HARYANA POWER GENERATION CORPORATION LTD.

DETAILED FEASIBILITY REPORT

(FINAL)

FOR

800 MW COAL BASED POWER PLANT AT PANIPAT THERMAL POWER STATION, PANIPAT, HARYANA

SUBMITTED BY

(An ISO 9001:2008 certified Company)

STEAG Energy Services India Pvt. Ltd.

(Formerly Evonik Energy Services India Pvt. Ltd.)

(A wholly owned subsidiary of STEAG Energy Services GmbH, Germany)

A-29, Sector-16, NOIDA-201301, India

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ABBREVATIONS

AC	ALTERNATE CURRENT
ACW	AUXILIARY COOLING WATER
AHP	ASH HANDLING PLANT
BOP	BALANCE OF PLANT
BFP	BOILER FEED PUMP
BMCR	BOILER MAXIMUM CONTINUOUS RATING
BMS	BURNER MANAGEMENT SYSTEM
CACA	CLOSED AIR CIRCUIT AIR COOLED
CACW	CLOSED AIR CIRCUIT WATER COOLED
CEA	CENTRAL ELECTRICITY AUTHORITY
CERC	CENTRAL ELECTRICITY REGULATORY COMMISSION
CHP	COAL HANDLING PLANT
CRT	CATHODE RETUBE
CW	CIRCULATING WATER
COD	COMMERCIAL OF DATE
CRH	COLD RE-HEATER
DCRTPP	DEENBANDHU CHHOTU RAM THERMAL POWER PLANT
DCS	DISTRIBUTED CONTROL SYSTEM
DC	DIRECT CURRENT
DG	DIESEL GENERATOR
DFR	DETAILED FEASIBILITY REPORT
DM	DEMINERALISATION
ECL	EASTERN COALFIELDS LIMITED
EHG	ELECTRO HYDRAULIC GOVERNING SYSTEM
EPABX	ELECTRONIC PRIVATE AUTOMATIC BRANCH EXCHANGE
EOT	ELECTRIC OVERHEAD TURNING
EPC	ENGINEERING PROCUREMENT & CONSTRUCTION
ESP	ELECTRO STATIC PRECIPITATOR
FGD	FLUE-GAS DESULFURIZATION
GIS	GAS INSULATED SUBSTATION
GCV	GROSS CALORIFIC VALUE
HP	HIGH PRESSURE
HPGCL	HARYANA POWER GENERATION CORPORATION LIMITED
HRH	HOT REHEAT
HSEB	HARYANA STATE ELECTRICITY BOARD

HSD	HIGH SPEED DIESEL
HFO	HEAVY FUEL OIL
ICT	INTERCONNECTING TRANSFORMER
IDC	INTEREST DURING CONSTRUCTION
IP	INTERMEDIATE PRESSURE
LT	LOW TENSION
LP	LOW PRESSURE
KV	KILO VOLT
LDO	LIGHT DIESEL OIL
MCL	MAHANADI COALFIELDS LIMITED
MCR	MAXIMUM CONTINOUS RATING
MoEF	MINISTRY OF ENVIRONMENT & FORESTS
MW	MEGAWATT
MT	METRIC TONNE
MS	MAIN STEAM
NH	NATIONAL HIGHWAY
NCL	NORTHERN COALFIELDS LIMITED
O&M	OPERATION AND MAINTENANCE
OWS	OPERATOR WORK STATIONS
PCB	POLLUTION CONTROL BOARD
PLCC	POWER LINE CARRIER COMMUNICATION
PLC	PROGRAMMABLE LOGIC CONTROLLER
PLF	PLANT LOAD FACTOR
PTPS	PANIPAT THERMAL POWER STATION
SCADA	SUPERVISORY CONTROL AND DATA ACQUISITION
SG	STEAM GENERATOR
STG	STEAM TURBINE GENERATOR
TEFC	TOTALLY ENCLOSED FAN COOLED
TETV	TOTALLY ENCLOSED TUBE VENTILATED
TMCR	TURBINE MAXIMUM CONTINUOUS RATING
TPS	THERMAL POWER STATION
TPH	TONN PER HOUR
UPSEB	UTTAR PRADESH STATE ELECTRICITY BOARD
UAT	UNIT AUXILIARY TRANSFORMER
VWO	VALVE WIDE OPEN

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The objective of the report is to establish the need of project, feasibility of the project at the suggested location, the techno-economic justification for selection of plant and equipment, financial analysis to work out the cost of generation, expenditure phasing and return on investment.

SALIENT FEATURES OF THE PROJECT

Location

The proposed supercritical unit will be located adjacent to the existing 1367.8 MW Panipat Thermal Power Plant at village Assan in Panipat district of Haryana. The proposed project site is situated on the Panipat Jind road about 11 km from Panipat Bus Stand. Panipat Thermal Power Station (PTPS) has a total installed generation capacity of 1367.8 MW comprising four units of 110 MW each (unit-1 up-rated to 117.8 MW), two units of 210 MW each and two units of 250 MW each.

Land

The total land requirement for the 800 MW is being met with the land available inside the PTPS plant boundary. The detailed facility wise land breakup is discussed in Chapter-3.

Water

Total raw water demand for proposed 800 MW unit is around 2600 m3/hr (25 Cusec). The water allocation sanctioned is 106.5 cusec from the Western Yamuna Canal, hence existing water allocation will be sufficient for proposed and existing unit (1x800MW+2x210MW+2x250MW).

Fuel

The estimated indigenous coal requirement is 3.55 million tonne per annum, considering gross calorific value of 3600 kcal/kg, 85% PLF and station heat rate of 2151 kcal/kWh. It has been confirmed by HPGCL that initially, coal for the proposed plant, shall be fed from coal linkage from Jharkhand (Dhori & South Karanpura). The coal will be unloaded at project site by wagon tippler or track hopper.

In view of the acute shortage of domestic coal, CEA has made mandatory for all the power stations to blend the domestic coal with imported coal in 70:30 ratio to meet the coal requirement. Therefore, in the DFR the blend of domestic coal of GCV 3600 kcal/kg and imported coal of GCV 5800 kcal/kg in 70:30 ratio has been considered for financial calculations and domestic coal has been considered for 800 MW plant design.

Power Evacuation

The power generated at 27 kV from the plant will be stepped to 400 kV voltage level through generator transformer and taken to a new 400 kV switchyard. The 400 kV switchyard will comprise 8 bays (1 no. generator bay, 1 no. station transformer bay, 1 bus reactor bay, 4 nos. line bays and 1 future bay). Subsequently, power will be evacuated through 2 nos. new 400 kV double circuit transmission lines to the 400 kV grid substations located at different load centres.

Technology and Capacity Selection

In order to improve the conversion efficiency and reduce the carbon footprint thrust is being given by the government to install supercritical units. A number of power generation utilities are going for supercritical technology and a large number of 660/800 MW unit sizes are under construction.

The generation efficiency of coal fired stations depends on the steam parameters adopted; higher the steam parameters higher the efficiency. The supercritical technology uses the steam pressure beyond the critical point of water/steam which is about 225 bar. Therefore, the supercritical units use higher steam pressure over 240 bar.

Any unit size from 660 MW to 800 MW of gross capacity at generator terminal having supercritical technology for the proposed plant can be considered, however, keeping in view the higher efficiency, improve heat rate and low per MW cost, 800 MW unit with supercritical technology has been proposed.

The schemes and the equipment parameters given in this report are suggestive only to demonstrate the techno economic feasibility of the proposed 800 MW unit.

Main steam pressure	-	247 bar
Main steam temperature	-	565ºC
Reheat steam temperature	-	593ºC

The above steam parameters support 800 MW units as efficient and proven supercritical units.

Project Schedule

It is estimated that the unit will be commissioned in 52 months. The date of issue of Letter of award for the project will be considered as the start date.

Project Cost & Tariff Projections

The project cost estimate for the proposed power plant has been worked out on the following basis:

a. Unit size considered is 800 MW with supercritical steam parameters.
b. The project is envisaged to be executed by a single EPC Contract or through a number of 4 or 5 split contracts. Site development and enabling works will be carried out by Haryana Power Generation Corporation Ltd. (HPGCL) through local contractors.
c. For the Balance of Plant (BOP), the cost estimate will be developed based on the rating / size of the equipment estimated and from in-house database of the consultant.
d. The cost of general civil and architectural works of the plant will be based on similar works for recently completed projects.
e. The economic plant life will be taken as 25 years for depreciation calculation as per CERC norms.
f. The interest during construction (IDC) will be calculated based on project schedule and ruling interest rates on loans.
g. The total time period is estimated to be 52 months for the unit of 800 MW from “zero date” up to date of commercial operation. Zero date is the date of award of contract for the project. IDC will be provided upto the date of commercial operation.
h. The project is proposed to be financed with 30% equity and 70% debt. Equity will be totally in rupee currency. The debt will have both rupee and foreign currency components. Exact financial package details will be finalized by HPGCL after discussion with prospective national and internaitonal lenders.

The estimated Capital Cost (including IDC) has been taken as Rs. 44189 million. The total levelised tariff has been arrived as Rs. 4.37/kWh (fixed cost - Rs. 1.65/kWh variable cost - Rs. 2.73/kWh). The first year tariff works out to Rs 4.64/kWh (fixed cost - Rs. 1.91/kWh variable cost - Rs. 2.73/kWh).

Project Viability

The viability of any project depends on the following parameters:

1. Land Availability
2. Water Availability
3. Fuel Availability
4. Infrastructure Development
5. Power evacuation arrangement
6. Ash Disposal arrangement
7. Rate of sale of power

The proposed unit being an extension of existing power plant, the availability of land water and fuel for proposed unit is adequate. Infrastructure and power evacuation requirement of proposed unit is adequate. The existing ash dyke is sufficient to accommodate the ash generated from the proposed unit. Rate of sale of per unit power is also justifiable. Considering the above aspects, the proposed unit at Panipat Thermal Power Station appears to be viable.

The coordinates of main structure and component have been shown in plot plan. The reference and detailing of the various components (Coordinate etc.) will be a part of Detailed Project Report. The details of pipeline corridors are also part of DPR. However indicative pipelines have been shown in plot plan.

Construction yard - FGD area (shown in plot plan) of proposed unit will be used as construction yard.

1.0 INTRODUCTION

INTRODUCTION

Haryana is one of the forerunner state to initiate reforms in its power sector in 1997. Pursuant to these reforms the State Electricity Board was unbundled and reorganized on August 14, 1998. Two wholly State-owned utilities were established to independently perform the functions of generation, transmission and distribution of power. Subsequently, two more Utilities were created for looking after power distribution.

HPGCL was incorporated as a company on 17th March, 1997 and was given the responsibility of operating and maintaining the State's own generation projects. The business of generation of power of erstwhile HSEB was transferred to HPGCL pursuant to power reforms in Haryana. As a result, HPGCL came into existence on August 14, 1998 for bringing in excellence in power generation in the State's own generating stations. In addition, it has been entrusted with the responsibility of setting up of new generating stations in order to keep pace with the ever –increasing demand of power.

The Corporation has an ambitious plan to add sufficient generating capacity in the State in order to bridge the gap between demand and supply. Two Units of 300 MW each were commissioned during FY 2008-09 at Deenbandhu Chhotu Ram Thermal Power Plant at Yamuna Nagar. The two units of 600 MW capacity each at Rajiv Gandhi Thermal Power Plant, Khedar, Hisar were commissioned in a record period of 43 and 49 months respectively, as compared to the norms of 44 and 50 months as stipulated by CEA. Additional 660 MW Unit with Supercritical Technology is being set up at Yamuna Nagar, as an expansion of the existing coal based 2x300 MW DCRTPP Yamuna nagar. The Haryana Power Generation Corporation Ltd. (HPGCL) has embarked on a mission to establish itself as a modern, growth oriented organization and is committed to powering Haryana's growth on all fronts by maximizing generation and minimizing the cost of power from existing plants as well as by planning and implementing new generation projects.

The Corporation has an ambitious plan to add sufficient generating capacity in the State in order to bridge the gap between demand and supply. It is in this context HPGCL proposes to set up a 800 MW coal fired power plant on the land available at Panipat thermal power station in Haryana.

