800 kW assisted by France, such details as unit capacity, machine speed, etc. of the generating equipment supplied by other international institutions are not disclosed at the present. As described in subsection 8.2.1(6), generating facilities operated for the base demand in the Phnom Penh power system are 18,000 kW (3 x 6,000 kW) only of steam turbine generator sets in the No. 2 Power Station. That capacity will be 20% to 25% of the generating requirement in the system for the years 1996 to 1999. It will be down to 14% to 17% when one unit (6,000 kW) is stopped for periodical inspection or failure. Since the generating equipment assisted by Japan is expected to be of high efficiency and low fuel consumption, the equipment will be operated for the system base demand. Type and function of the generating equipment from Japan will be selected in consideration of such an operation mode.

The existing generators and auxiliary equipment for the No. 5 Power Station are to be cannibalized for the No. 4 Power Station. However, the buildings, control room, office, machine foundations, overhead crane, and site can still be used. Therefore, installation of new generators on the existing No. 5 site would make good economic use of Japanese aid, and would also fit in well with the power generation balance on Phnom Penh's North/South grid.

A further problem is the lack of sub-contracting companies in Cambodia which can takeover construction and maintenance work. Our advice therefore, is at the time of constructing facilities with Japanese assistance, employees for each facility be recruited, and given practical experience working with Japanese contractors. This will enable local personnel to gain on-the-job training and experience in actual construction of the facility, and a knowledge of component functions.

8.2.3 Promotion of Hydroelectric Power Production

Combustion plants provide almost all power not only for Phnom Penh, but also throughout Cambodia. This presents a major drain on foreign currency, which is a major problem for Cambodia's development. Thus, it would be desirable to convert Cambodia's power source as much as possible to hydroelectric power which would make use of Cambodia's rich water resources, and enable her to reduce petroleum imports.

Over the medium term, this would involve developing the resources contained in the Caradamone mountain range to realize a hydroelectric power plant which would supply power to Phnom Penh and neighboring areas. Over the short term, however, the most realizable projects would be the Kirirom power station, which was in operation prior to the war, and the Prek Thnot power station, which was under construction.

The Kirirom power station operated at 10 MW and supplied power to Phnom Phenh. During the war, most of the generating machines and transmission lines were destroyed, but the dam and station building still remained. Austria has promised grant aid to repair the dam and to supply generating facilities, and a no-interest loan for restoration work. Completion of this project, as soon as possible, would be highly desirable.

The Prek Thnot project was designed to provide 18 MW of power, and to irrigate 70,000ha of crop land. While construction was started, the project was abandoned during war. Equipment was transported into Cambodia and has been stored in Phnom Penh. If construction begins again, the project could be completed relatively quickly. A project survey was recently conducted by the Australian Catholic Relief (ACR), with a view to recommencing work. Completion of this project should have top priority, as it would make a major contribution to rebuilding Phnom Penh's power grid.

In addition to Kirirom and Prek Thnot, development of the Camchay Power Project between Phnom Penh and Kampong Som would also provide considerable electricity. This plan is a 100,000 kW level project, which would supply power to both cities. Early realization of this project would also greatly assist Cambodia's output capacity.

Over the long term, development of the Mekong River Basin is necessary. As this would supply power not only to Phnom Penh, but also throughout Cambodia, construction of transmission lines would be required. In addition, studies should be made of the possibility of exporting excess power from this site to neighboring countries.

8.3 Distribution Facilities

8.3.1. Unification of Distribution Voltage

Operation and maintenance of the distribution lines in Phnom Penh is complicated, because there are three high voltage distribution lines (15 kV, 4.4 kV, 6.3 kV).

Moreover, the double-circuit 4.4 kV line is not connected to the other system and it can not be connected to the 3-phase load device for power transmission. Unification of distribution line voltage is a prerequisite for standard operation and maintenance.

The works required to boost the 4.4 kV system to 15 kV shall be executed under the technical assistance of the Government of France in the model areas. It is envisaged that EDP's staff will be trained during these works. The necessary equipment and materials required to boost the voltage shall be salvaged from the existing equipment supplied by the former Soviet Union, while the new equipment and materials required shall be provided by the Government of France. The Government of France shall also provide spare parts, in order to execute the works smoothly. On the other hand, it is envisaged that the above-mentioned trained staff, will be able to unify the small scale 6.3 kV distribution line network by utilizing transformers from the former Soviet Union.

Upgrade of the existing 4.4 kV and 6.3 kV systems to the 15 kV system to increase their line capacities, to improve their voltage regulation, and to reduce their line losses, will give benefit to both customers and EDP.

8.3.2 Density of Power Demand

Restoration and expansion plan will be formulated on the basis of the results of examination on areal demand density in the town.

Since there are no detailed areal demand records in addition to the present situation under load shedding, it is assumed that capacity of the distribution transformers installed in the area represents the present power demand. The private generating facilities operated in the town are excluded from the examination, because of inadequate data of the generators' installed capacity.

Following are demand densities of the city blocked into eight areas as shown in Figure I.8.1.

Power System	Area No.	Total Capacity of Transformers (kVA)	Area (km^2)	Demand Density (kVA/km^2)	Order of Density
North	1	7,047.5	2.920	2,414	6
	2	8,094.0	1.186	6,825	2
	3	9,379.0	1.917	4,893	4
	4	7,900.0	1.132	6,979	1
	5	10,439.0	1.820	5,736	3
South	6	10,450.0	3.030	3,449	5
	7	5,582.5	3.805	1,467	8
	8	9,365.0	6.910	1,355	7

High density areas are concentrated in the northern power system, in particular, in the north-eastern part of the town. There are government offices, embassies, central market as well as a number of shops, hotels, and restaurants. Power to this area is supplied by the No. 1 and No. 4 Power Stations through 4.4 kV and 15 kV lines.

8.3.3 Connection of Power Stations

The existing four power stations are divided into two power systems, the Northern power system covering the No.1 and No.4 Power Stations, and the Southern power system covering the No.2 and No.3 Power Stations. Furthermore, there are no connections among the power stations and both power systems are operating separately.

Flexible power exchange is impossible in this system under the above-mentioned circumstances, and the following problems hinder the operation of the power stations and the power systems.

(1) Quick response to restore a system fault is not conducted.
(2) Difficulty for operation stoppage of a generating set to make periodical inspections or overhaul.
(3) Each generating set is not operated economically.

Construction of exclusive connecting lines in order to connect all the power stations together including the No. 5 Power Station, is recommended for flexible power exchange among the power stations.

The other donors countries and international agencies do not at present, have any plans for implementation of above-mentioned countermeasures, therefore, it is expected that they will be carried out under the assistance of the Government of Japan.

It is recommended that the following transmission lines be installed (underground in residential areas).

(a) P/S No.1 - No.5 : 0.4km (underground)
(b) P/S No.5 - No.4 : 0.2km (underground)
(c) P/S No.5 - No.3 : 8.5km (overhead and underground)
(d) P/S No.3 - No.2 : 11.0km (overhead and underground)

8.3.4 Rehabilitation and Reinforcement of High Voltage Distribution Lines

(1) Recommendation and Implementation Program

High voltage distribution lines including transformers and switches were constructed about 25 years ago, and no renewal has been made since then. It is anticipated that more power failures will continue to occur unless measures are taken. Sizes of conductors and underground cables are insufficient for the growing power demand, and deteriorated insulators and other facilities will increase technical energy loss and troubles on the lines. Deterioration of protective devices and switches as well as insufficient installation of those devices and equipment are enforcing no-load switching operation in almost all substations and transformer houses in the system. Therefore, it takes more time to operate switching-off or switching-on of the facilities, and requires power interruption at switching time. Due to addition of switches, such time should be shortened and power interruption should be avoided.

The following measures should be implemented on the high voltage lines in order to:

(a) Increase distribution line capacity for reduction of energy losses and prevent further deterioration.

(b) Replace the existing deteriorated insulators for reducing power failures caused by superannuated materials.

(c) Add and/or renew protection devices and switches of substations and transformer houses.

EDP and UNDP reported that a lot of 15 kV cables, conductors, and equipment for distribution lines supplied by the former Soviet Union are stocked in EDP's warehouses. Improvement of high voltage lines in the network will be achieved by EDP itself, if donor countries supplement construction tools, safety equipment, testing apparatus, power fuses, load break switches, etc. with experts for construction and maintenance of distribution lines.

France is to supply about 60 transformers (40 kVA to 250 kVA unit capacity). While, UNDP and ADB are programming to assist in restoration of the distribution lines including improvement of low voltage lines.

(2) Assistance from Japan

Improvement of the distribution lines will be executed by EDP under assistance of France, UNDP, and ADB as discussed above. However, provision of new 15 kV lines from the No. 5 Power Station to the heavy loading area in the town will much improve the existing power supply in the area and advance the earliest effect of the power station. The Study Team's recommendable program is to construct new 15 kV lines from the No. 5 Power Station to existing substations (No. 8, No. 127 and No. 193) mainly to improve the heaviest loaded areas (No. 2, 4, 5) and adjacent areas. The program will give the following effects to the areal power systems:

- Stable power supply to such important facilities as governmental offices, embassies, and a railway factory,
- Stable power supply to the loading areas No. 1 and No. 3 from both the No. 4 and No. 5 Power Station through a newly arranged loop system network,
- More power supply from the No. 3 Power Station to other areas due to additional power supply from the No. 5 Power Station, and
- Release of over-loaded lines from the No. 20 substation.

It is recommended that the following facilities will be provided, under Japan's assistance, for the areas heavily loaded.

(a)	New 15 kV single circuit underground cable line from the No. 5 Power Station to the No. 8 substation	2.8 km approx.
(b)	New 15 kV single circuit underground cable line from the No. 5 Power Station to the No. 193 substation	3.3 km approx.
(c)	Upgrade of 4.4 kV lines to 15 kV lines among the No. 8, No. 7, and No. 127 transformer houses	1.2 km approx.
(d)	New 15 kV single circuit underground cable line from the No. 20 substation to the new transformer house	0.3 km approx.
(e)	Replacement of 250 kVA, 15 kV/380-220 V transformers	2 units
(f)	New transformer house for a 250 kVA, 15 kV/380-220 V transformer	1 unit

8.3.5 Rehabilitation and Reinforcement of Low Voltage Distribution Lines

Recommendations for the restoration of low voltage lines are outlined as follows:

(1) To modity the existing service wiring system (direct connection from substations or transformer houses to customers) to feeder system adopted in advanced countries. Low voltage feeders with adequate conductors on distribution poles should be provided and demand meters to each customers end should be installed. This system will improve the existing network on the following aspects:

(a) Reduction of energy losses,
(b) Application of appropriate power rate to customers,
(c) Improvement of the environment in the city due to rearrangement of the existing untidy lines, and
(d) Reduction of power failures due to avoidance of short circuits between conductors.

(2) To adopt insulated aerial bundled conductors to low voltage lines. Adoption of the conductors will give following effects.

(a) Improvement of the environment,
(b) Remarkable reduction of power failures due to a reduction of short circuits between conductors, and
(c) More income to EDP due to a reduction of illegal connections.

(3) To supply and install customer demand meters and breakers for prevention of power faults and their affect on other customers.

Both UNDP and ADB have programs for restoration of low voltage lines as well as for high voltage lines. France is supplying various tools and 10,000 customer demand meters.

8.4 Load Dispatching Facilities

Data transmission and system control equipment are essential for load dispatching facilities. Currently, the information collected, such as on circuit breakers, is conveyed to the load dispatching center using portable radios.

At present, the distribution line and dispatching center is monitored among power stations and between vehicles using two channel portable transceivers on community-shared bands.

Data on the condition of the power generators and feeders as well as the specific transformer interrupted are recorded in log sheets at the load dispatching center. However, the present system board cannot cope with the information received.

Therefore, recommendations for the load dispatching center are as follows:

8.4.1 Exclusive Communications for Load Dispatching

The transceivers in use have only two channels and it is almost impossible to communicate because of frequent interference. One improvement measure is to facilitate a power line carrier telecommunications system. It is, however, not practicable in the present situation as the systematical high voltage distribution network has not been fully consolidated. It is recommended that an exclusive line for data collection, 400 Mz 10-channel fixed radios in the load dispatching centers of the power stations and portable radios for operational vehicles monitoring the distribution lines, be installed.

The equipment recommended is as follows:

(a)	Load Dispatching Center	Fixed radios	1
(b)	Power stations	Fixed radios	5
(c)	Operational vehicles	Portable radios	4

Antennas will be installed at each station and on each vehicle. The recommended facilities will have 10 channels and will not interfered with each other even when all facilities are transmitting at the same time.

8.4.2 New System Control Panel for Distribution Line

A new system control panel should be installed for operation of the power generators, control of the circuit breakers, and assessment of the operational condition of the distribution lines for each system.

The system control panel indicates the location of the power stations, transformers, circuit breakers, disconnecting switches, and distribution lines on the connecting diagram as well as their operation condition.

The network is monitored manually by radios and its condition is indicated by lamps on the control panel. Automatic and remote control mechanisms are not recommended at present.

8.5 Other Recommendations

8.5.1 Maintenance Tools and Spare Parts

Having the proper tools and measuring instruments is vital for proper installation, operation, maintenance, and repair. However, there is a tremendous shortage of these tools and parts at the existing power stations.

EDP's central workshop is provided with general mechanical tools for repair of power equipment. It was observed that there is not a sufficient number of tools and measuring instruments in each power plant for proper operation and maintenance, and limited tools and instruments are circulated among the plants and distribution systems.

The insufficient and improper tools and instruments lead to delays in the inspection and repair of the equipment and cause faster deterioration of the facilities.

Shortage of spare parts accelerates deterioration of the facilities as well, and forces the interruption of their operation.

Detailed inspection is required on site for supply of necessary tools, instruments, and spare parts. Projects undertaken by donor countries and institutions assisting the reconstruction programs will supply sufficient number of tools, instruments, and spare parts for proper operation and maintenance.

It is recommended that assistance of Japan will include two years operation and maintenance.

8.5.2 Personnel Training

Owing to war, there has been an unavoidable decline in the skill of Cambodia's engineers and technicians. The Study Team strongly advises, therefore, that personnel training be carried out with regard to operation and maintenance of the power facilities, at the same time as the plant reconstruction project is instituted. The most appropriate method would be on-the-job training from the assisting institution, providing practical experience in operation and maintenance through the execution of the reconstruction project at each generating facility. In addition, the EDP has various catalogs and manuals on existing equipment and devices, however, most of these manuals are written in either French or Russian, the others are in German or English. They must therefore be translated into Khmer in order for the operation and maintenance personnel. UNDP has noted this problem and is examining a technical assistance project relating to training of human resources for the power facilities in Phnom Penh and Sihanoukville City. It would be highly desirable for this project to be realized as soon as possible.

