**CHAPTER II**

**REPORT PROPER**

This chapter is composed of the report proper and design calculations considered in the proposed 500 MW Coal-Fired Power Plant. The methods and data are also discussed in this chapter. It also presents the summary of equipment used in the proposed coal-fired power plant.

**Methodology**

This chapter presents the methodology used to come up with the three design options of a power plant that can meet the electric demand of a particular location.

* 1. Choose a location of the power plant by identifying the following:

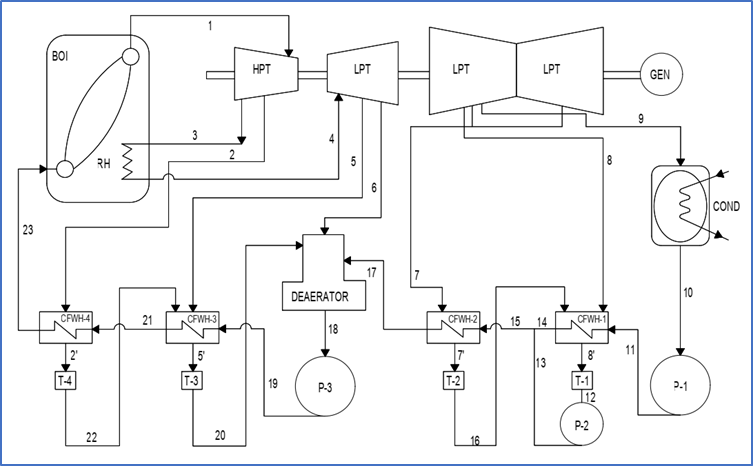
1. Topography;
2. Source of cooling water;
3. Nearness to the load center;
4. Type of land use;
5. Cost of land area;
6. Access to transportation; and
7. Other necessary factors that should be considered in the construction of a power plant.
   1. Identify the electricity demand, base and peak load in the chosen location to be used as the basis of the power plant capacity.
   2. Choose among the different types of power plant the particular design that will complement to the chosen location taking in to account both the advantages and disadvantages of each. Consider also the environmental impact, economic aspects and the likes that will possibly affect the efficiency and operation of the combined cycle power plant.
   3. Design three options and draw the corresponding schematic and T-S diagrams of each to increase the efficiency of the power plant considering the annual costs and revenue they will make for the following years.
   4. Provide all the necessary calculations to come up with work and efficiencies of turbines and other equipment required.
   5. Select the different equipment using various catalogs readily available in the internet based on the result of the calculations made and gather their specifications. List all equipment data needed for the calculations and identification.
   6. Perform basic engineering economics for power plants by calculating the fixed and operating costs of the project, depreciation, payback period, return of investment, and sensitivity analysis. Evaluate also the environmental impact by calculating the rate of emissions of the different harmful gases in the environment.

**Design Calculation**

The design options for the proposed power plant operate with a reheat regenerative rankine cycle. The diagram of each design is shown below.

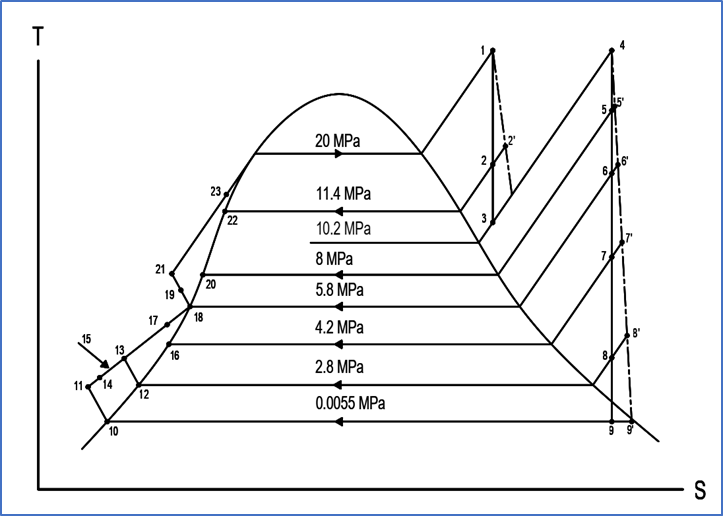
**Design Option 1**

The schematic and T-S diagram of design option 1 are shown as follows:



**Figure 4.** Schematic Diagram of Design Option 1

Design option 1 consists of 5 regenerative processes with 1 open feed water heater and 4 closed feed water heater. The design option has a thermal efficiency of 33.68 %.

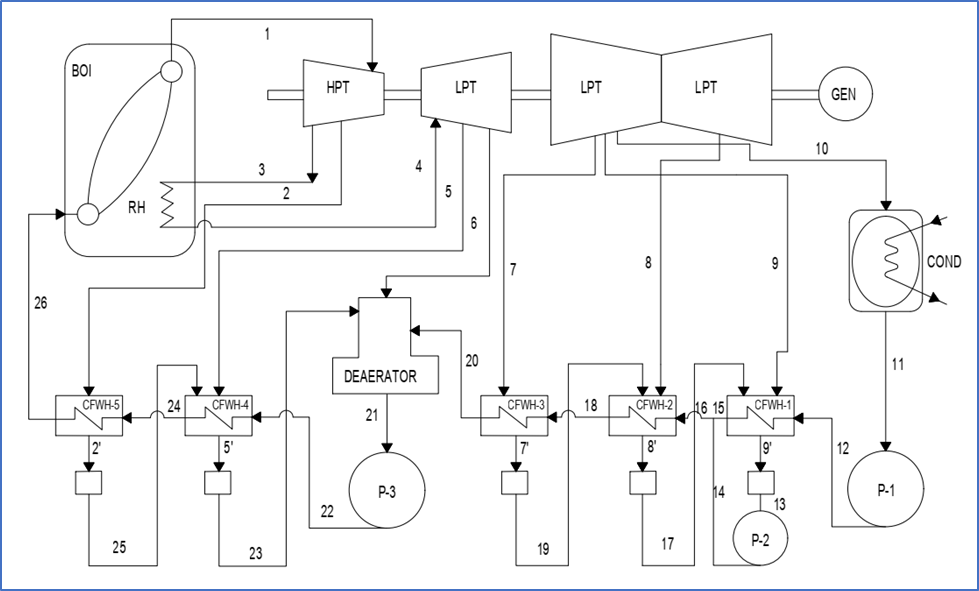


**Figure 5.** T-S Diagram of Design Option 1

The figure above shows the thermodynamic relationship within the design. The cycle consists of 23 state points with 8 operating pressures.

