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# Energy and Exergy Analysis of Coal Fired Power Plant

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## Abstract

**Increasing demand of power has made keen interest of study to improve the efficiency of power plant. From the energy Scenario we see that approximately 57% of energy is generated from coal fired power plant. It is the major source of energy production. The energy analysis is carried out for 32MW coal fired thermal power plant. Increasing demand of power has made keen interest of study to improve the efficiency of power plant. The energy assessment must be quality and quantity. The aim of the study is to identify the location and magnitude of useful energy lost during the process at various components of power plant.**

**The losses at various components are calculated using the energy and exergy balance equation.**

**The first law thermodynamics and second law of thermodynamic efficiencies of power plant has been calculated. The analysis shows that the exergy efficiency is low at each components of power plant, the major loss occur in power plant are Boiler, Turbine and Heat Exchangers. There is 42% loss in boiler and 38% loss in Turbine. The overall plant efficiency is 30%. Comparison of energy and exergy loss where the useful energy is loss is identified and improves the efficiency of the component by making the necessary arrangements to the system components.**

## Introduction

Electrical energy is universal energy, electric energy can be converted into all forms of energy, and hence the demand for electric energy is increase. Hence more no of power plant are placed, where 75%of power is generated by burning coal. The Energy conservation in a coal fired power plant is one of the important aspects to reduce the rate of consumption of fossil fuel, with rapid growing of civilization consumption of energy is also increasing rapidly. Energy security and $co_2$ emission reduction are the major concerns of today's world. Our earth crust has abundant amount of coal, the coal is spread over the world, the quality of the coal may vary some part have high calorific value coal and some have low calorific value coal. Energy consumption is one of the most important indicator showing the development stages of countries and living standards of communities [1]. As the primary source of energy for power production, transport and industry is from fossil fuels, hence we have to reduce the consumption of fossil fuel by increasing the efficiency of power plant and the systems we are running. Power plant runs on a thermodynamic process, improvements in thermodynamic process mainly depends on energy analysis.

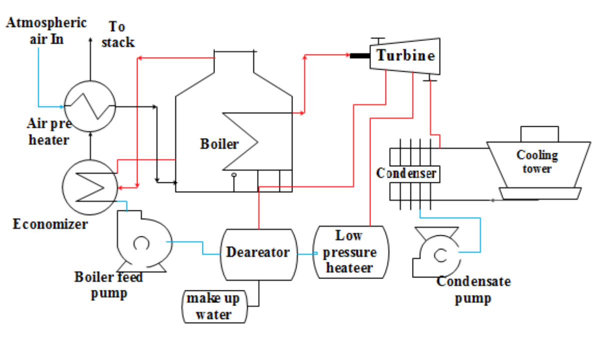
The energy analysis is based on first law of thermodynamic where irreversibility of the systems is not characterized, i.e. properties of system environment or degradation of energy quality is not considered. The real useful energy loss cannot be justified by the fist law of thermodynamics, because it does not differentiate between the quality and quantity of energy.

For achieving higher efficiency higher order analysis has to be done, Exergy analysis is based on second law of thermodynamics. Exergy define the theoretical useful amount energy available from the process, and destruction in exergy is called as Anergy. Exergy identifies the major sources of loss and areas for improving the performance of the system. It characterizes work potential of a system with reference to environment were maximum theoretical work done can be obtained. Destruction in exergy is proportional to entropy generation, which accounts for inefficiencies. Boiler efficiency therefore has a great influence on heating- related energy savings. It is therefore important to maximize the heat transfer to the water and minimize the heat losses 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, blow-down losses etc. To optimize the operation of a boiler plant, it is necessary to identify where energy wastage is likely to occur. A significant amount of energy is lost through flue gases as all the heat produced by the burning fuel cannot be transferred to water or steam in the boiler. As the temperature of the flue gas leaving a boiler typically ranges from 150 to 250 $^{o}$C, about10–30% of the heat energy is lost through it. Since most of the heat losses from the boiler appear as heat in the flue gas, the recovery of this heat can result in substantial energy saving. This indicates that there is huge savings potentials of a boiler energy savings by minimizing its losses. The modifications considered here, which increase efficiency by reducing the irreversibility rate in the steam generator, are decreasing the

fraction of excess combustion air and decreasing the stack-gas temperature [2].
This project has been conduct on exergy analysis in one of the units of Surana Thermal power plant, Raichur, Karnataka. The exergy analysis identifies the area where and how much the loss are occurring, and area of improvements are discussed to improve the efficiency of the power plant.

## 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 parameter reading is noted down. For these points enthalpy and entropy value is noted from the steam table. Individual energy and exergy analysis is calculated for each components of the system. The Exergy destruction at each point is calculated and the loss is determined with location and magnitude. The energy and exergy efficiency is also calculated and to identify the loss occurring in power plant component.




lay out of Thermal power plant

Fig: 1 Layout of Steam Power Plant with Point of interest

## Energy balance equation in power plant components

Energy balance for Boiler
$[(m1 \times h1) + (m13 \times h13) + (m14 \times h14)] = [m2 \times h2 + m11 \times h11 + E(boiler)$ (1)

Energy balance for Turbine
$[(m2 \times h2)] = [(m3 \times h3) + (m4 \times h4) + (m5 \times h5) + E(turbine) + W(turbine)]$(2)

Energy balance for Condenser
$[(m5 \times h5) + (m17 \times h17)] = [(m6 \times h6) + (m18 \times h18) + E(condensor)]$(3)

Energy balance for Condenser pump
$[(m6 \times h6) + (w(pump))] = [(m7 \times h7) + (E(condensor\ pump))]$(4)

Energy balance for Low pressure Heater
$[(m7 \times h7) + (m4 \times h4)] = [(m8 \times h8) + E low\ pressure\ heater$(5)

Energy balance for Deaerator
$[(m3 \times h3) + (m8 \times h8)] = [(m9 \times h9) + E(deareator)]$(6)

Energy balance for boiler feed pump
$[(m9 \times h9) + W(pump)] = [(m10 \times h10) + E(boiler\ feed\ pump)]$ (7)

Energy balance for Economizer
$[(m10 \times h10) + (m11 \times h11)] = [(m1 \times h1) + (m12 \times h12) + E(economizer)]$(8)

Energy balance for Air Pre Heater
$[(m12 \times h12) + (m16 \times h16)] = [(m13 \times h13) + (m15 \times h15) + E(air\ pre\ heater)]$ (9)

## Balance of Exergy in power plant components

Exergy balance for Boiler
$a1 = [(h1 - hr) - Tr(S1 - Sr)],$ (10)
$[(m1 \times a1) + (m13 \times a13) + (m14 \times a14)] = [m2 \times a2 + m11 \times a11 + A(boiler)$(11)

Exergy balance for Turbine
$[(m2 \times a2)] = [(m3 \times a3) + (m4 \times a4) + (m5 \times a5) + A(turbine) + W(turbine)]$ (12)

Exergy balance for Condenser
$[(m5 \times a5) + (m17 \times a17)] = [(m6 \times a6) + m18 \times a18 + A(condensor)$ (13)

Exergy balance for Condenser pump
$[(m6 \times a6) + (w(pump))] = [(m7 \times a7) + A condensor\ pump$ (14)

Exergy balance for Low pressure Heater
$[(m7 \times a7) + (m4 \times a4)] = [(m8 \times a8) + A low\ pressure\ heater$(15)

Exergy balance for Deaerator
$[(m3 \times a3) + (m8 \times a8)] = [(m9 \times a9) + A(deareator)]$(16)

Exergy balance for boiler feed pump
$[(m9 \times a9) + W(pump)] = [(m10 \times a10) + A(boiler\ feed\ pump)]$(17)

Exergy balance for Economizer
$[(m10 \times a10) + (m11 \times a11)] = [(m1 \times a1) + (m12 \times a12) + A(economizer)]$(18)

Exergy balance for Air Pre Heater

$$[(m12 \times a12) + (m16 \times a16)] = [(m13 \times a13) + (m15 \times a15) + A(air\ pre\ heater)] \quad (19)$$

**Exergy Efficiency of power plant**

Boiler =49%
Turbine=65%
Condenser=11%
Condenser Pump=86%
Low Pressure Heater=87%
Deaerator= 67%
Boiler feed Pump =95%
Economizer=73%
Air Pre Heater=71%

# Results and discussion

The energy losses at various components of power plant are determined and from the graph we can determine that major loss occurring in the plant through Boiler, Turbine and condenser. These results are based on first law of thermodynamics. On x-axis there are different components of power plant and y-axis represents the amount of heat lost in kW.

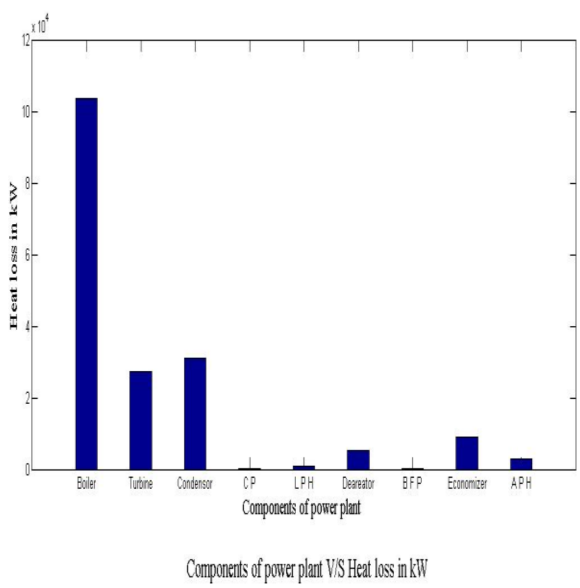



Fig: 5.1 Heat loss in kW of energy

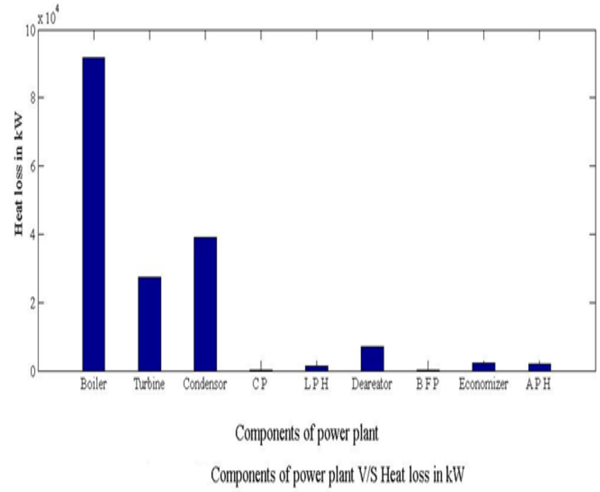



Fig: 5.2 Heat loss in kW of Exergy

The Exergy analysis of major components are done, where from the above graph we can identify the useful energy loss that is taking place in the plant are determined i.e. through Boiler, turbine even though major loss are in boiler and turbine both in energy and exergy calculation, but the loss are accurate as compared to energy calculation with exergy calculation. It is a second order calculation; hence the results are more accurate. On comparing the Graph in figure 5.1 and 5.2 we can see that the energy loss is more in figure 5.2. Hence the Boiler, turbine is to be redesigned to reduce the heat loss and better heat transfer in boiler, and by redesigning the turbine.

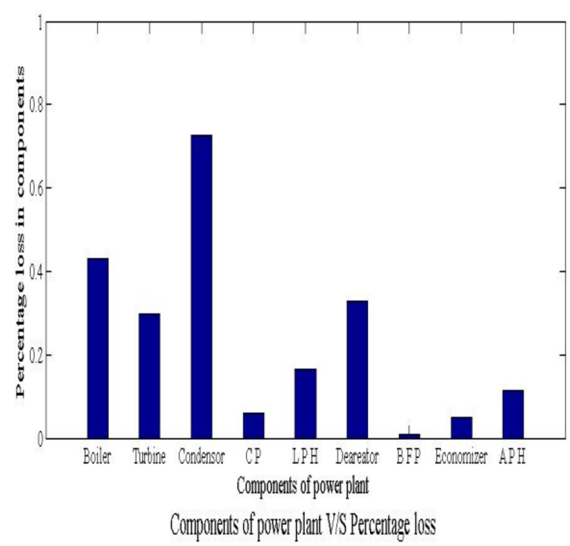



Fig: 5.3 Percentage of energy loss in components

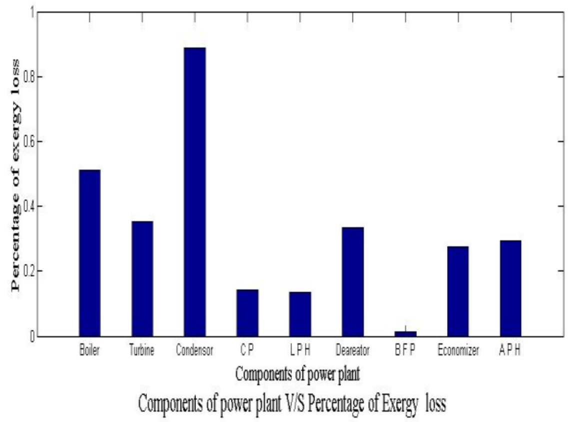



Fig: 5.4 Percentage of Exergy loss in components

The efficiency of components in the power plant is found out 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 can conclude that the major loss is taking place in boiler and turbine. Hence scope of saving energy is more in these components.

## Generator Power output

The above graph shows the power output of the generator for the respective mass flow rate of steam. As the mass flow rate increases the power output of generator also increase. The power output is a function of turbine steam flow rate. It is useful to determining the steam flow requirement at part load conditions of the turbine generator unit.

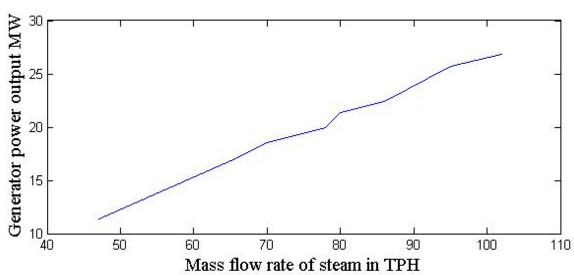



Figure: 5.5 Generator power output for the mass flow rate

# Conclusion

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

- The exergy analysis of the power plant identifies areas where most of the useful energy is lost and discusses potential of the lost energy for improvement of the plant energy efficiency.
- It shows that the boiler and turbine of a power generation plant is the major source of useful energy lost. Only negligible amounts of useful waste energy can be recovered through implementing some heat recovery system.
- In order to achieve significant improvement of energy efficiency the boiler and turbine systems need to be altered, which require further techno-economic study.
- From ultimate analysis of boiler we can see that complete combustion taking place but due to upward pressure of air, fuel contains fines 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.
- The percentage of fines is to be reduced or fuel injection type should be changed by studying the design of boiler. Thus efficiency can be improved.
- Even though loss in condenser is more the Quality of energy obtained is not, hence we have to concentrate on boiler and turbine to increase the efficiency of the plant.

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