Chapter 5 Basic Design

5.1 Outline of the Project

From the result of Sub-section 4.7.2 and 4.7.3, Bheramara CCPP is planned as a nominal 360MW high efficiency combined cycle power plant consisting an F class gas turbine generator, a heat recovery steam generator (HRSG), a steam turbine generator and related facilities. And the Project additionally includes the branch 230kV transmission line from adjacent main 230kV transmission line, new 230kV substation, rehabilitation of the existing 132kV transmission line and branch gas pipeline from the adjacent city gate station (CGS). Forced draft cooling tower system is utilized for the condenser cooling system and groundwater is used for water supply of the system.

5.2 Operational Requirements

5.2.1 General

The main components and their auxiliaries shall be designed to ensure that trouble free starts and operations are achieved throughout the design life of the new plant. Adequate redundancies for auxiliary facilities & equipment shall be made available to achieve high availability. The main components and their auxiliaries shall be designed to be able to start and rise up to full load by the initiation of a single push-button. The entire plant shall be suitable for continuous heat and power load operation keeping the required heat energy export.

5.2.2 Plant Duty

The new plant shall have high efficiency and reliability based on proven advanced technology. The new plant shall be so designed as to withstand the anticipated annual operating scheme specified in this specification with an annually averaged availability factor not less than 86.8 %, which is defined with ISO 3977-9:1999(E) Gas turbines -- Procurement -- Part 9: Reliability, availability, maintainability and safety.

(1) Start-up Time Schedule Requirements

The start-up time shall be as short as possible to cope with the function of this new plant. The new plant shall be designed to meet such start-up times as specified in the following table. The start-up time shall be defined as the time required from the initiation of the start button to the full load conditions, provided that the condenser vacuum is established and the new plant is ready for start. The time for air purge of special volume post gas turbine and synchronization shall be excluded.

Type of Start-up	Time (min.)
Cold start after stop of more than 36 hours	Max. 240
Warm start after stop of less than 36 hours	Max. 180
Hot start after stop of less than 8 hours	Max. 120
Very hot start after stop of less than 1 hour	Max. 60

(2) Service Life Time

The new plant and associated equipment shall be designed and constructed for the service time as specified below:

Minimum Service Time = 30 years
Equivalent Service Hours = 183,960 hours on a full load basis [1]

The new plant shall be designed for a continuous load operation with more than 6,132 actual operating hours per year on a basis of the full load. Necessary hours for starting and shutdown cycle are not included in the above operating hours.
Through the service time, the new plant and associated equipment shall continue to be operated with high efficiency, high reliability and excellent economy.
Any components of which service lives may be less than the above figures shall be designed for ease of replacement and maintenance.

(3) Start-up and Shutdown Times
The start-up and shut down operation of the new plant shall be performed automatically from the CCR (Central Control Room).
Full supervisory and control functions shall be provided for the safe, reliable and efficient operation of the new plant.
The new plant shall be capable of being auto-synchronized and initial-loaded from the CCR.
As a basis for design of the new plant, it is assumed that the new plant shall operate on a full load basis for the service time of 30 years, during which the high efficient and reliable operation shall be preserved.
For the design requirements as stated above, the following annual start-up times shall be considered:

Type of Start	Annual Times	Total Times through Service time
Cold Start (S/Down > 36h)	2	60
Warm Start (S/Down < 36h)	5	150
Hot Start (S/Down < 8h)	30	900
Very Hot (S/Down < 1h)	5	150
Total	42	1,260

The steam turbine shall be provided with a turbine bypass system to improve operational flexibility during start-up, load variation, shutdown and in emergency condition.

5.2.3 Control and Operation Philosophy

(1) Plant Automation
The degree of automation is such that the start-up/shutdown sequential control and the protection of the new plant shall be fully automated to enable overall supervision of the new plant by operators at the CCR. However, the start-up/shutdown control sequence shall include break points to allow the operator to intervene and provide normal assistance as needed.
The start-up/loading procedures, including draining and venting of the new plant, shall be selectable and controlled automatically dependant upon such state conditions of the new plant as very hot, hot, warm, or cold status.

(2) Plant Operation
The CCR shall be accommodated in the new turbine building of the new plant and be equipped with the state-of-the-art DCS (Distributed Control System) with data logging system so that generated power can be automatically controlled to meet the demands. The operator console which consists of LCD (Liquid Crystal Display) for monitoring of operating

1) Equivalent Service Hours : 24 x 365 x 30 x Plant Load Factor 70 %

conditions and keyboard panels with mouse for operation of the new plant will be installed as the operator console in the CCR.

The LCD operation will be employed to make a human-machine interface easier and to facilitate monitoring and operation and higher operating reliability.

The CPU shall be of duplicate configuration using the standby redundant system to ensure the reliability of the control system.

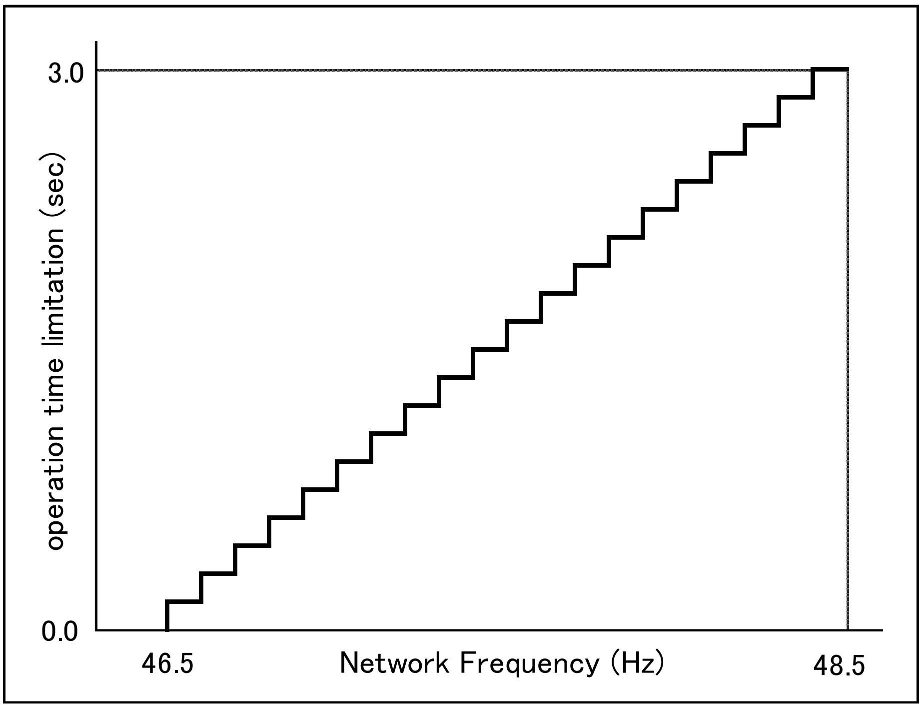
A Switching operation of generator circuit breaker shall also be performed from the DCS located in the CCR.

A Switching operation of electrical circuits in 132/230 kV substations shall be performed from the DCS located in the substation control room.

(3) Under and Over-frequency Operation

The gas turbine/generator and the steam turbine/generator shall be so designed that they can withstand the continuous operation under and over frequency from 48.5 to 51.5 Hz under load condition. They shall be capable of also load operation under the frequency range of 46.5 to 48.5 Hz with the operation time limitation. Control devices required to limit the load operation time as shown below, shall be provided in consideration of the requirement from Bangladesh Network System.

Operation Time Limitation



(4) Operational Vibration Levels

The relative shaft vibration levels of the gas turbine/generator and steam turbine/generator shafts under any load conditions at the rated speed shall be limited. The measurement method of the shaft vibration shall be in accordance with the ISO 7919 or equivalent standards. The vibration shall be measured as the unfiltered relative shaft peak-to-peak displacement in the vicinity of the main journal bearings of the said shafts. The operational vibration levels shall be such as tabled below as per ISO 7919-2:2001(E) Part 2 “Large land-based steam turbine generator sets” and ISO 7919-4:1996(E) Part 4 “Gas Turbine Sets”.

Type of Equipment	Vibration Level (p-p μm)
Gas Turbine/Generator	≦80
Steam Turbine/Generator	≦80

The vibration levels of the gas turbine/generator and steam turbine/generator shafts shall not exceed 80 μm throughout the Reliability Test. Should the vibration level of any equipment exceed the specified value during the Reliability Test of two (2) weeks, then the Test shall be cancelled and a new two (2) weeks Test shall be repeated after the vibration level has been rectified. After taking-over of the new plant, the vibration level of them shall not exceed the value during the Defect Liability Period.
The relative vibration level at an alarm point shall be set at the level not more than 120 μm for both gas turbine/generator and the steam turbine/generator. The trip value shall be set at 240 μm, if it is acceptable depending upon the operating experience of the same types of gas turbine/generator and the steam turbine/generator.

(5) Power Control
The plant power load will be demanded by SCADA system from the load dispatch center to the new plant. The new plant shall be automatically operated after setting the plant power load demand into the DCS through the operator console by the operator of the new power plant so that the plant power load demand will be satisfied.

5.3 Study on Basic Technical Issues

5.3.1 Expected Performance of Bherarma Combined Cycle Power Plants

(1) Candidate Models of CCPP
Four (4) models are available in the international market as the combined cycle power plant (CCPP) which is comprised of a 50 Hz use largest capacity gas turbine model of which turbine inlet temperature is of F class level. The F class models of gas turbines of four (4) original equipment manufacturers (OEMs) are matured with much operating experience and are deemed to be best suited for the Project from operating experience points of view. According to the Gas Turbine World 2007-08 GTW Handbook, the four (4) models of combined cycle power plants are as tabulated below:

Name of OEM of GT	Model of CCPP
Alstom	KA26-1 (with air quench cooler)
General Electric	S109FA, S109FB
Mitsubishi	MPCP1(M701F)
Siemens	SCC5-4000F 1×1

In choice of the candidate Models, it shall be considered that the used gas turbine can be operated in a simple cycle mode taking into account that it may be put into a commercial operation in advance to solve the impending shortage of power supply. For example, Alstom can supply two (2) types of GT26 gas turbines. One is GT26 with an air quench cooler, while the other is GT26 with a once through cooler that uses the steam to cool the air extracted from the air compressor for internal cooling of hot parts of the gas turbine. Therefore, the latter type of GT26 gas turbine can not be operated without cooling medium of steam. For such a reason, the GT26 gas turbine where ambient air is used as a cooling medium is chosen as a candidate CCPP for the Plant. Similarly, out of the two (2) types of S109 CCPP models that GE has, the model of S109FB is specified as a model for only combined cycle mode use in the said Handbook, therefore, this model is excluded from the study.

For the heat balance calculation of each model of CCPP, a bypass stack and a damper are considered.

(2) CCPP Performance Data on ISO Conditions

In the said GTW Handbook, performance data of above models of CCPPs are described at ISO conditions (101.33 kPa, 15^{O}C, 60% RH) on natural gas though any other necessary conditions than ambient temperature and pressure are not always specified. The performance data of the four (4) CCPP models are as described below:

Model of CCPP	Net Plant Output (kW)	Net Plant Efficiency (%)
KA26-1 with AQC	Not specified	Not specified
S109FA	390,800	56.7
MPCP1 (M701F)	464,500	59.5
SCC5-4000F 1×1	416,000	58.2

(3) Calculation Results of CCPP Heat Balance on Unfired Conditions

Performances of the four (4) models of CCPPs on rated and maximum capacity site conditions must be predicted to specify the performance requirements of the Plant in the Bidding Documents. For the purpose, the heat balances at the rated and maximum capacity site conditions were calculated using the gas turbine performance data on ISO conditions specified in the said GTW Handbook. The types of gas turbines to be used for calculation of the CCPP heat balances and their performance data cited from the said Handbook are as shown below:

Model of Gas Turbine	GT26 (AQC)	PG9371(FA)	M701F4	SGT5-4000F
ISO base rating (MW)	288.3	255.6	312.1	286.6
Efficiency (%)	38.1	36.9	39.3	39.5
Pressure ratio	33.9	17.0	18.0	17.9
Air flow rate (kg/s)	648.6	640.9	702.6	689.4
Exhaust gas temp (^{O}C)	616.1	602.2	596.7	577.2
Fuel gas flow rate (kg/s)	15.40	14.09	16.16	14.76
Fuel gas flow rate (MMcf/hr)	2.78	2.55	2.92	2.67

Where, the net specific energy (lower heating value) of the natural gas is assumed to be 49,150 kJ/kg (979.2 kJ/cf at 60^{O}F) calculated from the averaged volume fraction of the natural gas of Bangladesh. The correction of the performance data of above gas turbines to the site, inlet and exhaust conditions is conducted in accordance with various correction factors based on our many experiences with them. The inlet and exhaust pressure loss changes for combined cycle configuration are also predicted. The site conditions are designated as tabulated below as per the site survey results:

Type of Site Condition	Rated	Max. Capacity
Dry Bulb Temperature (^{O}C)	35.0	10.0
Relative Humidity (%)	80.0	80.0
Wet Bulb Temperature (^{O}C)	31.8	8.3
Barometric Pressure (kPa)	101.3	101.3

The rated site conditions are specified in accordance with ones for the existing gas turbine power plants, while the maximum capacity site conditions are specified as the monthly averaged minimum ambient temperature and the relative humidity for the time.

The installation capacities of electrical and auxiliary equipments must be determined to cope with the gas turbine maximum capacity and the performances of the bottoming system (HRSG and steam turbine) dependable upon it. The gas turbine maximum capacity is widely changeable depending upon the site ambient conditions (especially ambient dry bulb temperature). To determine the installation capacities of electrical and auxiliary equipments, therefore, the site ambient conditions where the gas turbine maximum capacity is defined must be specified. The gas turbine maximum capacity is larger as the ambient dry bulb temperature is lower as long as it is within the design maximum allowable capacity. Depending upon the design philosophy of gas turbine manufacturer, the ambient dry bulb temperature where the design maximum allowable capacity is defined is normally less than minus 10^{O}C. Therefore, if the site ambient dry bulb lowest temperature is higher than minus 10^{O}C, the gas turbine operating power output at the said lowest temperature will be the gas turbine maximum capacity.

The mean value of monthly averaged site ambient dry bulb lowest temperature is plus 10^{O}C according to the recorded data for five (5) years during the year 2002 to 2007 at Ishdri in the northwest of Bheramara site. Therefore, the installation capacities of electrical and auxiliary equipment shall be determined to meet the operating performances of gas turbine and bottoming system at the ambient dry bulb temperature of 10^{O}C. The relative humidity for the ambient temperature is 80%.

To obtain the plant net power output, auxiliary power requirements including the step-up transformers under steady state conditions at 100% load of the plant must be predicted. For the purpose, auxiliary power requirements except for the fuel gas compressor drive power requirement are assumed at 2.0 % of the total gross power output. The fuel gas compressor drive power requirement is calculated for each model of gas turbine on the terminal fuel gas conditions of 1.0 MPa and 25^{o}C for the rated and 10^{O}C for the maximum capacity site conditions.

The environment impact assessment shall be conducted in accordance with the performance data at the maximum capacity conditions where the impact on environments is maximized.

The cycle configurations and parameters of the bottoming system may be variable depending upon manufacturers of combined cycle power plants. However, the following cycle configurations and parameters are preliminarily assumed for calculation of CCPP heat balances.

GT Inlet Air Cooling System	Not considered
Exhaust Gas Leakage	0.5%
Cycle Configuration	Triple-pressure, reheat
Cooling System	Mechanical draft cooling tower
Type of HRSG	Unfired type
Steam Conditions at Turbine Inlet for Site Rated Conditions	
HP Steam	
Temperature	560 (540) ^{O}C
Pressure	11.8 (9.81) MPa
IP Steam (Mixture of hot reheat and IP SH steams)	
Temperature	560 (540) ^{O}C
Pressure	2.94 (2.45) MPa
LP Steam	
Temperature	Mixed temperature of LP SH and IPT outlet steams
Pressure	0.34 (0.29) MPa
Condenser Vacuum	Depends on cooling tower characteristics.

Where, bracketed figures are used for Siemens SCC5-4000F 1×1 CCPP where the gas turbine exhaust gas temperature is lower compared to other plants.
The leakage of 0.5% of the exhaust gas flow rate from the gas turbine is considered for calculation of heat balance of the bottoming system.

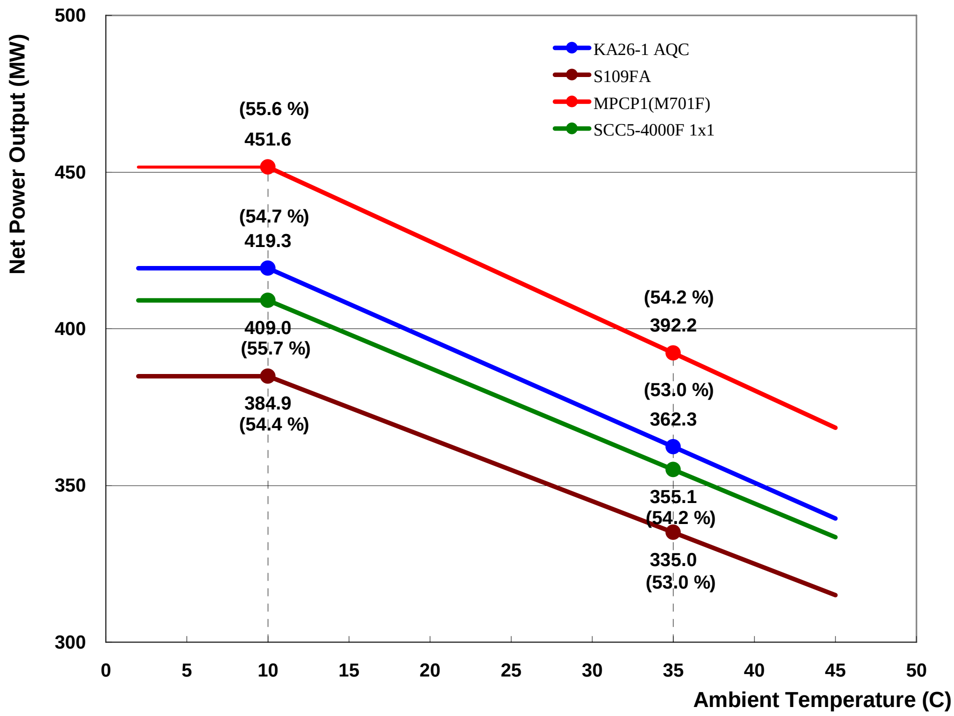
(4) Heat Balance Calculation Results under unfired conditions
Results of heat balance calculations for the said four (4) models of CCPPs under unfired conditions are summarized as tabulated below:

CCPP model	KA26-1 with AQC		S109FA		MPCP1 (M701F)		SCC5-4000F 1×1	
Site Condition	Rated	Max Cap	Rated	Max Cap	Rated	Max Cap	Rated	Max Cap
Plant Gross Power Output (MW)	374.7	433.5	344.9	396.3	403.9	465.0	365.6	421.1
Gas Turbine (MW)	245.5	288.7	221.8	260.8	270.5	318.1	244.1	287.0
Steam Turbine (MW)	129.2	144.8	123.1	135.5	133.4	146.9	121.5	134.1
Plant Gross Thermal Efficiency (%)	54.8	56.6	54.6	56.0	55.8	57.3	55.8	57.3
Auxiliary Power (MW)	12.4	14.2	9.9	11.4	11.6	13.4	10.5	12.1
Plant Net Power Output (MW)	362.3	419.3	335.0	384.9	392.2	451.6	355.1	409.0
Plant Net Thermal Efficiency (%)	53.0	54.7	53.0	54.4	54.2	55.6	54.2	55.7

As can be seen in the above table, the plant net power outputs of four (4) models of CCPPs are estimated to range from 335.0 MW to 392.3 MW at the rated site conditions under specified calculation conditions. The averaged net power output is calculated at 361 MW. Therefore, the nominal plant power output should be 360 MW. The requirement range of the plant net power output under unfired conditions to be prescribed in the tender documents should be “320 MW ~ 410 MW” in consideration of proper tolerance to expedite participation of many bidders in the bidding.
The plant net thermal efficiencies are predicted to range from 53.0% to 54.2% on the same conditions. Therefore, the requirement of the plant net thermal efficiency under unfired conditions to be prescribed in the tender documents should be “not less than 52.0%”.
The maximum net power outputs are estimated to be ranging from 396.3 MW to 465.0 MW. Any issues in Electrical network system in Bangladesh shall be analyzed against the power output of 500 MW in consideration of a certain margin.
The ambient temperature performance characteristics of four (4) models of CCPPs are shown in the next page. From this figure, it is found that each model of CCPP has the similar power output characteristics against the ambient temperature and that its plant net thermal efficiency is so close that it is within the range of ± 0.7%.
The following heat balance diagrams corresponding to the above calculation results are shown in the pages to be continued to this sub-section.

1) Heat Balance Diagram of KA26-1 with AQC at the rated site conditions
2) Heat Balance Diagram of KA26-1 with AQC at the maximum capacity site conditions
3) Heat Balance Diagram of S109FA at the rated site conditions
4) Heat Balance Diagram of S109FA at the maximum capacity site conditions
5) Heat Balance Diagram of MPCP1 (M701F) at the rated site conditions
6) Heat Balance Diagram of MPCP1 (M701F) at the maximum capacity site conditions
7) Heat Balance Diagram of SCC5-4000F 1×1 at the rated site conditions

8) Heat Balance Diagram of SCC5-4000F 1×1 at the maximum capacity site conditions



Ambient Temperature Performance Characteristics Curve

(5) Heat Balance Calculation Results under Duct-Fired Conditions

The duct-fired CCPP is a commonly employed system to augment the power output of the bottoming system of the CCPP. There are many experiences with this system which is a matured technology without any difficulties. The following table shows the sample of experiences of HRSGs with a duct firing system in Japan and outside countries of Japanese HRSG manufacturer.

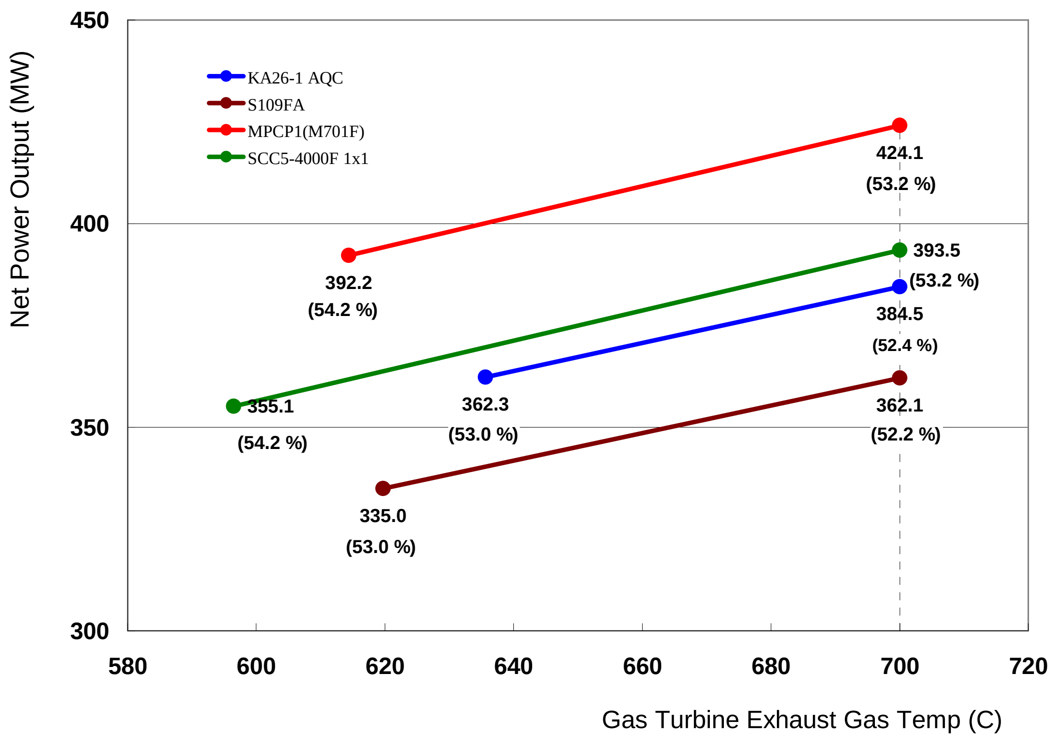
Range of GT Power Output (MW)	Units of HRSG
MW ≤ 50	18
50 < MW ≤ 200	5
200 < MW	5

In accordance with the present tariff systems of electricity and fuel tariffs of Bangladesh, even if the plant thermal efficiency and construction cost are sacrificed by the duct firing, it is envisaged that the plant shall be evaluated to be more economical because the economic effect due to the power output increase by means of the duct firing shall be sufficiently large to compensate the sacrifice of them. For study of the advantage of the duct firing, the performances of the four (4) models of CCPPs at the rated site were calculated under fired conditions up to 700^{O}C. The calculation results are as tabulated below:

Model of CCPP	Net Plant Output (kW)	Net Plant Efficiency (%)
KA26-1 with AQC	384,500	52.4
S109FA	362,100	52.2
MPCP1 (M701F)	424,100	53.2

SCC5-4000F 1×1 393,500 53.2

It is well known that the duct firing limit temperature without large design change of HRSG casing is generally said to be 750^{O}C. The above performance calculation was carried out for the firing temperature of 700^{O}C in consideration of proper tolerance. The next figure shows the relationship between the net power output and the duct firing temperature of four (4) CCPP models.



Relationship between Power Output and Duct Firing Temperature

(6) Performance and Economy Evaluation between Non-duct-firing and Duct-firing

1) Total Comparison

Comparison Item	Non-duct-firing	Duct-firing
Plant Net Thermal Efficiency (SCC5-4000F 1×1)	54.2 %	53.2%
Plant Net Power Output (SCC5-4000F 1×1)	355.1MW	393.5MW
Name of equipment to be additionally installed and their construction costs	-	Name of equipment Cost(1,000US$) A part of HRSG 2,900 A part of Steam turbine & acc. 11,100 A part of Electrical equipment 300 A part of Condenser/cooling system 1,000 A part of Fuel system 800 Duct-firing system 3,000 Total 19,100
Annual Revenue due to Sales of Incremental Electrical Power	-	6,932,000 US$

Comparison Item	Non-duct-firing	Duct-firing
Annual Cost due to Incremental Fuel Consumption	-	1,900,000 US$
Maintenance	-	The inlet temperature to HRSG is increased by duct-firing, while the temperature and pressure of the produced steam is not changed. The metal temperature of the heat transfer tubes of the HRSG is governed by the temperatures of fluids (steam, pressured water) inside the cubes. Therefore, the metal temperatures of cubes in case of duct-firing design remain unchanged compared with non-duct-firing.design. In turn, there is not any change for maintenance between non-duct-firing and duct-firing.