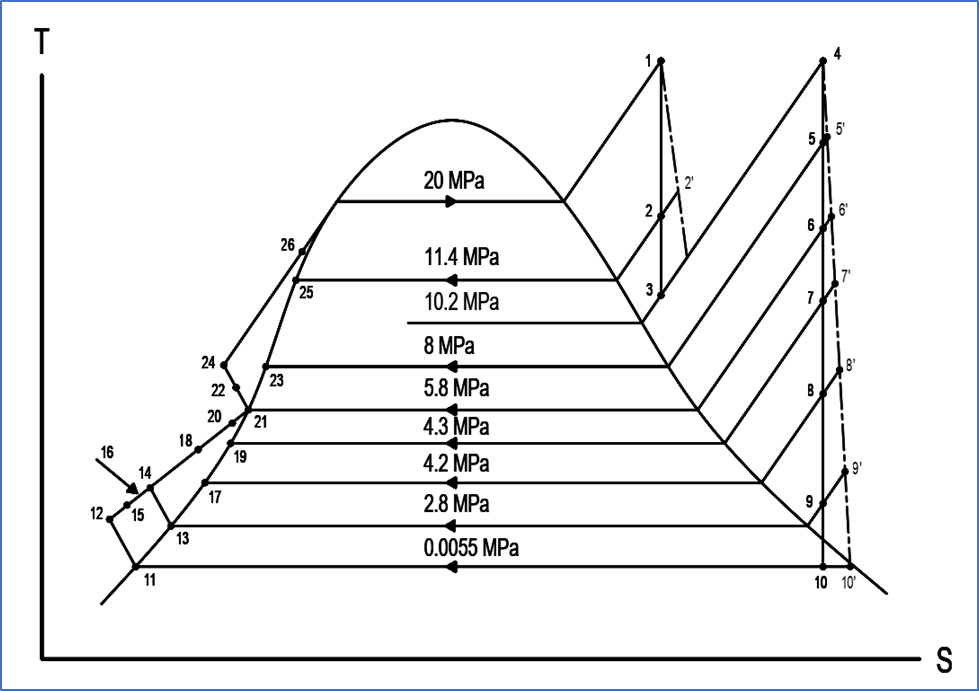
**Design Option 2**

The schematic and T-S diagram of design option 2 are shown as follows:



**Figure 6.** Schematic Diagram of Design Option 2

Design option 2 consists of 6 regenerative processes with 1 open feed water heater and 5 closed feed water heater. The design option has a thermal efficiency of 34.21 %.

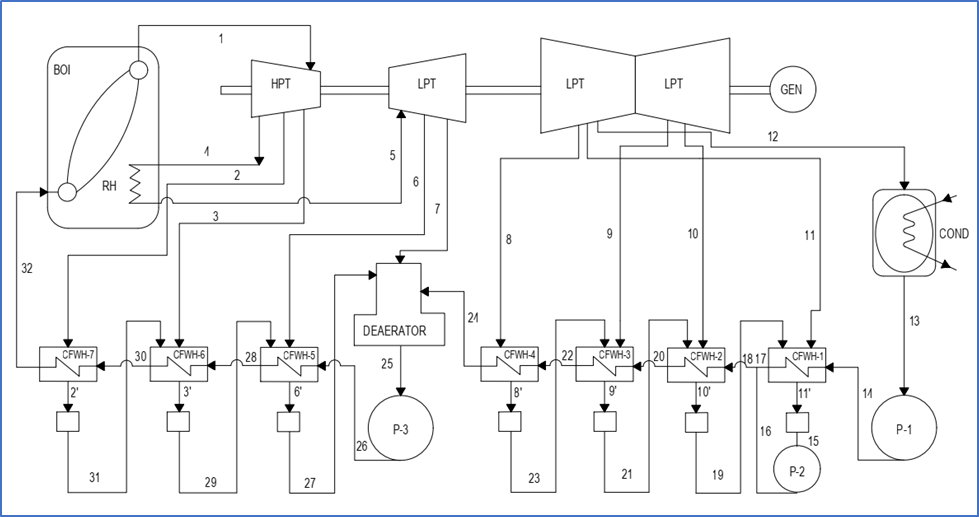


**Figure 7.** T-S Diagram of Design Option 2

The figure above shows the thermodynamic relationship within the design. The cycle consists of 26 state points with 9 operating pressures.

