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Exergy Analysis of Power Plant and its Emissions

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ABSTRACT: Due to increase in fuel price and demand in more energy requirement in everyday life, proper utilization of materials and resources are necessary. The increasing demand of power has made the power plants of scientific interest, but most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only.

The main objective of this project is to analyze individual components of systems. With the operating states temperature, pressure, mass flow rate of steam/water at each component the inlet and outlet points are considered to identify and quantify exergy loss of energy based on data from the power plant at 93% load. Exergy analysis for different components of a 210 MW thermal power plant has been performed.

KEYWORDS: Exergy, boiler efficiency, destruction, second law of efficiency.

I. INTRODUCTION

The general energy supply and environmental situation requires an improved utilization of energy sources. Complexity of power generating units has been increased considerably. There is increasing demand of strictly guaranteed performance, which requires thermodynamic calculation of high accuracy. The most commonly used method for evaluating the efficiency of an energy conversion process is the first law analysis. However there is increasing interest in the combined utilization of the first and second laws of thermodynamics, using such concept as exergy analysis, entropy generation and irreversibility (exergy destruction). In order to evaluate the efficiency with which the available energy is consumed.

POWER PLANT DESCRIPTION

Thermal power plants are one of the main sources of electricity in both industrialized and developing countries. The variation in the thermal power stations is due to the different fuel sources (coal, natural gas, naptha, etc). In a thermal power plant, one of coal, oil or natural gas is used to heat the boiler to convert the water into steam. In fact, more than half of the electricity generated in the world is by using coal as the primary fuel.

WORKING OF A COAL POWER PLANT

In a coal based power plant coal is transported from coal mines to the power plant by railway in wagons or in a merry-go-round system. Coal is unloaded from the wagons to a moving underground conveyor belt. This coal from the mines is of no uniform size. So it is taken to the Crusher house and crushed to a size of 20mm. From the crusher house the coal is either stored in dead storage(generally 40 days coal supply) which serves as coal supply in case of coal supply bottleneck or to the live storage(8 hours coal supply) in the raw coal bunker in the boiler house.

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COMPONENTS OF A COAL BASED POWER PLANT

1. Coal Conveyor
2. Stoker
3. Pulverizer
4. Economizer
5. Boiler Feed Pump
6. Deaerator
7. Feed Water Heaters
8. Boiler
9. Super heater
10. HP Turbine
11. Condenser
12. Generator

II. LITERATUE SURVEY

Naga Varun *et al.* [1] performed the exergy analysis for different components of a 210 MW thermal power plant and found that the maximum exergy destruction rate is observed in the Low pressure turbine.

A. Rashad *et al.* [4] carried out a detailed break-up of energy and exergy losses of plant at different loads (Maximum load, 75% load and, 50 % load). Energy losses mainly occurred in the condenser where (404.653 MW at max load, 306.747 MW at 75% load and 278.849 MW at 50% load) is lost to the environment.

PROPERTIES OF COAL IN POWER PLANT

Coal is a dense sedimentary rock, usually black, but sometimes dark brown, often with well-defined bands of bright and dull material; it is used primarily as fuel in steam-electric power generation, with substantial quantities used for heat and power applications in manufacturing and to make coke.

Table Coal Properties Operated with Blend

SL No.	Types of coal properties	Talcher	Imported coal	20I:80T
1	Calorific value	3738	6076	4205.6
2	Carbon (%)	42.25	69.35	47.67
3	Hydrogen (%)	3.21	5.66	3.7
4	Oxygen (%)	15.46	14.50	15.26
5	Nitrogen (%)	0.93	1.30	1.0
6	Sulphur (%)	0.55	0.95	0.63
7	Moisture (%)	6.12	7.48	6.39
8	Volatile matter	23.02	34.20	25.25
9	Ash	41.72	8.80	35.13
10	Fixed carbon	29.07	49.52	33.16

INTRODUCTION ON POWER PLANT EMISSIONS

Power generation is a significant source of pollutants that can impair human health and the environment. The main polluting elements are nitrogen oxide (NO2), Sulfur Di-oxide (SO2).The Clean Air Act has been successful in reducing these emissions, but power generation still contributes approximately (70% of SO2, 20% of NO2) emissions into the environment. These emissions from power generation contribute to a range of human health and environmental problems.

