Energy and Exergy Analysis of Steam and Power Generation Plant

Krishnakumar Dipak Pilankar[1]
Post Graduate Scholar
Dept. of Mechanical Engineering,
Rajiv Gandhi Institute of Technology,
Mumbai, Maharashtra, India

Dr. Rajesh Kale[2]
Associate Professor
Dept. of Mechanical Engineering
Rajiv Gandhi Institute of Technology,
Mumbai, Maharashtra, India

***Abstract*— This paper deals energy and exergy analysis of steam and power generation plant in a chemical and fertilizer industry. Conventional energy analysis is based on first law of thermodynamics and exergy analysis is based on second law of thermodynamics. The real energy loss in components cannot be justified by first law of thermodynamics alone, because it does not differentiate between quality and quantity of energy. First the main components of steam and power generation system selected. Selected components of the system are then analyzed separately and sites having largest energy and exergy losses are identified. By energy analysis, highest energy loss occurs in condensers where 47.16 MW is lost which represents 52.89% of total energy loss in plant. After condensers, energy loss in boilers is significant where 30.26 MW is lost which represents 34% of total energy loss. From exergy analysis highest exergy destruction occurred in two boilers where 238.6 MW exergy is destroyed, it represents 90.8% of total exergy destruction of plant. Exergy destruction in condenser is 4.426 MW which is only 1.78% of total exergy destruction. Total energy loss for plant is 89.17 MW while total exergy destruction for the plant is 260.7 MW. It is also seen that energy efficiencies of components are greater than exergy efficiencies. In power generation section, turbine 1 cycle is found to be more efficient than turbine 2 cycle. Energy and exergy efficiencies of turbine 1 cycle are found as 35.29% and 66.30% respectively and that of turbine 2 cycle are 32.07% and 64.33% respectively. For power generation cycle's exergy efficiencies are greater than energy efficiencies.**

Keywords—Energy; Exergy; Exergy Destruction; Efficiency; Analysis

I. INTRODUCTION

Steam has been a popular mode of conveying energy since the industrial revolution. Steam is used for generating power and also used in process industries such as sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fiber and textiles. Major part of this steam production comes from fossil fuels like coal and natural gas. Energy conversion of chemical energy of fuel into steam takes place in boiler mostly. This steam is then utilized for electricity generation and for the processes. There is vast potential for saving by improving the efficiencies of steam generation system. Performance assessment of steam and power generation system is very essential for industry for proper utilization of available energy resources. By assessing performance of plant one can pin point areas or components where energy conversion is poor and where the improvement is required. This will help to improve energy efficiency, minimize operating expenses and increasing the profitability of industry.

Most commonly used method for thermodynamical performance assessment is based on first law of thermodynamics i.e. energy analysis [1]. Another method used is exergy analysis which is based on 2nd law of thermodynamics. There is increasing interest in combine utilization of both first law and second law thermodynamics. Exergetic analysis provides distinction between energy losses to environment and internal irreversibilities in the process [2]. Conventional method of energy analysis is based on first law of thermodynamics which concerned with conservation of energy principle. The First Law deals with the amounts of energy of various forms transferred between the system and its surroundings and with the changes in the energy stored in the system. It treats work and heat interactions as equivalent forms of energy in transit [3]. However first law sometime gives misleading results about performance of energy conversion device and optimization through first law has almost reached saturation level [4]. Also first law is concerned with quantity of energy and its transformation from one form to another. It does not account quality aspects of energy [5].

The quality aspect of energy is accounted by second law of thermodynamics. Second law provides necessary means to determine quality as well as degree of degradation of energy during process. Exergy is defined as maximum amount of work which can be obtained by a system or stream of matter or energy when it brought from specified initial state to the state of its environment, that is, the dead state. Exergy is a measure of the potential of the system or flow to cause change, as a consequence of not being completely in stable equilibrium relative to the reference environment. Unlike energy, exergy is not conserved during any real process; it is always destroyed in a process. Exergy destroyed is proportional to entropy generated due to irreversibilities [5].

Aim of this project is perform combine energy and exergy analysis on steam and power generation plant. Components having major energy loss and exergy destruction will be determined. Results of energy and exergy analysis will be then compared. At time of analysis, plant is operated at total steam load of 500 TPH and power generation of 23.8 MW.

