

Thermodynamic Analysis of a 28 MW Thermal Power Station in IOCL, Guwahati

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ABSTRACT: In this work, a thermodynamic analysis of a 28MW thermal power station of IOCL, Guwahati has been carried out. The present study deals with both energy and exergy analysis of different components of the power station . The performance of the plant was estimated by calculating component wise energy and exergy losses and finally the overall picture for the said plant is presented. The exergy destruction percentage was found to be maximum in the boiler system (72.40%) followed by the deaerator (16.74%), and then the turbine (5.47%). Also the calculated thermal efficiency was 26%, while the exergy efficiency of the power cycle was only 24.27%

KEYWORDS:Energy, Exergy, Efficiency, Exergy destruction, Rankine cycle.

I. INTRODUCTION

Thermal Power Stations are important power generation systems and requires energy efficiency study .In usual practise first law of thermodynamics is used to do such efficiency analysis. However, to make a more precise analysis of such power generation systems acombined utilization of both first and second laws of thermodynamicsis used.Emphasis is given to find the available energy by using concepts of exergy and exergy destruction. Such analysis gives a clear picture of energy losses to the environment and internal irreversibility in the process.

The main objectives of this study are to analyse the thermal power station of IOCL, Guwahati from an energy and exergy perspective, to determine the sites of primary energy loss and exergy destruction, and to compare the efficiencies and find the sources of irreversibility in different components of the plant.

II. MATERIALS AND METHODS

This study has been carried out in Indian Oil Corporation Limited (IOCL) , Guwahati.IOCL uses its thermal power station, with a total installed capacity of 28 MW , for generation of electricity and process steam for the units.The power house consists of three steam turbines (1×12 MW, 2×8 MW) at 100% load. The operating conditions of the power station is given in below table 1.

Operating condition	Value
Mass flow rate of fuel	0.66kg/s
Mass flow rate of air	12kg/s
Steam temperature	450 °C
Steam Pressure	39kg/cm ² G
Feed water inlet temperature to boiler	105°C
Steam flow rate	57700 kg/hr (max)
Calorific value of fuel	42000 kJ/kg
Fuels fired	Fuel Oil , Naphtha and Refinery gas
Power output	28 MW max

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The methodology used in this study is based on basic law of mass and energy balances. The energy and exergy content and hence the first and second law efficiencies of each component of the plant is calculated by applying the energy and mass balance equations at each node of the plant.

III. ENERGY AND EXERGY ANALYSIS

Here in this study, the analysis of a thermal power plant, operating on Rankine cycle, is done which includes all the main components such as turbines, boilers, feed water pumps, deaerators and condensers.

ENERGY ANALYSIS

In an open flow system the energy transfer across the control surface includes work transfer, heat transfer, and energy associated with mass transfer. The first law of thermodynamics or energy balance for the steady flow process of an open system is given by:

$$\sum Q_k + m \cdot (h_i + C_i^2/2 + g \cdot Z_i) = m \cdot (h_o + C_o^2/2 + g \cdot Z_o) + W$$

Where Q_k is the heat transfer to system from source at temperature T_k , W is the net work developed by the system, m is the mass flow rate, C is the bulk velocity of the working fluid, Z , is the altitude of the stream above the sea level and g is the specific gravitational force. The first law efficiency η_1 of a system/system component is defined as the ratio of energy output to the energy input to the system/component i.e. $\eta_1 = \text{Desired output energy} / \text{Input energy supplied}$. In this analysis the kinetic and potential energy change has been ignored.

EXERGY ANALYSIS

Exergy of heat transfer Q is calculated from the relation, $W_{\max} = \psi_Q = Q \cdot (1 - T_0 / T)$ where, $W_{\max}$ is the maximum work done, Q is the heat transfer from control surface at temperature T . Exergy of steady flow stream of matter is the sum of kinetic, potential and physical exergy. The kinetic and potential energy are almost equivalent to exergy. The physical specific exergy ψ_i and ψ_o depends on initial state of matter and environmental state. Thus the specific exergy of a fluid stream is given by:

$$\psi = h - h_o - T_o \cdot (S - S_o)$$

IV. RESULTS AND INFERENCES

Finally calculations give the results of the energy analysis which is given in the table 2 below:

Components	1 st law Efficiency	Energy Loss(MW)	Energy Loss(%)
Turbine	93.6	1.30	1.89
Condenser	76.51	11.50	16.70
Feed Water Pump	76.97	0.46	0.67
Deaerator	62.59	18.50	26.87
Boiler	87.80	37.10	53.88
Power Cycle	26	68.86	

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It is seen from above table that energy loss in boiler (53.88%) is dominant over all other components of the TPS. According to the first law analysis, energy losses associated with the condenser and deaerator are significant because they represent about 16.70% and 26.87% respectively of the energy loss in the plant.

The results of the exergy analysis are given in below table 3:

Components	2 nd law efficiency	Exergy Destroyed (MW)	Exergy Loss(%)
Turbine	84.12	3.63	5.47
Condenser	35.15	2	3.02
Feed Water Pump	38.25	1.57	2.37
Deaerator	13.91	11.10	16.74
Boiler	57.61	48	72.40
Power Cycle	24.27	66.30	

As depicted in the above table, it is seen that the exergy destruction rate of the boiler is dominant over all other irreversibility in the cycle. It counts alone for (72.40%) of losses in the plant followed by deaerator (16.74%). An exergy analysis, however, showed that only 3.02 % of the exergy was lost in the condenser and 16.74% in deaerator. The real loss is primarily back in the boiler where entropy was produced. This demonstrates that significant improvements exist in the boiler system rather than in the condenser. Nonetheless, efficiencies based on 1st law analysis can often be non-intuitive or even misleading because it does not provide an ideal measure. In addition, losses of energy can be large quantity while it is thermodynamically insignificant due to its low quality. However, exergy analysis provides a measure of approach to ideal or deviation from ideal. The calculated exergy efficiency of the power cycle is (24.3%), which is low. Also the results indicate that at each point of power plant exergy destruction is much more than energy loss at that point. This indicates that available energy losses at that point are high resulting in lower second law efficiency or exergy efficiency. Also exergy efficiency is lower than energy efficiency for each points of power plant means the components of the plant require good maintenance. Thus tremendous opportunities are available for improvement. However, part of this irreversibility cannot be avoided due to physical, technological, and economic constraints.

V.CONCLUSION

It has been observed that Exergy efficiency is lower than Energy efficiency in almost all components of the power plant. The boiler is the major source of energy loss (53.8%) and exergy destruction (72.4%). The factors affecting exergy efficiency in a boiler are adiabatic combustion temperature and temperature difference of heat transfer. In order to achieve maximum exergy efficiency, during boiler design, boiler parameters need to be reviewed and changed without actually affecting the thermal efficiency. But we also cannot ignore the fact that in every plant component, such as a boiler, there is some basic characteristic irreversibility which cannot be eliminated due to physical, technological or economic constraints. 1st law efficiency cannot be the only parameter for analysing the performance of any power generation system. It can sometimes be misleading because it does not provide an ideal measure. Also losses of energy can be of large quantity while it may be thermodynamically insignificant due to its low quality. Exergy-based efficiencies and losses, however, provide measures of approach to ideal or deviation from ideal. The calculated exergy efficiency of the power station is 24.27 % which is low compared to modern power plants. The major source of exergy destruction is the boiler system where chemical reaction in the combustion chamber is the most significant source of exergy destruction. With increase in boiler temperature and pressure, the exergy efficiency increases, but the increase must be weighed against the added increase in equipment cost.



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