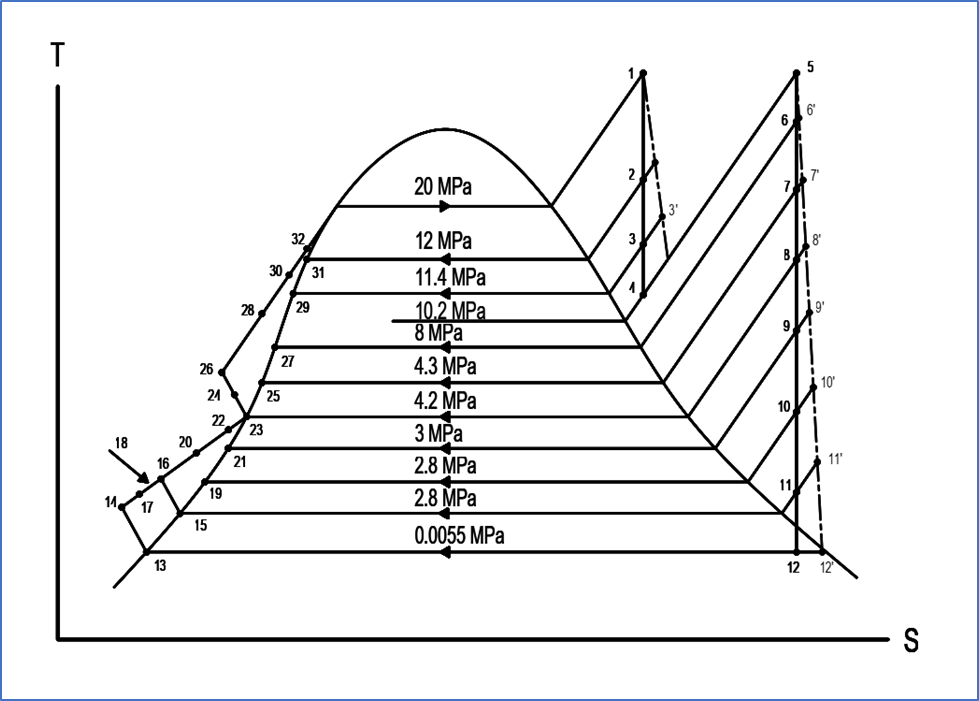
**Design Option 3**

The schematic and T-S diagram of design option 3 are shown as follows:



**Figure 8.** Schematic Diagram of Design Option 3

Design option 3 consists of 8 regenerative processes with 1 open feed water heater and 7 closed feed water heater. The design option has a thermal efficiency of 35.08 %.



**Figure 9.** T-S Diagram of Design Option 3

The figure above shows the thermodynamic relationship within the design. The cycle consists of 32 state points with 11 operating pressures.

**Design Data**

The design data includes the ambient conditions such as pressure, humidity and temperature of the proposed location for the steam power plant in Brgy. Lumaniag, Lian, Batangas.

**Table 3.0**

**Ambient Condition in Brgy. Lumaniag, Lian, Batangas**

|  |  |  |
| --- | --- | --- |
| **Pressure** | **mbar** | **1013.0** |
| Humidity | % | 77 |
| Temperature |  |  |
| Design Temperature | °C | 28 |
| Max. Temperature | °C | 36 |
| Min. Temperature | °C | 22 |

Table 3.0 shows the surrounding weather conditions in the proposed location at Brgy. Lumaniag, Lian, Batangas. The atmospheric pressure is 1013 mbar and the air has a relative humidity of 77 %. For the temperature of the location, the chosen design temperature is 28 °C as the maximum and minimum temperatures are 36 °C and 22 °C respectively.

**Design Calculation**

The design calculation enlists the calculations used in obtaining the mass of flow rate of steam, total heat added, heat loss, steam turbine work, pump work, net cycle work, thermal efficiency and steam rate.

**Table 4.0**

**Summary of Calculation for Design Option 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Equation** | **Symbol** | **Value** | **Units** |
| Mass flow rate of steam | ms = Pout/Wnet | ms | 664.92 | kg/s |
| Heat added in the boiler | Qb = ms(h1-h23) | Qb | 1,292,566.46 | kW |
| Heat added in the reheater | Qrh = (m1-m2)(h4-h3) | Qrh | 191,883.39 | kW |
| Heat Loss | Ql = (m23-m2-m5-m6-m7-m8)(h9a-h10) | Ql | 984,449.85 | kW |
| Turbine Work | Wt = m23(h1-h2a) + (m23-m2)(h2a-h3) + (m23-m2)(h4-h5a) + (m23-m2-m5)(h5a-h6a) + (m23-m2-m5-m6)(h6a-h7a) + (m23-m2-m5-m6-m7)(h7a-h8a) + (m23-m2-m5-m6-m7-m8)(h8a-h9a) | Wt | 514,083.00 | kW |
|
|
|
| Pump Work | Wp = (h11 - h10) + (h13-h12) + (h19-h18) | Wp | 14,843.58 | kW |
| Total Heat Added | Qa = Qb + Qrh | Qa | 1,484,449.85 | kW |
| Net Cycle Work | Wnet = Qa - Ql | Wnet | 500,000 | kW |
| Thermal Efficiency | eth = Wnet/Qa | eth | 33.68 | % |
| Steam Rate | SR = 3600/Wnet | SR | 0.0072 | kg/kWh |

This table shows the different parameters used to calculate the thermal efficiency of a reheat regenerative cycle for Design Option 1. The heat added and rejected of the cycle is determined by the energy balance equation for the system. Similarly, the turbine work and pump work is obtained by getting the difference of the enthalpies between the inlet and outlet of the component. The results obtained are based on the capacity of the coal fired power plant which is 500 MW. The design option 1 shows that the thermal efficiency is about 33.68%.