8.6 Environment Protection

There are no particular regulations/rules on general environment protection and preservation at present in Cambodia. However, every donor country and institution assisting rehabilitation and reconstruction of the power facilities should obey the following minimum measures in implementing their programs:

(1) Exhaust Gas

(a) NO_X exhaust density should be reduced by adjusting the equipment.

(b) SO_X, soot, and smoke is not required to be to be conttrolled if diesel oil is used for generation.

(2) Noise

Although no regulation/rule is established, noise from power stations will be reduced by provision of an intake air silencer and exhaust gas silencer.

(3) Vibration

Vibration will be much absorbed by provision of an elastic support for each diesel engine and generator set.

(4) Drainage of Water and Sludge

A sludge treatment device will segregate oil and water from diesel power stations. Water segregated from oil will be drained into the specified route, while segregated oil and sludge will be stocked in a waste oil storage tank for conveying to a specified place by tank lorry.

(5) Route Selection and Design of New Lines

Routes should be selected avoiding green belts, housing areas and scenic areas, as far as possible. Conductor arrangement on supports should be designed so as not to spoil the environment.

8.7 Project Assessment

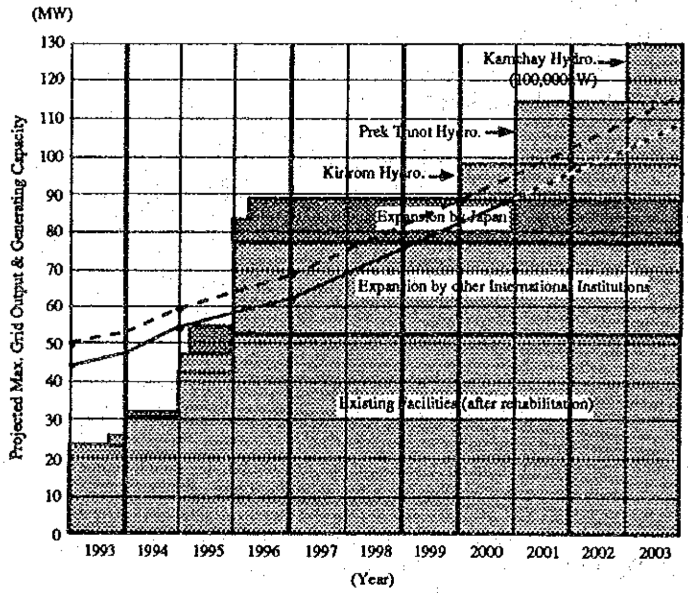
8.7.1 Generating Facilities

Power output from existing stations in Phnom Penh has fallen drastically owing to superannuation, and cannot be restored by Cambodia alone due to financial constraints. For this reason, supply has lagged far behind demand, severely hindering the reconstruction of Cambodia's infrastructure, and the recovery of her economy.

The first step to remedy this situation is to restore existing power facilities, and the second step is to increase generating output through expansion and installation of new generators and power stations.

Restoration of existing facilities through aid from the Czech Republic, Ireland, and UNDP can be expected to return output almost to rated capacity. Even if these restoration projects are completed by the end of 1995, however, total output still will not reach demand as of mid-1993.

Therefore, expansion plans for new facilities are required. Existing projects include assistance from France, Italy, ADB, and the World Bank, from which a total increased output of 26,400 kW can be expected. Most of these facilities should be functioning during 1996, however, the present power shortage will no doubt continue until this date. In addition, the gap between supply and demand will once again appear in 1998, and, based on present projected output, will not close until hydroelectric power comes on line some time during the year 2000.



Note: ——— maximum output required for grid demand
- - · maximum output including allowance for periodical inspection of the largest unit

Thus, pursuant to the above, supply of a 10 MW facility from Japan is highly essential, and would have the following effects:

(a) Phnom Penh needs to increase power capacity immediately. If Japan were to supply a 10 MW facility, it would be in operation by the beginning of 1995 and increase the total capacity in 1993 by 40%. This would be a major contribution to the timely execution of infrastructure rehabilitation as well as economic reconstruction plans.

(b) The generator would supplement total output for the Phnom Penh power grid until the end of 1999 when generation of hydroelectric power can be expected to begin. This will enable Phnom Penh's recovery projects, which have already begun to progress, to be implemented without being hindered by power shortages, and thus contribute to social stability and public welfare.

(c) Technology transferred during the realization of Japan's project will extend beyond normal operation and maintenance after construction, and beyond Phnom Penh's power grid. The transfer of technology will improve the level of technical skill throughout Cambodia's power sector, through skills acquired by engineers and technicians from the Ministry of Industry and EDP.

In conclusion, Japanese assistance for the 10 MW generating facilities would have the following merits:

(i) Increased power output would be a major contribution to all development sectors in Phnom Penh; and,

(ii) The project would improve technical and engineering skills in Cambodia concerning construction, operation, and maintenance of power plants.

8.7.2 Distribution Facilities

Not only Japan but also France, UNDP, and ADB will assist in the restoration of the distribution network, which will give the following effects to the Phnom Penh distribution network:

- Unification of distribution line voltages will enable the use of common maintenance materials and facilitate the system operation.

- Improvement of high voltage lines will increase the distribution capacity and thus meet growing demand, reduce energy losses in the system, and reduce power failures.

- Improvement of low voltage lines will reduce energy losses and failures in the system, prevent non-technical energy loss, facilitate the adoption of adequate power rates, and improve the town environment.

- Work implemented under assistance of international experts will help transfer technology to EDP's workers.

Sub-projects recommended for assistance of the Government of Japan will contribute the following to the power system in addition to the above effects:

(1) Interconnection of power stations

(a) To enable free power flow among the power stations.
(b) To reduce frequency of power failures due to the free power flow.
(c) To enable to program the optimum system operation.

Those effects will ensure economical power system operation and ensure quality of the services to customers.

(2) Additional lines from the No. 5 Power Station

(a) To ensure stable power supply to heavy loaded areas and to much improve energy losses and voltage regulation.
(b) To promote efficient activities in the administrative and economic fields leading to quick restoration of the municipality.

Assistance from Japan is to contribute to restoration of not only the power sector but also other sectors in Phnom Penh. Provision of the interconnection line meets the request of SNC, and reinforcement of the direct lines from the No. 5 Power Station is to increase the effect of the power station constructed under assistance of Japan.

8.7.3 Load Dispatching Facilities

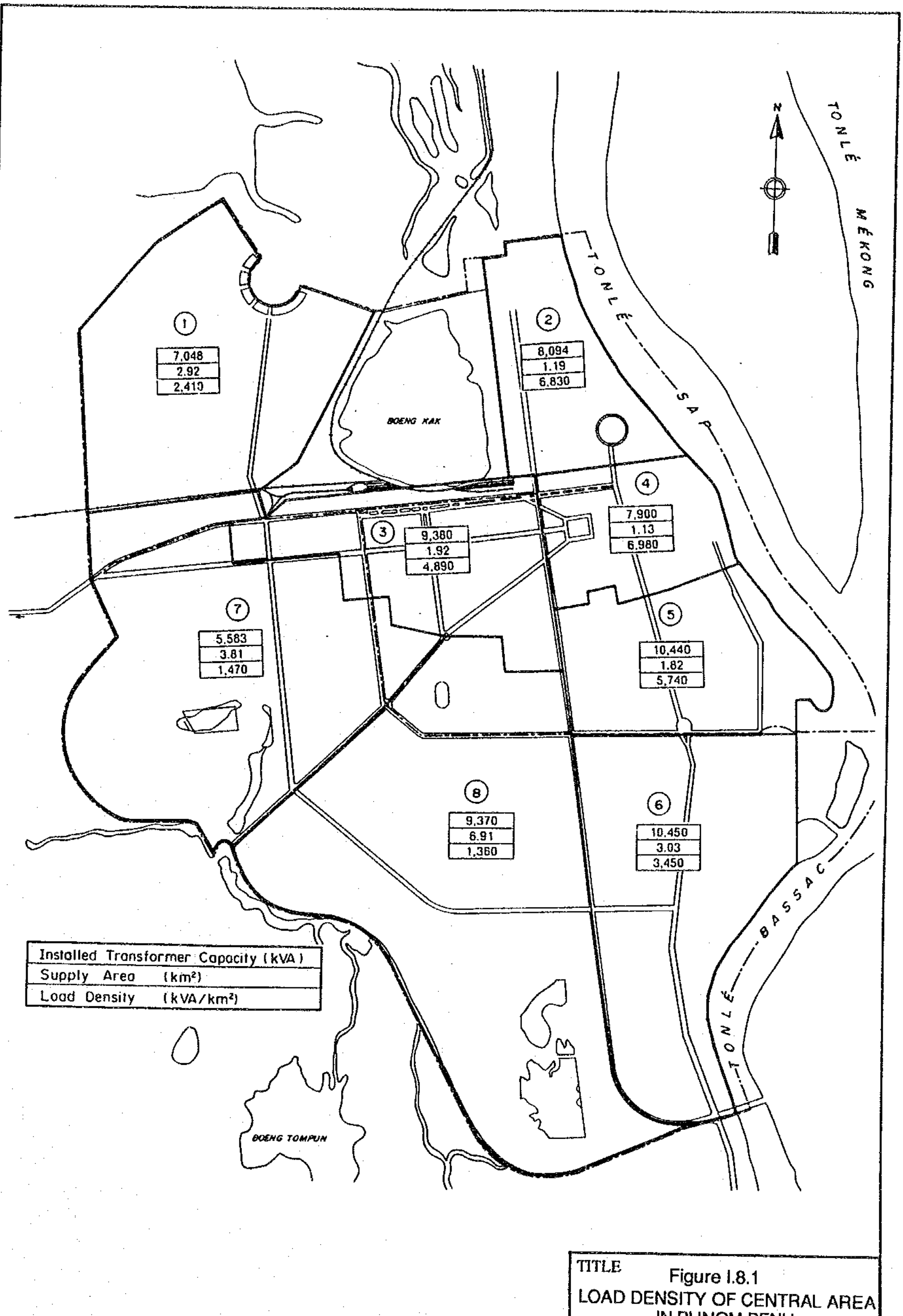
The effects of installing the equipment recommended for the power station are as follows:

(1) Quick and accurate communication without interference is possible because the new radios will have 10 channels and an exclusive line will be used for each power station.

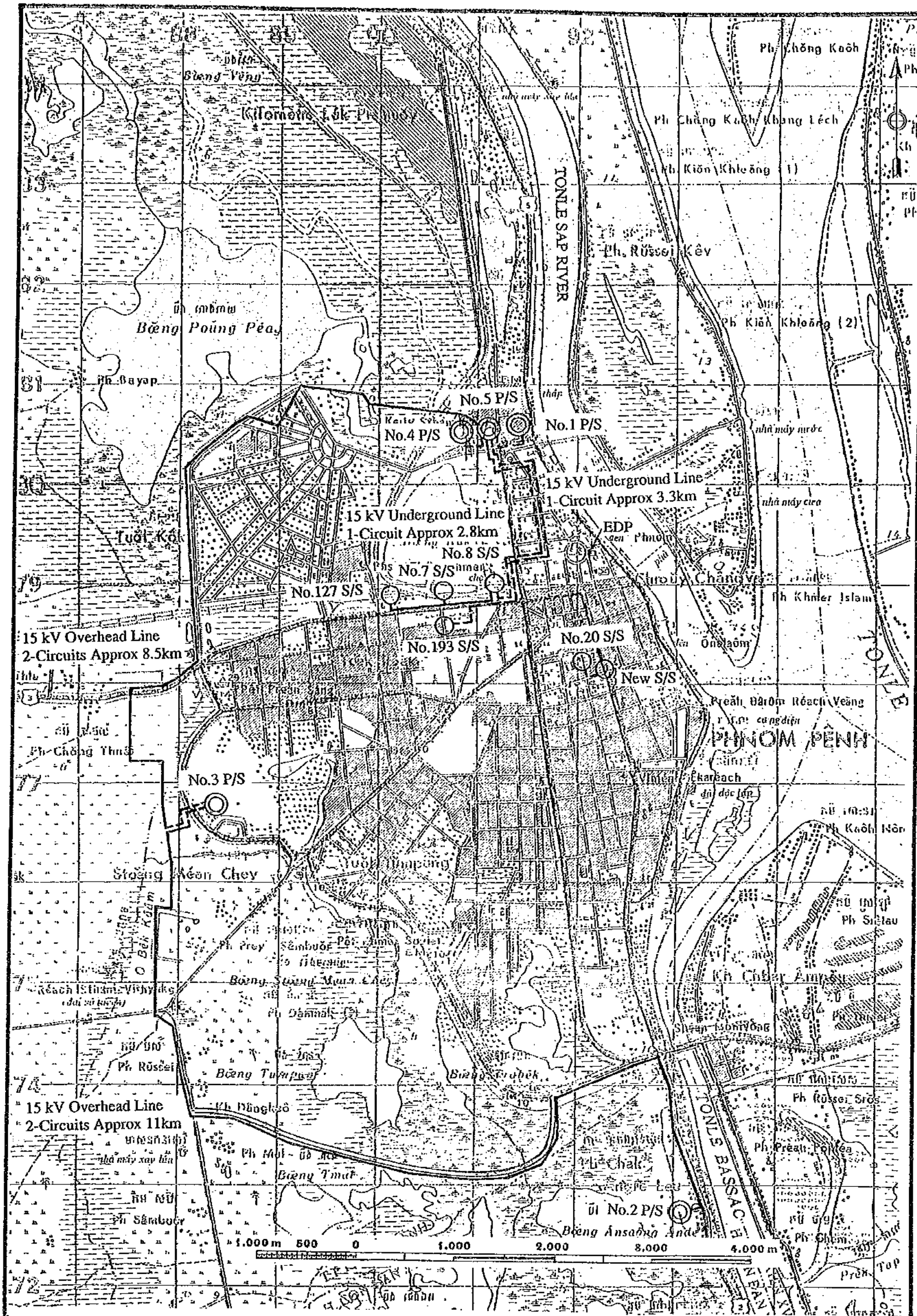
(2) The new radios will be able to relay accurate information on the condition of the distribution lines for the power stations between each system.