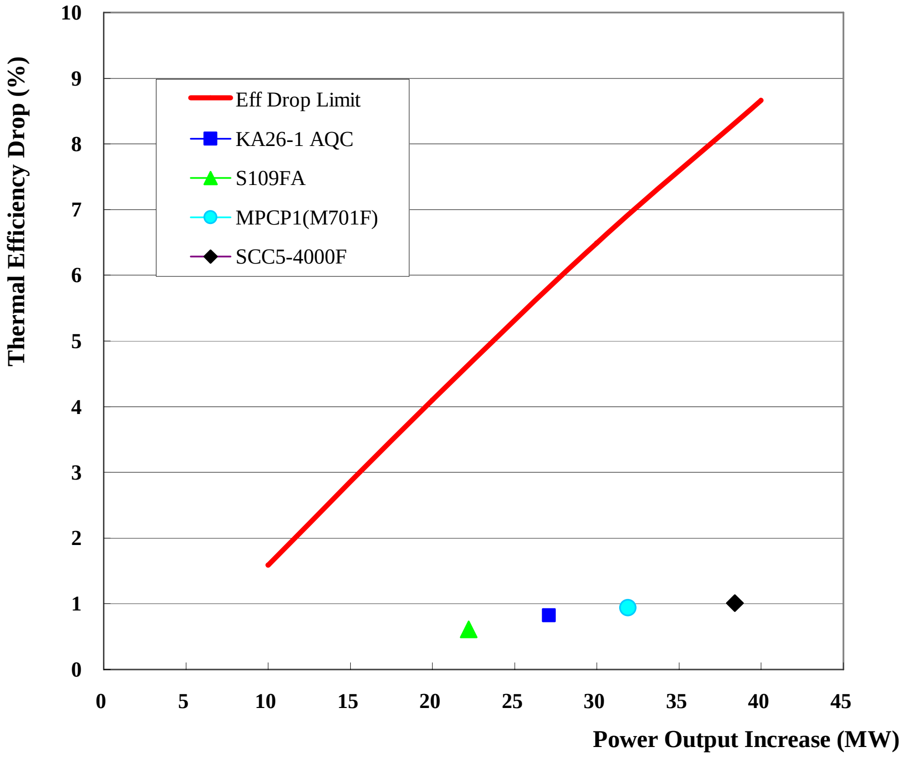
As shown in the above table, the additional cost due to installation of equipment for duct-firing could be paid back in about 4.3 years provided that additional costs such as for operation and maintenance are around 3 % of the additional installation costs for duct-firing. The construction cost for the incremental plant net power output is some 500 US$/kW.

2) Economical Evaluation

The following conditions are assumed for study of economical evaluation comparison between non-duct-firing and duct-firing:

Electricity tariff (Weighted mean value)	3.2 US cents/kWh
Fuel gas tariff	0.1 US cents/cf at 60 oF, 1 atm
Annual escalation rate (Electricity and fuel gas tariffs)	1.5%
Evaluation period	30 years
Construction period	3 years
Capacity factor	70% $\left(= \frac{APG}{8{,}760 \times RPO}\right)$
Transmission and distribution loss	8.0%
Discount ratio	10.0%
Construction cost increase	As per computer software

Where, APG and RPO denote Annual Power Generation (MWh) and Rated Power Output (MW) respectively.
The following curve (red solid line) shows the relationship between the plant net thermal efficiency drop limit and plant power output increase due to duct firing. If the calculated net thermal efficiency due to duct-firing is less than the thermal efficiency drop limit, the plant could be evaluated to be more economical by it. This relationship is obtained from the condition that the net present value for sales of increased power generation equals the net present value for cost of the increased fuel consumption plus the construction cost increase.



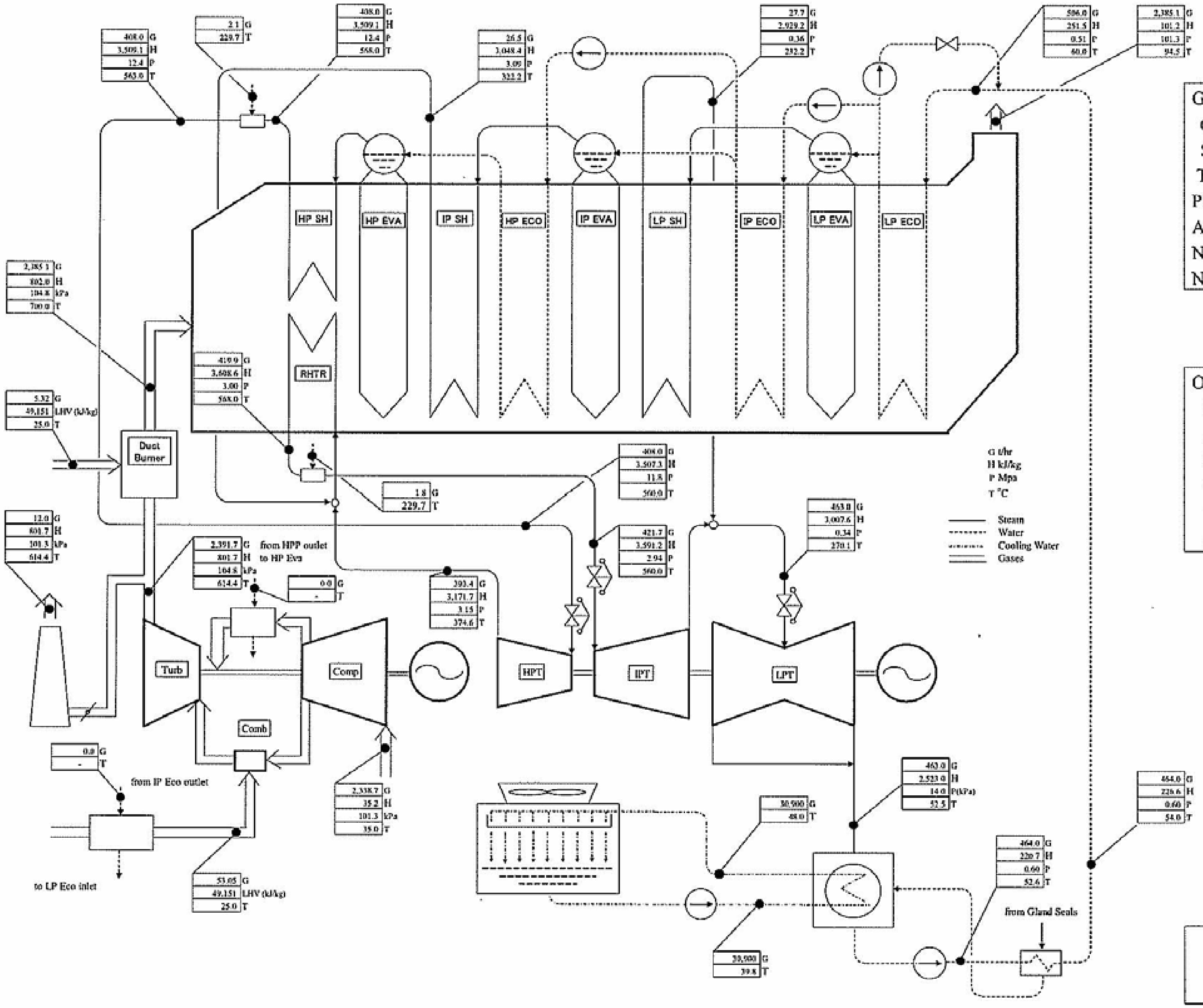
Relationship between Power Output Increase and Thermal Efficiency Drop Limit

The calculation results of four (4) models of CCPPs are shown with dotted points in this figure. It is clear that the duct firing is economically advantageous for every model of CCPP from the relationship between the thermal efficiency drop limit curve and calculated performances shown by dotted points.

From the study results described above, the CCPP with fired HRSG should be specified in the tender documents as an option of bidders. In such case, the requirement range of the plant net power output under fired conditions should be specified as “340 MW~450 MW” considering the proper tolerance to expedite participation of many bidders in the bidding.

The minimum value of the plant net thermal efficiency is calculated at 52.0% from the above calculation results. Therefore, the requirement of the plant net thermal efficiency under unfired conditions to be prescribed in the tender documents should be “not less than 51.0%”.

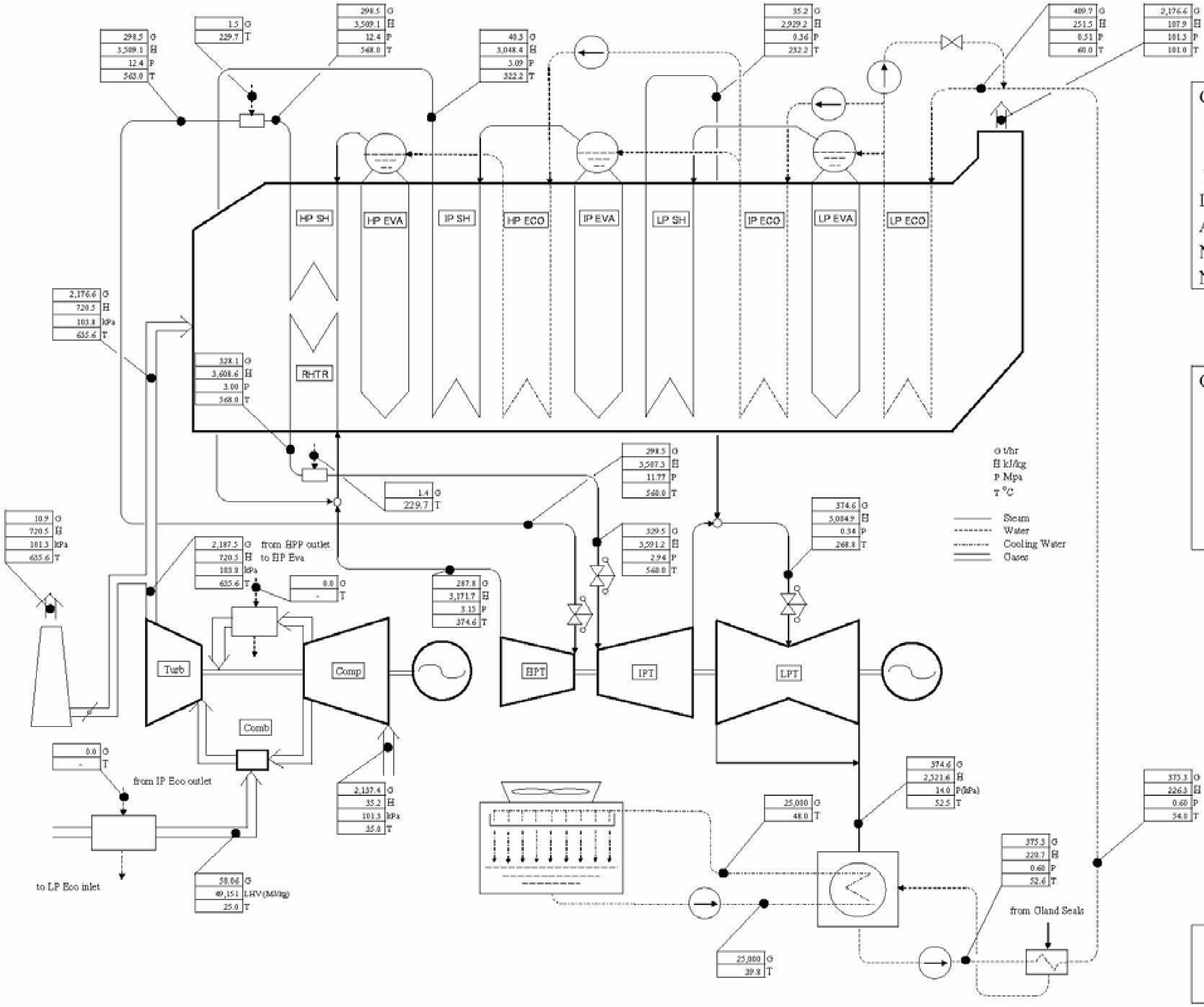
The heat balance diagram of MPCP1(M701F) at the rated site conditions under duct firing is attached after heat balance diagrams of four (4) models of CCPPs under no duct firing.



Gross Power Output		
Gas turbine	270,500	kW
Steam turbine	165,800	kW
Total	436,300	kW
Plant Gross Thermal Eff	54.8	%
Auxiliary Power	12,300	kW
Net Power Output	424,000	kW
Net Thermal Efficiency	53.2	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

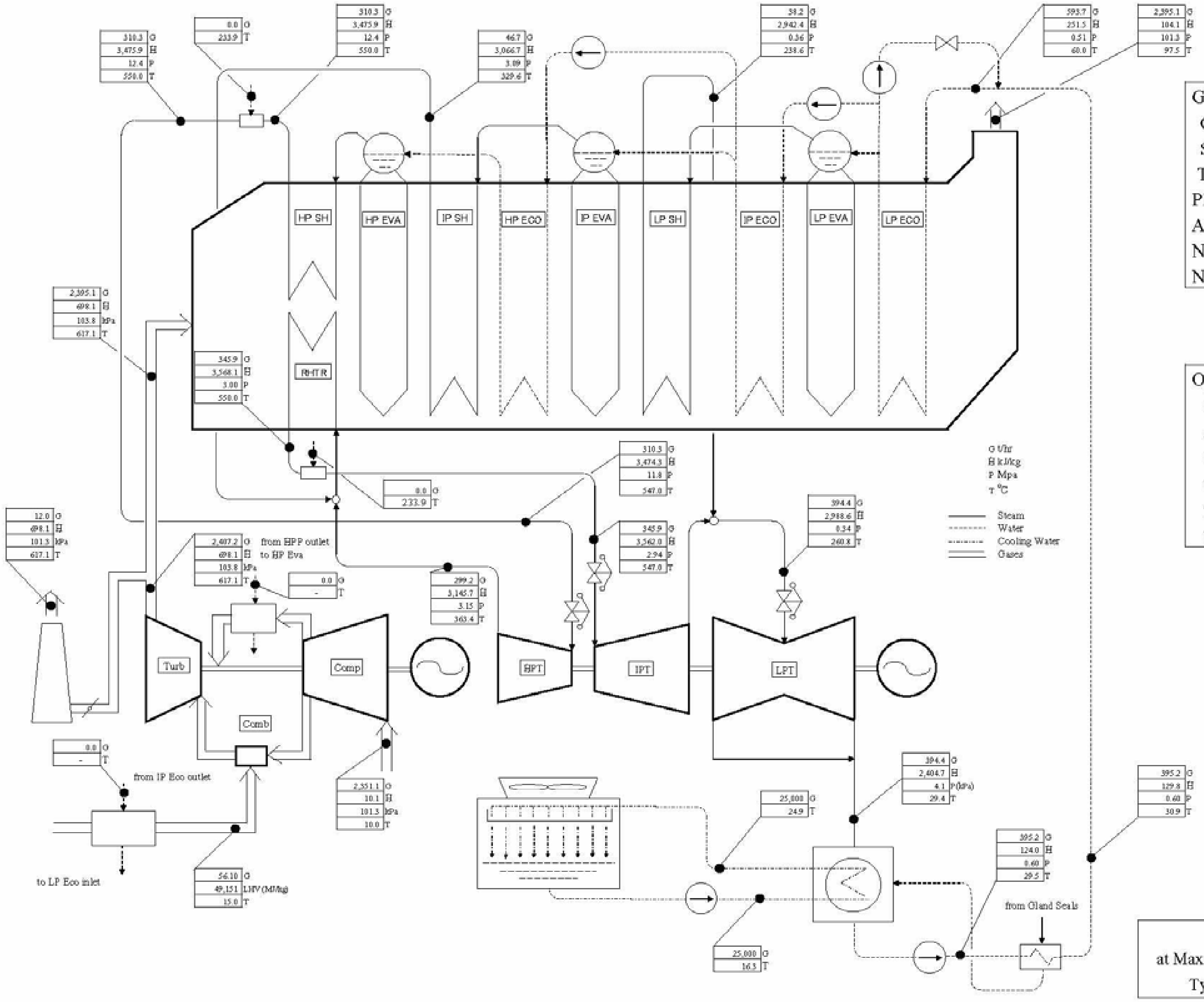
Heat Balance Diagram for Duct Firing
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4



Gross Power Output		
Gas turbine	245,500	kW
Steam turbine	129,200	kW
Total	374,700	kW
Plant Gross Thermal Eff	54.8	%
Auxiliary Power	12,400	kW
Net Power Output	362,300	kW
Net Thermal Efficiency	53.0	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

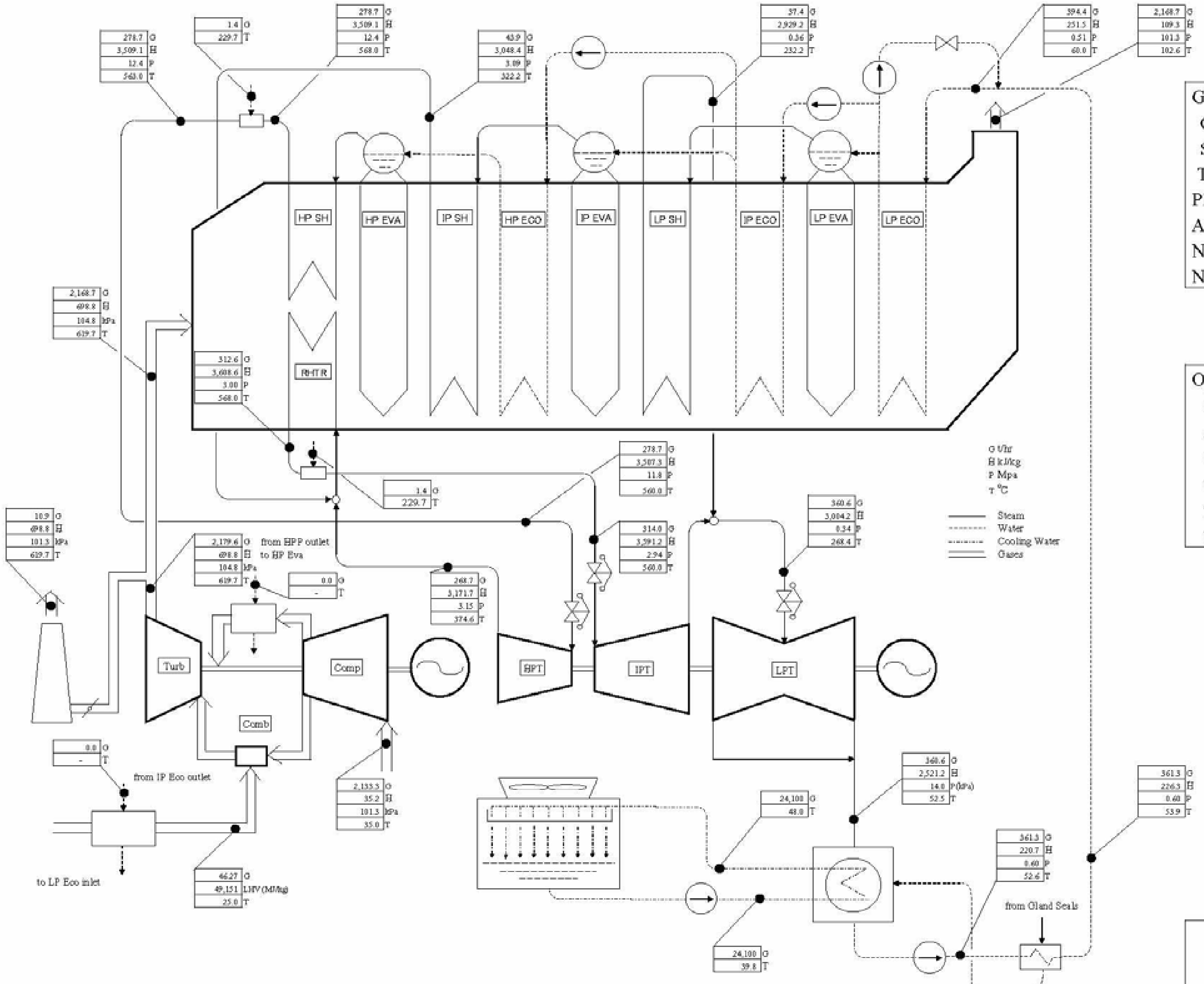
Heat Balance Diagram
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine ATM GT26 with AQC



Gross Power Output		
Gas turbine	288,700	kW
Steam turbine	144,800	kW
Total	433,500	kW
Plant Gross Thermal Eff	56.6	%
Auxiliary Power	14,200	kW
Net Power Output	419,300	kW
Net Thermal Efficiency	54.7	%

Operating Conditions		
Dry Bulb Temperature	10.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	8.3	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

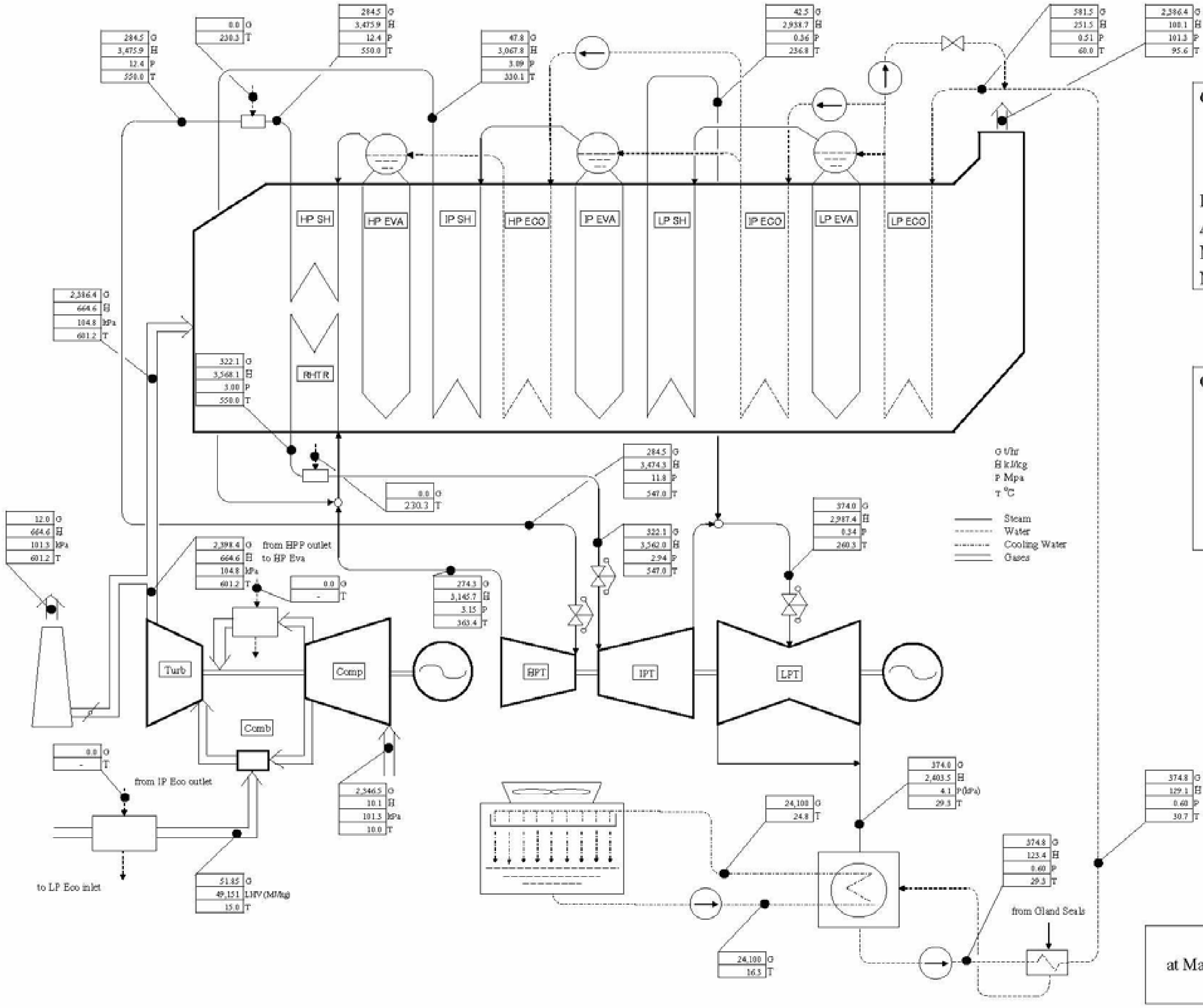
Heat Balance Diagram
at Max Capability Ambient Conditions on Natural Gas
Type of Gas Turbine ATM GT26 with AQC



Gross Power Output		
Gas turbine	221,800	kW
Steam turbine	123,100	kW
Total	344,900	kW
Plant Gross Thermal Eff	54.6	%
Auxiliary Power	9,900	kW
Net Power Output	335,000	kW
Net Thermal Efficiency	53.0	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

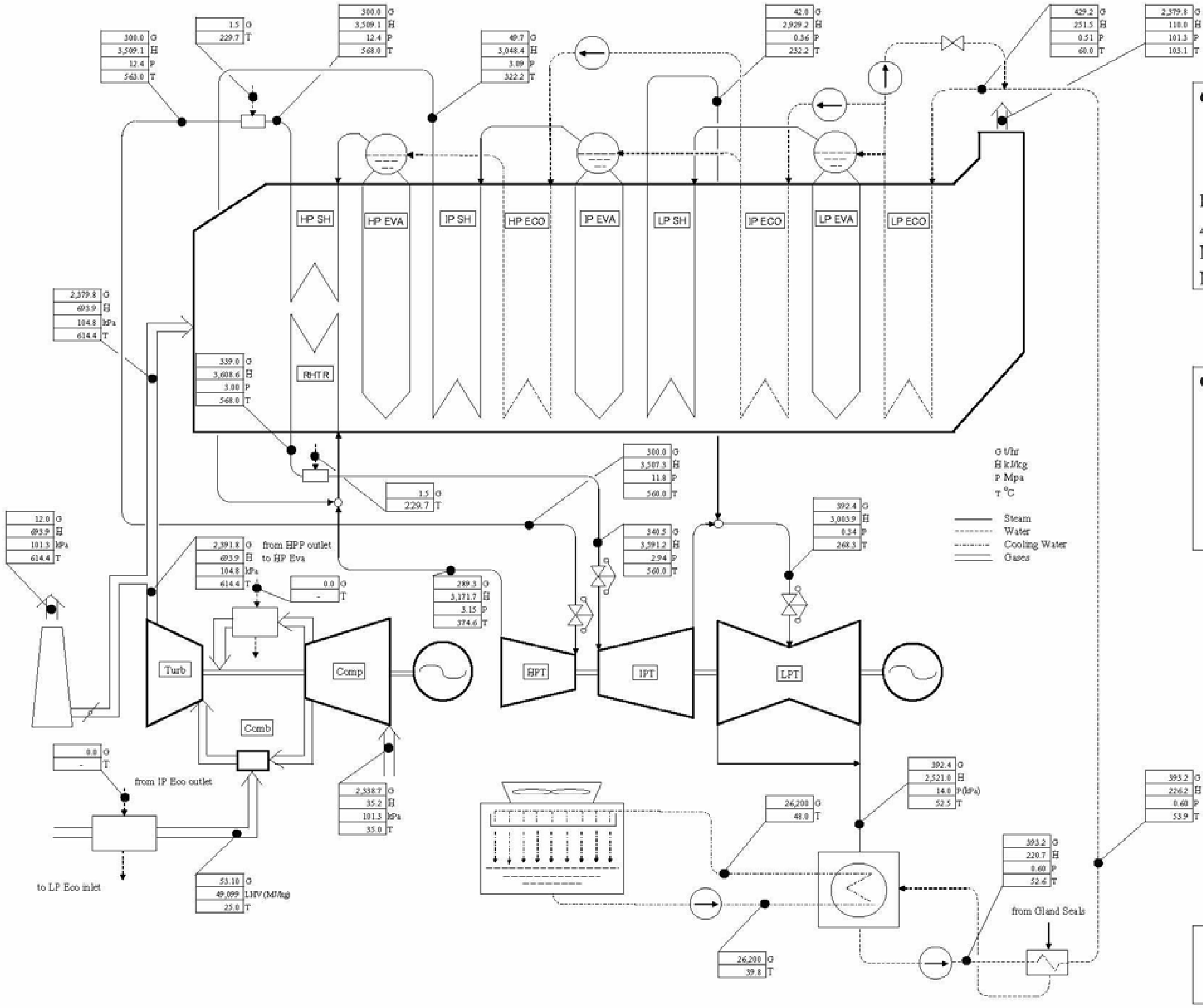
Heat Balance Diagram
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine GE PG9351(FA)