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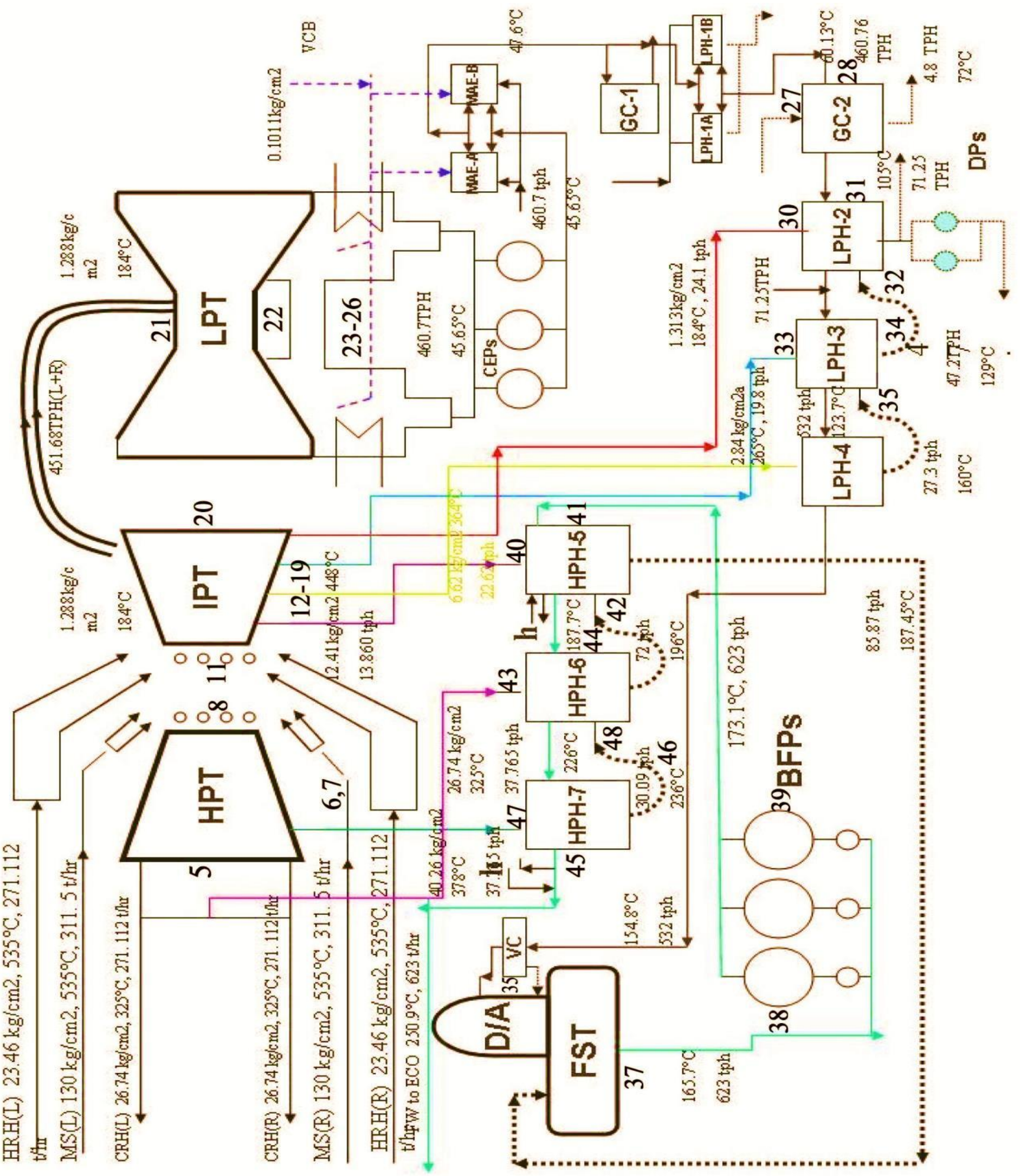