**Table 5.0**

**Summary of Calculation for Design Option 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Equation** | **Symbol** | **Value** | **Units** |
| Mass flow rate of steam | ms = Pout/Wnet | ms | 654.58 | kg/s |
| Heat added in the boiler | Qb = ms(h1 - h26) | Qb | 1,272,454.21 | kW |
| Heat added in the reheater | Qrh = (m1 - m2)(h4 - h3) | Qrh | 188,897.70 | kW |
| Heat Loss | Ql = (m26 - m2 - m5 - m6 - m7 - m8)(h10a-h11) | Ql | 961,351.90 | kW |
| Turbine Work | Wt = m26(h1-h2a) + (m26-m2)(h2a-h3) + (m26-m2)(h4-h5a) + (m26-m2-m5)(h5a-h6a) + (m26-m2-m5-m6)(h6a-h7a) + (m26-m2-m5-m6-m7)(h7a-h8a) + (m26-m2-m5-m6-m7-m8)(h8a-h9a) + (m26-m2-m5-m6-m7-m8-m9)(h9a-h10a) | Wt | 513,512.02 | kW |
|
|
|
| Pump Work | Wp = (h12 - h11) + (h14-h13) + (h22-h21) | Wp | 14,264.86 | kW |
| Total Heat Added | Qa = Qb + Qrh | Qa | 1,461,351.91 | kW |
| Net Cycle Work | Wnet = Qa - Ql | Wnet | 500,000 | kW |
| Thermal Efficiency | eth = Wnet/Qa | eth | 34.21 | % |
| Steam Rate | 3600/Wnet | SR | 0.0072 | kg/kWh |
| Generator Efficiency | eg = Gen. Output/Wt | eg |  | % |

This table shows the different parameters used to calculate the thermal efficiency of a reheat regenerative cycle for Design Option 2. The heat added and rejected of the cycle is determined by the energy balance equation for the system. Similarly, the turbine work and pump work is obtained by getting the difference of the enthalpies between the inlet and outlet of the component. The results obtained are based on the capacity of the coal fired power plant which is 500 MW. The design option 1 shows that the thermal efficiency is about 34.21%.

**Table 6.0**

**Summary of Calculation for Design Option 3**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Equation** | **Symbol** | **Value** | **Units** |
| Mass flow rate of steam | ms = Pout/Wnet | ms | 646.41 | kg/s |
| Heat added in the boiler | Qb = ms(h1 - h32) | Qb | 1,241,645.93 | kW |
| Heat added in the reheater | Qrh = (m32- m2-m3)(h5 - h4) | Qrh | 183,569.25 | kW |
| Heat Loss | Ql = (m32 - m2 - m3 - m6 - m7 - m8 - m9 - m10 - m11)(h9a-h10) | Ql | 925,215.19 | kW |
| Turbine Work | Wt = m32(h1-h2a) + (m32-m2)(h2a-h3a) + (m32-m2-m3)(h3a-h4) + (m32-m2-m3)(h5-h6a) + (m32-m2-m3-m6)(h6a-h7a) + (m32-m2-m3-m6-m7)(h7a-h8a) + (m32-m2-m3-m6-m7-m8)(h8a-h9a) + (m32-m2-m3-m6-m7-m8-m9)(h9a-h10a) + (m32-m2-m3-m6-m7-m8-m9-m10)(h10a-h11a) +(m32-m2-m3-m6-m7-m8-m9-m10-m11)(h11a-12a) | Wt | 512,859.36 | kW |
|
|
|
| Pump Work | Wp = (h14 - h13) + (h16-h15) + (h26-h25) | Wp | 12,369.08 | kW |
| Total Heat Added | Qa = Qb + Qrh | Qa | 1,425,215.18 | kW |
| Net Cycle Work | Wnet = Qa - Ql | Wnet | 500,000 | kW |
| Thermal Efficiency | eth = Wnet/Qa | eth | 35.08 | % |
| Steam Rate | 3600/Wnet | SR | 0.0072 | kg/kWh |
| Generator Efficiency | eg = Gen. Output/Wt | eg |  | % |

This table shows the different parameters used to calculate the thermal efficiency of a reheat regenerative cycle for Design Option 3. The heat added and rejected of the cycle is determined by the energy balance equation for the system. Similarly, the turbine work and pump work is obtained by getting the difference of the enthalpies between the inlet and outlet of the component. The results obtained are based on the capacity of the coal fired power plant which is 500 MW. The design option 1 shows that the thermal efficiency is about 35.08%.

**Summary of Calculation**

Table 7.0 shows the summary of calculations for Design Option 1 (4 closed feedwater heaters and 1 open feedwater heater), Design Option 2 (5 closed feedwater heaters and 1 open feedwater heater) and Design Option 3 (7 closed feedwater heaters and 1 open feedwater heater). The calculations included are the useful energy or the calculated output capacity, heat loss due to moisture in air and heat addition of the proposed steam cycle powerplant. Each value is in MW. In addition, individual efficiencies are shown in the table and the total steam turbine work of each design option.

**Table 7.0**

**Summary of Calculation for the Three Design Options**

|  |  |  |  |
| --- | --- | --- | --- |
| **HP – System** | **Design Option 1** | **Design Option 2** | **Design Option 3** |
| Useful Energy (kJ/kg) | 21817.43743 | 21817.43743 | 21817.43743 |
| Heat Loss due to moisture in Air (MW) | 984.44985 | 961.35190 | 925.21519 |
| Heat Gained (MW) | 1484.44985 | 1461.35191 | 1425.21518 |
| Mass flow rate of steam (kg/s) | 664.92 | 654.58 | 646.41 |
| Steam Rate (kg/kWh) | 0.0072 | 0.0072 | 0.0072 |
| Pump Work (MW) | 14.84358 | 14.26486 | 12.36908 |
| Thermal Efficiency (%) | 33.68 | 34.21 | 35.08 |
| Steam Turbine Work (MW) | 514.083 | 513.51202 | 512.85936 |

Based on the summary of calculations, design option 3 has the highest value of thermal efficiency among the three design options. Design Option 3 has a thermal efficiency of 35.08 %. Therefore, it can be concluded that design option 3 which has 7 closed feedwater heaters and 1 open feedwater heater is the best design among the three.

**Equipment Selection**

Selecting the best equipment is very important in order to have an efficient performance of a power plant by having high efficiency and longer service lives. Table 8.0 presents the comparison of Chinese, US and European equipment based on the relative cost, average efficiency, service life and maintenance costs.

