Energy and Exergy Analysis of Captive Power Plant

Rakesh Lolariya, Chirag Parekh

M.E. Thermal – Gujarat Technological University
Asst. Prof. Marwadi Education Foundation

Abstract - In the recent years, India has emerged as one of the fastest growing economies of the world necessitating equally rapid increase in modern energy consumption. With an imminent global climate change threat, India will have difficulties in continuing with this rising energy use towards achieving high economic growth. It will have to follow an energy-efficient pathway in attaining this goal. In terms of energy intensity, India occupies a relatively high position of 9 among the top 30 energy consuming countries of the world [1]. Energy efficiency is one of the most important measures, among others, to address these challenges. Energy efficiency makes available additional energy resources, which can partially address the issues of inadequacy and equity. Energy efficiency also reduces energy consumption as well as carbon intensity, which is a necessary condition for addressing climate change. India will have to follow an energy-efficient pathway to address the above three challenges [2].

I - Introduction

A considerable amount of energy, in a refinery, is utilized in Boiler, Heat Exchanger, Cooling Tower, Pump, Compressor, or unit and pipe work, heat recovery from processed fluids, etc., are all seen as an area where heat could be saved, which in turn saves fuel [6].

Industrial energy efficiency has emerged as one of the key issues in India. The industrial sector uses about 40% of total energy in the country [4]. India accounts for 4.5% of industrial energy use worldwide [5]. Accordingly, the International Energy Agency (IEA) World Energy Outlook energy consumption in Indian industry is projected to more than double by 2030 and so increases its share of total final energy consumption to 31% [5].

Exergy defines the theoretical useful amount of energy available from the process, and destruction of exergy is called as energy. Exergy identifies the major sources of loss and areas for improvement in the performance of the system. It characterizes work potential of the system with reference to environment were maximum theoretical work done can be obtained. Destruction of exergy is proportional to the entropy generation, which accounts for inefficiencies. Boiler efficiency therefore has great influence on heating related energy savings. It is therefore important to maximize the heat transfer to the water and minimize the heat loss in the boiler. Heat can be lost from boilers by a variety of methods, including hot flue gas losses, radiation losses, and in the case of steam boilers, blowdown losses, etc.

II - Methodology

Case study on thermal power plant major components of power plant of are listed points are selected carefully such that it measure the temperature mass flow rate pressure is noted down at each inlet and outlet of components of the system. At full load condition reading is noted down. For these point enthalpy and entropy value is noted from steam table. Individual energy and exergy analysis is calculated. The exergy destruction calculated at each point and the loss is determined with location and magnitude. The energy and exergy efficiency and effectiveness is calculated and this identify the loss occurring in power plant component.

Energy Balance Equation for Plant Competent

1. Energy balance for Boiler
   \[ m_1 \times h_1 + m_{13} \times h_{13} + (m_{14} \times h_{14}) = [m_2 \times h_2 + m_{11} \times h_{11} + (boiler)] \]

2. Energy balance for Condenser
   \[ m_{18} \times h_{18} + (condensor) \]

3. Energy balance for Condenser pump
   \[ m_6 \times h_6 + w_{pump} = m_7 \times h_7 + E_{condensorpump} \]

4. Energy balance for Low pressure Heater
   \[ m_7 \times h_7 + m_4 \times h_4 = m_8 \times h_8 + E_{lowpressureheater} \]

5. Energy balance for DE aerator
   \[ m_3 \times h_3 + m_8 \times h_8 = [m_9 \times h_9 + E_{deaerator}] \]

6. Energy balance for boiler feed pump
   \[ m_9 \times h_9 + W_{pump} = [m_{10} \times h_{10} + E_{boilerfeedpump}] \]

7. Energy balance for Economizer
   \[ m_{10} \times h_{10} + m_{11} \times h_{11} = [m_1 \times h_1 + m_{12} \times h_{12} + E_{economizer}] \]