Nomenclature

		Subscripts	
P	pressure (bar)	s	steam
T	temperature (°C)	f	fuel
m	mass flow rate (kg/s)	0	dead or reference state
h	specific enthalpy (kj/kg)	i	inlet
s	specific entropy (kj/kg K)	e	exit
E	energy flow rate (MW)	w	water
Q	heat transfer rate (MW)	Abbreviations	
W	work done (MW)	TPH	tones per hour
e_x	specific exergy (kj/kg)	TG	turbo generator
E_x	exergy flow rate (MW)	DA	deaerator
E_{xd}	exergy destruction (MW)	HPH	high pressure heater
W_T	turbine work (MW)	FP	feed pump
W_{shaft}	actual power developed at turbine shaft (MW)	BM	boiler master
η	energy efficiency or first law efficiency	PRDS	pressure reducing distribution system
Ψ	exergy efficiency or second law efficiency	CV	calorific value

PLANT DESCRIPTION AND WORKING

A. Plant Description

In this study the operating data of steam generation plant in chemicals and fertilizers industry is used. This steam generation plant also contains captive power plant. This plant falls in cogeneration category but steam is used separately for processes in other plants and in power generation. Normal steam production is 480 to 500 TPH of which around 150-170 TPH steam used in power generation section. The steam generation plant consist three boilers each having capacity of 275 TPH. Two boilers are kept operating and third boiler is kept as standby. Steam produced in steam generation plant used in turbo generating unit, urea plants, and chemical group of plants and in feed pumps. Fuel used is natural gas. Power generation Section consists of two turbo-generators each of 15 MW capacities. Turbines are of extraction-condensing type. This captive power generation takes care of high risk load of all plants. Operating load conditions of boiler and turbine are shown in Table 1.

Table 1 Operating data of boiler and turbine

Component	Parameter	Component number	
		1	2
Boiler	Boiler steam load (TPH)	250	250
	Steam temperature (°C)	510	510
	Steam pressure (bar)	103.198	102.267
	Mass flow rate of fuel (kg/s)	4.186	4.184
	Feed water inlet temperature °C	193.5	188
Turbine	Power generated (MW)	11.5	12.3
	Live steam flow (TPH)	73	76

B. Working

Fig. 1 shows the schematic diagram of plant. In Fig. 1, letter 'a' used with numbers to indicate that those streams are connected to deaerator 1, feed pump 1, HP heater 1, boiler 1, turbo generator 1 and condenser 1. Letter 'b' with numbers shows that those streams are connected to component number 2 e.g. deaerator 2, boiler 2 etc. Condensates from urea plants are stored in tank and are supplied to deaerators. TG return condensates lines are also connected to deaerators dome. HP heater condensate lines are connected to deaerator storage tanks. There are two no's of deaerators. Deaerator steam for heating water is fed to steam dome from 2 Ata PRDS, TG extraction-2 steam, feed pump exhaust and flash steam from boilers. From deaerators feed water passes to the high pressure heater through the boiler feed pumps. There are two number of HP heaters of shell and tube type. There are four feed pumps, two electric motor driven and two turbines driven. Normally two turbine driven feed pumps are running. Steam for these pumps comes from boiler master BM. Extraction 1 from TG sets is used for heating the feed water. From HP heaters feed water passes to the individual boiler via feed water control station. From boiler steam goes to boiler master where steam distributed according to requirement. Around 30% of the steam from the boiler master goes to two turbo generators. As explained earlier, there are two extractions in each turbine. Extraction 1 is utilized in HP heater while extraction 2 goes to deaerator. Remaining steam from turbine is then exhausted into condenser where it gets condensed. Condensate then goes to the deaerator.

