7. Design of Optimum Power Plant

7.1. General Design Concept of Sihanoukville Power Project

The Sihanoukville Power Plant will be designed on the basis of the following design concept:

- Plant Capacity and Expansion Plan

The Plant has a capacity of 180 MW but could be expanded to 270 MW capacity in future. However 180 MW plant would be constructed dividing into two stages at an interval of several years. And the time of expansion from 180 MW to 270 MW is expected not in near future but one decade or so after the completion of 180 MW plant.

Then a definition of plant capacity and construction stages are set as follows:

Plant nominal capacity: 180 MW
Definition of construction stages and these capacities:

The works of first 90 MW capacity plant	;	Stage 1
The works of second 90 MW capacity plant	;	Stage 2
The works of last 90 MW expansion plant	;	Stage 3

In this report, the detailed studies including required specifications of equipment, plant layout, construction cost, construction schedule, economic analysis, etc. will be discussed for the first two stages, Stage 1 and Stage 2. However any specific study will not be carried out for Stage 3 except for the issues of environmental impact study and required area space for the final plant.

- Utilities

Main utilities required for operation and maintenance of gas turbine combined cycle power plant are fuel(s), electricity, cooling water, plant make-up water, fire-fighting water, miscellaneous chemicals, lubricants, etc.

(i) Fuel(s)

Natural gas is used as main fuel and diesel oil is used as back up fuel. The availability of natural gas is now under study, but the pipeline of gas is expected to come to the plant from west edge of the plant boundary. Diesel oil will be supplied from Sihanoukville Oil Terminal through the oil pipeline, which will run along the railway and reach to the north-west edge of the plant boundary.

The gas pipeline will have a capacity for all three stages.

(ii) Electricity

The electric power necessary for normal start-up and normal shutdown operation of the plant will be supplied via step-down transformer from 220 kV transmission line. While, the electric power for normal continuous operation will be fed via step-down transformer from output circuit of the associated generators.

(iii) Cooling Water

The seawater will be used as the cooling medium for the turbine steam condensers. The seawater will be taken from and discharged to the sea in the west of the plant. The cooling water intake and discharged structures will be installed on the seabed of approx. 5 m depth, with enough distance to avoid hot water recirculation. Incoming and outgoing cooling water pipes are located under the seabed and under the ground from the seacoast to the plant with crossing the road and the railroad.

(iv) Plant Make-Up Water

Plant make-up water will be taken from Prey Treng Pond. However the water of Prey Treng Pond is already used by Sokimex Oil Terminal and the near-by residents, in addition, the water flow is not so plenty in dry season. Therefore a raw water storage tank with one month capacity will be provided in the plant.

(v) Fire Fighting Water

The water of Prey Treng Pond will be used for fire fighting. Two fire fighting water pumps, one is of electric motor-driven and the other is of diesel engine-driven, will be installed in the border of the pond.

(vi) Chemicals and Lubricants

Many kinds of chemicals and lubricants are required for operation and maintenance of gas turbine combined cycle power plant.

In Cambodia, all these chemicals and lubricants are assumed to be imported from other countries. Therefore, storage tanks and facilities for several months will be provided in the plant considering a required period for procurement.

- Power Transmission

The plant will be connected to 220 kV double-circuit transmission line. The transmission line will come from Takeo Substation via Kampot and enter into the plant at northeast edge of the plant boundary.
The plant will also provide a connection of high voltage transmission line to the city center of Sihanoukville. This transmission line will run south of the plant.

- Redundancy design philosophy

In general, "N + 1" basis will be applied to the equipment (or system) that is required to be operated continuously for maintaining full-output operation of the plant. Where, "N" is the required numbers of equipment for generating 100 % output of the plant.

However, "N" basis (i.e.. no spare) will be applied to the equipment categorized below:

- Main, but costly equipment, such as:
  gas turbine, HRSG, steam turbine, steam condenser, cooling water pump, etc.
- Equipment being unlikely to suffer frequent and/or accidental damages, such as:
  piping system, transformer, circuit breaker, etc.
- Equipment being considered not to be essential for continuous operation of the plant, such as:
  ventilation and air conditioning system, waste water treatment system, storing equipment, maintenance equipment, equipment for emergency use, etc.

For the control and supervising system, the following philosophy will be applied:

- Local instrument and controls will be single.
- Central control systems which is base on microprocessor technologies will be duplicate for main equipment, such as gas turbine, HRSG, steam turbine, etc.
- Data-way system for communication among the above mentioned central control systems will be duplicate.

- Black Start and Emergency Electric Power Source

  Emergency diesel generator will be installed to be able to start of the plant without incoming power supply. And UPS (Uninterrputible Power Supply) system will also be provided for supplying DC power for emergency control and lighting for safety shutdown of the plant.

- Inspection and Maintenance Philosophy

  Workshop and chemical laboratory will be provided in the plant.
  Normal inspection, maintenance and repairing will be carried out in situ, however a special maintenance for gas turbine will be carried out by gas turbine manufacturer in their factories.

7.2. <u>Basic Design Conditions of Power Plant</u>

7.2.1. Site Conditions

(1) Topography

The site area is generally hilly area covered with grass with elevation of EL. 1.0 m ~ 8.0 m, and a slope of approximately 1/50 - 1/70. Two creeks crossing the site are flow into a pond, that forms a part of southern border of the site area.

(2) Geology

The overburden in the site area is composed of mostly sand and silty sand with partly interbedded clayey layer having thickness of approximately 4 - 26 m. Rather thick overburden has been found in the area between two canals and swamps on southern boundary of the site. The overburden is thinning northwards.

(3) Meteorology

a. Ambient Temperature	28.8 ºC (Ave.), 33.7 ºC (Max.), 24.5 ºC (Min.)
b. Relative Humidity	86% (Max. monthly ave.), 76% (Min. monthly ave.)

c. Rainfall: 3,200 mm (Annual ave.), 675 mm (Max. monthly ave.)
45.3 mm/10 min (50 years-return period)

d. Wind
Averaged wind speed : 3 - 6m/sec
Wind direction : W and SW in rainy seasons
N and S in dry season
Maximum wind speed and direction :
24 m/sec, W-NW observed in 1996

(4) Oceanography

(a) Tide Level

CDL	(Chart Datum Level)	=	- 1.07 m + MSL*
MHWL	(Mean High Water Level)	=	0.37 m + MSL*
MSL	(Mean Sea Level)	=	+ 0.08 m + MSL*
MLWL	(Mean Low Water Level)	=	- 0.17 m + MSL*
HHWL	(Highest High Water Level)	=	+ 1.17 m + MSL*
LLWL	(Lowest Lower Water Level)	=	- 1.06 m + MSL*

* MSL at Hatien in Vietnam

(b) Wind Wave Height and Period

Probable wind wave with a return period of 50 years estimated as 3.8 m in significant wave height and 6.5 sec as significant wave period.

(5) Site Ground Elevation

The site ground elevation was determined to be 4.1 m + MSL considering the balance of soil for site preparation, safety for the maximum tide level and possible wave run-up height, and siphon limit of cooling water system.

7.2.2. Fuels

(1) Kind of Fuels

Sihanoukville gas turbine combined cycle project will use natural gas as main fuel and diesel oil as standby fuel. Refer to Section 3.1 regarding availability of fuels.

(2) Natural Gas Properties

The anticipated chemical composition and heating value based on typical natural gas are shown in Table 7.2-1.

Table 7.2-1 Properties of Typical Natural Gas

Components	Unit	
CO_2	vol. %	1.65
N_2	vol. %	1.92
CH_4	vol. %	95.49
C_2H_6	vol. %	0.72
C_3H_8	vol. %	0.07
C_4H_{10}	vol. %	0.02
C_5H_{12}	vol. %	0.10
High Heating Value	kJ/Nm^3	38,700
Low Heating Value	kJ/Nm^3	34,920

(3) Diesel Oil Properties

The anticipated chemical composition and heating value are shown in Table 7.2-2.

Table 7.2-2 Properties of Diesel Oil

Components	Unit	
Carbon	wt. %	86.22
Hydrogen	wt. %	13.10
Oxygen	wt. %	0.10
Nitrogen	wt. %	0.08
Sulfur	wt. %	0.20
Water & Sediment	wt. %	0.00
Ash	wt. %	0.00
High Heating Value	kJ/kg	44,430
Low Heating Value	kJ/kg	41,470

7.2.3. Cooling Water

(1) Quality Sea Water

(2) Temperature

Condenser Design Temperature	29°C
Permissible Temperature Rise	7°C

(3) Water Levels

See Section 7.2.1.(4).

7.2.4. Raw Water

(1) Source

Prey Treng Pond is the most likely fresh water source for the power plant.

(2) Quantity

In dry season, fresh water discharge observed at Prey Treng Pond is approx. 17 lit/sec in the end of February 2001. The quantity of fresh water is enough for the power plants. However, the 1-month reservoirs will be installed against water shortage during dry season considering increase of future fresh water demand for other consumers.

Variation of rainfall in dry season (from November to March) through 1991 to 2001 is as shown in Fig.7.2-1.

Return period of rainfall in dry season of 2001 is calculated as 1.4 year based on the above variation as shown in Table 7.2-3. As a result, the raw water quantity is expected to be supplied mainly from the Prey Treng Pond.

(3) Water Quality

Water analysis of Prey Treng Pond is shown in the Table 7.2-4.

Table 7.2-3 Non-Excess Probability Dry Season Rainfall at Sihanoukville

Return Period (year)	Probability (%)	Rd (mm)
20	5.00	23.51
10	10.00	88.74
5	20.00	167.69
3	33.33	241.46
2	50.00	318.75
1.5	66.67	396.04
1.2	83.33	492.83
1.1	90.91	558.42

RD : Rainfall in Dry Season (November - March)
Dry year : Probability 10% occurrence of Rd less than 88.74 mm.

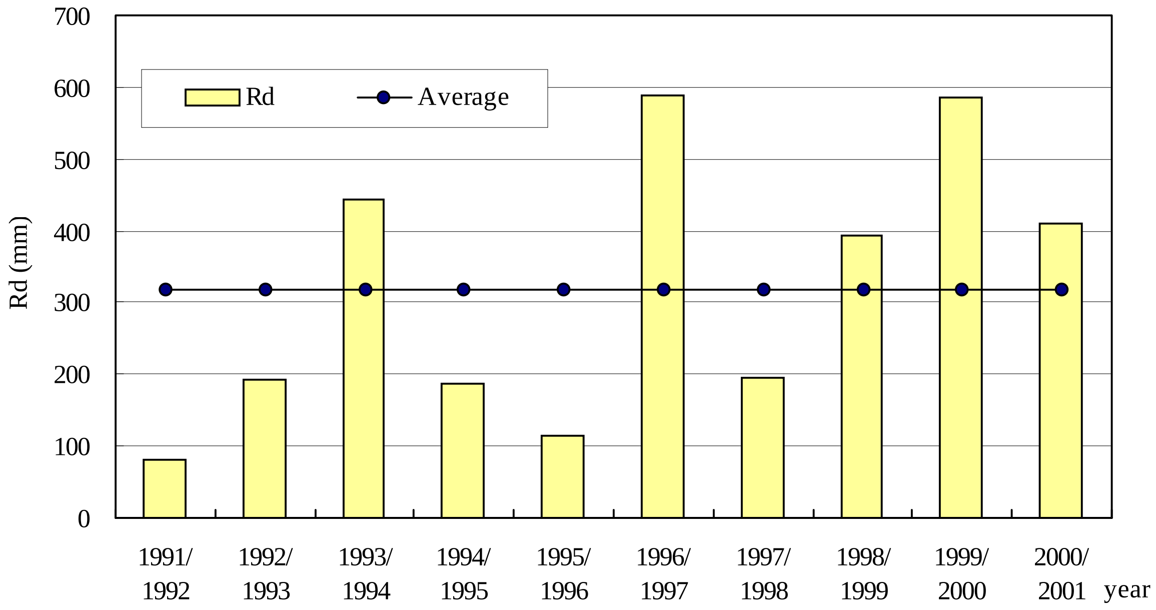


Fig.7.2-1 Variation of Rainfall in Dry Season

Table 7.2-4 Quality of Fresh Water

Parameter	Unit	Dry Season	Rainy Season
Color	-	Yellowish	Yellowish
Odor	-	No	No
pH	-	9.0	6.9
Salinity	ppt	0	0
Transparency	m	1.3	2.2
Dissolved Oxygen	mg/l	5.3	6.8
Turbidity	NTU	3.2	2.2
Total Hardness	mg/l as $CaCO_3$	12.0	8.1
Total Suspended Solids	mg/l	1.0	2.0
Total Solids	mg/l	65.0	36.0
Carbon Dioxide	mg/l	2.11	2.07
Cations			
Sodium	mg/l as Na	3.142	2.60
Potassium	mg/l as K	0.809	0.315
Calcium	mg/l as Ca	ND	ND
Magnesium	mg/l as Mg	2.92	1.96
Manganese	mg/l as Mn	Limit of Quantitation	ND
Iron	mg/l as Fe	0.918	0.731
Ammonia Nitrogen	mg/l as NH_3-N	0.185	0.14
Anions			
Chloride	mg/l as Cl	4.76	5.82
Bicarbonate Alkalinity	mg/l as $CaCO_3$	12.0	2.07
Sulfate	mg/l as SO_4^{2-}	3.1	2.1
Silica	mg/l as SiO_2	28.0 *	4.06
COD	mg/l	35.93	37.85
Oil and Grease	mg/l	ND	ND

* should be checked by further analysis

7.2.5. Seismic Design Condition

In Cambodia, the seismic coefficient defined as “the fraction of a weight to be used as a horizontal force in a quasistatic analysis” could be set as 0.05.

As for Tsunami, the area around the site has rare possibility of earthquake and Tsunami. In case of any Tsunami in the Gulf of Thai, that cannot reach to the site due to islands scattered in front of Sihanoukville.

7.2.6. Selection of Intake and Discharge Facility Types

For selecting the type of intake and discharge facility, estimation of construction cost and features of each type are compared between 1) Rubble stone type, 2) Steel pipe pile type and 3) Buried pipe type.

Considering construction cost in addition to less environmental impact, the buried pipe type is most prosperous.

7.3. Configuration of Combined Cycle Power Plant

7.3.1. Outline of Power Plant

Outline of power plant is as follows,

- Plant capacity: 180 MW
  Stage 1 : 1 × 90 MW
  Stage 2 : 1 × 90 MW
- Type of power plants: Gas turbine combined cycle
- Plant site: OP-4 site in Sihanoukville
  (Approx. 2 km south of Sokimex Oil Terminal)
- Mode of operation: Base load operation
- Fuel: Natural Gas and Diesel Oil
- Cooling water: Seawater
- Fresh water: Prey Treng Pond next to the site and the water reservoir will be installed in the site for shortage of water during dry season

7.3.2. Type of Combined Cycle Power Plant

Gas turbine combined cycle power plant is composed of gas turbines, HRSGs and steam turbines. On the gas turbine combined cycle power plant, one and more gas turbine(s) and correspondent number of steam turbine(s) are equipped to have necessary plant capacity. The number of HRSGs is the same as that of gas turbines and the waste heat in the gas turbine exhaust gases is converted to steam by the HRSGs to be utilized for steam turbines.

There are two types for gas turbine combined cycle power plant. One is single shaft type and the other is multiple shaft type. Table 7.3-1 shows the characteristics of both types.

Table 7.3-1 Comparison between Single Shaft and Multiple Shaft Configurations

	Single Shaft	Multiple Shaft
Capital Cost	Base	Same
Efficiency	Base	Better at higher load Worse at lower load
Availability	Base	Same
Operability	Base	Worse
Required Area	Base	Smaller

7.3.3. Capacity of Gas Turbines

One and more gas turbines are combined with a steam turbine to have necessary plant capacity for multiple shaft type gas turbine combined cycle plant.

It is necessary to decrease an influence of forced outage of the equipment on power system by applying many smaller gas turbines judging from the power system stability point.

For power system in Cambodia, the maximum permissible capacity drop is approx. 30 MW in case of stop of one (1) gas turbine judging from the power system stability point. Therefore, the maximum capacity of gas turbine is approx. 20 MW and the number of gas turbines is 3 sets for each stage of 90 MW.

7.3.4. Steam Condition

Steam condition at steam turbine inlet is as follows,

At natural gas firing

- Steam pressure 5.4 MPa
- Steam temperature 493°C

At diesel oil firing

- Steam pressure 5.5 MPa
- Steam temperature 497 °C

7.3.5. Condenser Vacuum

For the Project, inlet temperature of cooling water is 29°C, outlet inlet temperature of cooling water is 36°C (29+7) and saturation temperature is 40°C (36+4). Therefore, condenser vacuum is 7.38 kPa which is equivalent to the saturation pressure of 40°C.

7.4. Particulars of Main Equipment

7.4.1. Gas Turbine

(1) Major Specifications of Gas Turbine

The major specifications of gas turbines are as follows.

(a)	Capacity	20 MW class
(b)	Type	Indoor
(c)	Fuel	Natural gas and diesel oil
(d)	Number	3 sets per stage

(2) Performance at Site Conditions

Fuel type, atmospheric pressure, ambient temperature, relative humidity, etc will change the performance of gas turbine.

Natural gas and diesel oil will be used as fuels for the Project and regarding atmospheric condition atmospheric pressure is 1,013 hPa, ambient temperature is 28.8°C and relative humidity is 81% in Sihanoukville. Table 7.4-1 (natural gas firing) and Table 7.4-2 (diesel oil firing) show the performance of gas turbine at the above-mentioned site condition.

Table 7.4-1 Performance of Typical Gas Turbines with N.G. at Site Conditions

Manufacturer	GE	ANSALDO	ABB	MHI
Model	LM2500-PE	AGT25000	GT10B	MFT8
Capacity (kW)	19,670	23,480	22,220	22,610
Heat Rate (kJ/kWh)	10,216	10,513	11,015	10,262
Exhaust Temperature (°C)	538	479	557	482

Table 7.4-2 Performance of Typical Gas Turbines with D.O. at Site Conditions

Manufacturer	GE	ANSALDO	ABB	MHI
Model	LM2500-PE	AGT25000	GT10B	MFT8
Capacity (kW)	19,640	22,680	21,460	21,830
Heat Rate (kJ/kWh)	10,295	10,605	11,112	10,350
Exhaust Temperature (°C)	547	481	559	484

(3) Standard Gas Turbine

Each manufacturer has its peculiar model of gas turbine and a gas turbine made by one manufacturer has different performance and capacity compared to gas turbines made by other manufacturers. Therefore, we image the gas turbine (called the standard gas turbine hereafter) which has average performance of the gas turbines made by manufacturers so that we carry out the future feasibility study.

The performance of the standard gas turbine at site condition is as follows,

(a) Natural Gas Firing

- Capacity 20,600 kW
- Heat Rate 10,500 kJ/kWh (2,508 kcal/kWh)
- Exhaust Temperature 514°C

(b) Diesel oil Firing

- Capacity 20,000 kW
- Heat Rate 10,593 kJ/kWh (2,530 kcal/kWh)
- Exhaust Temperature 518°C

(4) Main Components of Gas Turbine

A gas turbine is composed of air filtration system, compressor, combustion system, turbine, exhaust gas system, lubricating oil system and starting system.
A gas turbine is connected to the generator through a reduction gear or directly.

(5) Maintenance Schedule

Periodical maintenance is required for gas turbines to keep high efficiency and ensure reliability. Generally combustor inspection takes place at intervals of 12,000 equivalent operation hours and hot gas path inspection takes place every 24,000 equivalent operation hours, i.e. after 1.5 years and 3 years respectively. Major inspection generally occurs every 48,000 equivalent operation hours (6 years).

7.4.2. Heat Recovery Steam Generator (HRSG)

(1) Type of HRSG

HRSG is installed to utilize heat of exhaust gas from gas turbine in order to produce steam for steam turbine. There are several types of HRSG shown in Table 7.4-3. Suitable type is selected according to the steam condition and available installation area or standard design of manufacturer.

Table 7.4-3 Type of HRSG

stage of steam pressure	circulation of boiler water	gas flow direction
single-pressure	natural circulation	horizontal
multi-pressure	forced circulation	vertical

(2) Stages of Steam Pressure

There are two types of HRSG in relation to number of stages of steam pressure. It is preferable to select multi-pressure HRSG for the Project to improve efficiency.

(3) Circulation System of Boiler Water

There are two types of boiler water circulation system, i.e. natural circulation and forced circulation. Natural circulation utilizes the difference of densities of water and water/vapour mixture within the circulation system. Forced circulation circulates the boiler water using boiler circulation pump. Table 7.4-4 shows comparison of characteristics of these two circulation types.

(4) Gas Flow Direction

There are two types of HRSG in relation to gas flow direction, i.e. horizontal gas flow type and vertical gas flow type. Table 7.4-5 shows comparison of these two types.

(5) Estimated Main Spec. of HRSG

Item	Unit	Natural Gas		Diesel Oil	
		HP	LP	HP	LP
Evaporation	t/h	85.8*	20.6*	84.9*	20.2*
Steam pressure	MPa	5.7	0.74	5.8	0.74
Steam temperature	°C	496	235	500	235
Feedwater temperature	°C	60		135	
Number of installation		One for each GT (Three for each stage of 90 MW)			

* Total evaporation of three HRSGs for 90 MW

(6) Stacks

A common stack will be provided for three HRSGs to help disperse the flue gas into the atmosphere.

The height will be 50 m and the diameter will be 3.9 m.

Table 7.4-4 Comparison between Natural Circulation and Forced Circulation Type of HRSG

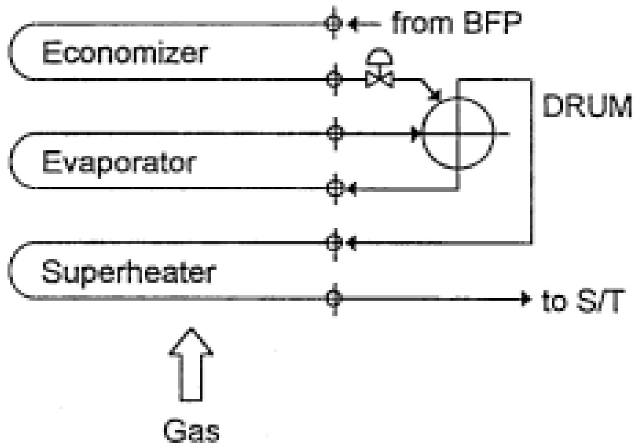
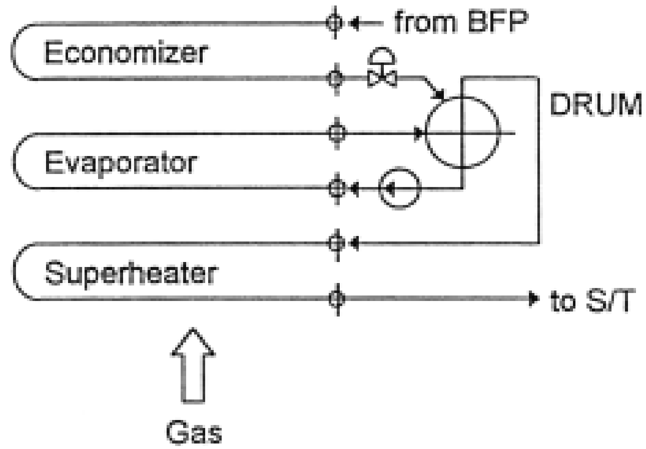
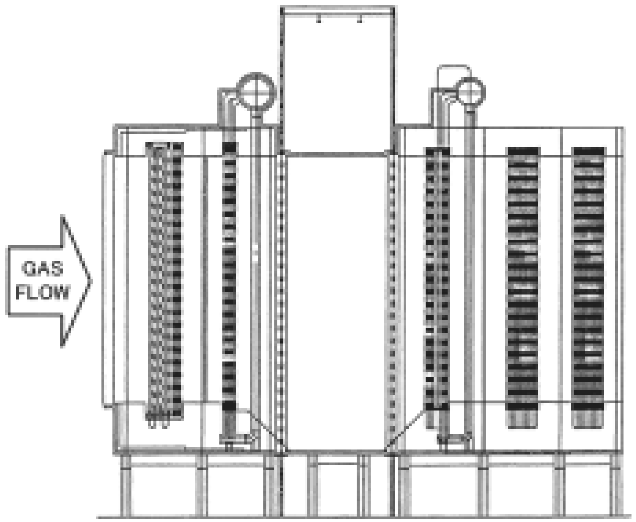
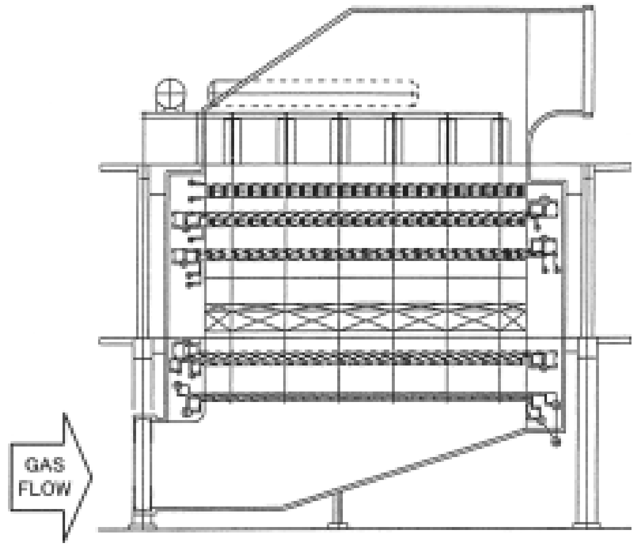
			natural circulation	forced circulation
Schematic system				
Applicable Range	Circulation Ratio		14 ~ 6	~ 4
	Pressure		below 17.7 MPa	below 19.6 MPa
Startup Time			Base	Shorter
Reliability	Stability of Water Circulation		Base	Better
	Possibility of Trouble		Base Circulation system is simple.	Higher Circulation system is rather complicated.
Size	Height		Base	Same
	Required space		Base	Same
Cost	Weight	Pressure parts	Base (100%)	Lighter (90%)
		Non-pressure parts	Base (100%)	Same
		Steel structure	Base (100%)	Same
	Auxiliary Power Consumption		Base (100%)	Larger (120%)
	Maintenance		Base	Maintenance cost of BCPs increase.
	Construction cost		Base	Same

Table 7.4-5 Comparison of Type of HRSG

			Horizontal Gas Flow Type	Vertical Gas Flow Type
Features of HRSG				
Features	Heat Exchange Area		Base	Same
	Pressure Drop of Exhaust Gas		Base	Same
	Startup Time&Load Variation		Base	Same
Size	Height		Base	Same
	Required space		Base (100%)	Smaller(98%)
Cost	Weight	Heat Exchange Tube	Base	Same
		Header	Base	Same
		Non-pressurized Parts	Base (100%)	Lighter (83%)
		Steel Frame	Base (100%)	Heavier (133%)
	Ease of Construction	Number of Welding	Base (100%)	Smaller (67%)
		Number of Module	2Modules	1Module
	Ease of Maintenance and Inspection		Base (Scaffolding is required.)	Easier (Scaffolding is not required.)
	Construction Cost		Base	Same

7.4.3. Steam Turbine

(1) Type

There are two types of steam turbines that are used for gas turbine combined cycle plant by exhaust flow direction. One is axial exhaust turbine and the other is down exhaust turbine.