(3) As information will be able to be relayed accurately and quickly, the present situation can be analysed on the system control panel immediately.

Other donor countries and international agencies do not, at present, have any plans for installation of the above-mentioned facilities, therefore, it is recommended that they be carried out under assistance from the Government of Japan.



TITLE
Figure I.8.1
LOAD DENSITY OF CENTRAL AREA IN PHNOM PENH



TITLE Figure I.8.2
LAYOUT OF DISTRIBUTION LINE FACILITIES & ROUTE MAP

Chapter 9

Recommendation on Operation of Power Industry and Power Sales System in Phnom Penh

CHAPTER 9 RECOMMENDATION ON OPERATION OF POWER INDUSTRY AND POWER SALES SYSTEM IN PHNOM PENH

9.1 Institutional Operation

(1) Organization of EDP

At present, EDP supplies electric power to Phnom Penh City and surrounding areas. When the existing supply territories and installed capacity are taken into account, it is deemed that the present departmental formation and structure of EDP is still capable of managing the present supply territories and installed capacity of the power stations. However, because both the supply territories and installed capacity are expected to be expanded rapidly in the future, it will be increasingly necessary to further develop the degree of specialization of the respective departments and stratification of hierarchical structures, as well as develop closer and more frequent communication and coordination among the respective departments.

In order to study the future organizational structures of EDP, it is necessary to execute further detailed review and analysis of the roles and functions of the respective departments.

The recent changes in the job descriptions of the Planning and Technical Office reinforced the functions of the office. Consequently, the office started formulating a power facility expansion program, overseas procurement planning of fuel and other materials such as spare parts, and administration of official development assistance. However, the functions and human resources of the office will have to be reinforced when electric power systems is expanded throughout the country so that the office will be able to plan and evaluate both generation and system planning, and investment planning.

In addition, EDP does not have organizational functions for the procurement and construction management for such major construction projects as construction of power stations and transmission lines. In order to promote efficient construction of power stations and transmission lines throughout the country in future, EDP needs to have organizational functions for construction projects.

(2) Consolidation of office equipment

Except for a personal computer used for preparing electricity bills, office equipment is in serious shortage in EDP at present. Therefore, it will be necessary to introduce more typewriters, photocopy machines, and other office equipment within an appropriate range in order to improve the office work efficiency.

(3) Education and training

Some causes of inefficient management and administrative work of an organization are due to the shortcomings of the organizational structure itself, and other causes are due to insufficient understanding of functions of the respective departments and interaction among the departments of the organization by the staff members of the organization. The former problem is not deemed so important for EDP judging from the present scale of its organization. However, the latter problem is considered to cause substantial reduction in the work efficiency of EDP. In order to improve work efficiency, it will be necessary for EDP to prepare its own work manuals and training materials and to institutionalize training and education for its employees.

The subjects for education and training on management and administrative work can be classified largely into two categories. The first category includes activities which are intended to further deepen recognition of EDP's own organizational roles and functions, and its social responsibilities as an electric power industry. The second includes activities which are intended to deepen understanding of and accumulate specialized knowledge pertaining to account management, labor control, and business management, safety control, engineering in specific fields, and other individual job items. Training and education on such subjects should be promoted, depending upon the number of years employed and the position of the employee continuously after recruitment to EDP.

9.2 Operation/Management of Facilities

(1) Execution of proper maintenance and repair

One of the serious problems encountered by EDP is the very low usage rate of power facilities. This low usage rate together with the problem of a huge amount of unpaid electricity accounts is oppressing the financial condition of EDP. The very low availability of power stations and distribution facilities has been caused by insufficient maintenance and repair of equipment. Maintenance and repair of equipment is hampered by excessively aged power plant equipment and distribution facilities, lack of spare parts, and inadequate maintenance and workshop tools. One of the reasons for the shortage of spare parts is deemed to be the lack of adequate funds for EDP resulting from difficulties in collecting the huge amount of unpaid electricity accounts. Thus, it is essential to work out and implement countermeasures for recovering the unpaid electricity accounts and not increasing the amount of unpaid bills during the course of future business activities.

Taking into account the present condition of the existing facilities, it will be very difficult both financially and technically to promote rehabilitation and modernization of the facilities solely by EDP. Therefore, official development aid is deemed to play a significant role.

(2) Shift work system

At present, the power stations and distribution lines are operated by four shift teams based on a four shift system. Since the four shift teams are engaged in the work at all times, it is difficult for any shift team member to take a complete dayoff. Should it become necessary for a shift worker to take a dayoff, the member will take it by mutually exchanging the members between teams. If it is impossible to take a dayoff on a predetermined day by schedule, a problem will occur in extending labor management. Therefore, it is proposed to modify the existing shift work system as follows:

Because there may be a considerable allowance for the number of members constituting the respective shift teams, one team can be added without changing the total number of shift work members. As a result, the number of shift teams will be increased from four to five. In this way, it will be possible for members of any team out of the five to take a complete dayoff. Furthermore, it will also be possible to carry out education and training of the operation staff during such a dayoff.

(3) Night time repair/maintenance work

Should trouble be reported on the distribution lines, the person in charge of distribution line operation will visit the trouble spot by car and switch off the line on the power station side. Thereafter, the person in charge of repair from the Public Light and Network Office will visit the site and carry out the repair work. Although the distribution lines are operated on a twenty-four hour basis, the repair staff from the Public Light and Network Office do not work on a twenty-four hour basis. If power failure occurs after the end of normal working hours, the repair work will be carried out the next morning. This in turn results in reduced availability of distribution lines. Such a slow counteraction to power failure in distribution lines is considered to be one of the major causes of low availability of distribution facilities.

Taking these conditions into consideration, it is proposed to execute repair work during the night. Because the road traffic is light and electric power load is low during the night, the repair work at night will be easier than during the day light hours.

(4) Storage of spare parts

For the management of spare parts in warehouses, it is deemed possible to improve the following points:

- For immediately locating the parts, a number should be entered on each shelf and a ledger be prepared to ensure easy location of the intended parts;
- An inventory of parts should be continuously kept so as to enable prompt and exact confirmation of the quantity;
- A sufficient space between stored parts should be provided for transformers and other heavyweight parts so that the rating nameplate is visible at a glance for easy inventory recording;
- Small parts should be stored in cases per unit quantity, and
- Sufficient working space should be set aside in order to load and unload parts smoothly.

(5) Safety control

Taking into consideration the insufficient safety control under present conditions, the following points are proposed for improvement:

- Clearing around and appropriate arrangement of power plant equipment and facilities;

- Appropriate indication and division of work areas and open sections using partitions, rope, etc.;
- Appropriate arrangement and reinforcement of lighting equipment;
- Improvement of safety on steps by providing handrails, etc.;
- Indication of dangerous overhead structures, high voltage, and high temperature parts by color identifications;
- Use of insulated helmet and shoulder protectors to prevent workers on a lift basket truck from electric shock; and
- Use of safety belts during work on poles.

9.3 Power Sales System

(1) Structure of electricity charges

Electricity charges are generally set according to the categories of consumers. Since the voltage and capacity of electric power required by consumers varies depending on the categories of consumers, the unit transmission and distribution cost from the power station to the individual consumers varies depending on those categories. However, electricity charges have not been set according to the categories of consumers in Cambodia, instead electricity charges vary depending on the payment methods. At present, most of EDP's consumers are Government agencies, international organizations, and commercial and residential consumers which use electricity mainly for lighting. Because there are almost no industrial consumers which demand a large capacity of electric power, electric power is supplied to consumers on low voltage distribution lines in Cambodia. Therefore, electricity charges have not yet been differentiated among consumers in Cambodia. As long as the present demand structure prevails in Phnom Penh and surrounding areas, it is not deemed necessary to set electricity charges according to the categories of consumers. However, when the electric power demand structure is diversified along with the development of medium and small-scale industries, it will become essential for EDP to set electricity charges according to the categories of consumers.

From a medium-term point of view, it will be necessary for EDP to start revising the electricity charges in order to prepare a tariff that reflects differential supply costs among consumers.

(2) Establishment of fair electricity charge system

The electricity charges applied at present by EDP vary depending on the payment methods. As shown in Figure 18, the charge is 170 Riel/kWh in the case of payment in local currency and U.S.$0.21/kWh in the case of payment in hard currency. However, if the charge is paid through a regional electricity wholesaler or a Collective Group, the charge is 180 Riel/kWh in local currency and U.S.$0.224/kWh in hard currency.

In view of such an electricity charge structure, the following problems can be pointed out: Even if the same category of electricity is supplied to all consumers, the electricity charge of 170 Riel/kWh when the electric power is supplied directly from EDP and paid directly to EDP is different from the electricity charge of 180 Riel/kWh when electric power is supplied through a Collective Group (the charge is paid to the group). As Cambodia is experiencing hyperinflation, the value of the U.S. dollar is increasing rapidly compared with the local currency. Therefore, this means that the substantive electricity charge paid in U.S. dollars is increasingly higher than that paid in local currency. Even if the same category of electric power is supplied in the same area, the fact that there are different electricity charges raises the issue of unfairness in the long run. The Collective Group System introduced in August 1991 is considered to have contributed significantly to preventing theft of electric power. However, the issue of unfairness caused by the Collective Group System has to be solved. The solution to this issue has to be formulated within the framework of the electric power industry organization. This means that this issue concerns not only EDP but also other electric power supply organizations.

Chapter 10

Master Plan for Rehabilitation and Reconstruction of Electricity Supply in Siem Reap City

CHAPTER 10 MASTER PLAN FOR REHABILITATION AND RECONSTRUCTION OF ELECTRICITY SUPPLY IN SIEM REAP CITY

10.1 General

As stated in Chapter 6, the problems facing the generating facilities at present are summarized below. This chapter states recommendations for the reconstruction of the power supply facilities on each issue.

10.1.1 Generating Facilities

Major problems facing the generating facilities are as follows:

(1) Improper function of synchronizers
(2) Damage of turbo-charger
(3) Shortage of materials and equipment for maintenance works
(4) Operation and maintenance technique
(5) Insufficient power generating facilities

10.1.2 Distribution Facilities

Major problems facing the distribution facilities are as follows:

(a) Unbalanced load allocation to the distribution line in the power system.
(b) The distribution lines for the major facilities in Siem Reap have not been restored.
(c) The power conductors and cables will become inadequate as the load increases.
(d) Insufficient supply of distribution and protection equipment.
(e) Insufficient supply of materials for operation and maintenance.

10.1.3 Load Dispatching Facilities

As stated in Chapter 6, a load dispatching facility is not operated in the Siem Reap power system at present. The facility will be required for the system in future when the power system is expanded.

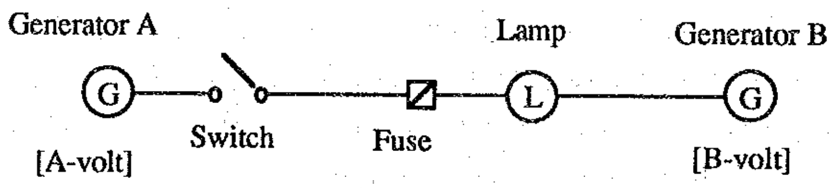
10.2 Generating Facilities

10.2.1 Synchronizer

It is basically possible to operate three (3) generating units in parallel. However, the fact is that sound synchronizing is not conducted due to failure of synchronizers. Urgent rehabilitation works of the synchronizers for the No.2 and No.3 generating units are recommended, since the present operation will cause faster deterioration of the existing facilities.

At present forced synchronizing operation is conducted between the No.2 and No.3 generating units everyday, without phase synchronizing but with adjustment of voltage and frequency of both units. Such forced operation will seriously damage the main circuit (switches and generator) and exciter (rectifier and regulator) of the No.3 generator. In fact, the main switch of the No.3 generator has been replaced once while the rectifier has been replaced 5 times. It is assumed that the electrical circuit devices for the No.2 generator are damaged. For release of such abnormal stresses from the generators, the following lamp synchronizing system is recommended to be applied as tentative measure. It should be mentioned that the best measure is to replace the present devices with genuine devices and the recommended measure is strictly tentative. The measure is not to synchronize using a synchroscope but using lamps only. It requires an experienced manual operation.

(1) Outline of lamp synchronizing system

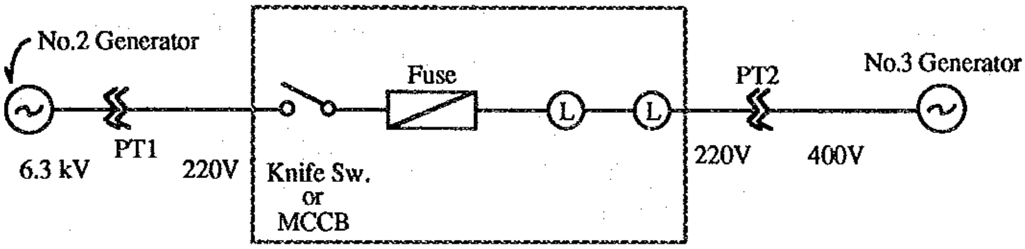


Switch-ON connects generator-A and generator-B through a lamp. Necessary conditions for synchronization are (a) same voltage, (b) same frequency, and (c) no phase difference. Voltage is regulated by a voltage regulator, and difference of frequency and difference of phase angles are adjusted by a speed regulator. The voltage difference and frequency difference are observed on a voltmeter and frequency meter, but frequency difference should be confirmed by the clearness of the lamp.

In case of no phase difference on the circuit, the lamp will be off. While, a difference of 180 degrees causes the lamp to shine the brightest. Thus, synchronization can be made on the condition of no difference in voltage and frequency.

(2) Reconstruction of lamp circuit for the No.2 generator

(a) Following circuit should be assembled in the control panel for the No.2 generator.



Part to be reconstructed.

PT1	: Potential transformer 6.3 kV/220 V in the No.2 generator panel
PT2	: Potential transformer 400/220 V in the No.3 generator panel
Knife Switch or MCCB	: Low voltage switch AC460 V, 10 A
Fuse	: Fuse for low voltage potential transformer, AC460 V, 2 to 3A
L	: 2 Lamps for AC 220 V

(b) Reference

Voltage circuits of the No.2 and No.3 generators to be synchronized should be in the same phase. Since there are various devices between the generator and lamps, the phase of those devices should be checked to be same.