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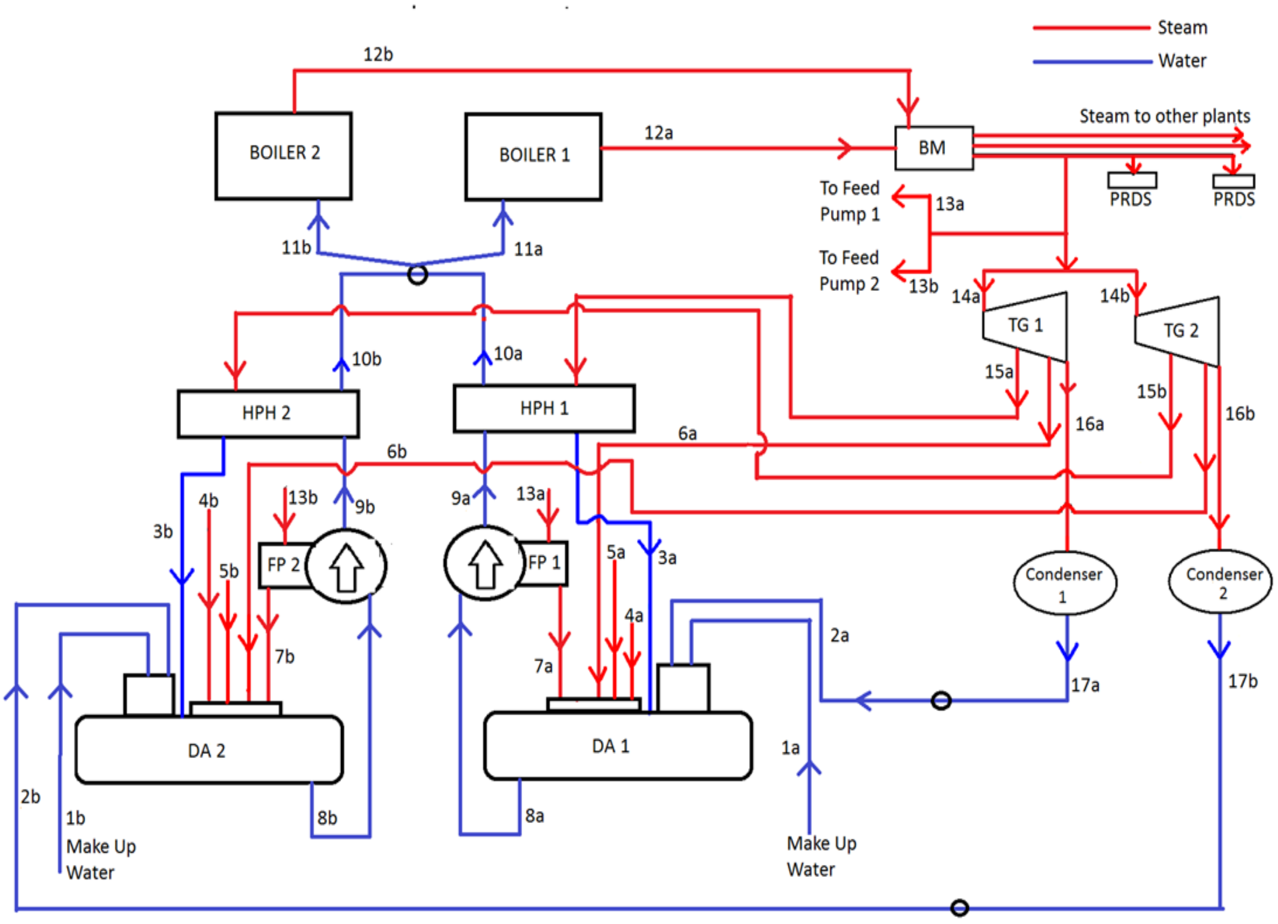

Fig. 1. Schematic diagram of the steam and power generation plant

II. METHODOLOGY AND DEFINITIONS

Mass, energy, and exergy balances for any control volume at steady state with negligible potential and kinetic energy changes can be expressed, by

$$\Sigma\, m_i = \Sigma\, m_e \quad (1)$$

$$Q - W = \Sigma\, m_e h_e - \Sigma\, m_i h_i \quad (2)$$

$$E_{x,heat} - W = \Sigma\, m_e e_{xe} - \Sigma\, m_i e_{xi} + E_{xd} \quad (3)$$

Where E_{xd} is exergy destroyed and $E_{x,heat}$ is net exergy transfer by heat at temperature T

$$E_{x,heat} = \Sigma\,(\,1 - T_o / T)Q \quad (4)$$

Specific exergy is given by

$$e_x = h - h_o - T_o\,(s - s_o) \quad (5)$$

Total exergy flow at any point is given by

$$E_x = m \times e_x = m \times [h - h_o - T_o\,(s - s_o)] \quad (6)$$

For steady state operation and considering each selected component in Fig. 1 as control volume, energy balance, energy efficiency, exergy balance and exergy efficiency can be defined.