The axial exhaust turbine has higher efficiency because of lower exhaust loss and it is possible to reduce the construction cost of foundation and building of steam turbine because of lower required level of installation. Therefore, the axial exhaust turbine has an advantage over down exhaust turbine.

The axial exhaust turbine will be applied to the Project.

(2) Major Specification

The major specification of the steam turbine for the Project is as follows.

• Type	Axial exhaust turbine		
• Rated output	28,200 kW		
• Rated speed of turbine	3,000 rpm		
• Steam condition	Steam pressure	(HP/LP) :	5.4 MPa / 0.7 MPa
	Steam temperature	(HP/LP) :	493°C / 234°C
• Condenser vacuum	7.38 kPa		
• Number of installation	One for each stage of 90 MW		

(3) Main Components of Steam Turbine

A steam turbine is composed of cylinder, blading, rotor, bearing, valves, control oil system, lubricating oil system and barring system.

A steam turbine is connected to the generator through a reduction gear or directly.

A condenser will be installed to condense the exhaust steam from a steam turbine by cooling water.

7.4.4. Generator

Main specifications of generator are recommended as mentioned below, considering every factor such as most advanced and proven technologies applicable in the world-wide market, economics, reliability, operationability and maintenability.

(1) Type of Protection and Cooling Method

Gas turbine generator and steam turbine generator will be of indoor type, considering easy operation and maintenance works in spite of weather conditions. As unit capacity of generator for this power plant will be less than about 50 MVA, applicable type will be open air cooled type, totally enclosed air cooled type with air-to-water heat exchanger or totally enclosed hydrogen cooled type with hydrogen gas-to- water heat exchanger, considering economical and technical points of view.

From view points of procurement of high purity hydrogen gas, safe operation and easy maintenance, application of totally enclosed hydrogen cooled type should be avoided.

Application of totally enclosed air cooled type is preferably recommended because of its better efficiency than open air cooled type. However, in case that gas turbine generator simple cycle will be installed and operated in advance of installation of whole combined cycle plant with boiler and stem turbine generator system, application of open air cooled type may be allowed for gas turbine generator, since cooling water may not be applicable.

(2) Rated Capacity and Rated Power Factor

Rated output of generator will be equal to the rated output of gas turbine or steam turbine as usual.

Rated power factor of 0.85 is recommended as most suitable, taking into account general application practice of power factor for air cooled generator and past records of average power factor of the network load in Phnom Penh.

(3) Rated Voltage

Rated voltage of generator can be determined as most suitable by manufacturers according to their design criteria, since generator output voltage is stepped up through main transformer to the rated voltage of the transmission lines and, therefore, is not subject to any external restraint.

(4) Insulation Class and Permissible Temperature Rise

Considering the importance of this power plant, application of class F insulation material and permissible temperature rise of class B is recommended to attain higher reliability.

(5) Type of Excitation System

Generally, either brushless excitation system or static excitation system is applicable to this project. Brushless type is preferable for this project because of its easy and less maintenance works.

7.5. Scope of Works

The power plant for the Project will be furnished on full turnkey basis including all works such as erection work, civil work, etc.

The Sihanoukville power plant will be implemented in three stages (i.e., Stages 1, 2 and 3). Each 90 MW plant will be constructed in each stage. However, common works such as site preparation, etc. have to be done in Stage 1.

The philosophy of expansion from Stage 1 (90 MW) to Stage 2 (total 180 MW) is as follows.

Note : The term "All works" means all works necessary for the whole plant of Stage 1, Stage 2 and Stage 3.

	Stage 1 (90 MW)	Stage 2 (Total 180 MW)
Civil Works		
Excavation	All works	None
Leveling and site preparation	All works	None
Soil disposal	All works	None
Foundations	Works related to 1st 90 MW	Works related to 2nd 90 MW
Intake pipes and discharge pipes	Works related to 1st 90 MW	Works related to 2nd 90 MW
Cooling water pump pit	Works related to 1st 90 MW and 2nd 90 MW	None
Bridge and culvert construction work of cooling water lines for crossing the existing provincial road/railway	All works	None
Road in the premises	All works	None
Tree planting and garden	All works	None
Parking lots	All works	None
Fence	All works	None
Fresh water pump pit	Works related to 1st 90 MW and 2nd 90 MW	None
RC raw water reservoirs	Works related to 1st 90 MW	Works related to 2nd 90 MW
RC filtered water storage tanks	Works related to 1st 90 MW and 2nd 90 MW (common use)	None
RC tanks for wastewater treatment plant	Works related to 1st 90 MW and 2nd 90 MW	None
Architectural Works		
Administration building	All works	None
Gas turbine rooms	Works related to 1st 90 MW	Works related to 2nd 90 MW
Steam turbine rooms	Works related to 1st 90 MW	Works related to 2nd 90 MW
Central control room	Works related to 1st 90 MW and 2nd 90 MW	None
Electrical room	Works related to 1st 90 MW	Works related to 2nd 90 MW
Emergency diesel generator room	Works related to 1st 90 MW and 2nd 90 MW	None
Pump rooms	Works related to 1st 90 MW	Works related to 2nd 90 MW
Canteen building	All works	None
Work shop	Works related to 1st 90 MW and 2nd 90 MW	None
Warehouse	Works related to 1st 90 MW and 2nd 90 MW	None

	Stage 1 (90 MW)	Stage 2 (Total 180 MW)
Water treatment house	Works related to 1st 90 MW and 2nd 90 MW	None
Guardhouse	All works	None
Ventilation and air conditioning system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Diesel oil receiving house	Works related to 1st 90 MW and 2nd 90 MW	None
Fresh water pump house	Works related to 1st 90 MW and 2nd 90 MW	None
Mechanical Equipment		
Gas turbine sets	Works related to 1st 90 MW (3 gas turbines)	Works related to 2nd 90 MW (3 gas turbines)
HRSG sets and stacks	Works related to 1st 90 MW (3 HRSGs)	Works related to 2nd 90 MW (3 HRSGs)
Steam turbine sets	Works related to 1st 90 MW (1 steam turbine)	Works related to 2nd 90 MW (1 steam turbine)
Deaerators	Works related to 1st 90 MW (3 deaerators)	Works related to 2nd 90 MW (3 deaerators)
Condensers	Works related to 1st 90 MW (1 condenser)	Works related to 2nd 90 MW (1 condenser)
Steam and water system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Main cooling water system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Closed circuit cooling water system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Fuel gas treatment/supply system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Diesel oil receiving system	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Oil storage tanks	Works related to 1st 90 MW (1 oil storage tank)	Works related to 2nd 90 MW (1 oil storage tank)
Diesel oil supply pumps	2 × 100% pumps (1 normal operation and 1 common standby for 1st 90 MW and 2nd 90 MW)	1x100% pump
Diesel oil supply system	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Pumps for water treatment system	2 × 100% pumps (1 normal operation and 1 common standby for 1st 90 MW and 2nd 90 MW)	1x100% pump
Pre-treatment system	2 × 100% trains (1 normal operation and 1 common standby for 1st 90 MW and 2nd 90 MW)	1x100% train
Fresh water transfer line	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Demineralization plant	2 × 100% trains and 1x100% regeneration equipment	1x100% train
Demineralized water storage tanks	Works related to 1st 90 MW	Works related to 2nd 90 MW
Demineralized water transfer line	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Potable water system	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Wastewater treatment system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Air compressors	2 × 100% compressors (1 normal operation and 1 common standby for 1st 90 MW and 2nd 90 MW)	1x100% compressor

	Stage 1 (90 MW)	Stage 2 (Total 180 MW)
Compressed air distribution system	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW
Cranes and Lifts	Works related to 1st 90 MW (Overhead crane for gas turbine building is of common use)	Works related to 2nd 90 MW
Fire prevention and fighting system	All pumps and works related to 1st 90 MW for hydrant system and facilitated for link with 2nd 90 MW / Fire fighting system for 1st 90 MW equipment	Fire fighting system for 2nd 90 MW equipment
Control and Instrumentation System		
Overall plant supervisory control system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Gas turbine generator supervisory control system	Works related to 1st 90 MW	Works related to 2nd 90 MW
HRSG supervisory control system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Steam turbine generator supervisory control system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Data acquisition system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Common facilities supervisory control system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Uninterruptible power supply for C & I system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Telecommunication equipment to/from load dispatching center	Works related to 1st 90 MW and expandable hardware capability for 2nd 90 MW	Works related to 2nd 90 MW
Electrical Equipment		
Generators and main circuit equipment	Works related to 1st 90 MW	Works related to 2nd 90 MW
Transformers	Works related to 1st 90 MW	Works related to 2nd 90 MW
High voltage and low voltage station electrical system	Works related to 1st 90 MW	Works related to 2nd 90 MW
DC system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Emergency diesel generator set	Works related to 1st 90 MW and 2nd 90 MW (common use)	None
Operational instruction system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Grounding system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Lighting system	Works related to 1st 90 MW	Works related to 2nd 90 MW
Lightning system	Works related to 1st 90 MW	Works related to 2nd 90 MW
In-plant substation	Works related to 1st 90 MW	Works related to 2nd 90 MW
Supervisory, operational and protective system for electrical equipment	Works related to 1st 90 MW	Works related to 2nd 90 MW
In-house communication system	Works related to 1st 90 MW and facilitated for link with 2nd 90 MW	Works related to 2nd 90 MW

7.6. Outline of Plant

7.6.1. Expected Performance of Plant

The performance of gas turbine combined cycle power plant applying the standard gas turbines is as follows;

(1) At Natural Gas Firing

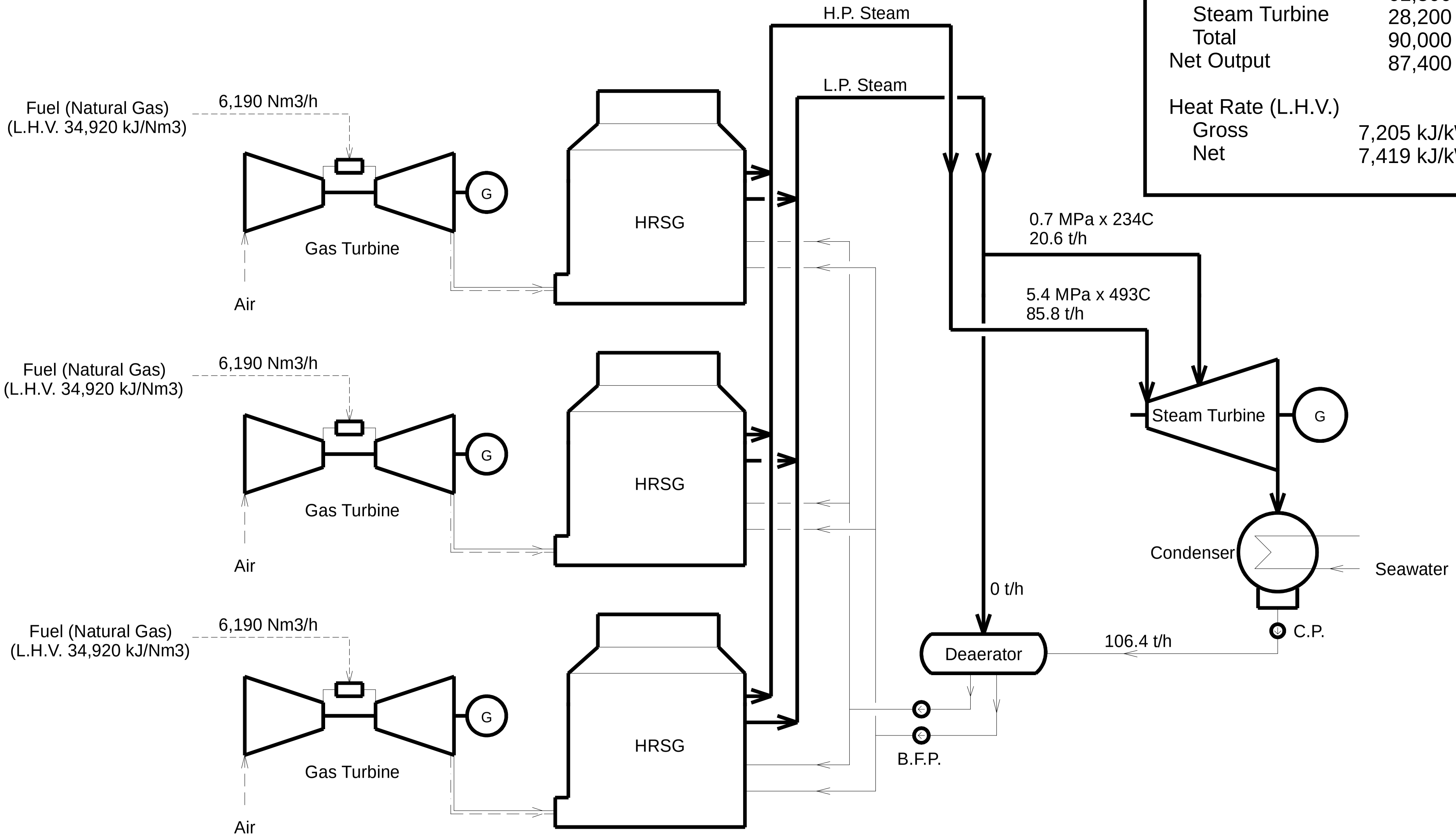
• Gross output	Gas turbines	61,800 kW (3 × 20,600 kW)
	Steam turbine	28,200 kW
	Total	90,000 kW
• Net plant output		87,400 kW
• Heat rate (LHV)	At generator terminal	7,205 kJ/kWh (1,721 kcal/kWh)
	At send out point	7,419 kJ/kWh (1,772 kcal/kWh)

Fig.7.6-1 shows the preliminary heat balance of gas turbine combined cycle power plant at natural gas firing.

(2) At Diesel Oil Firing

• Gross output	Gas turbines	60,000 kW (3 × 20,000 kW)
	Steam turbine	25,700 kW
	Total	85,700 kW
• Net plant output		83,100 kW
• Heat rate (LHV)	At generator terminal	7,418 kJ/kWh (1,772 kcal/kWh)
	At send out point	7,650 kJ/kWh (1,827 kcal/kWh)

Fig.7.6-2 shows the preliminary heat balance of gas turbine combined cycle power plant at diesel oil firing.



Fuel	Natural Gas
Gross Output	
Gas Turbine	61,800 kW
Steam Turbine	28,200 kW
Total	90,000 kW
Net Output	87,400 kW
Heat Rate (L.H.V.)	
Gross	7,205 kJ/kWh
Net	7,419 kJ/kWh

Fig.7.6-1 Heat Balance of Gas Turbine Combined Cycle Power Plant (Natural Gas)

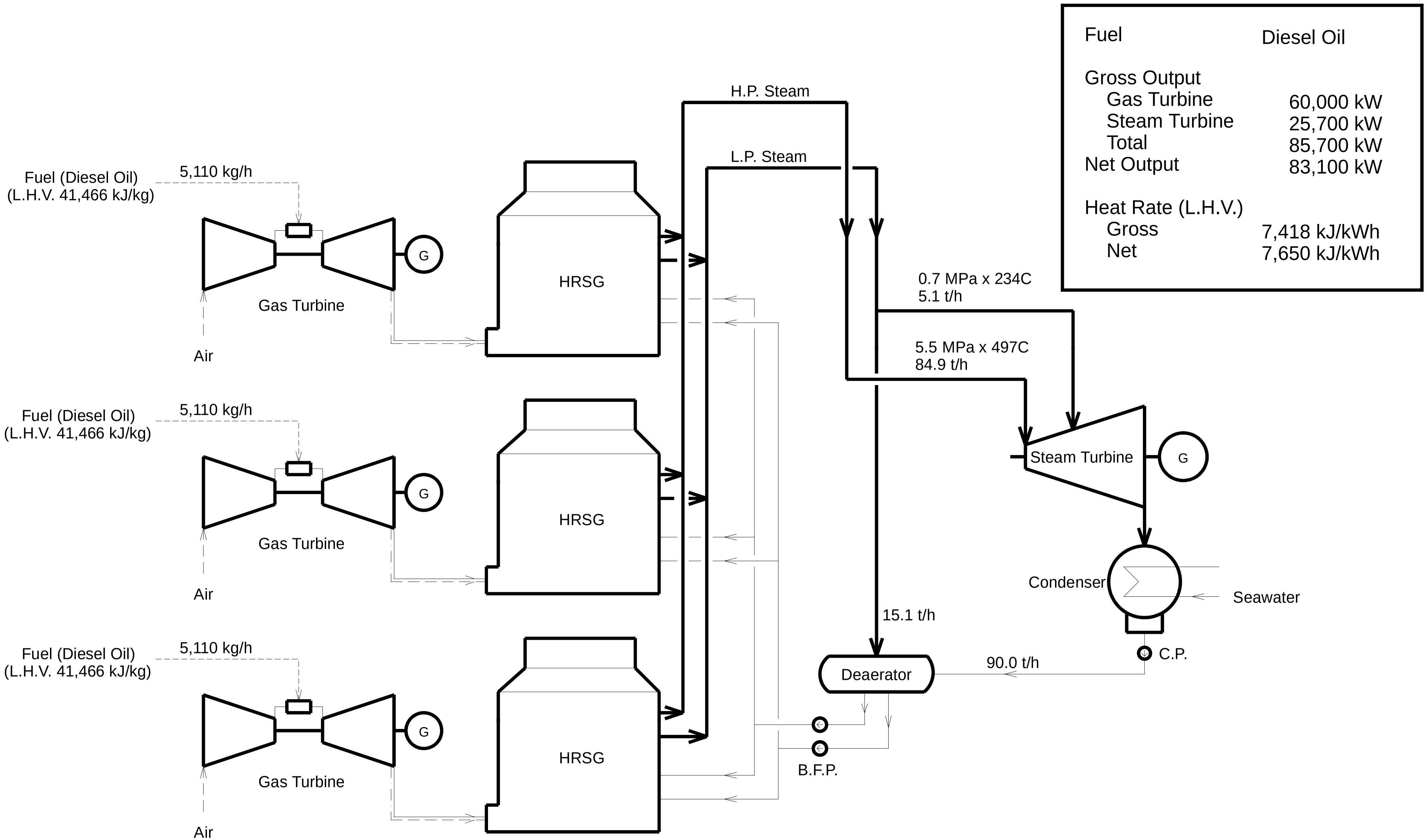


Fig.7.6-2 Heat Balance of Gas Turbine Combined Cycle Power Plant (Diesel Oil)

7.6.2. Steam/Water Cycle

(1) Steam Cycle

High-pressure superheated steam and low-pressure superheated steam are produced in the HRSG by heat of gas turbine's exhaust gas. Those steams expand in the steam turbine and rotate a generator that is connected with the steam turbine directly or through a reduction gear.

Turbine steam bypass system is provided with bypass facilities capable of allowing both steam turbine and HRSG unit start up or re-start ties to be minimized, and the unit to remain in operation supplying the unit auxiliary power demand, following disconnection from the grid.

The steam, which is exhausted from the steam turbine enters a condenser and is condensed by cooling water.
Heating steam for feedwater is supplied to a deaerator from the low-pressure steam line.

Refer to Fig. 7.6-3.

(2) Water Cycle

Condensate water is fed from a condenser to a deaerator directly (in case of diesel oil firing) or via LP economizer (in case of natural gas firing) by condensate pumps before entering the HRSG. The water is heated by the deaerator using low-pressure steam (in case of diesel oil firing) or by hot feedwater recirculation at LP economizer (in case of natural gas firing), and supplied to HRSGs by boiler feed water pumps as feedwater.

Two high-pressure boiler feedwater pumps and two low-pressure boiler feedwater pumps will be provided for each HRSG. The high-pressure boiler feedwater pumps will supply feedwater to the high-pressure line.

The feedwater temperature entering the HRSGs has to be controlled to prevent sulfuric acid corrosion and carbonic acid corrosion on the outside surface of the economizer tubes.

In this Project, the feedwater temperature is controlled to 135°C by steam heating in deaerator when firing oil, and to 60°C by hot feedwater recirculation at LP economizer when firing natural gas.

Refer to Fig. 7.6-3.