Gross Power Output		
Gas turbine	260,800	kW
Steam turbine	135,500	kW
Total	396,300	kW
Plant Gross Thermal Eff	56.0	%
Auxiliary Power	11,400	kW
Net Power Output	384,900	kW
Net Thermal Efficiency	54.4	%

Operating Conditions		
Dry Bulb Temperature	10.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	8.3	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

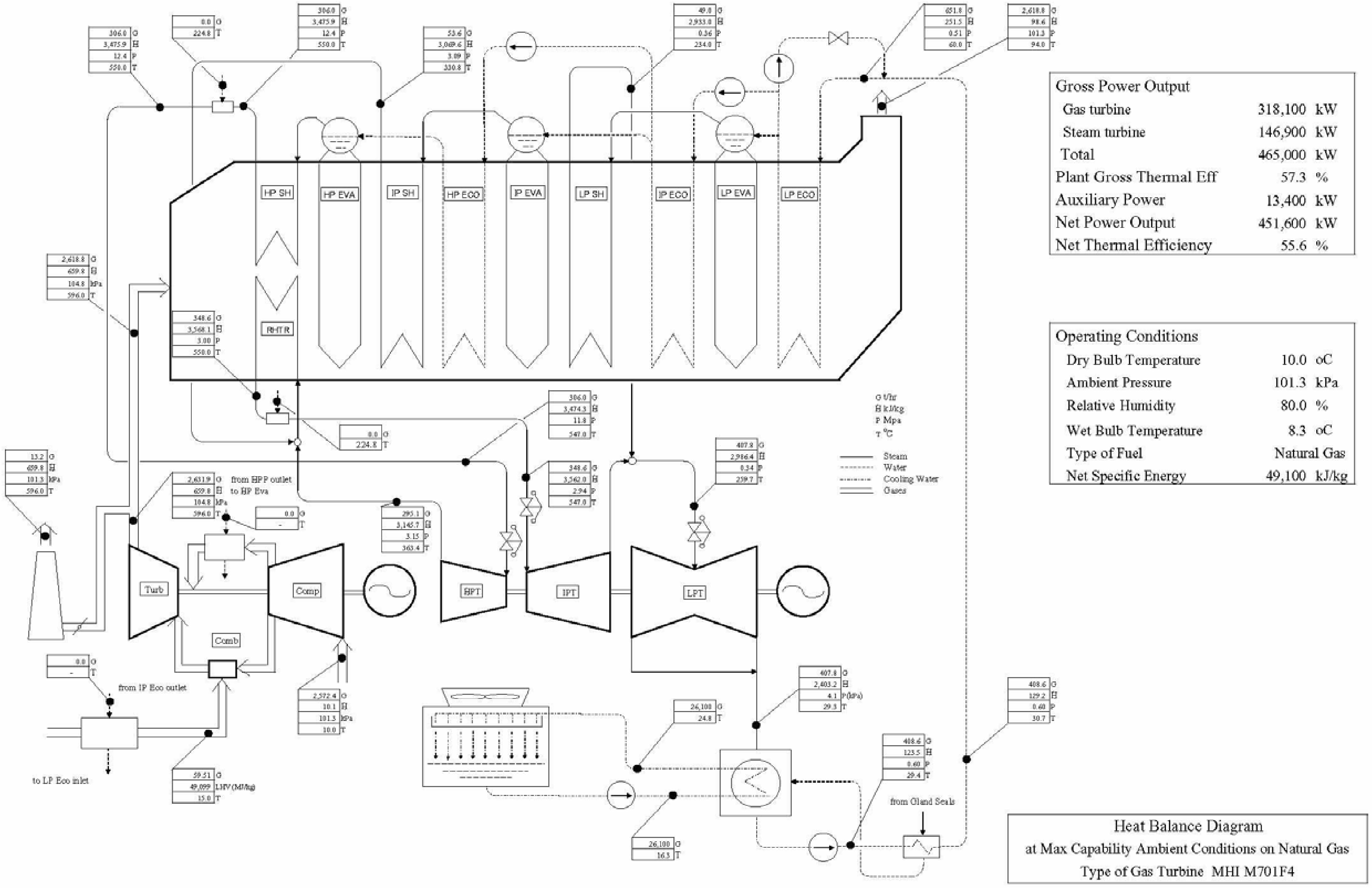
Heat Balance Diagram
at Max Capability Ambient Conditions on Natural Gas
Type of Gas Turbine GE PG9351(FA)

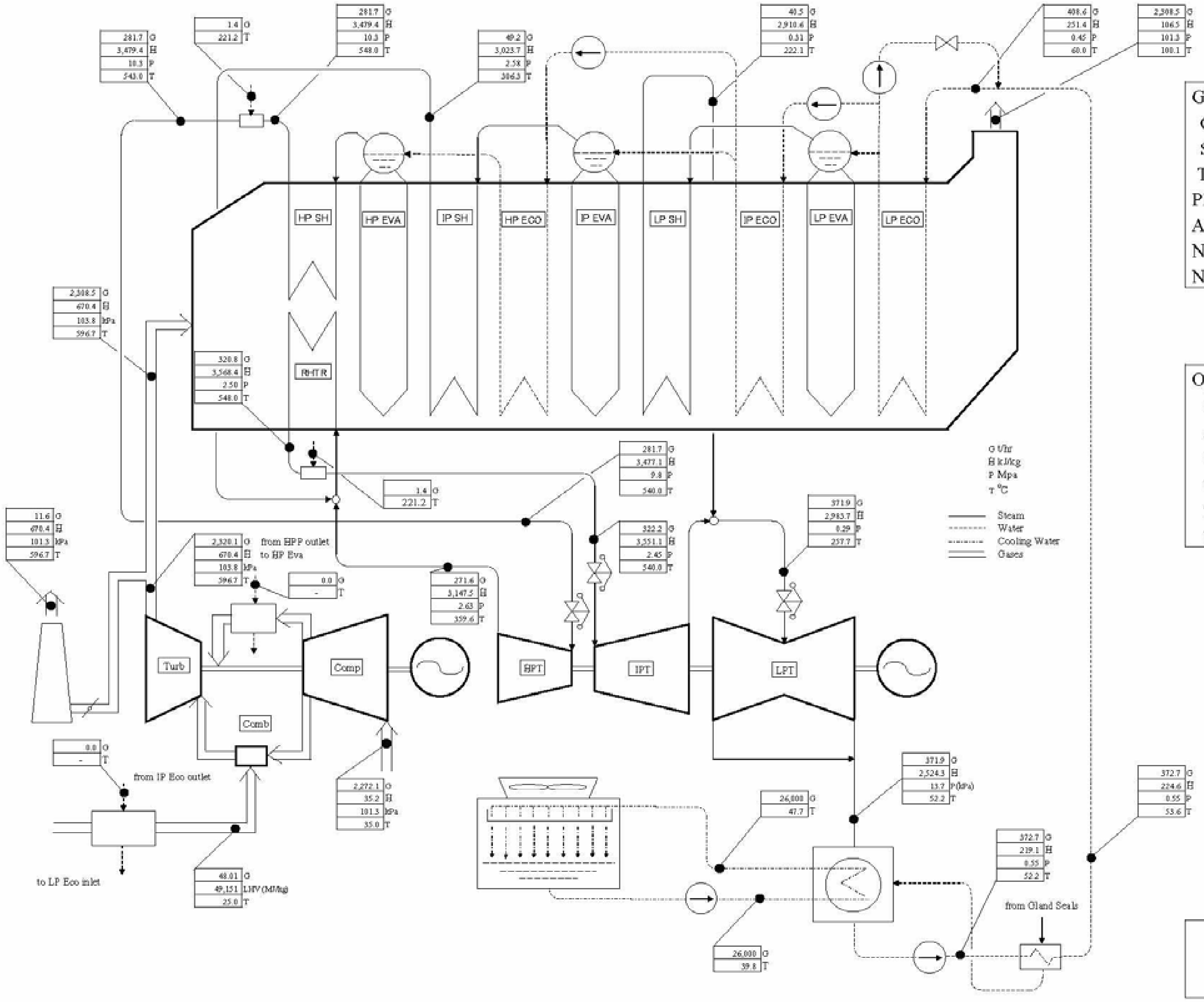


Gross Power Output		
Gas turbine	270,500	kW
Steam turbine	133,400	kW
Total	403,900	kW
Plant Gross Thermal Eff	55.8	%
Auxiliary Power	11,700	kW
Net Power Output	392,200	kW
Net Thermal Efficiency	54.2	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,100	kJ/kg

Heat Balance Diagram
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4

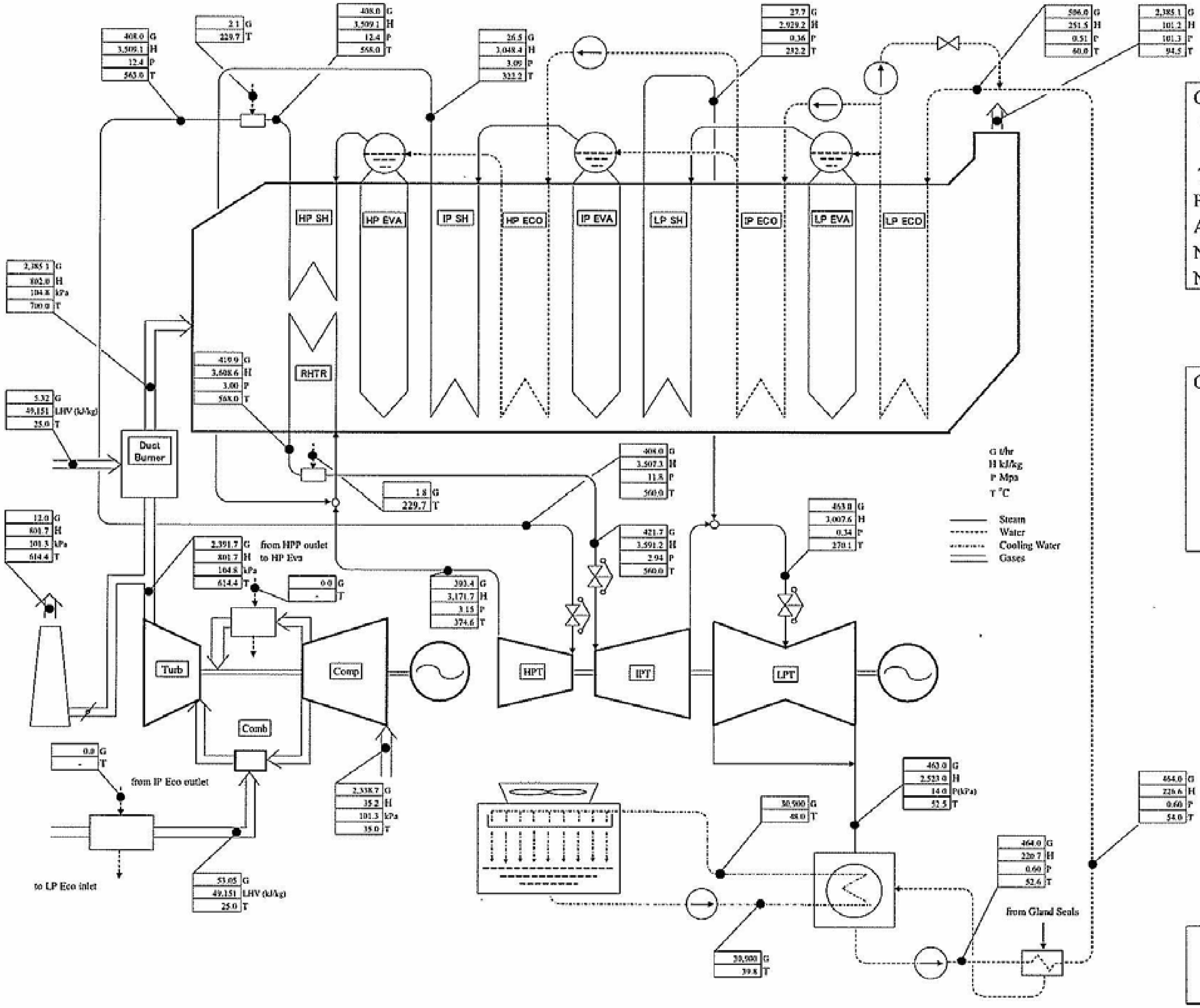

Gross Power Output
Gas turbine 318,100 kW
Steam turbine 146,900 kW
Total 465,000 kW
Plant Gross Thermal Eff 57.3 %
Auxiliary Power 13,400 kW
Net Power Output 451,600 kW
Net Thermal Efficiency 55.6 %
Operating Conditions
Dry Bulb Temperature 10.0 oC
Ambient Pressure 101.3 kPa
Relative Humidity 80.0 %
Wet Bulb Temperature 8.3 oC
Type of Fuel Natural Gas
Net Specific Energy 49,100 kJ/kg
HP SH
HP EVA
IP SH
HP ECO
IP EVA
LP SH
IP ECO
LP EVA
LP ECO
RHTR
Turb
Comp
Comb
HPT
IPT
LPT
from HPP outlet
to HP Eva
from IP Eco outlet
to LP Eco inlet
from Gland Seals
Steam
Water
Cooling Water
Gases
Heat Balance Diagram
at Max Capability Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4



Gross Power Output		
Gas turbine	244,100	kW
Steam turbine	121,500	kW
Total	365,600	kW
Plant Gross Thermal Eff	55.8	%
Auxiliary Power	10,500	kW
Net Power Output	355,100	kW
Net Thermal Efficiency	54.2	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

Heat Balance Diagram
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine SMS SGT5-4000F



Gross Power Output		
Gas turbine	270,500	kW
Steam turbine	165,800	kW
Total	436,300	kW
Plant Gross Thermal Eff	54.8	%
Auxiliary Power	12,300	kW
Net Power Output	424,000	kW
Net Thermal Efficiency	53.2	%

Operating Conditions		
Dry Bulb Temperature	35.0	oC
Ambient Pressure	101.3	kPa
Relative Humidity	80.0	%
Wet Bulb Temperature	31.8	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

Heat Balance Diagram for Duct Firing
at Rated Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4

5.3.2 Bottoming Cycle Optimization

(1) Study Content

The combined cycle plant is a combination of “Topping System” of a gas turbine with Brayton Cycle and “Bottoming System” of a boiler-steam turbine with Rankine Cycle. The performance and construction cost of the combined cycle plant is changeable due to how the bottoming system is designed for the given Topping System of the gas turbine. In general, the more complicated the cycle of the bottoming cycle is, the higher the performance and construction cost of the combined cycle plant is. In case of employment of the F class gas turbine, three (3) types of bottoming systems of triple pressure reheat and non-reheat, dual pressure non-reheat cycles will be considered.

In this study, the performance and construction cost are estimated for the three (3) types of combined cycle power plants. The difference of performances of each types combined cycle power plants is equal to the difference of electric power outputs because the performances are calculated for the condition of the same heat input. The difference of electric power output leads to the difference of the power sales amount through out the plant service life. On the other hand, the construction cost of the triple pressure reheat type plant that is more complicated is higher than the triple pressure and dual pressure non-reheat type plant. Therefore, the evaluation could be conducted by comparison between differences of the construction cost and present value of electric power sales amount through out the service life.

(2) Conditions for Comparison

1) Performance Conditions

Type of Gas Turbine	Siemens SCC5-4000F
Duct Firing at Post Gas Turbine	None
Ambient temperature	35^{o}C
Site elevation above sea	+14 m
Atmospheric pressure	0.1013MPa
Cooling water temperature at the inlet of condenser	26.7^{O}C
Fuel	
Type	Natural gas
Lower calorific value	50,011 kJ/kg

2) Economic Conditions

Service life	30 years
Plant factor	70%
Annual service hours	6,132 hours
Load factor	100%
Power sales price at the first years	2.19 Taka (3.2 US cents)/kWh
Escalation of power sales price	6.12% (average CPI in last 5 years)
Discount rate	8%
Exchange rate	68.52 Taka/$

(3) Performance Calculation results

Performances of each type of plants with triple pressure reheat and non-reheat, dual pressure non-reheat are as shown below:

	Triple pressure Reheat	Triple pressure Non-reheat	Dual pressure Non-reheat
Gas turbine gross power output (MW)	244.1	244.1	244.1
Steam turbine gross power output (MW)	121.5	116.3	114.3
Total gross power output (MW)	365.6	360.4	358.4
Plant gross thermal efficiency (%)	55.8	55.0	54.7

As can be seen from the performance calculation results, the total gross electric power output of the triple pressure reheat type power plant is higher by 5,200 kW and 7,200 kW respectively than that of the triple pressure non-reheat type and dual pressure non-reheat power plant for same fuel input. In other words, the former plant produces the electric power more than by 31.9 million kWh and 44.2 million kWh respectively than the latter plants.

(4) Deference of present value of power sales

The present value of the difference of annual power sales through the service life of 30 years can be calculated as follows using the conditions as described above:

Present value

Triple pressure Non-reheat type power plant:

$= (1+6.12/100)\times((1+8/100)^{30}-(1+6.12/100)^{30})/(8/100-6.12/100)/(1+8/100)^{30}\times 31.9\times 106\times 2.19/68.52$ = 23.6 million US$

Dual pressure Non-reheat type power plant:

$= (1+6.12/100)\times((1+8/100)^{30}-(1+6.12/100)^{30})/(8/100-6.12/100)/(1+8/100)^{30}\times 44.2\times 106\times 2.19/68.52$ = 32.7 million US$

(5) Deference of construction cost

Construction costs of each type of plants are estimated with computer software and are tabulated in Table I-5-3-1.

As can be seen from this table, the difference of construction costs compared with triple pressure reheat type power plant are minus 11.0 million US$ and minus 16.5 million UD$ respectively.

Table I-5-3-1 Comparison of Computer Estimated Construction Cost

Unit 1,000 US$

Name of Components	Triple pressure RH	Triple pressure NRH	Dual pressure NRH
1. Power Plant Installation & Related Works			
FOB Price of Imported Equipment			
a) Gas Turbine & Accessories	84,865	84,865	84,865
b) HRSG & Accessories	36,419	34,952	34,242
c) Steam Turbine & Accessories	42,216	40,515	39,692
d) Balance of Plant	66,958	64,261	62,957
e) Electrical Systems & Instrumentation and Control	45,750	43,906	43,015
(2) Marine, Flight and Insurance	7,312	7,018	6,876
(3) Inland Transportation and Insurance	3,659	3,511	3,440
(4) Construction, Election, Commissioning and Insurance	73,093	70,148	68,724

Name of Components	Triple pressure RH	Triple pressure NRH	Dual pressure NRH
2.Total Construction Cost without Substation,Transmission Line, Tax and Contingency	360,272	349,176	343,811
Difference of Construction Cost for Triple pressure RH type	0	11,095	16,461

(6) Conclusion

As can be seen from the above calculation results, the difference of present values of power sales between each type of plants through the service life is far larger than that of construction. This means that the reheat type plant is economically more advantageous than the non-reheat type plant. Therefore, it is definitely considered that the reheat type plant is recommendable as the combined cycle power plant for this project. The basic design and tender documents will be prepared on the condition that the reheat type plant will be employed for this project.

Under such situation, local gas price will be also raised to significant degree in near future. Therefore in economical point of view, higher efficiency is better solution against future gas price increase and thus we recommend F class CCPP with triple pressure reheat type for the Bheramara CCPP.

In case of adopting triple pressure reheat type with duct burner system, duct burner outlet flue gas temperature shall be designed with less than 700^{O}C to apply high temperature materials within reasonable equipment investment.

5.3.3 Exhaust Gas Bypass System

In case of a multi-shaft CCPP, the exhaust gas bypass system is usually equipped for a simple cycle operation due to any reasons which may happen to the bottoming system. In case of a single-shaft CCPP, this system may be equipped for the CCPP with an engagement/ disengagement clutch. This system will be also required when the gas turbine power package of topping system must be put into commercial operation in advance separately from the bottoming system due to any impending power demand. For the purpose, a bypass stack and a damper must be equipped in the high temperature gas stream between the gas turbine exhaust system and the heat recovery steam generator. This system must be of a huge shape of mechanical equipment to cope with the high temperature around 650^{O}C. Therefore, the system has an advantage to be contributable to the flexible operation, while the plant cost is higher and the operational reliability may be lessened. Besides, the performance loss may happen due to a leakage of gas turbine exhaust gas to atmosphere. Such issues are studied in the page to be continued.

(1) Operational Flexibility

The operational flexibility of the CCPP is changed depending upon existence or non-existence of the exhaust gas bypass system. In case of existence of the system, the plant can be transferred to the simple cycle operation without power failure when any troubles happen to the bottoming system. Otherwise, the plant shall be stopped depending upon the type of trouble of the bottoming system. For example, in case of occurrence of the trouble with the steam turbine section only, the plant can continue the operation in a simple cycle mode as all the generated steams are damped into the condenser through steam turbine bypass lines. But, such operation may be confined to the limited hours because it is not deemed to be of normal operation. As stated above, the operational flexibility of the plant shall be limited without the exhaust gas bypass system.

There are no differences between the plants with and without system as far as a start-up capability of the plant is concerned.

(2) Operational Reliability

Diverter or flap type damper is normally utilized for gas turbine applications with heat recovery steam generators. The size of the damper which will be used for the F-class gas turbine is as huge as approximately 7 m by 7 m. Besides, the temperature of the exhaust gas to which the damper is exposed is as high as 650^{O}C. The damper shall be designed to stably, smoothly and quickly operate and to keep the minimized gas leakage loss over the lifetime of the plant. It seems to be significantly difficult to design the damper in operation of such severe conditions so that it can fully meet such contradictory requirements. Because the huge metal constructed damper which will be exposed to the high temperature atmosphere can not keep the originally dimensioned shape over the lifetime of the plant. The specific figures on the operational reliability of the exhaust gas bypass system by users of the plants are not available. However, the drop of the plant operational reliability due to employment of the system could be inevitable. The operational reliability of the exhaust gas bypass system is mentioned in the section 4.7.3 [Study on Shaft Arrangement] in connection of the type of shaft arrangement.

(3) Cost Impact

By employment of the exhaust gas bypass system, the following equipment and works are additionally required:

- a bypass stack (7.5 m summit diameter, 45 m height) with a silencer (depending upon environment protection requirement)
- a diverter damper
- a guillotine damper (for maintenance of the bottoming system during the simple cycle operation)
- longer transition gas duct and expansion joints
- related site assembly, erection and civil works
- other related costs such as shipping, management and commissioning

The total cost impact for above items is roughly estimated at 6.4 MUS$.

(4) Phased Construction

The phased construction of the topping and bottoming systems could be expected by employment of the exhaust gas bypass system. This type of construction will be usually adopted when the earlier power supply requirement is a must due to unexpectedly steep increase of the power demand. The completion schedule of the phased construction plant is longer than the single phase construction plant, while the commercial operation of the gas turbine/generator package will start earlier by approximately six (6) months. This advantage shall be evaluated by the plant purchaser depending upon the extent of the early necessity of power supply.

(5) Performance

The excess exhaust pressure loss happens due to installation of the bypass system between GT exhaust and the heat recovery steam generator. Besides, some amount of exhaust gas will leak to atmosphere through the bypass damper, which results in power loss of the steam turbine. Consequentially, both the plant power output and efficiency will lower than the plant without the bypass system. Depending upon the type, size and system design of the damper, the steam turbine power output drop is reportedly approximately 0.5 – 1.5% as an average value over the lifetime of the plant. It means that the plant efficiency drops by 0.17 – 0.5%.

(6) Other Points of Views

More spacious footprint area is required for installation of the bypass system. In case of F-class gas turbine, it amounts to some 15 m length.

In case of no silencer in the bypass stack, the noise from the stack is much concerned even if the bypass operation will be limited to short time.

In case of installation of the silencer, steady and proper function over the plant lifetime of the silencer which is exposed to the high temperature and high velocity of gas is concerned.

Additional deliberate and daily maintenance works shall be required to keep the exhaust gas bypass system in a good condition so that it can be surely used whenever it is needed.

(7) Experience with Combined Cycle Power Plants with Bypass System

The following table shows the sample of reference combined cycle power plants of which gas turbines are of comparably larger size (more than 100MW).

No.	Year	Project	Model of CCPP	No. of Unit	Type of Damper
1	2008	El Atf	MPCP2(701F)	1	Diverter
2	2008	Sidi Krir	MPCP2(701F)	1	Diverter
3	2008	Emal	S209FA	2	Diverter
4	2008	Marafiq	S109FA	1	Diverter
5	2008	Muara Karang	MPCP2(701F)	1	Diverter
6	2007	Nubaria	S109FA	1	Diverter
7	2007	El Kureimat	S109FA	1	Diverter
8	2006	Aguirre	S309E	3	Diverter
9	2006	Chiyoda II	S209E	2	Diverter
10	2006	Chiyoda II	S209E	2	Guillotine
11	2006	ESSAR	S109E	1	Diverter
12	2005	Chiyoda I	S209E	2	Diverter
13	2005	Chiyoda I	S209E	2	Guillotine
14	2005	Cilegon	MPCP2(701F)	1	Diverter
15	2005	ESSAR	S109E	1	Diverter
16	2004	ESSAR	S109E	1	Diverter
17	2004	CEPC	MPCP2(701F)	1	Diverter
18	2004	TNB	MPCP2(701F)	1	Diverter
19	2001	Haripur	MPCP1(701F)	1	Diverter
20	2001	Phu My I	MPCP3(701F)	1	Diverter

As shown above, there are many experiences with combined cycle power plants with an exhaust gas bypass system worldwide. It is shown by this table that the exhaust gas bypass system is a technically matured one.