The expression for energy efficiency (η) and exergy efficiency (Ψ) for the component are obtained from following definitions

$$\eta = \frac{\text{energy in products}}{\text{total energy input}}. \quad (7)$$

$$\Psi = \frac{\text{exergy in products}}{\text{total exergy input}} \quad (8)$$

This equation establishes a relationship between the desired result (for instance, the heating of feed water, or the power in a turbine) and the input (the amount of energy or exergy spent to obtain the result). In some systems there is no universal agreement as to what are an input and an output. Therefore their efficiency must be defined by the expression

$$\text{Efficiency} = \frac{\text{Energy or Exergy Out}}{\text{Energy or exergy in}} \quad (9)$$

Operating data of the plant is collected form computer operated control room of the plant. Thermodynamic properties at various points indicated in Fig. 1 are shown in Table 2. Note that points with letter ‘a’ i.e. 1a, 2a … etc. indicates that those streams are connected to number 1 components e.g. boiler 1, HP heater 1, deaerator 1 etc. Points with letter ‘b’ i.e. 1b, 2b…. etc. indicates that those streams are connected only to number 2 components, e.g. boiler no.2.

Table 2 Thermodynamic properties of the points of steam and power generation plant

Point	Mass flow rate m (kg/s)	Pressure P (bar)	Temperature T (°C)	Specific enthalpy h (kj/Kg)	Specific entropy s (kj/kg K)	Specific exergy e_x (kj/kg)	Energy flow E (MW)	Exergy flow E_x (MW)
1a	48.71	5.08	63.0	264.11	0.868	7.492	12.865	0.365
2a	8.89	5.62	64.0	268.34	0.881	7.949	2.385	0.071
3a	11.39	10.66	182.7	776.68	2.169	125.961	8.845	1.435
4a	0.53	1.91	200.0	2871.23	7.531	595.795	1.520	0.315
5a	1.67	2.02	211.0	2892.82	7.549	611.860	4.821	1.020
6a	0	-	-	-	-	-	-	-
7a	3.78	1.92	230.0	2931.38	7.651	619.643	11.074	2.341
8a	74.93	4.15	115.0	482.73	1.473	42.816	36.171	3.208
9a	74.93	127.52	116.0	495.80	1.474	55.823	37.150	4.183
10a	74.93	127.52	197.0	843.84	2.285	157.870	63.229	11.829
11a	70.00	120.21	192.0	821.44	2.239	149.445	57.501	10.461
12a	69.44	103.20	510.0	3397.00	6.614	1399.418	235.903	97.182
13a	3.78	99.10	500.0	3376.17	6.605	1381.481	12.754	5.219
14a	21.11	97.12	496.0	3368.32	6.603	1374.118	71.109	29.009
15a	11.39	15.23	313.0	3066.48	6.962	963.585	34.924	10.974
16a	9.72	0.18	61.0	2415.15	7.378	186.017	23.481	1.808
17a	9.72	0.18	59.0	246.97	0.819	5.428	2.401	0.053
1b	42.40	5.08	63.0	264.11	0.868	7.492	11.198	0.318
2b	8.89	5.62	65.0	272.52	0.893	8.378	2.422	0.074
3b	8.33	10.59	171.1	723.97	2.052	108.656	6.033	0.905
4b	0.49	1.93	199.0	2869.10	7.521	596.863	1.406	0.292
5b	1.67	1.99	210.0	2890.96	7.554	608.746	4.818	1.015
6b	0	-	-	-	-	-	-	-
7b	3.07	1.91	227.0	2927.37	7.641	618.668	8.985	1.899
8b	64.85	4.15	114.0	478.49	1.462	41.890	31.029	2.717
9b	64.85	128.50	116.0	495.87	1.473	55.919	32.156	3.626
10b	64.85	128.50	186.0	795.51	2.181	141.130	51.587	9.152
11b	69.31	117.81	188.0	803.74	2.202	143.147	55.704	9.921
12b	69.44	102.27	510.0	3398.10	6.619	1398.926	235.979	97.148
13b	3.07	99.00	500.0	3376.29	6.605	1381.427	10.363	4.240
14b	20.28	98.10	496.0	3367.09	6.597	1374.666	68.277	27.875
15b	8.33	15.13	308.0	3055.67	6.946	957.515	25.464	7.979
16b	11.94	0.18	63.0	2438.80	7.450	187.986	29.130	2.245
17b	11.94	0.18	61.0	255.34	0.844	6.187	3.050	0.074