This recommendation is made under such condition that secondary voltage of the devices are same. In case a different voltages exist, additional transformers may be required in the circuit.

(c) Safety measures

Reconstruction of the circuit should be conducted using proper tools such as voltage detectors, testers, phase rotation meters, and materials, referring to the drawings so as not to make a wrong connection. Works under live condition are always prohibited.

10.2.2 Repair of Turbo-charger

A genuine turbo-charger is not locally available. The damaged turbo-charger for the No.1 generating set is tentatively replaced with a different type charger from the facilities in the old power plant. The No.1 generator's output is, accordingly, lowered than the rated.

If a genuine charger cannot be procured, the same type charger should be manufactured and installed after detailed investigation at site.

10.2.3 Expansion of Generating Facilities

The possible output from the three (3) generating units, which are operative at the present, cannot meet the present power demand. The construction of a new generating facility to promote tourism and the development of irrigation as well as upgrade of people's daily life is urgently required. Generating facilities with thermal power plants would be developed in the short term, while a hydropower plant would be developed in the middle and long term as same as in Phnom Penh. The number of rooms in the hotels is foreseen to increase to 400 by the end of 1993 and finally to 2,000 by 1995 from the present 250 rooms. To promote tourism which is high priority under the reconstruction and development work of the city, further expansion of at least 4,000 kW will be required in the present system by 1995, for which 50% of the facilities should be constructed to cover the base load mainly for supplying hotels and restaurants.

10.2.4 Other Recommendations

(1) Supply of Materials and Equipment for Maintenance Works

Under the present electric power network in Siem Reap, there exist no generating facilities other than the existing three (3) generating units. The power supply by utilizing the existing facilities will be required to be continued as far as possible, since no expansion scheme is planned. To achieve stable operation and to prevent further deterioration of the existing facilities, the procurement of appropriate and sufficient spare parts should be arranged.

(2) Upgrade of Operation and Maintenance Technique

Maintenance and proper inspection of the existing facilities, especially for the protection devices and control system, are not regularly carried out, which is a result of a lack of technical documents and absence of experienced operators. It is recommended to educate the staff by dispatching specialists and providing technical documents.

10.3 Distribution Facilities

Following are the Study Team's recommendation for reconstruction of the distribution facilities in Seam Reap city.

10.3.1 High Voltage Distribution Facilities

(1) Extension of the existing high voltage distribution line

One of the existing two main trunk lines of the distribution network shall be extended through the airport and the Angkor monument and connected to another distribution line.

This connection will make a loop system which will ensure the electricity supply.

The number of accidental break downs shall decrease, and stable electricity supply shall be ensured by the installation of automatic reclosing switches at the major junctions of the distribution lines.

(2) Installation of a new high voltage distribution line

The additional distribution lines for major demand for commercial use, such as hotels, and for a pumping station for agriculture are required for reinforcing the existing single circuit line. This reinforcement will contribute to increase the system capacity, to improve voltage regulation, and to reduce system energy losses. In addition, this new line will function as an alternative supply route when one route is faulted.

(3) Increase of the capacity of the existing high voltage distribution lines

The size of the existing overhead power lines and underground lines is not sufficient if demand increases.

Upgrade of sizes of the existing conductors and cables increases the line capacity, improves the line voltage regulation, and reduces the line energy losses.

(4) Boost of the voltage for high voltage distribution lines

The voltage shall be boosted from 6.3 kV to Cambodia's standard voltage (15-20 kV), and the capacity of distribution lines shall also be increased. The materials for operation and maintenance shall also be commonly used in the country's distribution network.

10.3.2 Low Voltage Distribution Facilities

The electrification rate shall be increased remarkably (the present rate is about 10%) by the increase of the generating facilities.

Low voltage lines in the city are operated at 380/220 V and 220/127 V corresponding to the standard voltage in the country, and accordingly the low voltage network can be expanded without modification.

Following the expansion of the distribution network, installation of consumer meters and protection equipment is required to ensure fair metering and stable electricity supply.

10.3.3 Other Recommendations

(1) Procurement of Maintenance and Operational Materials for Distribution Lines

The connecting equipment for consumer meters and underground cables is urgently required for the restoration of the power supply in Siem Reap City Consumer meters are rarely installed, and the monitoring of the power demand is poor in the city. Installation of the approved meters is required for effective and reliable collection of the tariffs to meet the increasing demand.

On the other hand, materials from the former Soviet Union for underground cables are safely stored, however they cannot to be used for remedy failures of the cables because there are no connecting materials.

(2) Increasing the Skill of the Staff

There is no need to train the staff for operation and maintenance of the present small distribution network. Modern materials for the expansion and new installation will be introduced and an increase of the skill level of the staff shall be a prerequisite for stable electricity supply. To increase the skill level, on-the-job training (OJT) and technical texts and manuals written in Khmer are necessary.

10.4 Load Dispatching Facilities

Since the present Siem Reap power system is operated with one power station in the distribution network, a load dispatching facility is not urgently needed. Distribution line patrol and switching operation are now achieved by use of transceiver radio sets at present, and no hindrance is observed.

(1) Future installation of radio sets

New radio sets will be required when many similar transceiver sets are used in the town and their communications interferes with the load dispatching works of the power system.

The recommended facility for the Siem Reap system is the same the one proposed to be applied to the Phnom Penh power system in Chapter 8. The facility will be capable of functioning for medium and long-term system expansion. Two (2) mobile radio sets for distribution maintenance vehicles and one (1) station radio set at the power station are to be provided. If a new generating facility is constructed at another location than the existing power station, an additional station radio set will be required.

When the hydropower station(s) is developed and connected with the Siem Reap power system in the future, the load dispatching system should be established in the power line carrier system, optical fiber cable communications system or other system under the overall development plan of the transmission line system.

(2) Future establishment of load dispatching facility

The facility will be installed either in the existing power station or a new power station, when new generating facilities are added to the power system and/or the distribution network is largely expanded.

The facility to be installed will be the same as that recommended in the Phnom Penh power system in Chapter 8. A collective supervisory board will show the operation of generating facilities, ON-OFF conditions of all switches in the power system, and working conditions of distribution lines. Those indications will be made manually by operators in the center; not by mechanically automatic devices for some period until the overall power system has been established in the country.

10.5 Project Assessment

(1) Generating Facilities

Improvement of the existing generating facilities and the supply of spare parts will much contribute to more efficient use and prevent further deterioration. The construction of new generating facilities will meet the rapidly increasing power demand and contribute to the acquisition of foreign currencies by the promotion of the tourism.

The recommended reconstruction will also produce an increased yield of grain as a result of activation of irrigation development as well as improvement of life style due to an increase of the electrification ratio (10% at present).

From these points of view, the implementation of the rehabilitation and reconstruction of generating facilities is recommended.

(2) Distribution Facilities

The effects of the plan are summarized below:

(a) Stable power supply will be secured.
(b) The tourism sector, one of the major sources of foreign exchange earnings, will be promoted.

(c) Increasing the electrification rate will raise the standard of living and social welfare.

(d) The fair and reliable collection of the tariff will be secured.

(e) Quick action in regard to failures will be possible.

(f) A decrease of power losses and an improvement of voltage regulation will be expected.

(g) An increase in the level of skill of the staff for operation and maintenance will be achieved.

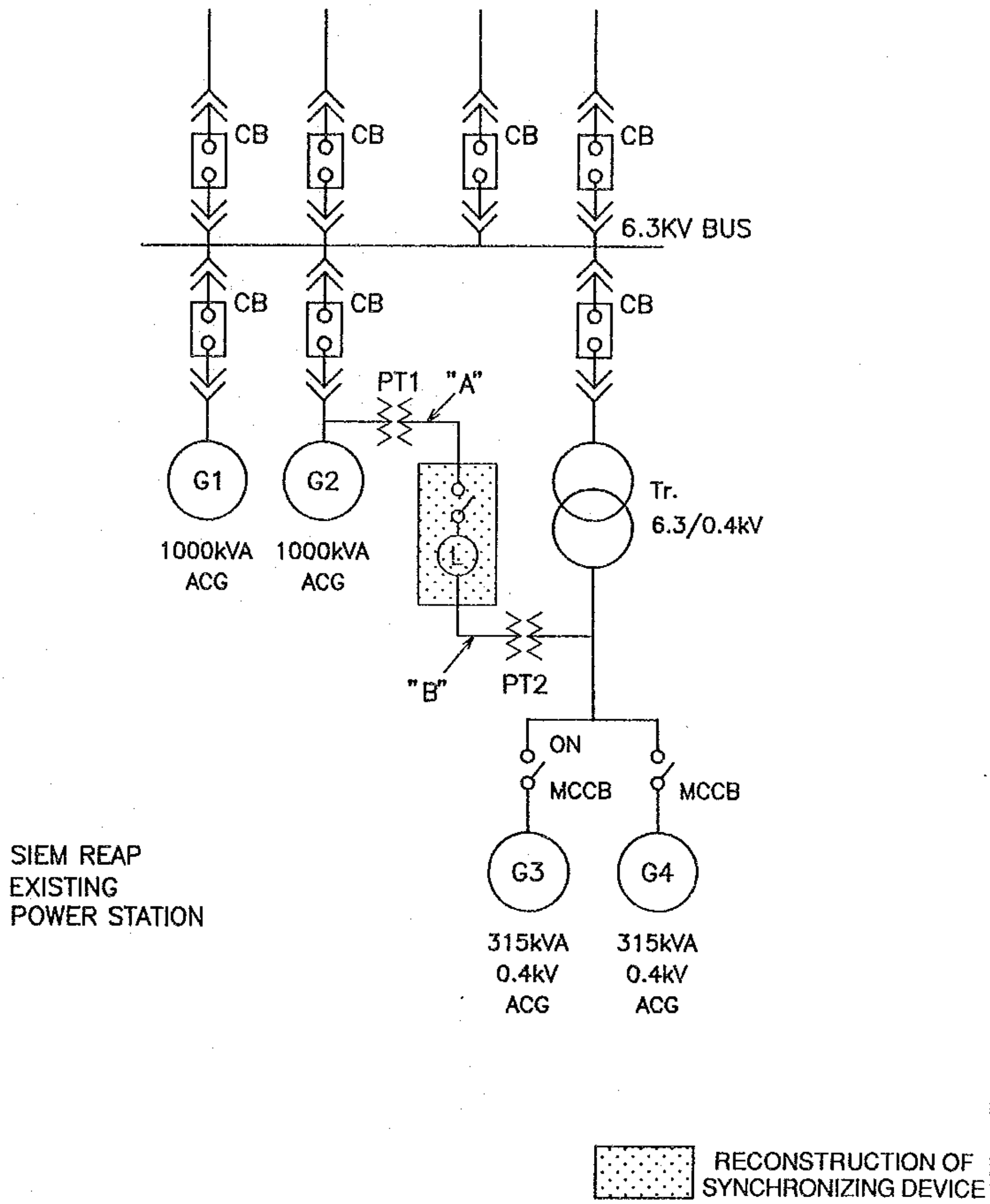
(3) Load Dispatching Facilities

Implementation of the recommended facilities will give the following essential effects to the Siem Reap power system:

(a) Exclusive communications channels of the power system will enable accurate and quick communications among power facilities.

(b) The facilities will enable the transmission of precise information and instructions for stable and economical system operation by controlling power generation of each generator and efficiently managing the distribution system.

(c) The collective supervisory board indicates operation condition of the system timely to enable prompt and optimum load management of the system and quick restoration of distribution line faults.



TITLE Figure I.10.1
SINGLE LINE DIAGRAM FOR
RECONSTRUCTION OF
SYNCHRONIZING DEVICE

Chapter 11

Recommendation on Operation of Power Industry and Power Sales System in Siem Reap

CHAPTER 11 RECOMMENDATION ON OPERATION OF POWER INDUSTRY AND POWER SALES SYSTEM IN SIEM REAP

11.1 Operation of Organization

The present power firm organization is considered applicable if the existing supply territories and installed capacity in Siem Reap are taken into consideration, However, the fact that no comprehensive planning and construction functions have not been incorporated in this organization is deemed to cause obstacles and raise serious problems in formulating construction plans and executing construction works to meet the expected electric power demand increase in the future. For this purpose, it is deemed necessary to establish a department or a section responsible for planning and construction as soon as possible. Along with the expansion of the supply territories and increase in installed capacity expected in the future, the promotion of specialization within the organization, formation of a hierarchical structure, and reinforcement of communication and coordination functions among the respective departments would be essential.

Regarding reinforcement of office equipment, execution of education and training, and so forth pertaining to operation of the organization, the recommendations for EDP are deemed applicable to the SEPE.

11.2 Operation of Power Equipment and Facilities

(1) Maintenance of equipment and facilities

Since the power plant equipment and facilities are comparatively new in contrast to those of EDP, the problem arising from unavoidably continuous operation of aged equipment is not considered as serious. However, serious problems have arisen in the procurement of spare parts since all of the existing equipment and components were manufactured in the former Soviet Union. Although a substantial quantity of spare parts can be acquired from the No. 4 diesel power unit, which was shut down after trial operation, the quantity of spare parts available is limited. Moreover, although some parts are available in the market in the city, it is very difficult to procure sufficient parts because of the shortage of funds at present. Since the equipment and parts will be aged more rapidly if the present situation continues, it is essential to remedy these procurement obstacles.

In order to become financial self-sufficient, SEPE should make efforts to improve its low ratio of sold energy, that is, the ratio of sold electrical energy to energy production. This in turn will make it possible to reduce the unit sales cost per kWh. Consequently, the financial situation will be improved, which will enable the firm to save the funds for procurement of spare parts. For this purpose, the monitoring system of meter inspection and electricity charge collection has to be reinforced. Moreover, it seems that Government agencies have not been charged for electricity. This is possibly a cause of the very low sold energy ratio. Therefore, it is deemed essential to collect electricity change also from Government agencies.

(2) Shift operation system and maintenance work

The existing shift work is carried out according to a very irregular system; the power station is operated by two shift teams and each team is then divided into two. Moreover, it is impossible for any shift team member to take a full dayoff. Therefore, the existing shift operation system is proposed to be improved also as described in the recommendations to EDP.

The maintenance work of distribution lines is carried out based on the same system as that of EDP. Therefore, should any trouble occur in distribution lines during the night, the repair work is carried over to the next day. Therefore, the distribution line maintenance system is proposed to be improved similarly according to the recommendations made to EDP.