2.0 SALIENT FEATURES

SALIENT FEATURES

2.1 SALIENT FEATURES

Agency	Haryana Power Generation Corporation Limited
Name of the project	9^{th} Unit at Panipat Thermal Power Plant
Capacity of the existing power plant	1367.8 MW (1x 117.8 + 3x110+2x210+2x250)
Capacity of the proposed power plant	800 MW
Location	Near village Assan Khurd, Panipat, Haryana.
Access to site	By Road - Jind road at about 11 kms from Panipat Bus Stand. Railway Station - Panipat
Availability of land	The total land requirement for the 800 MW is being met with the land available inside the PTPS plant boundary.
	The Project site is located at a latitude of 29°23'40.39" N and longitude of 76°53'8.26" E.
	Number of evictees – Nil
	Villages affected – Nil
	Flora and fauna – No wild life and no archaeological monument exist near the proposed project site.
Availability of coal, analysis, coal requirement and ash generated	
i) Source	Domestic coal for the proposed plant shall be sourced from Jharkhand (Dhori & South Karanpura) and imported coal from prospective suppliers of the world.
ii) Coal quality	A blend of indigenous (GCV 3600 kcal/kg) and imported (GCV 5800 kcal/kg) coal in 70:30 ratio as per CEA guidelines has been considered for financial calculations. However, 800 MW proposed plant has been designed on domestic coal in the DFR.
iii) Coal requirement	The annual requirement of domestic coal for the 800 MW power plant is estimated at 3.55 million tonnes considering heat rate of 2151 kcal/kWh, GCV of domestic coal 3600 kcal/kg and plant load factor of 85%.
iv) Ash generated	Estimated quantity of ash produced from the plant at 85% PLF is 1.49 million tonnes per annum.
v) Ash Utilization Plan	Ash will be utilized as per MOEF guidelines. Prospective users like cement plants, bricks

	and concrete block manufactures shall be identified and developer will fulfil guidelines.
Availability of water	The water requirement for the project shall be met from the Western Yamuna Canal. Estimated total consumptive water requirement for the project is about 2600 m^3/hr. The Western Yamuna Canal is running at a distance of 7-8 km from the proposed site.
Technical parameters of major equipment	
i) Steam generator	The steam generator (SG) would be designed for firing 100% coal and would be once - through boiler. The SG would be provided with adequate number of coal mills along with gravimetric feeders.
ii) Steam turbine generator	The MCR rating of the steam turbine generator (STG) would be 800 MW at the generator terminals, with valve wide open capacity of 105% MCR. Steam turbine would be a three cylinder machine.
iii) Stack	One 275 m high single flue stack for 800 MW unit.
iv) Power evacuation	Power will be evacuated through 2 nos. 400 kV double circuit transmission lines.
Project schedule	52 months
Project cost	Rs. 44189 millions.

3.0 PLANT LOCATION & INPUT REQUIRED

PLANT LOCATION & INPUTS REQUIRED

3.1 PLANT LOCATION AND ACCESS

The project site is located adjacent to the existing units of Panipat Thermal Power Station (PTPS) near village Assan in Panipat district of Haryana.The proposed project site is about 11 km from Panipat Bus Stand and accessible through Panipat Jind road . The nearest railway station from plant is Panipat.

Panipat Thermal Power Station (PTPS) has a total installed generation capacity of 1367.8 MW comprising four units of 110 MW each (unit-1 up-rated to 117.8 MW), two units of 210 MW each and two units of 250 MW each.

Haryana state map is shown as **Annexure-3.1** and the Panipat district map is attached at **Annexure-3.2**.

Satellite image of proposed site is shown at **Annexure-3.3.**

3.2 PLANT LAYOUT

The layout of the plant is shown at **Exhibit-3.1.** The plot plan shows the location of the Main Plant equipment and balance of plant. The plant layout has been developed keeping in mind the shape and size of the available land, clearance from existing facilities, best utilization of existing facilities, corridor for outgoing transmission lines, road/rail approaches, the water intake from Western Yamuna canal and the associated pipe corridor. The cooling tower has been located considering the safe distances from the switchyard and the main plant near water intake side. The water treatment plant and the DM water facilities are located near the main plant.

3.3 INPUTS REQUIRED FOR PROPOSED PROJECT

Besides the infrastructure logistics, the basic input requirements for the proposed project include:

i) Land
ii) Access
iii) Water
iv) Fuel
v) Construction power
vi) Power evacuation

3.3.1 Land

The break-up of land requirement for proposed 800 MW unit is as under:

S. No.	Particular	Required land for green field project (acres)	Available land for proposed extension unit within PTPS (acres)	Remarks
1.	Main plant and its auxiliaries area including chimney and switchyard	50	50	The land is available within plant boundary
2.	Balance of plant	50	50	The land is available within plant boundary

S. No.	Particular	Required land for green field project (acres)	Available land for proposed extension unit within PTPS (acres)	Remarks
3.	Water Reservoir	20	20	The estimated land requirement of 20 acres for the green field 800 MW unit has been worked out of storage. Since the available 20 acres of land for 800 MW (Unit-9) and 210 MW (Unit-5) unit (considering unit-1 to 4 will be phased out) will be sufficient for storage.
4.	CHP (stock pile area)	17	17	The estimated storage area requirement for the proposed 800 MW unit is 17 acres. However, the existing stock pile area of 17 acres (available for units #1 to 4 of 110MW each) would be adequate for the proposed unit.
5.	CHP, Water and AHP corridor	30	30	Existing land can accommodate the facility inside the plant boundary.
6.	Ash Dyke including green belt	-	-	The existing ash disposal area for unit 1 to 6 will also be utilised for disposal of ash to be generated from unit-9 (800 MW) PTPS. The existing ash dyke will be raised by 16 mtr. (in 3 stages) beyond EL 116.25 mtr. and thus additional capacity of 197 lacs cum will be created. This will be sufficient for the whole plant life. (HPGCL Letter attached as Annexure-3.4)
7.	Green Belt	50	50	The land is available within plant boundary
	Total Area	**217**	**217**	

The total land requirement for the 800 MW proposed unit is 217 acres which is being met with the available land within the plant boundary of PTPS.

Construction yard - FGD area (shown in plot plan) of proposed unit will be used as construction yard.

The site photographs are attached at the end of this report.

3.3.2 Access

The National Highway NH-1 passing through Panipat town is close to project site.

Construction of Road

The site is 11 km from Panipat bus stand and therefore the approach road connecting to NH-1 is to be strengthened. Internal roads with appropriate approach to different work centres need to be constructed.

Construction of Railway Access

The railway access is already there as the coal rakes are being received for existing units hence construction of fresh railway access is not required.

3.3.3 Water availability and conveyance

Total raw water demand for proposed 800 MW unit is around 2600 m3/hr (25 Cusec). The existing sanctioned water allocation is 106.5 cusec from the Western Yamuna Canal, hence existing water allocation will be sufficient for both proposed and existing units (1x800MW+2x210MW+2x250MW).

The W. Yamuna canal is around 7-8 kms from the proposed site. The pump house will be constructed at near the existing pump house.

3.3.4 Fuel availability and Transportation

The estimated requirement of domestic coal is 3.55 million tonne per annum, considering gross calorific value of domestic coal as 3600 kcal/kg, 85% PLF and station heat rate of 2151 kcal/kWh. It has been confirmed by HPGCL that initially, coal for the proposed plant, shall be fed from coal linkage from Jharkhand (Dhori & South Karanpura). According to CEA guidelines it is mandatory to use mix of domestic and imported coal in suitable proportion, however, CEA has recommended a mix in 70:30 ratio of domestic and imported coal respectively. For the DFR purposes, the plant has been designed for worst coal scenario i.e. on domestic coal but the financial calculations have been worked out using blended coal in 70:30 ratio. The imported coal will be sourced from prospective suppliers of the world.

Transportation of Coal to Plant Site

The domestic coal will be transported from coal fields to site by Indian Railways. It is envisaged that coal would be transported by Bogie Open High Sided Side discharge Wagon (BOX-N) or bottom opening broad guage rail (BOBR) wagons. As the HPGCL is getting imported coal for their existing units, the similar system will be used for transporting imported coal for the proposed unit also.

Start-up and Flame Stabilization Fuel

Start-up, warm up and low load (upto 30%) operation shall be carried out with LDO/HSD and HFO. Boiler will be so designed that oil firing for flame stabilization will not be required beyond 40% MCR. Ignition of heavy oil shall be directly by high-energy arc igniters. There shall be light diesel oil (LDO)/ HSD firing in at least one burner elevation to facilitate a cold start up of the unit when no auxiliary steam is available for HFO heating and atomization. HFO and LDO would be sourced from nearby oil refinery by railway tankers.

3.3.5 Construction Power

Construction power at 33 kV for the proposed plant can be drawn from the existing plant. The contactors will be required to arange their own diesel generating sets also.

3.3.6 Power Evacuation

The power generated from the plant will be stepped to 400 kV voltage level and taken to a new 400 kV switchyard. The proposed 400 kV switchyard will comprise 8 bays (1 no. generator bay, 1 no. station transformer bay, 1 bus reactor bay, 4 nos. line bays and 1 future bay). Power will be evacuated through 2 nos. new 400 kV double circuit transmission line to 400 kV grid substations located at different load centres.

3.4 ASH DISPOSAL

The estimated quantity of total ash produced from the plant is 200 TPH, which works out to 4818 tonnes per day and 1.49 million tonnes per annum at 85% PLF.

As per the MoEF notifications, a new coal based power station should make plans for 100% fly ash utilisation in a phased manner, within 4 years of commissioning. Hence, it is proposed to provide dry fly ash extraction and storage system to provide for fly ash utilisation and all possible measures will be undertaken to maximize utilization of ash produced. In order to fulfil MoEF guidelines on disposal of fly ash, developer will identify and ensure supply of required ash quality to prospective buyers like cement plants, bricks and concrete block manufactures.

As the sulphur content in domestic coal is low, a separate SOx removal system prior to discharge of flue gas from stack is not envisaged at this stage. However, as per the guidelines of CEA/MoEF, space provision will be kept for installation of FGD should statutes warrant the same at a later date. All plant emissions shall be maintained as per MOEF guidelines.

Fly ash utilization as per table-3.1 given below:

Table – 3.1, Fly Ash Utilization as per MOEF

Si. No.	Fly as utilization level	Target date
1.	At least 50% of fly ash generation	One year from the date of commissioning
2.	At least 70% of fly ash generation	Two year from the date of commissioning
3.	At least 90% of fly ash generation	Three year from the date of commissioning
4.	At least 100% of fly ash generation	Four year from the date of commissioning

4.0 SELECTION OF TECHNOLOGY AND UNIT SIZE

SELECTION OF TECHNOLOGY AND UNIT SIZE

4.1 SELECTION OF FUEL

Thermal power can be generated from liquid fuel, natural gas/LNG, lignite and coal. The proposed power plant is an extension of coal fired Panipat thermal power station (2x250 MW + 2x210 MW + 4x110 MW). Therefore the following points considered corroborate the selection of coal as a fuel for additional proposed unit.

1. The existing coal facility at power station can be extended for the proposed unit.
2. Existing clearances, permits and transportation facility for coal can be extended to new unit
3. Long term availability
4. Economical cost of generation as compared to other gas or liquid fuels.

4.2 FIRING ARRANGEMENTS FOR STEAM GENERATOR

For coal fired power plants, steam generator with any of the following firing arrangements is technically feasible:

- Atmospheric Fluidized Bed Combustion (AFBC)
- Circulating Fluidized Bed Combustion (CFBC)
- Integrated Gasification Combined Cycle (IGCC)
- Pulverized Fuel Firing (PF)

Atmospheric Fluidized bed boilers (AFBC) are in commercial use for quite some time in India. The technology is in a state of continuous development in India in order to burn inferior grades of fuel and considerable progress has been made towards perfecting the fluidized bed combustion for a wide band of fuels for capacity enhancement programs. Today in India, AFBC Boilers are more suited for power plants usually up to 40 MW capacities. This technology is not considered viable for the proposed plant in high capacity range.

Circulating Fluidized Bed Combustion (CFBC) technology is already in the market. Boiler manufacturers in India have also acquired the latest technology of CFBC boilers from overseas collaborators and the units are already in successful operation. CFBC is more suited for fuels having low calorific value and even those with higher sulphur content (>1%).

Integrated Gasification Combined Cycle (IGCC) technology and pressurized fluidized bed technology are at developmental stage even overseas. Plants using IGCC technology have limited operational experience even in advanced countries and are yet to be tried in India.

Pulverized Fuel Firing (PF) combustion is the most common and well proven among all the above technologies. PF fired boilers are most suited for higher capacity power plants and have the distinct advantage of better combustion efficiency with less auxiliary consumption as compared to any other technology in the market today.

The domestic coal used for the proposed station will have gross calorific value of 3400 to 3600 kcal/kg. With these considerations installation of pulverised coal fired boilers has been considered in this report.

4.3 CAPACITY SELECTION

For selecting the unit size and station configuration for the thermal power plant, important considerations are:

- Land availability
- Integration with existing facility
- Cost of energy generated from the station to be economical.
- Steady load requirement and low variations in maximum demand.
- Thermodynamic cycle efficiency.
- Operating flexibility for better load cycle.
- Station availability.
- Attainable Plant load factor.
- Specific investment requirement.
- Project timeframe and manpower requirement.
- Economic performance
- Environmental impact.