(8) Study Summary

As stated above, it goes without saying that the operational flexibility of the plant will be enhanced due to employment of the exhaust gas bypass system, while the drop of the operational reliability and the burden of the project cost will not be avoided. However, considering the backgrounds and location where this project is placed, the exhaust gas bypass system will be recommended all together the employment of the multi-shaft type CCPP.

5.3.4 Auxiliary Boiler

(1) Necessity

In case of multi-shaft CCPP without a standalone auxiliary boiler, the gas turbine can be started up together with the HRSG separately from the steam turbine/generator. After a certain period of the time the necessary steam for start-up can be available from the own HRSG and then the steam turbine/generator can be started up with own steam but the HRSG will be started up with higher oxygen concentration in the HRSG inlet feed water than normal operating condition because of starting up without gland sealing of steam turbine.

In case of multi-shaft CCPP with a standalone auxiliary boiler, gland sealing of steam turbine can be supplied from external sources before the gas turbine and HRSG were operated. As the necessary steam for start-up can be available from external sources, the steam turbine/generator can be started up without any loss of time and the HRSG can be started up within permissible oxygen concentration in the HRSG inlet feed water by gland sealing of steam turbine.

When a standalone auxiliary boiler will be applied to this project, then the tender shall recommend the specification for a standalone auxiliary boiler.

(2) Requirement Study

HRSG and Auxiliary Equipment shall be designed to be able to start up in the shortest time in the both case of open cycle circuit mode (the diverter damper is bypass stack open position) and combined cycle circuit mode (the diverter damper is bypass stack close opposition).

If a standalone auxiliary boiler shall not be applied to this project, the tender shall clarify the start up procedure without a standalone auxiliary boiler and start up time schedule, operating and permissible oxygen concentration in the HRSG inlet feed water during start up.

5.4 Scope of Works

5.4.1 Procurement and/or Manufacture

The Contractor will procure and/or manufacture the following facilities, but not limited to them, including expediting and quality inspection, for all equipment, materials for a complete and operational combined cycle power plant.

(1) Gas turbine, steam turbine, generators and auxiliaries
(2) Heat recovery steam generator (HRSG) and auxiliaries
(3) Gas turbine and steam turbine building including structural steel, siding, roofing, windows, doors and louvers
(4) Other buildings and houses for supplied equipment
(5) Administration building
(6) Camp
(7) Main stack
(8) Fuel gas supply system
(9) Waste water treatment system
(10) Fire protection system
(11) Drain recovery system
(12) Cathodic protection system
(13) Cooling tower system
(14) Closed cooling water system for cooling of lubricating oil and other cooling media
(15) Ventilation and air conditioning
(16) Site and building lighting

(17) Yard utility trenches/covers
(18) Roads within the new plant site
(19) Site drainage/Site sanitary
(20) Piling (if necessary) and foundations for equipment
(21) All civil works including foundations for supplied equipment and buildings and houses.
(22) Preparation, excavation and leveling works of site area including temporary storage area during construction and preparation of access road for carrying-in of heavy components.
(23) Fencing around the new plant Site, access road to equipment and drainages inside the new plant Site.
(24) Plumbing (toilets and showers)
(25) Gas supply piping (between CGS and gas compressor)
(26) Fuel gas compressors
(27) Fuel gas pre-treatment system
(28) Indirect type fuel gas heater (if necessary)
(29) Fuel oil tank
(30) Generator step-up transformers
(31) Unit and start-up transformers
(32) Electrical equipment and materials
(33) Emergency diesel generator
(34) Control and instrumentation equipment and materials
(35) PI system
(36) Simulator
(37) Service and instrument air supply system
(38) Continuous emission monitoring system
(39) 230kV Substation
(40) 132kV Substation
(41) Architectural materials
(42) Finish painting of equipment and materials
(43) Fire pump house including structural steel, masonry block walls, roofing, doors and louvers
(44) Temporary works and facilities for construction
(45) Spare parts for one major overhaul
(46) Standard and special tools
(47) Necessary temporary facilities on the downstream side from the connection points of utilities such as electric power, water and the like necessary for construction.

5.4.2 Works and Services to be provided by Contractor

The works and services to be provided by the Contractor will include furnishing a complete power plant of existing infrastructures of Bheramara CCPP to be used for the new power plant, including design, equipment, materials, transportation, erection, construction, and services as specified herein. Whenever the terms "provide", "furnish", "supply", "furnish and/or install", etc., are used, it is intended that the Contractor shall install the equipment and systems unless specific notation is made that the equipment, device, or system is to be installed by others.

The Works shall include all temporary and permanent works in place from initial site preparation to start-up and testing as required for a complete operable plant, including electrical power for construction activities.

The Services will include Contractor's and Vendors' services of technical instruction as required for placing the new plant into successful operation, and for training of the operation and maintenance personnel of the new plant.

The Contractor will coordinate checkout, start-up and perform initial operation of plant equipment and systems in coordination with plant operation staff. The new plant operating staff

of NWPGCL will be supervised by the Contractor. The Contractor shall work with NWPGCL to develop a plan for smooth transition from construction and start-up of the new plant.
Where required, the scope of additional works and services will be agreed during Contract signing.

(1) Engineering Services
1) Civil and Structural Systems
2) Architectural Systems
3) Mechanical Systems
4) Chemical Systems
5) Electrical Systems
6) Control and Instrumentation
7) Switchyard Systems
8) Fault and Load Flow Study for Electrical Systems

(2) Documents and Drawings
The new plant will be complete with all components specified herein, and the Works as required by Tender Documents, including, but not limited to preparation of the following design documents: Asterisk (*) denotes minimum submittal to the NWPGCL for approval. All other documents/drawings shall be submitted to the NWPGCL for information at the time of submission. The Contractor shall submit the list of documents and drawings with a classification of approval or information within 30 days from the notice to proceed.

*(1) Design Criteria Document for Systems and Facilities
*(2) Site Plot Plan
*(3) General Layout of Equipment at each Floor Level
*(4) Heat Balance Diagrams
*(5) Single Line Diagram
*(6) System Piping & Instrument Diagrams
*(7) Plane and Side Views Drawings of Building
*(8) Overall Plant Control Block Diagram
*(9) Bid Specifications
- Gas Turbine
- Steam Turbine
- Heat Recovery Steam Generator (HRSG)
- Circulating Water System
- Condenser
- Feed Water Pumps, Condensate Pumps
- Generator with exciter system
- Transformers (generator step-up, unit, start-up)
- MV Metal Clad Switchgear
- DCS with data logging system
(10) Concrete Foundation and Structures Drawings
(11) Procurement Specifications of Main Equipment
(12) Design Studies and Evaluations
(13) Detailed Design Drawings
(14) Logic Diagrams
(15) Schematic Diagrams
(16) Wiring Diagrams
(17) System Descriptions
*(18) Test and Inspection Schedules

*(19) Performance Test Procedures
*(20) Commissioning Procedures
*(21) Test and Inspection Reports
*(22) Performance Test Reports
*(23) Operation Manuals
*(24) Maintenance Manuals
(25) Equipment Instruction Books including Catalogues
(26) Erection Procedures
(27) As Built Drawings

(3) Construction and Start-up/Commissioning Services

The Contractor will provide the following services, but not limited to them, for the construction and start-up/commissioning of the new plant.

1) Construction management
2) Scheduling of construction
3) Construction labors, supervision, and tools
4) Construction equipment
5) Safety and loss control program
6) Quality assurance program
7) Procurement expediting
8) Equipment and materials receiving (including custom clearance), handling and storage
9) Preoperational checkout, testing, start-up and commissioning
10) To provide the lubricating oils, chemicals required for water treatment and miscellaneous chemical analyses consumables for start-up, testing, and initial operation.
11) To provide the lubricating oil for flushing of the lubricating oil system and any lubricants for initial fill-up.
12) Performance and reliability testing
13) Factory and on-site training of the NWPGCL operation and maintenance personnel
14) Six (6) months operation and maintenance support supervision by three (3) resident engineers (mechanical, electrical and I&C) after Provisional Acceptance
15) Construction closeout and site finishing
16) Construction of storage area
17) First aid and security (during construction)
18) Participate in coordination conferences and other meetings as the BPDB may request
19) Accommodation fees, daily allowance and traveling and transportation fees for witness of inspection and test at factories of equipment.
20) To acquire and secure all required local, state, and government permits (construction permits, etc.) for constructing the new plant

(4) Design Meetings

At least three (3) times of design meetings will be held at the office rooms of NWPGCL during implementation of the Project to ensure the completeness of the design of the new plant. These meetings will be also conducted to efficiently and effectively concentrate upon the finalization activities of documents and drawings to be submitted for approval by the Contractor.

The duration of each design meeting shall be within four (4) weeks. The meeting will be conducted separated into at least four (4) sessions of civil and architectural, mechanical, electrical, and I&C fields. The times of the meetings will be so scheduled that the meetings will be the most effective for efficient promotion of the Project on mutual agreement of NWPGCL and the Contractor.

All documents and drawings to be discussed at the coming design meeting have been in hand of NWPGCL by the time before one (1) month of the meeting.
The Contractor will bear all costs required to participate in these meetings.
The Contractor will submit the design meeting program including the list of names and expertise of participants, the list of items to be discussed, the detailed time schedule, the list of documents and drawings and any requirements to be prepared by NWPGCL within one (1) month from the Commencement Date for approval of NWPGCL / Consultant. The Contractor shall arrange at his cost the interpreters who he thinks are necessary on his side for the meetings.
NWPGCL has the right with that Bheramara CCPP could change and/or improve and/or rectify the designs of the Contractor at the design meetings if such things are beneficial to NWPGCL. The price adjustment of the Contract as per them will be reasonably made as per mutual agreement.

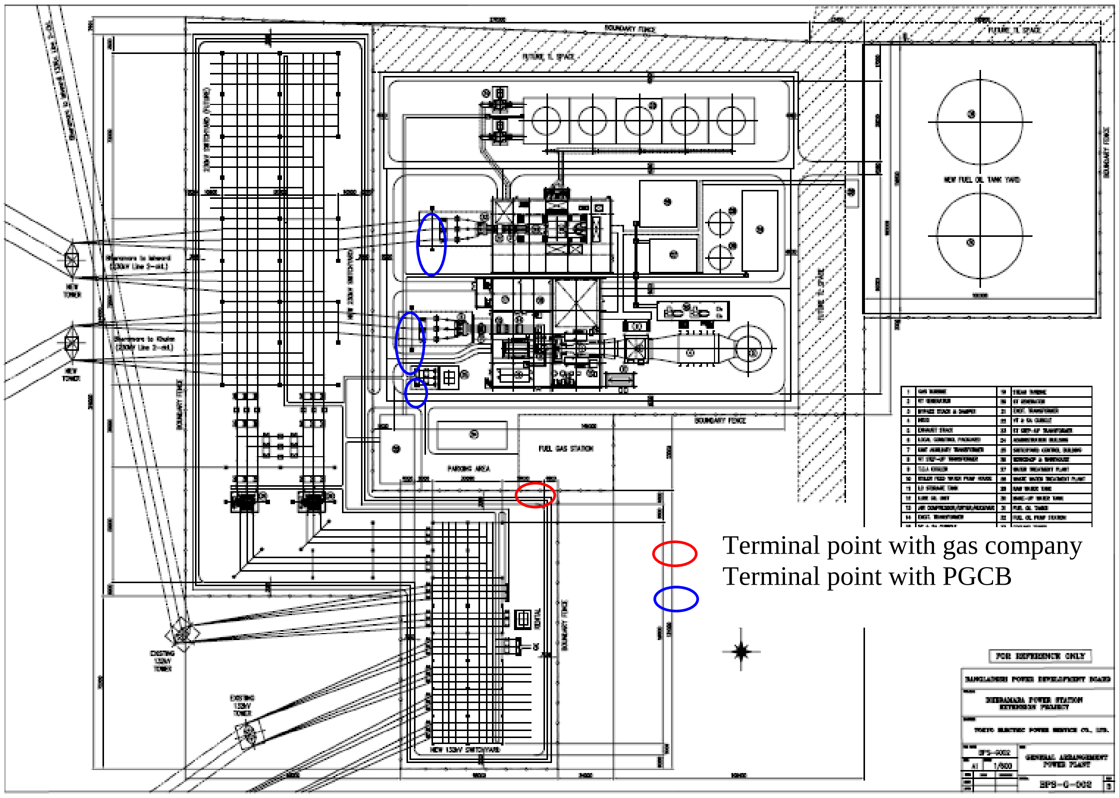
5.4.3 Works and Services to be provided by Employer

The following works and services associated with the new plant will be provided by NWPGCL and/or the Consultant employed by the NWPGCL.

(1) Drinking water, hot water, natural gas, electric power for use during construction.
(2) Electric power and auxiliary steam for start-up of the new plant
(3) Detailed Environmental Impact Assessment (EIA) Report
(4) Assistance for acquisition of all permits necessary for construction and operation of the new plant.
(5) Topography mapping/surveying
(6) Site soil investigation/borings
(7) Natural gas, electric power load, and heat export demand for commissioning and guarantee and reliability tests.
(8) Periodic provision of operation and maintenance record data and information during the Defect Liability Period of two (2) years to the Contractor and Consultant for evaluation of operation and maintenance conditions.
(9) Labors, facilities and tools available at the Site for the inspection at the end of Defect Liability Period.

5.4.4 Terminal Points

The planning of he terminal points between Bheramara CCPP, Gas Company and PGCB are shown as following.



5.5 Plant Design Considerations

5.5.1 Design Conditions

From data in Sub -section 7.1.2, the Plant shall be designed according to Table I-5-5-1 Design Conditions.

Table I-5-5-1 Design Conditions

Design Ambient Dry BulbTemp. /Relative Humidity for Performance Guarantee	35°C / 80%
Design Minimum Ambient Dry BulbTemp. /Relative Humidity for Maximum Capability of Generator	10°C / 80%
Minimum / Maximum Relative Humidity	60% / 95%
Minimum Ambient Dry BulbTemp. / Maximum Ambient Dry Bulb	5°C / 43°C
Barometric Pressure	0.1013 MPa
Elevation	EL+16 m
Minimum/Maximum River Water Level (*: average of 1976-2006)	LLWL = EL+4.22 m LWL = EL+5.47 m* MWL = EL+8.74 m* HWL = EL+13.63 m* HHWL = EL+15.19 m
Seismic Criteria	BNBC 1993; Zone III Basic Seismic Coefficient

	= 0.04g
Wind Design	60 m/s
Annual Rainfall	1,524 mm
Maximum Rainfall Rate	25 mm/hr (1hr continuous intention)
Snow Load	0 kg/m^2

5.5.2 Codes and Standards

(1) Mechanical, Electrical and Control Plant and Equipment

Except there are particular codes and standards in Bangladesh, the Plant and equipment shall be designed to the following acceptable International Codes and Standards.

1) Japanese Industrial Standards (JIS)
2) The U.S.A. codes and standards (ASME, ASTM etc)
3) The IEC recommendation
4) International Standards Organization (ISO)
5) The British codes and standards (BS)
6) The Federal Republic of Germany codes and standards (DIN)

(2) Civil and Architectural Works

The engineering, design and construction of civil and architectural works shall conform to the Bangladesh relevant codes and standards except where particular codes and standards are laid down in this Basic Design Document or the case where the particular ones must be applied. The latest revision of applicable Codes and Standards stated herein at time of the bid due date shall be applicable.

5.5.3 Site Layout

Layout of the Bheramara CCPP is planned as Figure I-5-5-1. Detail Drawing is attached as Attachment 4 BPS-G-002"General Arrangement Power Plant". Main considerations for arrangement of the equipments are as follows.

- At first location of 230kV S/S will be selected to the northwest side of the site taking into account future extension of the S/S.
- As for arrangement of the power block, the location of the cooling tower should be considered at first because location of air intake for gas turbine should be considered to minimize the influence of the exhaust of the cooling tower. According to the meteorological data, main wind direction during the summer season at the site is south. That's why the location of cooling tower is the north side of the site.
- Accordingly steam turbine generator will be arranged adjacent to the cooling tower. Gas turbine generator and HRSG will be arranged to the south of steam turbine generator. Gas turbine generator and steam turbine generator together with those associated equipments are installed inside the turbine building.
- Central Control Room, electrical room and battery room are set up in the turbine building.
- Diesel oil tanks will be sited next to the existing diesel oil tanks. Those will be two 20,000 kl tanks, one tank contains diesel oil about enough capacity of oil for 7 days operation. And required area and height of retention basin will be calculated according to the NFPA30. A calculation result is summarized in Table I-5-5-2.

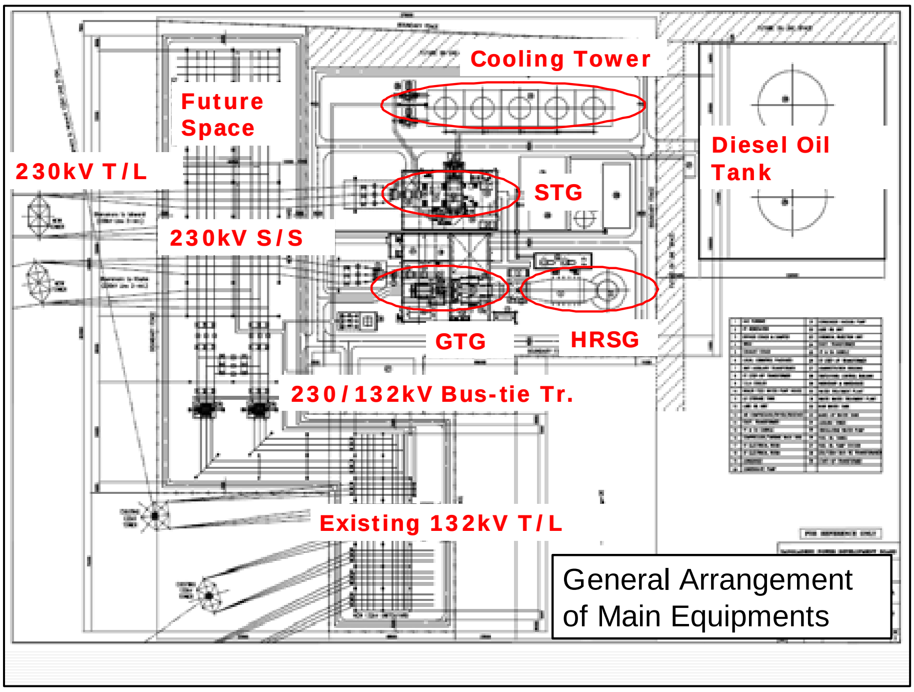


Figure I-5-5-1 General Arrangement of Main Equipments

Table I-5-5-2 Calculation result for Diesel Oil Tank

NFPA30 Requirement	Interval of two tanks	Diameter of Tank x 2/6
	Height of retention dike	Over 0.9m
	Capacity of retention dike	Over 100% of effective capacity of tanks
	Distance between retention dike and tank	Over 15m
Calculation Result	Diameter of tank	37m
	Height of tank（maximum oil level）	18m
	Capacity	20000kL
	Effective capacity	19000kL
	Margin rate	5%
	Height of retention dike	2.0m
	Length of area (east and west)	100m
	Length of area (north and south)	116.5m
	Interval of two tanks	12.3m
	Base area	9500m^2
	Capacity of retention dike	19000m^3
	Distance between retention dike and tank (east and west)	31.5m
	Distance between retention dike and tank (north and south)	15.1m

5.5.4 Environmental Requirements

(1) Airborne Emissions

The plant exhaust emissions shall not exceed the emission limit specified in this project shown on Table I-5-5-3 based on power output range of 75-100% of plant capacity with natural gas and diesel oil firing.

Table I-5-5-3 Emission Limit of Pollutant

Pollutant	Emission Limit	
NOx	Natural Gas	40 ppmv
	Diesel Oil	100 ppmv
CO	Natural Gas	20 ppmv
	Diesel Oil	50 ppmv
Particulates	Natural Gas	10 mg/m^3N
	Diesel Oil	10 mg/m^3N
SO_2 *	Diesel Oil	200 ppmv

(Note) The above are based on 15% O_2 dry condition.
* Considering 1% max of sulphur content.

(2) Noise Control

Ambient noise level for all equipment operating under steady state conditions shall not exceed 85 dB(A) at a height of 1 m and a distance of 1 m from the edge of the equipment or the enclosure. Equivalent noise level at a height of 1 m on the power station boundary shall not exceed 70 dB(A). Maximum Noise level for this project are summarized on Table I-5-5-4.

Table I-5-5-4 Noise Standards

Condition	Maximum Noise level
At 1m from the edge of the equipment or the enclosure	Not more than 85 dB(A)
At the power station boundary	Not more than 70 dB(A)

All measurement of noise and testing shall be done in accordance with ANSI B133.8.
To comply with the above stated noise criteria, any modifications necessary, including the installation of additional and/or improved sound attenuation equipment shall be implemented.

(3) Treated Wastewater Quality

The treated wastewater discharge quality shall meet the standards on Table I-5-5-5 World Bank and Bangladesh Standards for Effluent.

Table I-5-5-5 Effluent Standards

Sl. No.	Parameter	Unit	World Bank Standards	Bangladesh Standards for Inland Surface Water
1.	Ammoniacal Nitrogen (N molecule)	mg/l	-	50
2.	Ammonia (free ammonia)	”	-	5
3.	Arsenic (As)	”	-	0.2
4.	BOD_5 20°C	”	-	50
5.	Boron	”	-	2
6.	Cadmium (Cd)	”	-	0.05
7.	Chloride	”	-	600
8.	Chromium (total Cr)	”	0.5	0.5
9.	COD	”	-	200
10.	Chromium (hexavalent Cr)	”	-	0.1
11.	Copper (Cu)	”	0.5	0.5
12.	Dissolved Oxygen (DO)	”	-	4.5-8
13.	Electrical Conductivity	μmho/cm	-	1200
14.	Total Dissolved Solids (TDS)	mg/l	-	2,100
15.	Fluoride (F)	”	-	7
16.	Sulfide (S)	”	-	1
17.	Iron (Fe)	”	1	2
18.	Total Kjeldahl Nitrogen (N)	”	-	100
19.	Lead (Pb)	”	-	0.1
20.	Mangaense (Mn)	”	-	5
21.	Mercury (Hg)	”	-	0.01
22.	Nickel (Ni)	”	-	1.0
23.	Nitrate (N molecule)	”	-	10.00
24.	Oil & grease	”	10	10
25.	Phenol compounds(C_6H_5OH)	”	-	1.0
26.	Dissolved Phosphorus (P)	”	-	8
27.	Radioactive Materials	As determined by Bangladesh Atomic Energy Commission		

Sl. No.	Parameter		Unit	World Bank Standards	Bangladesh Standards for Inland Surface Water
28.	pH		”	6-9	6-9
29.	Selenium		mg/l	-	0.05
30.	Zn (Zn)		”	1.0	5.0
31.	Total Dissolved solid		”	-	2,100
32.	Temperature	Summer	^{O}C	-	40
		Winter	^{O}C	-	45
33.	Total Suspended Solid (TSS)		mg/1	50	150
34.	Cyanide (CN)		”	-	0.1
35.	Total Residual Chlorine			0.2	-
36.	Temperature increase		^{O}C	Less than or equal to 3 *	-

(source) Pollution Prevention and Abatement Handbook, Word Bank Group, 1998
Schedule 10, Rule 13, Environment Conservation Rules, 1997
(Note) * The effluent should result in a temperature increase of no more than $3^{O}C$ at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.

(4) Environmental Monitoring Facilities

The Continuous Emission Monitoring System (hereinafter called ‘CEMS’) shall be installed to monitor flue gas from the Plant. CEMS shall be required to monitor amount of the flue gas and its concentrations of NOx, SO_2, Particulates and CO.

The continuous monitoring system for amount of the effluent from the wastewater treatment system and its pH value and turbidity shall be monitored. The monitoring shall be conducted at the treated water pit of the wastewater treatment system in the Plant.

5.5.5 Gas Turbine

The basic design functions to be required to the gas turbine which will be employed for this project are as described hereon.

The gas turbine shall be of an open cycle heavy duty single-shaft type of which turbine inlet temperature level is of F-class. The gas turbine shall be supplied by original equipment manufacturers. The gas turbine shall be capable of operating on a simple cycle mode because it is scheduled to put into commercial operation in advance separately from the bottoming system considering present impending power supply shortage situation in Bangladesh. For the purpose, an exhaust gas bypass system shall be equipped. The following four (4) models of gas turbines could be identified with Gas Turbine World 2007-08 GTW Handbook (Volume 26) as F-class gas turbines.

Name of OEM	Type of Model
Alstom Power	GT26 with air quench cooler

GE Energy Gas Turbine	PG9351 (FA)
Mitsubishi Heavy Industry	M701F4
Siemens Power Generation	SGT5-4000F

The gas turbine power output shall be specified on a basis of continuous base load with the load weighting factor of 1.0 for calculation of the equivalent operating hours (EOH) which will be a scale of the inspection interval of hot gas path parts.

The gas turbine shall be normally operated on indigenous natural gas specified in the sub-section 5.5.8 "Fuel Supply System" and be equipped with the function to be operated on Diesel oil equivalent to No.2-GT oil specified in ASTM D-2880 for emergency operation in case of lack of the natural gas.

The gas turbine shall be of an advanced design to meet the NOx emission requirement of less than 40 ppm (15% O_2 basis on dry volume) on a dry condition for operation on the specified natural gas under 75 – 100 % load. It shall be also capable of operating to meet the NOx emission requirement of less than 100 ppm (15% O_2 basis on dry volume) with injection of water for operation on the oil fuel.

The gas turbine shall be of proven design with manufacturer's design practices to basically meet the requirements of ISO 21789 Gas turbine applications – Safety.

It can be allowable that the gas turbine will be equipped with the evaporative type inlet air cooling system to augment the gas turbine power output. According to climate data recorded for six (6) years from 2002 to 2007 at Ishurdi near Bheramara site, the temperature difference between averaged dry and wet bulb temperatures is estimated at 2.8^{O}C. This means that the gas turbine inlet ambient temperature could be decreased by at least 2.4^{O}C utilizing the current evaporative cooling system with many experiences. Consequentially, the power output increase of some 1.3% (equivalent to some 5 MW) will be expected with increase of the fuel consumption of some 0.9%. Such situation implies that the adoption of the inlet air cooling system is economically and technically advantageous.

The gas turbine to be proposed shall be of similar model to the gas turbines, of which at least one (1) gas turbine has the experience of successful commercial operation with not less than 6,500 hours of actual operating hours on the Bid closing date.

The gas turbine design shall be with a minimum number of bearings, and shall be located on a steel frame or on adequate steel structures and concrete foundation, sized for the transient maximum transmittal torque imposed on the shaft in case of short circuit of the generator or out-of-phase synchronization, whichever is larger. The power output shall be taken out at the cold end of the shaft.

The gas turbine shall be directly coupled to the generator without any power transmission gear.

5.5.6 Heat Recovery Steam Generator

(1) Type of Circulation

HRSG could be of natural or forced circulation type. In natural circulation units, the thermal head differential between water and steam-water mixture is responsible for the circulation through the system.