(3) Management of parts and safety control

The management of spare parts and safety control of ESDR are in the same situation as that of EDP. Therefore, the present situation is recommended to be improved similarly according to the propositions made to EDP.

11.3 Electric Power Sales System

As mentioned previously, the management system of meter reading and electricity charge collection of SEPE is required to be reinforced. One of the methods to improve the system is the introduction of the regional electric power wholesaler or the so-called "Collective Group" system adopted by EDP. However, since the supply territories of SEPE are much smaller than those of EDP, the introduction of the wholesaler system is required to be studied to determine whether it is actually feasible or not in the long run. If such a system is introduced, the problem of fairness will be raised as pointed out already in the case of EDP. At the same time, it is desired at present to collect electricity charge from Government agencies, prevent theft of electric power by reinforcing inspection of distribution lines, and improve the monitoring system of electricity charge collection.

In addition, it is supposed that substantial errors have been made in reading watthour meters, and some meters are deemed to have been manipulated by consumers to indicate smaller readings. Therefore, it will be necessary to establish a calibration system in order to inspect watthour meters. In the system, the meters calibrated should be sealed to prohibit manipulation.

Chapter 12

Conclusion and Recommendation

CHAPTER 12 CONCLUSION AND RECOMMENDATION

The Study Team consisting of 12 members visited both the cities of Phnom Penh and Siem Reap for 30 days from January 11 to February 9, 1993 and examined the actual situation of the power market in the areas. The Study Team submitted its Progress Report to the Ministry of Industry, Cambodia. Succeedingly, the Study Team submitted to the authorities concerned its Interim Report in March and the Draft Final Report in June 1993 for formulating the Master Plan for rehabilitation and reconstruction of electricity supply in both cities, based on its study and discussions with the Cambodian authorities and international institutions in Phnom Penh.

Both cities force scheduled load shedding everyday, since power demands exceed actual power generating capacities. Unless measures are adopted in the existing power systems, deterioration of the existing facilities will be accelerated and the system will fall into a critical condition. There is another issue in the power sector, i.e., the existing distribution systems in both cities have never been renewed since their construction, and only some parts have been repaired as tentative measures. Those facilities produce a remarkable voltage drop and system energy losses. In the Phnom Penh system, there is no interconnection line for power exchange among the existing power plants. Several countries and international institutions are to assist the improvement of the power systems under such serious conditions.

The Study Team prepared the recommended plans for rehabilitation and reconstruction of power systems in both cities based on power demand forecasts in the detailed examination of the present situations. Plans for rehabilitation and reconstruction of the Phnom Penh power system, recommended to be implemented under the grant aid of the Japanese Government in the Master Plan Study, have been further studied in the Basic Design.

It is forecasted that power demands in Phnom Penh and Siem Reap cities will grow at the respective rate of about 9% and 23% annually. The Study Team recommends the following comprehensive rehabilitation and reconstruction plans for both cities.

Phnom Penh Power System

(1) Generating Facilities

(a) Rehabilitation of all generating facilities except those installed in the No. 1 and No. 5 Power Stations. Total output of about 28 MW is excepted to be restored due to the rehabilitation.

(b) Medium and long-term development of hydropower generating plants as the main energy source in the country. The hydropower plants destroyed and interrupted during war are scheduled to begin their generation around the end of 1999.

(c) Short term development of diesel-engine generating facilities till operation of hydropower plant has begun. By the end of 1999, about 37 MW diesel generating facilities are anticipated to newly be added to the power system.

(2) Distribution and Load Dispatching Facilities

(a) Construction of an interconnection line among power plants for exchange of power in both power systems.

(b) Unification of the three (3) distribution line voltages for effective system operation and improvement of the voltage regulation and system energy losses.

(c) Repair and reinforcement of high and low voltage lines for upgrade of power quality.

(d) Supply of adequate tools and instruments for proper operation and maintenance.

(e) Renew of the existing load dispatching facilities for efficient system operation and quick response to system faults.

(3) Management of Power System

(a) Re-organization of power the utility for more efficient functioning.

(b) Introduction of adequate office equipment for efficient business.

(c) Education and training of employees to improve their abilities by expatriate experts.

(d) Review of the operation system of power facilities for efficient and safe operation and maintenance.

(e) Establishment of warehouse management and safety control.

(f) Revision of the power tariff system and establishment of a meter calibration system.

Siem Reap Power System

(1) Generating Facilities

(a) Improvement of synchronizing devices for the No. 2 and No. 3 generators for safe operation of machines.

(b) Increase of output of the No. 1 generating unit due to improvement of its turbo-charger.

(c) Stage wise addition of new generating units (4 MW at least by the year 1995) before hydropower is expected to be connected.

(2) Distribution and Load Dispatching Facilities

(a) Construction of a high voltage network due to extension of the existing lines.

(b) Upgrade of line voltage and conductors/cables in the high voltage system for improvement of voltage regulation and energy losses.

(c) Promotion of electrification due to expansion of the low voltage network.

(d) Supply of tools and instruments required for proper operation and maintenance.

(e) Provision of a load dispatching system in the expanding power system for efficient system operation and quick response to system faults.

(3) Management of Power System

(a) Re-organization of the power utility for more efficient functioning.

(b) Introduction of adequate office equipment for efficient business.

(c) Education and training of employees to improve their abilities by expatriate experts.

(d) Review of the operation system of power facilities for efficient and safe operation and maintenance.

(e) Establishment of warehouse management and safety control.

(f) Revision of the power tariff system and establishment of a meter calibration system

Examining in detail the programs for rehabilitation and reconstruction by other donor countries and institutions, the Study Team recommends that the following facilities be implemented urgently in the Phnom Penh power system under the assistance of Japan.

(A) Addition of 10 MW diesel engine generating facilities to the No. 5 Power Station.

For covering deficit power supply until hydropower plants are operating, 10 MW generating facilities are required in addition to the program implemented by other donors. The facilities from Japan will be operated for the base-load requirement in the system because the machines will have high efficiency and low fuel consumption.

(B) Construction of interconnection line among power plants for effective system operation.

(C) Construction of new high voltage lines from the No. 5 Power Station to heavily loaded areas for release of over-load condition of the existing lines.

(D) Improvement of the existing load dispatching facilities.

Japan's assistance to those facilities should give the following effects to the power system:

(a) The new 10 MW Power Station will produce power equivalent to 40% of the total output of the system in February 1993, and contribute much to the improvement of the power shortage condition.

(b) The interconnecting lines makes smooth power exchange between the present two (2) power systems and results in technical efficiency and economical operation of the system.

(c) Direct 15 kV lines from the No. 5 Power Station promise stable power supply to the important areas in the city and improve voltage regulation and energy losses in these areas.

(d) Improvement of the existing load dispatching facilities ensures efficient and economical operation of each generating unit in the system and results in quick restoration of system faults.

Besides those direct effects, the recommended plans should indirectly contribute to restoration of infrastructures in various fields and improvement of people's welfare and living standard. It is concluded that the recommendations mentioned above should be realized under Japan's assistance as urgently as possible in combination with other donors.

ANNEX I

ANNEX I

Roles and Undertakings of Respective Offices of EDP

(1) Personnel, Salary, and Labor Office

(a) Research and preparation of plans for production and organization of EDP and its branches.

(b) Management of high- and low-level staff members, which includes recruitment, dismissal, salary, promotion, fine, and pension; as well as proposing disabled laborers to the Director for consideration.

(c) Preparation of salary tables and other allowances for each month, and preparation of draft statistics of number of staff members and wage bills for each year.

(d) Monitor and control absentees, sick leave, maternity leave, annual leave, and overtime of the respective offices of EDP.

(e) Prepare plans and subjects of technical training inside the country as well as abroad.

(f) To provide allowances and safety materials for laborers.

(2) Administration Office

(a) To receive letters and documents, keep records, prepare reports, deliver to concerned offices, and submit them to the Director for consideration.

(b) To prepare weekly schedules of respective offices, submit them to the Director for consideration and approval, and inform other related Offices of implementation.

(c) To promote living conditions of EDP staff members every month.

(d) To maintain administrative buildings of EDP.

(e) To receive Cambodian and foreigner guests, be in charge of managing and maintaining guest houses of EDP, provide foods for them.

(f) To build up the Party Committee.

(3) Planning Role

(a) To recapitulate planning of technical generation and budget of each year, implement plans of EDP, prepare annual plans based on the plans prepared by the Municipality and Government, and inform other EDP offices of the plans for implementation.

(b) To have the Director of EDP follow up the guidelines and plans prepared by Municipality, and monitor implementation of the plans. Together with other economic units inside and outside the Municipality, to make contracts for purchase and sales — transport of raw materials, spare parts, fuel for generation, and distribution lines — so that problems in generation and distribution are not caused.

(c) To keep statistics and reports on implementation and situations, by analyses and assessment of the results of planned production, technique, and finance for the Municipality and State, monthly, quarterly, and semiannually.

(4) Accounting and Financing

(a) To keep records, make notice of due instructions to other offices, carry out permanent control of book keeping on expenditures and income, cashier, receive and deliver materials and spare parts, and manage assets of EDP.

(b) To send accounts when due with state budget, bank, and other EDP offices appropriately, according to accounting method regulated by the Municipality and the State.

(c) To prepare reports on accounting monthly, quarterly, and annually, and control accurately the statistics submitted by other EDP offices.

(d) To assist the Director of EDP on economic affairs, keep financial records, and carry out economic analyses and control.

(e) To make a financial plan with the approval of the production and technical plans of EDP.

(f) To make requests for capital and Bank credit, to withdraw money, to balance expenditures and income, and to prepare financial reports accurately.

(g) To provide capital to other EDP offices for generation, production, investment, and construction.

(h) To participate in drawing up contracts.

(i) To operate automatic calculators, assign personnel and train them for the operation.

(j) To manage distribution and expenditures of EDP.

(k) To collect sales, balance arrears of EDP and its branches monthly, quarterly, and annually.

(l) To issue invoices according to meter readings.

(m) To give information-deposit, number of customers to the Inspection Office in order to facilitate control.

(5) Sales Office

(a) To keep statistics and registration of meters for each customer, office, enterprise, and handcraft industry; recapitulate and analyze economic effectiveness of power generation, in Phnom Penh city.

(b) To keep current records of connections and meters, and add new enterprises and household customers when necessary.

(c) To repair connections.

(d) To control customers, settle complaints from customers, and make customers pay debts and fines.

(e) Check losses, and evaluate the loss of EDP and its branches monthly.

(f) Recapitulate reports on the results of production and sales monthly, quarterly, and annually.

(6) Network

(a) To control and maintain equipment.

(b) To install and repair distribution lines.

(c) To make plans for development.

(d) To control statistics and plans.

(7) Distribution

(a) To dispatch electricity.

(b) To decrease power failures and improve repairs.

(c) To control distribution instruments.

(8) Warehouse and Transport

(a) To supply and transport materials, spare parts, and fuel.

(b) To issue purchase orders through the Municipality or Ministry of Trade, or directly to foreign firms.

(c) To control accepting and transporting of goods from ports to warehouses.

(d) To keep good control and maintenance of warehouses.

(e) To keep records of stored materials monthly.

(f) To control stored materials annually.

(g) To control and maintain vehicles.

(9) Meter Office

(a) To maintain control and make adjustment of meters.

(b) To repair meters.

(c) To seal meters after adjustment.

(d) To place a designated mark on sealed meters.

(10) Inspection, Management, and Control

(a) To provide documents and send them to the competent authority in order to judge theft.

(b) To control implementation of political guidelines and other decisions.

(c) To control implementation of contracts between EDP and customers.

(d) To monitor and control usage of electricity by customers.

(e) To settle complaints from customers.

(f) To prepare reports on the results of monitoring and controlling electricity usage by customer.

(g) To give advise and instructions to customers to promote safe usage and economical consumption of electricity.

(11) Technical Research and Construction

(a) To study and investigate new and old designs.

(b) To estimate new and old works.

(c) To prepare draft plans and estimate construction costs.

(d) To supervise construction and repair works at site.

(e) To accept and deliver documents and letters.

(f) To carry out typing.

(g) To receive and deliver materials for construction and repair works.

(h) To keep records of worker attendance at site.

(i) To prepare reports daily, monthly, and annually.

(j) To keep inventory records.

(k) To carry out new concrete-steel-wood construction works.

(l) To carry out modern concrete and steel construction works.

(m) To be in charge of foundation construction works.

(n) To be in charge of electric pole construction works.

(o) To be in charge of concrete preparation.

(p) To be in charge of steel and electric pole production.

(q) To be in charge of steel material production.

(12) Workshop

(a) To carry out mechanical and electric installation and repair.

(b) To repair reserve and mobile machines (generators).

(c) To repair and install transformers.

(d) To carry out lathe and welding works of spare parts - to repair batteries.

(e) To repair coils and carry out carpentry.

(f) To estimate, study, and investigate electricity, plans, and services.

(g) To set the norm with regard to workshops.

(h) To use equipment and assets, and to increase capital provided by EDP.

Part II

Basic Design Level Study

Chapter 1

Introduction

CHAPTER 1 INTRODUCTION

Pursuant to the request from the Government of Cambodia (GOC) to the Goverment of Japan (GOJ) as stated in Part I, GOJ decided to conduct the Master Plan Study. The Japan International Cooperation Agency (JICA) then conducted a survey of generating facilities, distribution systems, and load dispatch facilities in Phnom Penh.

The on-site survey for the Basic Design Level Study was performed for twenty days between January 11 and 30. As requested, this survey examined: Phnom Penh's power facilities, distribution system, and load dispatch facilities within the project area; the existing facilities, cooling water pipelines, fuel supplies, distribution line routes, and the present surrounding load dispatching facilities surrounding the No. 5 power station site; and issues concerning generation, distribution, and dispatch systems relating to the Electricité de Phnom Penh (EDP) Maintenance Program Survey. The Team also collected data necessary for basic design and engaged in discussions with the Ministry of Industry, which is the Cambodian agency responsible for this study, and in discussions with EDP, the state enterprise responsible for execution of the project, the Project for Rehabilitation of Electric Power Supply in Phnom Penh. As a result of these discussions, the basic design concept and criteria for realization of the Basic Design Study were determined by the Team. Agreement from GOC was then obtained.