The choice of capacity for the coal fired station depends largely upon considerations of efficiency and adherence to environmental norms. Increase in steam parameters namely pressure and temperature lead to increase in efficiency, which in turn, reduces emission of greenhouse gases. Increase in steam pressure beyond 221 bar leads to supercritical conditions in the thermodynamic steam water cycle and results in sizeable efficiency improvement. While supercritical steam parameters can be applied to unit capacities of 300 MW and above, they have been more effective in capacity range of 600 MW and above.

Any unit size from 660 MW to 800 MW of gross capacity at generator terminal having supercritical technology for the proposed plant can be considered, however, keeping in view the higher efficiency, improve heat rate and low per MW cost, 800 MW unit with supercritical technology has been proposed.

The schemes and the equipment parameters given in this report are suggestive only to demonstrate the techno economic feasibility of the Panipat Thermal Power Station.

Main steam pressure	**:**	**247 bar**
Main steam temperature	**:**	**565ºC**
Reheat steam temperature	**:**	**593ºC**

Data from the units of the proposed size, which are in operation worldwide, indicate that an availability of above 85% is achievable.

5.0 DESCRIPTION OF MAJOR SYSTEMS

DESCRIPTION OF MAJOR SYSTEMS

5.1 INTRODUCTION

The equipment will be designed for a gross generation of 800 MW by single unit. A valve wide-open margin will be provided to increase the swallowing capacity of the steam turbine by 5%. With this the plant and facilities will be designed to give a gross generation of 800 MW. The major features of main plant equipment and systems are covered under this section.

5.2 STEAM GENERATOR AND ACCESSORIES

The steam generators shall be once through, single/double pass (Tower type/ two pass type), single reheat, radiant furnace, dry bottom, balanced draft, outdoor type, pulverised coal fired steam generating units having supercritical steam parameters with all necessary auxiliaries, integral piping, elevator etc.

The furnace will be radiant, dry bottom type with tangential or opposed wall firing and enclosed by water-cooled and welded membrane walls. The furnace bottom shall be suitable for installation of a water impounded bottom ash hopper. Spray type attemperator is envisaged to control the superheater outlet temperature for varying loads. The superheater and reheater tubes will be a combination of radiation and convector types. Economiser will be non- steaming type and shall be of modular construction so that addition of loops is possible.

The fuel oil system will be provided for boiler start up and for flame stabilization during low load operation with or without coal firing. Two (2) types of fuel oils will be used:

- Light Diesel Oil (LDO) for boiler start up (up to 10% of BMCR).
- Heavy Furnace Oil (HFO) for low load operation and flame stabilization for minimum capacity of 30% of BMCR.

The boiler auxiliaries /systems such as air heater, Electrostatic precipitators, fans etc shall also be designed to deliver maximum continuous rating when firing range coal. The boiler shall be capable of being started with LDO during cold start up. LDO shall have the facility for air atomization. The BMCR gross generation capacity shall be 2640 T/hr for 800 MW at 565 deg C. The reheat steam shall be heated to the temperature of 593°C. The reheat flow of the steam generator varies with the turbine load and operating condition. The parameters are worked out as per heat balance diagrams. For all conditions, re-heater flow is approximately 90% of main steam flow. The plant shall be suitable for variable pressure operation and in case of load rejection; boiler firing rate shall be brought down to a safe level to maintain stability of boiler. The boiler shall be suitable for accepting feed water at a lower temperature corresponding to HP heater out condition at TMCR. PLC / DCS based Burner Management System (BMS) shall be provided for the control, sequencing and protection of Steam Generator.

5.2.1 Electrostatic Precipitator

In the proposed design, flue gas from the air heater flows through the ESP before passing into the ID fans. The ID fans discharge the flue gas into the stack. The function of the electrostatic precipitator (ESP) system is to remove the particulate matter from the flue gases, so as to maintain the flue gas particulate emissions limit below the permitted level.

Adequate number of ESP units will be provided for each boiler. Each ESP unit consists of four parallel passes with requisite number of fields. High voltage power supply for each field shall be fed from a separate TR set unit. Type of emitting electrodes, collector plates and rapping mechanism shall be as per the standard proven design of the supplier.

The ESP will have a collection efficiency of around 99.9% or better. ESP shall be designed in such a way that the dust concentration level at outlet is maintained below 50 mg/Nm3 at TMCR with worst coal, to meet PCB norms, with one field in shutdown condition.

Fly ash collection hoppers will be located beneath each field. Fly ash will be collected by ESP hoppers of 8 hours storage capacity and removed periodically by pneumatic ash handling system.

5.3 STEAM TURBINE AND ACCESSORIES

5.3.1 Turbine

The steam turbine will be supercritical, multi-stage, multi cylinder, tandem compound, single reheat, regenerative, condensing design directly coupled with the generator; and suitable for indoor installation. The plant would be designed to operate as a base load station. The turbine design will cover adequate provision for quick start-up and loading of the units to full load at a fast rate. Apart from constant pressure operation, the turbine will also have the facility for sliding pressure operation.

The steam turbine will consist of three cylinders; high-pressure turbine (HP), intermediate pressure turbine (IP); and double flow low-pressure turbine (LP).

The turbine will be directly coupled to the generator. The critical parameters of the turbine are as follows:

i.	Type	Impulse, tandem compound, single reheat, double flow LP, condensing.
ii.	Turbine maximum continuous rating (Gross)	800 MW
iii.	Steam condition at TMCR a. Main Steam pressure at HP inlet b. Main Steam temperature at HP inlet c. Reheat Steam temperature IP inlet d. Exhaust pressure	 247 Kg/ Cm^2 565 deg C 593 deg C 76 mm Hg
iv.	Rated Speed	3000 rpm

The above parameters correspond to the worst conditions specified.

HP turbine will be provided with steam at about 247 kg/cm^2 for 800 MW set at 565ºC from main steam piping which conveys super-heated steam from Steam Generator super-heater outlet. Main steam piping at the turbine end will be connected to separate emergency stop and control valves. Each control valve is having its own hydraulic actuator connected to Electro Hydraulic Governing System (EHG). The control valves are modulated depending on the load demand to adjust first stage pressure accordingly. The governor senses the speed and modulates the control valve position to match with the speed-load curve setting of the machine. The droop characteristics provides 3-5% droop and is adjustable. The emergency stop valves are provided with their own actuators and control system to take care of all requirements of shutting off the steam supply instantaneously under emergency conditions and also to provide suitable control adjustments and openings based on the logics provided for shut off purpose.

The steam from exhaust of HP turbine is taken to re-heater through cold re-heat (CRH) piping. From CRH piping, steam is tapped off to meet the requirement of steam for HP heater. The balance steam after getting reheated in the boiler to a temperature of 593°C is taken back to the IP section of the steam turbine through Hot Reheat (HRH) piping. The HRH pipes at the turbine end carrying the reheated steam will be connected to IP turbine stop and intercept valves. The stop and intercept valves on IP turbine will be controlled from EHG in tandem with HP stop and control valves. The direction of steam flow in HP and IP sections is kept in opposite direction so as to balance the thrust and minimize the load on thrust bearing provided.

The MS, CRH and HRH piping will be routed and supported to take care of static and dynamic loads including thermal expansions. Routing and pipe support using constant and variable load hangers will be provided based on the pipe flexibility analysis to be carried out during detailed engineering stage. Drains will be provided to drain low points in the piping system and at strategic locations to avoid water entry into the turbine.

The steam from the exhaust of the IP section is taken through crossover pipes to a double flow L.P. turbine from where the exhaust steam is drawn to the condenser, which is kept at a vacuum depending on the cooling water temperature. Openings are provided in IP and LP sections of the turbine casing for extraction of steam for feed water heating.

The high / intermediate pressure turbine casing and rotor are manufactured from alloy steel with high creep resistant and rupture properties suitable for the operating condition. The blades are designed and manufactured of corrosion and erosion resistant alloys with high damping coefficient for vibration. The last stage blades of the LP turbine will be provided with protection from erosion under operating conditions. The rotor after manufacture will be balanced at high speed to ensure low vibration at site. The rotor is designed for an over speed of approx 3600 rpm for a period of not less than two to three minutes. The percentage over speed and its duration will be calculated depending upon the transient speed rise, entrapped steam in downstream of shut off valve and response time of control and actuating systems.

5.3.2 Condenser

Double pass Steam Surface Condenser with tubes of welded type will be provided below LP turbine exhaust. The condenser will be of divided water box construction. Condenser will be horizontal, surface type with integral air-cooling section. Condenser hot well will be sized for three (3) minutes storage capacity (between normal and low-low level) of total design flow with the turbine operating at VWO condition, 3% make-up, and design backpressure.

The condenser will be adequately sized to cater to all conditions of turbine operation including abnormal operating conditions. Tube plugging margin of 5% will be considered for sizing of the heat transfer surface of the condenser. Stainless steel / cupro-nickel / aluminium-brass tubes will be used in the condenser.

5.4 WATER SYSTEM

Water in the plant will be used for cooling of condenser, cooling of SG & TG auxiliaries apart from various other services including SG makeup, fire protection system, air-conditioning & ventilation system and plant potable water service.

The water system consists of various sub-systems listed below and discussed in the subsequent paragraphs of this chapter. The proposed scheme of water system is as shown at **Exhibit-5.1**. The following systems will be part of water system.

- Raw water system
- Raw water Reservoir
- Cooling water (CW) system
- Make up water system for cooling towers
- Auxiliary cooling water (ACW) system
- Water treatment (WT) system
- Service & potable water system
- Fire protection system
- Effluent Reuse and Recycling

The total water requirement for 800 MW units has been summarized in table – 5.1 below:

Table – 5.1

S. No.	Description	DM Water	Filtered water	Clarified water	Raw Water
A	**DM Water requirement**				
1	Heat cycle make-up	79.2			
2	Make-up for DMCW	6.6			
3	Hydrogen Generation Plant	1.32			
4	Condensate polishing	2.64			
5	Chemical feeding system	5.28			
	Total	95.04			
	DM plant input required by considering 10 % of regeneration water		104.54		
B	**Potable water requirement**		73.18		
	Total filtered water requirement		177.72		
C	**Clarified water requirement**				
1	Input to filtration plant			177.72	
2	Service water			95.04	
3	Cooling Tower make-up			2413.05	
	Total clarified water requirement			**2685.81**	
D	Raw Water requirement				
1	Input to clarifier by considering 53.71 m^3/hr sludge disposal			2739.53	
2	**Total raw water requirement**				**2739.53**
3	RO plant recovery				- 144.59
	Total raw water requirement for the plant				**2594.94 (say 2600)**

Note: All values are in m^3/hr

COC is considered 5 for river/canal water

5.4.1 Raw Water Supply & Treatment Plant

Make up water requirement for the plant shall be made available from Western Yamuna canal. The quantity of makeup water requirement is near about 2600 m^3/hr. Raw Water shall be supplied through 2 x 100% pumps for 800 MW unit (1 working and 1 standby) to clarifier to remove the suspended solid. The clarified water shall be used for the cooling tower make-up, service water, potable water, DM plant, fire-fighting system etc.

5.4.2 Water Treatment Plant

The pre-treatment plant shall consist of two nos. (2x100%) clarifiers each has a capacity of about 1350 m^3/hr, along with mixing of lime and alum with raw water. Clarified water will be stored in a clarified water storage tank of eight hours capacity from where water will be distributed to different users by providing following pumps.

1. 2x100% pumps capacity of each pump 55 m^3/hr for supplying water to DM plant.
2. 2x100% pump, capacity of each pump 40 m^3/hr for supplying water to potable water tank.
3. 2x100% pump, capacity of each pump 50 m^3/hr for supplying water to service water tank.

5.4.3 Condenser Cooling Water (CCW) System

The plant CW system shall include the CW and auxiliary CW pumping system, natural draught cooling tower, and cooling tower make-up.

The Condenser Cooling Water shall be pumped from the CW pump house. 3x50% CW Pumps with two working and one standby shall be used for each unit. The Water requirement for Condenser Cooling of unit shall be ~ 141000 cum/hr. The main cooling water pump shall be vertical mixed flow type pumps coupled with vertically mounted electric motors.

3x50% auxiliary cooling water pumps will be supplied for supply of auxiliary, cooling water to 3x50% heat exchangers, which will be used for cooling of generators, air compressors, turbine oil coolers and Boiler Feed Pump lube oil coolers for both the units. The auxiliary cooling water pumps shall be mixed flow vertical pumps.

The main cooling water pumps and auxiliary cooling water pumps shall be located inside the CW pump house to be located adjacent to the cooling tower.

One (1) no. of Natural draught cooling towers (NDCT) of RCC construction shall be provided for cooling the hot CW return from condenser and plant auxiliaries for both the units. The NDCT shall be designed considering wet bulb temperature 28°C and CW temperature range 9°C.

The clarified water will be used for cooling tower make-up. Cooling tower blow-down will be treated in the clarifier & RO system to utilize that further into the plant water system. The condenser cooling water system shall be provided with adequate chlorine dosing system.