**Table 8.0**

**Equipment Selection**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Relative Capital Cost | Php/kW | Average Efficiency | T1 years | T2 years | O&M |
| Chinese Equipment | ₱74,324,187,000.00 | 9.80 | 0.42 | 1 | 25 | ₱1,362,283,634.72 |
| US Equipment | ₱74,605,257,247.50 | 9.80 | 0.43 | 1 | 25 | ₱1,362,283,634.72 |
| European Equipment | ₱74,751,908,000.00 | 9.80 | 0.46 | 1 | 25 | ₱1,362,283,634.72 |

T1 – Interval of Major Maintenance

T2 – Interval Between Complete Replacement

Table 8.0 shows that equipment from the three different manufacturers differs in terms of relative capital cost and average efficiency. It can be observed that the efficiency of European Equipment has the highest efficiency among the three equipment. These equipment has the same interval of major maintenance and complete replacement.

Further comparison of the given equipment will be shown in Table 9.0 which will be useful in selecting the best equipment.

**Table 9.0**

**Comparison of Given Equipment**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Chinese Equipment | | US Equipment | | European Equipment | |
|  |  | PHP | % | PHP | % | PHP | % |
| Total equity | Php | 23,377,487,102.07 |  | 23,348,164,414.77 |  | 23,332,865,057.42 |  |
| Total loan | Php | 8,918,902,440.00 |  | 8,952,630,869.70 |  | 8,970,228,960.00 |  |
| Total capital cost | Php | 74,324,187,000.00 |  | 74,605,257,247.50 |  | 74,751,908,000.00 |  |
|  | Php/kW | 148,648.37 |  | 149,210.51 |  | 149,503.82 |  |
| Average generation | GWh | 4200 |  | 4200 |  | 4200 |  |
| DSCR, first year | [ ] | 3.49 |  | 3.48 |  | 3.47 |  |
| FIRR | [ ] |  |  |  |  |  |  |

From Table 9.0, it can be observed that the given equipment are compared based on economic aspect such as the total amount of equity, loan and capital cost. Average generation, rate of return and debt service cover ratio of the three equipment are also compared.

**Summary of Equipment**

Table 10.0 shows the specification of the equipment used in the coal-fired power plant. Some details of each component are also listed such as the tag number and selection parameter. The page number of the catalogue is also included in the table.

**Table 10.0**

**Summary of Equipment**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tag No.** | **Component** | **Selection Parameter** | **Specification** | **Page No.** |
|  | Boiler | **Fuel:** Sub-bituminous Coal  **Pressure:** 200 bar  **Temperature:** 540 °C  **Reheat Pressure:** 102 bar  **Reheat Temperature:** 422 °C | **Model:** GE CFB Technology – Two Pass Boiler  **Typical Fuels:** Bituminous, Sub-bituminous, Lignite A, Oil and Gas  **Capacity:** up tp 1,350 MWe  **Pressure:** up to 330 bar  **Temperature:** 650 °C / 670 °C  **Reheat Pressure:** 330 bar  **Reheat Temperature:** 670 °C |  |
|  | Steam Turbine | **Power Output:** 500 MW  **Inlet Pressure:** 200 bar  **Inlet Temperature:** 540 °C | **Model:** GE STF-D850  **Capacity:** up to 1000 MW  **Pressure: up to** 245 bar/ 3553 psi  **Temperature:** up to 585 °C/ 1085 °F  **Reheat Temperature:** up to 585 °C/ 1085 °F |  |
|  | Condenser | **Pressure:** 55 mbar  **Circulating Water Temperature:** 34.58 °C | **Model:** GE Single Vacuum Type Condenser  **Condenser Thermal Load:** 1,820 MW  **Absolute Pressure:** 55 mbar  **Circulating Water Temperature:** 25 °C |  |
|  | Closed Feedwater Heater | **Low Pressure Rating:** 406-623 psig  **High Pressure Rating:** 1653-1740 psig | **Model:** Energyen SPX Heater  **Low Pressure Rating:** 400-800 psig  **High Pressure Rating:** 1600-4800 psig |  |
|  | Deaerator | **Mass flow rate:** | **Model:** Eurowater Deaerator  **Tank Volume:** 11,575 liters  **Steam Requirements:** 3240 kg/hr |  |
|  | Boiler Feed Pump | **Pressure:** 58 bar  **Temperatue:** 268 °C  **Efficiency:** 86.23 % | **Model:** Flowserve Multistage Boiler Feedwater Pumps  **Flow:** 5220 m3/h  **Head:** 4270 m  **Pressure:** 517 bar (7500 psi)  **Temperature:** 315 °C (600 °F) |  |
|  | Condensate Extraction Pump | **Pressure:** 0.055 bar  **Temperature:** 34.58 °C | **Model:** Flowserve Vertical, Multistage Condensate Extraction Pumps  **Flow:** 13,600 m3/h (60,000 gpm)  **Head:** 1070 m (3500 ft)  **Pressure:** 100 bar (1450 psi)  **Temperature:** 230 °C (450 °F) |  |
|  | Circulating Water Pump | **Flow:** 180 000 m3/h  **Pressure:** up to 5 bar  **Temperature:** 30 °C | **Model:** Flowserve Vertical Circulating Water Pump  **Flow:** 181 700 m3/h  **Head:** 110 m (350 ft)  **Pressure:** 5 bar (75 psi)  **Temperature:** up to 65 °C |  |
|  | Steam Trap | **Pressure:** 406 psig  **Temperature:** 332.80 °C | **Model: Series 460 High Pressure Steam Traps**  **Operating Pressure:** 150 – 900 psig  **Operating Temperature:** 482.22 °C (900 °F) |  |
|  | Generator | **Power:**  **Efficiency:** 100 % | **Model:** Water-Cooled GIGATOP Generator  **Frequency:** 60 Hz  **Power Factor:** 0.85  **Apparent Power:** up to 1,120 MVA  **Efficiency:** up to 98.9 %  **Terminal Voltage:** up to 26 kV |  |

The table above shows the list of equipment and specifications used in the design of the proposed coal-fired power plant. Each component is named with tag numbers and has selection parameter used in the calculation of the design options.