III. Energy and Exergy Balance Equations and Efficiency Formulae for Components

A. Boiler

Boiler is main component of steam generation. Boiler energy balance, exergy balance and efficiencies can be obtained by different ways but in an industry, a main criterion is fuel to steam conversion. So in this study steam to fuel efficiencies are considered. Boiler energy efficiency is given as

$$\text{Boiler efficiency} = \frac{\text{energy gain by steam}}{\text{energy supplied by fuel}} \tag{10}$$

Or

$$\eta_{boiler} = \frac{m_s \times (h_s - h_w)}{m_f \times CV} \tag{11}$$

Where h_s and h_w are enthalpies of steam an feed water resp. and CV is the calorific value of fuel (Natural gas).

$$\eta_{boiler} = \frac{m_s \times (h_{12} - h_{11})}{m_f \times CV} \quad (12)$$

In equation (12), if we write points 11 and 12 with 'a' i.e.11a and 12a we will get energy efficiency formula for boiler 1. If we write with 'b' i.e. 11b and 12b we will get energy efficiency formula for boiler 2. Same way other components formulas can be derived.

Exergy efficiency of boiler is given by

$$\text{Exergy efficiency} = \frac{\text{exergy gain by steam}}{\text{exergy supplied by fuel}} \quad (13)$$

$$\Psi_{boiler} = \frac{m_s \times (e_{x12} - e_{x11})}{m_f \times e_{xf}} \quad (14)$$

e_{xf} is the exergy of a fuel can be calculated by using equation

$$\zeta = \frac{e_{xf}}{LHV_f} \quad (15)$$

ζ term is the ratio of chemical exergy of the fuel to the LHV(lower heating value) or of fuel. The value of ζ is taken as 1.06 for natural gas. Calorific value (CV) or LHV of natural gas (fuel) is taken as 46500 kj/kg.

B. *HP heater*

Feed water flow through HP heater, feed pump and deaerator is not known but it can be easily found by HP heater energy balance.

Energy supplied by steam = energy gain by feed water (16)

$$m_{15} \times (h_{15} - h_3) = m_{10} \times (h_{10} - h_9) \quad (17)$$

Exergy balance of HP heater is given as

$$m_{15} \times (e_{x15} - e_{x3}) = m_{10} \times (e_{x10} - e_{x9}) + E_{xd} \quad (18)$$

Exergy efficiency of HP heater

$$\Psi_{HPH} = \frac{m_{10} \times (e_{x10} - e_{x9})}{m_{15} \times (e_{x15} - e_{x3})} \quad (19)$$

C. *Feed pump*

Energy balance of feed pump is derived as

$$m_{13} (h_{13} - h_7) = m_9 (h_9 - h_8) + E_{loss} \quad (20)$$

Energy efficiency of feed pump

$$\eta_{FP} = \frac{m_9 \times (h_9 - h_8)}{m_{13} \times (h_{13} - h_7)} \quad (21)$$

Exergy balance of feed pump is derived as

$$m_{13} \times (e_{x13} - e_{x7}) = m_9 \times (e_{x9} - e_{x8}) + E_{xd} \quad (22)$$

Exergy efficiency

$$\Psi_{FP} = \frac{m_9 (e_{x9} - e_{x8})}{m_{13} (e_{x13} - e_{x7})} \quad (23)$$