Figure 3.1 TURBINE EXTRACTION SYSTEM

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EXERGETIC ANALYSIS

Table Data recorded at 93% loading

S No	Components	Temperature (Centigrade)	Pressure (bar)	Mass (kg/s)
1	Economizer inlet	240	140	173.05
2	Economizer outlet	278	137	173.05
3	Super heater inlet	345	128	173.05
4	Super heater outlet	535	128	173.05
5	HP Turbine inlet	535	128	173.05
6	Tapping	378	40	173.05
7	Tapping	378	40	165
8	HP Turbine outlet	330	26	165
9	Re heater inlet	330	26	165
10	Re heater outlet	535	22	154
11	IP Turbine inlet	535	22	154
12	Tapping 1	448	12	152
13	Tapping 1	448	12	152
14	Tapping 2	350	6	150
15	Tapping 2	350	6	140.01
16	Tapping 3	265	2.5	140.01
17	Tapping 3	265	2.5	137.5
18	Tapping 4	200	1.5	137.5
19	Tapping 4	200	1.5	130.8
20	IP Turbine outlet	180	1.5	130.80
21	LP Turbine inlet	180	1.3	130.80
22	LP Turbine outlet	50	0.9	130.80
23	Condenser inlet 1	50	0.1	130.80
24	Condenser inlet 2	30	1.03	808
25	Condenser outlet 1	45	0.1	130.8
26	Condenser outlet 2	40	1.013	808
27	LPH 2 inlet 1	200	1.5	669
28	LPH 2 inlet 2	85	15	130.80
29	LPH 2 outlet	98	14.2	130.8
30	LPH 3 inlet 1	260	2.5	5.5
31	LPH 3inlet 2	102	13	130.80
32	LPH 3 outlet	117	12	147.7
33	LPH 4 inlet 1	381.5	6.0	7.23
34	LPH 4 inlet 2	120	12	147.7
35	LPH 4 outlet	150	9	147.7
36	Deaerator inlet	152	8.5	147.7
37	Deaerator outlet	162	7.0	173.05
38	BF Pump inlet	162	7.0	173.05
39	BF Pump outlet	165	155	173.05
40	HPH 5 inlet 1	445	12	3.83
41	HPH 5 inlet 2	170	152	173.05
42	HPH 5 outlet	187	148	173.05
43	HPH 6 inlet 1	320	26	10.02
44	HPH 6 inlet 2	187	150	173.05

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45	HPH 6 outlet	226	147	173.05
46	HPH 7 inlet 1	375	39.5	8.35
47	HPH 7inlet 2	226	147	173.05
48	HPH 7 outlet	240	145	173.05

Table Exergy Values for Various Components

S No	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Specific Exergy (kJ/kg)	Exergy (MW)
1	1003.21	2.803	172.47	29.84
2	1205.16	3.086	290	50.18
3	2930	5.890	1179.3	204.07
4	3430.12	6.551	1482.7	256.58
5	3430.12	6.55	1482.7	256.58
6	3112.36	6.691	1122.9	194.31
7	3112.36	6.691	1122.9	185.27
8	3078.62	6.744	1064.7	175.68
9	3078.62	6.744	1064.7	175.67
10	3505.08	7.480	1280.6	197.21
11	3505.08	7.480	1280.6	197.21
12	3364.41	7.522	1127.4	171.36
13	3364.41	7.522	1127.4	169.11
14	3166.22	7.548	921.4	138.21
15	3166.22	7.548	921.4	129.01
16	2999.18	7.619	723	103.08
17	2999.18	7.619	723	99.53
18	2872.9	7.644	599	81.34
19	2872.9	7.644	599	78.34
20	2832.74	7.555	586.21	72.67
21	2832.74	7.555	586.21	72.67
22	2600	8.76	158.48	20.72
23	2600	8.76	158.48	20.72
24	125.4	0.43	3.82	3.08
25	130.80	0.62	5.52	0.72
26	158.84	0.53	4.21	3.40
27	2872.9	7.64	599.5	4.0
28	355.3	1.15	14.48	1.9
29	409.64	1.03	24.42	3.2
30	2989.86	7.64	717.40	4.0
31	426.36	1.35	28.32	3.70
32	489.06	1.51	42.75	6.31
33	3231.97	7.607	969.65	7.01
34	501.6	1.545	45.75	6.75
35	627	1.838	83.842	12.38
36	635.36	1.86	84.75	12.51
37	677.16	1.962	97.05	16.79
38	677.16	1.962	97.05	16.79
39	705.88	2.216	117.16	20.27
40	3262.26	7.513	1027.9	3.936

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41	730.6	2.256	120.36	20.82
42	781.66	2.384	134.31	23.42
43	3054.8	6.704	1061.65	10.63
44	781	2.384	120.36	20.82
45	944.68	2.731	175.40	30.35
46	3157.4	6.673	1123.4	9.38
47	944.68	2.731	199.40	34.5
48	1003.2	2.817	198.39	34.33