In forced circulation units, circulating pumps (BCPs) circulate the steam-water mixture through the tubes of the evaporator to and from the drum.

Advantages claimed for forced circulation design are quick warm/hot startup capabilities. However, natural circulation designs do not need circulation pumps to maintain the circulation of steam water mixture through the evaporator tubes, thereby saving operating cost and concerns about pump failure or maintenance. Availability of natural circulation type HRSG is higher because of the absence of the critical rotating equipment such as circulation pumps.

There is no difference in cold startup time periods due to the fact that in the transient heat up phase, the bulk of the time is spent on heating the metal and water of the evaporator module, which is nearly the same whether it is a natural or a forced circulation HRSG.
In summary, both natural and forced circulations HRSG are widely used in the industry, while the natural circulation design has an edge over the forced circulation design as discussed above. Hence the natural circulation types HRSG are proposed for this project.
A comparison table (Table I-5-5-6) for the type of HRSG circulation is provided for reference.

Table I-5-5-6 HRSG Circulation Comparison

Item	Natural Circulation	Forced Circulation
Features	Simple Evaporator circuitry without any pump or valves	Complicated evaporator circuitry with BCP and valves
	No auxiliary power consumption	Increase of BCP power consumption
	Lower construction and maintenance cost	Increased construction and maintenance cost for BCP and piping for water circulation system
	Simplified control high reliability and availability (no load restrictions due to pump failure)	Complicated control due to BCP operation
	Start up time at cold start up is no difference between both types.	
	To be necessary the time until taking natural circulation force, start up time at warm and hot start up is longer than forced circulation.	Start up time at warm and hot start up is shorter than natural circulation because circulation pumps are applied.
HRSG Specification:		
Heating surface:	Base	Same
Steel structure volume:	Base	Same
Boiler circulating pump (BCP):	Not required	To be provided (2 x 100%)
Stability of water:	Base	Same
Drum size:	Base	Same
Steam/water side pressure drop:	Base	Higher

(2) Flue Gas Flow Direction

HRSG is available for both horizontal and vertical flow directions. Vertical flow directional HRSG occupy less floor space. Also the HRSG forms part of the main stack and hence the main stack requires less material.
A comparison of both types of HRSG is furnished in the enclosed Table I-5-5-7.

Table I-5-5-7 Gas Flow Orientation Comparisons

Description	Horizontal Gas Flow Type	Vertical Gas Flow Type
Arrangement: Installed Area Distance from GT outlet to Stack inlet Height Stack	 Base Base Base Taller stack is mandatory	 Smaller Shorter Same or a little higher Independent higher stack is not required
Circulation System	Natural circulation system	Natural or Forced circulation system
Heating Surface Support System	Top support system by hanger (Free to slide lower)	Same
Operability	Base	Same
Maintenance and Inspection	Base	Easier for Natural circulation system but a little complex for Forced circulation system
Economics: Equipment Cost Operation Cost	 Base Base	 A little higher Same for Natural circulation system but higher for Forced circulation system

(3) Conclusion

In view of above reasons, HRSG of natural or forced circulation types are all acceptable for this project. However, natural circulation type HRSG will be preferred.

With regard to flue gas flow direction, horizontal or vertical gas flow types are all acceptable for this project. The flue gas flow direction will be decided based on manufacturer’s recommendation and the layout proposed during contract stage etc.

5.5.7 Steam Turbine

The steam turbine shall be of a reheat, triple-pressure, two-casing, condensing type directly connected to the generator. The steam shall be downward or axially exhausted to a surface condenser which is cooled by the fresh circulating water which is in turn cooled with a forced draft wet type cooling tower.

The steam turbine shall be of the manufacturer's standard proven design and construction to allow economical and reliable service with less maintenance works.

The steam turbine to be proposed shall be of similar design to the steam turbines of which at least one (1) unit shall has the commercial operation hours not less than 6,500 hours on the Bid closing time.

The steam turbine and auxiliary systems shall be designed to run continuously under all specified operating conditions over the specified lifetime of the plant.

The steam turbine maximum capability shall be such as satisfies the conditions of steam pressure, temperature, flow as developed by the HRSG when the gas turbine is operated on the maximum capability ambient conditions. In case that the HRSG is supplementary fired, the steam turbine shall be sized to cope with the maximized capability of the HRSG in consideration of the supplementary firing over the specified ambient conditions.

The steam turbine shall be designed so that the expected life expenditure of the main components (casing and rotor) shall not exceed 75% of the expected lives of them at the end of the specified service hours when it will be operated on the specified conditions.
The steam turbine shall be provided with necessary number of bore scope ports for easy inspection of the operating conditions of the blades and rotor at periodical intervals, if applicable.

5.5.8 Fuel Supply System

(1) Fuel gas supply system

The new plant shall be operated on the specified natural gas.
The gas turbine and heat recovery steam generator shall be designed to operate on the specified natural gas. The typical specification is as shown in the Table I-5-5-8.
The fuel gas supply system shall cover all the equipment required for the start-up, shutdown and continuous operation of the gas turbine. A booster compressor station, a pre-treatment system, and a gas pressure-regulating device shall be also included in the scope of the Contractor. The pre-treatment system shall be facilitated to clean the specified gas to the extent that it will be used for the gas turbine without any difficulties. The specific energy (caloric value) is expressed on the conditions of 35˚C of ambient temperature and 101.3kPa of ambient pressure.

Table I-5-5-8 Specifications of Gas

Properties	
Compositions	(mol. %)
Methane	95.982
Ethane	2.444
Propane	0.528
Normal Butane	0.130
Isobutane	0.139
Normal Pentane	0.000
Isopentane	0.100
Oxygen	0.000
Nitrogen	0.361
Carbon Dioxide	0.316
Hydrogen Sulfide	(no data)
Total	100.0
Hydrogen Sulfide (g/ m3)	0.000
Specific Energy (kJ/kg)	
Gross specific energy	54,466
Net specific energy	49,099
Specific Gravity (kg/m3N)	0.7511
Temperature (˚C)	Min. -12˚C, Max. 32˚C Perf. point 25˚C
Pressure at Terminal (MPa)	Max. 1.2 MPa(g) Min. 0.8 MPa(g)

(2) Fuel oil supply system

The new plant shall be operated on the HSD for emergency.

The gas turbine and heat recovery steam generator shall also be designed to operate on the specified HSD. The typical specification is as shown in the Table I-5-5-9.
The fuel oil supply system shall cover all the equipment required for the start-up, shutdown and continuous operation of the gas turbine same as the fuel gas supply system. The HSD fuel oil tanks which have a capacity of 20,000m^3 x 2, a pre-treatment system, and an oil pressure-regulating device shall be also included in the scope of the Contractor. The pre-treatment system shall be facilitated to clean the specified oil to the extent that it will be used for the gas turbine without any difficulties.

Table I-5-5-9 Specifications of HSD

Test	Method	Limit
Sp. Gr. @ 60^{o}F/60^{O}F	ASTM D 1298	Min. 0.820 / Max. 0.870
Color ASTM	ASTM D 1500	Max. 3.0
Flash point p.m. (c.c.) ^{O}F	ASTM D 93	Min. 100
Pour point ^{o}F	ASTM D 97	Max. -40
Viscosity kinematic @100^{O}F cst	ASTM D 445	Less than 9.0
Viscosity RW-1 Second @100^{O}F converted	Converted	Max. 50
Sediment %wt.	-	Max. 0.01
Water %Vol.	-	Max. 0.10
Carbon residue, conradson	ASTM D 189	Lass than 0.1
Ash %wt.	ASTM D 482	Max. 0.01
Neutralization Value:		
Strong acid number mgs. KOH/g	-	NIL
Total acid number mgs. KOH/g	-	Max. 0.5
Cetane Index (calculated)	ASTM D 976	Min. 45
Sulfur content %wt.	ASTM D 1551	Max. 1.0
Copper Strip corrosion(3 hrs @ 212 ^{O}F)	ASTM D 130	Max. No.1 strip
Distillation:		
90% recovered (vol) at ^{O}C	ASTM D 86	Max. 360
L.H.V. (Low Heating Value)		18,500 BTU/Lb
Min. Ambient Temperature		41^{O}F

As described on section 4.5.5 the HSD will be used for emergency, on this section the result of calculation for amount of HSD for emergency and capacity of HSD storage tanks is shown as follows;

Assumption

Type of Model	M701F
Net Output (ISO)	312,100 kW
Heat Rate	8,683 Btu/kWh
LHV of HSD	18,500 Btu/lb

Result of calculation
312,100 kW x 8,683 Btu/kWh / 18,500 Btu/lb x 0.453592 lb/kg = 67,000 kg/h
67,000 kg/h x 24 hours / 0.85 kg/m^3 = 1,900 KL/day
2,000 KL/day when a margin of ambient of winter is taken into account

As a result of studying the amount of HSD for emergencies that must be storaged at the Bheramara CCPP, it is necessary to install HSD tanks capable of storaging the HSD for emergency use from out of order to restore service of gas supply facility for seven days

(2,000 KL/day x 7 days = 14,000KL: i.e., 20,000 KL when a margin of safety is taken into account). With consideration given to the maintenance of the HSD tanks, it has been determined that two 20,000 KL HSD tanks should be installed in the Bheramara CCPP.

5.5.9 Water Treatment System

The process water for demineralized water, potable water and sanitary water, fire fighting water and miscellaneous service water shall be produced through pretreatment system from under ground water.
The process water for cooling tower shall be produced from under ground directly.
The demineralized water shall be used as HRSG make-up water, auxiliary cooling water, chemical dosing preparation etc.
The EPC Contractor shall confirm the quality of the produced demineralized water whether it is acceptable to the HRSG.
The pre-treatment system consists of coagulator and filter, etc.
The demineralizer system consists of chemical storage and regeneration equipment, etc.
Necessity and specification of pre-treatment system will be decided based on quality of ground water.
The EPC Contractor shall take appropriate countermeasures if required.
The conceptual flow diagram is shown on Figure I-5-5-2 “Water Mass Balance Diagram”.

Stream No.	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
Flow m^3/h	1300	100	100	99	98	50	1	2	1200	600	600	15	15	67	67	48

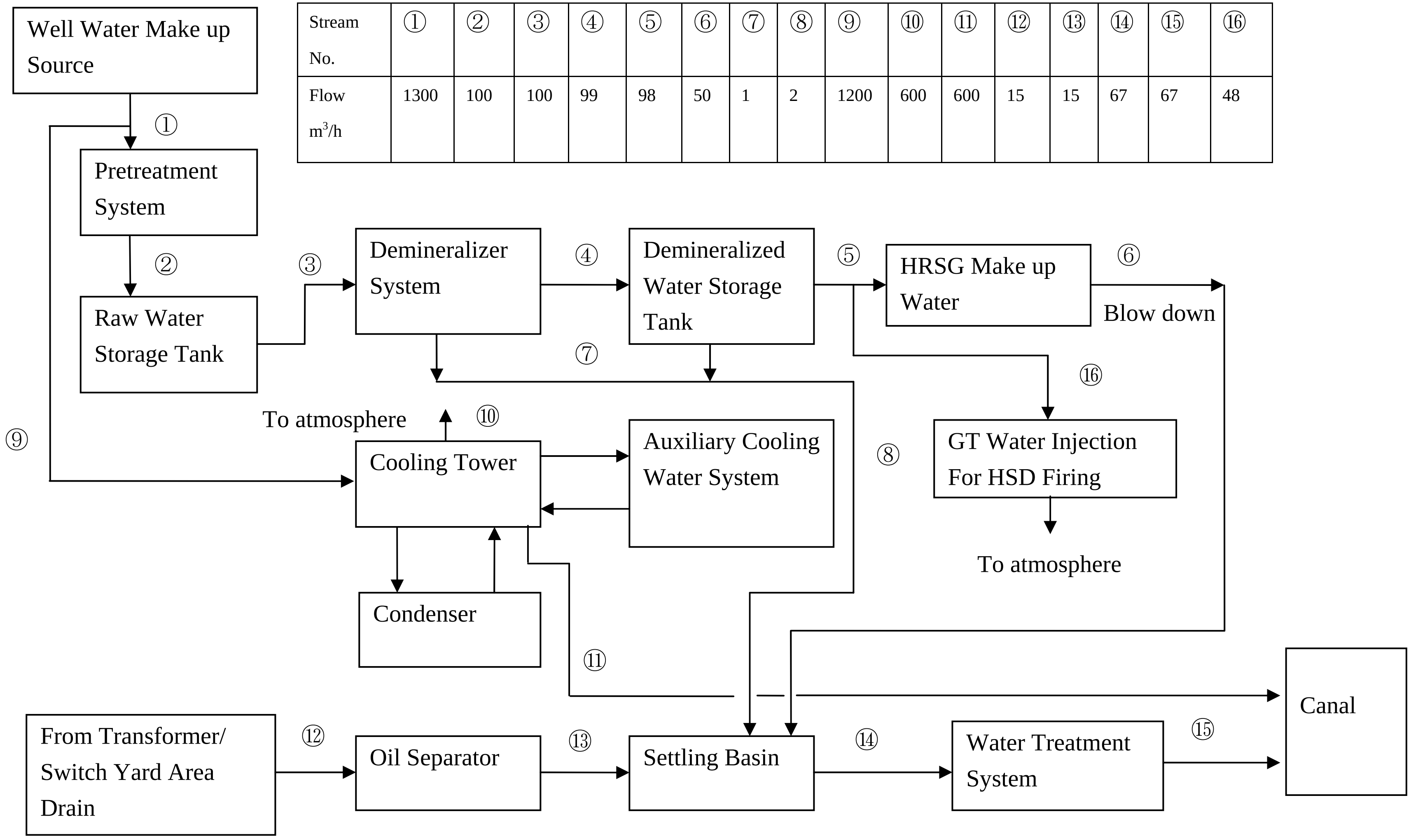


Figure I-5-5-2 Water Mass Balance Diagram

5.5.10 Wastewater System

Wastewater shall consist of neutralized regeneration waste from HRSG blowdown, floor drains from the gas turbine and steam turbine buildings, contaminated yard drains from the transformer area.
Sewage and sanitary wastewater shall be treated in purifying facility.
Floor drains from the gas turbine and steam turbine building and contaminated yard drains from the transformer area shall be treated in oil/water separators.
After treatment, these clean wastewater streams shall be discharged through the main drainage pipe to river.
The cooling tower drain without treatment shall be discharged through the main drainage pipe to river.

5.5.11 Fire Fighting System

(1) Fire safety philosophy

The Bheramara CCPP will be designed and built with the provision of a safe operating environment and personnel. This will be achieved by separation and segregation of equipment with sufficient distances and by selection of suitable equipment and materials.
Hazardous areas are designated and suitable equipment is selected for use in these. Different fire fighting systems will be installed depending on the operational characteristics of the equipment, area and building to be protected.
The fire fighting capacity of the Bheramara CCPP has to withstand a fire during two (2) hours according to NFPA 850 will be minimum 300 m^3 and pressure of approximately 10 bar.
The Bheramara CCPP will have its own fire water fighting system with pump house and the fire water will be provided from the raw water tanks.
The diagram of the fire fighting system is shown in attachment BPS-M109.
The new pumps are consists of:

One (1) 100% electric jockey pump
One (1) 100% electric driven main pump
One (1) 100% diesel engine driven main pump

The water demand and required pressure for the worst case condition will be ensured by electrically driven main pump, the second duty diesel engine driven pump shall be on stand-by, for the case of main supply failure. The engine driven pump will be of the same capacity than the electric driven main pump.

Table I-5-5-10 List of protected areas and fire fighting and detection systems types

Item	Building or Area	Fire Fighting System
1	Gas turbine	CO_2 extinguishing system
2	Steam turbine lube oil package, lube oil piping	Spray water dry type
3	Steam turbine bearings	Spray water dry type
4	Steam turbine building indoor	Wet stand pipe house system
5	Generator unit, auxiliary and start up transformer	Spray water dry type
6	Oil tanks	Form system, Dike protection
7	Control room	Cable basement: sprinkler system Control room: argonite or similar

Item	Building or Area	Fire Fighting System
8	Electrical/Switchgear	Sprinkler system if required and portable fire extinguishers
9	Yard	Hydrants
10	Common	Protective signaling for fire and gas detection systems with main panel in the control room

(2) Fire fighting system description

The fire fighting system of the Bheramara CCPP will be provided for the plant as described in the following. The fire fighting system will generally follow the applicable stipulations of NFPA codes.

Extinguishers will be sized, rated and spaced in accordance with NFPA 10. Local buildings fire alarms, automatic fire detectors and the fire signaling panel will be in accordance with NFPA 72.

It will be assured that a dedicated two (2) hour fire water supply to cover the system design flow rate is available for the facility in accordance with NFPA.

A main firewater pipeline will be provided to serve strategically placed yard hydrants and supply water to the sprinkler and spray system.

The firewater distribution system will incorporate sectionalizing valves so that a failure in any part of the system can be isolated while allowing the remainder of the system to function properly. Fuel oil tanks are furnished with foam fire fighting systems.

5.5.12 Electrical Equipment

(1) Electrical System

1) Evacuation of Power

Figure I-5-5-3 shows the scheme of power station and 230 / 132kV substation. The electrical system will be designed on the basis of the multi shaft configuration of the having two (2) generators, Gas Turbine Generator (hereinafter called as “GTG”) and Steam Turbine Generator (hereinafter called as “STG”) and two (2) generator step-up transformers, Gas Turbine Transformer (hereinafter called as “GT transformer”) and Steam Turbine Transformer (hereinafter called as “ST transformer”). The voltage of the power output from the gas turbine and steam turbine generators will be stepped up to 230kV via GT transformer and ST transformer. The output from these two GT transformers and ST transformer is transmitted to the 230kV substation respectively. The bus switching arrangement utilizes breaker and one half bus scheme.

During the unit operations, the power source to the unit auxiliary loads will be fed from the GTG via the unit transformer. During the unit shut down and the unit start-up, the power source to the unit auxiliary loads will be fed from 132kV substation via the start-up transformer. The unit transformers shall be connected to the 6.9kV unit bus A via the circuit breakers. On the other hand, the start-up transformer shall be connected to the 6.9kV unit bus B via the circuit breakers. The power will be distributed to the auxiliary loads from the unit bus.

The auxiliary system and associated equipment shall be designed with flexibility and adequate redundancy to provide a reliable source of power for all auxiliaries that will be required for the new plant.

GT Generator is synchronized at 230kV power system via GT circuit breaker when GTG is attained at rated speed and voltage. Next ST Generator is synchronized at 230kV power system via ST circuit breaker when STG is attained at rated speed and voltage.

GTG and STG can be synchronized at 230kV power system breaker which is formed by one half bus scheme. For that reason there is no need to introduce GT and ST circuit breakers. However 230kV substation shall be owned by PGCB. Also GTG and STG are synchronized by NWPGCL. As a result GT and ST circuit breakers shall be set at power station side (2nd side of GT and ST transformer) for synchronization by NWPGCL.

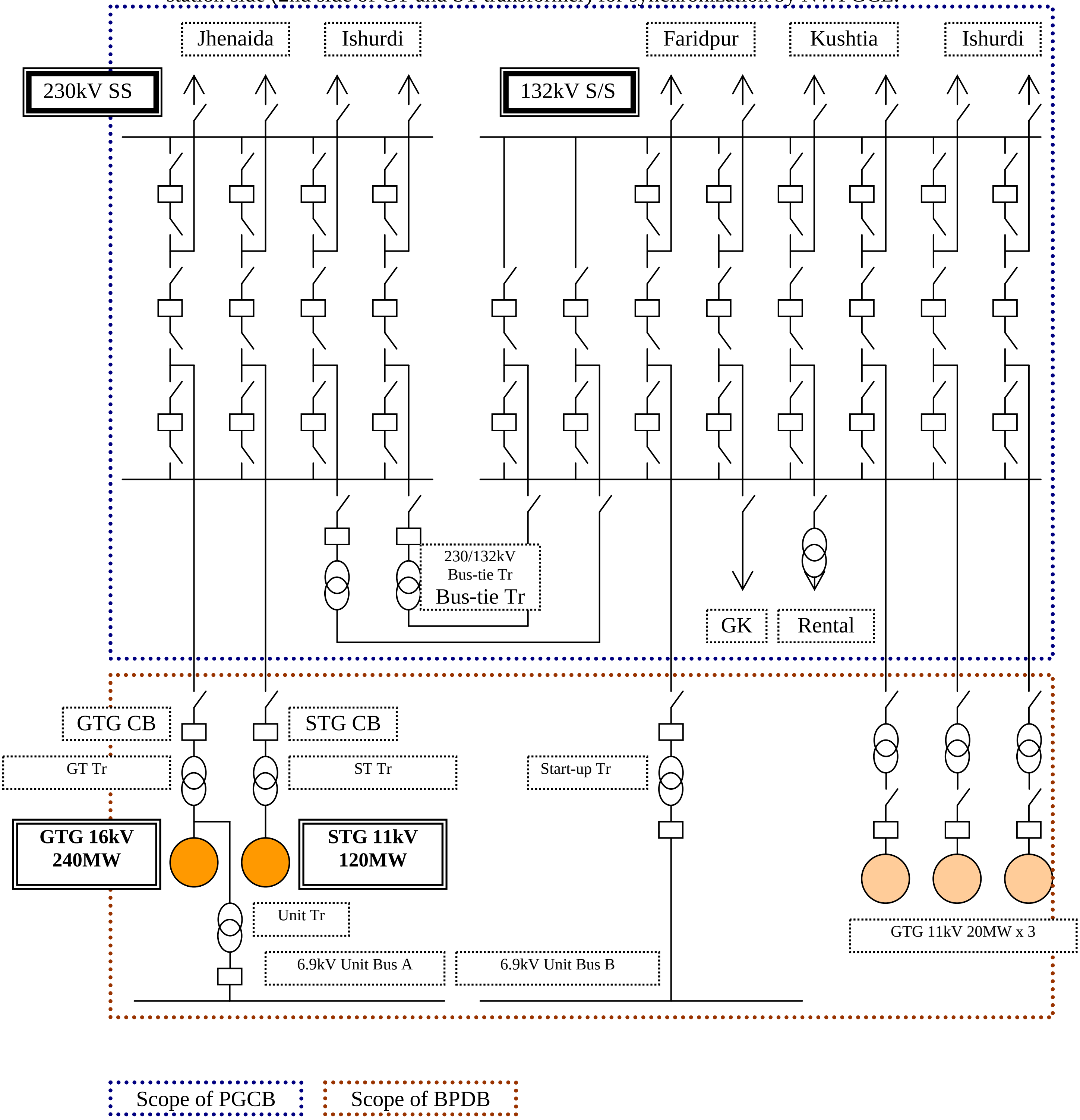


Figure I-5-5-3 The scheme of power station and 230 / 132kV substation

2) Generator Main Circuit

Attached Single Line Diagram shows the Generator Main Circuit.

The design of generator main circuit shall be based on the multi shaft configuration of the having two (2) generators (GTG and STG) and two (2) generator step-up transformers (GT transformer and ST transformer). Each generator, transformer, PT is connected to Isolated Phase Bus (IPB) and transmitted 230kV substation via each generator circuit breaker and generator disconnecting switch.

(2) Generators

1) GT Generator and ST Generator

The overview specifications of the Generators are shown below.

Table I-5-5-11 Overview Specifications of the Generators

Generator	GT Generator	ST Generator
Type	Three Phase Synchronous	Three Phase Synchronous
Number of Poles	2	2
Number of Phases	3	3
Rated Capacity	248MVA	131.6MVA
Frequency	50Hz	50Hz
Rated Speed	3,000rpm	3,000rpm
Terminal Voltage	16kV	11kV
Power Factor	0.80（Lagging）	0.80（Lagging）
Rotor Cooling Method	Hydrogen or Water Cooled	Hydrogen or Water Cooled
Stator Cooling Method	Hydrogen or Water Cooled	Hydrogen or Water Cooled

2) Type of Generator Cooling System

The generators for the gas turbine and the steam turbine shall be of air cooled or H_2 gas cooled type. The Bidder shall have the application experience with similar capacity to the generator specified in his Bid. The generator manufacturer shall have the experience to have provided at least two (2) air-cooled generators and/or two (2) H_2 gas cooled generators, of which capacities shall not be less than 280MVA on IEC conditions.

Either air-cooled or hydrogen gas-cooled system can adapt to the gas turbine generator and the steam turbine generator.

3) Comparison of Generator Cooling System

Comparison of both cooling systems is as follows;

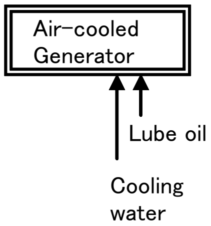
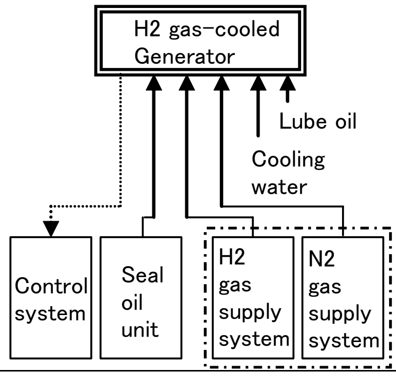
As a result of recent technological advance of cooling performance and windage loss reduction, an air-cooled system is adopted in generators of higher than 300MVA class.

An air-cooled system has some advance from hydrogen gas-cooled system such as; simpler system, easy operation and maintenance, saving cost. On the other hand adoption of air-cooled system make generator downsized so that air-cooled system has advantage for transportation and construction stage.

Therefore, the generators for the gas turbine and the steam turbine shall be of air cooled or H_2 gas cooled type. The Bidder shall have the application experience with similar capacity to the generator specified in his Bid.

The generator manufacturer shall have the experience to have provided at least two (2) air-cooled generators and / or two (2) H_2 gas cooled generators, of which capacities shall not be less than 280MVA on IEC conditions.

Table I-5-5-12 Comparison of cooling system

	Air-Cooled	Hydrogen Gas-Cooled
1) Equipment		
Efficiency	Equal	Base
Configuration (Supporting Equipment)	Simpler  	Base 
2) Operation/ Maintenance	Easier	Base
3) Construction	Easier/Shorter	Base
4) Installation Space (total)	Smaller	Base
5) Cost (initial and running)	Cheaper	Base

(3) Excitation Method

1) Excitation System

Each generator will be provided with thyristorised static excitation system which makes it possible to provide full ceiling voltage, either positive or negative, almost instantaneously under conditions of system disturbances. The system shall include transformer, automatic voltage regulator system (hereinafter called as "AVR") cubicle, thyristor, convertor cubicle and field circuit breaker. Current transformer for control, regulation, protection and metering of the generator would be either provided in the generator stator terminal bushing both on the lines as well as neutral sides, or would be housed in IPB.

2) Automatic Voltage Regulator System

The generator manufacturer shall have AVR. AVR detects generator voltage and control the reactive power to control the generator voltage.

