Energy and Exergy Analysis of Thermal Power Plant: A Case Study of DCM Shriram Ltd

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Abstract— In this paper energy and exergy analysis method for thermal power plant and analysis carried out on 55 MW coal base thermal power plant of DCM – Shriram Ltd. In the present, increasing demand of power has made the power plants of scientific interest, but majority of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only. The first law of thermodynamics does not give all the ideas about the useful energy loss because the difference between the quality and quantity cannot be justified by it. In the energy analysis we can presents only quantitative results while in exergy analysis one can presents qualitative results about actual energy consumption. In this analysis it is shown that exergy efficiency is less at each and every point of power plant's component compare to energy efficiency. It also presents major losses of available energy at combustor, super heater, economizer and air-pre heater section. In this article it is also shown energy efficiency, exergy efficiency, exergy destruction and energy losses comparison charts.

Key words: Energy, Exergy, Entropy, Analysis

I. INTRODUCTION

In the power generation sectors the energy consumption and its conservation are the most critical factors to be optimized. In the India comparing with all other sources of power production coal is the main source of the power production. Around 58.75% of the power generation is from coal based power plants of the total installed capacity. Natural gas contribute around 8.91%, Nuclear and oil contribute around 2.11% and 0.52%.The share of coal and petroleum is expected to be around 66.8% in the total commercial energy produced. The share of crude oil in production and consumption is expected to be around 6.7% and 23% by 2021-22 Ease of use.

One of the indicators which show the development and living standards a community is Energy Consumption. The overall performance of any power plant can be measured through energetic performance criteria which are based on First law of thermodynamic. It is a simple energy balance without taking into account the quality of energy used. Exergetic analysis, based on second law of thermodynamics, takes in to account the energy quality. The energetic and exergetic analysis will provide a complete picture to enhance the overall plant's efficiency.

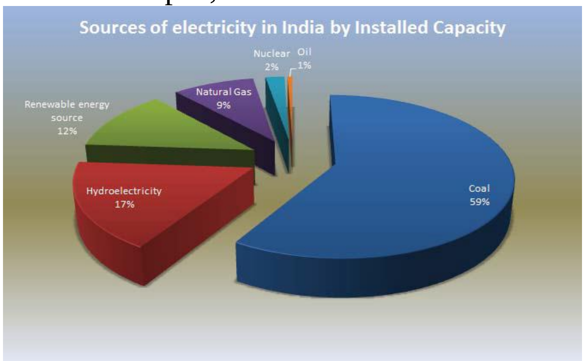

Fig. 1: Sources Electricity Graph

II. ENERGY AND EXERGY ANALYSIS

A. Energy Analysis:

1) Energy Analysis for Boiler:

$E_{in} = m_f h_f + m_{pa} h_{pa} + m_{sa} h_{sa}$

$E_{out} = m_g h_g + m_{sg} h_{sg}$

$\Delta E = E_{in} - E_{out}$

$\eta_{I=} E_{out} / E_{in}$

Where, E_{in}=Energy enter to the combustion chamber

E_{out} = Energy exit from the combustion chamber

ΔE = Energy loss,

η_I = First law efficiency

m_{pa}= Mass of primary air

h_{pa} = Enthalpy of primary air,

m_{sa} = Mass of secondary air,

h_{sa} = Enthalpy of secondary air

m_f = Mass of fluid

h_f = Enthalpy of fluid

m_g = Mass of flue gas

h_g = Enthalpy of flue gas

2) Energy Analysis for Air Pre Heater:

$E_{in} = mc_p\ (\Delta T)_{aph}$

$E_{out} = m_{pa}\ (\Delta h_{pao} - \Delta h_{pai}) + m_{sa}\ (\Delta h_{sao} - \Delta h_{sai})$

$\Delta E = E_{in\ -}\ E_{out}$

$\eta_{I=} E_{out} / E_{in}$

Where, $(\Delta T)_{aph}$ = Flue gas temperature difference in Air Preheater

c_p = Specific heat of flue gas

3) Energy Analysis for Economizer:

$E_{in} = mc_p\ (\Delta T)_{eco}$

$E_{out} = m_{fw}\ (\Delta h_{fwo} - \Delta h_{fwi})$

$\Delta E = E_{in\ -}\ E_{out}$

$\eta_{I=} E_{out} / E_{in}$

Where, m_{fw} = Mass of feed water

h_{fw} = Enthalpy of feed water

4) Energy Analysis for Super Heater:

$E_{in} = mc_p\ (\Delta T)_{sh}$

$E_{out} = m_{sh}\ (\Delta h_{sao} - \Delta h_{shi})$

$\Delta E = E_{in\ -}\ E_{out}$

$\eta_{I=} E_{out} / E_{in}$

5) Energy Analysis for LP Heater:

$E_{in} = m_{lp} (\Delta h_{lpi} - \Delta h_{lpo})$
$E_{out} = m_{fw} (\Delta h_{fwo} - \Delta h_{fwi})$
$\Delta E = E_{in} - E_{out}$
$\eta_I = E_{out} / E_{in}$

Where, m_{lp} = Mass of condensate from LP heater
h_{lp}= Enthalpy of condensate of LP heater

6) Energy Analysis for HP Heater:

$E_{in} = m_{hp} (\Delta h_{hpi} - \Delta h_{hpo})$
$E_{out} = m_{fw} (\Delta h_{fwo} - \Delta h_{fwi})$
$\Delta E = E_{in} - E_{out}$
$\eta_I = E_{out} / E_{in}$

Where, m_{hp} = Mass of condensate from HP heater
h_{hp}= Enthalpy of condensate of HP heater

7) Energy Analysis for Turbine:

$E_{in} = m_s h_s$
$E_{out} = W_T + m_d h_d + m_{hp-1} h_{hp-1} + m_{hp-2} h_{hp-2} + m_{hp-1} h_{hp-2} + m_{lp} h_{lp} + m_c h_c$
$\Delta E = E_{in} - E_{out}$
$\eta_I = E_{out} / E_{in}$

B. Exergy Analysis:

1) Exergy Analysis for Boiler:

$\Psi_{in} = m_g (h_{gi} - T_o s_{gi}) + m_{pa} (h_{pa} - T_o s_{pa}) + m_{sa}(h_{sa} - T_o s_{sa})$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$

2) Exergy Analysis for Air Pre Heater:

$\Psi_{in} = m_g(h_{gi} - T_o s_{gi}) - m_g(h_{go} - T_o s_{go})$
$\Psi_{in} = m_{pa} \{(h_{pao} - T_o s_{pao}) - (h_{pai} - T_o s_{pai})\} + m_{sa}\{(h_{sao} - T_o s_{sao}) - (h_{sai} - T_o s_{sai})\}$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$
$\eta_{II} = \Psi_{out} / \Psi_{in}$

3) Exergy Analysis for Economizer:

$\Psi_{in} = m_g(h_{gi} - T_o s_{gi}) - m_g(h_{go} - T_o s_{go})$
$\Psi_{out} = m_{fw}\{(h_{fwo} - T_o s_{fwo}) - (h_{fwi} - T_o s_{fwi})\}$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$
$\eta_{II} = \Psi_{out} / \Psi_{in}$

4) Exergy Analysis for Super Heater:

$\Psi_{in} = m_g(h_{gi} - T_o s_{gi}) - m_g(h_{go} - T_o s_{go})$
$\Psi_{out} = m_{sup}\{(h_{supo} - T_o s_{supo}) - (h_{supi} - T_o s_{supi})\}$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$
$\eta_{II} = \Psi_{out} / \Psi_{in}$

5) Exergy Analysis for LP Heater:

$\Psi_{in} = m_{lp}(h_{lpi} - T_o s_{lpi}) - m_{lp}(h_{lpo} - T_o s_{lpo})$
$\Psi_{out} = m_{fw}\{(h_{fwo} - T_o s_{fwo}) - (h_{fwi} - T_o s_{fwi})\}$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$
$\eta_{II} = \Psi_{out} / \Psi_{in}$

6) Exergy Analysis for HP Heater:

$\Psi_{in} = m_{hp}(h_{hpi} - T_o s_{hpi}) - m_{lp}(h_{hpo} - T_o s_{hpo})$
$\Psi_{out} = m_{fw}\{(h_{fwo} - T_o s_{fwo}) - (h_{fwi} - T_o s_{fwi})\}$
$\Delta\Psi = \Psi_{in} - \Psi_{out}$
$\eta_{II} = \Psi_{out} / \Psi_{in}$

7) Exergy Analysis for Turbine:

$E_{in} = m_s (h_s - T_o s_s)$
$E_{out} = m_d (h_d - T_o s_d) + m_{hp}(h_{hp-1} - T_o s_{hp-1}) + m_{hp}(h_{hp-2} - T_o s_{hp-2}) + m_{hp}(h_{lp} - T_o s_{lp}) + m_c(h_c - T_o s_c)$
$\Delta E = E_{in} - E_{out}$
$\eta_I = E_{out} / E_{in}$

III. RESULTS

Component	**η_I %**	**η_{II} %**	**ΔE (KJ/S)**	**ΔΨ (KJ/S)**
Boiler(Furnace)	90.50	60.80	19676.3670	76614.0315
L.P. Heater	85.81	54.59	733.6201	1484.8870
H.P.Heater-1	91.46	70.45	1096.1410	1434.3652
H.P.Heater-2	87.65	58.95	771.6363	1020.5055
Economiser-1	80.66	68.05	2052.9062	1996.9805
Economiser-2	82.73	64.57	2666.4879	3475.4749
L.T. Super Heater	98.61	42.90	180.0619	5284.9464
H.T. Super Heater	88.65	56.93	935.9488	2274.3897
Screen Super Heater	94.80	63.57	1017.1287	4764.3191
Turbine	95.26	93.77	9767.7087	5269.6530
Upper APH	37.35	30.45	2710.0600	2047.9673
Middle APH	98.33	58.34	115.1464	1428.7156
Bottom APH	93.40	32.71	142.6832	721.1365
Additional APH	77.96	49.80	572.1286	510.8773

Table 3.1: Plant Results at Part Load 54 MW

The results show that at every point of the power plant the energy efficiency is less than the exergy efficiency. This means the exergetic efficiency is lower than the first low efficiency which marks that the power plant requires good maintenance.