The cooling water circuit will be designed to operate at optimum cycles of concentration in order to limit fresh water consumption and minimize blowdown.

5.4.4 Auxiliary Cooling Water (ACW) System

The ACW system meets the cooling water requirements of DM water in plate heat exchangers. DM water is used for cooling of the auxiliary equipment related to TG & SG units such as turbine lube oil coolers, hydrogen coolers, seal oil coolers, stator water coolers, ID/FD/PA fans bearing oil coolers, mill lube oil coolers, BFP auxiliaries such as lube and working oil coolers, seal water coolers, drive motors, etc., condensate pump bearings, air preheater bearings, sample coolers, air compressors and ash handling system compressors.

A closed loop system using passivity DM water is proposed for the ACW system. The DM water of boilers, turbine & station auxiliary's water is circulated through all equipment coolers for cooling. The hot water from the auxiliaries is cooled in the plate type heat exchangers by the circulating water from the ACW pumps located in the C.W pump house.

The auxiliary cooling water system would be on unit basis and the equipment of the system for unit will be as follows:

- (i) 3 x 50 % capacity de- mineralized cooling water pumps.
- (ii) 3 x 50 % capacity ACW pumps.
- (iii) 3 x 50 % heat exchanger.
- (iv) 1 nos. DMCW tanks for makeup.

The water treatment (DM) plant will provide make up water to closed loop circuit of the primary cooling water system.

5.4.5 DM Plant

The 800 MW unit will be provided with a 3 x 100% DM plant chains (55 m^3/hr capacity for each chain) to ensure make-up requirement of heat cycle at the rate of about 3% of the BMCR steam flow. Clarified water from Pre-treatment plant shall be supplied to DM plant for the above purpose.

The Demineralised Water shall be generated after the completion of treatment process of clarified water through set of 2 x 100% pressure filters, activated carbon fillers, Anion Exchangers, Cation Exchangers, and Mixed Bed Exchangers. Degasser towers, Degasser pumps, blowers for mixed bed exchanges, blowers for pressure filters, acid and alkali storage towers, Acid and Alkali measuring tank, pipes & valves.

5.4.6 Service and Potable Water Systems

The service water system covers supply of clarified water required for seal water for clinker grinders, ventilation, air conditioning system, fly ash & bottom slurry and water pumps, air washer and miscellaneous water requirements such as plant washing. Two (2) horizontal, centrifugal pumps, (1W + 1S) will pump water from the clarified water storage tank to the service water overhead tank. Water from the overhead tank to the different consumer points would be distributed by gravity.

Requirements of the plant potable water system will be met from the clarified water storage tank. Two (2) (1W + 1S) horizontal, centrifugal plant potable water pumps, will draw suction from the clarified water storage tank for further distribution of potable water to various consumption points in the plant and colony.

5.4.7 Effluent Recycling and Reuse System

The Plant is designed for minimum liquid effluent to be sent out of the plant. The liquid effluents will be collected and treated / recycled generally as per the following:

i) Effluents from Boiler, Turbine and other areas, which may contain oil traces, will be sent to oil/water separator. The oil will be pumped out periodically and trucked offsite for disposal. The treated water of significantly low quantity will be directed to central monitoring basin.

ii) The clarifier sludge generated in pre-treatment and cooling tower blowdown treatment system shall be further thickened and dried in thickener. The dry sludge from the sludge drying bed shall be manually sent through truck for offsite disposal.

iii) The cooling tower blowdown will be used as quench water for boiler blowdown. The quenched water shall be treated in the effluent treatment plant. A clarifier and RO will be provided to maximize the blowdown recovery. The RO rejects will be utilized as makeup water for ash handling system, even after ash-water re-circulation from ash pond. This is due to mostly evaporation losses in the pond and ground tank.

iv) Rainfall runoff from the coal pile will contain mainly suspended solids. This runoff will be routed to the settling basin for retention and settling of suspended solids, and the clear water from there shall be used for dust suppression in the coal pile area. During excessive rain, when the runoff is not expected to contain substantial amount of suspended solids after initial hours of heavy rains, the clean runoff shall be directed to central monitoring basin for storage and further reuse. The pump, which shall be used for coal pile dust suppression, shall be used for transferring the runoff from settling basin to central monitoring basin. Provision shall also be kept for disposal of coal pile runoff to ash pond via central monitoring basin and ash slurry sump.

v) Filter backwash waste, which is generated in raw water pre-treatment system and contains high-suspended solids, shall be taken back to raw water clarifier to minimize wastewater effluent.

vi) Wastewater generated during offload air heater wash will be taken to settlement basin, the capacity of which shall be adequate to hold one air heater wash volume. The air heater wash water shall contain high- suspended solids. After settlement of suspended solids in settlement basin the clear water will be taken to central monitoring basin.

vii) The oil sumps will collect water from areas where there are possibilities of contamination by oil (for transformer yard, fuel oil storage area) and the drains from such areas will be connected to an oil separator. From the oil separator the clear water will be discharged to the guard pond, while the oily waste sludge will be collected separately and disposed. Water collected in the guard pond will be subjected to treatment (if necessary) and then discharged to storm water drains.

viii) Fly ash will be disposed in dry form. During retrieval of dry fly ash from silos, adequate water injection into the ash-conditioner will be made to avoid dust nuisance. During exigencies, it may be necessary to dispose both bottom and fly ash in wet form to ash pond. Wastewater generated in fly ash handling system will contain some suspended solids. This wastewater will be taken to small collection sump. This collection sump will be provided with weir chamber, where suspended solids will be settled. The overflow clear water will be pumped to ash slurry sump. From the ash slurry sump, the content shall be disposed to Ash pond. During "emergency excess water or unacceptable quality water in central monitoring basin shall be taken to ash slurry sump for final disposal to ash pond.

ix) All the plant liquid effluents will be mixed in the central monitoring basin. However there may be some occasional variations in suspended solids and pH. A provision for chemical dosing is kept to adjust suspended solids and pH. If the treated water quality in central monitoring basin is inacceptable limit, the water shall be used either for plant green belt development or for miscellaneous plant uses. Excess water or unacceptable quality water in central monitoring basin shall be taken to ash slurry sump for final disposal to ash pond and finally utilized for ash water system and green belt development.

Scheme for proposed Effluent treatment system is shown in the attached at **Exhibit-5.2**

5.5 COAL HANDLING PLANT

The Coal Handling System for the proposed 800 MW units will receive coal by Railways open top wagons (BOXN) or bottom opening broad guage rail (BOBR) wagons. Railways will be undertaking the operation for transporting the coal from the coal mine to the project site. All transporting facilities including wagons and locomotives to transport the coal from the mine to the plant will not form part of the project site. In Plant coal handling system will consist of:

- Track hopper/Wagon Tippler
- Belt Conveyors
- Belt Scales
- In line Magnetic separators
- Metal detectors
- Coal Sampling Unit
- Stacker cum reclaimers
- Dust suppression system
- Dust extraction system in enclosed areas like transfer point, bunkers
- Hoists/ Equipment handling facilities
- Control and instrumentation
- Electrical System
- Ventilation System in Conveyor Tunnels and Bunker floor
- In-motion weigh bridge
- Safety and protective instrumentation

Coal handling system scheme is as shown at **Exhibit-5.3**.

In order to have uninterrupted coal supply to the proposed unit, coal handling system of 800 MW unit will be so designed that in an emergency situation the coal will be taken to junction tower of existing CHP-II & III. This emergency conveying system will be studied in detail during detailed project report.

Coal for the proposed plant shall be fed from coal linkage from Jharkhand (Dhori & South Karanpura).

The Coal Handling Plant (CHP) will be designed to operate throughout the year with indigenous coal and having an average gross calorific value of 3600 kcal/kg.

Considering a gross plant heat rate of 2151 kcal/kWh, the coal consumption for the plant at full load with design GCV of 3600 kcal/kg will be:

Coal consumption per hour at full load	=	$\frac{\text{800 MW x 2151 kcal/kwh}}{\text{3600 kcal//kg}}$
	=	478 t/ph
Coal consumption/day	=	11472 tonnes

Coal consumption (annual)	=	478 x 8760 x PLF x10^{-6}
At 85% PLF	=	3.55 MT/year

5.6 ASH HANDLING SYSTEM

The ash handling system will be designed to collect, transport and dispose bottom ash, coarse ash and fly ash from ESP hoppers. Fly Ash from ESP hoppers and Air preheater hoppers shall have dry ash as well as wet ash handling and transportation system. The ash will be transported to Ash utilization project and / or ash dump area in wet form. The ash handling system will consist of two major systems, namely bottom ash and Fly ash system.

The System proposed is for wet disposal of the Bottom Ash, dry extraction of the Fly Ash.

The quantum of ash generation would depend on the plant load factor and the quality of coal being fed. Considering average ash content of 42% in coal about 200.76 T per hour of ash will be generated from the proposed station.

The ash handling system of proposed unit will be designed to meet the following requirements:-

a)	Coal consumption at full load	: 478 tph
b)	Ash content (design)	: 42%
c)	Ash generated	: 200.76 tph
d)	Bottom ash generated 30%	: 60.23 tph
e)	Coarse ash generated 10%	: 20.07 tph
	(APH hoppers, economizer hoppers flue gas duct).	
f)	Fly ash generated 80% (ESP hoppers)	: 160.61 tph

Dry fly ash of 800 MW unit will be collected in a two silo. The storage capacity of each silo will be 1700 cu.m (ash collected in 16 hours while firing design coal).

The demand for dry fly ash in nearby cement manufacturing units would need to be explored and firmed up.

5.6.1 Bottom Ash System

This system is continuous type bottom ash removal system. The bottom ash resulting from the combustion of coal in the boiler falls through dry ash hopper-cum-transition chute, into the water filled trough provided with a continuously moving scrapper chain conveyor for transferring the wet ash to the clinker grinder.

The crushed ash through clinker grinders gets discharged into the local sump. Individual local sump is provided for each unit. From the sump the slurry is transported to the Dewatering bin. From dewatering bin ash is transported to bottom ash silo. Silo is provided for 800 MW unit capacity to store 16 hours ash.

5.6.2 Coarse Ash System

Coarse ash collected in Economiser & Air Pre-heater hoppers, will be extracted by the flushing apparatus located below each hopper. Coarse ash slurry will be routed to the surge tank. Ash slurry from the surge tank will be pumped to the slurry sump with 2 x 100% capacity horizontal centrifugal slurry pumps through adequately sized carbon steel pipes. The contents of coarse ash from various hoppers will be pumped out in the 90 minutes in a shift of 8 hours simultaneously with bottom ash removal system.

Water requirements for flushing will be tapped from LP ash water pumps discharge header. The scheme for bottom & coarse ash are shown at **Exhibit-5.4**.

5.6.3 Fly Ash System

Fly ash collected in the ESP hoppers will be extracted in dry / wet form by vacuum system. Suitable number of streams with adequate capacity shall be provided. For disposal of fly ash in slurry form, to ash slurry sump welling head, collector tank and air washer for each stream will be provided. Fly ash, if in dry form, will be collected in intermediate hoppers.

For conveying ash from intermediate hoppers to silos, pressurised conveying system will be adopted.

The ash collected in the hoppers in eight hours will be cleared in about six hours time. Dust separator will be provided on each intermediate hopper. A vent filter will be mounted on each silo to reduce the environmental pollution. Fly ash disposal scheme is as shown at **Exhibit-5.5**.

5.6.4 Ash Disposal Area

Ash generation from proposed unit # 9 would be 95 lacs tonne for the total plant life. Ash slurry from the slurry sump would be pumped into the ash disposal area. Ash shall be disposed off to the existing ash dyke area. The existing ash disposal area for unit 1 to 6 will also be utilised for disposal of ash to be generated from unit-9 (800 MW) PTPS. The existing ash dyke will be raised by 16 mtr. (in 3 stages) beyond EL 116.25 mtr. and thus additional capacity of 197 lacs cum will be created. This will be sufficient for the whole plant life.

5.7 MISCELLANEOUS SYSTEMS

5.7.1 Fuel Oil System

a) System requirement

Light Diesel Oil (LDO) will be used for start-up and HFO for firing support during low load operation and for stabilizing of flames. The HFO/LDO will be brought to the plant fuel oil handling area by railway wagons. The fuel oil handling system will include receipt, unloading, storing and subsequent pressurization and pumping to boiler burners at the desired flow rate, temperature and pressure.

b) LDO System

A suction header will be provided for unloading of LDO. Flexible hoses with quick disconnector couplers will be provided to connect LDO tankers to the suction header. The oil pressurization system will be provided to supply oil to burners. This pressuring system will contain suction header, pressurization pumps, filters, strainer piping with fittings and supports, valves etc.

c) HFO System

HFO will be brought to the plant by railway tankers and unloaded to the storage tanks by means of unloading pumps. Necessary strainers and tanker heating arrangement will be provided. The storage tanks will be provided with floor coil heaters and outflow heaters. The pressurizing and heating (P&H) system will feed the boiler burners at the required pressure and temperature. The fuel oil heaters will be of steam heating type and all HFO lines will be steam traced.