(4) GT Start-up Method

Motor Driven Torque Converter and Thyristor Start-up Method

GT Start-up Method shall be Motor Driven Torque Converter or Thyristor Start-up Method. It depends on contractor's recommendation.

(5) Transformers

Attached Single Line Diagram shows each transformer.

1) GT Transformer

GT Transformer shall step up from GTG voltage (16kV) to transmission line voltage (230kV).
GT Transformer shall have tap changing mechanism, oil insulation three (3) phase transformer or four (4) single phase transformer (One for spare). Cooling type shall be ONAF (Oil Natural Air Forced). Phase connection shall be Δ-Y (Delta-Star) type.

2) ST Transformer
ST Transformer shall step up from STG voltage (11kV) to transmission line voltage (230kV).
ST Transformer shall have tap changing mechanism, oil insulation three (3) phase transformer or four (4) single phase transformer (One for spare). Cooling type shall be ONAF (Oil Natural Air Forced). Phase connection shall be Δ-Y (Delta-Star) type.

3) Unit Transformer
Unit Transformer shall step down from GTG voltage (16kV) to Unit Bus A (6.9kV).
Unit Transformer shall have tap changing mechanism, oil insulation three (3) phase transformer or four (4) single phase transformer (One for spare). Cooling type shall be ONAN (Oil Natural Air Natural). Phase connection shall be Δ-Y (Delta-Star) type.

4) Start-up Transformer
Start-up Transformer shall step down from transmission line voltage (132kV) to Unit Bus B (6.9kV).
Start-up Transformer shall be oil insulation three (3) phase transformer or four (4) single phase transformer (One for spare). Cooling type shall be ONAN (Oil Natural Air Natural). Phase connection shall be Y-Y-Δ (Star-Star-Delta with Stabilizing Winding) type. Y-Y-Δ connection makes detection of grounding fault current easier.
The overview specifications of the Transformers are shown below.

Table I-5-5-13 Overview Specifications of the Transformers

Transformer		GT Transformer	ST Transformer	Unit Transformer	Start-up Transformer
Rated Voltage	1st	16.0kV	11.0kV	16.0kV	132.0kV
	2nd	230.0kV	230.0kV	6.9kV	6.9kV
Rated Current	1st	11,547A	8,398A	722A	87.5A
	2nd	803A	402A	1,674A	1,674A
Rated Capacity	1st	320MVA	160MVA	20MVA	20MVA
	2nd	320MVA	160MVA	20MVA	20MVA
Phase Connection		Δ-Y	Δ-Y	Δ-Y	Y-Y-Δ (Stabilizing Winding)
Cooling Type		ONAF (Oil Natural Air Forced)	ONAF (Oil Natural Air Forced)	ONAN (Oil Natural Air Natural)	ONAN (Oil Natural Air Natural)

(6) Single Phase Transformer and Three Phase Transformer
In Comparison to Three Phase Transformer and Single Phase Transformer is shown in following Table.
BPDB requested JICA TEAM to introduce Single Phase Transformer for this project. For sure Single Phase Transformer has advantage in case of transportation or replacement of one phase transformer by accident. On the other hand, Single Phase Transformer is more expensive because of necessity of the spare transformer, control equipment for each

transformer and each basement. Three Phase Transformer and Single Phase Transformer are equal in performance aspect.
Therefore Transformer Method shall be Three Phase Transformer or Single Phase Transformer Method. It depends on contractor's recommendation.

Table I-5-5-14 Three Phase Transformer and Single Phase Transformer

Type	Three Phase Transformer	Single Phase Transformer
Unit	One (1)	Four (4) : Three (3) + Spare One (1)
Transportation	Base	Easier
Cost	Base	Higher
Space	Base	Larger
Construction	Base	Longer
Management	Base	Same
Reliability	Base	Same

(7) Generator Circuit Breaker and Disconnecting Switch

GT Circuit Breaker, Disconnecting Switch and ST Circuit Breaker, Disconnecting Switch are set at 2nd side of GT and ST transformer for synchronization.
GT Generator is synchronized at 230kV power system via GT circuit breaker when GTG is attained at rated speed and voltage. Next ST Generator is synchronized at 230kV power system via ST circuit breaker when STG is attained at rated speed and voltage.
GT and STG can be synchronized at 230kV power system breaker which is formed by one half bus scheme. For that reason there is no need to introduce GT and ST circuit breakers. However 230kV substation shall be owned by PGCB. Also GTG and STG are synchronized by NWPGCL. As a result GT and ST circuit breakers shall be set at power station side for synchronization by NWPGCL.
GT and ST circuit breakers shall adapt the load capacity. The normal specifications of the GT and ST circuit breakers are shown below.

- Rated Normal Current : 800 – 1,250 A
- Rated Short Circuit Breaking Current : 25.0 – 31.5 kA

(8) Unit Electric Supply

The unit electric supply shall be configured from unit transformer and start-up transformer.
The equipment used for power plant operation shall be powered from the unit transformer.
The equipment used for common equipment (water handling, waste water handling, etc) shall be powered from the start-up transformer system.
Moreover, as electric power source for emergencies, 1 set of 3 phase diesel fueled generator is installed for power plant and this enables obtaining safety electricity upon total cessation of the operation of the power plant.

1) 6.9kV Unit Bus

6.9kV Unit Bus shall supply necessary auxiliary power for plant operation.
The design of generator main circuit shall be based on the two (2) configuration of A and B.
Unit Transformer shall step down from GTG voltage (16kV) to Unit Bus A (6.9kV) and Unit Bus A shall supply necessary auxiliary power and 415kV Unit Bus.
Start-up Transformer shall step down from transmission line voltage (132kV) to Unit Bus B (6.9kV) and Unit Bus B shall supply necessary auxiliary power.
Unit Bus A and B (6.9kV) are connected via bus-tie circuit breaker and disconnecting switch. Basically the bus-tie circuit breaker and disconnecting switch are opened. The

bus-tie circuit breaker and disconnecting switch are closed at start-up and shutdown stage. Unit Bus B evacuates Unit Bus A the electric power in that case. Also Unit Bus B evacuates Unit Bus A the electric power when plant accidentally tripped.

2) 415kV Unit Bus
415kV Unit Bus shall supply medium motors and auxiliary power for switching.

3) 220V DC Electric Supply System
220V DC Electric Supply System shall have two (2) battery equipment and DC load shall be supplied the power from DC distribution board. Plant can stop safely by DC power from battery under blackout condition.

4) Emergency Diesel Generator Equipment
Plant shall have one (1) Emergency Diesel Generator Equipment.
It shall be capable for restart-up of the plant by power from Emergency Diesel Generator Equipment. Emergency AC power shall be supplied from Emergency Diesel Generator to 415kV Emergency Bus.

5.5.13 Protection and Control System

(1) Generator-Transformer Protection
The GTG, GT transformer and STG, ST transformer together form the plant. The protections considered are shown in the following table.

Table I-5-5-15 Generator Main Circuit Protection

Name	Factor
GT Generator differential	$87G_1$
GT Transformer differential	$87T_1$
ST Generator differential	$87G_2$
ST Transformer differential	$87T_2$
Current unbalance	46
Loss of excitation	40
Reverse power	67
Stator ground detection	51GN
Generator overexcitation	24
Generator overvoltage	59
Generator undervoltage	27G
Generator over/under frequency	81

The generator-transformer as a unit and severally protected by 87G and 87T. As a back-up protection for generator, restricted earth fault relay as well as voltage type ground fault relay is also proposed.

(2) System Configuration of the Control and Monitoring Equipment
The design of all instrumentation and control systems shall provide the maximum security for plant personnel and equipment while safely and efficiently operating the new plant under all conditions with the highest possible availability.
The configuration of the system for control and monitoring of fully automated operation of the plant will be the DCS (Distributed Control System) from the perspective of technology and cost. The DCS equipment undertakes control and monitoring of whole power plant including the common equipment.

- The computing and electric power section shall be duplex and the input and output of the DCS will be single.
- Power supply shall be duplex with both AC and DC (butted method)
- Operation during normal times will be through the use of a mouse while confirming the CRT screen.

(3) Power Plant Control and Monitoring System

The operating and monitoring system of the power station are configured by DCS, information management system, maintenance and repair system, network system and related equipment.

The DCS is comprised of the CRT operation system, turbine control system, data assembly system, sequence control system, process I/O system and peripheral equipment. Each independent system is interfaced with DCS.

(4) DCS Function of the Power Station

The design of the control system for the new plant shall utilize the state-of-the-art DCS (Distributed Control System) with data logging system in combination with proprietary controls furnished with the gas turbine / generator, steam turbine / generator, HRSG and BOP (Balance of Plant), gas compressor system and so on.

The operator console of the plant installed in the CCR (Central Control Room) shall be used for the primary operator interface and shall contain four (4) LCD (Liquid Crystal Display) with keyboards and mouse. On the other, the operator console of the substation installed in the Substation Control Room shall be used for the primary operator interface and shall contain two (2) LCD (Liquid Crystal Display) with keyboards and mouse.

The gas turbine control system, steam turbine control system and HRSG and BOP control system shall be tied into the DCS with redundant communications links and hardwired signals for critical control signals.

Those remaining control and monitoring signals for gas compressor control system, heat sources supply control system and so on shall be brought directly or via Remote I/O into the DCS I/O cabinets.

The LCD graphics shall provide the operator with control, monitoring, recording/trending, status, and alarming of equipment and process conditions.

The detector/instrument for protection/control of the gas turbine, the steam turbine and HRSG shall be redundancy/triple configuration to enhance the reliability of the new plant.

The control system shall be designed to operate and control the new plant with fully automatic, and shall give information of conditions of the new plant and guidance of operation/trouble shootings during start-up, steady state operation and shutdown to the operators.

The configuration of control logic and graphic display of the control system shall be designed for maintenance engineers to be able to easily and correctly modify and change them at site.

DCS shall have the following functions

1) Turbine automatic operation control system

- Gas Turbine operation, Control and protection including Gas Turbine supervisory instruments.
- HRSG control and protection
- Steam Turbine control and protection including Turbine supervisory instruments
- Hydraulic operated Diverter Damper control (GT Exhaust System)
- Generator protection, excitation, voltage regulation and synchronization systems
- Auxiliary system control
- Balance of plant control

2) Data collection equipment
- Scan and alert
- Process computation (including performance computation)
- Data log function and data display

3) Common equipment DCS function
- Diesel oil supply system
- Water treatment system
- Waste water treatment system, etc.

These systems have independent monitoring and control. In the event of a defect in the devices, the impact on the power station will be large. For this reason, calculation system, power supply system and etc. are multiplexed in order to contribute to the reliable operation of system.

1) Maintenance function

Maintenance tools (Engineering Work Station) for the maintenance of DCS are installed and these tools shall have the following functions.
- Control system setting/modification function
- System diagram setting/modification function

5.5.14 Civil and Building Works

(1) General

1) General Requirements

This part covers the civil and building Works associated with all plants, structures and buildings included in the Contract. The civil and building works under this section involve the supply of all machinery, plants, materials, tools and equipment, labors and supervision necessary for the execution and maintenance of the works and on completion the removal of all plants, equipment, excess materials, debris etc. from the Site.

The EPC Contractor shall submit his detailed plans to NWPGCL for endorsement and to the relevant local authorities for approval prior to the commencement of the civil and building works construction.

The following items shall be submitted to NWPGCL for approval respectively in advance.

- Detailed design drawings
- Structural calculation sheets
- Performance calculation sheets for the building facilities
- Anti-disaster plan
- Finish schedule
- Total color coordination scheme, sample catalogues
- Explanation of execution methods of the respective work
- Reports of progress of the respective work
- Reports of quality assurances and the completion

Requirements of all local authorities whether temporary or otherwise, in order to obtain planning approval, building plan approval, permit to commence work, other approvals on commencement of construction, certificate of fitness etc. will be complied with at the EPC Contractor's cost.

Special attention shall be given to design of building and structures with respect to noise abatement measures. The acceptable statutory limits of sound levels shall be complied with.

For all enclosed building/structures, proper ventilation and lighting shall be designed and provided by the EPC Contractor.
Where existing fences, roads and landscaping are affected for the laying of new services (such as new pipes, cables, roads, drains, trenches etc.), such facilities shall be reinstated at the EPC Contractor’s own cost to the approval of NWPGCL.
All buildings/superstructures construction shall be correctly planned to avoid interference with the structures existing in Bheramara plant. To minimize the interference with the new construction, the existing facilities and services will be relocated and demolished under another contract, prior to the commencement of the civil works construction.
Civil and Building Works shall include geological exploration, site preparation, design and construction of storm and plant drainage systems, underground utilities and circulating water pipes, road work, paving and gravel surfacing, main/auxiliary buildings and structures including their foundations, indoor and outdoor equipment foundations, building facilities such as lighting, lightning protection, sanitary and sewage, air conditioning and ventilation and all other necessary items to complete the new plant.

2) Statutory Requirements

Power Plant design and its execution shall be carried out in accordance with the following international or local codes and standards whichever more severs. All codes and standards shall be the latest edition. Contradicting items in the local regulations shall predominate over other Standards, unless the particular local Standard is declared expressly “not applicable” as whole or in parts by NWPGCL.
In this regard, the EPC Contractor is advised to acquaint himself thoroughly with the local statutory regulations and requirements before tendering. All costs, fees, etc. associated with obtaining approval from local bodies shall be deemed to be included in the EPC Contract Price.
Applicable International Codes and Standards:

- American Concrete Institute (ACI 318) for concrete work
- American Institute of Steel Construction (AISC) for steel construction
- American Iron and Steel Institute (AISI)
- American Society of Civil Engineering (ASCE)
- American Society for Testing and Materials (ASTM) for material quality control
- American Association of State Highway and Transportation Officials (AASHTO) for road and drainage
- American Welding Society (AWS) for Welding
- American Water Works Association (AWWA) for concrete pipe and water distribution piping
- National Fire Protection Association (NFPA)
- American Society of Mechanical Engineers (ASME)
- American National Standards Institute (ANSI)

Applicable Local Codes and Standards:

- Bangladesh National Building Code-1993 (BNBC)

If the EPC Contractor wishes to base the work on his national Standards or recommendation, he shall submit with and for the particular case a tabulated list of the differences between the proposed national Standards and recommendation and the applicable codes and standards as the above. The decision to accept such alternative standards or recommendation shall solely rest with NWPGCL the on the basis of their judgment.

3) Materials, Samples and Sources

All materials and products for the civil and building works shall be procured locally and sourced from local manufacturers unless it can be proven that they are not locally available.

Samples of all civil and building materials and products proposed to be used in the Works may be called for any time by NWPGCL shall be kept for reference. Samples shall be submitted for NWPGCL consideration before placing orders with suppliers. Ample time shall be allowed between request for approval and actual installation/construction.

(2) Site Conditions

1) Site Area

The prescribed construction-site is shown on the drawing “Plot Plan” in ATTACHMENT 2.

The area of approximately 250m x 250m + 100m x 100m is prepared for the Project and the temporary area for construction is also prepared and available depending upon the requirement of the EPC Contractor.

2) Site Elevation

Site elevation should be the same as the existing Bheramara station as following.

GL=EL+16.00m

3) Site Situation

The EPC Contractor shall execute all necessary surveys for the setting out of the work and the site to be formed prior to the commencement and after the completion of earthwork. The work shall also include all surveys that are required during the progress of the contract. All ground levels and 1st floor level quoted on all Drawings shall be referred to EL.

The EPC Contractor shall establish new control points for setting out of the Works. Sufficient benchmarks shall also be located around the Site on prominent features which will not be displaced by the construction works and to which reference can be made for checking the levels at site. These benchmarks shall be made as permanent as possible and protected against displacement. The EPC Contractor shall also establish two permanent control points at a suitable location as directed by NWPGCL as future reference points. The control points shall be referenced with coordinates and levels.

Grid reference and reduced levels of benchmark shall be shown on the drawings as well as the origin of structures and all terminal points to construction grid coordinates shall be clearly indicated on drawings.

4) Geological

Geological conditions are shown in the Section 4.6.4 Soil Investigation of this document.

5) Ambient Conditions

Site climatic parameters in general are given in Section 7.1.2 Summary of Natural Environment and Socio Environment of this Document.

(3) Scope of Work

The Contract intends to cover the supply of all materials and the execution of all works necessary to complete the works including design and demolition works. In case there are any materials or works which are not referred to the specifications or drawings, but the necessity

for which may reasonably be implied or inferred from the Specification and drawings or which are usual or essential to the completion of all works in all trades, the same shall be deemed to be included in the EPC Contract Price.
All the civil and building works include, but not limited to, the following principal features:

- GT and ST buildings for 1 GT unit and 1 ST unit with the CCR (Central Control Room), associated rooms, auxiliaries, fixtures and building facilities
- Auxiliary buildings for Gas compressor, etc.
- Warehouse and Workshop
- All outdoor structures, stacks, equipment foundations such as HRSG, auxiliary equipment, outdoor switch yard, pipe, cable supports, etc. supplied by the EPC Contractor
- Groundwater supply system
- Drinking water supply system
- Waste water treatment system of discharged contaminated drain/overflow water from the plant equipment
- Jetty
- Roads, pavements, landscaping, outdoor lighting and other outdoor works in the prescribed construction-site including fencing of the boundary of the new plant
- Site preparation work including demolition of structures and compensation of demolished structures, as well as, preliminary grading to EL+15.00m.

The works shall be complete in all respects and shall include, but not limited to, the following:

1) Site Civil Work

Plan and execution of the works shall include the design and execution of works as stipulated below:

- Earth work (grading, excavation, soil disposal, back filling, etc.) within the Plant compound
- Cooperating works with the demolition work of underground structures to be done
- Pipeline of supply and discharged water to be extended from, or connected to, the existing facilities
- Road, storm drainage, retaining wall, fencing, hedging, landscaping and other outdoor work items in the designated division
- Reconstruction and/or repairing of existing road within the new power plant compound
- Pavement for road (except for the existing road outside of the Plant compound) and other area necessary for installation and maintenance in the premises of the existing plant
- Reconstruction and/or repairing of existing storm drainage facilities within the Plant compound
- Necessary storm drainage facilities addition to the existing one
- Reconstruction and/or repairing of existing fencing around the proposed division, if required

2) Building Works

a. Structural Work

Structural work shall include the design and execution of works as stipulated below:

- Foundations and structures of all buildings
- Concrete work of foundations and pedestals except settling the anchors for machineries or equipment in all buildings,

- Superstructures for all building including all concrete and steel structural works
- Foundations and basins for all outdoor structures and equipment including all concrete works, miscellaneous steel/metal works, etc.

b. Architectural Work
Architectural work shall include the design and execution of works as stipulated below:

- Architectural work items for the GT/ST building and all auxiliary buildings comprising of necessary building finishes, miscellaneous steel/metal works including supports, access, platforms, walkways, ladders and handrails, etc. required for the operation, inspection and maintenance of plant equipment.
- Total color coordination for all buildings and structures in association with the landscaping of the civil work
- Signboards, signposts, room name plate and other sign works related with architectural works
- Furnishings

c. Building Facilities
Building Facilities shall include the design and execution of the works as stipulated below:

- Indoor and outdoor lighting system including convenient and power outlet
- Ventilation and air conditioning system for all buildings
- Water supply system and sanitary facilities for inside of GT/ST building/rooms and auxiliary buildings or areas
- Floor drainage and storm drainage system for GT/ST building and auxiliary buildings include oil collection pit, etc.
- Lightning protection system for buildings and outdoor structures including grounding
- Elevator in GT/ST building

5.5.15 Substation

(1) 230kV substation
The overview specification of the 230kV substation is shown below.

Table I-5-5-16 Overview Specifications of the 230kV Substation

Voltage	230 kV
Type of Bus bar	Breaker and One-half System
Type of Substation	Outdoor Conventional Type
Number of Bay	Four (4)
Number of Circuit Breaker	Twelve (12)

Figure I-5-5-3 shows the scheme of 230kV substation.
The existing power station is connected to the 132 kV national grid systems. The 360 MW Combined Cycle power plant will be connected to the 230 kV substation. The power output via GT and ST transformers shall be transmitted to the 230 kV substation with two (2) circuit lines.
New 230kV substation shall be of air insulated outdoor type. The bus switching arrangement utilizes breaker and one half bus scheme. A method of interconnecting several circuits and breakers in a substation so that three circuit breakers can provide dual switching to each of

two circuits by having the circuits share one of the breakers, thus a breaker and one-half per circuit; this scheme provides reliability and operating flexibility. In case of 230kV substation, there are four (4) circuit breaker bays and twelve (12) circuit breakers.
The power output via the GT and ST transformers shall be transmitted to the 230kV substation with two (2) circuit lines.
Circuit breakers shall adapt the load capacity. The normal specifications of circuit breakers are shown below.

- Rated Normal Current : 1,600 – 2,000 A
- Rated Short Circuit Breaking Current : 40.0 – 50.0 kA

Transmission capacity of each circuit of 230kV connection line shall satisfy at least the maximum output from each generator of the new plant.
GIS (gas insulated switchgear) is applied in one location in Dhaka, which has a land-use regulation. In other sites, conventional switchgear, such as ACB and so on, is applied. It is confirmed that conventional switchgear should be installed for this project.
In addition, it is confirmed that 230kV substation will be owned by PGCB. The facility border between NWPGCL and PGCB locates between secondary side of main transformer and circuit breaker of generation. PGCB requests that control panel for substation should be installed near substation instead of central control room of power station.

(2) 132kV substation
The overview specification of the 132kV substation is shown below.

Table I-5-5-17 Overview Specifications of the 132kV Substation

Scheme	Existing Substation	Replaced Substation
Voltage	132 kV	
Type of Bus bar	Breaker and One-half System	
Type of Substation	Outdoor Conventional Type	
Number of Bay	Six (6)	Eight (8)
Number of Circuit Breaker	Seventeen (17)	Twenty-two (22)

Existing 132kV substation is operated more than 30 years, and many facilities have aged deterioration.
On May 2008, VCT and LA were replaced because of the insulation failure (refer to Figure I-5-5-4). In addition, spare parts of GCB, OCB, etc of existing switchgear are discontinued at present, and it is impossible to replace the facilities after the occurrence of the accident (refer to Figure I-5-5-5, 6). Therefore, they request us to include the replacement of 132kV substation in this project in order to satisfy the reliability of 132kV substation, because 132kV substation is planned to be connected with 230kV substation. Following examples shows the plan for replacement of 132kV substation.
Figure shows the scheme of existing power station 132kV substation and the scheme of replaced 132kV substation.
132kV substation shall be of air insulated outdoor type. The bus switching arrangement utilizes breaker and one half bus scheme. Figure I-5-5-3 shows the scheme of power station and 230 / 132kV substation. A method of interconnecting several circuits and breakers in a substation so that three circuit breakers can provide dual switching to each of two circuits by having the circuits share one of the breakers, thus a breaker and one-half per circuit; this scheme provides reliability and operating flexibility.

The power from 132kV substation via the Start-up transformer shall be transmitted to the 6.9kV house bus with two (2) circuit lines. This received power is for supply of starting and stopping auxiliary power.
Existing 132kV substation, there are now six (6) circuit breaker bays and seventeen (17) circuit breakers. Replaced 132kV substation shall extend two (2) circuit breaker bays, and then there shall be eight (8) circuit breaker bays and twenty-two (22) circuit breakers.
Circuit breakers shall adapt the load capacity. The normal specifications of circuit breakers are shown below.

- Rated Normal Current : 1,250 – 1,600 A
- Rated Short Circuit Breaking Current : 25.0 – 31.5 kA

Also Existing 132kV substation is now owned by BPDB so that replaced 132kV substation will be owned by BPDB or PGCB after removal of existing power plant. It is recommended that replaced 132kV substation shall be owned by PGCB because the 132kV substation not only perform as switchyard of power station but also as substation in power system.
The 132kV substation of air insulated outdoor type is located in the same area of 230kV substation which power provide to the local area.
The power source to the 132kV substation is fed from the Common Bus via the Start-up transformer and / or the 230kV substation via the 230 / 132kV Bus-tie transformers.
The EPC Contractor shall install 230 / 132kV connection line with the 230 / 132kV Bus-tie transformers and the Start-up transformer located in the new plant site to supply power for start-up and shut down of the new plant.