**Equipment Description**

Each component plays an important role in a power plant to have an efficient performance. The major equipment of the proposed coal-fired power plant are briefly discussed below.

1. Steam Turbine

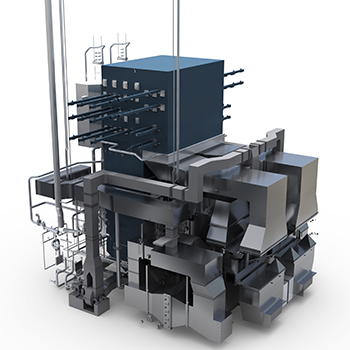
The steam turbine is a prime mover for the conversion of heat energy of steam into work on a revolving shaft, utilizing fluid acceleration principles in jet and vane machinery. The chosen turbine STF – D850 is manufactured by GE which consists of double-flow LP sections and a separate HP. The main inlet pressure is up to 245 bar with main steam inlet and reheat temperatures up to 585 °C. The operating capacity of the steam turbine is up to 1000 MW with steam turbine efficiency of 49%.



**Figure 10.** STF Turbine, GE

2. Boiler

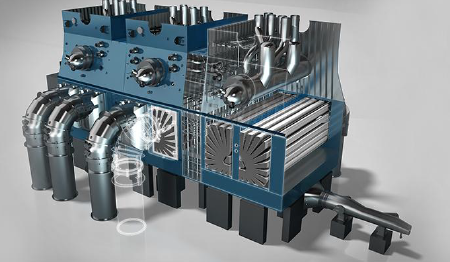
The steam boiler is an integrated assembly of several essential components the function of which is to produce steam at a predetermined pressure and temperature. The chosen boiler design is manufactured by GE with up 1350 MW electrical for coal units. The type of fuel used is sub-bituminous coal which is suitable for the design of the boiler. Its operating pressure ranges up to 330 bar with temperature up to 650 °C.



**Figure 11.** Two Pass Boiler, GE

3. Condenser

A condenser's primary function is to maintain low pressure on the exhaust side of steam turbine rotor. This helps the steam to spread to a greater degree, resulting in an improvement in the resources available for mechanical work conversation. The secondary function of the condenser is to supply the boiler with pure and hot feed water, as the condensed steam discharged from the condenser and collected in a hot well can be reused as the boiler's feed water. Using a condenser at a power plant is to increase the power plant's output by raising the steam exhaust pressure below atmospheric pressure. The proposed power plant used GE Single Vacuum Type Condenser having a pressure of 55 mbar and a thermal load of 1820 MW.



**Figure 12.** Condenser, GE

4. Closed Feedwater Heater

For a traditional power plant, a feed-water heater is used to preheat boiler feed water. The heat source is steam bled from the turbines, and the goal is to increase the cycle's thermodynamic efficiency. The most popular feedwater heater design is a shell and tube exchanger with the feedwater flowing within the tubes and the external steam condensation. The proposed power plant used Energyen SPX Heater that can be installed in both low and high pressure.



**Figure 13.** SPX Heater, Energyen

5. Deaerator

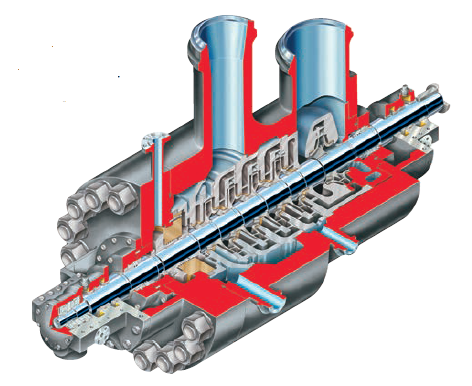
Deaerators are mechanical devices that extract dissolved gasses from feedwater in boilers. Deaeration protects the steam system against the effects of corrosive gases. This is achieved by reducing the dissolved oxygen and carbon dioxide content to a point where corrosion is minimized. Deaerators use steam to heat water to the maximum saturation temperature corresponding to the deaerator's steam pressure, and to scrub and take dissolved gases away. The steam flow may be parallel, opposite, or counter to the flow of water. The deaerator consists of a portion of deaeration, a storage tank and a ventilator. In the deaeration part, it is heated and agitated by steam bubbles through the water. Steam is cooled by water flowing in and condensed at the condenser vent. The vent emits non-condensable gases and some steam.



**Figure 14.** Deaerator, Eurowater

6. Boiler Feed Water Pump

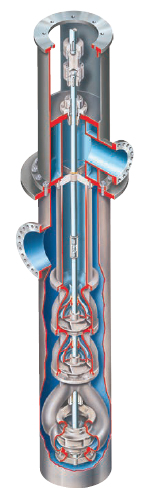
A BFP or boiler feed pump is used in boiler feed water system to increase the water pressure; high enough so it can be pumped into the boiler drum. It helps maintain proper working of a boiler providing continues feed water supply. A continues feed water supply is essential for steam boilers; as it not only avoid overheating but any further damage to the boiler. Boiler feed pump must not only be able to supply feed water requirement; but also work as a condensate and makeup water pump when required. To ensure proper operation of these pumps; feed water must be free from steam, air and insoluble solids.



**Figure 15.** Boiler Feedwater Pump, FLOWSERVE

7. Condensate Extraction Pump

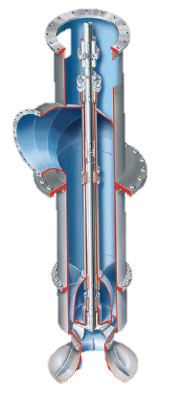
The CEP or condensate extraction pump is used to do the initial part that draws the condensate under vacuum from the condenser hot well with some positive pressure at the discharge. This water, after passing through several heaters and deaerators, reaches the suction of the BFP that is used to pump water at a very high pressure. It sends the water to the boiler after it passes through a number of HP heaters



**Figure 16.** Condensate Extraction Pump, FLOWSERVE

8. Circulating Water Pump

The purpose of circulating water pump is to provide cooling water for the condenser. The water that will be used is from Nasugbu Bay then pumped through the tubes in condenser to remove the heat of vaporization from steam exiting the turbine. These pumps will circulate the cooling water or circulating water for a higher efficient performance of the proposed power plant.



**Figure 17.** Circulating Water Pump, FLOWSERVE

9. Steam Trap

To remove the condensate from the closed feedwater heater, steam traps are used. The function of steam trap is to remove both air and noncondensable gases from the steam system. Its purpose is to prevent the steam leaving the system before it gives up its latent energy. It is designed to close in the presence of steam and drain the condensate to have a higher efficiency.



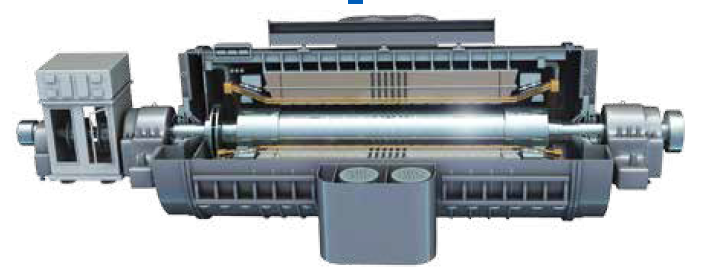
**Figure 18. Steam Trap, EMERSON**

10. Drip Pump

After the feedwater heater, the extracted steam will be converted into drip which is pumped by the drip pump back to the previous reheater. Drip goes in opposite direction of feedwater. The extracted steam rejects heat in Low Pressure Feedwater Heater 3 then drip will go to Low Pressure Feedwater Heater 2 because the temperature or enthalpy of drip in Heater 3 is more that Heater 2.

11. Generator

The heat is produced from a source in a steam turbine powered generator. sThere is a boiler containing water, and the heat is used to turn it into high temperature, high pressure steam. Steam output depends on the heat transfer flow rate and surface area, and the heat used for combustion. This boiler steam is forced through nozzles into the turbine which spins the blades mounted on a shaft. The steam turbine consists of a casing that is fastened to stationary blades within and a rotor has rotating blades on the periphery. The proposed power plant used Water Cooled GIGATOP Generator with an apparent power of 1,120 MVA and efficiency up to 98.9 %.



**Figure 19.** Water-Cooled Generator, GIGATOP

12. Pulveriser

After the coal has been transported from Caluya, Antique. It will be prepared in the pulveriser for higher combustion efficiency. There will be a hopper that will transfer the coal to the pulveriser until it reached the boiler through the feeder. The pulverized coal will be transported to the feeder for combustion

13. Chimney

The exhaust gases or smoke produced by boiler is exhausted in the chimney. These exhaust gases are referred as flue gas which are discharged to the atmosphere at such a height that the pollutants are kept within acceptable limits at ground level. For coal-fired power plants, flue gas is typically at about 120 °C. For the system, Natural Draught will be used as the proposed power plant will be using a chimney. For units with a capacity of 500 MW, flues are about 200 m high and 6 m in diameter.

**Process/ Schematic/ System Diagram**

1. Fuel System

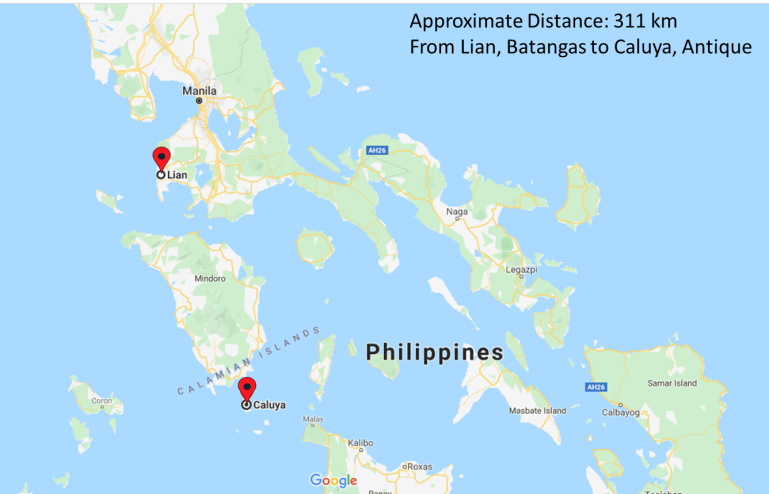
The fuel system of a power plant provides and prepares the fuel for burning in the combustor. The proposed power plant will be using a sub-bituminous coal which is widely used in generating steam power and industrial purposes. It contains less sulfur but more moisture approximately 10 to 45 percent than other bituminous coal types. Sub-bituminous coal produces ash that has higher alkaline content than other coal ash that can help reduce acid rain typically caused by coal-fired power plant emissions.

Fuel of the power plant will be produced by Semirara Mining and Power Corporation which owns and mines its own fuel source (coal). The corporation produces sub-bituminous coal that is appropriate for use in a wide range of combustion facilities.

2. Transport System

The proposed power plant will use a sub-bituminous coal which will be produced by Semirara Mining and Power Corporation. Coal will be shipped to the port area where it will be conveyed in the coal storage for future use. It is important to consider the transport system for it has a part in the investment costs which is the transport cost. Available rod will also be considered for easy transportation which is one of the parameters in choosing the best location for the proposed power plant.

Semirara Mining and Power Corporation is located at Caluya, Antique which is more than 300 km from Lian, Batangas.



**Figure 20.** Transport System

3. Exhaust System

The inlet and exhaust pressures and inlet temperature of the steam in a steam engine determine the potential energy required at the turbine inlet. Water moves over an alternating series of fixed and rotating blades to release the energy inside the turbine and as a result extends from high pressure to low pressure.

The HRSG absorbs heat from the exhaust gas turbine to produce steam at temperatures up to ~650 ° C, and 13–20 MPa pressure. While SC systems have been developed, the generation of heat recovery steam is most frequently applied under subcritical conditions.

4. Storage System

It is important that adequate quantity of coal should be stored. Coal storage offers protection against coal supply disruption when there is delay in coal transport or strike in coal mines. The coal may also be bought and stored for future use, if the prices are low. The amount of coal to be stored depends on the availability of storage space, transportation facilities, the amount of coal to be stored on the power station both away from and close to coal mines.

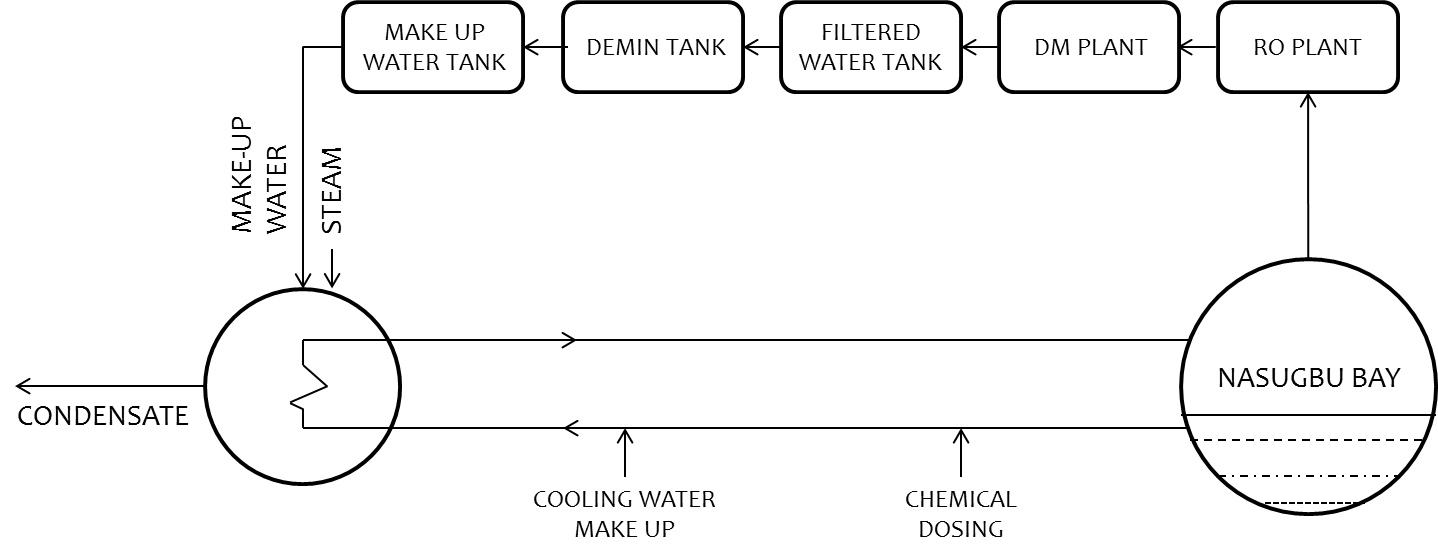
Usually coal needed for one month of power plant service is stored in the case of power plants located at a longer distance from the collieries while coal need is stored for around 15 days in the case of power plants located close to collieries. Coal storage is not desirable for longer periods as it blocks the capital and results in a loss of coal quality.

5. Instrumentation and Control System

In order for a power plant to run efficiently, it is important to consider the instrumentation and control system which plays a major role in profitable operation of a plant. This system includes the sensors that can detect the measured values and controllers which receive these values. New coal-fired power plants are built with modern and advanced systems that can help in achieving the maximum efficiency of a power plant. It can also reduce the maintenance costs through better monitoring of plant equipment condition and detect equipment malfunctions that may lead to power plant shutdown.

6. Water Treatment System

Water treatment for generating electricity is a critical process which needs a reliable technology. High purity water ensures proper steam generation system operation, and reduces blowdown frequency and boiler chemicals usage. High purity water can also protect better against erosion and equipment destruction. When the operational pressure of the power plant rise, the demands on water quality do become more stringent. The specifications are strict for the existing equipment running at Supercritical pressures. Continuous developments and changes in techniques of preserving water quality, understanding the processes of degradation and discovering new additives have resulted in a more sustainable and effective operation of the water system.



**Figure 21.** Water Treatment System Diagram

7. Cooling System

All steam power plants work by heating water in the boiler until it turns into steam. The steam is then used to spin the turbine, which then drives an attached generator, which produces electricity. Water used by the condenser to cool the steam is withdrawn from nearby rivers, lakes, and other bodies of water which are near to the plant; that is the Nasugbu Bay for the proposed design. Surrounding bodies of water is one of the parameters considered in choosing the best location for the proposed power plant for an easy access of water for the cooling system.

8. Ash Handling System

Pulverized coal burning boilers (PC) have furnaces at the bottom. Under the boiler, the large ash particles are stored in a water-filled ash hopper, Fly-ash is stored with either an electrostatic precipitator or a baghouse in dust collector. A PC boiler contains around 80% fly ash and 20% bottom ash. Ash must be collected and transported from various plant locations, as shown in figure. Pyrites, which are the pulverizer rejections, are disposed of with the ash device at the edges. Three major factors for the ash disposal systems should be considered such as, Plant sites, Fuel source and Environmental regulation. For many ash management systems needs for water and land are essential considerations. The amounts of ash to be disposed of depend on the king of fuel. Sites where ash is stored and disposed of are regulated by environmental legislation.