Flow diagram for HFO & LDO fuel oil systems are shown at **Exhibit-5.6.**

5.7.2 Compressed Air System

Compressed air system would cater to the requirements of instrument and service air of the 800 MW unit. Instrument air is required for operating control valves, pneumatic tools, various control system bag filters purging. Service air is required for cleaning purposes during regular and shut down maintenance. Instrument air is also dehumidified and dried to requisite level before it is admitted to the instrument air system. Oil free air is required from the compressors especially for instrument air. Two (2) nos. (1 working + 1 standby) screw type air compressors along with driers, one for each compressor, would be provided for instrument air.

The instrument air distribution will be through main header and it will be ensured that sudden leakage in any part of the instrument air lines will not affect air to any of the supply points. The service air line is also connected to the main header of instrument air to meet the redundancy. The plant air system will be designed and provided suitable manifolds to allow adequate discharge points in all operation and maintenance areas. Two (2) nos. (1 working + 1 standby) screw type air compressors along with driers, one for each compressor, would be provided for plant service air. These compressors will be same as instrument air compressors.

Schematic diagram of Compressed Air System is as shown at **Exhibit-5.7.**

5.7.3 Air Conditioning System

Various control rooms of the plant units having a group of sophisticated and precision control and protection devices as well as computer rooms will be air-conditioned to have controlled environment for proper functioning and operating personnel. Various types of air-conditioning systems as required will be provided (viz.) centralized chilled water, DX type AC system; package air-conditioning plants & split window AC. The following areas will be air-conditioned:

a) Central Control Room consisting of Controls, Control Equipment rooms, Telecommunication Rooms, Microprocessor based DCS, Computer and Programmers Rooms, Data Storage Rooms, UPS Rooms, Instrumentation Laboratory and Steam & Water Analysis Rooms, Conference Room, Shift Charge Engineer's Room (If applicable), Relay Rooms.
b) ESP Control Room.
c) Coal Handling Plant Control Room
d) Switchyard Control Room including Computer Rooms, Telemetry Room, PLCC & Telex Room
e) Required areas in Service/Facilities Building/Administration Building
f) Water Treatment Plant Control Rooms, Water and Fuel Analysis Room, Instruments Room.

g) Any other area, which contains control and instrumentation equipment requiring air conditioning or otherwise requires being air-conditioned.

A central water cooled chilled water type air conditioning plant will be provided for air conditioning of central Control Room and its associated area as well as administration building and related facilities. Chilled water from the central plant will be pumped to various air-handling units catering each area or groups of areas.

For other areas, either package type air-conditioning unit or D-X type air conditioning unit, spilt type window AC will be provided as per requirement.

5.7.4 Ventilation System

Adequate ventilation system is considered as detailed below for the power plant machine room building, ESP control building; and other areas such as DG set room, air compressor room, A/C plant room, DM plant building, Battery rooms and various pump houses such as fuel oil pump house, DM water pump house etc. to achieve:

i) Dust free comfortable working environment.
ii) Scavenging out structural heat gain and heat load from various equipment, hot pipes, lighting etc.

a) Turbine and Generator building

Supply air system will be provided with evaporative cooling plant by a set of air washers with cooling water coils. The system will include supply air fans, inlet louvers, bird screens, viscous filters, cooling coils, re-circulating water system with circulating water pump sets, bank spray nozzles & flooding nozzles, eliminator plates and sump tank etc for supply and distribution of cooled air at various locations. The exhaust system will consist of roof extractors (for machine room). The system will be designed to maintain close to ambient dry bulb temperature inside the building.

Various rooms of the power plant building such as cable spreader room, switchgear room etc. will be ventilated by means of pressurized supply and exhaust fans suitably located.

b) ESP control building

For ventilation of this building, ambient air will be drawn through unitary air filtration unit comprising fresh air intake louver, dry type filter and cooling coils conveying water [supplied from an independent source] and supplied to the space by means of centrifugal fans through ducting, grilles, etc.

c) Other building

Other areas such as DG set room, air compressor room A/C plant room etc will be ventilated by means of dry system comprising axial flow fan, dry filter wherever required, cowls, ducting etc. Fire dampers will be provided on ductwork routed through electrical installation areas. Ventilation system of respective areas will be suitably interlocked with fire detection system to minimize spreading of fire.

The normal design criteria for ventilation system shall consider:

(i) For number of Air changes in TG – 6 Air changes per hour.
(ii) For various Auxiliary plant building – 20 Air changes per hour.
(iii) For building like battery room, Chlorination plant – 30 Air changes per hour.

5.7.5 Chemical Dosing System

Boiler water chemical dosing system will be provided for chemical conditioning of the boiler water, condensate and feed water.

The boiler chemical dosing system will be designed to introduce chemicals into the steam, feed water and condensate cycles to control corrosion and deposition. The chemical dosing system is composed of the following major components.

- Phosphate dosing system
- Ammonia dosing system
- Hydrazine dosing system

The phosphate dosing systems will be designed to inject di-or trisodium phosphate solution directly into the boiler drum. The phosphate dosing system will consist of solution tank, agitator, chemical metering pumps, piping, valves, instrumentation and controls.

The ammonia dosing system will be designed to inject ammonia solution into the condensate. The ammonia dosing system will consists of solution tank, agitator, measuring tank, chemical metering pumps, piping, valves, instrumentation and controls. A tank and transfer pumps will be provided for bulk storage and transfer of ammonia to the dosing system.

The Hydrazine dosing system will be designed to inject a hydrazine solution into the boiler feed pump suction piping. The Hydrazine dosing system will consist of solution tank, agitator, measuring tank, chemical metering pumps, piping, valves, instrumentation and controls
Automatic dosing system shall also be considered.

5.7.6 Chlorination Plant

Chlorination plant shall be provided for chlorine dosing in the water pre-treatment plant and CW system to avoid the growth of algae and bacteria. Separate chlorination plant shall be provided for water PT plant and CW system. CW chlorination system would consist of one (1) number of chlorinator-evaporator sets of adequate capacity and PT chlorination system shall consist of one (1) number of chlorinator sets of adequate capacity with associated pumps etc.

Each chlorination system shall be provided with required chlorine tonne containers, instrumentation, panels, chlorine leak detectors etc. Complete chlorination plant shall be located indoor. Chlorine leak absorption system as plant emergency measure shall be provided for each of the chlorination plants to neutralize chlorine leakage from the plant.

Along Chlorination plant, ozone plant shall also be considered.

5.7.7 Hydrogen Gas System

Hydrogen gas with a purity of 99.9% is needed to cool the turbo-generators. A hydrogen generation plant has been envisaged in order to fill up high pressure hydrogen cylinders which are required for generator initial fill up and regular makeup required for generator rotor cooling.

Hydrogen generation is accomplished by water electrolysis process. It is proposed to provide a hydrogen generation plant of 8 Nm^3/hr for the project with two streams of electrolysers each of capacity 4 Nm^3/hr with two hydrogen compressors each of capacity 6 Nm^3/hr along with auxiliaries.

The plant shall be designed as per the regulations of the Explosives Authority with all the required safety aspects, instrumentation control, including On-line hydrogen purity analyzer system and control panel.

5.7.8 Cranes, Hoists and Elevators

In order to facilitate the handling of various equipments during erection and maintenance of the power plant, a number of cranes and hoists will be required at various locations.
One (1) electrically operated travelling type (EOT) crane of adequate capacity shall be provided for handling heavy equipment in the machine room/turbine building during erection & maintenance.

The generator stator will be the heaviest piece of equipment. To avoid extra load on the turbine building columns and foundations, the generator stator will be lifted by jacking / cribbing process. EOT crane will be utilized for other heavy pieces to be lifted such as generator rotor, LP turbine rotor etc.

Conventional and special type of cranes for maintenance of a few important equipment in SG and TG packaged plants such as FD/PA/ID fans, pulverizes, air heaters, condenser water box, ESP transformer rectifier sets etc. will be provided. For various pump houses, clarification plant; Filtration plant; Demineralising plant; Fuel oil pump house; Intake pump house; Under slung cranes of adequate capacity, pendant operated, with electrical hoists will be provided. For circulating water pump house, a pendant operated 40/5 tonne capacity electric overhead travelling crane will be provided.

Maintenance cranes/handling devices of suitable capacities will be considered for all other areas such as compressor house; hydrogen generating plant; coal handling plant transfer points etc. Monorails for lifting heavy motors and other equipment within the power house not covered by EOT crane such as miscellaneous pumps, heat exchangers etc will also be provided. Suitable rails embedded on floor for dragging the horizontal feed water heaters to have the approach under EOT cranes will also be provided.

Elevators

One (1) 2000 kg capacity goods elevators will be provided for boiler area.

One (1) 500 kg capacity elevator will be provided for stack. Further, one (1) passenger elevator of 1000 kg capacity will be installed in the service building annexed to power plant building. Two-passenger elevator of 544 kg for TG building will also be provided. Elevators envisaged for the power plant will conform to IS: 3534 and IS: 4666.

5.7.9 Fire Protection System

For protection against fire, all yard equipment and plant equipment will be protected by a combination of hydrant system; fixed foam system for oil handling areas; automatic high velocity and medium velocity spray system sprinkler system for coal conveyors; auto-modular gas based system for control rooms apart from portable and mobile fire extinguishers located at strategic areas of plant buildings and adequate Passive Fire Protection measures. The systems will be designed as per the recommendations of

NFPA or approved equals in accordance with the Tariff Advisory Committee of the Insurance Association of India stipulations.

General scheme for fire fighting and protection system is as shown at **Exhibit-5.8.**

5.8 ELECTRICAL SYSTEMS

5.8.1 General Description

The system consists of one unit STG of 800 MW rating, the generation voltage being 27 kV. The 800 MW generator output will be connected to the proposed 400 kV switchyard through step-up Generator Transformers. The generated power will be evacuated using 2 nos. new 400 kV double circuit transmission line system to the 400 kV grid substations located at different load centres. Start up power will be taken from station transformers at 400 kV.

Three voltage levels i.e. 11 kV, 3.3 kV and 415V are adopted for feeding the plant auxiliaries.

5.8.2 General Principles of Design Concept

The design concept of the electrical system as a whole is based on the requirements for the safe and reliable performance of steam turbine generator set and the interconnected electrical system with provision for easy maintenance and overhauling.

The design principles and standards delineated herein is generally in compliance with latest IEC/IS Standards and the Code of Practice already established in the country and also CEA notification dated 21/2/2007 (Technical standards for connectivity to the grid).

Indian Electricity Rules wherever applicable have also been complied with.

5.8.3 Electrical System Arrangement

Isolated Phase Bus Duct will be provided for connection of each generator with its respective generator transformer set & neutral earthing equipment and tap off connections to respective Unit Auxiliary transformers, Voltage Transformers and Surge Protection Cubicles.

Two (2) nos. 45 MVA, 27 kV/11.5 kV, three-phase Unit Auxiliary Transformers (UAT) have been envisaged to cater total unit auxiliary load of 800 MW Unit. The transformers will be rated to meet the auxiliary loads required to run the Unit at MCR. Further, one no. 90/45/45 MVA, three phase, three windings 400/11.5/11.5 kV Station Transformer (ST) has been envisaged. The Station transformers will be rated to meet the total station auxiliary loads required to run the Plant at MCR. The Station Transformers will be supplied power from the proposed 400 kV switchyard.

For supply of unit and station auxiliary loads of the proposed power plant, following voltage levels have been envisaged:

- 11 kV level through 27 kV/ 11.5 kV Unit Auxiliary Transformers and 400/11.5/11.5 kV Station Transformer.
- 3.3 kV level through 11/3.45 kV Auxiliary/Service transformers
- 415 V level through 11/0.433 kV Auxiliary/ Service Transformers
- 415 V emergency power through Emergency DG set
- 220 V DC for emergency drives, lighting, control and protection systems.
- 48 V DC for Power Line Carrier Communication (PLCC) and SCADA systems

The power supply for various 11kV unit/station auxiliary motors and auxiliary/service transformers for unit/station services will be fed from 11kV Unit/Station switchgears. For feeding 3.3kV motors for unit/station services, 3.3 kV system has been envisaged through suitably rated 11/3.45 kV auxiliary/service transformers. In addition to this, 11/3.45 kV service transformers have been envisaged for each of Coal Handling Plant, Ash handling plant and raw water intake pump house where 3.3 kV supplies are required. All 3.3 kV switchgears will have 2 x 100% incoming feeders, to be fed by 2 x 100% auxiliary/service transformers, and bus coupler to achieve maximum redundancy and reliability during operation. In order to limit the fault level of 3.3 kV switchgears, paralleling of two incomers has not been envisaged.