Figure I-5-5-4 VCT and LA of 132kV substation after replacement

Figure I-5-5-5 132kV substation GCB (1979)

Figure I-5-5-6 132kV substation OCB (1982)

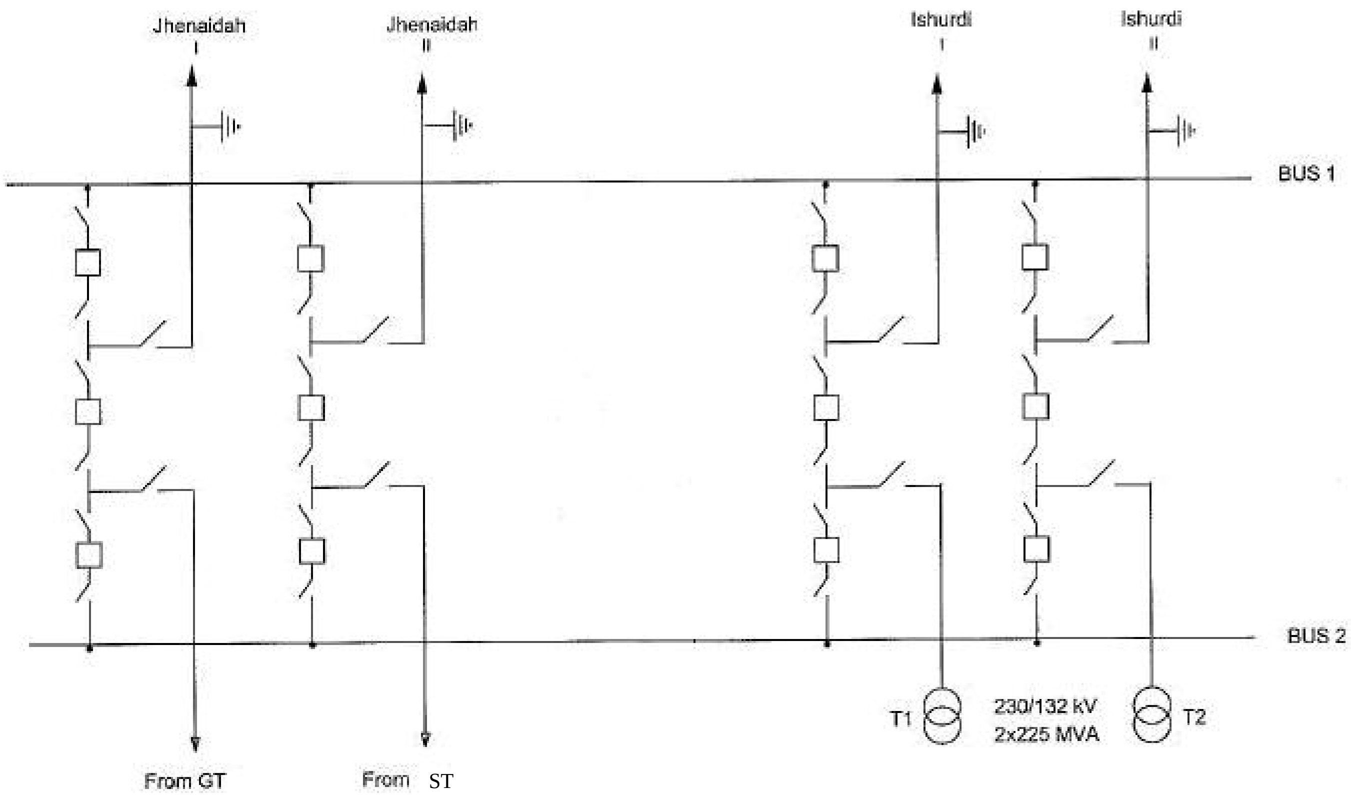


Figure I-5-5-7 The scheme of 230kV substation

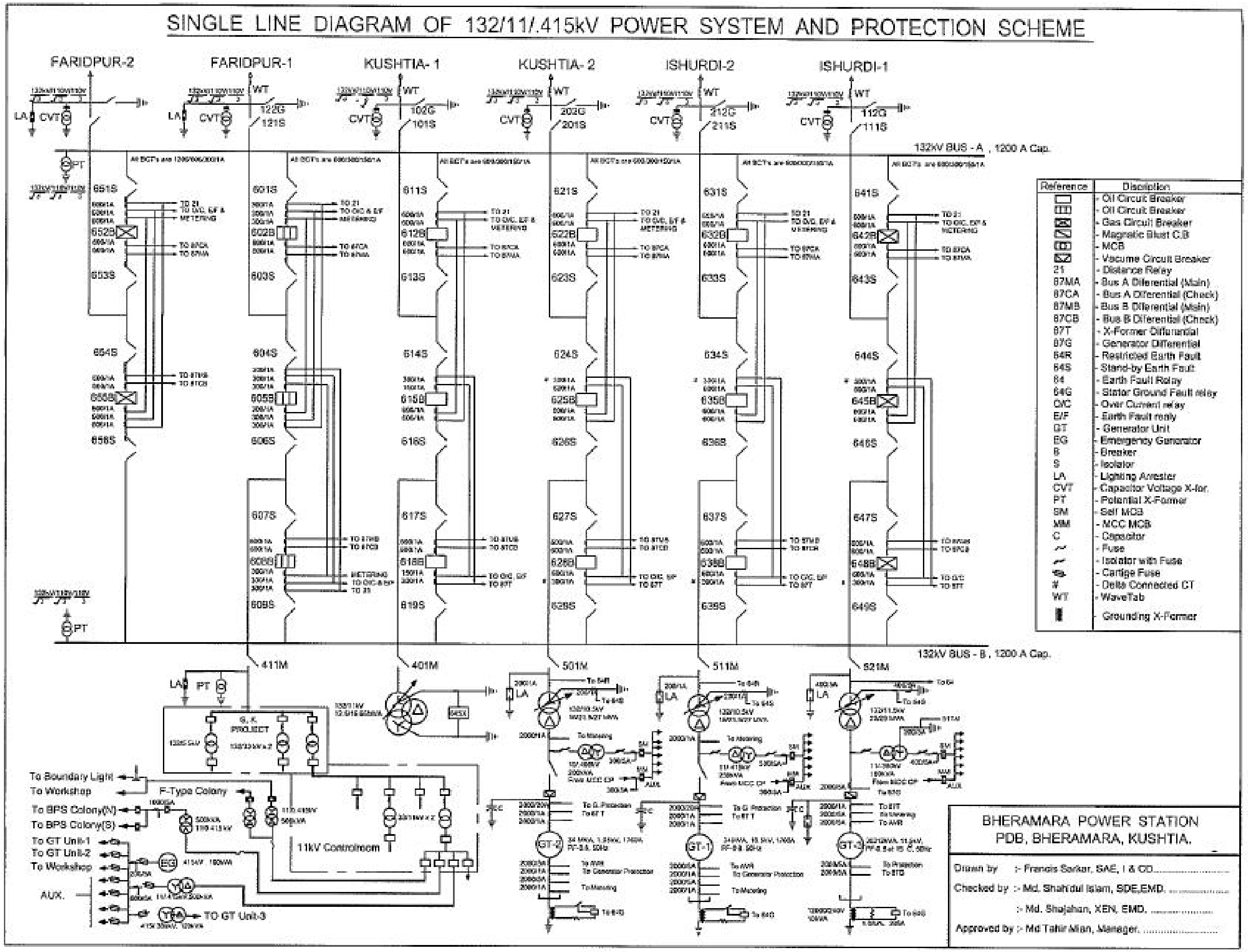


Figure I-5-5-8 The scheme of existing power station 132kV substation

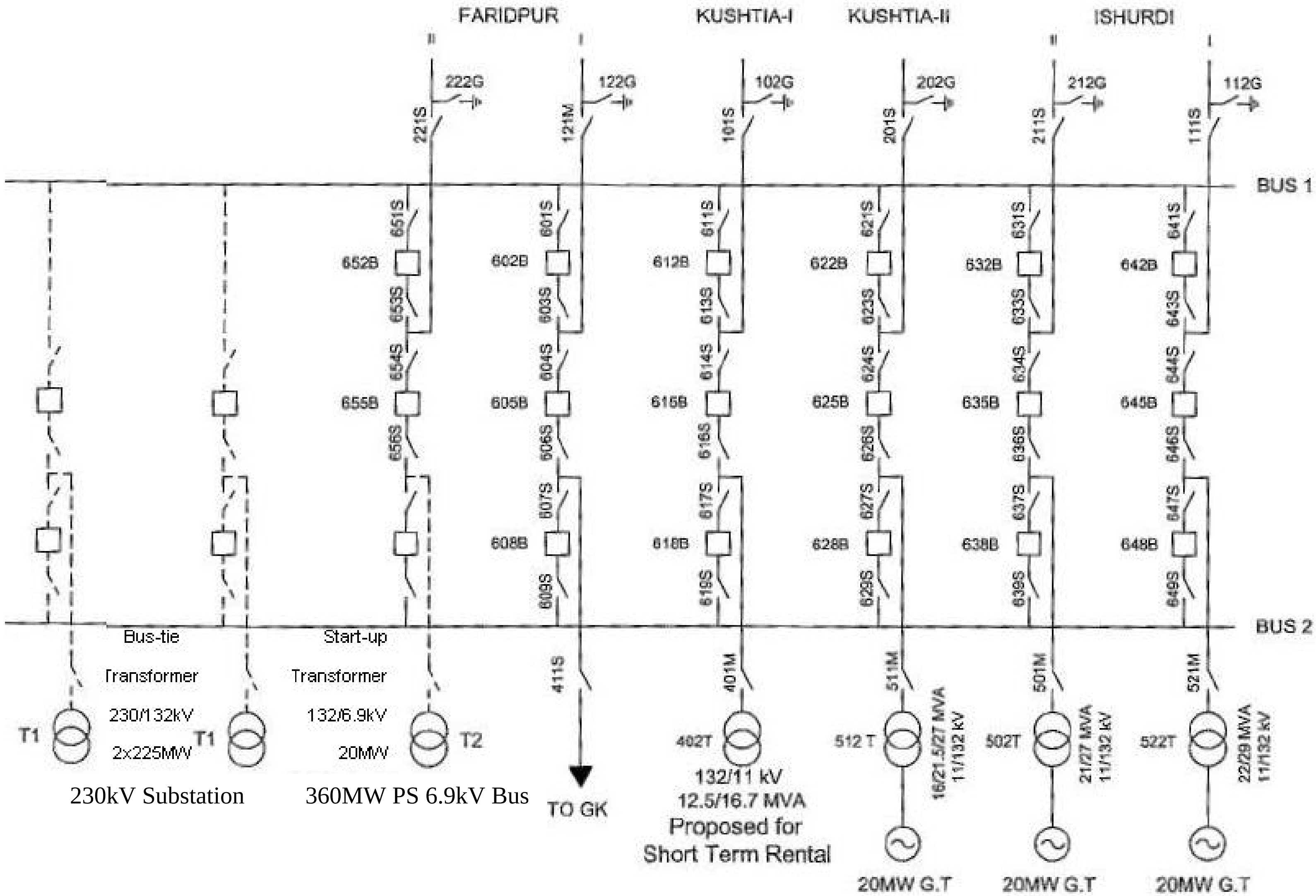


Figure I-5-5-9 The Scheme of Replaced 132kV Substation

(3) 230/132kV Bus-tie Transformer

230/132kV Bus-tie Transformer shall step down from 230kV substation voltage to 132 kV substation voltage.

230/132kV Bus-tie Transformer shall be oil insulation three (3) phase transformer or four (4) single phase transformer (One for spare). Cooling type shall be ONAF (Oil Natural Air Forced). Phase connection shall be Y-Y-Δ (Star-Star-Delta with Stabilizing Winding) type. Y-Y-Δ connection makes detection of grounding fault current easier.

The overview specifications of the Transformers are shown below.

Table I-5-5-18 Overview specifications of the 230/132kV Bus-tie Transformers

Transformer		230/132kV Bus-tie Transformer
Number		2
Rated Voltage	1st	230kV
	2nd	132kV
Rated Current	1st	565A
	2nd	984A
Rated Capacity	1st	225MVA
	2nd	225MVA
Phase Connection		Y-Y-Δ (Stabilizing Winding)
Cooling Type		ONAF (Oil Natural Air Forced)

(4) 230kV Substation Bus

Power Flow at 230kV Substation is shown in the following figure. Upper one shows the normal case and lower one shows accident case of tripping at 230kV Bheramara-Jhenaidah one circuit. In this case generating power from Bheramara CCPP is installed as 425MW.

As the result Table shows In Feed and Load Capacity of feeders at 230kV substation. Bheramara CCPP maximum output of 425MW causes a current flow of 1,066Amp. This current flow is no difference between normal and accident case.

Capacity of bus shall be exceeded 1,066Amp of the total power infeed.

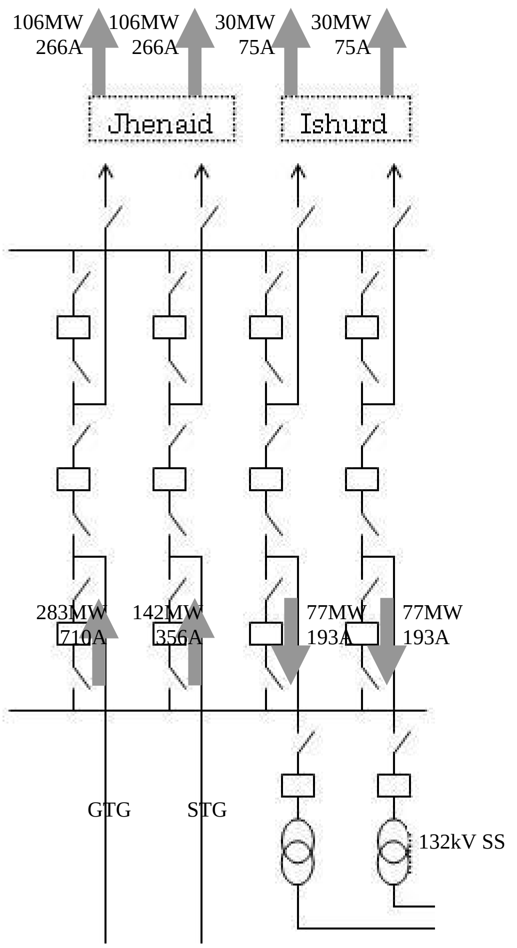


Figure I-5-5-10 Power Flow at 230kV Substation (Normal)

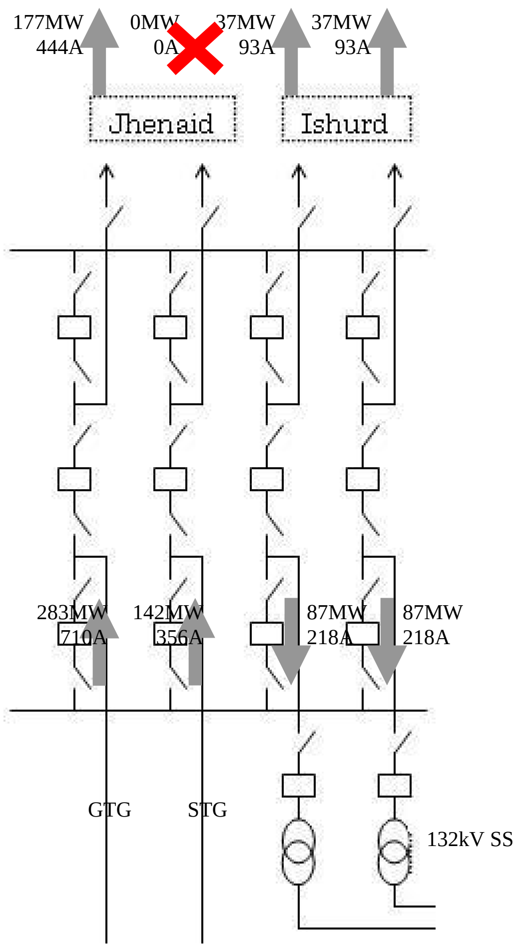


Figure I-5-5-11 Power Flow at 230kV Substation (Tripping at 230kV Bheramara-Jhenaidah One circuit)

Table I-5-5-19 In Feed Capacity of feeders at 230kV substation

In Feed	Normal		Accident Case	
	MW	Ampere	MW	Ampere
Generator	425	1,066	425	1,066

Table I-5-5-20 Load Capacity of feeders at 230kV substation

Load	Normal		Accident Case	
	MW	Ampere	MW	Ampere
Jhenaidah	212	532	177	444
Ishurdri	60	150	74	186
132kV SS	154	386	174	436
Total	425	1,066	425	1,066

(5) 132kV Substation Bus

Existing 132kV 'breaker and a half' bus system including circuit breakers and disconnecting switches has capacity of 1,200Amp. Figure I-5-5-12 shows the power flow of 214MW and the current flow of 936Amp at existing 132kV substation on 17th September 2007, the maximum demand recorded (4,130MW) day.

Power Flow at replaced 132kV Substation is shown in the following figures. Figure I-5-5-13 shows the normal case and Figure I-5-5-14 shows accident case of tripping at 230kV Bheramara-Jhenaidah one circuit. In this case generating power from Bheramara CCPP is installed as 425MW.

Also Table I-5-5-20 and Table I-5-5-21 shows In Feed Power and Load Capacity of feeders at 132kV substation. Bheramara CCPP maximum output of 425MW causes a power flow of 276MW and a current flow of 1,207Amp in the normal case. Also Bheramara CCPP maximum output of 425MW causes a power flow of 312MW and a current flow of 1,365Amp via 230/132 kV bus-tie transformer in the accident case of tripping at 230kV Bheramara-Jhenaidah one circuit.

Existing 132kV 'breaker and a half' bus system including circuit breakers and disconnecting switches will be in shortage capacity. In a view of this, bus system including circuit breakers, disconnecting switches and the other related equipment shall be replaced by 1,600Amp capacity.

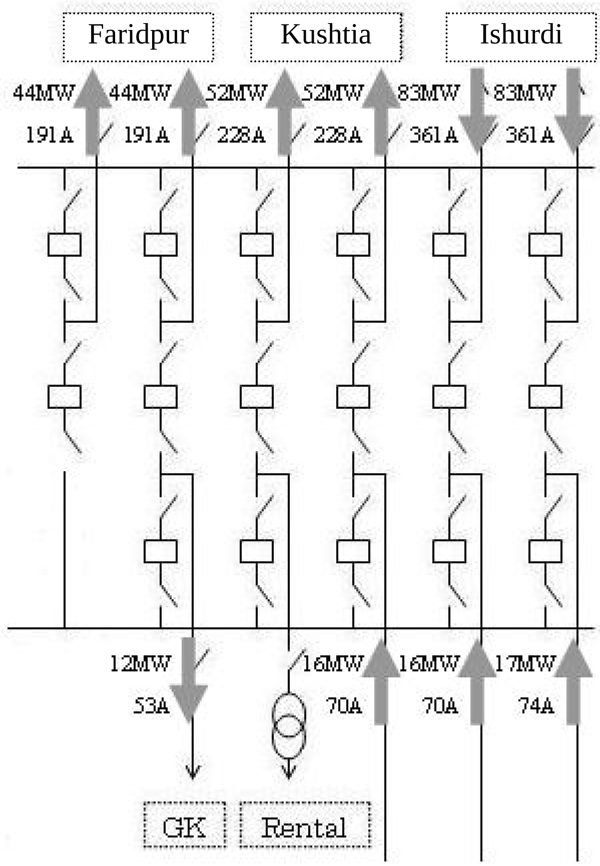


Figure I-5-5-12 Power Flow at Existing 132kV Substation
(Max Demand 4,130MW on 17th Sep 2007)

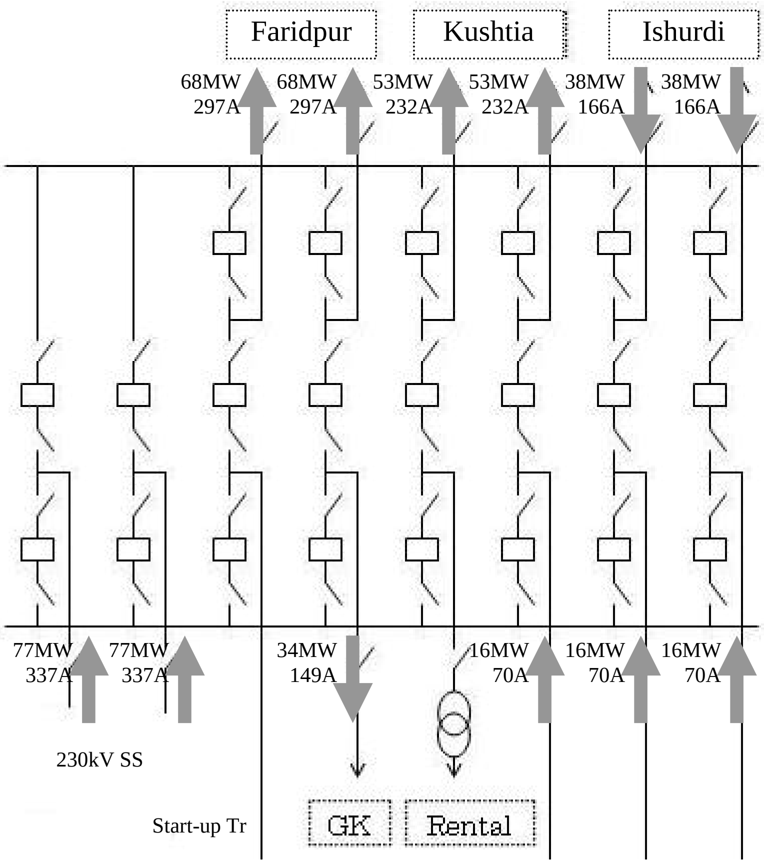


Figure I-5-5-13 Power Flow at 132kV Substation (Normal)

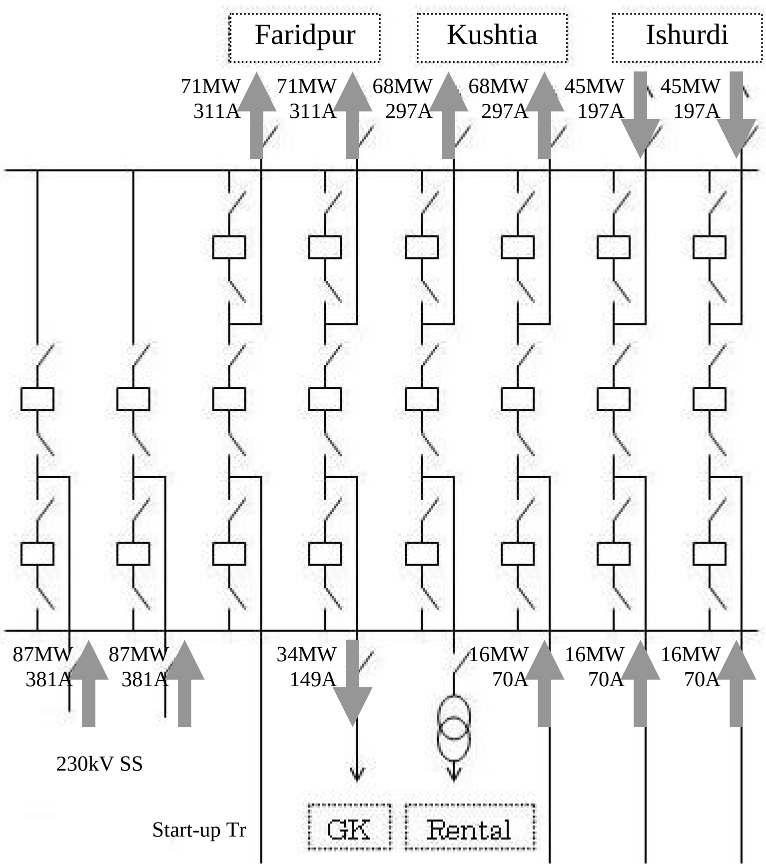


Figure I-5-5-14 Power Flow at 132kV Substation
(Tripping at 230kV Bheramara-Jhenaidah One Circuit)

Table I-5-5-21 In Feed Capacity of feeders at 132kV substation

In Feed	Normal		Accident Case	
	MW	Ampere	MW	Ampere
Generator	48	210	48	210
230kV SS	154	674	174	762
Ishurdi	76	332	90	394

Table I-5-5-22 Load Capacity of feeders at 132kV substation

Load	Normal		Accident Case	
	MW	Ampere	MW	Ampere
Faridpur	136	594	142	622
Kushtia	106	464	136	594
GK	34	149	34	149
Total	276	1,207	312	1,365

5.5.16 Transmission Line

(1) Outline of connection with transmission line

The location of existing 230kV line that is connected with new Bheramara power station is shown in Figure I-5-5-15. Existing 132kV line is passing between existing 230kV line and

new Bheramara power station, and it is necessary to cross over the existing 132kV line in order to connect existing 230kV line and Bheramara power station.
As for the tower that is modified to connect the existing 230kV line and new Bheramara power station, dead end tower near new Bheramara power station should be selected.

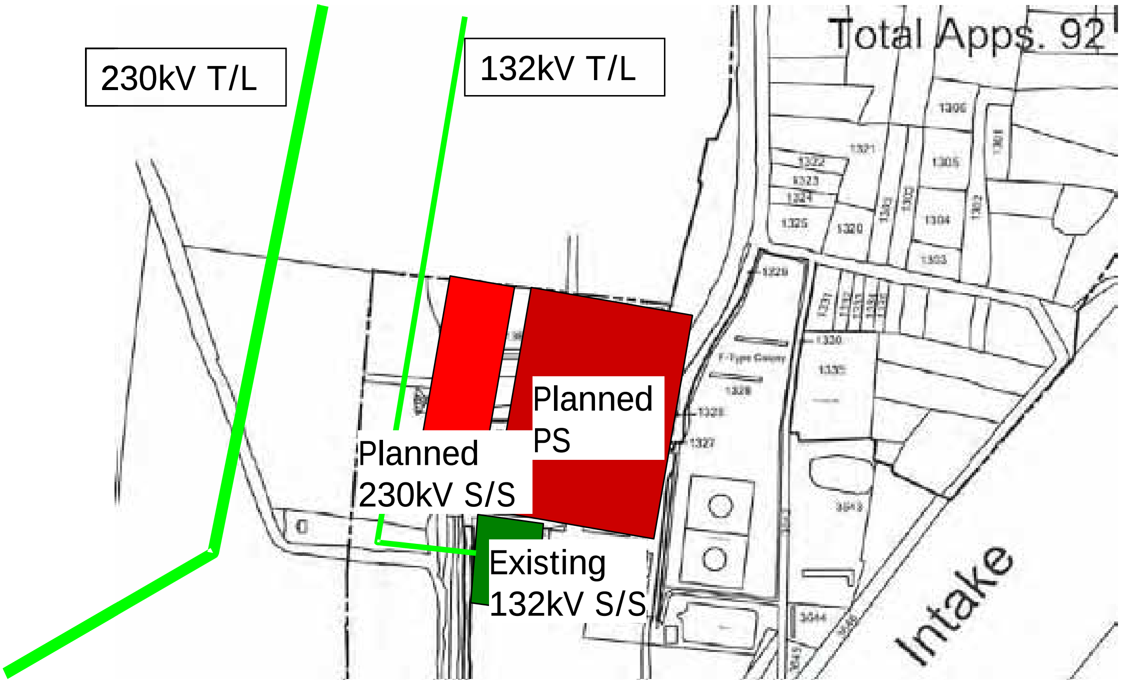


Figure I-5-5-15 Transmission system around Bheramara power station

(2) Condition of design of facilities

This project locates close to existing 230kV line, and weather and geological condition of this project is the same as the condition of existing 230kV. Therefore, design criteria of existing 230kV line should be applied for this project.

1) Conductor and Ground wire

Technical characteristics of conductor and ground wire applied for this project are shown on Table I-5-5-23. For this project, two (2) ground wires are installed, and one of those ground wires is OPGW.

Table I-5-5-23 Technical characteristics of conductor, ground wire and OPGW

	Conductor	Ground wire	OPGW
Type	AAAC	S	-
Standard	ASTM B399	BS 183	IEC 61089
Component of strand wires	37/4.176 mm	7/4.0 mm	-
Overall diameter	29.23 mm	12 mm	Less than 12 mm
Weight	1399 kg/km	690 kg/km	Less than 690 kg/km
Ultimate tensile strength	146.10 kN	74.80 kN	-

The number of conductor is two (2), and its interval is 450mm.

2) Load condition on conductor and ground wire

Load condition on conductor and ground wire is shown on Table I-5-5-24.

Table I-5-5-24 Load condition on conductor and ground wire

	Conductor	Ground wire	OPGW
Maximum load condition			
Maximum tension	73.05 kN	37.40 kN	50% of ultimate tensile strength
Wind pressure	1270 N/m^2	1595 N/m^2	1595 N/m^2
Temperature	5^{O}C	5^{O}C	5^{O}C
EDS condition			
Maximum tension	29.22 kN	14.96 kN	20% of ultimate tensile strength
Wind pressure	0 N/m^2	0 N/m^2	0 N/m^2
Temperature	30^{O}C	30^{O}C	30^{O}C

Sag of ground wire and OPGW should be designed to be less than 90% of conductor sag at 5 degree.

3) Insulator

Characteristics of insulator applied for this project is shown on Table I-5-5-25.

Table I-5-5-25 Characteristics of insulator

	Suspension/ Jumper Suspension	Heavy Suspension	Tension	Upright Low Duty Inverted Low Duty
Pollution Category	Medium II			
Nominal Creepage	4900 mm			
Insulator Unit Reference	U120B	U210B	U210B	U120B
Unit Puncture Voltage	110 kV	125 kV	125 kV	110 kV
Number of Insulator Units per string	17	14	2 x 14	17
Max. Insulator String length	2482 mm	2380 mm	2380 mm	2482 mm
Mechanical/ Electromechanical Failing load	120 kN	210 kN	210 kN	120 kN

4) Tower

Configuration of tower is double circuit three phase vertical formation, and its classification is shown on Table I-5-5-26.