Chapter 2

Outline of the Project

CHAPTER 2 OUTLINE OF THE PROJECT

2.1 Project Objectives

As mentioned in Part I, if the power generation system, distribution system, and telecommunications and load dispatching system in Phnom Penh are not addressed soon, the capital city will face the following problems:

(a) Over-loading caused by an insufficient power generating system and excessive voltage drops on the distribution system;

(b) Unreliable power supply; and

(c) Outage of the whole system caused by irrelevant load dispatching orders.

The above-mentioned problems cause not only decreases in the employment opportunities in the industrial sector, stagnation of industrial activities, lower living standards but also economic demerit due to increases in power losses and maintenance costs. GOC intends to plan rehabilitation and reconstruction of generating plants, distribution systems, and load dispatching systems in order to avoid such problems. The aim of the Project is to rehabilitate and reconstruct the most effective and urgent sub-projects: Reconstruction of the No. 5 power station, construction of an interconnection line, construction of city distribution lines, and rehabilitation of the load dispatching system.

2.2 Components of the Project

2.2.1 Components of the Project

The components of the Project requested by GOC and selected in the Basic Design Study to be implemented under grant aid from GOJ are as follows:

Components requested by GOC	Components selected in the Basic Design Study
1. Construction of No. 5 power station (5,000 kW x 3 sets)	Selected (5,000 kW x 2 sets)
2. Construction of interconnection lines (Approx. 20 km)	Selected (adding city lines)
3. Rehabilitation of load dispatching system	Selected

The Project components requested by GOC are based on the master plan study by UNDP partly. The results of discussions and examinations with MOI, PPM (Phnom Penh Municipality) and EDP on the Basic Design Study are shown in Appendix "Minutes of Discussion". The three project components mentioned above are the most effective and urgent sub-projects and are selected for the Basic Design Study in the Master Plan Study undertaken by JICA. The rehabilitation and reconstruction works for the selected facilities are appropriate countermeasures, as explained below, for maintaining stable and reliable power supply in Phnom Penh.

(1) Construction of No. 5 power station

As discussed in Section 7.1 of Chapter 7 of Part I "Power Demand Forecast in Phnom Penh" and Section 8.2 of Chapter 8 of Part I "Master Plan Study on Rehabilitation of Generating Plant in Phnom Penh", a 10 MW generating plant is required in the No. 5 power station. The No. 5 power station is planned to be operated as a base load power station in the power system. To determine the number of units and capacity, a technical and economic study was carried out. As a result of this study, 2 sets of 5 MW each are selected for the No. 5 power station. A comparison of this study is shown in Table II.2.1.

(2) Construction of distribution lines

As discussed in Section 8.3 of Chapter 8 of Part I, an interconnection line between the Southern and Northern areas is not constructed yet. The high voltage distribution lines having small transmission capacity exist in the city in a separate system. It is not possible to interconnect the existing distribution lines because of transmission capacity and operational problems. Therefore, a new interconnection line is planned to be constructed outside the urban area since there is not enough space for it in the urban area. In addition to the above interconnection line, city distribution lines are planned to be constructed in the center of the city (Northern area, near the No. 5 power station). The existing distribution lines to the center of the city have deteriorated and power supply reliability has decreased, this area is also the electric load center.

(3) Establishment of telecommunications and load dispatching system

As discussed in Section 8.4 of Chapter 8 of Part I, there is fundamental equipment for load dispatching system. However, the existing system does not function effectively because of poor performance of the equipment and operational problems.

A new system and equipment aimed at solving the above problems will be installed under the Project to enhance the existing system. As the existing city telephone cable lines are crossed and some are damaged, an exclusive radio system is to be established for the new load dispatching system.

By the implementation of the selected sub-projects, power supply in Phnom Penh can be effectively stabilized. Cost efficiency will also be improved by a reduction of system losses and voltage drops.

For implementation of the Project, the following major equipment is required:

1. Generating plant
   - No. 5 power station, 5 MW x 2 units

2. Distribution system
   - Northern - Southern system interconnection line, approximately 19.5 km, 20 kV (design), 15 kV (operation)
   - City distribution lines and distribution switchgear

3. Telecommunications and load dispatching system
   - Collective supervisory equipment
   - Radio equipment

A detailed equipment list is given in Section 2.3.3.

2.2.2 Outline of Major Facilities and Equipment Requested

As a result of discussion with MOI and EDP and detailed survey, and subsequent careful examination and study, the major facilities and equipment requested are selected and outlined as follows:

(1) Generating facilities

(a) Diesel engine generator

From the viewpoint of economical construction and convenient of operation and maintenance, 2 units of 5,000 kW diesel engine generator are planned to be installed in the No. 5 power station. As this power station will function as a base load power station to cover the system demand, 24-hour operation is required. Therefore, the diesel engine generator should have a medium or slower speed, i.e. 750 rpm or less, considering its operational life.

(b) Starting compressed air supply system

There are two methods to start the diesel engine generators: compressed air starting method and motor starting method. The compressed air starting method is more reliable than the motor starting method. So, the compressed air starting method is applied for the diesel engine generators. For black start of generators, compressed air storage tanks are provided with the air starting system.

(c) Fuel oil supply system facilities

It is envisaged to use the existing fuel oil supply system of the No. 4 power station also for the No. 5 power station, but the storage capacity of the existing system is insufficient for both power stations. Therefore, a new fuel oil supply system with two sets of oil storage tank (1,000 m^3 x 2 sets which represents a 30-days capacity) will be provided for the No. 5 power station. The fuel oil supply system will be provided with an oil transmission system. Normally, fuel oil is transported by tanker and unloaded on the Tonle Sap river bank. Therefore, a new transmission pipeline and pump set are required for the system.

(d) Lubricating oil supply system

For lubrication of moving parts of the machines, a lubricating oil supply system is required. A lubricating oil pump set will be provided with the system.

(e) Cooling water supply system

There are many cooling water supply methods. In case the power station operates constantly and it is easy to take raw water, the method using a cooling tower is applied normally. Therefore, this method is adopted for the system. Raw water is taken from the Tonle Sap river by a floating pump station, transmitted to the power station by a new transmission pipeline, and treated by new treatment facilities to be provided in the power station site. The raw water requirement is estimated to be 170 m^3/day.

(f) Air intake and exhaust system

An air intake system with filters to prevent dirty air will be provided for ignition of diesel engines. The exhaust system will be provided with a silencer and chimney for reducing noise and diffusing hot exhaust gas.

(g) Main transformer

To step up the generator voltage of 6.3 kV to the distribution voltage of 15 kV, a main transformer will be provided. It will be equipped with an on-load tap changer for ensuring stability of distribution voltage. The capacity of the transformer is 6,300 kVA according to IEC standards. For ease of operation and maintenance a two-bank constitution is planned.

(h) Station service transformer

A station service transformer will be provided for stepping down the generator voltage of 6.3 kV to a lower voltage. For ease of operation and maintenance of station service transformers, a two-bank constitution is adopted. The voltage ratio is 6.3 kV/400-230V.

(i) 6.3 kV switchboards

6.3 kV switchboards with control and protection equipment will be provided for the generator switchgear and primary of the main transformer. The 6.3 kV switchboards will be of metal-clad type for security measures. The rated current of the switchboards will be 1,200A, and the rated interrupting capacity will be 31.5 kA.

(j) 15 kV switchboards

15 kV switchboards with control and protection equipment are provided for interconnection line feeders and city service distribution lines. The rated voltage of the 15 kV switchboards is 17.5 kV according to IEC standards. The rated current of the switchboards will be 600A considering future expansion of distribution loads, and the rated interrupting capacity will be 25 kA. The 15 kV switchboards will be of metal-clad type for security measures.

(k) Low voltage switchboard and motor control center

The low voltage switchboard is provided for distribution of power to low voltage motors, equipment, lighting, etc. in the power station. The motor control center is provided for automatic operation of auxiliary equipment in the power station.

(l) DC power source (battery/charger)

A DC power source is provided for control and protection of equipment and emergency lighting facilities. The DC power source equipment consists of an alkaline battery, charger, and DC panel. The calculated battery capacity and voltage are 100 AH, 110V, respectively.

(m) Control and protection equipment

A one man control mode is adopted for control of diesel engine generators because the operation is very easy and the system composition is simple. This method is basically manual operation. In the Japanese regulation, protection equipment is to be provided for power generating plants of 500 kW or more. Therefore, protection equipment should be provided for the power station. Protection equipment for transformers and distribution line feeders should also be provided to prevent faults. The control and protection equipment are provided complying with the Japanese regulation and standards.

(n) Maintenance tools, instruments, and spare parts

As discussed in Part I, supply of maintenance tools, instruments, and spare parts were recommended for effective operation and maintenance of the power station. One set of tools, instruments, and special tools will be provided for the power station as well as spare parts for two years of operation.

(o) Civil and building works

Civil and building works necessary for the new power station are itemized below:

(i) Land formation and slope protection in the power station area.
(ii) Disaster prevention works (environmental effect against land slide and water drainage).
(iii) Civil foundation work (foundations for oil storage tank, settling basin, cooling water pond, etc.)
(iv) Civil work for maintenance (access road to the power station, lubricating oil stock yard).
(v) Building work (lighting, air conditioning/ventilation, potable water supply, etc.)
(vi) Repair work for the powerhouse (finishing, pit/duct, etc.)
(vii) Safety and security works (fences, oil drainage protection, warning boards, lightning protection, grounding, etc.)

(2) Distribution line facilities

(a) Interconnection line

At present, there are two separate distribution systems, i.e. the northern system and southern system, and thus power inter-trade does not occur. For effective use of power generating facilities and energy, interconnection lines are required.

The capacity of the interconnection line required is 20,000 kW in total, 10,000 kW x 2 circuits, for shut downs for maintenance and repair of faults. The line support planned is steel tubler pole. The conductor planned is HAL 120 sq.mm. For underground lines, 20 kV cross-linked polyethylene insulated and polyethylene sheathed armour cable (XLPE) will be used. The cable will be 3 core, 150 sq.mm.

(b) City service distribution line and distribution facilities

Two underground distribution line feeders will be installed for the heavily loaded area in the city center from the No. 5 power station. The distribution capacities of one feeder is planned to be 5,000 kVA considering power bypass in case of emergencies. The line will be constructed underground because there are many houses in the area. The cable will be 20 kV XLPE 3 core 150 sq.mm, for protection of the line and for interconnection of the lines. Distribution facilities will be provided at the related substations and distribution stations.

The rated voltage of distribution facilities is 17.5 kV (IEC). At the same time as upgrading of system voltage from 4.4 kV to 15 kV, two step-down transformers will be replaced with new 15 kV transformers. For the heavily loaded area, one distribution station will be constructed having a 250 kVA transformer.

(3) Telecommunications and load dispatching system

(a) Fixed radios

For effective operation of load dispatching orders, telecommunication equipment is essential for communication between the load dispatching center (LDC) and power stations. The existing city telephone lines are deteriorated and there are many crosswired sections and, thus, the telephone lines are not reliable. The power line carrier (PLC) telephone system is not applicable over the distribution lines. Therefore, a radio system will be applied for the load dispatching system. One fixed station will be provided for LDC as well as 1 set for each power station, in total 6 sets.

(b) Mobile radios

For quick restoration of power facilities in power stations, substations, and distribution lines, mobile radio equipment is required. The existing radio equipment uses the citizen band system, so much interference occurs. Safety is hampered by this poor communication condition. Therefore, a new system and equipment should be provided. EDP has 4 maintenance cars and one is used by chief engineer. New radio equipment will be mounted on the four maintenance cars.

(c) Collective supervisory board for load dispatching system

For effective operation of power facilities and enhancement of power supply reliability, data from the power stations should be indicated on the collective supervisory board. The existing system board is not useful for load dispatching. For this purpose, a new collective supervisory board will be provided and data such as operation status and power output from the power stations will be collectively indicated on the board. New system equipment is designed for future expansion.

(d) Power supply

Power supply equipment for fixed radios and the collective supervisory board will consist of an alkaline battery and charger. The battery voltage will be DC 24V or 12V.

(e) Maintenance tools and spare parts

Maintenance tools and spare parts for two years will be provided.

2.3 Outline of the Project

2.3.1 Implementing Agency and Organization of EDP

As discussed in Section 5.4 of Chapter 5 of Part I "Operation of EDP", the implementing agency is EDP. EDP will also be responsible for operation of all the power facilities in Phnom Penh after completion of the Project. The actual operation of the No. 5 power station will be undertaken by recruited staff. Operation of the distribution system and load dispatching system will be carried out by the existing staff. The recommended organization for operation and maintenance of the No. 5 power station is described as follows:

Since management of a power station depends on conditions such as operating period, generating system, kind of fuel used, scope of automation, start-stop condition, and location, each power station should have its own managing and administration system in accordance with the actual situation.

For smooth operation and maintenance of the power station, an organization shall be established to define individual duties and responsibilities. Based on this organization and a flexible management, steady power supply and increased efficiency of routing work can be obtained.

In this Project, an organization will be proposed to manage each individual power station. The following organization is considered essential:

Superintendent	Administration Department	General Affairs Group	8 persons
		Labour Relation Group	4 persons
		Accounting Group	4 persons
		Fuel Group	4 persons
	Generating Department	Generation Group	4 persons
		Environmental Protection & Safety Control Group	4 persons
	Chief Shift Engineer	Operating Group	@3 persons x 4 teams
	Maintenance Department	Electrical & Control Group	4 persons
		Mechanical Group	6 persons

Hence, a total of 51 staff is deemed to be required for the power station.

The operating group consists of 4 teams and each team will have three members; three 8-hour shifts will operate per day which will ensure continuous night operation. The other groups will work usual office hours.

For the new power station, the number of necessary personnel is shown in Table-II.2.2.

2.3.2 Outline of the Project Area and Site Conditions

The Project area is Phnom Penh city which is located at the junction of the Tonle Sap river and Mekong river. The elevation of Phnom Penh ranges between 8.5 m to 12.0 m above sea level. A map of Phnom Penh city is shown in Figure-I.5.1.

(1) No. 5 power station

At present, there are four power stations in Phnom Penh. These are located outside the urban area. The No. 5 power station is located in the northern area of the city adjacent to the existing No. 4 and No. 1 power stations. As the No. 5 power station is located about 600 m from the Tonle Sap river, cooling water is very accessible. The level of the No. 5 power station is approximately 12 m above sea level. There are no residents within 50 m of the No. 5 power station.