8. Energy balance for Air Pre Heater

General Layout of Power Plant
Balance Exergy Equation

(10) Exergy balance for Boiler
\[ m_1 \times a_1 + m_{13} \times a_{13} + (m_{14} \times a_{14}) = [m_2 \times a_2 + m_{11} \times a_{11} + \text{boiler}] \]

(11) Exergy balance for Turbine
\[ m_2 \times a_2 = [m_3 \times a_3 + m_4 \times a_4 + m_5 \times a_5 + \text{Aturbine} + W_{\text{turbine}}] \]

(12) Exergy balance for Condenser
\[ m_5 \times a_5 + m_17 \times a_{17} = m_6 \times a_6 + m_{18} \times a_{18} + A \text{condensor} \]

(13) Exergy balance for Condenser pump
\[ m_6 \times a_6 + W_{\text{pump}} = m_7 \times a_7 + A \text{condensorpump} \]

(14) Exergy balance for Low pressure Heater
\[ m_7 \times a_7 + m_4 \times a_4 = m_8 \times a_8 + \text{Alow-pressureheater} \]

(15) Exergy balance for DE aerator
\[ m_3 \times a_3 + m_8 \times a_8 = [m_9 \times a_9 + \text{Ade-aerator}] \]

Energy balance for boiler feed pump
\[ m_9 \times a_9 + W_{\text{pump}} = [m_{10} \times a_{10} + A \text{boiler-feedingpump}] \]

(17) Exergy balance for Economizer
\[ m_{10} \times a_{10} + m_{11} \times a_{11} = [m_1 \times a_1 + m_{12} \times a_{12} + A \text{economizer}] \]

(18) Exergy balance for Air Pre Heater
\[ m_{12} \times a_{12} + m_{16} \times a_{16} = [m_{13} \times a_{13} + m_{15} \times a_{15} + A \text{airpreheater}] \]

III - Exergy Efficiency of Plant

- Boiler =54%
- Turbine=63.7%
- Condenser=11.68%
- Condenser Pump=79.23%
- Low Pressure Heater=87.11%
- DE aerator= 67.67%
- Boiler feed Pump =95.54%
- Economizer=73.00%
- Air Pre Heater=71.09%

IV - Result & Discussion

The energy and exergy losses of various point of power plant are noted down and from the graph we can determine that major & minor loss occurring in the plant through Boiler, feed water pump, Turbine and condenser. These results are based on first law and second law of thermodynamics. On x-axis there are different point of power plant and y-axis represents the amount of heat lost in kW.
The efficiency of components in the power plant is found using energy and exergy calculation. From the above graph we can see that the efficiency of loss in Boiler and turbine is more as compared to other components of power plant, hence we should improve the efficiency of boiler and turbine by redesign. Even though the percentage loss in condenser is more the quality of the energy is not good. By comparing the graph figure 5.3 and 5.4 we came to on conclusion that the major losses is taking place in boiler, feed water pump and turbine. Hence scope of saving energy is more in these components.

V - Conclusion

The following conclusions have been drawn from the drawn from the site study at thermal power plant,

- The exergy and energy analysis of the power plant component identifies where most of the useful energy is loss and discusses potential of the lost energy & improvement of the plant energy efficiency & effectiveness.
- It shows that the boiler, feed water pump and turbine of a power plant is the major source of useful energy losses. Only negligible amounts of useful waste energy can be recovered through implementing some heat recovery system.
- In order to achieve efficient improvement of energy in boiler, feed water pump and turbine systems need to be altered, which required further thermo economic study.
- By doing ultimate analysis of boiler we can see that complete combustion is take place but up-ward pressure of air, fuel contains fines unwanted components which flies with flue gas and burns at the top of boiler by increasing the temperature of super heater and leaving the boiler at very high temperature.
- Percentage of fines unwanted component is to be reduced fuel injection type should be changed by studying the design of boiler. So, efficiency can be improved.
- Though losses in condenser is more than quality of energy obtained not, hence we had to concentrate on boiler, feed water pump and turbine to increase the efficiency & effectiveness of the plant.

References