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PERFORMANCE ASSESSMENT OF A COAL FIRED THERMAL POWER PLANT

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Abstract

In current scenario the rate at which demand for power is increasing, is substantially higher than the rate at which it is generated. The growing demand for power has made the power plants of scientific interest. Boiler is the heart of a thermal power plant, as the chemical energy of fuel i.e. coal is converted in to heat energy in a boiler, so its efficiency directly affects the overall efficiency of the plant. With time performance of boilers deteriorate due to several factors like fouling, poor operation and maintenance etc. So it becomes necessary to calculate the boilers performance from time to time, to improve the overall plant performance. In present work important parameters like boiler efficiency, evaporation ratio, and heat rate are calculated for a 250 MW thermal power plant, to evaluate the overall performance of the plant.

Index Terms: Thermal power plant, Boiler efficiency, Unit heat rate, Evaporation ratio.

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1. INTRODUCTION

Energy is the primary and basic need of human beings, everything what happens in the world is the expression of flow of energy in one of its forms. And the standard of living of any country is directly related to the per capita energy consumption. Rapid urbanization and continuous increase in population has soured the energy demand. Currently 80% of world electricity requirements are fulfilled from fossil fuel fired thermal power plants, and 20 % from different nonconventional energy resources such as solar, wind, geothermal, tidal, biogas [1]. Seeing the dependence on fossil fuels for fulfilling the electricity demands it becomes necessary to access the performance of various components of a thermal power plant. Working of a coal fired thermal power plant is based on Rankine cycle, and has got four main components viz. boiler, turbine, condenser and feed pump.

Chemical energy of fuel is converted in to heat energy in a boiler, which is an enclosed vessel that provides a means for combustion heat to be transferred to water to convert it into steam. Steam under high pressure and temperature is then sent to a turbine where the hot steam expands and heat energy is converted to mechanical work, which is further converted to electrical energy through an electrical generator.

A boiler is a complex integration of evaporator, reheater, super heater, economizer, air pre heater along with various auxiliaries such as pulveriser, fans etc. [2] and considered to be the key part of a power plant as it is the place where fuel is burnt and heat energy is transferred to working substance (water) [3]. The purpose of performance assessment is to calculate the actual efficiency of boiler, which can be compared with the design value to know the variations in performance and maintain the efficient operating conditions. In present work energy analysis of boiler is done, using direct method [4], where the boiler efficiency and evaporation ratio are calculated.

1.1 Boiler operation

The steam generator under study is a radiant reheat, natural circulation, single drum, and semi outdoor type unit, designed for 100% coal firing which is the principal fuel. Water from economiser enters the boiler drum and exits from final super heater (FSH) as super saturated steam. Figure 1 and Figure 2 gives a brief outlook of the path followed by water and flue gas respectively during the operation.

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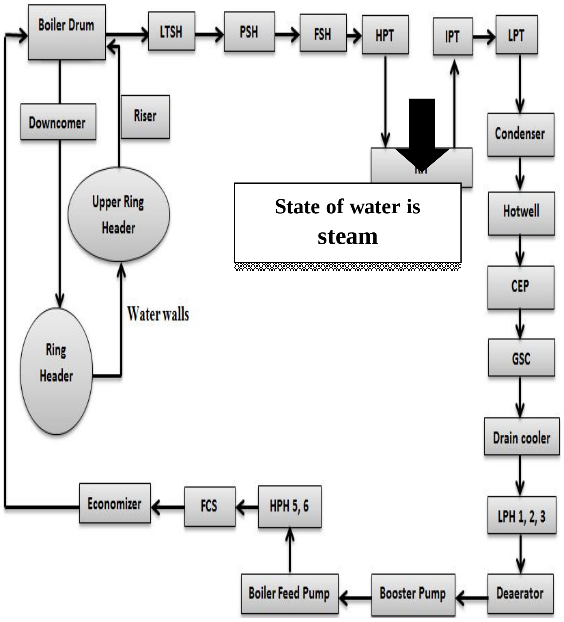

Fig.-1: Feed water path

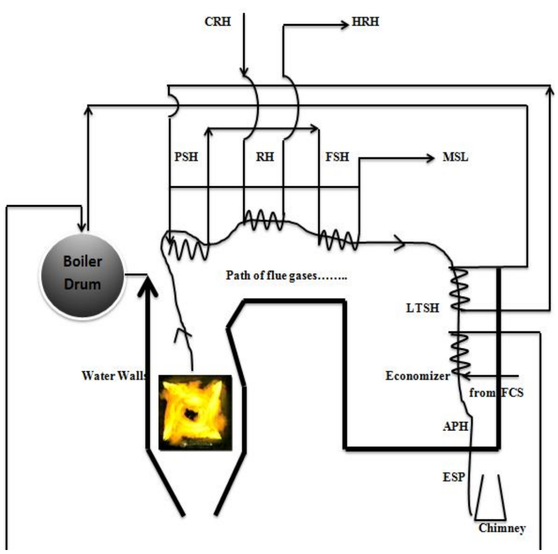

Fig.-2: Flue gas path

1.2 Performance Parameters

1.2.1 Boiler Efficiency

Efficiency is defined as the ratio of output energy to input energy. Boiler efficiency can be calculated by two methods, as mentioned below,