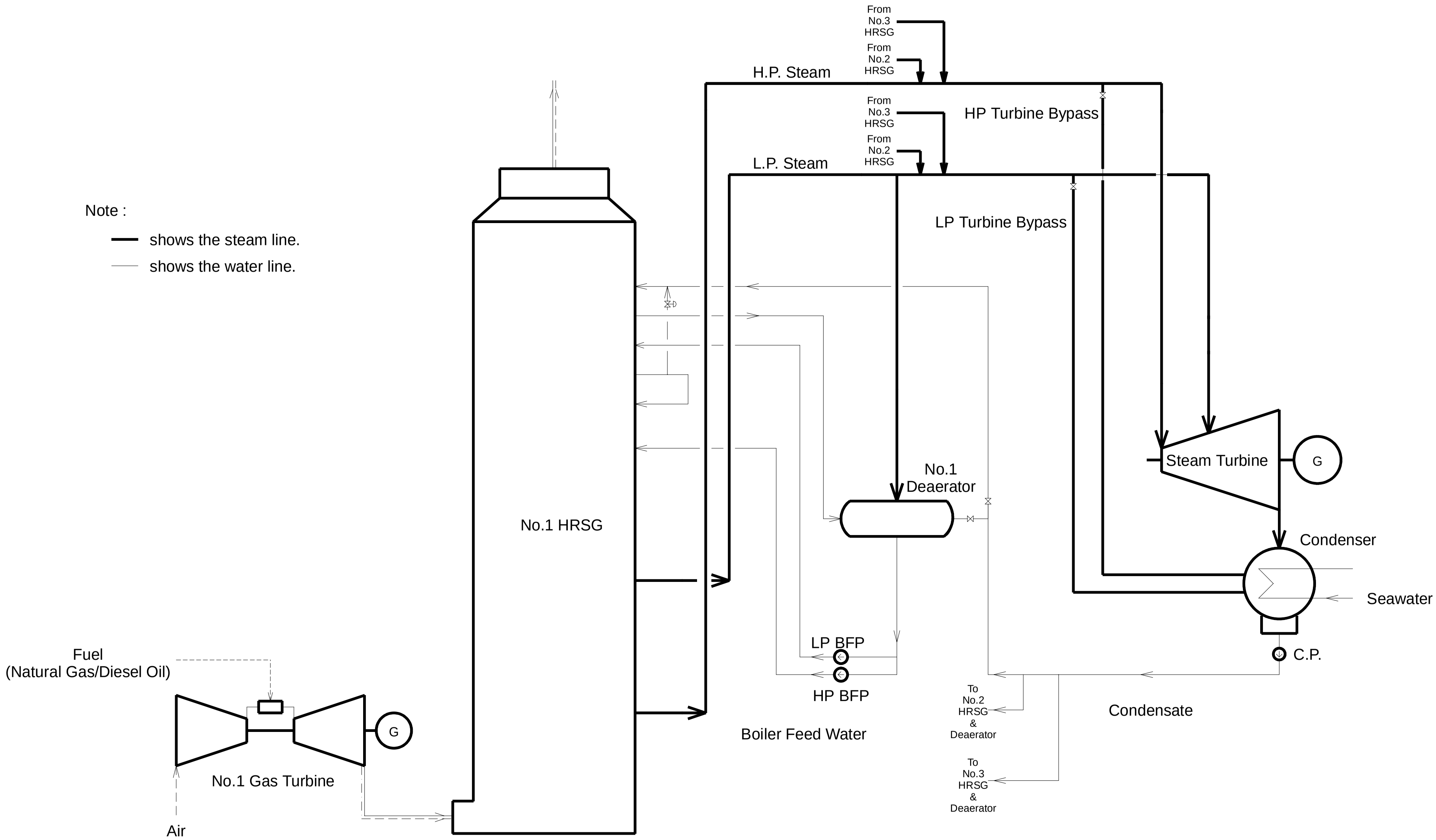


Fig.7.6-3 Steam and Water System of Gas Turbine Combined Cycle Power Plant

7.6.3. Fuel Supply and Storage System

(1) Kind of Fuel

Natural gas and diesel oil will be used as fuel for the Project.

(2) Natural Gas Supply Plan

Natural gas will be used as main fuel. The natural gas will be supplied to the site boundary by pipeline.

A filter separator unit for each gas turbine is recommended for protecting the gas turbine fuel equipment from particulates and moisture carry-over from the gas treatment plant. Gas flow meters will be installed in the incoming supply pipeline and the gas turbine supply pipelines.

(3) Diesel Oil Supply Plan

Diesel oil will be used as standby fuel when natural gas is not available. In Cambodia, all of liquid fuels are currently imported.

Diesel oil for the Project will be supplied from Sokimex Oil Terminal because the site is located approx. 2 km south of this oil terminal. For the Project, pipeline transport is selected because of the short distance between the site and the oil terminal.

(4) Diesel Oil Storage Plan

The storage tank capacity will be 5,180 ton equivalent to oil consumption for 14 days. One storage tank per each stage will be installed.

7.6.4. Cooling Water System

(1) Outline

The cooling water system will be provided to supply cooling water to power plant equipment that requires a cooling medium for their operation. The cooling water system consists of primary cooling water system with seawater (herein after called Main Cooling Water System) and secondary cooling water system with fresh water (herein after called Closed Circuit Cooling Water System).

(2) Main Cooling Water System

The main cooling water system provides the total seawater requirements for the condensers and the closed circuit cooling water system.

The main cooling water system will be of once through type using seawater drawn from an off shore intake and an adequate interval between intake and discharge points will be considered to prevent the hot water from recirculation into the cooling water intake.

It is desirable that the temperature rise of main cooling water system will be not more than 7°C under the rated conditions to minimize the effect on aquatic organisms, fishes, etc. Furthermore, the effluence should result in a temperature increase of no more than 3°C at the edge of the zone that is 100 m away from the point of discharge.

The quantity of cooling water per stage is estimated as follows:

a.	For condenser	:	8,000 m^3/h
b.	For closed circuit cooling water system	:	1,000 m^3/h
c.	Total per stage of 90 MW	:	9,000 m^3/h

The main cooling water system will consist of screening plant, chlorine injection system, cooling water pumps, seawater booster pumps for closed circuit cooling water system, etc.

Fig.7.6-4 shows the flow diagram of main cooling water system.

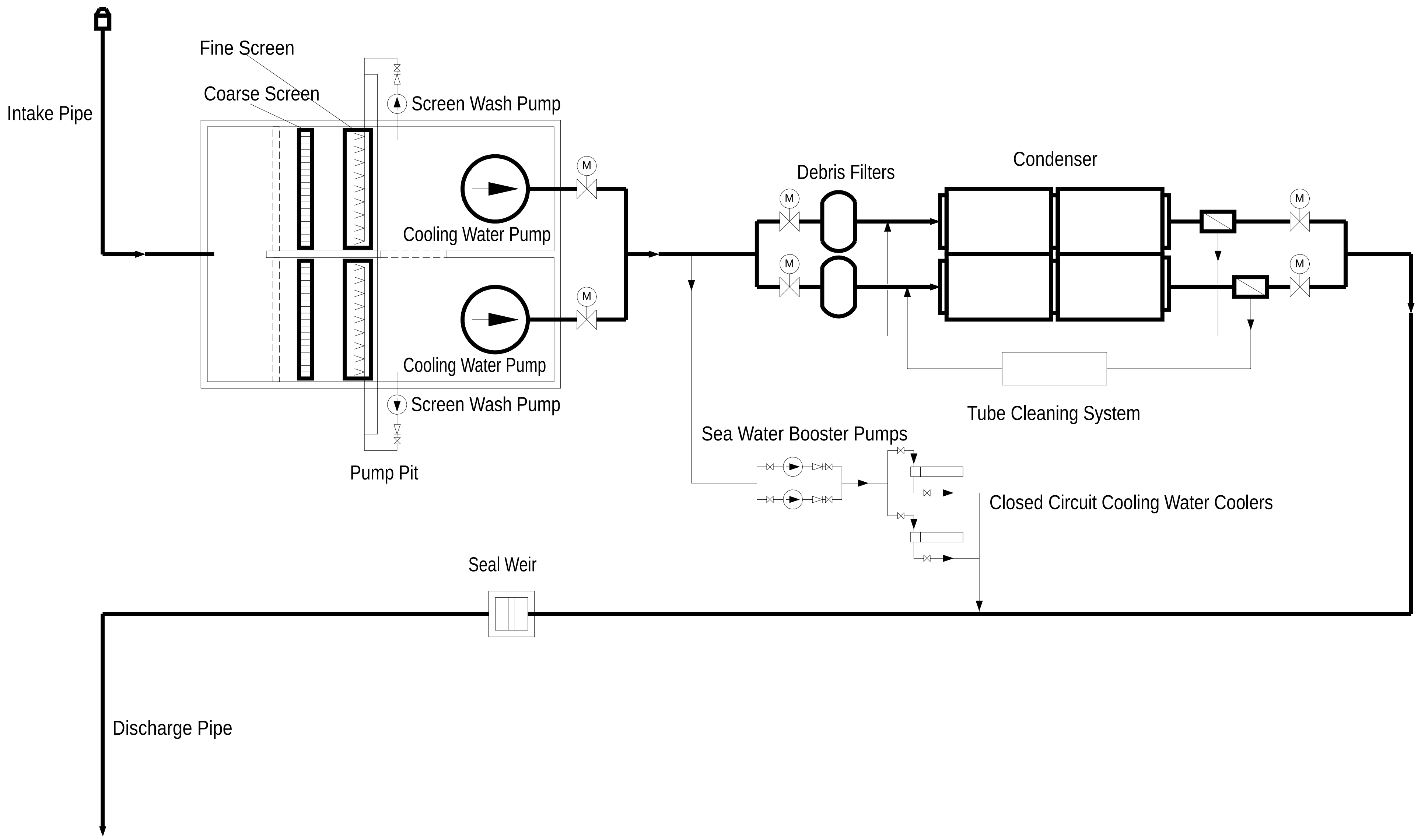


Fig.7.6-4 Flow Diagram of Main Cooling Water System

(3) Closed Circuit Cooling Water System

The closed circuit cooling water system is provided to supply cooling water to the miscellaneous power plant equipment that requires a cooling medium for their operation.

Demineralized water will be used as an intermediate cooling medium between the equipment coolers and seawater. The cooling water is cooled by seawater using the water coolers.

Each Stage will be provided with a closed circuit cooling water system. Each system consists of water coolers, head tank, circulating pumps and distribution system.

7.6.5. Fresh Water Supply System

(1) Fresh Water Source

Fresh water demand for the plant with capacity of 90 MW × 2 is about 9 m^3/h and after extension (90 MW × 3) it is about 13 m^3/h. Prey Treng Pond is the most suitable for fresh water source of the power station because of near location. However, it is expected that water supply from Prey Treng Pond is not sufficient in dry season. Therefore, the water reservoirs are necessary.

(2) Fresh Water Supply System

The water supply system will provide the total requirement of main plant cycle make-up, potable and auxiliary service water for the power plant.

The principal demand of fresh water is as follows.

a. Demineralized water for main plant cycle make-up.
b. Demineralized water for make-up and re-filling to closed circuit cooling water system.
c. Potable water for power plant services.
d. Filtered water to auxiliary station services (floor washing, irrigation, etc.)

The system is illustrated in Fig.7.6-5.

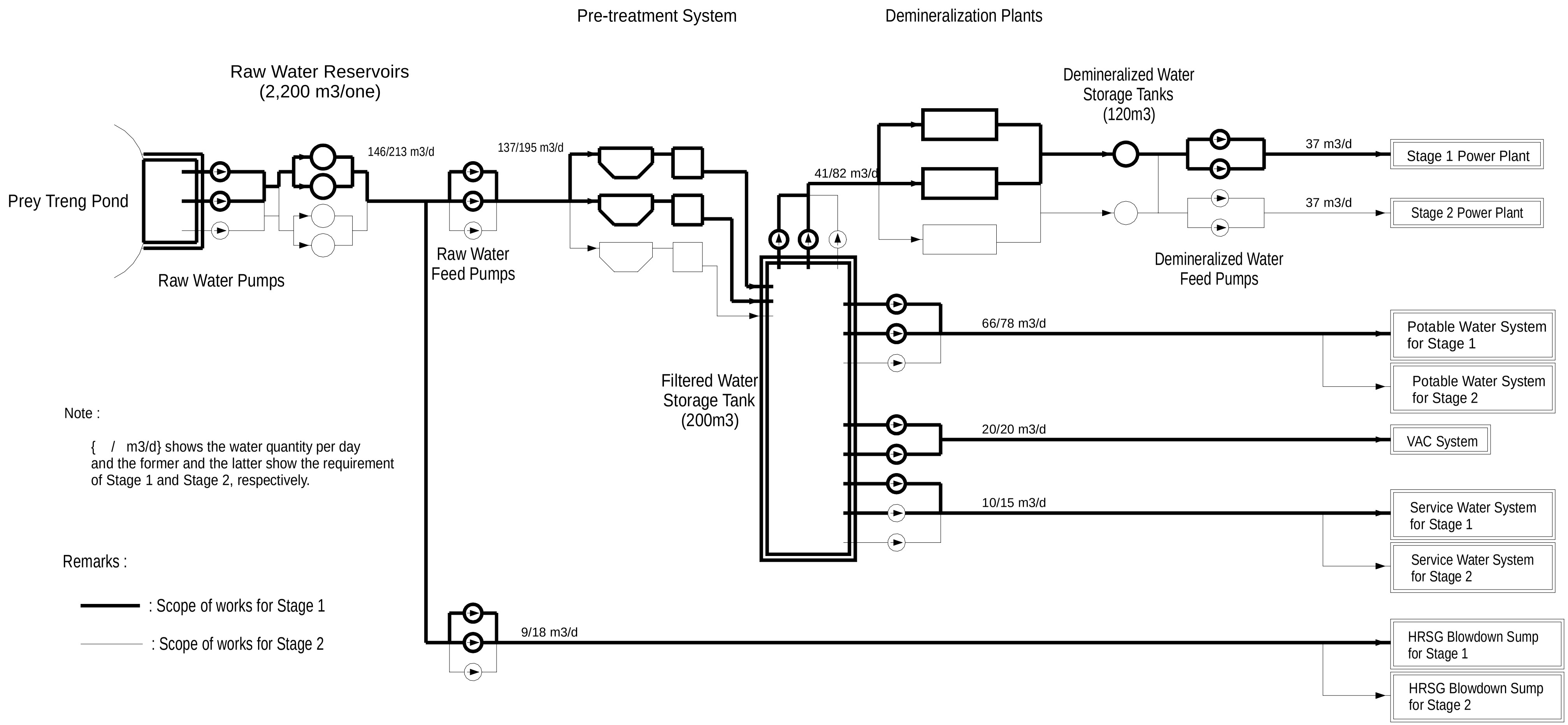


Fig.7.6-5 Flow Diagram of Fresh Water Supply System

7.6.6. Wastewater Treatment System

The wastewater treatment system will be designed to collect and process the waste water discharged from the power station so that the effluent water quality meets the applicable environmental regulatory standards before it is discharged or reused.

The system will handle the liquid wastes from various plant sources including regularly discharged chemical waste, intermittently discharged chemical waste, oil waste, sewage waste and storm water run off. Each type of wastewater will be collected in a separate collection system and will then be treated with a process most appropriate to the nature of the waste.

The system is illustrated in Fig.7.6-6.

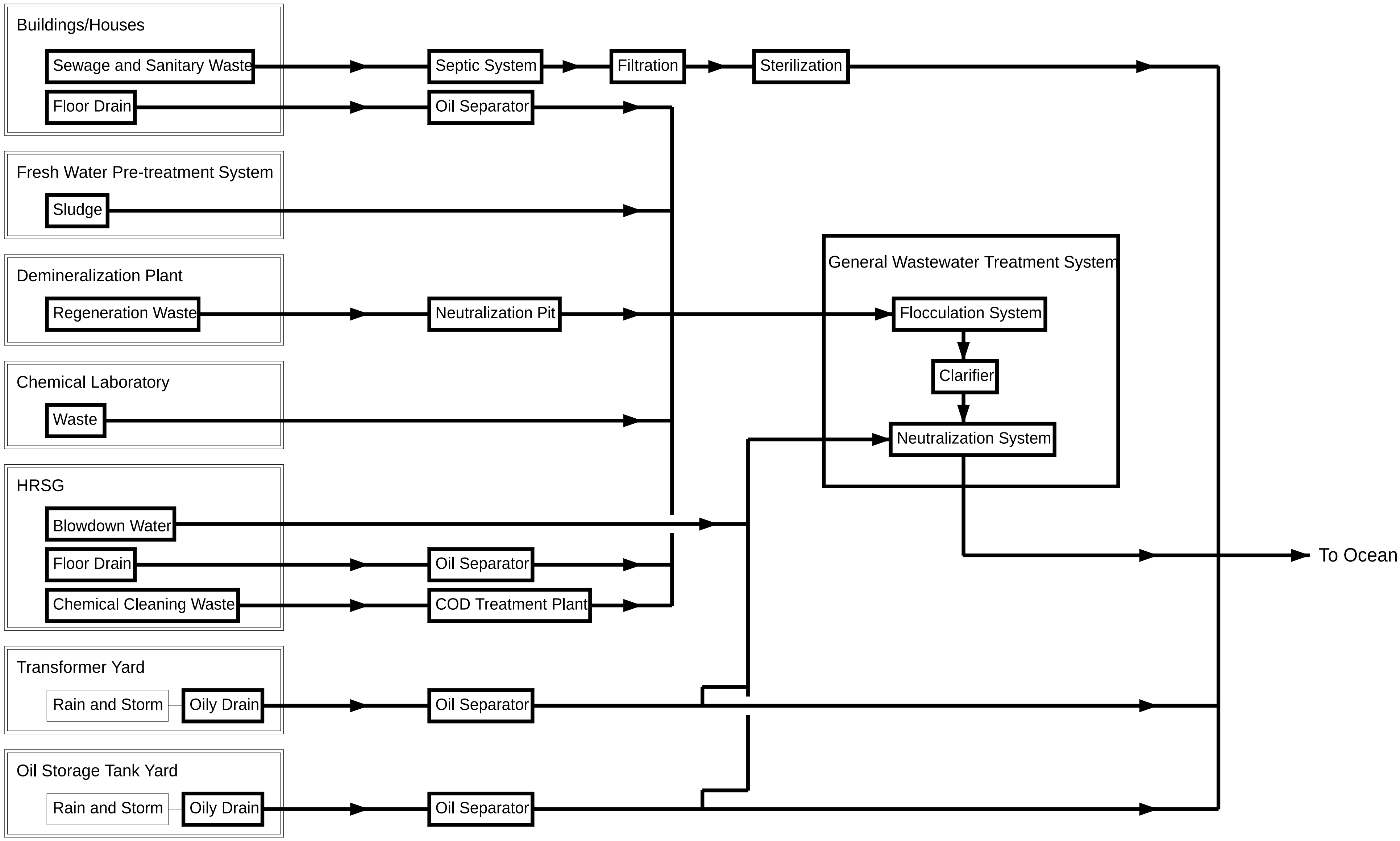


Fig.7.6-6 Flow Diagram of Wastewater Treatment System

7.6.7. Compressed Air Supply System

Compressed air supply system is composed of instrument and service compressed air systems. The normal working pressure of both systems will be 7 bar (g).

The system is illustrated in Fig.7.6-7.

The instrument air system will supply clean, dry and oil free compressed air for operation of diaphragm valves, valve positioners, pneumatic controllers, transmitters and other control devices requiring compressed air for operation.

The service air system will supply compressed air required for maintenance tools or operational purposes in the area of gas turbine rooms, steam turbine rooms, HRSGs, fuel oil pumping units, workshop, warehouse, laboratory, etc.

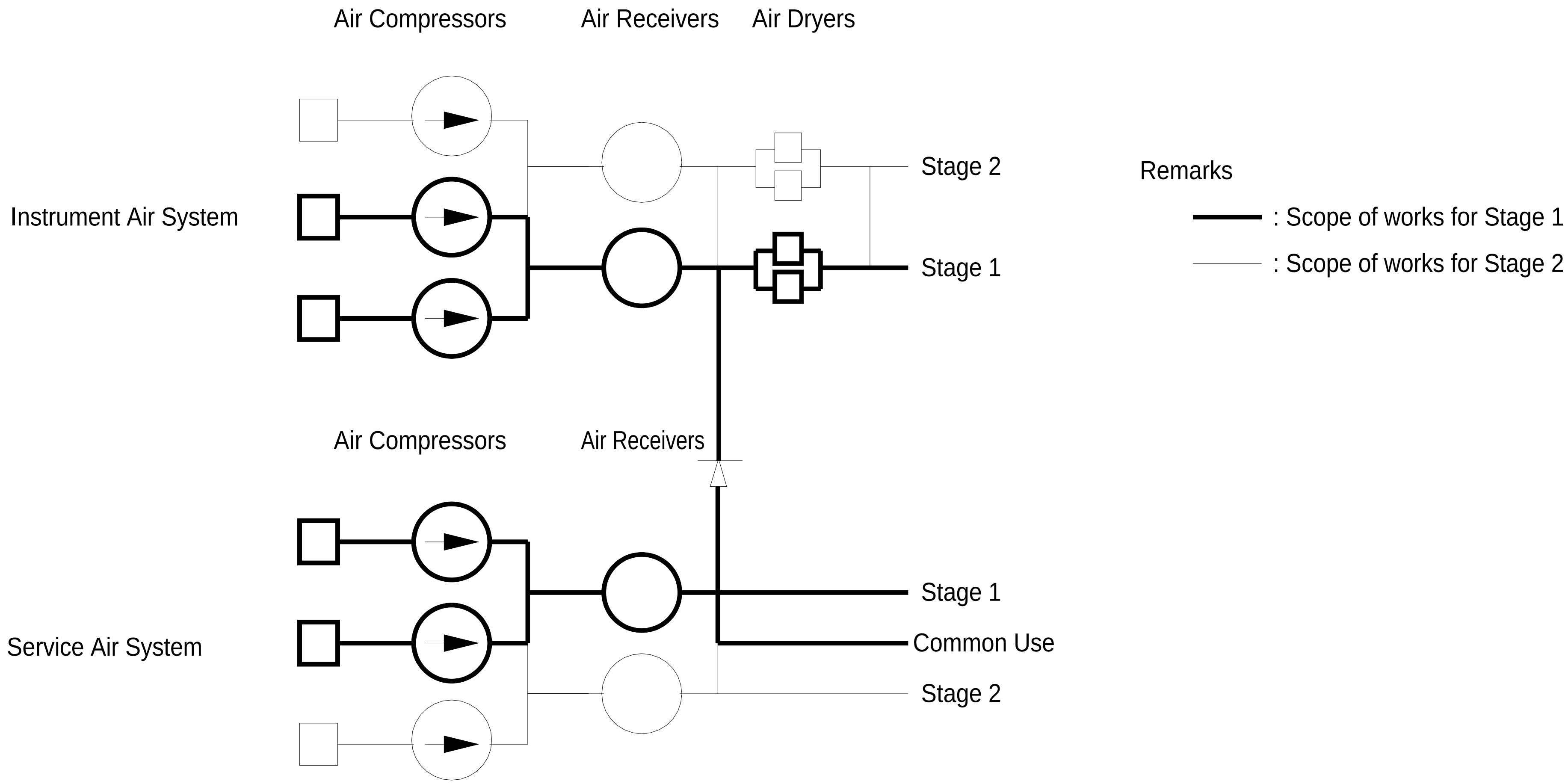


Fig.7.6-7 Flow Diagram of Compressed Air System

7.6.8. Electrical System

(1) Configuration of Station Auxiliary Electrical Supply System

Considering reliability, operationability and economics, recommendable configuration of generator output circuits and station auxiliary electrical supply system is as shown in Fig.7.6-8. In this scheme, when the in-plant substation is live under electrical power receiving from transmission line, start-up power for gas turbine can be received through either one of two routes. One is through substation, main transformer and block transformer and the other is through substation and station transformer. Generator is synchronized with and put into the live substation at the circuit breaker in LV side of main transformer. It is generator low voltage side synchronization system. As shown in Fig.7.6-8, three windings type is applied to main transformer, to attain simple layout and economics.
Station transformer is used commonly for Stage 1 and Stage 2 and serves station common loads.

(2) Emergency Diesel Generator

A emergency diesel generator will be provided for whole power station to supply electric power for safe preservation of the plant and for start up of a gas turbine generator unit under blackout condition of the whole power station. The blackout condition of the whole power station means that all generating units have no electric generation and no electric power can be expected from external networks such as transmission lines.

(3) In-Plant Substation and Future Extension

As shown in Fig.7.6-8, double busses and single circuit breaker scheme is recommended for 220 kV in-plant substation. For the time being, almost all of generated power is scheduled to be sent to Phnom Penh through Kampot and Takeo. Transmission line with two circuits is planned from the power station to Kampot. It is recommended that first circuit will be installed at Stage 1 and second circuit will be installed at Stage 2, considering economics. Area plan for the in-plant substation includes appropriate area space necessary for future extension such as Stage 3 and transmission line feeder to Sihanoukville city area.