D. *Deaerator*

Energy balance is given as

$$m_1h_1+m_2h_2+m_3h_3+m_4h_4+m_5h_5+m_6h_6+m_7h_7 = m_8h_8+E_{loss} \quad (24)$$

Energy efficiency

$$\eta_{DA} = \frac{m_8h_8}{m_1h_1 + m_2h_2 + m_3h_3 + m_4h_4 + m_5h_5 + m_6h_6 + m_7h_7} \quad (25)$$

Exergy balance of deaerator is given as

$$m_1e_{x1}+m_2e_{x2}+m_3e_{x3}+m_4e_{x4}+m_5e_{x5}+m_6e_{x6}+m_7e_{x7}=m_8e_{x8}+E_{xd} \quad (26)$$

Exergy efficiency

$$\Psi_{DA} = \frac{m_8e_{x8}}{m_1e_{x1} + m_2e_{x2} + m_3e_{x3} + m_4e_{x4} + m_5e_{x5} + m_6e_{x6} + m_7e_{x7}} \quad (27)$$

E. *Turbine*

Energy input (E_{in}) to the turbine derived as

$$E_{in} = m_{14}h_{14} \quad (28)$$

Energy out (E_{out}) from turbine given as

$$E_{out} = m_{15}h_{15} + m_6h_6 + m_{16}h_{16} \quad (29)$$

Turbine work done (W_T)

$$W_T = E_{in} - E_{out} = m_{14}h_{14} - m_{15}h_{15} - m_6h_6 - m_{16}h_{16} \quad (30)$$

Actual Power/work develop by turbine shaft (W_{shaft})

$$W_{shaft} = \text{Generator power} \times \eta^{-1}_{gearbox} \times \eta^{-1}_{generator} \quad (31)$$

Where $\eta_{gearbox}$ =0.984 and $\eta_{generator}$ =0.9803 are gearbox and generator efficiencies respectively.

Energy or first law efficiency of turbine is given as

$$\eta_{turbine} = \frac{W_{shaft}}{W_T} \quad (32)$$

Exergy input to turbine is derived as

$$E_{xin} = m_{14}e_{x14} \quad (33)$$

Exergy out from turbine

$$E_{xout} = m_{15}e_{x15} + m_6e_{x6} + m_{16}e_{x16} \quad (34)$$

Exergy destruction in turbine

$$E_{xd} = E_{xin} - E_{xout} - W_{shaft} \quad (35)$$

Exergy or second law efficiency of turbine

$$\Psi_{turbine} = \frac{W_{shaft}}{E_{xin} - E_{xout}} \quad (36)$$

F. Condenser

In condenser energy is rejected to environment (cooling water) external to the plant. This heat rejection is necessary for power cycle to complete. Efficiency term for condenser is not used. For condenser amount of heat rejected and exergy destruction are considered, which are of more importance.
Heat/energy rejected in condenser is given by

$$Q_{rej} = m_{17} \times (h_{16} - h_{17}) \tag{37}$$

Exergy destruction in condenser is given as

$$E_{xd} = m_{17} \times (e_{x16} - e_{x17}) \tag{38}$$

G. Turbine power cycle

Energy efficiency / thermal efficiency of turbine cycle is given as

$$\eta_{cycle} = \frac{\text{power developed at shaft}}{\text{heat supplied or net energy input to cycle}} \tag{39}$$

Heat supplied or net energy input to the cycle is given by

$$Q_{in} = W_T + Q_{rej} \tag{40}$$

Or

$$Q_{in} = m_{14}h_{14} - m_{15}h_{15} - m_6h_6 - m_{17}h_{17} \tag{41}$$

Energy efficiency of turbine cycle

$$\eta_{cycle} = \frac{W_{shaft}}{Q_{in}} \tag{42}$$

Exergy efficiency of turbine cycle is given as

$$\Psi_{cycle} = \frac{\text{Power developed at turbine shaft}}{\text{net exergy input to cycle}} \tag{43}$$

$$\Psi_{cycle} = \frac{W_{shaft}}{E_{xi}} \tag{44}$$

E_{xi} is net exergy input to the turbine cycle, it derived as

$$E_{xi} = m_{14}e_{x14} - m_{15}e_{x15} - m_6e_{x6} + m_{17}e_{x17} \tag{45}$$

IV. RESULTS AND DISCUSSIONS

Energy and exergy analysis is performed on the components of plant using above relations. All the calculations were done using Microsoft Excel software.