Oil filled / dry type, outdoor / indoor (as per application) LT auxiliary / service transformers of suitable ratings will be provided to meet the 415 V unit/station load requirements of the proposed power plant. The transformers will be located at different load centres to feed the respective 415 V switchgears in that area. All 415 V switchgears will have 2x100% incoming feeders, to be fed by 2x100% LT auxiliary/service transformers, and bus coupler to achieve maximum redundancy and reliability during operation. In order to limit the fault level of 415 V switchgears, paralleling of two incomers has not been envisaged.

Plant emergency power will be provided from emergency 415 V, 3-ph, 50 Hz Diesel Generator (DG) Sets to take care of any emergency situation particularly in the case of grid failure condition. One 100% capacity emergency DG Set has been envisaged for each unit with automatic starting facility to restore the supply at respective 415 V Unit Emergency Switchgear for supplying emergency power required for safe shutdown of the respective unit. In case of total AC power failure, the Diesel generator will start automatically and supply power to respective 415 V Unit Emergency Switchgear where all essential loads are connected. Moreover, one stand by emergency DG set of same capacity will be provided for the two units to feed emergency loads of one unit at a time due to failure of Emergency DG set of that particular unit. Provision will be made for synchronizing 415 V Unit Emergency Switchgear with the respective 415 V Unit auxiliary Switchgear for testing and taking in/out of the DG, as required.

The design concept of the electrical auxiliary system as a whole is based on the requirements for the safe and reliable operation of the Plant with provision for easy maintenance. The design and performance requirements of equipment will be generally as per latest Indian Standards and the Codes of Practice, IEC Recommendation. Indian Electricity Rules, wherever applicable will also apply.

All electrical equipment for the proposed power plant will be designed for the following conditions:

Voltage variation	-	± 10%
Frequency variation	-	- 5% to +3%
Combined voltage and frequency variation (absolute sum)	-	10%
Design ambient temperature	-	50º C

Following fault levels will be considered for design of all electrical equipment at various voltage levels. Fault levels shall be restricted to the same.

System	**Fault Level**	**Duration**
400 kV	40/50 kA	1 second

11 kV	40 kA	1 second
3.3 kV	40 kA	1 second
415 V	50 kA	1 second
220 V DC	10 kA	1 second
48 V DC	10 kA	1 second

The creepage distance for exposed bushing/insulators will be minimum 25 mm/kV.

The insulation level for Transformer windings, bushings and other insulators are given as follows:

Nominal system voltage (kV)	Highest system voltage (kV)	Rated 1 Min power Freq. withstand Volt (kV rms)	Rated Lightning impulse withstand voltage (kV peak)
3.3	3.6	10	40
11	12	28	75
27	36	70	170
400	420	630	1425

The 400 kV system will be solidly earthed. The neutral point of generator will be earthed through single-phase dry-type earthing transformer with a loading resistor, connected at its secondary side, to limit the earth fault current to about 5-10 amps. The 11 kV systems will be low resistance earthed to limit the earth fault current to about 300 Amps. 415 V systems will be solidly earthed. The DC systems will be unearthed.

5.8.4 Generator

The turbo-generators will be of 3 phase, 50 Hz, horizontal mounted, two pole, cylindrical rotor type directly driven by the turbine and rated for 800 MW at 0.85 lagging to 0.95 leading power factor. It will generally comply with the requirements specified in IEC-34.

The generation voltage is envisaged as 27 kV (or any other voltage as per manufacturer's standard design).

The Generator will be designed with adequate margin for operation with 47.5Hz.

The Short Circuit Ratio (SCR) will be 0.49 (minimum). The class of insulation for stator and rotor will be class F. However as per normal practice the temperature rise of various parts during operation will be limited to class B limits as per IEC 34. The generator will be Wye connected and the star point will be connected to earth through neutral grounding transformer, the earth fault current to a safe value of less than 10 A.

The insulation of stator and rotor winding shall be of Class-F with a temperature rise limited to Class B. the generator stator winding will be wound to form double-star and the generator neutral will be earthed through a single-phase earthing transformer with a loading resistance, connected at its secondary side.

The generator will have following associated equipment / auxiliaries:

a. **<u>Gas System</u>**
The generator gas system will consist of Hydrogen and CO_2 systems. The rotor windings and the core will be directly cooled by hydrogen gas. The hydrogen gas make-up will be supplied from hydrogen supply system. The generator will have

shaft driven hydrogen blowers and stator mounted hydrogen to water heat exchangers. There will also be 2x100% dryers along with online dew point monitoring system provided for the hydrogen gas system. For purging of hydrogen from generator casing CO_2 will be used. The gas system will consist of hydrogen and CO_2 cylinders, gas manifold, relief valve, hydrogen regulator, piping, fittings, valves, gauges, temperature measurement, H_2 purity monitors and annunciation and control system. Hydrogen will flow in a closed loop circuit and in a closed loop circuit in turn will be cooled by DM water.

b. **Stator winding cooling System**

The stator winding will be directly cooled by DM water, flowing inside the hollow stator conductor. The stator core will be directly cooled either by DM water. The stator water cooling system will include 2 x 100% AC driven primary water pumps, 2 x 100% filters, mixed bed demineraliser, water to water heat exchanger etc. The system will be complete with instrumentation for temperature measurement, measurement of pressure differential and local control and annunciation panel.

c. **Shaft Seal Oil System**

Shaft Seal Oil system will be provided to prevent escape of hydrogen from the generator. The system will consist of normal and standby AC driven pumps, standby DC driven pump, coolers, filters, pressure regulators, oil tanks, vacuum pump and other valves and fittings. A complete local control and annunciation panel also will be provided.

d. **Generator Excitation System**

A complete generator excitation (static or brushless) and regulation system will be provided for the generator. It will be rated to continuously carry at least 10% above rated generator field current requirement. The ceiling voltage will be at least 150% of the field voltage required at rated condition. The nominal excitation system response ratio will be not less than 2. The Automatic Voltage Regulator (AVR) will be micro processor based digital type and provided with three channels namely, two Auto and one Manual channels, with a selector switch for bump less transfer from one to other. The Auto and Manual channels will be completely independent of each other and take voltage/current input from separate voltage/current transformers. The AVR will have following parameters.

Range of voltage level adjustment in all modes of operation	-	±10%
Frequency range of operation	-	47.5 to 51. 5Hz
Accuracy at which generator terminal voltage to be held	-	better than 0.5%
Range of transformer drop compensation	-	0 to 15%
Maximum change in generator voltage when AVR is under all conditions of excitation	-	less than 0.5%
Manual control range	-	70% of no load to 110% full load excitation

The AVR will be provided with following built-in facilities.

- Voltage transformer fuse failure circuit with changeover to manual.
- Volt/Frequency (V/F) limiter circuit.
- Rotor earth fault detector.
- Rotor angle limiter
- Stator current limiter
- Rotor current limiter
- Power System Stabiliser (PSS) suitable for damping various modes of electromechanical oscillations.

The generator will have adequate number of temperature detectors provided for measurement of temperature of core, winding, bearings etc. It will also be equipped with following monitoring devices.

- Generator core monitor
- Generator winding temperature monitor

Online temperature monitoring for water in stator conductor

5.8.5 Transformers

a) Generator Transformer

The generated voltage of 27 kV will be stepped-up to 400 kV by step-up transformers connected to generator through isolated phase bus duct. Connection between Generator Transformer high voltage terminal and 400 kV switchyard equipment will be made by 400 kV overhead lines.

The 800 MW unit shall have a bank of three (3) single phase transformers each of rating 315 MVA, 27/420/√3 kV.

However, the final value of the Generator transformers impedance at the principal tap will be selected so that it is compatible with the 400 kV and bus duct fault level and full load regulation.

b) Unit Auxiliary Transformers (UATs):

Two (2) numbers Unit auxiliary transformers will be provided in order to feed the unit auxiliary loads at 11 kV. The transformer will be of two winding three phase type rated for 45 MVA, 27/11.5 kV with ONAN/ONAF cooling. The tap-changers shall be off-circuit type. The capacity of these transformers will be finalized during detailed engineering stage and will be rated to meet unit auxiliary loads at MCR condition.

c) Station Transformer (ST)

For power supply to all station auxiliaries, start up, shut down and unit auxiliaries, one (1) number station transformer will be provided in order to feed common auxiliary loads at 11 kV. These transformers will be three winding, three phase type rated 90/45/45 MVA, 400/11.5/11.5 kV, ONAN/ONAF Cooling, ON-LOAD tap changer shall be provided on these transformers having range of ± 10% of nominal voltage @ 1.25 tap. The capacity of these transformers will be finalized during detailed engineering stage and will be rated to meet station auxiliary loads at MCR condition.

d) 11/3.45 kV Unit Auxiliary Transformers/ Service Transformers for CHP & AHP

For power supply to all 3.3 kV unit and station auxiliary motors and loads, 2x100% 11/3.45 kV transformers have been envisaged for the following systems:
3.3 kV system for each unit
3.3 kV system for Coal Handling plant

3.3 kV system for Ash Handling Plant
3.3 kV system for raw water intake pump house

Each transformer will be rated for 11/3.45 kV, three phase, Dyn1, 50 Hz, ONAN cooled, outdoor type and provided with OFF circuit tap changer (OCTC) having range of ±5% of nominal voltage @ 2.5% tap. The rating for these transformers will be finalized during detail engineering stage.

5.8.6 Bus Duct

a) Generator Bus duct

Generator will be connected to Generator Transformer Set & Neutral earthling equipment through main bus duct and respective unit Auxiliary transformers, Voltage Transformers and Surge Protection Cubicles through tap off- bus duct. The bus duct will be of isolated phase, continuous type with aluminium conductor in aluminium enclosure. Lightning arresters and surge capacitors of proper rating will be located within Surge Protection Cubicles. The current Transformers for measuring and protection purposes will be provided inside the enclosure of the bus duct both at line side, neutral side and Unit Auxiliary transformer side. The maximum temperature of the bus conductors & connections and enclosure will be limited to 105^0C and 80^0C respectively.

A generator neutral earthling cubicle housing the dry type neutral earthling Transformer and secondary loading resistor will be located near the neutral star point of the generator.

The bus duct enclosure will be of welded construction. The bus ducts will be naturally cooled, dust tight and weather proof in construction. Bus duct pressurization arrangement using clean dry air will be provided.

b) 11 kV and 3.3 kV Bus Ducts (Phase-segregated)

11kV and 3.3 kV bus ducts will be metal enclosed, phase segregated type and natural air-cooled. Bus conductor shall be of aluminium alloy, adequately sized for continuous rated current and short circuit current for duration of minimum one (1) second.

5.8.7 Neutral Grounding Equipment

The function of neutral grounding equipment is to connect neutral of each system to ground while limiting the fault current to reasonable values and providing detection for ground faults.

The Neutral Grounding Equipment will consist of following:

- Generator neutral will be grounded through a cast epoxy distribution transformer and resistor combination to limit the fault current to less than 10 amps.
- 11 kV and 3.3 kV transformer's neutrals will be grounded through resistors to limit the fault current to 300 Amps. The resistors will be rated for 10 seconds operation.
- Generator transformer neutral on 400 kV side and 433 V transformers neutral will be solidly grounded.
- The DG set neutral will be unearthed.

5.8.8 415v Switchgear, Motor Control Centres (MCC) & Distribution Boards (DB)

The LT transformers will feed power to the 415V switchgears, which in turn would distribute power to various MCC's and Distribution Boards located at load centres. The

415 V switchgears / MCC would have duplicate incomers and bus couplers so that a change-over can be made from either of the two step-down transformers to restore power in case of failure of any one of the above two transformers. Similarly, all DB's will have 2 x 100% incomers from 415V Switchgear / MCC. Incomers, bus couplers and outgoing feeders including starter modules will be of draw out construction and modular design. The Distribution Boards will be fixed type but of modular design. The degree of protection of the switchboards will be EP-52/42.

Air break type circuit breakers will be used in the 415 V Switchgear / MCC.

A ground bus will extend across the full length of the Switchgear/MCC/DB. One spare feeder for each rating/ type will be provided in Switchgears / MCC and will be considered for rating selection. A short circuit calculation will be done to establish short circuit withstand capability of the switchgear. Motors rated 75kW and below will be Contactor/MCCB operated and those above 75kW will have circuit breaker control.

Motor control circuits will include emergency stop push button near the motor as per Indian statutory requirement.

5.8.9 Electric Motors

To feed power to various unit/station drives, the voltage rating for the motors will be as follows:

Below 0.2 kW	-	240 V, single phase
From 0.2 kW upto 200 kW	-	415 V, three phase
Above 200 kW upto 1500 kW	-	3.3 kV, three phase
Above 1500 kW	-	11 kV, three phase
DC motors	-	220 V DC

All SV motors will be squirrel cage three/ single phase induction motors. Lifts/Crane motors may be of slip ring type. DC motors will generally be of shunt/compound wound type rated for 220 V DC. All motors will be rated for continuous duty. Lifts/Crane motors will be rated for intermittent duty. Inching type motors as per the requirement will be provided.