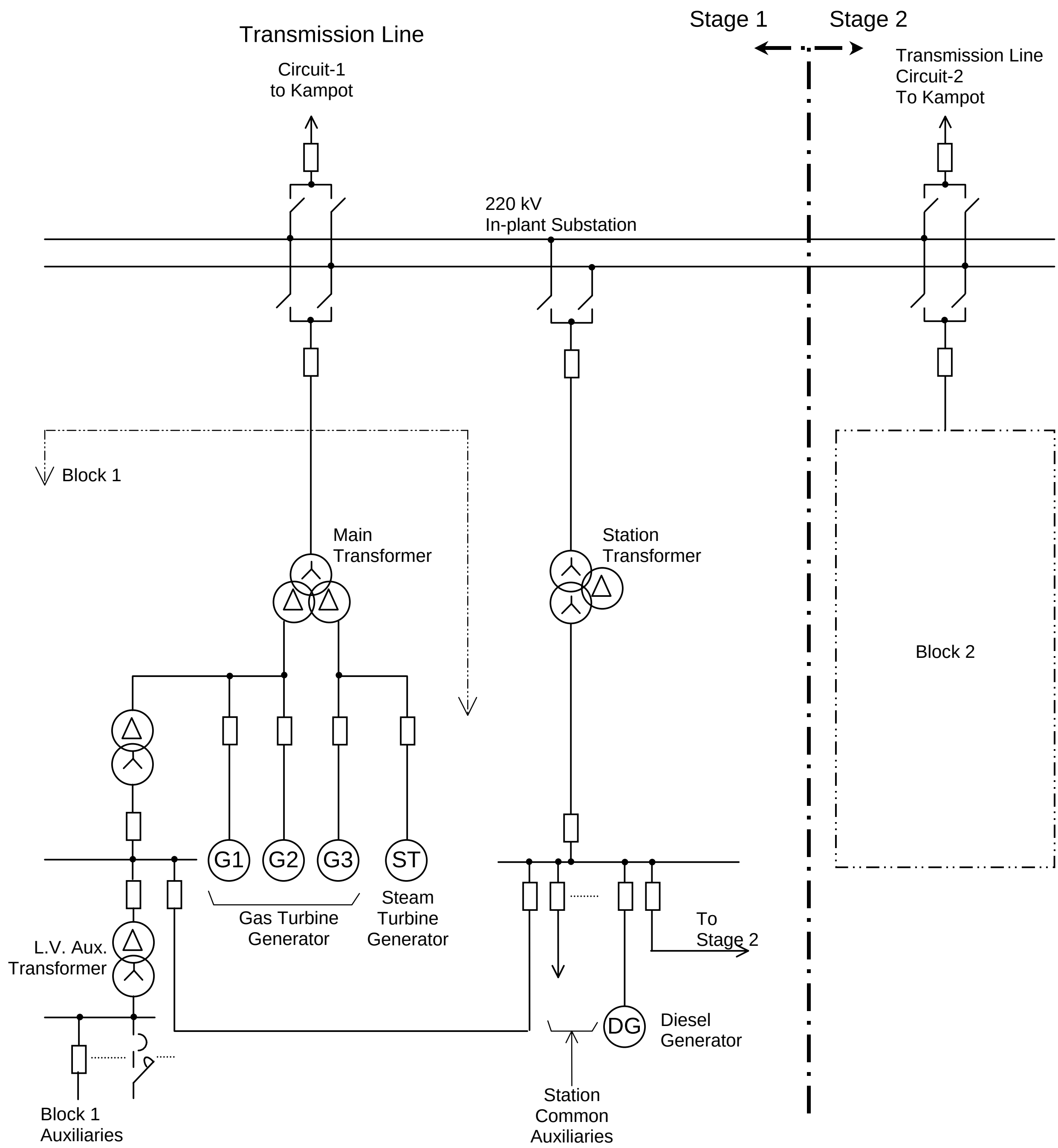


Fig.7.6-8 Preferable Typical Scheme for Station Auxiliary Electrical Supply

7.6.9. Control and Supervising System

(1) System Configuration

Considering reliability, maintenability and flexibility for future extension, distributed control system (DCS) is applied and control and supervising functions are centralized in central control room. DCS is based on micro-computer technologies and the systems are distributed as per function group such as Station common control, station data management, gas turbine control, steam turbine control and coordination control, heat recovery steam generator control and etc. This scheme is ordinary for thermal power plant, including combined cycle power plant, in the worldwide market.

Redundancy design concept such as duality will be applied to vital control and supervising functions including communication data way.

(2) Human-Machine Interface

CRT operation concept will be applied for human-machine interface to achieve most efficient operation and monitoring. Operator's console with touch screen controlled CRT's will be provided in most suitable allocation for operation and monitoring of the plant. All information necessary for operation and monitoring of the plant will be displayed in manner of characters and graphics and operators can operate the plant by touch screen operation and / or key board operation with CRT's.

(3) In-House Communication Systems

Communication systems will be provided for exchange of operation data and direct telephone system between the power station and the dispatching center in Phnom Penh, and sending and receiving of intertrip protection signal for transmission line. For data way, optical cable system as first way and power line carrier system as back- up will be recommended. Both of optical cable and power line(transmission line) will be installed separately as a part of other transmission line project. Optical fiber integrated grounding wire will be recommended to be installed instead of simple grounding wire for transmission line.

7.6.10. Fire Protection System

The fire protection system will be provided to minimize the damage by a fire for the power plant equipment and buildings. One fire engine will be provided. The carbon dioxide (CO_2) system will be provided for the area where use of wet system is not suitable.

The system will comprise fire detection and fire fighting system.

A main fire detection panel will be located in the central control room of power plants and a local fire panel will be located in each block area. Fire fighting system will be able to be started in the main fire detection panel or local fire panels.

Fire fighting system of non attended equipment and region (i.e. outdoor transformers, oil tanks, etc.) will be actuated automatically by the fire alarm signals of the detectors.

Each fire protection system will form a complete system as defined by the National Fire Protection Association (NFPA) Codes and recommended practices.

7.6.11. Design of Foundation

(1) Oil Storage Tank

Considering the SPT value near the tank, shallow foundation can be applied by improving partly the ground by replacing soil.

Approximately 1 m depth of soil layer shall be replaced by compacted sand layer to avoid any consolidation and liquifaction.

(2) Heavy Equipment such as HRSG, Gas Turbine, etc.

The location of HRSG, gas turbine and main transformer is around borehole BH-3, where under thick overburden of silty sand the layer with SPT value of over 50 at approximately - 10 m + EL. could be as supporting layer for steel piles of about 900 mm dia. as their foundation works.

(3) Intake and Outlet of Cooling Water System

Intake and outlet structures are located offshore westward of the site with a water depth of approximately 5 m. Pipes connecting those facilities to intake pit and discharge pit, respectively, are buried under sea bed. Overburden that consists of sand with very loose, 0 SPT value, should be replaced by rubble stones and reinforced soil up to supporting layer. Thickness of rubble stone should be more than 1.5 m.

(4) Offshore Cooling Water Pipes

Pipes are buried under the seabed with a depth of approximately 2 m below the seabed.

Foundation shall consist of 0.5 m thick rubble stone layer and reinforced soil covering pipes on it.

7.6.12. Building Work

(1) General

Buildings and the related architectural structures are mainly as follows;

(a) Main Buildings

1) powerhouse inclusive of central control room, gas turbine room, steam turbine room, electrical room, pump room, emergency diesel generator room, etc.
2) administration building

(b) Ancillary Buildings

3) workshop
4) warehouse
5) canteen building
6) guard house
7) water treatment house

(c) Outdoors

8) stack
9) perimeter wall fence
10) gardening

(2) Site Condition for Building Design

Buildings are designed and specified in consideration with the site conditions shown below.

(a) Meteorological Condition

1) wind speed; 26.9(m/s): provable wind speed with return period over 50 yeas
2) rainfall; 127.3 (mm/hr): provable rain fall with return period over 50 years
3) atmosphere; sea coast, heavily salt laden atmosphere
4) average temperature; D.B.T. 28.8 (°C)
5) average relative humidity ; 81 (%)

(b) Geological Condition

The ground surface of the site is layered with silt and sand at 10 ~ 15 m deep on sand stone layer (N > 50) as shown on the geological survey data. In this land condition, consideration will be given to structural design of the building. It is necessary for foundation of main buildings and structures to be reinforced with concrete piles against unequal subsidence.

(c) Seismic Condition

Earthquake over magnitude 4 has never been recorded in Cambodia.
In this condition, following seismic design criteria will be applied to the Project;

$$Cd = C \bullet I \bullet K$$

Where: Cd : equivalent seismic coefficient at the ground level
C : base seismic coefficient of 0.05
I : importance factor of building and structure
K : structural type factor

Vertical seismic load will not be considered.

(3) Main Buildings and Structure

(a) Powerhouse

Powerhouse houses six (6) gas turbine generators, two (2) steam turbine generators and their associates equipment for the Stage 1 of 90 MW and Stage 2 of 90 MW. The powerhouse for Stage 1 should be provided with preparatory joint structure and covering walls for Stage 2 extension.

The powerhouse will be framed by structural steel of superstructure and be supported by pile foundation, and its exterior walls and roof shall be finished with corrugated steel sheet.

(b) Administration Building

The administration building will include office room, conference room, guest room, directors room, communication computer room, chemical laboratory, and sanitary rooms in the building.

The building to be constructed in Stage 1 will be of two stories with reinforced concrete made, and be sized enough to cover accommodation through whole stages as requested.

(c) Ancillary Building

Workshop	;	Mechanical and electrical workshop will be provided with tool shelves and a lifter in the building for repairing and inspection of machines. The building will be made of structural steel with steel corrugated sheet roof and walls.
Warehouse	;	The building of warehouse will be made of structural steel with steel corrugated sheet roof and wall.
Guardhouse	;	Guardhouse is situates in adjacent to the administration building.
Canteen building	;	Canteen building will be provided near the administration building.
Water treatment house	;	For water treatment equipment including chemical injection system, the water treatment house will be provided, which is reinforced concrete made. A stock room of water treatment chemicals is also needed in the house.

(d) Outdoors

Stack, site perimeter fence, gardening and so on will be necessary to complete the work of power plant.

(4) Ventilation and Air-conditioning System

The recommended design condition and configuration of ventilation/air conditioning system are as follows;

(a) Design Condition

1) Outdoor air condition

   Dry bulb temperature; 33°C, Relative humidity; 81%

2) Indoor air condition

   1. Air conditioned rooms (central control room, relay room, administration building etc.)

      Dry bulb temperature ; 25°C, Relative humidity ;50 ± 5%

      For control equipment rooms ; 23~24°C will be preferable

   2. Ventilated rooms (gas/steam turbine generator room, auxiliary rooms, etc.)

      Dry bulb temperature ; 38°C max. (outdoor air temperature +5°C)

      Mechanical ventilation will be provided for keeping the limit.

7.7. Plant Layout

Fig.7.7-1 shows the plot plan of the combined cycle power station. The area of power station premises will be approx. 13.1 ha.

(1) Power Plant Zone

Power plants of Stage 1 and 2 will be located in the center of the site and the extension space for Stage 3 will be taken up on the north side of Stage 1 and 2 area. Fig.7.7-2 shows the general arrangement of the power plant.

(2) In-plant Substation Zone

In-plant substation area will be located on the east side of power plant area in consideration of the transmission line route from the substation to Kampot, which is to the northeast from the power station, and prevention of direct attack of sea breeze. The extension space for Stage 3 is included in the area. The substation area will be also located midway between Stage 1 and Stage 3 power plants in consideration of the bus duct connection between each generator transformer and the substation.
Furthermore, a future extension space will be taken up in the east part of the in-plant substation area to supply power to Sihanoukville City and an industrial zone that is under planning.

(3) Oil Storage Yard

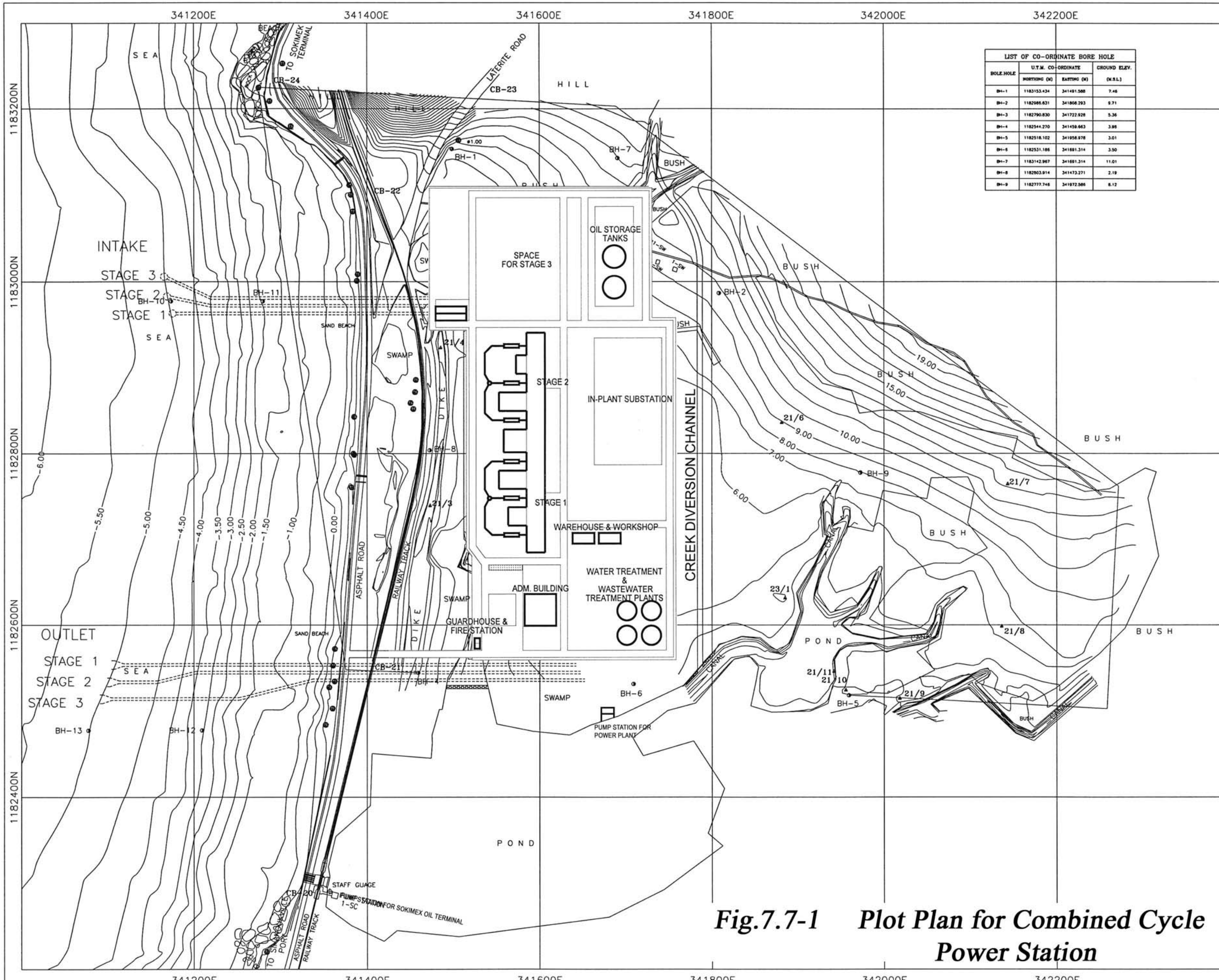
Oil storage yard will be located in the north part of the site because Sokimex Oil Terminal lies on the north side of the site. Two diesel oil storage tanks will be installed for Stage 1 and Stage 2 in the yard. An extension space will be taken up in the north part of the yard to install an additional future tank for Stage 3.

(4) Administration Zone and Access

An administration building will be located on the south side of power plant area. The building faces the sea (the west) and there is an open space with garden and parking lots in front of the building. There is Prey Treng Pond on the south side of the building. An access from the existing provincial road to the power station will be located in the southwest part of the site and a guardhouse and a fire station will be installed at the entrance of the power station.

(5) Other Zones

Cooling water pump pit is located in the northwest part of the site and discharge pipes are located in the southwest part of the site to ensure sufficient intervals between intake and discharge points of cooling water.
Water treatment plant and wastewater treatment plant is located in the south part of the site because Prey Treng Pond as fresh water source is on the south side of the site.
Warehouse and workshop are located near the Stage 1 power plant zone.



LIST OF CO-ORDINATE BORE HOLE

BOLE.HOLE	U.T.M. CO-ORDINATE NORTHING (M)	U.T.M. CO-ORDINATE EASTING (M)	GROUND ELEV. (M.S.L.)
BH-1	1183153.434	341491.588	7.46
BH-2	1182986.631	341808.293	9.71
BH-3	1182790.830	341722.928	5.36
BH-4	1182544.270	341459.663	3.98
BH-5	1182518.102	341958.978	3.01
BH-6	1182531.186	341691.314	3.50
BH-7	1183142.967	341691.314	11.01
BH-8	1182803.914	341473.271	2.19
BH-9	1182777.748	341972.586	8.12

LEGEND

- PERMANENT HORIZONTAL AND VERTICAL CONTROL
- TRAVERSE STATION (TEMPORARY)
- WATER PIPELINE
- SPOT HIGHT
- CONTOUR LINE INTERVAL 0.50 M..
- BORE HOLE
- BUILDING
- 1-SW ONE STOREY WOODEN HOUSE
- 1-SC ONE STOREY CONCRETE HOUSE
- TREES PERIMETER
- #X.XX TREE WITH STEM DIAMETER
- BOUNDARY LINE

NOTES

1. THE CO-ORDINATE AND ELEVATION WAS REFERED FROM G.P.S. "CB-11"
2. THE CO-ORDINATES WHERE SHOWN IN THIS DRAWING ARE U.T.M. CO-ORDINATE.
3. THE ELEVATION REFERED FROM MEAN SEA LEVEL.
4. MORE INFORMATION SEE SURVEY REPORT.

LIST OF CO-ORDINATE CONTROL POINT

STA.	U.T.M. CO-ORDINATE NORTHING (M)	U.T.M. CO-ORDINATE EASTING (M)	ELEVATION (M.S.L.)	REMARKS
CB-11	1176532.855	337612.506	6.460	CONCRETE MONUMENT
CB-20	1182292.327	341341.277	3.346	CONCRETE MONUMENT
CB-21	1182557.109	341405.936	3.102	CONCRETE MONUMENT
CB-22	1183102.181	341405.512	3.442	CONCRETE MONUMENT
CB-23	1183221.407	341538.451	20.223	CONCRETE MONUMENT
CB-24	1183220.930	341291.716	2.320	CONCRETE MONUMENT
CB-25	1185379.873	346353.658	18.428	CONCRETE MONUMENT
CB-26	1185144.836	350827.338	3.272	CONCRETE MONUMENT
CB-27	1185075.592	350795.057	2.455	CONCRETE MONUMENT

SCALE 0 25 50 100 150 200 m.

No.	REVISION	APPROVE	DATE

CONSULTANTS

NEWJEC

NEWJEC INC.

OSAKA JAPAN

PROJECT

SIHANOUKVILLE CCGT FEASIBILITY STUDY SIHANOUKVILLE, CAMBODIA

TITLE

ARCHITECT	
STRUC. ENGINEER	
CIVIL ENGINEER	
ENVIR. ENGINEER	
SURVEY ENGINEER	
DRAWN BY	SHEET No.
CHECKED BY	DATE / DATE
APPROVED BY	DATE / SCALE

Fig.7.7-1 Plot Plan for Combined Cycle Power Station

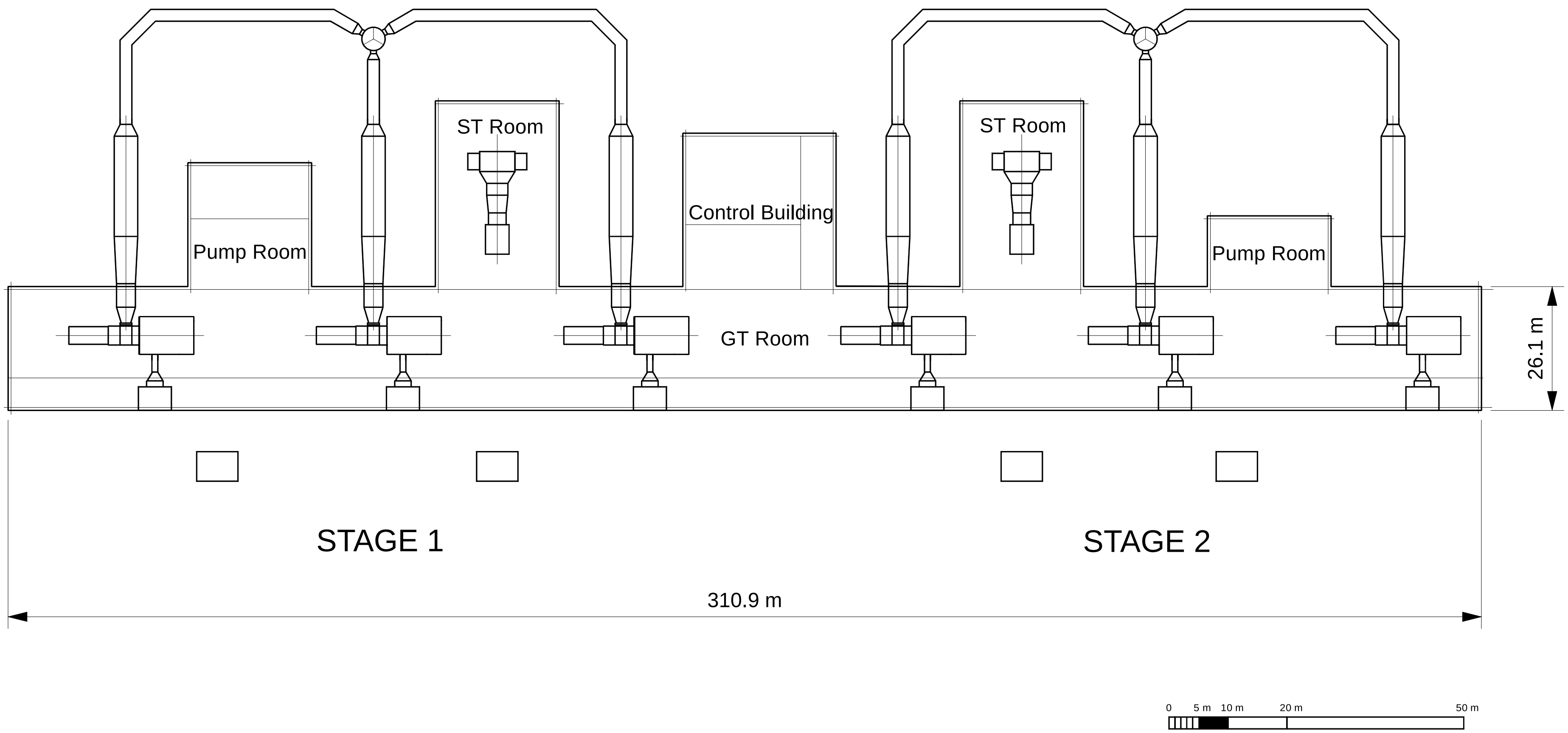


Fig.7.7-2 General Arrangement of Power Plants

8. Results of Environmental Impact Study

8.1. Possible Environmental Impact of the Project

8.1.1. Impacts of Project Construction

Plans and Assumptions

Impact study is based on the following plan and assumptions:

a. In general, each stage will be constructed separately, one after the other.

b. Site grading for all stages will be carried out at the start of construction of Stage 1.

c. Some structures that will serve more than one stage (such as workshop, warehouse, fresh water pump pit, canteen, etc.) will be sized for Stage 1 to also serve Stage 2 or Stages 2 and 3.

d. Stacks, cooling water structures and pollution control systems for all units will be designed to comply with environmental requirements at ultimate site development of 270 MW even though the Stages 1 and 2 may operate for years before ultimate site development is achieved.

Potential Impacts

The main potential impacts of construction are the following:

a. Traffic congestion and accidents along the access road.
b. Noise.
c. Squatting and encroachment on areas near the plant site.
d. Erosion and sedimentation during site preparation.
e. Siltation and salinization of soil during construction of cooling water system.
f. Water pollution to Prey Treng Pond due to spills, sanitary wastes and process wastes during construction.
g. Resettlement of households from project areas.
h. Cumulative effects of interference with operating units by construction works of extension.
i. Creation of temporary employment and economic activity.

8.1.2. Impacts of Operation

Potential Impacts. The main potential impacts of operation are outlined in the following paragraphs, even though they do not appear to be serious.

a. Air Pollution by exhaust gas.
b. Water pollution to the seawater and Prey Treng Pond by effluents from the plant.
c. Mortality of marine ichthyoplankton by heated cooling water and chlorination of cooling water.
d. Contribution to permanent employment and economic activity in the Sihanoukville area.