(a) *Direct Method*- for a boiler in a coal fired thermal power plant, coal is the input and steam is output. In this, also known as input-output method, energy gained by steam is compared with the energy content of coal. And efficiency is evaluated as follows:

$$\eta_b = \frac{\text{Steam flow rate} \times (\text{steam enthalpy} - \text{feed water enthalpy})}{\text{Fuel firing rate} \times \text{Gross heat in fuel}}$$

(b) *Indirect Method*- in this method, various losses are accounted separately, and then the percentage efficiency is calculated by deducting the summation of all the losses from 100. So, the efficiency is difference between the losses and energy input to boiler. In the present work efficiency is calculated using direct method, and following assumptions are taken during the calculation,

- The flow rate of feed water is constant, however practically the flow rate of steam is less than the initial value due to tapping at different locations, blow down, etc.
- The enthalpy of combustion air is not added into the heat input which also contributes to the heat input into the boiler.
- Reheating of the steam is not considered.

1.2.2 Overall Efficiency

It represents the efficiency of entire unit, and is evaluated as follows:

$$\eta_0 = \frac{Load\ of\ plant\ in\ MW}{\dot{m}_c \times CV_c}$$

Where, $\dot{m}_c$= mass flow rate of coal, in kg/hr
and CV_c= calorific value of coal in kJ/kg

1.2.3 Unit Heat Rate

Unit heat rate (UHR) is the reciprocal of overall efficiency, expressed in units of heat and electricity i.e. kJ/kWhr. Is evaluated as given below

$$\text{UHR} = \frac{\dot{m}_c \times CV_c}{Load\ of\ plant\ in\ MW}\ \text{kJ/kWhr}$$

1.2.4 Evaporation Ratio

Evaporation ratio is defined as the ratio of steam generated to coal burnt.

$$\text{Evaporation ratio} = \frac{\text{Quanitity of steam generated}}{\text{Quantity of coal consumed}}$$

1.2.5 Turbo Alternator efficiency

Instead of calculating individually the thermal efficiency, efficiency of turbine and generator, it is preferred to calculate the turbo alternator efficiency as a single performance parameter, which is the product of above mentioned three efficiencies. And is calculated as below

$$\eta_{ta} = \eta_t \times \eta_g \times \eta_t$$

$$\eta_{ta} = \frac{Load\ in\ MW}{m_{ms}(H_{ms} - h_{fw})}$$

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Where, m_{ms}= mass flow rate of main steam, kg/h
H_{ms}= enthalpy of main steam, kJ/kg
h_{fw} = enthalpy of feed water, kJ/Kg

1.2.6 Turbo Alternator Heat Rate

Turbo alternator efficiency represents the efficiency of turbine, generator, and thermal cycle with units of heat and electricity, and is reciprocal of turbo alternator efficiency. It is evaluated as follows

$$THR = \frac{m_{ms}(H_{ms}-h_{fw})}{Load\ in\ MW} \text{ kJ/kWhr}$$

2. RESULTS AND DISCUSSION

In order to calculate the mentioned performance parameters, various data are required to be measured at various inlet and exit points of equipments of power plant. Table 1 shows the list of data measured from a 250 MW coal fired thermal power plant.

Table-1: Data of 250 MW thermal power plant

S.No	Data	Unit	Actual Value
1.	Load	MW	250
2.	Feed water temperature	^{0}C	246
3.	Main steam temperature	^{0}C	538
4.	Main steam pressure	Bar	151
5.	Drum pressure	Bar	167.4
6.	Main steam flow rate	kg/hr	740900
7.	Coal flow	kg/hr	157000
8.	Gross calorific value	Kcal/kg	3600
9.	Gross calorific value	kJ/kg	15048
10.	Enthalpy of main steam	kJ/kg	3417
11.	Enthalpy of feed water	kJ/kg	1068

Table 2 represents the final calculated values of the performance parameter.

Table-2: Calculated value of performance parameter

S.No	Performance parameter	Unit	Actual Value
1.	Boiler efficiency	%	73.66
2.	Overall efficiency	%	38.09
3.	Unit heat rate	kJ/kW hr	9450.14 4
4.	Evaporation ratio	Unit less	4.72
5.	Turbo alternator efficiency	%	51.7
6.	Turbine heat rate	kJ/kW hr	6961.5

3. CONCLUSION

Analysis presented in this article is based on direct method, where reheating is neglected to simplify the analysis, however more accurate results can be obtained by considering reheating of steam. Indirect method of analysis where losses are calculated may give more accurate results for boiler efficiency. The overall efficiency is found to be 38.09%, which is a low value and shows that the entire process in a power plant is associated with loss at every point; reason is the irreversibility's associated with the natural processes, which can be estimated by carrying out the second law analysis, to improve the entire plant performance and conserve energy.

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