Motor enclosures will conform to the degree of protection IP-54 (indoor) and IPW-55 (outdoors). For hazardous areas, approved type of flameproof and increased safety enclosure will be provided.

The motors will generally be of self-ventilated type totally enclosed fan cooled (TEFC). Alternatively for large motors, closed air circuit air cooled (CACA) / closed air circuit water cooled (CACW) / totally enclosed tube ventilated (TETV) type cooling arrangement will be adopted.

MV motors will have class F insulation with temperature rise limited to class B. LV motors will have class B insulation.

5.8.10 Control & Relaying

The unit control room will have number of control and relay panels for the generator, its auxiliaries, 11 kV switchgear, 3.3 kV switchgear and 415 V switchgears. All required control, protective relays and metering for generator including excitation system, and unit auxiliary transformers to safeguard against abnormal system conditions will be provided in this control room.

Synchronisation of generator will be done from the unit control room which will be provided with panel mounted measuring instruments like ammeter, voltmeter, VAR meter, frequency meter, synchroscope etc. and mimic with switch position indication, audiovisual annunciation with discrimination to draw operator’s attention for abnormal operating condition and tripped condition.

5.8.11 Protective System

For protection of equipment against abnormal system conditions, adequate protective devices will be installed in the respective switchgears and/or control and relay panels. A group of such protective devices will be necessary to protect the equipment under different abnormal conditions arising in the system.

5.8.12 Intercommunication System

An intercommunication system will be provided to facilitate plant operation by establishing quick communication among the operating personnel at various location of plant.

The plant Communication System will consist of the following:

- Walkie Talkie System
- Telephone system completes with EPABX, telephone sets in the Power Plant and associated administration buildings.
- P&T (Posts and Telegraph) telephone system.

Walkie Talkie System

Walkie–Talkie communication system is proposed to be provided for effective communication for operation & maintenance of the power plant.

Telephone System

The Power plant and housing colony will be provided with microprocessor based intercom telephone system to facilitate inter-communication for operation/ administrative purposes. This consists of an Electronic Private Automatic Branch Exchange (EPABX) of suitable capacity. All the instruments for subscribers will also have the provision for hooking up with P&T lines.

The telephone sets will be installed in various areas of power plant and colony. The EPABX at Power plant and EPABX at colony will be interconnected.

In hazard areas such as oil storage, wall telephone sets with explosion proof and corrosion resistant metal cases will be provided.

5.8.13 Illumination System

Suitable illumination is necessary to facilitate normal operation and maintenance activities and to ensure safety of working personnel. This will be achieved by artificial lighting.

For outdoor yard illumination, floodlights will be installed at suitable locations to provide requisite level of illumination. Pole mounted high-pressure sodium vapour lamp fixtures will be used for approach and work roads.

The station emergency DC lighting will be fed from station 220 Volt DC distribution system during extreme emergencies. On failure of the AC supply, these lights will glow from DC system.

5.8.14 400 kV Switchyard

A 400 kV switchyard will have breaker and half arrangement comprising 4 diameters. There will be 8 bays; 1 generator transformer bay, 1 station transformer bay, 4 line bays, 1 bus reactor bay and 1 future bay. This switchyard will facilitate the interconnection between generator transformer and 400 kV double circuit transmission line systems. A single line diagram of 400 kV switchyard is attached as **Exihibit-5.9.**

5.8.15 Power & Control Cables

Main factors which are considered for selection of sizes for power cables are as follows:

- System short circuit current
- Deaerating factors due to higher ambient temperature and grouping of cables.
- Continuous current rating.
- Voltage drop during starting and under continuous operation.
- Standardisation of the cable sizes to avoid too many sizes of cables.

11 kV and 3.3 kV power cables will be 11 (UE) and 3.3 (UE) volt grade, single/ multi core, 90 Deg C rating under normal running condition and 250 Deg C under short circuit condition, heavy duty with stranded annealed copper/ aluminium conductor, extruded semi-conducting conductor screen, XLPE insulation, extruded semi conducting insulation screen, extruded PVC inner sheath, round wire armour and extruded FRLS PVC overall sheath. These cables shall have phase identification colour coding.

LT power cables will be 1,100 V grade with stranded aluminium conductor. XLPE insulated, extruded PVC inner sheathed, galvanized steel strip/ wire armoured (for multi-core cables only) and with FRLS PVC outer sheath. The cables would be suitable for effectively earthed system.

Control cables will be multi-core 650/1100 V grade PVC insulated, PVC sheathed, round steel wire armoured and with FRLS PVC outer sheath having 4 sq.mm stranded copper conductors for C.T. and control circuits and 2.5 sq.mm conductors for P.T. circuits.

Fire survival cables (FS) will be used for system, which are necessary for protection and safe shutdown of plant in case of fire.

5.8.16 Plant DC System

A reliable DC power source will be provided to supply those loads which are required to function for security, protection and safe shutdown of plant in the event of failure of normal AC power supply.

5.8.17 Lightning Arrestors

390 kV, 10 kA for 400 kV metal oxide (gapless) surge arrestors of heavy-duty station class (discharge class III & IV) shall be provided on each phase of 400 kV. The arrester will include a digital impulse counter and leakage current detector.

Lightning arrestors shall be provided near line entrances and power transformers so as to achieve proper insulation coordination for the whole substation. They shall be provided with PRD and diverting ports suitable to prevent shattering of porcelain insulators in case of arrestors' failure.

5.8.18 Supervisory Control and Data Acquisition (SCADA) System

The operation and supervision of the new 400 kV switchyard will be through Supervisory Control and Data Acquisition (SCADA) System. The system will be designed to work on 48 V DC System.

The SCADA System will perform the following minimum functions as:

- Monitor and display the status of various equipments like circuit breakers, isolators and earth switches.
- Real time monitoring of various electrical parameters like voltage, frequency, current, active power, reactive power, oil and winding temperature of transformers, transformer tap positions, integrated demand, etc.
- Operation of various circuit breakers, isolators and earth switches through interactive dynamic graphics during “normal conditions”.
- Generate alarm signals of on occurrence of abnormal conditions.
- Display, log, trend and archive the various analogue and digital parameters acquired by the system and perform pre and post trip analysis, keeping records of all system faults and sequence of faults and operation of protective relays.
- Interface with the plant Distributed Control System (DCS) through communication link to facilitate the exchange of various digital and analogue parameters for information and monitoring purpose only.

An integrated and functionally distributed microprocessor based SCADA system has been envisaged to meet the above-mentioned functional requirements and reliable operation.

5.8.19 Emergency Power Supply System

The emergency power system provides power to essential auxiliary loads required to permit a safe shut down of the unit in the event of a plant blackout. In addition, power is provided for auxiliaries and services required for personnel safety and minimum plant maintenance during the blackout.

In order to meet the above requirement, one (1) no. 415 V, 2000 kVA, 3-phase, 50 Hz emergency Diesel Generator (DG) has been envisaged to cater emergency load of the unit. The exact rating of DG set will be decided during the detail design stage.

5.8.20 Uninterruptible Power Supply (UPS) System

Two sets of uninterruptible power supply systems of continuous duty have been envisaged to supply regulated altered and uninterrupted 240 V, 50 Hz single phase power within acceptable tolerances to critical AC loads like computerized data acquisition system, microprocessor based control and instrumentation system, control systems, annunciation system; indicators/recorders mounted on unit control boards and other critical loads of such nature.

5.8.21 Generator and Switchyard Protection & Control

The details of the protections that will be provided for the various electrical equipment viz., Generators, generator transformers (GT), Station transformers (ST), unit Auxiliary transformer (UAT), service transformers, 400 kV switching equipment, 400 kV transmission lines, motors, switchgear, etc., are indicated below:
The selection of the protective scheme will be based mainly on reliability, sensitivity, selectivity and technical merits. All main protections will be of fast acting type in order to

isolate the faulty system from the healthy system in the shortest possible time, to minimise damage to the equipment and ensure continuity of power supply.

One set of generator relay panels (GRP) will be provided for the unit. This set of panels will be located in the unit control room. The following protection schemes will be provided on the GRP. The protections will be divided into two groups; each group being 100% redundant and on separate DC supply, so that even if one group of protections is not available or under maintenance, the generator is protected by the other group.

5.9 INSTRUMENTATION AND CONTROL SYSTEM

The control and instrumentation system shall be designed to ensure safe, efficient and reliable operation of the plant under all operating regimes, namely start up, shutdown, normal operation and under emergency conditions.

The state of the art control and instrumentation system shall include but not be limited to the following:

A functionally distributed microprocessor based DCS, designed for CRT operation, control and monitoring with in-built Sequence of Events (SER) recording and Annunciation system, including control desk and system cabinets. The DCS Monitor based plant operation shall result in cost effective power generation with optimum fuel consumption and reduced emission levels. It shall relieve the operator from tedious manual operation as most operations of the plant shall be automatic with sequential start-ups of major plant equipment. The design of the control and instrumentation system would be such as to permit on line localization, isolation and rectification of fault in the minimum possible time. Ease of maintenance would be given due importance at system design stage.

The DCS shall provide a comprehensive integrated control and monitoring system to operate, control and monitor the Steam Generator and auxiliaries, Steam Turbine-Generator and Auxiliaries and Balance of Plant (BOP) systems.

Monitoring and control, data acquisition, alarm annunciation, fast response time, fail safe design, sequence of events recording, online diagnostic and online maintenance are some of the inherent features of the DCS to be designed for the proposed power plant.

Plant operation and control shall be through the Operator Work Stations (OWS) located on the Unit Control Desk (UCD) in the Central Control Room, which shall consist of colour graphic LCD (TFT) monitor, keyboard/mouse.

The main plant including Steam Generator and its auxiliaries, Steam Turbine Generator and its auxiliaries and Balance of Plant equipment and auxiliaries etc. shall be controlled and monitored through DCS. DCS shall include the modulating controls of the plant including coordinated Master Control, Steam Generator modulating controls, Turbine governing and other Turbine modulating controls, and modulating controls for Balance of Plant equipment.

All open loop control functions for the main plant including Steam Generator (e.g., FSSS) and the Steam Turbine Generator (e.g., ATRS) and their auxiliaries along with Balance of Plant (BOP) equipment and systems shall be implemented in the DCS.

DCS shall also include sequential start up, shutdown of the plant including Steam Generator, Turbine Generator and BOP Equipment and Systems.

The control functions shall be backed up by protection, interlocks and safety functions. This would cause pre-planned actions in cases where unsafe conditions develop faster than the control capability of modulating controls or before the operator can be expected to respond to the plant upset conditions in any regime of plant operation.

Operation and Monitoring of Plant Electrical and downstream System shall be performed through DCS. Additionally, DCS shall have a Software link for monitoring of electrical system.

Sequence of Event Recording system shall be provided for recording and printing trip and causes of trip for quick diagnostic of fault and remedial action.

DCS shall perform online performance calculations to determine plant/equipment efficiency and to detect and alarm unit/equipment malfunctions.

The plant offsite systems like Water treatment, Coal handling, Ash handling, Instrument and Service air system etc. shall be controlled and monitored through the respective Local Control panels and control systems. Independent and stand-alone PLCs in hot redundant configuration shall be used for control and monitoring of these offsite systems. PC based Operator Work Stations (OWS) with LCD (TFT)/ KBD/ Mouse shall be provided for these offsite systems, which shall be kept in the respective Local Control Rooms. Additionally, control and monitoring of these offsite packages shall be possible from DCS Operator Work Stations (OWS) from Central Control Room.

Redundant Software link shall be provided between the offsite package PLCs and DCS for data exchange shall.

5.10 CIVIL ENGINEERING ASPECTS

5.10.1 Geo-Technical Investigations & Soil Profile

The proposed new unit will be erected within the premises of existing Panipat thermal power station therefore it can be construed that the geo-technical conditions and soil profile would be identical to existing plant. The similar treatment is suggested for new unit also. Pilling would be required for most of the foundations.

5.10.2 Main Plant Building

The Main Plant Building would house the turbo-generators; the boiler feed pumps, electrical systems and instrumentation & controls systems. The building shall be steel framed structure with infill masonry walls with foundations and floor & roof slabs of reinforced concrete. The steel framed structure shall be designed for the worst combination of loading. The design of steel structures shall be to IS: 800 and RCC structures designed to IS: 456.

Architectural finishes appropriate to the area shall be provided: mosaic flooring, granite flooring, surface hardened floors, plain concrete floors, glass blocks, louvers, glazing etc. For access to the maintenance bay motorized steel rolling shutters shall be provided.

5.10.3 Boiler Structure

The boiler structure shall also be framed steel structure housing/supporting the Boiler and related equipment including primary and secondary air fans, burners, air heaters, economizers, hoppers, ducts, piping etc.

The stairs, platforms, walkways shall be provided for utility and safety and shall be of gratings and chequered plates with toe plates and hand railing. Temporary access openings shall be provided for erection of boiler and its accessories.

All boiler, electrostatic precipitators, fans, mills, duct supports shall have reinforced concrete foundations with the heavy equipment foundations designed for static and dynamic loadings.

5.10.4 Transformer Bay

The transformer foundations shall be of RCC construction having fire walls to compartmentalize the bays but open from the front so that the transformer can be brought in or taken out on rail tracks at the time of installation as well as for maintenance. Care is taken to ensure that oil spillage is contained and proper drainage system provided around the gravel filling for these transformers. Fencing shall also be provided around the transformer area as per the norms.

5.10.5 Switchyard

Galvanised steel structures shall be provided to support the conductors, current and voltage transformers, circuit breakers, insulators etc.

RCC isolated footings and pedestals shall support these structures. Towers supporting the gantries for stringing shall have mat foundations accommodating the four pedestals / legs of the towers. RCC cable trenches shall be fitted with pre-cast covers; gravel will be laid out in the switchyard area.

5.10.6 Chimney

Single flue chimney of 275m height shall be provided. The floor slabs shall be of RCC / grating & chequered plate construction. The chimney flue shall have the appropriate fire resistant / acid proof lining. Other provisions for lightning protection, aircraft warning lights & special aviation warning bands painting, staircase and elevator shall be as per the IS codes and aviation norms.

5.10.7 Coal Handling System

The coal handling system shall include the Transfer Tower and conveyor galleries.
Transfer points provided at every change of direction shall be of structural steel framework having metal cladding and RCC roofing & flooring.

5.10.8 Water System

The De-mineralisation plant building shall be of RCC framed construction with infill brick walls with the DM water tanks resting on RCC ring walls. Acid /alkali proof lining shall be provided in the areas as required.

The CW pump house shall have superstructure in steelwork with high grade concrete for fore bay and sump construction having necessary arrangements for steel stop log gates. The pump house cladding shall be in brickwork with normal architectural finishes.

5.10.9 Natural Draught Cooling Towers

A closed cycle cooling system with natural draught cooling towers is proposed. These towers shall be suitably located away from electrical installations and major structures also considering wind direction to ensure minimum re-circulation and ingress of drift to other areas.

5.10.10 Miscellaneous Buildings

Other auxiliary buildings and the type of construction proposed is as indicated **Table-5.1.**

Table-5.1

S. No.	Building /Structure	Type of construction
1.	ESP Control Room	Single storey building; foundations columns, beams, slabs (floor & roof) of reinforced concrete with brick cladding & mosaic flooring.
2.	Diesel Generator Building	RCC columns, beams & slab with surface hardened floor, brickwork walls.
3.	Fuel Oil Pump house	RCC foundations, columns , beams & slab and brick cladding
4.	DM Plant /Water Treatment Plant	RCC foundations, columns, beams & slab and brick cladding
5.	Raw Water Intake Pump house	RCC foundations, Steel /RCC columns & beams, concrete floor & slab with brick cladding.
6.	CW pump house	RCC foundations, Steel /RCC columns & beams, concrete floor & slab with brick cladding.
8.	Fire Fighting Pump house	RCC foundations, Steel /RCC columns & beams, concrete floor & slab with brick cladding.
9.	Switchyard Control Room	Single storey building, foundations columns, beams, slabs (floor and roof) of reinforced concrete with brick cladding and mosaic flooring.

6.0 ENVIRONMENTAL ASPECTS

ENVIRONMENTAL ASPECTS

6.1 INTRODUCTION

A comprehensive Environmental Impact Assessment study is to be got conducted after the approval of Terms of Reference (TOR) from MoEF to assess the existing baseline environmental conditions, assess the impact of the proposed plant on the environment and towards preparation of an Environmental Management Plan. This study document is also a prerequisite towards obtaining clearances from the Pollution Control Boards at Centre & State level as also from the Ministry of Environment & Forest.

The proposed plant will be provided with necessary equipment and systems to meet all applicable environmental regulations. The plant has been envisaged to have the following features, which will help in reducing emissions and effluents.

- Low NOx burners have been envisaged to reduce the NOx generation and consequent emission.
- High efficiency Electrostatic Precipitators have been envisaged to limit the particulate emissions to 50 mg/Nm^3, which is less than the prevailing permissible limit of 100 mg/Nm^3.
- 275 m single-flue chimney has been envisaged for the plant, , which will help dispersion of air borne emissions over lager area and thus reducing the impact of the power plant on ground level concentrations.
- Closed cooling water system with cooling towers envisaged, thus reducing significantly the water requirement for the plant. River water is envisaged for condenser cooling.
- Ash pond water will be re-circulated and Zero discharge is envisaged from the plant.
- Zero liquid effluent discharge scheme has been envisaged for the Plant. All effluents in the plant will be treated and recycled.
- Dust extraction and dust suppression systems have been envisaged in the coal handling plant.
- Green belt will be developed as per MoEF stipulations

The proposed power plant could contribute to the following types of environmental pollution:

i. Atmospheric pollution through particulate and gaseous emissions.
ii. Pollution from solid and liquid waste discharge.
iii. Thermal pollution of surrounding area.
iv. Noise pollution.

The above mentioned contaminants may be discharged from the power plant at the following points:

a. Chimney – Discharge of flue gases and heat
b. Coal Handling Plant – dust nuisance during loading /unloading.
c. Ash handling system – dust nuisance from fly ash & dust flying at ash dyke.
d. Cooling - Discharge of heat into the surroundings
e. Waste water, oil, unwanted chemicals etc. run-off through surface drains
f. Noise from equipments – Not to exceed 85dBA at a distance of 1 metre and at a height of 1.5 metre from any equipment and not more than 90dBA for turbine generator set.

HPGCL shall comply with all environment safeguards that will be stipulated in the environment clearance to be given by MoEF (Govt. of India) and NOC from Haryana State Pollution Control Board.

7.0 PROJECT COST ESTIMATES AND FINANCIAL ANALYSIS

PROJECT COST ESTIMATES AND FINANCIAL ANALYSIS

The objective of this section is to estimate and analyze the project cost, cost of generation and levelised tariff for the proposed project in order to assess overall financial viability of the project.

7.1 BASIS OF COST ESTIMATES

The project cost estimate for the proposed power plant has been worked out on the following basis;

Unit size considered is 800 MW for financial analysis. Unit will be commissioned within 52 months from zero date (as per CERC norms). The cost of main equipment package including steam generator with auxiliaries and turbine generator with auxiliaries has been worked out considering the cost of similar projects and work out to be Rs.26971 Million.

The cost of balance of plant and other equipment has been estimated based on preliminary design and in-house cost data.

The project is planned to be financed by domestic equity and term loan. Taxes and duties on supply of equipment, civil works, contract and erection and commissioning have been worked out as per the prevalent practice. The economic plant life has been taken as 25 years for depreciation calculation as per CERC norms.

7.2 CIVIL WORKS

The Project cost includes;

- Power station building and all other plant structures.
- Foundations for all major structures.
- Chimney
- Cost of site grading and levelling and boundary wall.
- Cost of approach roads inside plant boundary and drainage.
- Cost of water corridor and desalination plant has been considered.
- Cost of cooling tower.
- Coal handling system including stock yard.
- Ash handling system including ash dyke.
- Excluding raw water reservoir

7.3 MECHANICAL AND ELECTRICAL WORKS

- Cost of transmission has not been considered
- Cost of initial spares for mechanical and electrical equipment Rs 881.00 Million
- FGD plant cost has not been considered in the project cost estimates.

7.4 INVESTMENT COST

The estimated cost of the plant including equipment and civil cost amounts to Rs. 33573 Million. Adding physical contingency, pre-commissioning cost, overhead expenses and taxes and duties, basic project cost before financing and IDC, amounts to Rs. 36612 Million.

Financing expenses and interest during construction (IDC) add Rs. 7577 Million to the Basic Project Cost, bringing the total financing requirement to Rs.44189 Million. The specific cost of the project is Rs. 55.24 Millions per MW.

The project is proposed to be financed with a debt equity ratio of 70:30.

The detailed breakdown of total financing requirement cost has been given in **Appendix-II** placed at the end of this Report.

7.5 ASSUMPTIONS

General Parameters and Assumptions:
Operational Parameters
The plant is configured with steam generators of 800 MW capacity and their auxiliaries, steam turbine and generator sets of 800 MW capacities and other balance of plant equipment. Imported and Domestic coal (70:30) is the main fuel for the unit with HFO as the start-up fuel. The financial analysis is carried out based on the assumption that the plant will be running on blended coal with 85% availability and 85% plant load factor (PLF). Basic data for the purpose of estimation of operational expenses are as follows:

Plant Load factor and Plant availability
Plant load factor 85% and plant availability of 85% has been considered for the 800 MW station to recover full fixed cost as per the regulatory commission's guidelines

Station Heat Rate
As per CERC guidelines, a station heat rate of 2151 Kcal/kWh is permitted for the coal fired plants of unit size of this range with the steam driven boiler feed pumps.

Fuel
The gross calorific value (GCV) of coal has been considered as 3600 Kcal/Kg and 5800 Kcal/kg for domestic coal and imported coal respectively for blending in ratio of 70:30 and the GCV of auxiliary fuel has been considered as 10,000 Kcal/L.

Auxiliary Power Consumption
Auxiliary power consumption has been considered @ 5.25% of generation as per new CERC norms for the power plants of this range with turbine driven BFPs and natural draft cooling tower.

Financial Parameters
The other major assumptions made to compute the financial results are as follows:
No cost of financing for equity has been considered.

Taxes and Duties
Taxes and Duties have been considered as per the current practice. Indirect taxes including development surcharge and education cess applicable have been considered for estimating the cost of project are as follows:

Table-6.1

Description	Unit	Application
Import Duty	Nil	Mega Power Project
Excise Duty*	10.3%	On domestic goods (on domestic power equipments)
Central Sales Tax*	2.06%	On domestic goods
Service Tax	12.36%	On local services (engineering, erection and commissioning, training and owner's/ lender's consultant)

**- taxes are included in plant & equipment costs*

Depreciation
Appendix-VI furnishes details of depreciation. The economic plant life has been taken as 25 years for depreciation calculation as per CERC norms.

Loan Structure
The rate of interest, repayment period and the moratorium period of the proposed loan structure has been shown in the **Table-6.2**.

Table-6.2

Description	Unit	RTL (Rupee Term Loan)
Interest Rate	%	14%
Repayment Period	Years	11
Moratorium	Months	6
Repayment Mode	Instalments	Quarterly

The rate of interest on working capital loan is assumed to be 12.25 % p.a.

Appendix-I placed at the end of this section summarizes the general parameters and assumptions underlying the investment cost estimate.

Financial Aspects and Cost of Generation

Major Assumptions
A debt & equity ratio of 70:30 including IDC is considered. The capital cost would be financed through the following sources:

Equity
Equity contribution Rs. 13256.73 Million

Loan
Rupee Term Loan Rs. 30932.36 Million

Phasing of funds (drawl of debt and equity) is indicated in the **Appendix-III**

7.6 OPERATING COST

Fuel Cost
Cost of coal at site has been considered for domestic coal as Rs.4305 / MT and imported coal as Rs. 6800/ MT.

Operation & Maintenance
Annual fixed operation and maintenance cost has been considered as Rs.1.838 million per MW of generation based on 2014-2019 as first year of operation as per CERC norms and escalated at the rate of 6.24 % per annum as per CERC norms.

7.7 ESTIMATED PROJECT COST AND COST OF GENERATION

The estimated Capital Cost (including IDC) has been taken as Rs. 44189 million. The total levelised tariff has been arrived as Rs. 4.37/kWh (fixed cost - Rs. 1.65/kWh variable cost - Rs. 2.73/kWh). The first year tariff works out to Rs 4.64/kWh (fixed cost - Rs. 1.91/kWh variable cost - Rs. 2.73/kWh). Details of input data & assumptions, project cost & levelised tariff are given in Appendices.

7.8 SENSIVITY ANALYSIS

The tariff sensitivity due to variation in coal price and coal GCV has been worked out and the same is tabulated below:

S. No.	Particulars	70% Domestic + 30% imported coal		
		Coal cost (Rs/MT)	GCV (kcal/kg)	Levelised Tariff (Rs/kWh)
	800 MW (HR-2151 kcal/kWh)			
1	**Base Case**	**5053**	**4260**	**4.37**
2	**Variation in Coal Cost only**			
	5% increase	5306	4260	4.51
	5% decrease	4801	4260	4.23
	10% increase	5559	4260	4.66
	10% decrease	4549	4260	4.09
3	**Variation in GCV only**			
	5% increase	5053	4473	3.97
	5% decrease	5053	4047	4.23
	10% increase	5053	4686	3.86
	10% decrease	5053	3834	4.37