8.2. Impact Mitigation Planning

8.2.1. Impact Mitigation by Plant Design

Mitigation of impacts through avoidance and minimization of project and environmental conflicts is an important general theme of the feasibility study that is already documented by the following events:

a. The JICA Study Team includes an environmental specialist to actively pursue environmental matters.

b. Environmental considerations have been addressed from the beginning of the feasibility study and were an integral part of project site selection and evaluation.

c. A year-long environmental baseline survey was carried out to develop information for a full environmental impact assessment and environmental mitigation plan for the project.

d. Preliminary design of the cooling water intake and discharge structures has already reduced (i) the potential for aesthetic impacts and impacts of construction by arranging for pipelines to be placed under the seabed and (ii) reduced the potential for environment and impingement of fish at the intake structure by specifying a low intake velocity of 0.2 m/s.

e. Arrangements for chlorination of the cooling water have already considered chlorine shocking method.

f. Preliminary design work for the cooling water discharge structures has already attempted to reduce the size of the thermal mixing zone by the design and placement of the structures.

g Cumulative effects of constructing one stage while operating one or more other stages have already been considered to ensure the adequacy of dry-season water supply and available space for construction laydown.

h. In general, the environmental standards of Cambodia is considered in the development of the project design and mitigating measures. Where there are gaps or ambiguities in the Cambodian standards, the design will follow World Bank or comparable guidelines.

i. Efforts to obtain plant makeup water from Prey Treng Pond without significantly disrupting the seasonal water levels or ecological structure of the pond, or interfering with Sokimex's water supply, have already been considered in the choice of water source and preliminary design of the make-up water system. Tentative plans call for on-site water storage tanks with storage capacity sufficient to provide make-up water for 1 month.

j. Stack configuration and height have been established on the basis of more than 50 runs of the US EPA ISC3 (Industrial Source Complex 3) model. Finally, the common stack with 50-m height (one per stage) was selected to satisfy all Cambodia standards even when diesel oil is used for three stages.

k. To reduce costs, impacts and future interference of operating units and units under construction, construction of Stage 1 will include some facilities for Stages 2 and 3.

l. Public participation in mitigation planning has included interviews of selected stakeholders by the environmental baseline survey team concerning demographic, socio-economic, ecological, fisheries and archaeological conditions in the project area; and discussions between landowners (of areas required for the project) and the office of the 1st Deputy Governor of Sihanoukville concerning their willingness to sell their land to the project.

m. To facilitate Government approval of the project, Ministry of Environment should be contacted as early as possible after completion of the EIA for advice on submittal of the Environmental Examination Application and the EIA. After Government approval of the project, a land acquisition committee will be formed to handle all aspects of land acquisition. This committee and the office of the Governor of Sihanoukville Municipal Province will handle all aspects of resettlement of residents from the acquired land. Therefore the EIA report will not include any plans for resettlement or restoration of income of these residents.

8.2.2. Mitigation During Project Construction

The following requirements should be addressed in tender documents:

a. Control traffic congestion along the access road by vehicles used for construction.
b. Control night-time noise along the access road by vehicles used for construction.
c. Control squatting and encroachment in the site and wastewater.
d. Control diseases and promote safety of workers.
e. Protect Prey Treng Pond from sedimentation during site preparation.
f. Control spoils from cooling system construction.
g. Management resettlement to provide adequate benefits without attracting newcomers to the site.
h. Minimize interference with operating unit(s) during construction of Stages 2 or 3.
i. Provide convenient construction lay-down area for Stage 3. (this is a responsibility of project owner)
j. Provide guidance for temporary employment to encourage the distribution of project benefits to affected persons and communities.

8.2.3. Mitigation During Project Operation

a. Monitor the concentration of NOx, SOx and particulars emission in flue gas once each month.
b. Prevent accidental spills of fuel or chemical.
c. Monitor operation and maintenance of wastewater treatment facilities, including periodic testing of effluents prior to discharge.
d. Monitor cooling water’s dispersion condition and react to findings.

9. Organization for Management and Operation of Power Plant

9.1. Organization and Personal Allocation

Sihanoukville C/C Power Station is the first large-scale fossil-fired power station in Cambodia, this power station should be properly organized so as to meet its specific property and features.

The organization of Sihanoukville C/C Power Station and the responsibility of each perennial are shown in Fig.9.1-1.

In case of Stage 1 and Stage 2 (180 MW) Power Plant, the organization would consist of about 150 members. However, it is necessary to reconsider allotted duties and the numbers of each section personnel according to the actual conditions of the organization management and the capacity of personnel in the EDC.

9.2. Training Plan of Operation and Maintenance Engineer

A training program is classified into the following three types basically.

(1) Classroom in Cambodia domestic and other foreign countries
(2) OJT (On the Job Training)
(3) Training by advisors after beginning commercial operation

Program of classroom training and OJT is shown in Table 9.2-1.

It is a tremendous social loss to make a significant high efficiency power plant like a combined cycle fall into unoperational conditions that results in failure of power supply, due to human error, inappropriate maintenance of equipment and inappropriate control of materials.

Therefore, to operate the plant effectively and continuously and to improve operation and maintenance personnel ability, several contractor’s engineers of large experience should be stayed continuously at the plant as the advisor after completion of the plant up to expiration of the warranty period.

The following technical experts take charge of the advisor.

(1) Gas turbine engineer

(2) Steam turbine engineer

(3) C&I engineer

The schedule of Training Plan is shown in the Fig.9.2-1.

Combined Cycle P/S		personnel (Stage1 & 2)	Function
Superintendent's room		3	· Overall management (station manager, and 2 vice station managers (administration, technical))
Office section	Administration personnel	26	· Administration (Commercial, Personnel matter, Labor management, Education, Health administration, Public welfare, Document management etc) Others (Drivers, Medical staffs, Security guards, Office workers)
	Accounting personnel	7	· Accounting, Material procurement, etc.
Technology section	Technical personnel	12	· Data Evaluation and Statistics (Environment, Efficiency of the plant etc)
	Chemical personnel	7	· Chemical affairs (Quality control of supply water, Chemical analysis, etc.)
Operation section	Operator	53	· Operation (4 groups on 3 shifts)
	Logistics personnel	16	· Logistics for Operation (Material control for operation such as fuel, disposal control of sludge, sewage & etc., planning an education for operating, etc.)
Maintenance section	electrical maintenance personnel	16	· Maintenance (Electrical & C&I)
	Mechanical maintenance personnel	11	· Maintenance (GT, ST & HRSG, BOP)
	Total	151	

Fig.9.1-1 Organization and Function of Sihanoukville Combined Cycle Power Station

Table 9.2-1 Program of Classroom Training and OJT

Type	Location	Subject	Trainer	Trainee	Duration (Working Day)	Time	Number of Trainees
Classroom	in Foreign Countries	① General	Consultant	Managers & Engineers	1	at start of project	3 ~ 4
		② Project management			4		
		③ Design/Environment	Contractor and/or Electric Power Co.	Engineers & Technicians	15	during manufacturing	5 ~ 6 personnel × 2 times
		④ Operation			43		
		⑤ Maintenance & Material control			2		
		⑥ Power Station Tour			2		
	at Site	⑦ Operation	Contractor	Engineers & Technicians	10	during erection	10 personnel × 2 times
		⑧ Maintenance & Material control			5		
O.J.T.	at Site	⑨ Construction	Contractor	Technicians	full time during construction/ erection/ operation	during construction/ erection/ operation	all operators & maintenance pesonnel
		⑩ Operation					
		⑪ Maintenance & Material control					

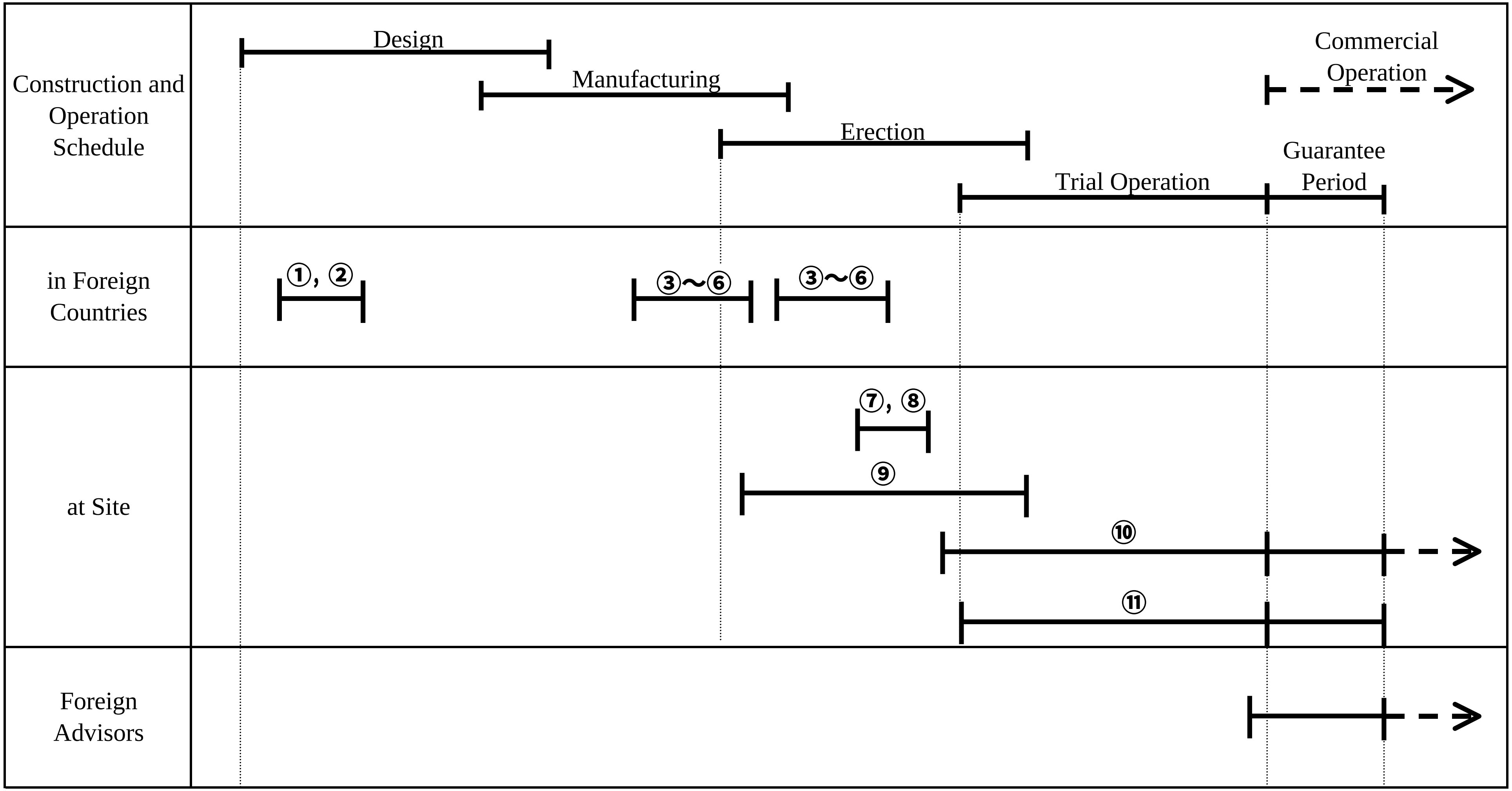


Fig.9.2-1 Schedule of Training Plan

10. Expected Project Implementation Schedule

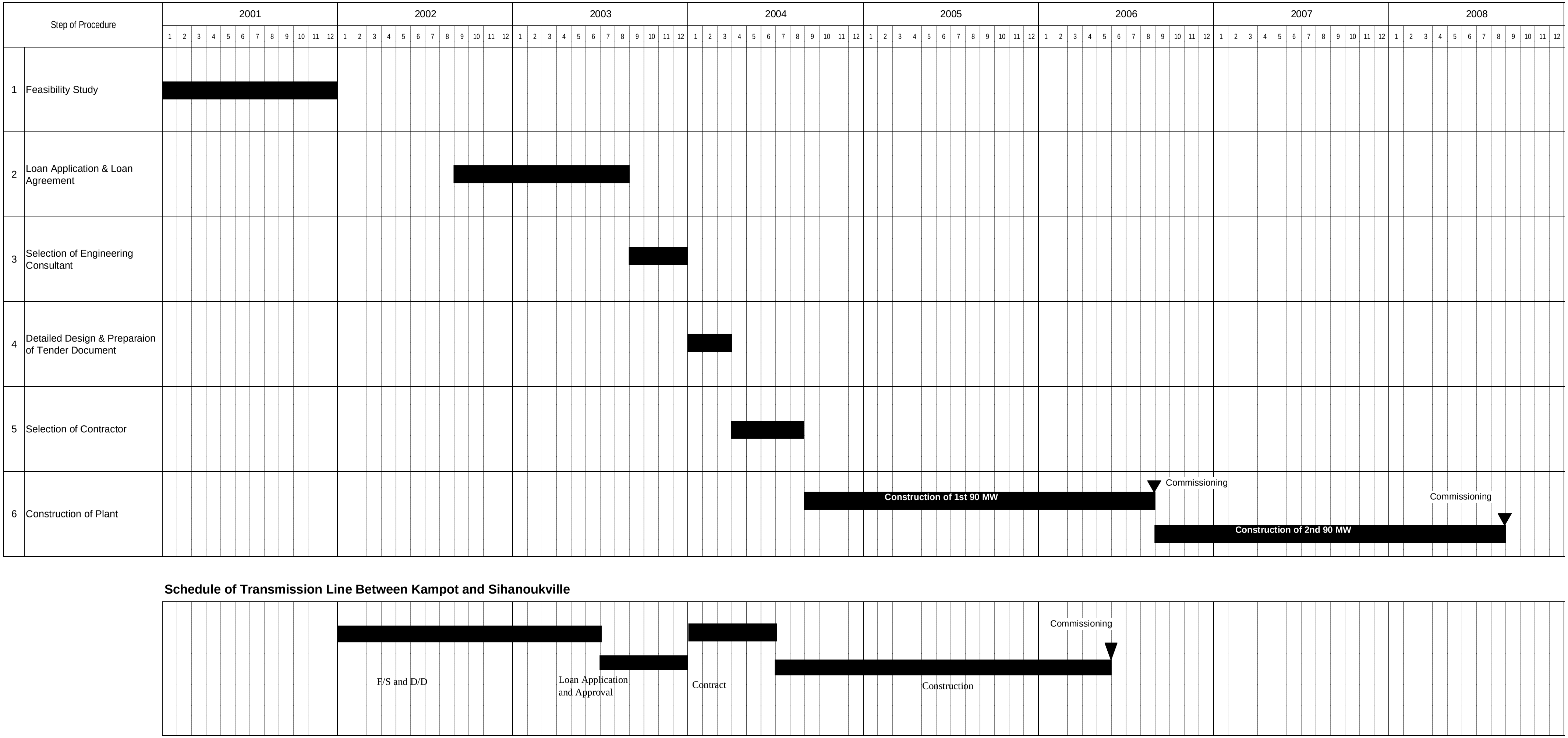
The expected project implementation schedule is shown in Fig. 10-1.
This schedule is based on the optimum power development plan discussed in Chapter 2.

At the time of start of this feasibility study, the Sihanoukville power plant had been envisaged to be commenced in 2004 (90 MW) and in 2005 (90 MW) according to the then existing power development plan of Cambodia. However, that power development plan was already amended by EDC in 2000. According to the latest power development plan included in EDC's annual report of the year 2000, the Sihanoukville power plant with 90 MW capacity is planned to be commenced in 2007 in a high scenario without IPP2. This annual report does not discuss about the power development plan after 2007, so the time of commencement of the 2nd stage of Sihanoukville (90 MW) is not shown in the report.

The optimum power development plan in Chapter 2 of this report suggests that the required time of commencement of Sihanoukville power plant should be 2006 for Stage 1 and 2008 for Stage 2 in Base Case, and 2006 for Stage 1 and 2009 for Stage 2 in Low Case, respectively. The implementation schedule of 180 MW power plant shown in Fig. 9-1 is based on two years interval for the case of Base Case.

While the construction plan of the transmission line between Kampot and Sihanoukville has not been decided until now. The required period from commencement of feasibility study to completion of construction of this transmission line is assumed approximately 53 months in Fig.10-1. As shown in Fig.10-1, a possible commencement time of the Sihanoukville power plant depends on the implementation schedule of transmission line. Therefore, for keeping the implementation schedule of power plant, the feasibility study of transmission line is recommended to start before making a decision on the Sihanoukville Power Plant Project.

Fig.10-1 Approximate Implementation Schedule of 180 MW CCGT



11. Economic and Financial Analysis

11.1. Construction Cost

The construction cost for the Sihanoukville Combined Cycle power plant is estimated to be 100.2 Million for Stage 1 and 74.6 Million for Stage 2 as shown in Table 11.1-1.

Table 11.1-1 Estimate of Construction Cost (as of 2001)

(unit : 1,000 $)

	Stage 1			**Stage 2**		
	F/C	L/C	Total	F/C	L/C	Total
Mechanical	44,290	3,330	47,620	41,100	3,090	44,190
Electrical	19,250	1,230	20,480	14,610	930	15,540
Civil Works	5,450	6,650	12,100	2,520	3,090	5,610
Building & Structure	3,400	1,830	5,230	1,570	850	2,420
Spare Parts & Others	6,720	0	6,720	3,470	0	3,470
Subtotal	**79,110**	**13,040**	**92,150**	**63,270**	**7,960**	**71,230**
Note: The above items include physical contingency of 5 %.						
Training	100	0	100	50	0	50
Owner's Administration Fee	0	2,600	2,600	0	1,300	1,300
Engineering Consultant Fee	4,390	0	4,390	2,040	0	2,040
Land Acquisition	0	740	740	0	0	0
Resettlement & Compensation	0	30	30	0	0	0
Mine Survey	0	190	190	0	0	0
Subtotal	**4,490**	**3,560**	**8,050**	**2,090**	**1,300**	**3,390**
Grand Total	**83,600**	**16,600**	**100,200**	**65,360**	**9,260**	**74,620**

	F/C	L/C	Total
Associated Transmission Line (Site ~ Kampot)	8,640	2,160	10,800

11.2. Economic Analysis

11.2.1. Objective

Economic analysis is carried out to verify the economic validity of the implementation of project from the viewpoint of the whole Cambodian economy.

11.2.2. Fuel and Fuel Price

CIF price (Cost, insurance and freight) are used for oil fuels because the all oil fuels in Cambodia are imported from overseas at the moment.
Concerning the natural gas, of which exploring is expected in future; the estimated exploring cost is envisaged to be higher than the world market and to be consumed in the domestic due to the less efficiency of the gas reserve. The natural gas price is estimated 4 $/MMBTU at power plant site including the markup provisionally.

Table 11.2-1 Fuel Prices for Economic Analysis

Fuel Type	Fuel Price (CIF Price)	Remarks
Diesel Oil *1)	237 $/MT	Average from 1996 Nov. ~ 2001. July
Heavy Fuel Oil *2)	154 $/MT	Average from 1996 Nov.~ 2001. August
Natural Gas	4.0 $/MMBTU	Engineer's assumptions (L.H.V. base) 3.5 $/MMBTU and 4.5 $/MMBTU are also testified in the economic analysis.

Source: *1) and *2) EDC

11.2.3. Fuel Shift

Since some fuel types seem to be applicable to the project at the moment, the following fuel scenarios are considered in the economic analysis.

(1) Natural Gas will be used for whole period of 20-years economic lifetime from the beginning (**Base Case**).

(2) Diesel Oil will be used for the first 5 years and Natural Gas will be used for the next 15 years.

(3) Diesel Oil will be used for the first 10 years and Natural Gas will be used for the next 10 years.

(4) Diesel Oil will be used for whole period of 20-years economic lifetime from the beginning.

11.2.4. Calculation Conditions

The project characteristics, which were revealed in the course of the study, and assumed condition, are summarized in Table 11.2-2.

Table 11.2-2 Project Characteristics and Assumed Conditions

Items	Value	Unit	Remarks
Installed capacity	180	MW	90 MW x 2 stages
Capacity Factor (Average 54%)		%	2006 2007 2008 2009 2010 2011 2012 ~ ST-1 24 75 55 63 67 70 50 ST-2 - - 18 63 67 70 50
Construction cost	164.4	M.$	Excluding Engineering and Administration Fees ST-1: 93.2 M.$, ST-2 :71.2 M.$
Scheduled maintenance days	49	Days	For kW and kWh adjustments use only
Forced outage rate	8.0	%	
Station use	2.8	%	
Natural Gas			
Fixed O/M cost	20.0	$/kW-year	
Fuel price	4.0	$/MMBTU	LHV base, domestic price including markup
Heat rate	6,829	BTU/kWh	
Fuel cost	27.32	$/MWh	
Variable O/M	1.0	$/MWh	
Diesel Oil			
Fuel price	6.02	$/MMBTU	LHV base, CIF Price for Diesel :237 $/ton
Heat rate	7,030	BTU/kWh	
Fuel cost	42.32	$/MWh	
Variable O/M	2.5	$/MWh	
Construction period	2	Years	Disbursement schedule are 40 % and 60 %.
Construction start	2004, 2006		2-staged construction
Operation start	2006, 2008		Each operation of 90 MW
Economic life time	20	Years	

A diesel power plant with equivalent capacity to the project is set as an alternative thermal power plant in view of current supply system in Cambodia.

The following table shows the plant properties to be used as the representative of equivalent diesel power plant.

Table 11.2-3 Characteristics of Alternative Diesel and Assumed Conditions

Items	Value	Unit	Remarks
Installed capacity	197.8	MW	98.9 MW x 2 stages, (Middle Speed)
Annual generation		GWh	2006 2007 2008 2009 2010 2011 2012~ ST-1 192.8 602.4 441.8 506.1 538.2 562.3 401.7 ST-2 - - 144.5 506.1 538.2 562.3 401.7
Construction cost	271.0	M.$	Excluding Engineering and Administration Fees
Scheduled maintenance days	28	days	
Forced outage rate	20	%	
Station use	4.6	%	
Fixed O/M cost	21.0	$/kW-year	
Variable O/M cost	3.0	$/MWh	
Fuel Price	3.99	$/MMBTU	LHV base, CIF Price for HFO: 154.0 $/ton
Heat rate	7,888	BTU/kWh	HFO
Fuel cost	31.49	$/MWh	HFO
Construction period	2	years	Disbursement schedules are 50 % and 50 %.
Construction start	2004, 2006		2-staged construction
Operation start	2006, 2008		Each operation of 90 MW
Economic life time	20	years	
kW Adjustment	1.099		
kWh Adjustment	1.019		

11.2.5. Calculation Cases and Results

(1) Calculation Cases

10 calculation cases, with combination of fuel conversion scenario and natural gas price, are conducted as shown in Table 11.2-4.

Case Nos. 100s, 200s and 300s are focusing on the timing of natural gas fuel availability and Case No. 400 represents the case of diesel oil for the whole economic life time to understand the economic advantage of the natural gas.

Concerning the natural gas price, 4.0, 3.5 and 4.5 $/MMBTU are assumed.

(2) Calculation Results

Table 11.2-4 also presents the results of economic analysis. Typical case (Case No. 100) is demonstrated in Table 11.2-5.

The economic indices show the excellent economic performance of the project except the Case No. 400 because the construction cost of the project is cheaper than that of the alternative diesel power plant and the natural gas fuel cost is also cheaper than the heavy fuel oil.

Table 11.2-4 Calculation Cases and Summary of Results

1. *Calculation Cases*

Se.No.	1	2	3	4	5	6	7	8	9	10
Case No.	100	110	120	200	210	220	300	310	320	400
A Fuel Conversion Scenario										
(1) Natural Gas for full 20 years	◎	○	○							
(2) Diesel Oil 5 years + NG 15 years				○	○	○				
(3) Diesel Oil 10 years + NG 10 years							○	○	○	
(4) Diesel Oil for full 20 years										○
B Natural Gas Fuel Price										
(1) 4.0 US$/MMBTU	◎			○			○			
(2) 3.5 US$/MMBTU		○			○			○		
(3) 4.5 US$/MMBTU			○			○			○	
C Diesel Oil Price (CIF)										
(1) 237 US$/ton				○	○	○	○	○	○	○

Note: ◎means Base Case.

2. *Calculation Results*

Economic Internal Rate of Return (EIRR)	%	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	3.81*1
Net Present Value of Cost	M.US$	249.3	233.7	264.2	276.3	266.5	285.5	299.0	294.1	303.6	321.7
Net Present Value of Benefit	M.US$	345.0	345.0	345.0	345.0	345.0	345.0	345.0	345.0	345.0	345.0
B - C	M.US$	95.7	111.3	80.8	68.7	78.5	59.5	46	50.9	41.4	23.3
B/C		1.38	1.48	1.31	1.25	1.29	1.21	1.15	1.17	1.14	1.07

Note: Net Present Value as of 2001 is dicounted value with 10 % discount rate.
N.A means EIRR>100 %
*1: For the Case No. 400, B-C becomes positive on condition that the discount rate is higher than 3.81 %, unless B-C becomes negatve.