(2) Distribution lines

The route of the interconnection line is proposed to be located outside the urban area and the city service distribution lines are planned to be installed in the northern urban area. As the interconnection line is designed as an overhead line, it is not possible to cross the center of the urban area. Therefore, the interconnection line is planned to be located outside of the urban area. The suburbs are mainly paddy fields and swampy areas. The city service distribution lines are proposed to be underground because there are many buildings and trees which would hinder installation of overhead lines.

(3) Telecommunications and load dispatching system

LDC is located in the EDP head office. A room for LDC is already prepared. Load dispatching orders will be received from the power stations (No. 1 - No. 5) and mobile stations (4 sets).

2.3.3 Outline of the Facilities

(1) Generating plant

A new powerful diesel engine generating plant is to be constructed on the existing No. 5 power station area and the generated energy will be distributed from the No. 5 power station effectively. An outline of the components required for the generating plant is given below:

(a) Diesel engine generators, 5,000 kW x 2 units

(b) Starting air system, air compressors with air tank x 2 sets

(c) Fuel supply system, oil storage tank 1,000 m^2 x 2 sets

(d) Lubricating oil supply system

(e) Cooling water supply system, floating pump station and water treatment facilities

(f) Air intake and exhaust system, with silencer and filter

(g) Main transformers, 6,300 kVA x 2 sets

(h) Station service transformers, 630 kVA x 2 sets

(i) 6.3 kV switchboards

(j) 15 kV switchboards

(k) Low voltage AC panels and Motor Control Center

(l) DC supply switchboards (battery DC 110 V and charger 100 AH)

(m) Control and protection system

(n) Maintenance tools, instruments, and spare parts

(o) Civil and building works

(2) Distribution system

(a) Interconnection lines among the No. 5 power station and each existing power station

Overhead and underground interconnection lines are planned to be installed for distribution of power among power stations, easy maintenance of power stations, and quick restoration of power outage.

Major features of the interconnection lines are as follows:

(i)	No. 5 P/S - No. 1 P/S	Approx. 0.4 km (UG, 1 circuit)
(ii)	No. 5 P/S - No. 4 P/S	Approx. 0.2 km (UG, 1 circuit)
(iii)	No. 5 P/S - No. 3 P/S	Approx. 8.5 km (OH, 2 circuits)
		Approx. 0.5 km (UG, 2 circuits)
(iv)	No. 3 P/S - No. 2 P/S	Approx. 11.0 km (OH, 2 circuits)
		Approx. 1.4 km (UG, 2 circuits)

Note: UG: Underground line
OH: Overhead line
P/S: Power Station

(b) City service distribution lines

Two circuits of city service distribution lines and distribution stations/substations are planned to be constructed for the growing demand in the center of the city.

Major features of the city distribution lines and distribution station/ substations are as follows:

(i) City distribution line from No. 5 P/S to No. 8 S/S by UG, 1 circuit .... Approx. 2.8 km

(ii) City distribution line from No. 5 P/S to No. 193 S/S by UG, 1 circuit .... Approx. 3.3 km

(iii) City distribution line from No. 8 S/S to No. 7 D/S and from No. 7 D/S to No. 127 D/S by OH, 1 circuit .... Approx. 1.2 km

(iv) City distribution line from No. 20 D/S to New S/S by UG, 1 circuit.. Approx. 0.3 km

Note: D/S: Distribution substation
S/S: Substation

(c) Expansion and replacement of distribution transformers

For upgrading of the existing system voltage of 4.4 kV and 6.3 kV, the existing transformers will be replaced with new transformers of 15 kV capacity. In addition to the above, a new substation is to be constructed because of heavy loads around the No. 20 substation.

Major features of the transformers to be replaced and constructed are as follows:

(i) Replacement of D/Tr., 15 kV/380-220V 250 kVA .... 2 sets

(ii) Construction of D/Tr., 15 kV/380-220V 250 kVA .... 1 set

Note: D/Tr.: Distribution transformer

(d) Distribution switchgear

Distribution switchgear is to be installed for protection of distribution facilities.

Major features of the distribution switchgear are as follows:

(i) Metal-clad switchboard with CB

No. 1 power station (Single bus bar) .... 1 set
No. 2 power station (Double bus bar) .... 2 sets
No. 3 power station (Single bus bar) .... 4 sets
No. 4 power station (Single bus bar) .... 1 set

(ii) Metal-enclosed switchboard with LBS
(No. 8 S/S, No. 7 D/S, No. 127 D/S, No. 20 S/S) .... 4 sets

Note: CB: Circuit Breaker
LBS: Load Break Switch

(3) Telecommunications and load dispatching system

For effective use of the power facilities and quick restoration of power outage, the following facilities for the telecommunications and load dispatching system will be installed:

(a) Fixed radio station equipment (LDC, each power station)
(b) Mobile radio equipment
(c) Collective supervisory board for the load dispatching system
(d) Power supply equipment
(e) Maintenance tools and spare parts

2.3.4 Operation and Maintenance Plan

Before commercial operation of the new power station, distribution system, and telecommunications and load dispatching system begins, the system for operation and maintenance should be well established to avoid any obstacles. The following are the prerequisites, including the necessary budget which has to be fulfilled by Cambodian side, before operation begins.

(1) Proper arrangement of manuals

The condition of manuals at the existing power stations and management sections differ. A common problem throughout the power stations and management sections is that most manuals are not written in Cambodian. After commencing construction of the new power station, distribution lines, and load dispatching system, the contractor will supply English manuals when equipment and machines are procured. These manuals shall be stored and arranged properly so that power station personnel can refer to them whenever they are needed. At the same time, it is required that brief figures (flow charts, etc.) and summaries of the manuals in Cambodian be prepared with the cooperation of the contractor during the trial operation stage, so that they can be easily understood by the engineers working at the power station.

Operation manuals including flow charts and/or diagrams written in Cambodian shall also be prepared so that the operators can easily understand the operation procedures.

(2) Recruitment of personnel

For operation and maintenance of distribution lines and load dispatching system, most of the existing staff will conduct the work. By the implementation of the Project, the work load will increase. In this case, recruitment of personnel is required for the extended power system.

In consideration of preparatory training, it is necessary to recruit the required number of personnel for the power station before commercial operation starts. The operation and maintenance of the distribution lines and load dispatching system will be carried out by the existing organization with some recruited personnel. Most of the experienced personnel such as engineers, technicians, skilled workers, and operators, can be recruited from the existing No.4 power station, and the others will be shifted from EDP's organization or recruited from outside the organization.

(3) Preparatory training

Preparatory training is needed for newly assigned personnel such as engineers, technicians, skilled workers, and operators, to understand and master the procedures for operation and maintenance of the new power station. It is suggested that the above-mentioned manuals written in English and Cambodian language can be used as the texts for preparatory training. Training in the following areas is recommended to be conducted during the construction period:

(a) Layout of power station
(b) Single line diagram/block diagram of auxiliaries
(c) Arrangement of equipment/facilities
(d) Operation method
(e) Maintenance method
(f) Safety control method
(g) Recording/reporting method

(4) Spare parts

Spare parts for erection, trial operation, and for two years operation will be supplied by the Contractor. After that, various spare parts will be procured in accordance with the running of the power station. A system of storing, procuring, and arranging spare parts should be established in order to maintain the stock required for normal operation.

After commercial operation for a period of two years, the spare parts which are considered to be necessary for power station operation, in general, are to be procured by the Cambodian side as shown in Table-II.2.3.

(5) Steady supply of fuel and lubricating oil

Fuel and lubricating oil have to be supplied timely and continuously as soon as the power station starts its operation. In order to secure enough fuel and lubricating oil for operation of new generating facilities, amount of consumption should be estimated. Fuel and lubricating oil shall be secured by the concerned authorities.

An order for additional supply has to be placed timely to the appropriate Government organization. Fuel and lubricating oil to be procured for the No. 5 power station is shown in Table-II.2.4.

(6) Operation and maintenance expenditure

For operation and maintenance of the new power station and distribution lines, expenditure for fuel and lubricating oil, spare parts, personnel, and office equipment is required. The budget for operation and maintenance shall be provided timely and yearly. An estimation of the annual budget for operation and maintenance of the Project is shown in Table-II.2.5.

2.4 Necessity of Technical Assistance

As previously stated, foreign assistance projects for power stations in Phnom Penh were implemented many years ago. However, the equipment and facilities are old and the operation method was different from the Japanese method. Although the fundamental theory is same as Japan's, the core of the technical staff of EDP is required to train for safe and effective operation and maintenance of the Project facilities and system.

The technical assistance will be considered from the result of the preparatory training.

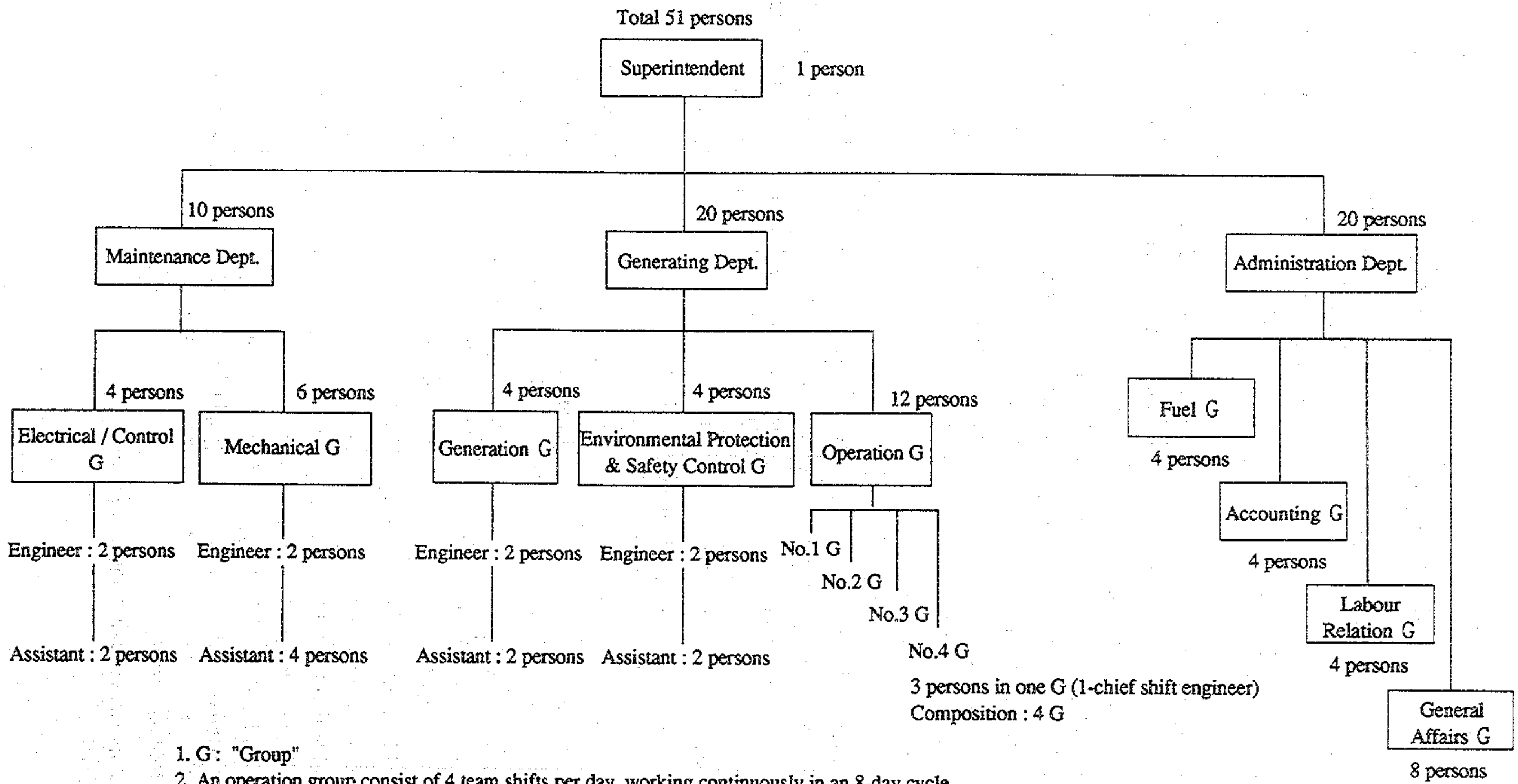
Table II.2.1 Case Study of Unit Number and Capacity

Item No.	Description	Case-A (10.2 MW) 3,400KW× 3 sets	Case-B (10 MW) 5,000KW× 2 sets
1	Type of Engine	4-cycle, water-cooled, direct fuel injection diesel engine	4-cycle, water-cooled, direct fuel injection diesel engine
2	Engine Power Output	4,250 ps	7,090 ps
3	Speed	750 rpm	750 rpm
4	Cooling Method	Forced Water Cooled	Forced Water Cooled
5	Starting Method	Air Starting	Air Starting
6	Type of Generator	Open, Weather-proof	Open, Weather-proof
7	Generator Capacity	3,750 kVA	6,250 kVA
8	Generator Voltage	6.6 or 11 kV	6.6 or 11 kV
9	Number of Pole	8	8
10	Type of Exitor	Brushless	Brushless
11	Exitor Cooling Method	Self Air Cooled	Self Air Cooled
12	Dimension (mm)	9,500L×4,000W×3,900H	12,500L×4,000W×4,000H
13	Weight	55 tons	80 tons
14	Fuel Consumption Rate(*)	150g / ps. hr	150g / ps. hr
15	Lubricant Consumption Rate(*)	2g / hr	2g / hr
16	Period to be Taken for Ordinary Maintenance	8 days / set / time	10 days / set / time
17	Delivery Period	10 months / 3sets	9 months / 2sets
18	Total Construction Cost Comparison	120 - 125% / 3 sets	120 - 125% / 2sets
19	Equipment Cost Comparison	120 - 125% / 3 sets	120 - 125% / 2sets
20	Existing DG	Possible to use	Possible to use
21	Maintenance Cost Comparison	120%	100%
22	System Operation	Easy	Easy
23	Parallel Operation	Normal	Normal
24	Economic Fuel Consumption on Load	Economical	Economical
25	Kind of Fuel	Light Oil, A, (C)**	Light Oil, A, C

(*) : Reference rate

(**) : Special consideration is required

Table II.2.2 Organization for Operation and Maintenance of No.5 Power Station



1. G : "Group"
2. An operation group consist of 4 team shifts per day, working continuously in an 8-day cycle.
   The groups often work in usual office time schedule.