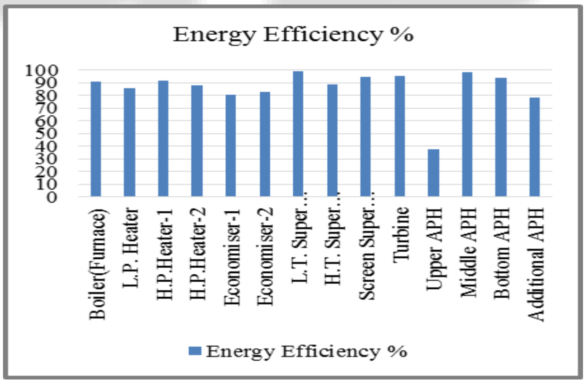

Fig. 3.1.1: Energy efficiency chart

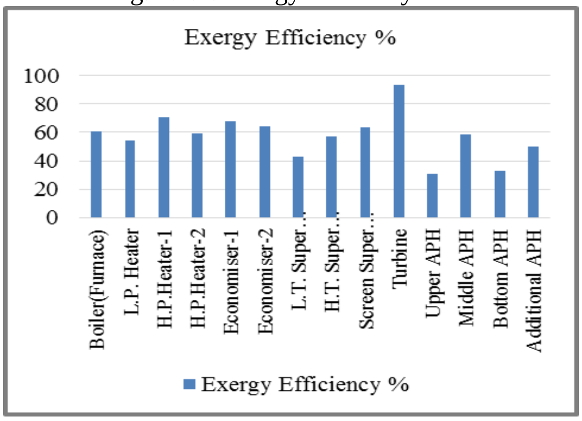

Fig. 3.1.2: Exergy efficiency chart

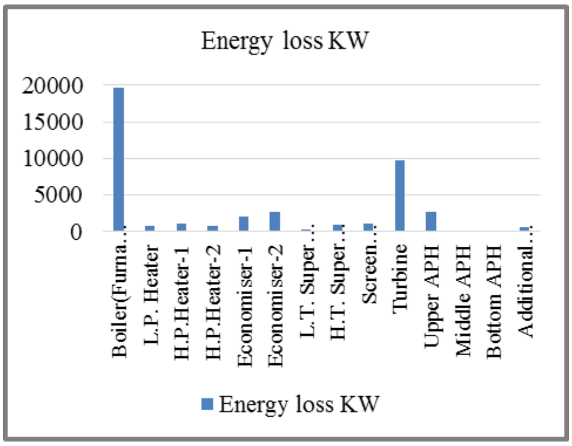

Fig. 3.1.3: Chart 3.1.3 Energy loss chart

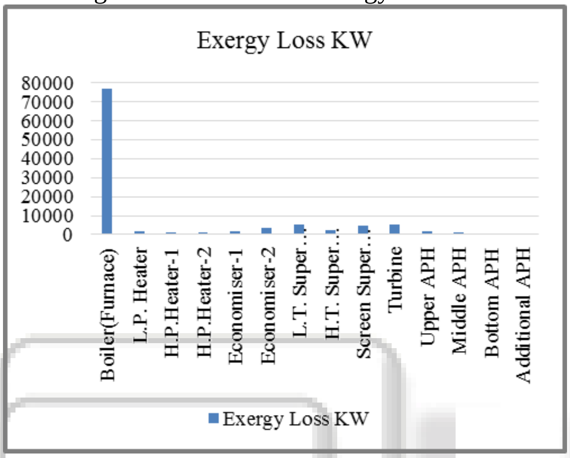

Fig. 3.1.4: Chart 3.1.4 Exergy loss chart

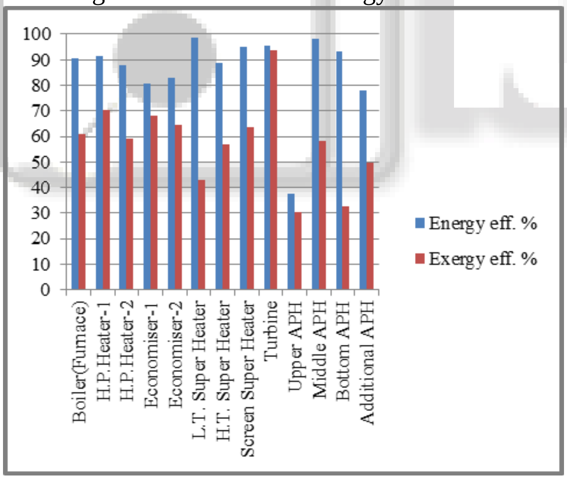

Fig. 3.1.5: Energy v/s Exergy efficiency chart

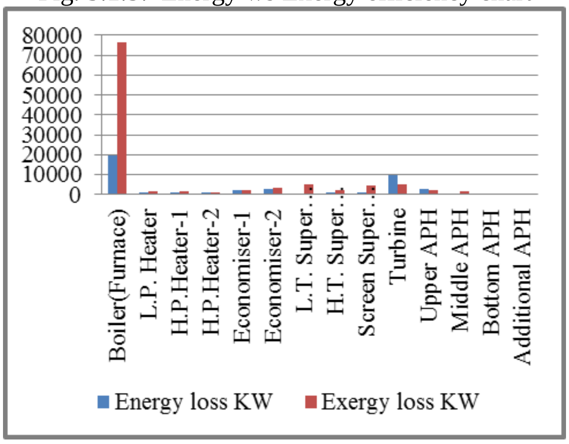

Fig. 3.1.6: Energy v/s Exergy loss chart

IV. CONCLUSION

1) It has been found that the energy efficiency is higher than the exergy efficiency.
2) Economiser-2, L.T. Super heater and Screen super heater are also another components that contributes to major loss of exergy in the power plant.
3) Major exergy loss occurs in the furnace (Boiler) that means it is not adiabatic and it needs proper combustion and the reason for the same is the irreversibility in the combustion process. The exergy loss can be reduced by applying proper insulation modification in the current furnace.
4) In the heat recovery system the Economiser-1 and Economiser-2 are the major affected components in that way it requires proper maintenance.

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