Table 11.2-5 Economic Calculation for Case No.100

Case No.	100	EIRR	3715.05%	NPV-C	249.27 M.US$	NPV-B	345.01 M.US$	B-C	95.74 M.US$	B/C	1.38 at 10% Discount Rate

Sihanoukville C.C.Project

Rated Capacity	90 MW			Scheduled Maintenance		49 days		
Construction Period	2 years			Forced Outage Rate		8.0%		
Disbursement	60%	40%		Station Use		2.8%		
Fuel Type 1	NG			Life Time		20 years		
Fuel Price	4 $/MBtu							
Fuel Cost	27.32 $/MWh							
Fuel Conversion	1 years after commencement of operation							
Fuel Conversion from	1 to	1						
Conversion System	0.0 M.US$ for Whole Stages							

1st Stage 1

Construction Cost	93.2 M.US$							
Operation Start	2006 year		9 months					
Years	2006	2007	2008	2009	2010	2011	2012	2026
Capacity Factor	0.24	0.75	0.55	0.63	0.67	0.70	0.50	0.33
Generation Energy	189.2	591.3	433.6	496.7	528.2	551.9	394.2	260.2
Station Use	5.3	16.6	12.1	13.9	14.8	15.5	11	7.3
Sending-out Energy	183.9	574.7	421.5	482.8	513.4	536.4	383.2	252.9
Fixed O/M cost	20 $/kW-year							

2nd Stage 1

Construction Cost	71.2 M.US$					
Operation Start	2008 year		9 months			
	2008	2009	2010	2011	2012	2028
Capacity Factor	0.18	0.63	0.67	0.70	0.50	0.33
Generation Energy	141.9	496.7	528.2	551.9	394.2	260.2
Station Use	4	13.9	14.8	15.5	11	7.3
Sending-out Energy	137.9	482.8	513.4	536.4	383.2	252.9
Fixed O/M cost	20 $/kW-year					

Alternative Diesel Power Plant

Equiv. Capacity	98.9 MW			Scheduled Maintenance		28 days		
Constr. Period	2 years			Forced Outage Rate		20.0%		
Disbursement	50%	50%		Station Use		4.6%		
F.Type 4	HFO			Life Time		20 years		
Fuel Price	154 $/ton			kW Adjustment Factor =		1.099		
Fuel Cost	31.49 $/MWh			kWh Adjustment Factor =		1.019		

1st Stage

Construction Cost	135.5 M.US$		1,370 $/kW					
Operation Start	2006 year		9 months					
	2006	2007	2008	2009	2010	2011	2012	2026
Capacity Factor	-	-	-	-	-	-	-	-
Generation Energy	192.8	602.4	441.8	506.1	538.2	562.3	401.7	265.1
Station Use	8.9	27.7	20.3	23.3	24.8	25.9	18.5	12.2
Send.-out Energy	183.9	574.7	421.5	482.8	513.4	536.4	383.2	252.9
Fixed O/M cost	21 $/kW-year							

2nd Stage

Construction Cost	135.5 M.US$		1,370 $/kW			
Operation Start	2008 year		9 months			
	2008	2009	2010	2011	2012	2028
Capacity Factor	-	-	-	-	-	-
Generation Energy	144.5	506.1	538.2	562.3	401.7	265.1
Station Use	6.6	23.3	24.8	25.9	18.5	12.2
Send.-out Energy	137.9	482.8	513.4	536.4	383.2	252.9
Fixed O/M cost	21 $/kW-year					

Fuel Data

Type No.	Symbol	Fuel Name	Fuel Price-1(CIF)	Fuel Price -2	Efficiency	Fuel Cost	Variable O/M Cost
1	NG	Natural Gas	4.0 $/MBtu	4.0 $/MBtu	6,829 Btu/kWh	27.32 $/MWh	1.0 $/MWh
2	DO	Diesel Oil	237 $/ton	6.02 $/MBtu	7,030 Btu/kWh	42.32 $/MWh	2.5 $/MWh
3	LNG	Liquid Natural Gas	- $/MBtu	- $/MBtu	- Btu/kWh	- $/MWh	- $/MWh
4	HFO	Heavy Fuel Oil	154 $/ton	3.99 $/MBtu	7,888 Btu/kWh	31.49 $/MWh	3.0 $/MWh

Note: Fuel Price based on L.H.V. (Low Heating Value)
Fuels Price-1 except Natural Gas are CIF (Cost, Insurance and Freight) prices and NG is assumed to be domestic pro

Unit Conversion Factor

1 kWh = 860 kcal = 3,413 BTU
1 BTU= 0.252 kcal
1 cu.ft = 0.0283 m3
1 Lb = 0.4536 kg

Density

Diesel Oil 0.8297
Heavy Fuel Oil 0.9361

Initial Construction Cost and Conversion System Cost

Type No.	F.Type	1st Stage F/C M.US$	1st Stage L/C M.US$	1st Stage Subtotal M.US$	2nd Stage F/C M.US$	2nd Stage L/C M.US$	2nd Stage Subtotal M.US$	Whole Stages F/C M.US$	Whole Stages L/C M.US$	Whole Stages Total M.US$	System Cost M.US$
1	NG	79.2	14.0	93.2	63.3	7.9	71.2	142.5	21.9	164.4	0.0
2	DO	78.0	14.0	92.0	63.3	7.9	71.2	141.3	21.9	163.2	1.2
3	LNG	-	-	-	-	-	-	-	-	-	0.0

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cost: Sihanoukville C.C. Plant	Construction Cost	M.US$	-	-	-	23.6	45.7	23.9	-	-	-	-	-	-	-	-	-
	Conversion System	M.US$	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-
	Generation Energy	GWh	-	-	-	-	-	189.2	591.3	433.6	496.7	528.2	551.9	394.2	394.2	394.2	394.2
	Sending -out Energy	GWh	-	-	-	-	-	183.9	574.7	421.5	482.8	513.4	536.4	383.2	383.2	383.2	383.2
	Fixed O/M cost	M.US$	-	-	-	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Variable O/M cost	M.US$	-	-	-	-	-	0.2	0.6	0.4	0.5	0.5	0.6	0.4	0.4	0.4	0.4
	Fuel Type		-	-	-	-	-	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
	Fuel Cost	M.US$	-	-	-	-	-	5.2	16.2	11.8	13.6	14.4	15.1	10.8	10.8	10.8	10.8
	Construction Cost	M.US$	-	-	-	-	-	16.2	36.7	18.3	-	-	-	-	-	-	-
	Conversion System	M.US$	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-
	Generation Energy	GWh	-	-	-	-	-	-	-	141.9	496.7	528.2	551.9	394.2	394.2	394.2	394.2
	Sending -out Energy	GWh	-	-	-	-	-	-	-	137.9	482.8	513.4	536.4	383.2	383.2	383.2	383.2
	Fixed O/M cost	M.US$	-	-	-	-	-	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Variable O/M cost	M.US$	-	-	-	-	-	-	-	0.1	0.5	0.5	0.6	0.4	0.4	0.4	0.4
	Fuel Type		-	-	-	-	-	-	-	NG	NG	NG	NG	NG	NG	NG	NG
	Fuel Cost	M.US$	-	-	-	-	-	-	-	3.9	13.6	14.4	15.1	10.8	10.8	10.8	10.8
	Total Cost	M.US$	0.0	0.0	0.0	23.6	45.7	47.3	55.3	38.1	31.8	33.4	35.0	26.0	26.0	26.0	26.0
Benefit : Alternative Diesel Plant	Construction Cost	M.US$	-	-	-	23.0	67.8	44.7	-	-	-	-	-	-	-	-	-
	Generation Energy	GWh	-	-	-	-	-	192.8	602.4	441.8	506.1	538.2	562.3	401.7	401.7	401.7	401.7
	Sending -out Energy	GWh	-	-	-	-	-	183.9	574.7	421.5	482.8	513.4	536.4	383.2	383.2	383.2	383.2
	Fixed O/M cost	M.US$	-	-	-	-	-	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	Variable O/M cost	M.US$	-	-	-	-	-	0.6	1.8	1.3	1.5	1.6	1.7	1.2	1.2	1.2	1.2
	Fuel Type		-	-	-	-	-	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO
	Fuel Cost	M.US$	-	-	-	-	-	6.1	19.0	13.9	15.9	16.9	17.7	12.6	12.6	12.6	12.6
	Subtotal Cost	M.US$	0.0	0.0	0.0	23.0	67.8	53.5	22.9	17.3	19.5	20.6	21.5	15.9	15.9	15.9	15.9
	Construction Cost	M.US$	-	-	-	-	-	23.0	67.8	44.7	-	-	-	-	-	-	-
	Generation Energy	GWh	-	-	-	-	-	-	-	144.5	506.1	538.2	562.3	401.7	401.7	401.7	401.7
	Sending -out Energy	GWh	-	-	-	-	-	-	-	137.9	482.8	513.4	536.4	383.2	383.2	383.2	383.2
	Fixed O/M cost	M.US$	-	-	-	-	-	-	-	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	Variable O/M cost	M.US$	-	-	-	-	-	-	-	0.4	1.5	1.6	1.7	1.2	1.2	1.2	1.2
	Fuel Type		-	-	-	-	-	-	-	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO
	Fuel Cost	M.US$	-	-	-	-	-	-	-	4.6	15.9	16.9	17.7	12.6	12.6	12.6	12.6
	Total Cost	M.US$	0.0	0.0	0.0	23.0	67.8	76.5	90.7	69.1	39.0	41.2	43.0	31.8	31.8	31.8	31.8
Eco. Indices	B-C		0.0	0.0	0.0	-0.6	22.1	29.2	35.4	31.0	7.2	7.8	8.0	5.8	5.8	5.8	5.8
	Disc. Rate 10%		1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386	0.350	0.319	0.290	0.263
	NPV for Cost as of 2001		0	0	0	17.72	31.21	29.37	31.19	19.55	14.85	14.16	13.51	9.1	8.29	7.54	6.84
	NPV for Benefit as of 2001		0	0	0	17.27	46.31	47.51	51.15	35.45	18.21	17.47	16.6	11.13	10.14	9.22	8.36
	NPV for Sending-out Energy		0	0	0	0	0	114.2	324.13	286.97	450.94	435.36	414.1	268.24	244.48	222.26	201.56

	Year		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Cost: Sihanoukville C.C. Plant	Construction Cost	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93.2
	Conversion System	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Generation Energy	GWh	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	260.2	-	-	-	-	8569.9
	Sending -out Energy	GWh	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	252.9	-	-	-	-	8330.4
	Fixed O/M cost	M.US$	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	-	-	-	-	37.8
	Variable O/M cost	M.US$	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	-	-	-	-	8.7
	Fuel Type		NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	-	-	-	-	
	Fuel Cost	M.US$	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	7.1	-	-	-	-	234.6
	Construction Cost	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71.2
	Conversion System	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Generation Energy	GWh	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	260.2	-	-	8286.1
	Sending -out Energy	GWh	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	252.9	-	-	8054.6
	Fixed O/M cost	M.US$	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	-	-	37.8
	Variable O/M cost	M.US$	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	-	-	8.4
	Fuel Type		NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	-	-	
	Fuel Cost	M.US$	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	7.1	-	-	226.9
	Total Cost	M.US$	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	22.2	13.0	9.2	0.0	0.0	718.6
Benefit : Alternative Diesel Plant	Construction Cost	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135.5
	Generation Energy	GWh	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	265.1	-	-	-	-	8732.5
	Sending -out Energy	GWh	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	252.9	-	-	-	-	8330.4
	Fixed O/M cost	M.US$	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	-	-	-	-	44.1
	Variable O/M cost	M.US$	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.8	-	-	-	-	26.1
	Fuel Type		HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	-	-	-	-	
	Fuel Cost	M.US$	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	8.3	-	-	-	-	274.2
	Subtotal Cost	M.US$	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	11.2	0.0	0.0	0.0	0.0	479.9
	Construction Cost	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135.5
	Generation Energy	GWh	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	401.7	265.1	-	-	8443.4
	Sending -out Energy	GWh	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	383.2	252.9	-	-	8054.6
	Fixed O/M cost	M.US$	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	-	-	44.1
	Variable O/M cost	M.US$	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.8	-	-	25.2
	Fuel Type		HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	-	-	
	Fuel Cost	M.US$	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	8.3	-	-	265.0
	Total Cost	M.US$	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	27.1	15.9	11.2	0.0	0.0	949.7
Eco. Indices	B-C		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	4.9	2.9	2.0	0.0	0.0	3715.05%
	Disc. Rate 10%		0.239	0.218	0.198	0.180	0.164	0.149	0.135	0.123	0.112	0.102	0.092	0.084	0.076	0.069	0.063	
	NPV for Cost as of 2001		6.21	5.67	5.15	4.68	4.26	3.87	3.51	3.2	2.91	2.65	2.04	1.09	0.7	0	0	249.27
	NPV for Benefit as of 2001		7.6	6.93	6.3	5.72	5.22	4.74	4.29	3.91	3.56	3.24	2.49	1.34	0.85	0	0	345.01
	NPV for Sending-out Energy		183.17	167.08	151.75	137.95	125.69	114.19	103.46	94.27	85.84	78.17	58.52	32.19	19.22	0	0	4313.74

11.3. <u>Financial Analysis</u>

11.3.1. Objective

Financial analysis is carried out to verify the financial feasibility of the project from the viewpoint of the project owner and lenders. Therefore, market prices, which include taxes & duties, and subsidiaries, are used in the analysis.

Financial analysis is conducted in US$ term because US$ currency is prevalent in Cambodia[1] as well as Cambodian Riel.

11.3.2. Power Tariff Forecast

The average power tariff as of 2000 is 554 Riel/kWh[2] (or 14.57US¢ /kWh) and the power tariff rate is shown in Table 11.3-1.

The future power tariff is assumed based on EDC Report, ADB Project Report[3] and the World Bank Project Report[4], which are shown in Tables 11.3-2 and 11.3-3.

Table 11.3-2 Future Power Tariff Scenario (Riel/kWh)

	2001	2002	2003	2004	2005	2006	2007
ADB *1)	652	700	752	728	730	746	778
EDC *2)	608	613	620	628	636	646	656

*1) ADB "Provincial Power Supply Project", November 2000, Appendix-9, Page 4, Table A9.1

*2) EDC Report, page 14

---

1 Invoice of power tariff is made in Cambodian Riel and payment is allowed to be done by Riel or US$ term for an example.

2 " Prepared and Analyses Study, EDC's Strategic Planning for Year 2001, 2002 and 2003 within Planning until 2010 ", Page 14, EDC, November 2000

3 "Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Kingdom of Cambodia for the Provincial Power Supply Project" , November 2000

4 "The World Bank Cambodia Rural Electrification and Transmission Project (PHRD TF025765) Feasibility Study Report for the Transmission Link between Phnom Penh and the Southern Region of Cambodia, Project Overview", April 2001

Table 11.3-3 Exchange Rate Forecast (Riel/$) and Power Tariff Forecast (¢/kWh)

	2001	2002	2003	2004	2005	2006	2007
Exc. Rate *3)	3,971	4,149	4,335	4,530	4,734	4,946	5,169
EDC	15.31	14.79	14.31	13.86	13.44	13.06	12.68
ADB *4)	16.42	16.87	17.35	16.07	15.42	15.08	15.05
World Bank *5)	16.1	16.1	16.1	14.5	13.8	13.4	12.5

*3) EDC Report, page 14
*4) ¢/kWh for ADB portion is calculated by using the above exchange rate.
*5) World Bank "Project Overview Report", Page 58, Table 7
Note: Exchange Rate against US$ is assumed to be devaluated 4.5 % annually by EDC.

Based on the above forecast, the average power tariff from the year 2006 onwards is assumed to be 13.0 ¢/kWh.

However, the average power tariff consists of the following cost. Therefore, the power tariff contributing to the project finance is the power tariff less indirect cost.

- Direct operation costs (Fuel cost, Fixed O/M and Variable O/M costs)
- Power purchase cost from IPP
- Maintenance cost of transmission and distribution lines
- Overhead head

According to the EDC's statement of operation, the costs other than the direct operation cost in 1997 and 1999 were approximately 85% of total costs. Therefore, power tariff contributing to the project is set at 11.05 ¢/kWh (13 ¢/ kWh × 85% = 11.05).

Table 11.3-1 Tariff Structure of EDC (as of November 2001)

1. Phnom Penh Operation (Effective in August 2000)	Existing Power Tariff	
	Riel/kWh	c/kWh (1US$=3900 Riel)
Sector		
I. Residential Sector		
0-50 kWh/month	350	8.97
51-100 kWh/month	550	14.10
>100 kWh/month	650	16.67
II. Industrial & Handicraft Sector		
<45,000 kWh/month	600	15.38
45,000 - 80,000 kWh/month	550	14.10
80,000 - 130,000 kWh/month	550	14.10
>130,000 kWh/month	500	12.82
MidiumVoltage	480	12.31
III. Commercial & Service Sectors		
<45,000 kWh/month	650	16.67
45,000 - 80,000 kWh/month	600	15.38
80,000 - 130,000 kWh/month	600	15.38
>130,000 kWh/month	500	12.82
MidiumVoltage	480	12.31
IV. Hotels & Guest Houses		
<45,000 kWh/month	650	16.67
45,000 - 80,000 kWh/month	600	15.38
80,000 - 130,000 kWh/month	600	15.38
>130,000 kWh/month	500	12.82
MidiumVoltage	480	12.31
V. Embassy, Foreigners' Houses,NGO Go	800	20.51
VI. Government Institutions	700	17.95

2. Sihanoukville Operation (Effective in Feb.& Jul.1999)	Riel/kWh	c/kWh
Sector		
I. Residential Sector	500	12.82
II. Industrial & Handicraft Sector		
<20,000 kWh/month	670	17.18
20,000 - 50,000 kWh/month	670/610 a)	17.18 15.64
50,000 - 110,000 kWh/month	670/560	17.18 14.36
>110,000 kWh/month	670/513	17.18 13.15
III. Commercial & Service Sector		
<20,000 kWh/month	740	18.97
20,000 - 50,000 kWh/month	685	17.56
50,000 - 110,000 kWh/month	625	16.03
>110,000 kWh/month	570	14.62
IV. Hotel & Guest Houses		
<20,000 kWh/month	760	19.49
20,000 - 50,000 kWh/month	700	17.95
50,000 - 110,000 kWh/month	650	16.67
>110,000 kWh/month	610	15.64
V. Houses for Foreigners	740	18.97
VI. Embassy, Government Institutions	760	19.49

Note: a) 670/610 - night/day time

3. Siem Reap Operation (Effective in July 1999)	Riel/kWh	c/kWh
Sector		
Overall Sector		
<20,000 kWh/month	875	22.44
20,000 - 50,000 kWh/month	735	18.85
50,000 - 110,000 kWh/month	670	17.18
>110,000 kWh/month	620	15.90

4. Kampong Cham Operation	Riel/kWh	c/kWh
Sector		
Flat Rate	850	21.79

11.3.3. Fuel Cost and Fuel Conversion

The fuels applicable to the project are assumed to be diesel oil and natural gas.

(1) Fuel Cost

The fuel prices used in the financial analysis are market prices including the taxes and duties.
Taxes and duties shown in Table 11.3-4 are considered in the financial analysis.

Table 11.3-4 Taxes and Duties on Fuel

Fuel Type	Import Tax	Social Fund	VAT
Diesel Oil	20 %	1.40 $/ton	10 %
Natural Gas	None *1)	1.40 $/ton	10 %

Note: Taxes and duties for natural gas are assumed values.
*1) Natural Gas is assumed to be domestic product.

The fuel cost before taxes and duties are set at 237 $/ton (CIF Price) for diesel oil and 4.0 $/MMBTU (L.H.V. base) for natural gas. Annual escalation of 2 % is estimated for diesel oil and 0 % for natural gas from the year 2001 onwards.

(2) Fuel Shift

As mentioned in the economic analysis, natural gas is expected to be exploited in Cambodia in future. The timing of fuel shift is assumed as follows as well as economic analysis.

(a) Natural Gas will be used for whole period of 20-years economic lifetime from the beginning (**Base Case**).
(b) Diesel Oil will be used for the first 5 years and Natural Gas will be used for the next 15 years.
(c) Diesel Oil will be used for the first 10 years and Natural Gas will be used for the next 10 years.
(d) Diesel Oil will be used for whole period of 20-years economic lifetime from the beginning.

11.3.4. Implementation Method

The following two implementation methods for Sihanoukville C.C. Project are considered.

(1) Option 1 : EDC will implement the project by using official loan.

(2) Option 2 : The private investor will implement the project by his own finance and loans, and sell the power to EDC based on the Power Purchase Agreement (BOT).

11.3.5. Calculation Conditions

Based on the above considerations, the calculation conditions in the financial analysis are summarized in Table 11.3-5.

Table 11.3-5 Sihanoukville C.C. Project Calculation Conditions

Items	*EDC Project*	*IPP Project (BOT)*
Installed Capacity	90 MW × 2 stages = 180 MW	
Annual Capacity Factor (Average 54%)	2006 2007 2008 2009 2010 2011 2012~ ST-1 24% 75% 55% 63% 67% 70% 50% ST-2 - - 18% 63% 67% 70% 50%	
Station Use	2.8 %	
T/L and Distribution Loss	15.7%	0% (Sales at P/S exit)
Salable Energy	Generation Energy × 81.94%	Generation Energy × 97.2%
Construction Cost for Stage 1 F/C L/C inc. duties and taxes Total (inc. T/L)	After escalation 101.6 Million $ 45.3 Million $ 146.9 Million $	Import tax will be exempted.*1) 101.6 Million $ 31.9 Million $ 133.5 Million $
Construction Cost for Stage 2 F/C L/C inc. duties and taxes Total (inc. T/L)	After Escalation 75.5 Million $ 29.5 Million $ 105.0 Million $	Import tax will be exempted.*1) 75.5 Million $ 18.8 Million $ 94.3 Million $
Escalation L/C F/C	 2.4 % per annum 2.4 % per annum	
Disbursement Schedule Stage 1 Stage 2	2004 2005 2006 2007 2008 22.8% 50.3% 26.9% - - - - 22.2% 51.3% 26.5%	

Items	*EDC Project*	*IPP Project (BOT)*
Finance Planning Financial Source Interest Rate (=IDC) Commitment Fee Grace Period Repayment Period Loan Limit Top Front Fee Finance Source Interest rate (=IDC) Commitment Fee Front End Fee Grace Period Repayment Period Loan Limitation	 Subsidiary Loan - 1 3.5 % per annum - 8 years 23 years including grace period 100 % of F/C or 85 % of the project cost - Subsidiary Loan - 2 3.5 % per annum - - 8 years 23 years inc. 5 years grace period 100 % of F/C or 90 % of the construction cost inc. IDC	 OIL US$ Loan LIBOR+1 % *2) (3.46 + 1 = 4.46) 0.25 % of remaining loan 5 years 15 years 60 % of debt portion 1.0 % of loan amount Bank Syndicate Loan LIBOR+2.5 %(3.46 + 2.5=5.96) 0.5 % 1.25 % of loan amount 5 years 15 years including grace period None
Equity : Debt	-	30 % : 70 %
Economic Life Time	20 years	
Depreciation Method	Accelerated method with 11 % for 20-years economic lifetime	
Power Tariff as of 2006 excluding maintenance cost of T/L, D/S and overhead	11.05 ¢/kWh	¢/kWh for PPA PPA: Power Purchase Agreement
Operation Cost Fixed O/M Cost Variable O/M Cost Fuel Cost	 ST-1: 40.2 $/kW-year (inc. T/L: 41.5) ST-2: 31.7 $/kW-year Natural Gas : 1.0 $/MWh Diesel Oil : 2.5 $/MWh Natural Gas : 30.27 $/MWh Diesel Oil : 58.28 $/MWh	
Tax and Duties Profit Tax	 20%	9 % with 8 years Tax Holiday *1)
Commencement of Operation	Stage 1: 2006 Sep.1 Stage 2: 2008 Sep.1	
Discount Rate	10 %	
Exchange Rate	1 $ = 4000 Riel as of 2001	

Note : *1) Power Purchase Agreement between Leader Universal Holdings Berhad Delcom Services SDN BHD INTERCORE INC. and EDC, Appendix K, page 94.