Results of energy analysis of the steam and power generation plant are summarized in Table 3. Note that HP heaters are not included. To find out feed water flow, it is assumed there is no energy loss in HP heater to surrounding. Total energy lost for the plant is 89.17 MW. Energy analysis also reveals that energy loss in two condensers is much higher than any other components although only 30% steam is used in power cycles. Energy loss in two condensers is 47.16 MW which is 52.89% of total energy loss in the plant. Two boilers are the second major contributors to energy loss. Energy loss in two boilers is 30.26 MW which is about 34% of total energy loss. In deaerators 9.87 MW of energy is lost. For condenser efficiency is not defined as it reject heat to environment. Most of the components have first law efficiencies or energy efficiencies greater than 85% except two feed pumps. However energy analysis can be sometime misleading because it does not consider quality of the energy. Energy loss can be large in quantity but it becomes insignificant when quality of energy is poor.

Table 3 Energy analysis results

Component	Energy loss (MW)	Percentage energy loss	Energy efficiency (%)
Boiler 1	15.827	17.75	91.87
Boiler2	14.437	16.19	92.58
FP 1	0.701	0.79	58.30
FP2	0.526	0.59	61.86
DA 1	5.246	5.88	87.33
DA 2	3.559	3.99	89.79
Turbine 1	0.783	0.88	93.84
Turbine 2	0.932	1.05	93.19
Condenser 1	21.080	23.64	-
Condenser 2	26.080	29.25	-
Total	89.170	100.00	-

Results of exergy analysis are summarized in Table 4. It is found that maximum exergy destruction occurs in two boilers. In boilers around 238.6 MW exergy destroyed which is 90.8% of total exergy destruction. This shows that exergy destruction in two boilers is dominant over all components. Main reason for this exergy destruction is combustion process which is highly irreversible and heat transfer through finite temperature difference across heat exchanging components in boiler. Next to boiler major source of exergy destruction is turbine. In two turbines around 3.5% exergy destroyed. In condensers exergy destroyed is only 1.5% of total exergy destruction. This is because in condenser energy is ejected to environment at low temperature and pressure i.e. quality of energy is poor. According to energy analysis energy losses in two condensers are significant as they are about 53% of total energy lost in plant. However, exergy analysis showed that only 1.5% exergy destroyed in condensers. Real loss occurs in two boilers. First law analysis tells us that scope for improvement exists in condenser however second law analysis showed that scope for improvement is more in boiler rather than in condenser.

Table 4 Exergy analysis results

Component	Exergy destruction (MW)	Percentage exergy destruction	Exergy efficiency (%)
Boiler 1	119.563	45.51	42.06
Boiler2	119.071	45.32	42.28
HPH 1	1.889	0.72	80.19
HPH 2	1.545	0.59	78.15
FP 1	1.903	0.72	33.86
FP2	1.492	0.57	36.29
DA 1	2.338	0.89	57.84
DA 2	1.787	0.68	60.32
Turbine 1	4.305	1.64	73.47
Turbine 2	4.899	1.86	72.24
Condenser 1	1.756	0.67	-
Condenser 2	2.171	0.83	-
Total	262.719	100.00	-

Fig 2 shows graphical representation of energy loss and exergy destruction of components. Fig 3 shows comparison between energy and exergy efficiencies of components. It is found that exergy efficiencies all components are less compared energy efficiencies. Boilers have much less exergy efficiency than energy efficiency. It was assumed that there is no energy loss in two HP heaters so their energy efficiencies will be 100%. However their exergy efficiencies are less than 100%, with HP heater 1 having higher exergy efficiency than HP heater 2.

Performance of turbine power generation cycles is summarized in Table 5.