III. RESULTS AND DISCUSSION

Table: Exergy, Percentage of Exergy Destruction and Second Law Efficiency

93% loading				
Components		Exergy destruction (MW)	Exergy destruction (%)	2nd Law efficiency (%)
HP Turbine	Stage 1	7.29	8.8	86
	Stage 2	4.03	4.8	65
IP Turbine	Stage 1	4.47	5.39	87
	Stage 2	1.17	1.41	82
	Stage 3	2.55	3.07	95
	Stage 4	0.53	1.00	90
	Stage 5	0.42	0.50	78
LP Turbine		21.51	25.9	60
Total		42.27		
Condenser		19.68	23.76	17.31
Pumps		3.48	4.2	58.25
LP Heaters	LPH 2	2.7	3.26	54.23
	LPH 3	1.39	1.67	81.9
	LPH 4	1.37	1.65	89.9
HP Heaters	HPH 5	1.33	1.6	94.6
	HPH 6	1.1	1.32	96.50
	HPH 7	9.5	11.47	78.23
Total		17.39		
Power Cycle		82.82		

REASONS

- Load will affect the performance of plant. Machine should be run at the rated load for the efficiency of plant. Therefore from the graph we can conclude that each of these elements related to each other since every change of value of it will affect others.
- Extractions of steam are taken from all the three stages of turbines casing and connected to heaters. Extraction permits more steam to flow through the turbine to generate additional electricity during periods of low thermal demand.

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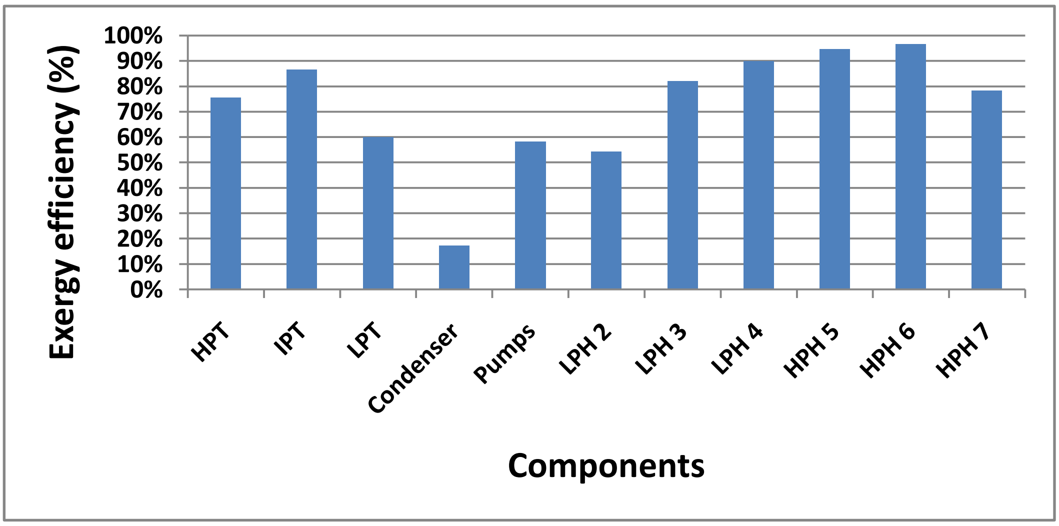
- Exergy destruction (%) is calculated by ratio of exergy destruction to the total exergy destruction of power cycle.
- Usually HPT is totally operates in high temperature zone where as IPT is a bit less in temperature so heat losses will be more in HPT compared to IPT.
- In condenser exergy destruction (%) is high as the heat energy is transferred to the circulated water, the steam gets condensed.



The second law efficiency or exergy efficiency is a measure of how far a device or power cycle efficiency is ideal from the operating conditions.From the Figure in case of power producing equipment's, the IPT has high exergy efficiency whereas LPT has lowest efficiency. This is due to when turbine blades get rotated by high pressure and high temperature steam, the steam loses its energy. This in turn will result in a low pressure and low temperature steam at the outlet of the turbine.

IV. CONCLUSIONS AND FUTURE SCOPE

- Exergy is a better tool than energy in the design of sustainable processes. Since exergy also includes the second law of thermodynamics it is a more complete and accurate concept than energy. 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.
- The exergy output should be maximized to improve efficiency.
- Efficiency is decreased with the decrease in load.
- In the condenser also exergy destruction rate is high. This is due to the low quality of heat energy.

FUTURE SCOPE

- High pressure turbine runs in high temperature zone, so heat losses will be more

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- To improve efficiency, we should look for a way to reduce irreversibility in boiler, because this component had a high contribution to exergy destruction.
- About 62% of the exergy use in our present society originates from fossil fuels; the rest is composed mainly of wood for construction and paper, firewood, food, hydropower and nuclear deposits.

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