*2) LIBOR is 3.46 % as of October, 2001 (Source: www.bankrate.com/brm/news/biz/ratechart.asp)

11.3.6. Calculation Cases and Calculation Results

(1) Calculation Cases

Based on the above considerations, 27 cases as summarized in Table 11.3-6 are conducted.

(a) Case numbers of 1000s are the cases that the project is implemented by Subsidiary Loan-1.

(b) Case numbers of 2000s are the cases that the project is implemented by Subsidiary Loan-2.

(c) Case numbers of 3000s are the case that the project is implemented by IPP and the power tariff for PPA, which satisfies the ROE of 20%, is calculated. Power selling to EDC is assumed at power station outlet.

(d) Case numbers of 4000s are focusing on generation cost excluding VAT and Profit Tax to compare the power purchase cost from Vietnam and IPP1. And distribution loss is also excluded for the comparison basis.

In association with the above implementation methods, Table 11.3-7 shows the summary of the total project cost including all costs.

(2) Calculation Results

Table 11.3-6 also shows the calculation results of the financial analysis and Case No. 1000 is demonstrated in Table 11.3-8.

(a) Project IRR

If the natural gas is used for the full economic lifetime or put into the operation before the 5th year, the project IRR of 10% is expected. On the other hand, if the diesel oil is used for the full economic life time, the project IRR cannot be calculated and the financial attractiveness will be eliminated.

Therefore, from the viewpoint of the project EIRR, the financial attractiveness will be expected on condition that the natural gas becomes available before the 5th year from the commencement of commercial operation.

(b) ROE & DSCR

As shown in Table 11.3-7, since EDC bears IDC portion only under the Subsidiary Loan Agreement, ROE presents the good performance for any cases. However, in view of DSCR, the minimum DSCR becomes less than 1.0 or negative if diesel oil is fired more than 10 years during the operation period. The DSCR less than 1.0 means that EDC has to borrow the additional loan for the interest payment and principal repayment due to shortage of own cash.

Therefore, the implementation of the project will be accepted by the Lenders if the natural gas is warranted to be put into the operation before the 5th year from the commencement of the commercial operation, unless the implementation will not be accepted.

(c) Levelised Production Cost

At the price of natural gas of 4.0 $/MMBTU, levelised production cost including taxes and duties under the effective power tariff of 11.05 ¢/kWh varies from 7.84 ¢/kWh to 9.45 ¢/kWh for the cases that the natural gas will be put into the project within the first 5 years during the operation period and 10.96 ¢/kWh to 12.85 ¢/kWh if natural gas is put into the project on 11th year or not put into the project. If the natural gas is available from the beginning of the operation, levelised production cost can be expected to be 30 % less in comparison with the case that the natural gas is put into the operation on 11th year.

(d) IPP Project

In case of the IPP project, the hurdle rate for the financial feasibility is set at 20 % of ROE. To achieve the ROE more than 20 %, the power tariff selling to EDC (at P/S exit) requires from 7.70 ¢/kWh to 9.85 ¢/kWh under the condition that natural gas is put into within 5 years and its price is 4.0 $/MMBTU.

These selling prices will be equivalent to 9.13 ¢/kWh to 11.68 ¢/kWh at consumer's end level taken into account of T/L and D/L loss of 15.7%.

EDC has to purchase at more expensive cost than that of EDC implementation because the selling price to EDC at consumer's end is higher than the levelised production cost for the case of EDC.

If the diesel oil is used for the full operation period, the selling price of 14.39 ¢/kWh to EDC exceeds the expected power tariff of 13.00 ¢/kWh and cannot be accepted by EDC.

(e) Production Cost without Taxes

- Comparison with the current purchase tariff from IPP1

  EDC purchases the power from IPP1s in Phnom Penh Operations at 8.94 ¢/kWh (1997) to 10.95 ¢/kWh (2000) based on the PPA. The above purchase prices do not include the duties and taxes, because EDC bears duties and taxes imposed on fuel, of which fuel is used by IPP1, instead of

IPP1.

The levelised production cost for Case No. 4000 is excluded duties and taxes, and profit tax to keep the same cost level with the current purchase tariff from IPP1.

The levelised production cost of the project of 5.78 ¢/kWh is clearly lower than the current purchase tariff from IPP1.

- Comparison with the power import from Vietnam

According to Power Purchase Agreement signed on July 24, 2000, the conditions on the power purchase from Vietnam are set as follows:

a. Commencement of power purchase : year 2003[5]

b. Source of supply : Thot Not substation via Chau Doc

c. Interconnecting point : Border between Cambodia and Vietnam

d. Metering point : Chau Doc substation

e. Supply capacity : 80 MW between 2003 to 2005

: 200 MW after year 2005

f. Power tariff effectiveness : 5 years

g. Currency in payment : US$

Table 11.3-9 Power Purchase Prices from Vietnam

Dry Season (November ~ June 30)	Peak hours	(18:00 ~ 22:00)	8.50 ¢/kWh
	Normal hours	(04:00 ~ 18:00)	6.25 ¢/kWh
	Off-peak hours	(22:00 ~ 04:00)	4.50 ¢/kWh
Wet Season (July ~ October 31)	Peak hours	(18:00 ~ 22:00)	8.00 ¢/kWh
	Normal hours	(04:00 ~ 18:00)	6.00 ¢/kWh
	Off-peak hours	(22:00 ~ 04:00)	3.00 ¢/kWh

The average purchase price at the border is estimated to be about 6.0 ¢/kWh[6].

If the purchase price of 6.0 ¢/kWh at the border price converts to the equivalent prices at Takeo and at Phnom Penh taking into consideration

5 As mentioned in Section 2.4, available import year seems to be delayed.

6 Dry Season = (8.5 × 4 + 6.25 × 14 + 4.5 × 6) / 24 = 6.2, Rainy Season = (8.0 × 4 + 6.0 × 14 + 3.0 × 6) / 24 = 5.6, whole year = (6.2 × 8 + 5.6 × 4) / 12 = 6.0

of transmission line loss, the above border price will be as shown in Table 11.3-10 in comparison with the levelised production costs of Case No. 4000 and 4100.

Table 11.3-10 Comparison of Purchase Price and LPC

	Power Purchase From Vietnam	Levelised Production Cost (LPC)
At Phnom Penh	6.0 /(1-0.02) = 6.12 ¢/kWh	5.78 ¢/kWh (No. 4000)
At Takeo	6.0 /(1-0.01) =6.06 ¢/kWh	5.73 ¢/kWh (No. 4100)

Note) T/L loss from Chau Doc to Phnom Penh and to Takeo is assumed to be 2.0 % and 1.0 % respectively as mentioned before.

Based on the above comparison, it is expected that if the natural gas, of which exploring cost is 4.0 $/MMBTU, will be put into the operation from the commencement of the commercial operation, production cost of the project will be less than the purchase price from Vietnam.

Further more, if the Shihanoukville Industrial Zone is realized in future[7], the project will be more advantageous in virtue of its location.

[7] According to ADB information, the improvement of Sihanoukville Air Port from the domestic air port to the international air port is under negotiation between RGC and Bangkok Airways to induce the overseas investors.

Table 11.3-6 Calculation Cases and Results for Financial Analysis

1. Calculation Cases

Se.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Case No.	1000	1010	1020	1100	1110	1120	1200	1210	1220	1300	1400	2000	2010	2020	2100	2110	2120	2300	3000	3010	3020	3100	3110	3120	3300	4000	4100
A. Finance Sources																											
(1) Subsidiary Loan - 1	◎	○	○	○	○	○	○	○	○	○	○															○	○
(2) Subsidiary Loan - 2												○	○	○	○	○	○	○									
(3) OIL + Bank Syndicate Loan																			○	○	○	○	○	○	○		
B Implementation Method																											
(1) Implemented by EDC	◎	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○								○	○
(2) IPP																			○	○	○	○	○	○	○		
C Fuel Conversion Scenario																											
(1) Natural Gas for full 20 years	◎	○	○								○	○	○	○					○	○	○					○	○
(2) Diesel 5 years + NG 15 years				○	○	○									○	○	○					○	○	○			
(3) Diesel 10 years + NG 10 years							○	○	○																		
(4) Diesel Oil for full 20 years										○								○							○		
D Natural Gas Price (inc. Taxes)																											
(1) 4.43 US$/MMBTU	◎			○			○				○	○			○				○			○				○	○
(2) 3.88 US$/MMBTU		○			○			○					○			○				○			○				
(3) 4.98 US$/MMBTU			○			○			○					○			○				○			○			
E Diesel Oil Price (inc. Taxes)																											
(1) 326.54 US$/ton										○								○							○		
F T/L from Kampot to Site																											
(1) Including T/L (11.8 M.US$)	◎	○	○	○	○	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
(2) Excluding T/L											○																
G Power consumption at																											
(1) Phnom Penh	◎	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
(2) Takeo																											○
H Value Added Tax & Profit Tax																											
(1) No VAT																										○	○
(2) No Profit Tax																										○	○

2. Calculation Results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1 Project IRR (%)																											
Stage-1	11.6	12.7	10.5	6.6	7.1	5.9	3.0	3.4	2.6	N.A.	13.2	11.6	12.7	10.5	6.6	7.1	5.9	N.A.	8.9	9.0	8.9	10.0	10.1	10.0	8.0	20.7	21.0
Stage-2	16.5	17.7	15.2	12.1	12.8	11.2	7.1	7.5	6.5	N.A.	16.5	16.5	17.7	15.2	12.1	12.8	11.2	N.A.	14.1	14.1	14.2	16.9	17.1	16.7	12.3	27.6	28.0
Stage-1 & Stage-2	13.5	14.5	12.3	8.7	9.4	8.1	4.8	5.2	4.3	N.A.	14.5	13.5	14.5	12.3	8.7	9.4	8.1	N.A.	10.9	11.0	10.9	12.6	12.8	12.5	9.6	23.0	23.4
2 Return on Equity (%)																											
Stage-1	210	224	197	46	48	43	1	4	-2	N.A.	237	210	224	196	45	47	43	N.A.	15.0	15.0	14.9	14.7	14.7	14.8	15.0	309	313
Stage-2	244	258	230	91	94	88	33	35	31	N.A.	244	245	258	230	91	94	88	N.A.	29.4	29.4	29.5	30.2	30.3	30.2	29.2	337	342
Stage-1 & Stage-2	213	226	199	59	61	57	14	16	11	N.A.	238	213	226	199	59	61	56	N.A.	20.0	20.0	20.0	19.9	19.9	20.0	20.1	310	314
3 Min. Debt Service Coverage Ratio																											
Stage-1	1.0	1.1	0.9	1.0	1.1	0.9	0.1	0.1	0.1	-0.6	1.1	1.0	1.1	0.9	1.0	1.1	0.9	-0.6	1.0	1.0	1.0	0.6	0.5	0.7	0.9	1.8	1.8
Stage-2	1.5	1.6	1.4	1.5	1.6	1.4	0.2	0.2	0.2	-0.9	1.5	1.5	1.6	1.3	1.5	1.6	1.3	-0.9	1.5	1.5	1.5	2.3	2.4	2.2	1.2	2.6	2.7
Stage-1 & Stage-2	1.5	1.6	1.4	1.1	1.1	1.1	0.1	0.1	0.1	-0.9	1.5	1.5	1.6	1.3	1.1	1.1	1.1	-0.9	1.2	1.2	1.2	1.0	0.9	1.1	1.1	2.4	2.4
4 Levelised Production Cost (¢/kWh)																											
Stage-1	8.12	7.77	8.49	10.07	9.90	10.28	11.44	11.36	11.55	13.04	7.90	8.15	7.79	8.53	10.10	9.92	10.31	13.08	7.26	6.89	7.66	9.14	8.94	9.34	11.86	6.09	6.02
Stage-2	7.48	7.12	7.84	8.65	8.39	8.91	10.34	10.21	10.48	12.59	7.48	7.49	7.13	7.86	8.66	8.41	8.94	12.61	6.34	5.96	6.73	7.52	7.25	7.80	11.25	5.40	5.34
Stage-1 & Stage-2	7.84	7.48	8.20	9.45	9.24	9.67	10.96	10.86	11.08	12.85	7.72	7.86	7.50	8.23	9.47	9.26	9.71	12.88	6.86	6.48	7.25	8.43	8.20	8.66	11.59	5.78	5.73
Power Tariff for PPA (¢/kWh) at P/S exit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.70	7.32	8.09	9.85	9.68	10.04	12.13	-	-

Table 11.3-7 Total Project Cost and Finance Arrangement for Sihanoukville Combined Cycle Project

Subsidiary Loan - 1 (Unit :Million US$)

	Stage-1			Stage-2			Stage-1 & Stage-2		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
Construction Cost	79.9	16.0	95.9	62.4	8.8	71.2	142.3	24.8	167.1
Physical Contingency	3.8	0.6	4.4	3.0	0.4	3.4	6.8	1.0	7.8
Price Contingency	8.5	1.6	10.1	10.1	1.4	11.5	18.6	3.0	21.6
Duties and Taxes	0.0	24.7	24.7	0.0	18.9	18.9	0.0	43.6	43.6
IDC by EDC	7.6	0.0	7.6	5.4	0.0	5.4	13.0	0.0	13.0
Associated T/L	9.4	2.4	11.8	0.0	0.0	0.0	9.4	2.4	11.8
Total	109.2	45.3	154.5	80.9	29.5	110.4	190.1	74.8	264.9

	Stage-1		Stage-2		Stage-1 & Stage-2	
	Amount	Portion	Amount	Portion	Amount	Portion
Loan - A	122.2	79.1%	86.1	78.0%	208.3	78.6%
RGC	24.7	16.0%	18.9	17.1%	43.6	16.5%
EDC	7.6	4.9%	5.4	4.9%	13	4.9%
Total	154.5	100.0%	110.4	100.0%	264.9	100.0%

2. Subsidiary Loan - 2 (Unit :Million US$)

	Stage-1			Stage-2			Stage-1 & Stage-2		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
Construction Cost inc.IDC	81.7	16.0	97.7	63.7	8.8	72.5	145.4	24.8	170.2
Physical Contingency	3.8	0.6	4.4	3.0	0.4	3.4	6.8	1.0	7.8
Price Contingency	8.5	1.6	10.1	10.1	1.4	11.5	18.6	3.0	21.6
Duties and Taxes	0.0	24.7	24.7	0.0	18.9	18.9	0.0	43.6	43.6
IDC by EDC	7.6	0.0	7.6	5.4	0.0	5.4	13.0	0.0	13.0
Associated T/L	9.4	2.4	11.8	0.0	0.0	0.0	9.4	2.4	11.8
Total	111.0	45.3	156.3	82.2	29.5	111.7	193.2	74.8	268.0

	Stage-1		Stage-2		Stage-1 & Stage-2	
	Amount	Portion	Amount	Portion	Amount	Portion
Loan - B inc.IDC	124.0	79.3%	87.4	78.2%	211.4	78.9%
RGC	24.7	15.8%	18.9	16.9%	43.6	16.3%
EDC	7.6	4.9%	5.4	4.8%	13.0	4.9%
Total	156.3	100.0%	111.7	100.0%	268.0	100.0%

3. Overseas Investment Loan + Bank Syndicate Loan (Unit :Million US$)

	Stage-1			Stage-2			Stage-1 & Stage-2		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
Construction Cost	79.9	16.0	95.9	62.4	8.8	71.2	142.3	24.8	167.1
Physical Contingency	3.8	0.6	4.4	3.0	0.4	3.4	6.8	1.0	7.8
Price Contingency	8.5	1.6	10.1	10.1	1.4	11.5	18.6	3.0	21.6
Duties and Taxes	0.0	11.3	11.3	0.0	8.2	8.2	0.0	19.5	19.5
IDC & Financial Fee	8.9	0.0	8.9	6.2	0.0	6.2	15.1	0.0	15.1
Associated T/L	9.4	2.4	11.8	0.0	0.0	0.0	9.4	2.4	11.8
Total	110.5	31.9	142.4	81.7	18.8	100.5	192.2	50.7	242.9

	Stage-1		Stage-2		Stage-1 & Stage-2	
	Amount	Portion	Amount	Portion	Amount	Portion
OIL	59.9	42.1%	42.2	42.0%	102.1	42.0%
Bank Syndicate Loan	39.8	27.9%	28.1	28.0%	67.9	28.0%
IPP Own Finance	42.7	30.0%	30.2	30.0%	72.9	30.0%
Total	142.4	100.0%	100.5	100.0%	242.9	100.0%

Table 11.3-8 (1/2) Profit and Loss Statement for Case No. 1000

Case No.	1000

1st Stage

Rated Capacity	90 MW								
Construction Period	2 years								
Subsidiary Loan Condition									
Source - A Loan	122.2 M.US$		Interest Rate		3.5%				
Relend by MEF to EDC	24.7 M.US$		Grace Period		8 years				
Total Loan Amount	146.9 M.US$		Repayment Period		23 years				
EDC Equity	7.6 M.US$								
Total Project Cost	154.5 M.US$								
Construction Cost	122.2 M.US$								
Operation Start	2006 year	9 months							
Years	2006	2007	2008	2009	2010	2011	2012	2026	
Capacity Factor	0.24	0.75	0.55	0.63	0.67	0.70	0.50	0.33	
Generation Energy	189.2	591.3	433.6	496.7	528.2	551.9	394.2	260.2	
Station Use	5.3	16.6	12.1	13.9	14.8	15.5	11	7.3	
Sending-out Energy	183.9	574.7	421.5	482.8	513.4	536.4	383.2	252.9	
T/L and D/S Loss	28.9	90.2	66.2	75.8	80.6	84.2	60.2	39.7	
Salable Energy	155.0	484.5	355.3	407.0	432.8	452.2	323.0	213.2	
Fixed O/M cost	40.2 $/kW-year for Plant								
	41.5 $/kW-year including Transmission Line								

2nd Stage

Rated Capacity	90 MW						
Construction Period	2 years						
Subsidiary Loan Condition							
Source - A Loan	86.1 M.US$		Interest Rate		3.5%		
Relend by MEF to EDC	18.9 M.US$		Grace Period		8 years		
Total Loan Amount	105.0 M.US$		Repayment Period		23 years		
EDC Equity	5.4 M.US$						
Total Project Cost	110.4 M.US$						
Construction Cost	86.1 M.US$						
Operation Start	2008 year	9 months					
Years	2008	2009	2010	2011	2012	2028	
Capacity Factor	0.18	0.63	0.67	0.70	0.50	0.33	
Generation Energy	141.9	496.7	528.2	551.9	394.2	260.2	
Station Use	4	13.9	14.8	15.5	11	7.3	
Sending-out Energy	137.9	482.8	513.4	536.4	383.2	252.9	
T/L and D/S Loss	21.7	75.8	80.6	84.2	60.2	39.7	
Salable Energy	116.2	407	432.8	452.2	323	213.2	
Fixed O/M cost	31.7 $/kW-year for Plant						
	31.7 $/kW-year including Transmission Line						

Average Power Tariff as of: 2006

Tariff at Consumer's end	13.0 c/kWh
Effective Tariff for the Project	11.05 c/kWh
Tariff escalation	0.0%

Profit Tax

Tax Holiday	0 years
Profit Tax	20%

Depreciation Method

Accelerated Depreciation of	11.0%	for	20 years

Imposed Duties and Taxes on Fuel

Fuel Type	Standard Price for Tax Calculation	Import Duties Rate	Import Duties Amount	Social Fund Rate	Social Fund Amount	Sub Total	VAT 10%	Total Taxes
NG	4 $/MBTU	0%	0.00	1.4 $/ton	0.032 $/MBTU	4.03	0.40	0.432
DO	275 $/ton	20%	55.00	1.4 $/ton	1.4 $/ton	331.4	33.14	89.54

Unit Conversion Factor

1 kWh =	860 kcal =	3,413 BTU	
1 BTU=	0.252 kcal		
1 cu.ft =	0.0283 m3		
1 Lb =	0.4536 kg		
1 Nm3=	0.7536 kg for Natural Gas		

Density

Diesel Oil	0.8297
Heavy Fuel Oil	0.9361

Heat Value

Natural Gas	8,341 kcal/Nm3
Diesel Oil	9,904 kcal/kg

Scheduled Maintenance	- days	Fuel Type	1 NG
Forced Outage Rate	-	Fuel Price	4 $/MBtu
Station Use	2.8%	Fuel Cost	30.27 $/MWh
Economic Life Time	20 years	Fuel Conversion	1 years after commencement of operation
T/L and D/S Loss	15.7%	Fuel Conversion from	1 to 1
		Conversion System	0.0 M.US$ for Whole Stages

Fuel Cost as of 2001 and Fuel Escalation

Type No.	Symbol	Fuel Name	Fuel Price-1(CIF)	Fuel Price aft Tax	Fuel Price -2	Efficiency	Fuel Cost	Variable O/M	Fuel Escaltion
1	NG	Natural Gas	4.0 $/MBtu	4.43 $/MBTU	4.43 $/MBtu	6,829 Btu/kWh	30.27 $/MWh	1.0 $/MWh	0.0%
2	DO	Diesel Oil	237 $/ton	326.5 $/ton	8.29 $/MBtu	7,030 Btu/kWh	58.28 $/MWh	2.5 $/MWh	2.0%

Note: Fuel Price based on L.H.V. (Low Heating Value)

1. Profit and Loss Statement

Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Conversion System	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generation Energy	GWh	-	-	-	-	-	189.2	591.3	433.6	496.7	528.2	551.9	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	260.2	-	-	-	-
Salable Energy	GWh	-	-	-	-	-	155	484.5	355.3	407	432.8	452.2	323	323	323	323	323	323	323	323	323	323	323	323	323	323	213.2	-	-	-	-
Effective Power Tarif	c/kWh	-	-	-	-	-	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Sales Revenue	M.US$	-	-	-	-	-	17.2	53.8	39.4	45.2	48.0	50.2	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	23.7	-	-	-	-
Fixed O/M cost	M.US$	-	-	-	-	-	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	-	-	-	-
Variable O/M cost	M.US$	-	-	-	-	-	0.2	0.6	0.4	0.5	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	-	-	-	-
Fuel Type		-	-	-	-	-	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	-	-	-	-
Unit Fuel Cost	$/MWh	-	-	-	-	-	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	-	-	-	-
Fuel Cost	M.US$	-	-	-	-	-	5.7	17.9	13.1	15.0	16.0	16.7	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	7.9	-	-	-	-
Earning after operatio	M.US$	-	-	-	-	-	7.6	31.6	22.2	26	27.8	29.2	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	11.8	-	-	-	-
Depreciation	M.US$	-	-	-	-	-	17	15.1	13.5	12	10.7	9.5	8.4	7.5	6.7	6	5.3	4.7	4.2	3.7	3.3	3	2.6	2.3	2.1	1.9	1.7	-	-	-	-
Interest Payment	M.US$	-	-	-	-	-	-	5.1	5.1	5.1	5.1	5.1	4.8	4.5	4.1	3.8	3.4	3.1	2.7	2.4	2.1	1.7	1.4	1.0	0.7	0.3	0.0	-	-	-	-
Earning before Tax	M.US$	-	-	-	-	-	-9.4	11.4	3.6	8.9	12	14.6	6.7	7.9	9.1	10.1	11.2	12.1	13	13.8	14.5	15.2	15.9	16.6	17.1	17.7	10.1	-	-	-	-
Profit Tax	M.US$	-	-	-	-	-	0	2.3	0.7	1.8	2.4	2.9	1.3	1.6	1.8	2	2.2	2.4	2.6	2.8	2.9	3	3.2	3.3	3.4	3.5	2	-	-	-	-
Profit after Tax	M.US$	-	-	-	-	-	-9.4	9.1	2.9	7.1	9.6	11.7	5.4	6.3	7.3	8.1	9.0	9.7	10.4	11.0	11.6	12.2	12.7	13.3	13.7	14.2	8.1	-	-	-	-
Conversion System	M.US$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generation Energy	GWh	-	-	-	-	-	-	-	141.9	496.7	528.2	551.9	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	260.2	-	-
Salable Energy	GWh	-	-	-	-	-	-	-	116.2	407	432.8	452.2	323	323	323	323	323	323	323	323	323	323	323	323	323	323	323	323	213.2	-	-
Effective Power Tarif	c/kWh	-	-	-	-	-	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Sales Revenue	M.US$	-	-	-	-	-	-	-	12.9	45.2	48.0	50.2	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9	23.7	-	-
Fixed O/M cost	M.US$	-	-	-	-	-	-	-	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	-	-
Variable O/M cost	M.US$	-	-	-	-	-	-	-	0.1	0.5	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	-	-
Fuel Type		-	-	-	-	-	-	-	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	-	-
Unit Fuel Cost	$/MWh	-	-	-	-	-	-	-	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	30.27	-	-
Fuel Cost	M.US$	-	-	-	-	-	-	-	4.3	15.0	16.0	16.7	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	7.9	-	-
Earning after operatio	M.US$	-	-	-	-	-	-	-	5.6	26.8	28.6	30.0	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	12.6	-	-
Depreciation	M.US$	-	-	-	-	-	-	-	12.1	10.8	9.6	8.6	7.6	6.8	6.0	5.4	4.8	4.3	3.8	3.4	3.0	2.7	2.4	2.1	1.9	1.7	1.5	1.3	1.2	-	-
Interest Payment	M.US$	-	-	-	-	-	-	-	-	3.7	3.7	3.7	3.7	3.7	3.4	3.2	2.9	2.7	2.5	2.2	2.0	1.7	1.5	1.2	1.0	0.7	0.5	0.2	0.0	-	-
Earning before Tax	M.US$	-	-	-	-	-	-	-	-6.5	12.3	15.3	17.7	9.4	10.2	11.3	12.1	13.0	13.7	14.4	15.1	15.7	16.3	16.8	17.4	17.8	18.3	18.7	19.2	11.4	-	-
Profit Tax	M.US$	-	-	-	-	-	-	-	0.0	2.5	3.1	3.5	1.9	2.0	2.3	2.4	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.7	3.8	2.3	-	-
Profit after Tax	M.US$	-	-	-	-	-	-	-	-6.5	9.8	12.2	14.2	7.5	8.2	9.0	9.7	10.4	11.0	11.5	12.1	12.6	13.0	13.4	13.9	14.2	14.6	15.0	15.4	9.1	-	-
Total Profit or Loss	M.US$	-	-	-	-	-	-9.4	9.1	-3.6	16.9	21.8	25.9	12.9	14.5	16.3	17.8	19.4	20.7	21.9	23.1	24.2	25.2	26.1	27.2	27.9	28.8	23.1	15.4	9.1	-	-

Table 11.3-8 (2/2)   Cashflow Calculation for Case No. 1000

Case No.	1000

2. Project IRR, FIRROE, and Debt Service Coverage Ratio

2-1. Project Cashflow and Project IRR

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total	Project IRR
Investment	0.0	0.0	0.0	-33.4	-74.1	-39.4	0.0	0.0																							-146.9	
Earning after Operation	0.0	0.0	0.0	0.0	0.0	7.6	31.6	22.2	26.0	27.8	29.2	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	11.8	0.0	0.0	0.0	0.0	434.8	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	-3.3	-1.7	-2.8	-3.4	-3.9	-2.3	-2.5	-2.6	-2.8	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	-3.5	-3.6	-3.6	-2.0	0.0	0.0	0.0	0.0	-60.4	
Cashflow for ST-1	0.0	0.0	0.0	-33.4	-74.1	-31.8	28.3	20.5	23.2	24.4	25.3	17.6	17.4	17.3	17.1	17.0	16.9	16.8	16.7	16.6	16.5	16.4	16.4	16.3	16.3	9.8	0.0	0.0	0.0	0.0	227.5	**11.6%**
Investment	0.0	0.0	0.0	0.0	0.0	-23.3	-53.9	-27.8																							-105.0	
Earning after Operation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	26.8	28.6	30.0	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	12.6	0.0	0.0	434.8	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.2	-3.8	-4.3	-2.6	-2.8	-2.9	-3.1	-3.2	-3.3	-3.4	-3.5	-3.5	-3.6	-3.7	-3.7	-3.8	-3.8	-3.8	-3.9	-2.3	0.0	0.0	-68.2	
Cashflow for ST-2	0.0	0.0	0.0	0.0	0.0	-23.3	-53.9	-22.2	23.6	24.8	25.7	18.1	17.9	17.8	17.6	17.5	17.4	17.3	17.2	17.2	17.1	17.0	17.0	16.9	16.9	16.9	16.8	10.3	0.0	0.0	261.6	**16.5%**
Cashflow for All Stages	0.0	0.0	0.0	-33.4	-74.1	-55.1	-25.6	-1.7	46.8	49.2	51.0	35.7	35.3	35.1	34.7	34.5	34.3	34.1	33.9	33.8	33.6	33.4	33.4	33.2	33.2	26.7	16.8	10.3	0.0	0.0	489.1	**13.5%**

2-2. Equity Cashflow and ROE

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total	ROE
Equity Cashflow	0.0	0.0	0.0	-0.6	-2.5	-4.5	0.0	0.0																							-7.6	
Earning after Operation	0.0	0.0	0.0	0.0	0.0	7.6	31.6	22.2	26.0	27.8	29.2	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	11.8	0.0	0.0	0.0	0.0	434.8	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	-2.3	-0.7	-1.8	-2.4	-2.9	-1.3	-1.6	-1.8	-2.0	-2.2	-2.4	-2.6	-2.8	-2.9	-3.0	-3.2	-3.3	-3.4	-3.5	-2.0	0.0	0.0	0.0	0.0	-48.1	
Principal Repayment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	0.0	0.0	0.0	0.0	-147.0	
Interest Payment	0.0	0.0	0.0	0.0	0.0	0.0	-5.1	-5.1	-5.1	-5.1	-5.1	-4.8	-4.5	-4.1	-3.8	-3.4	-3.1	-2.7	-2.4	-2.1	-1.7	-1.4	-1.0	-0.7	-0.3	0.0	0.0	0.0	0.0	0.0	-61.5	
SUM : ST-1	0.0	0.0	0.0	-0.6	-2.5	3.1	24.2	16.4	19.1	20.3	21.2	4.0	4.0	4.2	4.3	4.5	4.6	4.8	4.9	5.1	5.4	5.5	5.8	6.0	6.3	0.0	0.0	0.0	0.0	0.0	170.6	**210.4%**
DSCR : ST-1	-	-	-	-	-	-	5.75	4.22	4.75	4.98	5.16	1.27	1.28	1.30	1.32	1.34	1.36	1.38	1.40	1.43	1.47	1.49	1.54	1.57	1.62	1	-	-	-	-	Mini.	1.00
Equity Cashflow	0.0	0.0	0.0	0.0	0.0	-0.4	-1.8	-3.2																							-5.4	
Earning after Operation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	26.8	28.6	30.0	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	12.6	0.0	0.0	434.8	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.5	-3.1	-3.5	-1.9	-2.0	-2.3	-2.4	-2.6	-2.7	-2.9	-3.0	-3.1	-3.3	-3.4	-3.5	-3.6	-3.7	-3.7	-3.8	-2.3	0.0	0.0	-59.3	
Principal Repayment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	0.0	0.0	-105.0	
Interest Payment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.7	-3.7	-3.7	-3.7	-3.7	-3.4	-3.2	-2.9	-2.7	-2.5	-2.2	-2.0	-1.7	-1.5	-1.2	-1.0	-0.7	-0.5	-0.2	0.0	0.0	0.0	-44.2	
SUM : ST-2	0.0	0.0	0.0	0.0	0.0	-0.4	-1.8	2.4	20.6	21.8	22.8	15.1	15.0	8.0	8.1	8.2	8.3	8.3	8.5	8.6	8.7	8.8	9.0	9.1	9.3	9.5	9.7	3.3	0.0	0.0	220.9	**244.1%**
DSCR : ST-2	-	-	-	-	-	-	-	-	6.57	6.89	7.16	5.08	5.05	1.77	1.79	1.83	1.86	1.87	1.92	1.96	2.00	2.04	2.10	2.14	2.21	2.27	2.35	1.47	-	-	Mini.	1.47
Equity Cashflow for All	0.0	0.0	0.0	-0.6	-2.5	2.7	22.4	18.8	39.7	42.1	44.0	19.1	19.0	12.2	12.4	12.7	12.9	13.1	13.4	13.7	14.1	14.3	14.8	15.1	15.6	9.5	9.7	3.3	0.0	0.0	391.5	**212.8%**
DSCR for All Stages	-	-	-	-	-	-	5.75	5.31	5.51	5.78	6	2.04	2.06	1.5	1.52	1.55	1.57	1.6	1.63	1.66	1.7	1.73	1.78	1.82	1.88	1.55	2.35	1.47	-	-	Mini.	1.47

3. Levelised Production Cost   Discount Rate = 10%   Levelised Production Cost (LPC) for All Stages **7.84** c/kWh

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total	LPC c/kWh
Conversion Factor	1.000	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239	0.218	0.198	0.180	0.164	0.149	0.135	0.123	0.112	0.102	0.092	0.084	0.076	0.069	0.063		
Equity Cashflow	0.0	0.0	0.0	0.6	2.5	4.5	0.0	0.0																							7.6	
Fixed and Variable O/M	0.0	0.0	0.0	0.0	0.0	3.9	4.3	4.1	4.2	4.2	4.3	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	0.0	0.0	0.0	0.0	86.4	
Fuel Cost	0.0	0.0	0.0	0.0	0.0	5.7	17.9	13.1	15.0	16.0	16.7	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	7.9	0.0	0.0	0.0	0.0	258.9	
Principal Payment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	0.0	0.0	0.0	0.0	147.0	
Interest Payment	0.0	0.0	0.0	0.0	0.0	0.0	5.1	5.1	5.1	5.1	5.1	4.8	4.5	4.1	3.8	3.4	3.1	2.7	2.4	2.1	1.7	1.4	1.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	61.5	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.7	1.8	2.4	2.9	1.3	1.6	1.8	2.0	2.2	2.4	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.5	2.0	0.0	0.0	0.0	0.0	48.1	
SUM : ST-1	0.0	0.0	0.0	0.6	2.5	14.1	29.6	23.0	26.1	27.7	29.0	31.9	31.9	31.7	31.6	31.4	31.3	31.1	31.0	30.8	30.5	30.4	30.1	29.9	29.6	23.7	0.0	0.0	0.0	0.0	609.5	
Salable Energy for ST-1	0.0	0.0	0.0	0.0	0.0	155.0	484.5	355.3	407.0	432.8	452.2	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	213.2	0.0	0.0	0.0	0.0	7022.0	
Discounted Outflow	0.0	0.0	0.0	0.5	1.7	8.8	16.7	11.8	12.2	11.7	11.2	11.2	10.2	9.2	8.3	7.5	6.8	6.2	5.6	5.0	4.5	4.1	3.7	3.3	3.0	2.2	0.0	0.0	0.0	0.0	165.4	
Discounted Energy	0.0	0.0	0.0	0.0	0.0	96.2	273.5	182.3	189.9	183.6	174.3	113.2	102.9	93.6	85.0	77.3	70.3	63.9	58.1	52.8	48.0	43.6	39.7	36.1	32.8	19.7	0.0	0.0	0.0	0.0	2036.8	**8.12**
Equity Cashflow	0.0	0.0	0.0	0.0	0.0	0.4	1.8	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	
Fixed and Variable O/M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3.4	3.4	3.5	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	0.0	0.0	69.3	
Fuel Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	15.0	16.0	16.7	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	7.9	0.0	0.0	250.3	
Principal Payment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	0.0	0.0	105.0	
Interest Payment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	3.7	3.7	3.7	3.4	3.2	2.9	2.7	2.5	2.2	2.0	1.7	1.5	1.2	1.0	0.7	0.5	0.2	0.0	0.0	0.0	44.2	
Profit Tax	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.1	3.5	1.9	2.0	2.3	2.4	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.7	3.8	2.3	0.0	0.0	59.3	
SUM : ST-2	0.0	0.0	0.0	0.0	0.0	0.4	1.8	10.5	24.6	26.2	27.4	20.8	20.9	27.9	27.8	27.7	27.6	27.6	27.4	27.3	27.2	27.1	26.9	26.8	26.6	26.4	26.2	20.4	0.0	0.0	533.5	
Salable Energy for ST-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.2	407.0	432.8	452.2	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	213.2	0.0	0.0	6789.4	
Discounted Outflow	0.0	0.0	0.0	0.0	0.0	0.2	1.0	5.4	11.5	11.1	10.6	7.3	6.7	8.1	7.3	6.6	6.0	5.5	4.9	4.5	4.0	3.7	3.3	3.0	2.7	2.4	2.2	1.6	0.0	0.0	119.6	
Discounted Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.6	189.9	183.6	174.3	113.2	102.9	93.6	85.0	77.3	70.3	63.9	58.1	52.8	48.0	43.6	39.7	36.1	32.8	29.8	27.1	16.3	0.0	0.0	1597.9	**7.48**

11.4. Conclusion

In the course of the economic and financial analyses, the following conclusions are induced under the current assumed conditions.

(1) Total project cost including the duties and taxes, IDC and other financial fees, and the associated transmission line from the Site to Kampot is anticipated to be 155 Million US$ for Stage 1 and 110 Million US$ for Stage 2 respectively.

(2) If the natural gas is put into the operation before the 5th year from the commencement of the commercial operation, the good economic and financial performances are expected. On the other hand, if the diesel oil is fired during the full operation period, the economic and financial feasibility of the project will not be expected.

(3) Especially, if the natural gas is available from the beginning of the commercial operation, production cost of the project will be much lower than the current purchase price from IPP1 and be less expensive than the power purchase from Vietnam in future.

(4) Natural Gas price of 4.0 $/MMBTU seems to be rather conservative in comparison with the current world market prices[8]. Therefore, if the natural gas price is available at less than 4.0 $/MMBTU, more economic and financial attractiveness will be expected.

(5) Based on the above considerations, Fig.11.4-1 presents the various power costs related to the EDC activities and results of financial analysis. As shown in Fig.11.4-1, Sianoukville C.C Power Plant with natural gas firing for full 20 years operation period presents the lowest cost among the each cost level and is expected to contribute to reduction of future power tariff of EDC remarkably.

(6) The only issue to be overcome by EDC in order to implement the project seems to be financial problem. The current management of EDC has been suffering from a

[8] According to "2001 World Development Indicators, World Bank", the average price of natural gas from the year 1998 to 2000 is 2.72 $/MMBTU at Europe and 2.81 $/MMBTU in US.

deficit since 1997. Under the current financial situation of EDC, it seems to be difficult to bear the IDC, even though the EDC occupies only 5 % of the total project cost. Since Sihanoukville Combined Cycle Project requires the huge investment amounted to be around 265 Million US$ and is the first big project for EDC, the improvement of the EDC management will be desirable until the implementation of the project.

12. Issues in Implementation of Project

12.1. Fuel

In the Project, natural gas is planned as main fuel and diesel is as back-up fuel. However, as stated in Section 3.1, natural gas is not available at present in Cambodia. The Cambodian government is studying several options to make natural gas available, namely, development of gas resources offshore in the Cambodian territory and import from neighboring countries. However, every option has some issues respectively, then it seems to be difficult to get conclusion in a short time.

The most preferable option to realize utilization of natural gas would be a development in the Cambodian territory. That could be considered the most beneficial solution to Cambodia due to effective use of own natural energy resources, proceeding a plan by own decision without disturbance by others and saving of foreign currency.

Meanwhile, according to the information of the gas developer, Woodside Co., the development of natural gas in offshore Cambodia is not necessarily favorable in economic aspect because of relatively small reserved volume per well. This means that many wells should be drilled, then the development cost becomes higher. In addition, since, at present, there is no significant gas consumer other than this Sihanoukville power project in Cambodia, the construction cost of pipeline per unit volume of gas becomes more costly. Generally price of natural gas tends to become cheaper in proportion to increase of demand. It is said that the size of 180 MW power generation is rather small to ensure economical price of natural gas, and preferable size would be larger than 300 MW.

Therefore, attainable gas price counting such disadvantageous conditions in is a key point to realize this Project.

If the Cambodia government makes a policy that future power development is based on gas fired gas turbine combined cycles, and shows in his power development plan a planned size and commissioning time of specific power plant, that plan would accelerate strongly the development of natural gas.

12.2. Implementation Schedule

12.2.1. Relation with Transmission Line between Kampot and Sihanoukville

In the study of the optimum power development plan, the Sihanoukville power plant is concluded to commence Stage 1 in 2006 and Stage 2 in 2008. However, as shown in Fig.10-1, the attainable commissioning time of Stage 1 depends on the schedule of transmission line between Kampot and Sihanoukville.

The concrete plan of this transmission line is not exist so far, and neither a feasibility study is commenced. The schedule shown in Fig.10-1 is only an imaginary and not-confirmed schedule that can keep the required completion of the Sihanoukville power plant. Therefore, to ensure the schedule of completion time of the power plant, the feasibility study of transmission line is recommended to start as soon as possible without waiting the final decision of the power plant construction.

12.2.2. Relation with Available Time of Natural Gas

Meanwhile, another issue is a time that natural gas becomes available to the Plant if it is intended to use natural gas from the start of the Plant. The Plant is planned to use diesel oil as back-up fuel, therefore, the Plant can be operated by using diesel oil until natural gas comes with a demerit by high fuel cost in short period. However, even if diesel oil is used initially, the specific available time of natural gas needs to be confirmed at the time of decision of construction of the Project. Otherwise, it would become difficult to convince a lender to arrange a loan for the Project.

According to the information from the developer of natural gas, the expected time from a signing of production sharing contract (PSC) to commercial production of natural gas is about 5 years. However, so far the signing of PSC between CNPA and the developer is not yet done, therefore it is questionable whether natural gas becomes available in 2006. In addition, to conclude to supply natural gas to the Project it is required to agree the price of gas. Generally this kind negotiation requires so long period, so, to assure the commissioning time of the Project as required, the relevant parties, MIME and EDC, should take an initiative of the negotiation.

12.3. Structure of Power Generation in Cambodia

At present, the biggest power supply source is IPP1 with capacity of 37.1 MW, which is a independent power supplier. Other power plants are mostly of small diesel power plant with capacities between several thousand kW to 20 MW less. In addition to these, Kirirom hydropower (12 MW), which is also IPP, is planned to start in 2003, and the power trade with Vietnam is planned to start in 2004. And, excepting the Sihanoukville power plant, all planned power plants in future are of hydro power plant, namely Kamchay (47- 127 MW), Stung Atay (110 MW), St. Russei Chrum (125 MW) and Battambang (60 MW).

IPP1 and Kirirom can not be expected to take a role of load adjusting operation because of Take-or-Pay power purchase agreement. And other hydro power plants will be operated to generate power in correspondence to a utilizable water quantity without load adjusting. Therefore load adjustable power sources are only the Sihanoukville P/P, C-6 (18MW) and the interconnection with Vietnam except the existing diesel power plants that are planned to retire in future.

The Sihanoukville power plant is a new and high efficiency plant, therefore, it is expected to operate on high base-load and supply cheap power. However, due to the above situations the Sihanoukville P/P could not operate at so high load as to perform the expected role.

Another problem related to hydropower is that the operation load of hydropower is significantly different by the seasons, namely, high-load operation in the wet season and low-load operation in the dry season. To compensate this load difference the thermal power plant has to operate on high load in the dry season and low load in the wet season. The capacity of such thermal power plant is determined considering the minimum load of hydropower in the dry season, that results in the low capacity factor and low economic performance of thermal power plant. In other words, higher reserve margin is required as a whole power generation system.

From the above mentioned points of view, it goes without saying that introduction of IPP with high power price should be avoided, but the power generation balance between hydropower and thermal power should also be studied in the power development plan with considering the investment cost and operation cost required in whole system.

Expansion of thermal power generation capacity in future power development would be beneficial to realize a cheaper price of natural gas.

12.4. Management, Operation and Personal Allocation

Most of power plants in Cambodia are of diesel generator power plant except one small capacity boiler-turbine power plant. They have never experienced of operation of gas turbine as well as gas turbine combined power plant. Therefore, it is recommended that the operators or staff to be assigned to the Sihanoukville power plant will have training immediately after the decision of construction, preferably actual operation training in a similar power plant outside the country. In addition, during the first 2 or 3 years operation of the Plant, for training EDC's operators, it is recommended to employ skillful expatriate engineers as temporary staffs who are assigned to the operation team leaders. For management and administration for a whole power plant, it is also recommended to employ expatriate staff for initial stage, who can manage and make plans for operation, maintenance & inspection, procurement of materials, etc.

The required number of staff for the Sihanoukville power plant is estimated 151 at the time of Stage 2 completion. Of them, the number of engineer is 115.
While the total number of employee of EDC as of 2000 is 1,513, and the total number of personnel classified into "Engineer", "Vocational Technician" and "Skilled worker" is 858. And, the number of employees belong to the power plants is about 540 in total, about 330 in Phnom Penh area and about 210 in the regional power stations, respectively.

From the above data, the present staff capacity of EDC seems to be able to supply the required staff for the Sihanoukville power station on the condition that the existing old diesel power plants in Phnom Penh area will be closed down step by step. However, this needs relocation of a significant number of employees from the capital city Phnom Penh to the regional city Sihanoukville, of which distance is about 260 km. Therefore, some part of staff may be required to be hired newly in the Sihanoukville area.

12.5. Finance

In the course of the study, the project cost including the associated transmission line from the site to Kampot is estimated to be 265 Million US$ (or 31,800 Million Japanese Yen), in which an official soft loan will be applied amounted to 212 Million US$ (or 25,400 Million Japanese Yen).
The JBIC loan is also one of the candidates of the official soft loan. The latest loan amount financed by JBIC to the Government of Cambodia was 4,100 Million Japanese Yen, which was applied to "Sihanoukville Port Urgent Rehabilitation Project" in 1999.
Since the required finance amount of 25,400 Million Japanese Yen extremely exceeds the above actual finance amount, JBIC may not be able to afford the required finance by itself. Co-finance by JBIC and ADB is also one of the alternatives for the finance planning.

Stage 2 is planned to be constructed after 2 years since Stage 1 is constructed. However, the implementation of Stage 2 might be delayed in view of the finance procurement.

13. Overall Assessment and Recommendation

13.1. Overall Assessment

(1) The Sihanoukville power plant is recommended to commence on 2006 for Stage 1 of 90 MW and 2008 for Stage 2 of another 90 MW. However, possible commencement time will depend on the schedule of transmission line between Takeo and Sihanoukville and also depend on the time natural gas becomes available.

(2) The most preferable plant type is natural gas fired gas turbine combined cycle plant.

(3) The optimum plant site is Option-4, which is located about 9 km away from the urban area of Sihanoukville City in north-northeast direction and just near Sokimex Oil Terminal.

(4) The fuels used in the plant are natural gas as main and diesel oil for back up. Supply source of natural gas is still under studying on several options, but the most preferable option may be development in Cambodia territory.

(5) The power plant is preferably use natural gas from the start of the operation. The target price of natural gas is around 4.0 $/MMBTU (LHV Base, tax free) to keep the levelised power production cost of less than 6 ¢/kWh.

(6) The levelised production cost is estimated to remain 7.8 ¢/kWh in the financial analysis even though the natural gas (4 $/MMBTU) is put into the operation from the commencement. The production costs of natural gas combined cycle power plants in Southeast Asia are said to be 4.0 ~ 5.0 ¢/kWh. The above 7.8 ¢/ kWh seems to be still expensive in comparison with those in Southeast Asia.
The reasons why the production cost of the project becomes rather expensive may be explained by the following circumstances, which the power sector in Cambodia encounters.

(a) The natural gas price is envisaged to be relatively costly in comparison with the world market prices due to the inefficiency of the gas fields and undevelopment of natural gas demand in Cambodia.

(b) MIME and EDC plan the implementation of hydropower plants in future. Due to the introduction of hydropower plants in future, the project has to be operated not as a base load power plant but as a load adjustment power plant.

(c) The plant cost has to become rather costly due to the small output capacity and small unit capacity of the plant because of the constraint resulting from the small power system in Cambodia.

(7) With the project design, the environmental management plan and the environmental monitoring plan (as set fort in this report and in the EIA Report), environmental impacts can be mitigated to ensure project compliance with applicable environmental standards and guidelines of Cambodia and major lending institutions.

13.2. Recommendation

(1) The feasibility study of transmission line between Kampot and Sihanoukville should be commenced as soon as possible.

(2) For accelerating the development of natural gas, MIME and EDC should actively participate in the process of development and negotiation with gas developer, and be recommended to indicate the concrete demand forecast of natural gas in Cambodia.

(3) The power development plan should be made considering optimum balance of hydropower plant and thermal power plant. Installation of additional power plant using natural gas would encourage the development of natural gas.