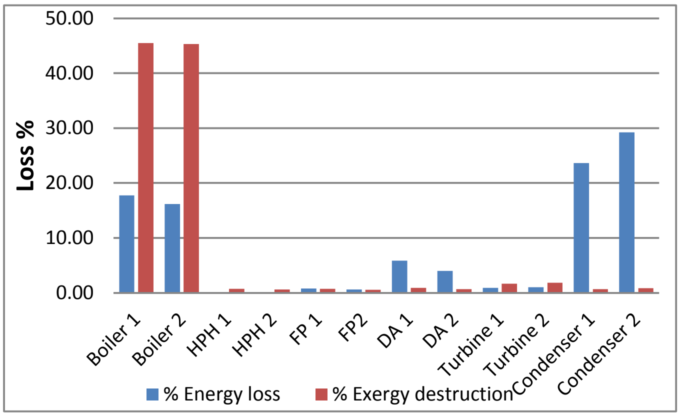

Fig. 2. Percent energy loss and percent exergy destruction in components

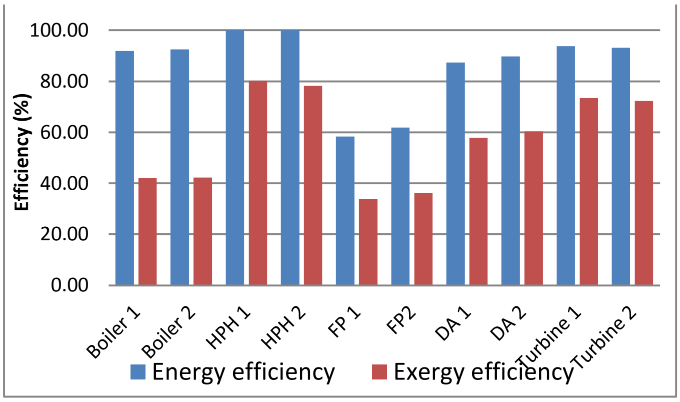

Fig. 3. Comparison between energy and exergy efficiencies

Table 5 Analysis results of power generation cycles

Parameter		TG 1 cycle	TG 2 cycle
Energy loss (MW)	*Total*	21.86	27.01
	In condenser	21.08	26.08
	In turbine	0.78	0.93
Exergy destruction (MW)	*Total*	6.06	7.07
	In condenser	1.76	2.17
	In turbine	4.30	4.90
Energy or thermal efficiency (%)		35.29	32.07
Exergy efficiency (%)		66.30	64.33
Power generated (MW)		11.50	12.30

It is clear from Table 5 that exergy efficiencies of both turbine cycles are greater than thermal/energy efficiencies. The reason for low thermal efficiencies is large quantity of heat rejection in condenser to environment. Exergy efficiencies are higher because exergy destruction in condenser is very less compared to energy rejected. Analysis also showed that turbine 1 cycle is more efficient due comparatively less energy and exergy loss.

V. CONCLUSIONS

This paper represents an energy and exergy analysis performed on steam and power generation plant. The analysis performed when total steam load of the plant was 500 TPH and power generation of 23.8 MW from two turbo generators. Highest energy loss was found in two condensers where 47.16 MW energy loss which was around 53% of total energy loss. Next to condensers it was two boilers where major energy loss occurred. Energy loss in boilers was 30.26 MW which represents 34% of total loss. But the results obtained from exergy analysis were different from energy analysis. Exergy analysis showed that energy loss in condensers is insignificant due to its low quality as this energy is lost at low pressure and temperature. Exergy analysis proved that major losses are occurring in boiler rather than in condenser. In two boilers exergy destruction was 238.6 MW which represents 90.8% of total exergy destruction in plant. After boilers it was two turbines where 9.2 MW exergy destroyed which represents 3.5% of total destruction. Exergy destruction in two condensers was very less. Less than 5% exergy is destroyed in deaerators, HP heaters and feed pumps.

Exergy efficiencies of all components were less than energy efficiencies. However exergy efficiencies of two turbine cycles were higher than energy or thermal efficiencies.

Exergy efficiencies of two boilers were considerably less than energy efficiencies on account large exergy destruction. Exergy destruction in boilers is mainly due to highly irreversible combustion process and heat transfer through finite temperature difference. Analysis also showed that in power generation, turbine 1 cycle (TG 1 cycle) is more efficient than turbine 2 cycle (TG 2 cycle). Both the energy and exergy efficiencies of TG 1 cycle were greater than TG 2 cycle.

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