Table I-5-5-26 Designation and use of towers

Designation	Angle of deviation/ Entry	Description	Type of insulator set
2DL	0^O	Intermediate	Suspension
2D1	0^O-10^O	Angle	Heavy suspension
2D25	10^O-25^O	Angle/ Section	Tension
2DT6	25^O-60^O 0^O-30^O	Angle Terminal	Tension Tension

Several types of leg extensions are prepared depending on the designation of tower. It is shown on Table I-5-5-27.

Table I-5-5-27 Leg extensions

Designation	Range of leg extensions
2DL, 2D25, 2DT6	1.5m, 3.0m, 4.5m, 6.0m, 9.0m
2D1	1.5m, 3.0m, 4.5m, 6.0m, 9.0m, 12.0m, 15.0m, 18.0m, 21.0m, 25.0m

5) Condition of tower design

Span length applied to tower design at intact conditions and broken wire conditions are shown on Table I-5-5-28 and 29.

Table I-5-5-28 Span length for tower design at intact conditions

Suspension and tension tower		
Wind span		420 m
Maximum weight span	Suspension tower	760 m
	Tension tower	760 m
Minimum weight span	Suspension tower	180 m
	Tension tower	0 m
Dead end tower		
Wind span		315 m
Maximum weight span		570 m
Minimum weight span		0 m

Table I-5-5-29 Span length for tower design at broken wire conditions

Suspension and tension tower		
Wind span		315 m
Maximum weight span	Suspension tower	570 m
	Tension tower	570 m
Minimum weight span	Suspension tower	130 m
	Tension tower	0 m

All specified wind spans have been adjusted for spatial effects using the expression (wind span x 0.75 + 30m) for tower design purpose.

6) Clearance

The minimum clearance is shown on Table I-5-5-30. Maximum conductor temperature is 80 degree.

Table I-5-5-30 Minimum clearance

Object	Minimum clearance
Ground	8.0 m
Roads	9.0 m
Building, structure, wall, etc	6.0 m
Trees	4.5 m
Shrubs	4.0 m
Railway	10.0 m

In case, transmission line crosses the other transmission line, its clearance is shown on Table I-5-5-31. Temperature of conductor of higher transmission line is 80 degree, and temperature of conductor or ground wire of lower transmission line is 5 degree.

Table I-5-5-31 Minimum clearance at crossing point

Object	Minimum clearance
Between upper side conductor and lower side ground wire	4.6 m
Between upper side tower and lower side conductor	15.0 m

(3) Design of crossing point with 132kV line

The location of tower for this project line should be determined based on the cost, environmental aspect, above mentioned criteria and so on.
Followings are the main points that should be considered.

- Dead end tower near new Bheramara power station should be used to connect existing 230kV line with new Bheramara power station.
- As for the crossing point, the position where conductor/ ground wire of existing 132kV line is low should be selected as much as possible.
- In order to reduce the conductor dip of cross point, tower location should be selected, i.e. crossing at right angle with existing 132kV line, construction near existing 132kV line, etc.
- It is necessary to avoid passing over the Mosque near Bheramara power station.

1) Location of tower, etc by GPS

Locations of existing tower of 230kV line and 132kV line, mosque and so on were obtained by GPS, and those are shown on Table I-5-5-32.

Table I-5-5-32 Coordinate data

Object	North latitude	East longitude	Note
Tower A of 132kV line	24°3′7.1″	89°0′56.4″	
Tower B of 132kV line	24°2′56.6″	89°0′57.4″	
Tower A of 230kV line	24°3′11.8″	89°0′53.0″	Dead end tower
Tower B of 230kV line	24°3′3.4″	89°0′51.1″	Suspension tower
Tower C of 230kV line	24°3′54.8″	89°0′49.1″	Dead end tower
Mosque	24°2′57.7″	89°0′53.5″	

2) Contents of design

There are two (2) methods to cross over existing 132kV line by using standard tower applied by PGCB. One is the application of high gantry (special gantry), and the other is the reduction of the conductor height of existing 132kV line. Both cases are studied in this project.

a. Case 1 (Application of special gantry)

Figure I-5-5-16 shows the overview using special gantry.

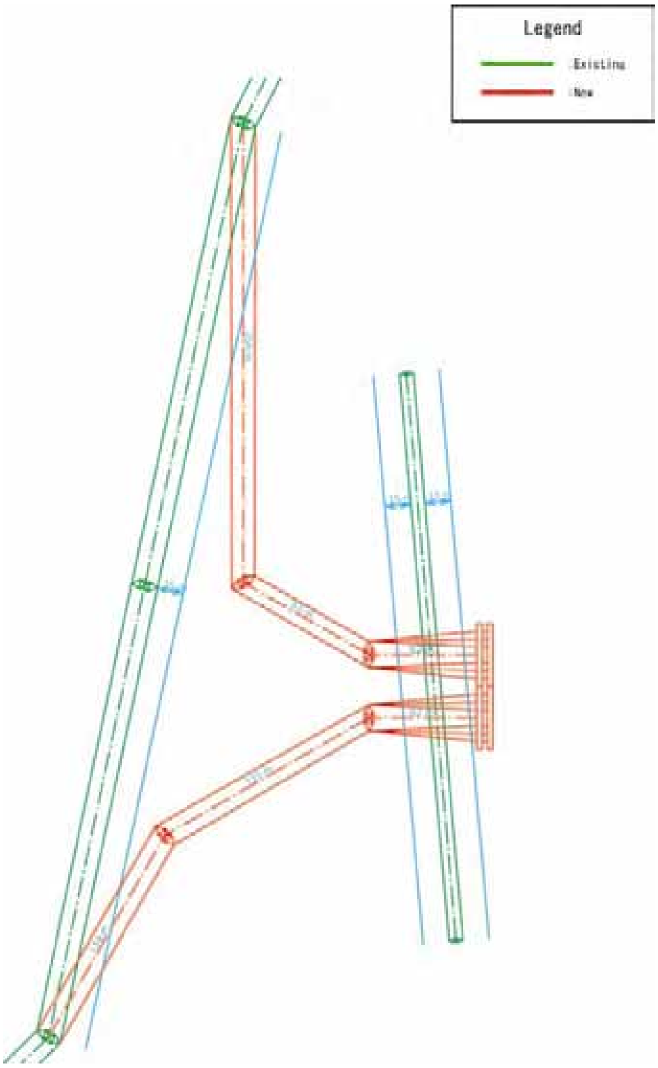


Figure I-5-5-16 Overview using special gantry

Figure I-5-5-17 shows the profile of existing 132kV line, and the height of ground wire is less than 24 meters.

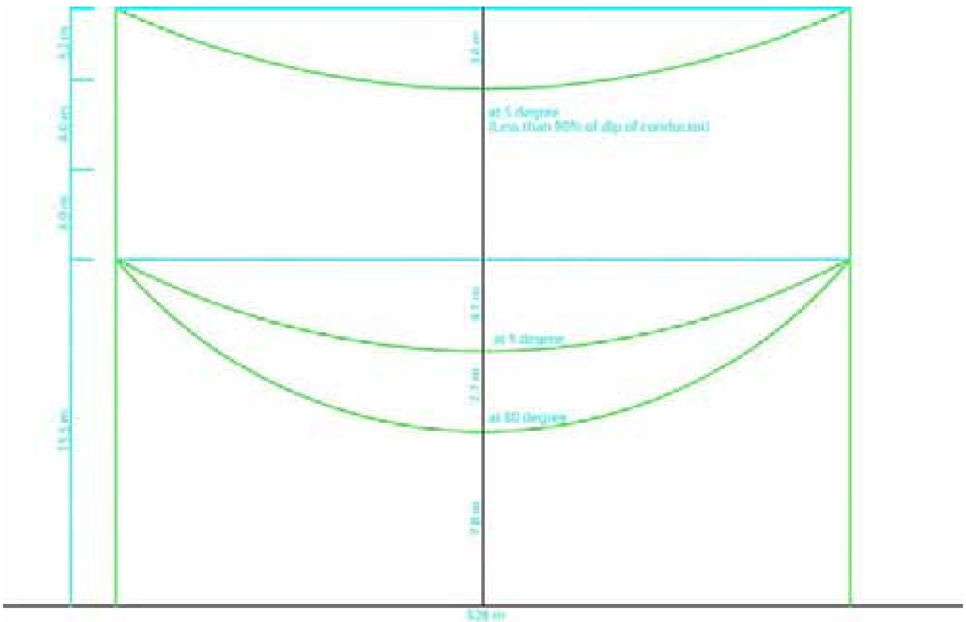


Figure I-5-5-17 Profile of existing 132kV line

The study of crossing point of existing 132kV line was carried out based on the above-mentioned results, and it was confirmed that leg extension of tower should be 9 meters and that the height of gantry should be 35 meters in order to satisfy the necessary clearance.

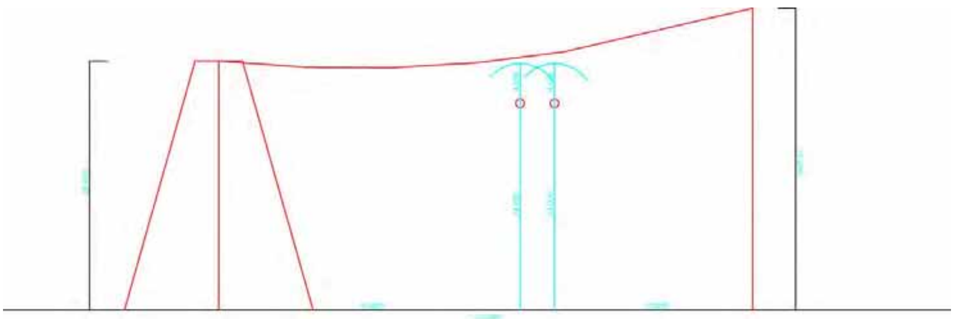


Figure I-5-5-18 Profile of 230kV line at crossing point of existing 132kV line

As for the type of tower between existing 230kV line and existing 132kV line should be 2DT6, because the deviation angle is more than 25 degree.

b. Case 2 (Reduction of conductor height of existing 132kV line)
Figure I-5-5-19 shows the overview by reduction of conductor height of existing 132kV line.

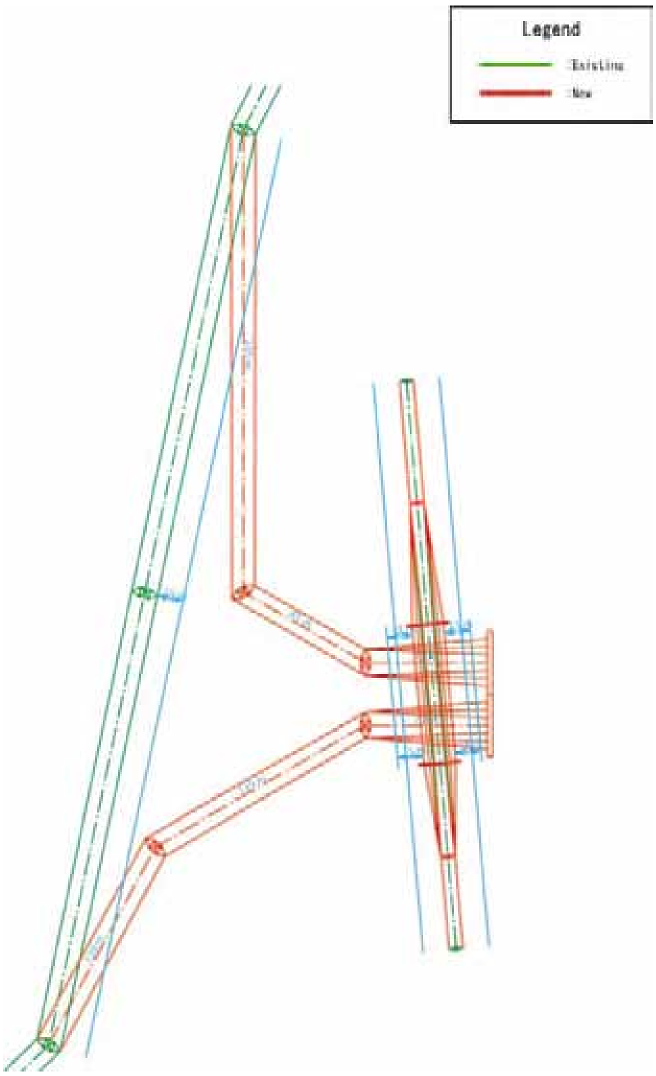


Figure I-5-5-19 Overview by reduction of conductor height of existing 132kV line

As a result, the height of ground wire is less than 13.5 meters at the crossing point. In addition, it is necessary to construct the new tower between existing tower and new gantry in order to satisfy the necessary clearance from ground, because the tension between existing tower and gantry is low.

Figure I-5-5-20 shows its profile.

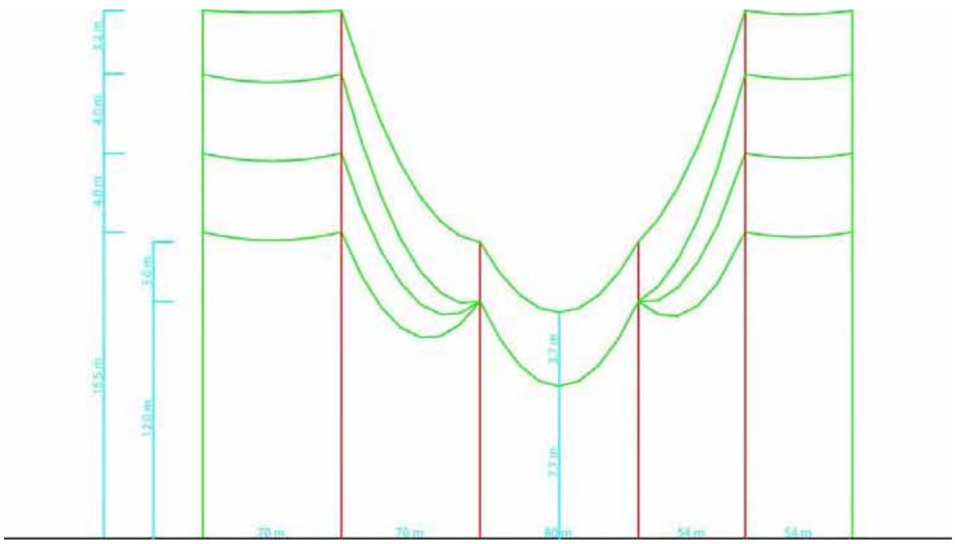


Figure I-5-5-20 Profile of 132kV line after the adoption of height reduction

The study at the cross point of transmission line was carried out based on the above profile. It was confirmed that the extension of tower should be 3 meters using standard gantry (17 meters height) in order to satisfy the necessary clearance.

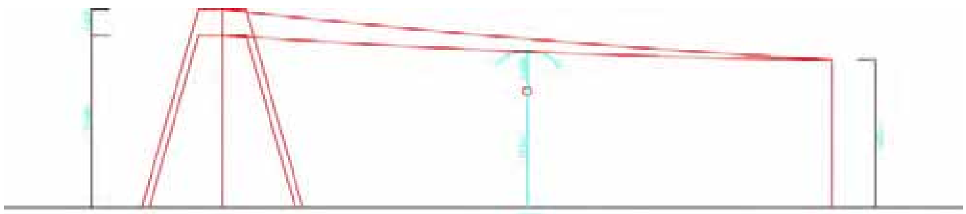


Figure I-5-5-21 Profile of 230kV line at the crossing point of 132kV line

As for the type of tower between existing 230kV line and existing 132kV line should be 2DT6, because the deviation angle is more than 25 degree.

(4) Quantities of line materials

Quantities of line materials are shown as follows.

Case 1

Tower (2DT6, Leg extension 0m)	2 units
Tower (2DT6, Leg extension 9m)	2 units
Special gantry for 230kV line	2 units
Double tension set (including insulator disc)	48 sets (for new tower) 12 sets (for existing tower)
Insulator set for gantry	12 sets (for special gantry) 12 sets (for standard gantry)
Spacer damper	24 span-phase
Tension set for GW	8 sets (for new tower) 2 sets (for existing tower) 2 sets (for special gantry) 2 sets (for standard gantry)
Damper for GW	8 sets (for new tower) 2 sets (for existing tower)

	2 sets (for special gantry)
	2 sets (for standard gantry)
Tension set for OPGW	8 sets (for new tower)
	2 sets (for existing tower)
	2 sets (for special gantry)
	2sets (for standard gantry)
Damper for OPGW	8 sets (for new tower)
	2 sets (for existing tower)
	2 sets (for special gantry)
	2 sets (for standard gantry)
Conductor	1 km
GW (1)	1 km
OPGW (1)	1 km

Case 2

For 230kV line

Tower (2DT6, Leg extension 0m)	2 units
Tower (2DT6, Leg extension 3m)	2 units
Double tension set (including insulator disc)	48 sets (for new tower) 12 sets (for existing tower)
Insulator set for gantry	12 sets (for gantry)
Spacer damper	24 span-phase
Tension set for GW	8 sets (for new tower)
	2 sets (for existing tower)
	2 sets (for gantry)
Damper for GW	8 sets (for new tower)
	2 sets (for existing tower)
	2 sets (for gantry)
Tension set for OPGW	8 sets (for new tower)
	2 sets (for existing tower)
	2sets (for gantry)
Damper for OPGW	8 sets (for new tower)
	2 sets (for existing tower)
	2 sets (for gantry)
Conductor	1 km
GW (1)	1 km
OPGW (1)	1 km

For 132kV line

Tower (1DT6, Leg extension 0m)	2 units
Special gantry for 132kV line	2 units
Double tension set (including insulator disc)	24 sets (for new tower) 12 sets (for existing tower)
Insulator set for 132kV special gantry	24 sets (for gantry)
Damper	4 span-phase
Tension set for OPGW	4 sets (for new tower)
	2 sets (for existing tower)
	4sets (for special gantry)
Damper for OPGW	4 sets (for new tower)
	2 sets (for existing tower)

	4 sets (for special gantry)
Conductor	0.5 km
OPGW (1)	0.5 km

Quantities of this project are not so much and the specification is the same as other 230kV line project. Therefore, spare parts and tools are not included for this project.

(5) Construction cost for transmission facilities

Construction cost for transmission facilities is estimated by multiplication of above mentioned quantities and standard unit prices (including labor cost). The standard unit prices have been prepared referring to the recent contract prices of such international competitive bidding projects as “Baghabari – Serajganj – Bogra –Double Circuit Line”.

The result of case 1 and case 2 are shown in Table I-5-5-33 and Table I-5-5-34 respectively.

Table I-5-5-33 Construction cost for transmission facilities (Case 1)

				Foreign Currency (FC) Price (in EURO)							Local Currency (LC) Price (in Taka)			
Item	Description	Unit	Qty	Unit Price FOB	Total Price	Insurance	Freight	Total Price CIF	Erection Cost	Total F/C Cost	Local Transport & Handling Cost	Local Insurance	Election Cost	Total L/C Cost
A1	Towers													
	Tower type 2DT6 Standard	each	2	32,683.00	65,366.00	300.00	3,690.00	69,356.00		69,356.00	111,728.00	2,012.00	279,318.00	393,058.00
	Tower type 2DT6 E9	each	2	44,778.00	89,556.00	410.00	5,066.00	95,032.00		95,032.00	155,306.00	2,798.00	388,264.00	546,368.00
	Special Gantry	each	2	44,778.00	89,556.00	410.00	5,066.00	95,032.00		95,032.00	155,306.00	2,798.00	388,264.00	546,368.00
A2	Insulator & Fittings													
	230kV, twin 210kN tension set for twin 37/4.176 AAAC	each	60	1,412.00	84,720.00	255.90	1,319.10	86,295.00		86,295.00				
	230kV, single inverted low duty tension set for twin 37/4.176 AAAC	each	24	458.00	10,992.00	33.00	319.00	11,344.00		11,344.00				
	Spacer Damper for twin 37/4.176 AAAC for all six phases	span-phase	24	23.00	552.00	2.00	24.00	578.00		578.00				
	Tension set for 7x4.0mm GSW earthwire	each	14	16.00	224.00	1.00	14.00	239.00		239.00				
	Vibration damper for 7x4.0mm GSW earthwire	each	14	6.00	84.00	0.00	4.00	88.00		88.00				
	OPGW (7x4.0mm S earthwire equivalent) tension set, complete assembly	each	14	85.00	1,190.00	3.00	41.00	1,234.00		1,234.00				
	Vibration damper for 7x4.0mm S earthwire equivalent OPGW	each	14	31.00	434.00	4.00	13.00	451.00		451.00				
A3	Phase conductor, earthwire and OPGW													
	Phase conductor 37/4 AAAC including the necessary midspan joints and repair sleeves, six nos. twin conductors on the line	route-km	1	40,871.00	40,871.00	123.47	41,935.70	82,930.17		82,930.17	73,440.00	1,323.00	293,760.00	368,523.00
	7x4.00mm S earthwire including the necessary midspan joints and repair sleeves, one earthwire on the line	route-km	1	723.00	723.00	2.18	771.30	1,496.48		1,496.48	6,630.00	119.44	26,520.00	33,269.44
	7x4.00mm S earthwire equivalent OPGW inclusive of joint boxes, fixing clamps, fusion splices and connections to the joint boxes, one OPGW on the line	route-km	1	3,922.00	3,922.00	11.85	4,036.45	7,970.30		7,970.30	7,650.00	1,399.00	194,132.00	203,181.00
	Modification of existing facilities	Unit	2										180,000.00	180,000.00
	Total									452,045.95				2,270,767.44

Table I-5-5-34 Construction cost for transmission facilities (Case 2)

				Foreign Currency (FC) Price (in EURO)							Local Currency (LC) Price (in Taka)			
Item	Description	Unit	Qty	Unit Price FOB	Total Price	Insurance	Freight	Total Price CIF	Erection Cost	Total F/C Cost	Local Transport & Handling Cost	Local Insurance	Election Cost	Total L/C Cost
A1	Towers													
	Tower type 2DT6 Standard	each	2	32,683.00	65,366.00	300.00	3,690.00	69,356.00		69,356.00	111,728.00	2,012.00	279,318.00	393,058.00
	Tower type 2DT6 E3	each	2	39,701.00	79,402.00	364.00	4,488.00	84,254.00		84,254.00	119,840.00	2,158.00	299,600.00	421,598.00
A2	Insulator & Fittings													
	230kV, twin 210kN tension set for twin 37/4.176 AAAC	each	60	1,412.00	84,720.00	255.90	1,319.10	86,295.00		86,295.00				
	230kV, single inverted low duty tension set for twin 37/4.176 AAAC	each	12	458.00	5,496.00	17.00	160.00	5,673.00		5,673.00				
	Spacer Damper for twin 37/4.176 AAAC for all six phases	span-phase	24	23.00	552.00	2.00	24.00	578.00		578.00				
	Tension set for 7x4.0mm GSW earthwire	each	12	16.00	192.00	1.00	12.00	205.00		205.00				
	Vibration damper for 7x4.0mm GSW earthwire	each	12	6.00	72.00	0.00	3.00	75.00		75.00				
	OPGW (7x4.0mm S earthwire equivalent) tension set, complete assembly	each	12	85.00	1,020.00	3.00	35.00	1,058.00		1,058.00				
	Vibration damper for 7x4.0mm S earthwire equivalent OPGW	each	12	31.00	372.00	3.00	11.00	386.00		386.00				
A3	Phase conductor, earthwire and OPGW													
	Phase conductor 37/4 AAAC including the necessary midspan joints and repair sleeves, six nos. twin conductors on the line	route-km	1	40,871.00	40,871.00	123.47	41,935.70	82,930.17		82,930.17	73,440.00	1,323.00	293,760.00	368,523.00
	7x4.00mm S earthwire including the necessary midspan joints and repair sleeves, one earthwire on the line	route-km	1	723.00	723.00	2.18	771.30	1,496.48		1,496.48	6,630.00	119.44	26,520.00	33,269.44
	7x4.00mm S earthwire equivalent OPGW inclusive of joint boxes, fixing clamps, fusion splices and connections to the joint boxes, one OPGW on the line	route-km	1	3,922.00	3,922.00	11.85	4,036.45	7,970.30		7,970.30	7,650.00	1,399.00	194,132.00	203,181.00
	Modification of existing facilities	Unit	2										180,000.00	180,000.00
B1	Towers													
	Tower type 1DT6 Standard	each	2	11,955.97	23,911.94		1,408.06	25,320.00	242.66	25,562.66	37,716.00		77,000.00	114,716.00
	Gantry for 132kV line	each	2	4,907.16	9,814.32		577.92	10,392.24	135.52	10,527.76	15,480.00		43,000.00	58,480.00

				Foreign Currency (FC) Price (in EURO)							Local Currency (LC) Price (in Taka)			
Item	Description	Unit	Qty	Unit Price FOB	Total Price	Insurance	Freight	Total Price CIF	Erection Cost	Total F/C Cost	Local Transport & Handling Cost	Local Insurance	Election Cost	Total L/C Cost
B2	Insulator & Fittings													
	132kV, single 120kN tension set for 37/3.59 AAAC	each	36	244.00	8,784.00	14.00	185.00	8,983.00	108.00	9,091.00			2,090.00	2,090.00
	132kV, single inverted low duty tension set for 37/3.59 AAAC	each	24	176.00	4,224.00	6.00	82.00	4,312.00	120.00	4,432.00			6,480.00	6,480.00
	Vibration damper for 37/3.59 AAAC	span-phase	4	15.00	60.00	1.00	10.00	71.00	2.00	73.00			200.00	200.00
	OPGW (7x3.25mm S earthwire equivalent) tension set, complete assembly	each	10	67.00	670.00	1.00	22.00	693.00	10.00	703.00			650.00	650.00
	Vibration damper for 7x4.0mm S earthwire equivalent OPGW	span-phase	10	15.00	150.00	1.00	22.00	173.00	5.00	178.00			650.00	650.00
B3	Phase conductor, earthwire and OPGW													
	Phase conductor 37/3.59 AAAC including the necessary midspan joints and repair sleeves, six nos. single conductor on the line	route-km	0.5	12,778.00	6,389.00	36.00	75.00	6,500.00	161.00	6,661.00			44.00	44.00
	7x4.00mm S earthwire equivalent OPGW inclusive of joint boxes, fixing clamps, fusion splices and connections to the joint boxes, one OPGW on the line	route-km	0.5	2,100.00	1,050.00	4.00	7.00	1,061.00	55.00	1,116.00			15.00	15.00
	Modification of existing facilities	Unit	2										100,000.00	100,000.00
	Total									398,621.37				1,882.954.44

(6) Recommended Case

Although case 2 is carried out at a low price comparing with case 1, case 1 is recommended because of the system reliability during construction, the length of construction period, complication of construction and so on.