Table II.2.3 Recommended Spare Parts List for the No.5 Power Station

The spare parts will be recommended by the contractor, but at least the following will be necessary for normal operation of the power station. The list showing the quantity of spare parts required for one set will be submitted by the contractor.

1. Expendable spare parts for 1 year per 5,000kW set — 1 set

    Cylinder cover
    Intake valve
    Exhaust valve
    Fuel injection valve
    Piston
    Crank pin bearing
    Main bearing
    Fuel injection pump
    Air cooler

2. Standard spare parts for auxiliary equipment per 5,000kW/year — 1 set

Table II.2.4 Fuel and Lubricating Oil Consumption and Storage Tank Capacity

Calculated conditions: Rated output of diesel generator : 5,000kW/unit

Plant efficiency: 68%
- routine maintenance 15 days
- interim maintenance and repair 15 days
- average load factor 75%

Kind of fuel: JIS K2204-2 equivalent
heating value 10,200 kcal/kg
specified quality 0.86 kg/liter

1. Fuel consumption

0.205kg/kWh × (1/0.86) × 5,000kW = 1.19kl/h = 28.6kl/D

Annual consumption	1.19kl/h × 8,760h x 68% = 7,089kl/yr/set
Tank capacity	28.6kl/D × 30D = 858kl
Suggestion	1,000kl/unit

Annual fuel consumption = 7,089 (kl/yr/set) × 2 sets = 14,178 (kl/yr)

Say 14,200 (kl/yr)

2. Lubricating oil consumption

0.0015kg/kWh × (1/0.90) × 5,000 kW = 8.33 l/h = 200 l/D

Annual consumption	8.33 l/h × 8,760h × 68% = 49,620 l/yr
Tank capacity	200 l/D × 30 D = 6 kl

Annual fuel oil consumption = 49,620 (l/yr/set) × 2 sets = 99,240 (lr/yr)

Say 99,300 (lr/yrs)

No.5 power station

Annual fuel oil required	14,200 (kl/yr)
Annual lubricating oil required	99,300 (lr/yr)

Table II.2.5 Estimation of Annual for Operation and Maintenance

1. No.5 power station

(1) Fuel & lubricating oil cost

Fuel = 14,200 (kl) × $\frac{275.84}{0.86}$ (US$/kl) = US$3,916,928 ≑ 3,917,000

Lubricating oil = 99,300 (l) × 1.25 (US$/l) = US$124,125 ≑ 124,000

Total US$4,041,000

(2) Remunerations

Annual remunerations : average monthly rate : 45 US$/occupation/month

45$/mon × 51 = US$27,540/yr

total about US$27,550

(3) Spare parts

Annual cost for spare parts for generating facilities will be about US$322,500 per set.

2 sets : 2 × US$322,500 = US$645,000

Hence, total annual cost for operation and maintenance of 2 units of 5,000 kW facility will be US$4,714,000.

2. Distribution lines

(1) Spare materials (mainly insulator, cable head)

Pin type insulator	1,200 (pcs) × 0.1 × 100 (US$/pc.) =	US$12,000
Disc insulator	1,200 (pcs) × 0.1 × 20 (US$/pc.) =	US$2,400
Cable head	2 sets (3 feeders) × 2,000 (US$/set) =	US$4,000
Total		US$18,400

(2) Remunerations (additional cost only)

45 (US$/occupation/month) 10 persons	US$450
Total	US$18,850

Annual expenses for distribution lines will be US$37,250.

Chapter 3

Basic Design

CHAPTER 3 BASIC DESIGN

3.1 Design Policy

The design policy for the system is to ensure high reliability and safety, to be compatible with the existing facilities for easy operation and maintenance, and to be flexible for future expansion considering the existing technical level of EDP. The design will be formulated under the following criteria:

3.1.1 Natural Conditions

Natural conditions such as ambient temperature, wind velocity, humidity, thunder storm activity and rainfall in the project area are very important factors for the design of the facilities. The basic design criteria were worked out from historical climatic records for the eleven (11) years from 1981 to 1991 and the present EDP design standards.

3.1.2 Special Site Conditions for Erection

(1) Road construction work

Site erection works for the Project facilities will be carried out in accordance with the standards and/or practice of EDP. However, it is noted in Cambodia that finishing works, including paving and asphalting of public roads and footpaths which are excavated and backfilled for the construction of the project facilities, are performed by the contractor at his expense. Therefore, before the commencement of the work, the contractor shall shall submit an application for permission for the work and traffic limitation through EDP to the Road Department.

(2) Frequency allocation

In Cambodia, permission for use of a radio frequency is obtained from the Ministry of Telecommunications and Transportation. The contractor shall submit an application for permission to use a selected frequency through EDP to the Ministry of Telecommunications and Transportation.

3.1.3 Procurement of Local Materials and Equipment

All equipment and materials to be provided under the Project will be imported from Japan. However, raw materials such as aggregate, timber, and brick, will be procured in Cambodia.

3.1.4 Operation and Maintenance Organization for the Project

(1) From the viewpoint of the existing operation and maintenance works at the No. 2 and No. 4 power stations and distribution system, the capability of EDP for operation and maintenance of the system has been proved. However, the training of recruited personnel is required for operation and maintenance of the No. 5 power station.

(2) The training of the chief engineer for the No. 5 power station, and linesmen for the distribution lines and load dispatching system is to be conducted by the Japanese contractor during site erection as follows:

(a) No. 5 power station

The training on assembly and disassembly works for the chief engineer of operation and maintenance divisions in the No. 5 power station is to be carried out during the erection and installation period. Moreover, during tests at site and trial operation they will observe the work so that technical knowledge can be transferred. Operators in the power station will also observe the tests at site and trial operation and receive on-the-job training.

(b) Distribution lines

The training of linesmen belonging to EDP will be conducted by the Japanese contractor during site erection. The practical use of the working teams from EDP is effective in executing the overall Project works and to minimize power shutdowns during erection.

Tools and materials for the erection of insulated wires will be procured under the Project and sufficient quantities will be supplied taking into account not only the erection but also the proper operation and maintenance of the distribution system after completion. Technical knowledge will be transferred to the technical staff from EDP through on-the-job-training during site works.

(c) Load dispatching center

The training of staff for operation and maintenance works and future upgrading of the system is to be conducted by the Japanese contractor during site erection work through the transfer of basic technical knowledge on the load dispatching system.

(3) The core technical staff of EDP for operation and maintenance of the power stations, distribution system, and load dispatching system in Phnom Penh has been trained during past foreign projects and their technical knowledge will be further improved through on-the-job training during the Project.

3.2 Design Conditions

3.2.1 Climatic Conditions

The climatic data used in this Report were provided by the Department of Meteorology and the Ministry of Agriculture.

(1) Temperature, humidity

According to the meteorological records in Phnom Penh, the average maximum and minimum temperatures are 40.5°C and 13.3°C respectively. The climatic conditions shown below, which are the same values as the values that were used for other power stations in Phnom Penh, were used for the Project.

Minimum temperature:	13°C
Maximum temperature:	40°C
Mean temperature:	27°C

The maximum relative humidity recorded in Phnom Penh is 94%. Table II.3.1 shows the records of temperature, humidity, and precipitation.

(2) Wind velocity

As shown in Table II.3.2 the maximum recorded wind velocity in Phnom Penh in the past eleven years was 20.0 m/s. In the basic design a maximum wind velocity of 25 m/s was applied as this is the value adopted by the Mekong Committee.

(3) Rainfall intensity

Figure II.3.1 shows maximum daily rainfall versus excess probability that was obtained from the statistic analysis of the rainfall data for the past eleven years in Phnom Penh. It can be assumed that rainfall intensity is equal to 50% of daily rainfall because it usually rains for several hours in the rainy season. The rainfall intensity of 1/10 probability is as follows:

100 mm x 0.5 = 50 mm/hr

(4) Thunder

Table II.3.3 shows the data on thunder recorded in Phnom Penh. The table shows the number of times thunder is recorded during the rainy season in Phnom Penh. From analysis of the data, it is deemed that a lightning rod is necessary in the power station to protect the facilities.

3.2.2 Water Quality Conditions

The cooling water for new diesel engines will be supplied from the Tonle Sap river. A quality test on a water sample taken from the Tonle Sap river was carried out in order to determine the basic characteristics of the river water. The characteristics of the river water were found to be as follows:

(1) Water Quality

The results of the test are shown in Table II.3.4. The pH-value shows that the river water is almost neutral. The color and the turbidity are relatively high because of the suspension of fine soil grains. The content of Nitrogen and Phosphorus are negligible. From the results it can be concluded that there is no pollution due to human activity. The water quality is relatively good. The water is not corrosive and it can be used as cooling water for diesel engines. Changes in water quality can be expected due to variations in the turbidity in the rainy season.

(2) Microorganisms

The result of the microscopic examination of the water sample is shown in Table II.3.5. Between the floating rod bacilli, fine silica grains are kept in suspension. The microorganisms are of plankton type, Bacillariophycea and Cyanophycea, reflecting the influence of the Tonle Sap lake. As the ratio of BOD and nutrient salt are low, no increase in the population of microorganisms is expected.

Due to the presence of microorganisms, some problems may occur in the cooling pipes. Adherent to the pipe surface, the plankton slime may thicken gradually, leading to obstruction and local perforation of the pipe.

It is expected that no destruction due to ferrous bacteria will occur at present.

(3) Recommendations

(a) To monitor the river water quality and the lake environment continuously focussing on:
- increasing human activity
- species and quantity of bioorganisms.

(b) To remove of floating plankton and the silica grains from the cooling water.

(c) To install injection equipment for a disinfectant and slime control agent.

3.2.3 Ground Foundations

A geological survey, using hand-operated auger, was carried out in order to determine the ground foundation conditions of the No. 5 powerhouse. The location of borings and test pits are shown in Figure II.3.2, and the soil profiles are shown in Figures II.3.3(1) and (2). From the results of the survey the following soil conditions were obtained.

- The site of the No. 5 power station is located on reclaimed ground in a lake. The thickness of the embankment varies between two to four meters.
- The embankment can be divided into two layers. The surface clay layer is about one meter thick and includes a lot of bricks and concrete. The lower layer consists of gravels and clay. Both layers are very compacted.
- Under the embankment there is the original hard clay layer.
- N-values of the reclaimed ground and the original ground are expected to be more than ten.

3.3 Design Criteria

3.3.1 General

(1) Applied standards

Materials and equipment will be designed, manufactured, and tested in accordance with the requirements of the Japanese Industrial Standards (JIS), Japanese Electro Technical Committee Standards (JEC), International Electrotechnical Commission (IEC), Japanese Cables Standard (JCS), British Standard (BS), International organization for Standardization (ISO), and other international standards.

(2) Basic Insulation Level (BIL) of electrical equipment

BIL of electrical equipment for the design of the facilities will be selected considering BIL applied to the existing facilities in the system, as follows:

(a)	20 kV system for interconnection line	125 kV
(b)	15 kV system	95 kV
(c)	6 kV system	60 kV

3.3.2 Generating Facilities

All materials, designing, manufacturing, inspection, and tests of the generating facilities which will be installed for the power station shall be in accordance with the following design criteria and standards.

(1)	Installed capacity	:	Rated output per unit 5,000 kW x 2 units
(2)	Fuel	:	Diesel oil equivalent to JIS K 2204-2
(3)	Applicable Standard	:	The international standards concerned manufacturing
(4)	Unit of measurement and language	:	In all correspondence, drawings ,and documents, metric units of measurement and the English language shall be used.
(5)	Speed regulation	:	Less than ±4% (for D/G only, instantaneous less than 15% and permanent less than 5%)
(6)	Voltage regulation	:	Less than ±5%
(7)	Generator rated voltage	:	6,300V

3.3.3 Distribution Facilities

(1) Design wind pressures on structures

The wind pressures worked out from the above-mentioned wind velocity are applied to each structure as follows:

(a) Conductors and wires : 36 kg/m^2
(b) Tubular structures (poles, etc.) : 45 kg/m^2
(c) Insulators and hardware : 36 kg/m^2

(2) Sag calculation

Sag of overhead conductors will be computed on the basis of the following assumptions:

(a) Maximum conductor temperature is 75°C, taking into account temperature rise due to current flow.

(b) Minimum conductor temperature is 13°C (the likelihood of such a case, that is when wind velocity is maximum and air temperature is minimum, is very rare).

(c) Every Day Stress (EDS) is calculated under an ambient temperature of 27°C in still air.

(d) Minimum factor of safety of conductor stress at maximum wind pressure at 13°C is 2.5 and for EDS it is 4 against the ultimate tensile strength of the conductors.

(e) The maximum sag of the conductors is calculated under the conditions of maximum conductor temperature in still air.

(3) Minimum factors of safety

(a) Structures, tubular poles, other kinds of supports under maximum working loads against their ultimate strength 2.5
(b) Conductors under maximum working tensions against their ultimate tensile strength 2.5
(c) Insulator sets under maximum loading conditions against their mechanical breaking strength 2.5
(d) Foundations of structures and support under simultaneous maximum loads against ultimate ground bearing capacity and uplift resistance 2.5

(4) Required minimum clearances

The following minimum clearances for conductors will apply:

(a) Lowest point of conductors above ground

	20 kV line	LV line
Road crossing	7.5 m	6.0 m
Along road	7.0 m	6.0 m
General terrain	7.0 m	5.0 m

(b) Space between 20 kV insulated conductor and LV insulated conductor .... 0.6 m
(c) Phase space between 20 kV insulated conductors .... 0.5 m
(d) Vertical space between 20 kV insulated conductors .... 0.6 m
(e) LT phase space between insulated conductors .... 0.2 m
(f) Space between 20 kV bare conductors and LV bare conductors .... 1.0 m
(g) Space between 20 kV bare conductors and LV insulated conductors 0.8 m
(h) Phase space between 20 kV bare conductors .... 0.8 m
(i) Vertical space between 20 kV bare conductors .... 1.0 m
(j) Phase space between LV bare conductors .... 0.3 m

Note: LV: low voltage

3.3.4 Telecommunication and Load Dispatching System

(1) Telecommunication Facilities

(a) Frequency allocation: 400 MHz band

The frequency band of the existing facilities is 144 MHz. To avoid interference, another frequency band is required to be allocated for the new equipment. 400 MHz band is suitable for the new equipment because of flexible expansion and channel arrangement.

(b) Number of channels

The required total number of channels is 8 channels. The following sets are required: