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# Calculation of exergy destruction of various components by performing exergy analysis on stage-i of Dr. Narla Tatarao thermal power station (N.T.T.P.S)

## N Naga Varun and T Subba Reddy

**Abstract**
For any nation to develop power generation plays a crucial role. The performance of a power plant is analyzed by using the Energy balance and it is done by using the first law of thermodynamics. But to know how much energy is being utilized in reality exergy analysis has to be performed which is also called as second law of thermodyanamic analysis because the vital parameter quality is being considered in the exergy analysis. This paper deals with the exergy destruction calculation by performing exergy analysis for various components for a 210 mw plant of vijaywada thermal power station (Stage-1 Unit-1) and from the analysis it is clear that exergy destruction is more in condenser.

**Keywords:** Available energy, exergetic destruction, second law efficiency

## 1. Introduction
With the increase in the global warming along with food clothing and shelter one particular parameter playing an important role along with these basic needs that is Power and it so essential which the life style is not at all an issue. Our country depends on both renewable and non renewable sources but the major part is occupied by conventional source that is coal. It is used in a thermal power plant which drives the prime mover. From the facts and figures around 58.75% to 60% the power generation is from coal. Around 8.91% is from natural gas where as oil and nuclear contribute to 0.52% and 2.11%. 66.8% is from coal and petroleum. The percentage of crude oil expected around 7% and 22% by 2021-22 [1].
To measure the life style of the people we have so many indicators to measure among them the power consumption is one which shows the living standards of the people.
This particular papers deals with the evaluation of exergy destruction and calculation of second law efficiency. Why because in general the power plant efficiency is valuated with the help of energy analysis which is on 1st law of T.D which in general will not consider the quality of the energy there by will not be getting the correct analysis of the performance which is simply a energy balance.
Here we will be calculating the exergy destruction on 2 nd l a w of thermodynamics, which considers the energy quality. The 1st and 2nd anal ysis will provide a complete picture to improve the plant efficiency.

## 2. Individual components
2.1 **Boiler:** used to convert water into steam
2.2 **Super-heater:** to ensure that only dry steam is entering into the turbine.
2.3 **Re-heater:** to make sure that dry steam is entering into intermediate pressure turbine after the expansion in the high pressure turbine
2.4 **Economiser:** the purpose is to heat the water coming from condenser in advance before reaching the boiler by which fuel supply rate can be decreased [2].
2.5 **Turbines:** In thermal power plants, the turbine takes the steam as input and gives power as output.
2.6 **Deaerator:** Is to remove any air and dissolved gases.
2.7 **Condenser:** This converts water into steam
2.8 **Feed water heater:** Like economizer feed water heaters are used to heat the water coming from the condenser by tapping the turbines.

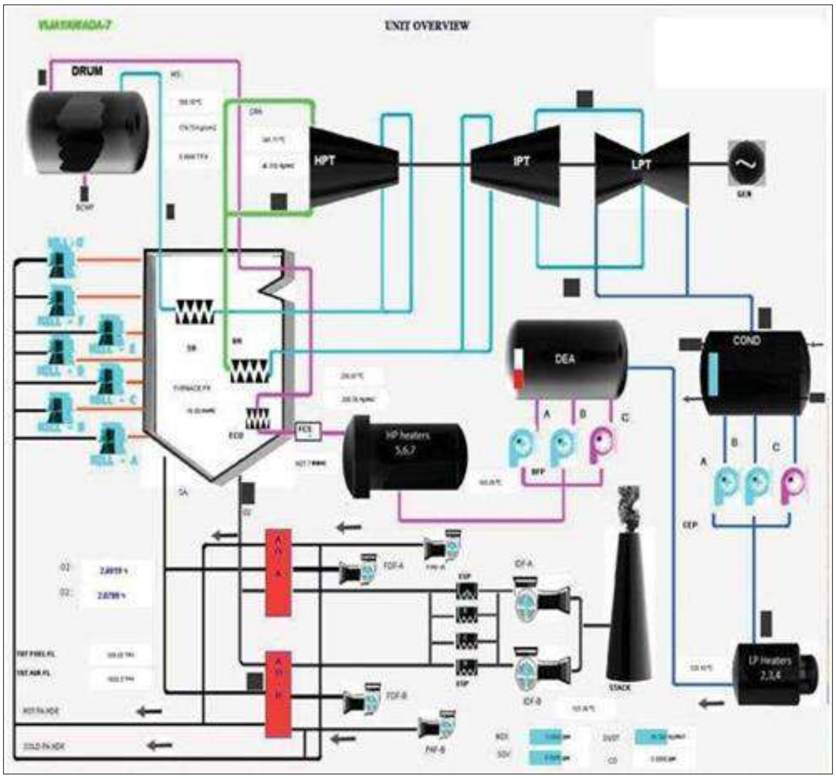
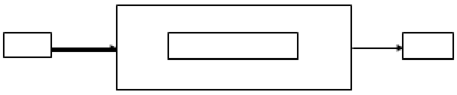



**Fig 1:** General layout

## 3. Modelling of exergy
### 3.1 Exergy modelling for thermal components



Specific exergy for any component is given by

$$\Psi = h - h_o - T_o\,(s - s_o)$$

Where ho, so, to indicates reference states Overall Exergy:

$$\overset{o}{X} = \overset{o}{m}\Psi = \overset{o}{m}\left[h - h_o - T_o(s - s_o)\right]$$

$\dot{m}$ implies flow rate.

Inlet exergy =

$$Ex_{in} = \dot{m}[(h_1 - h_0) - T_0(s_1 - s_0)] \text{------------} \rightarrow 3$$

Outlet exergy =

$$Ex_{out}\ \dot{m}[(h_2 - h_0) - T_0(s_2 - s_0)] \text{------------} \rightarrow 4$$

Destruction of exergy (I) =

$$I = Ex_{in} - Ex_{out} - W \text{----------------} \rightarrow 5$$

% Destruction of Exergy = (Destruction in Exergy/Overall Destruction in energy of the cycle) *100---□6 2nd law efficiency is.

1. Original W.D to Ideal work [3]

$$\eta_{II} = \frac{\text{Actual Workdone}}{\text{Maximum theoritical work}} \text{---------------} \rightarrow 7$$

In other terms

2. Original thermal efficiency to the maximum possible thermal efficiency [4]

$$\eta_{II} = \frac{\text{Exergy Output}}{\text{Exergy Input}} \text{-----------------} \rightarrow 8$$

## 4. Turbine layout
The turbine house and remaining components of Dr. N.T.T.P.S are shown in the below figure 2. Along with the figure the operating parameters are also shown by using the above mentioned equations. Thus the obtained results are tabulated in Table 1, 2 and 3.

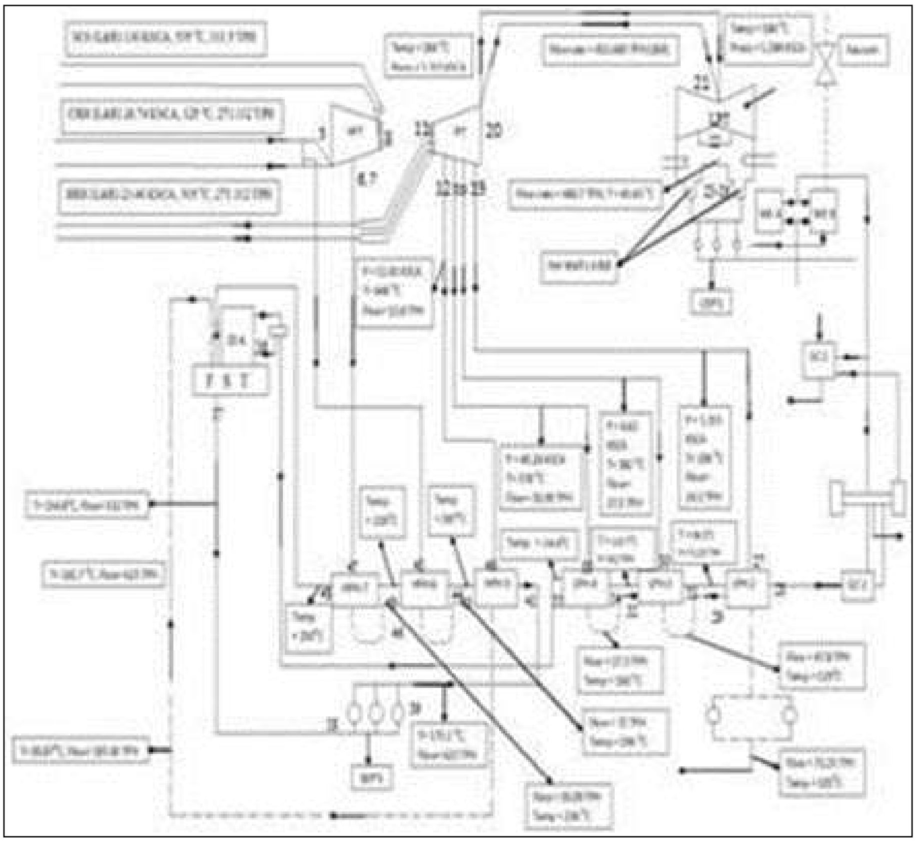


**Fig 2:** Turbine Layout

| COMPONENTS | Points | T (°C) | P (bar) | m (kg/s) | H (kJ/kg) | Entropy (kJ/kg-K) | (kJ/kg) | X (MW) |
|---|---|---|---|---|---|---|---|---|
| Economizer inlet | 1 | 247 | 142 | 173.05 | 1071.81 | 2.741 | 258.99 | 44.81 |
| Economizer outlet | 2 | 278 | 137 | 173.05 | 1205.18 | 3.028 | 306.84 | 53.09 |
| S.H inlet | 3 | 345 | 128 | 173.05 | 2930 | 5.9 | 1089.48 | 202.37 |
| S.H Outlet | 4 | 535 | 128 | 173.05 | 3430.12 | 6.581 | 1471.3 | 254.6 |
| HPT inlet | 5 | 535 | 128 | 173.05 | 3430.12 | 6.581 | 1471.3 | 254.6 |
| Tapping | 6 | 378 | 40 | 173.05 | 3113.25 | 6.6911 | 1115.36 | 193.01 |
| Tapping | 7 | 378 | 40 | 165 | 3113.25 | 6.6911 | 1115.36 | 184.03 |
| HPT Outlet | 8 | 330 | 28 | 165 | 3078.82 | 6.7444 | 1064.78 | 175.68 |
| R.H Inlet | 9 | 330 | 28 | 165 | 3078.82 | 6.7444 | 1064.78 | 175.67 |
| R.H outlet | 10 | 535 | 23 | 154.20 | 3539.87 | 7.459 | 1311.85 | 202.02 |
| IPT Inlet | 11 | 535 | 23 | 154.20 | 3539.87 | 7.459 | 1311.85 | 202.02 |
| Tapping 1 | 12 | 441 | 12 | 154.20 | 3364.39 | 7.522 | 1117.23 | 172.05 |
| tapping 1 | 13 | 441 | 12 | 150.38 | 3364.39 | 7.522 | 1117.23 | 167.986 |
| Tapping 2 | 14 | 388 | 6.5 | 150.38 | 3227.98 | 7.6081 | 955.03 | 143.59 |
| Tapping 2 | 15 | 388 | 6.5 | 143 | 3227.98 | 7.6081 | 955.03 | 136.56 |
| Tapping 3 | 16 | 261 | 2.8 | 143 | 2999.18 | 7.616 | 723.86 | 103.511 |
| Tapping 3 | 17 | 261 | 2.8 | 137.5 | 2999.18 | 7.616 | 723.86 | 99.530 |
| Tapping 4 | 18 | 208 | 1.3 | 137.5 | 2872.9 | 7.644 | 589.18 | 81.012 |
| Tapping 4 | 19 | 208 | 1.3 | 130.80 | 2872.9 | 7.644 | 589.18 | 77.064 |
| IPT outlet | 20 | 114 | 1.3 | 130.80 | 2842.3 | 7.688 | 551.31 | 72.11 |
| LPT inlet | 21 | 114 | 1.3 | 130.80 | 2842.3 | 7.688 | 551.31 | 72.11 |
| LPT Outlet | 22 | 38 | 0.1 | 130.80 | 2600 | 8.16 | 161.48 | 21.12 |
| Condenser inlet1 | 23 | 38 | 0.1 | 130.80 | 2600 | 8.16 | 161.48 | 21.12 |
| | 24 | 30 | 1.013 | 800 | 125.83 | 0.436 | 4.21 | 3.40 |
| Condenser outlet 1 | 25 | 45 | 0.1 | 130.80 | 191.8 | 0.649 | 6.58 | 0.860 |
| | 26 | 40 | 1.013 | 800 | 167.62 | 0.572 | 5.5 | 4.40 |
| DEAERATOR | 36 | 154.5 | 5.5 | 147.7 | 651.9 | 1.887 | 95.28 | 14.07 |
| DEAERATOR | 37 | 160 | 7.18 | 173.05 | 697.35 | 1.992 | 109.23 | 18.90 |
| BFP INLET | 38 | 165 | 7.18 | 173.05 | 697.35 | 1.992 | 109.23 | 18.90 |
| BFP OUTLET | 39 | 165 | 151 | 173.05 | 705.889 | 1.974 | 123.169 | 21.31 |

**Table 2:** Showing exergy values for LP heaters

| COMPONENTS | Points | T(°C) | P (bar) | $\dot{m}$ (kg/s) | H (kJ/kg) | Entropy (kJ/kg-K) | (kJ/kg) | $\dot{X}$ (MW) |
|---|---|---|---|---|---|---|---|---|
| LPH 2 inlet 1(S) | 27 | 200 | 1.5 | 6.69 | 2872.9 | 7.644 | 589.18 | 3.94 |
| LPH 2 inlet 2(W) | 28 | 87 | 16.68 | 130.80 | 365.60 | 1.156 | 28.28 | 3.69 |
| LPH 2 Outlet | 29 | 99.3 | 13.7 | 130.80 | 417.10 | 1.298 | 37.18 | 4.86 |
| LPH 3 inlet 1(S) | 30 | 265 | 2.78 | 5.5 | 2999.18 | 7.616 | 723.86 | 3.98 |
| LPH 3 inlet 2(W) | 31 | 106 | 13.7 | 130.80 | 417.10 | 1.298 | 37.18 | 5.60 |
| LPH 3 Outlet | 32 | 120 | 12 | 147.7 | 504.48 | 1.526 | 50.10 | 8.29 |
| LPH 4 inlet 1(S) | 33 | 381.5 | 6.40 | 7.23 | 3227.98 | 7.6081 | 955.03 | 7.23 |
| LPH 4 inlet 2(W) | 34 | 120 | 12 | 147.7 | 504.48 | 1.526 | 50.10 | 8.29 |
| LPH 4 Outlet | 35 | 154.5 | 8.5 | 147.7 | 651.90 | 1.887 | 95.28 | 14.07 |

TABLE 3: SHOWING EXERGY VALUES FOR HP HEATERS

| COMPONENTS | Points | T(°C) | P (bar) | $\dot{m}$ (kg/s) | H (kJ/kg) | Entropy (kJ/kg-K) | (kJ/kg) | $\dot{X}$ (MW) |
|---|---|---|---|---|---|---|---|---|
| HPH 5 inlet 1(S) | 40 | 448 | 12.17 | 3.83 | 3364.39 | 7.522 | 1117.27 | 4.282 |
| HPH 5 inlet 2(W) | 41 | 173.1 | 155 | 173.05 | 740.81 | 2.053 | 134.39 | 23.25 |
| HPH 5 Outlet | 42 | 187 | 150 | 173.05 | 804.03 | 2.194 | 155.31 | 26.87 |
| HPH 6 inlet 1(S) | 43 | 325 | 26.24 | 10.49 | 3066.75 | 6.7249 | 1058.76 | 11.10 |
| HPH 6 inlet 2(W) | 44 | 187 | 150 | 173.05 | 804.03 | 2.194 | 155.31 | 26.87 |
| HPH 6 Outlet | 45 | 226 | 147.2 | 173.05 | 974.63 | 2.550 | 219.11 | 37.91 |
| HPH 7 inlet 1(S) | 46 | 378 | 39.5 | 8.35 | 3113.23 | 6.6911 | 1115.38 | 9.313 |
| HPH 7 inlet 2(W) | 47 | 226 | 147.2 | 173.05 | 974.63 | 2.550 | 219.11 | 37.91 |
| HPH 7 Outlet | 48 | 247 | 145 | 173.05 | 1071.81 | 2.741 | 258.99 | 44.81 |

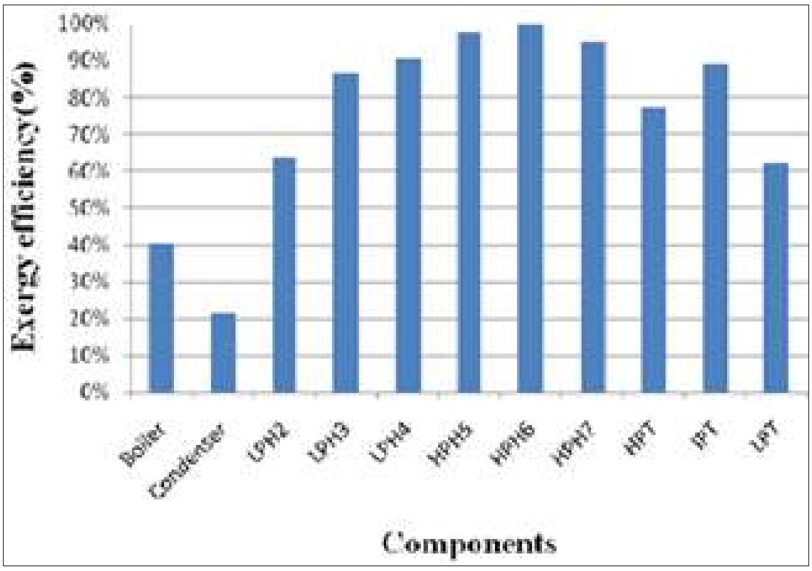
## 5. Discussions

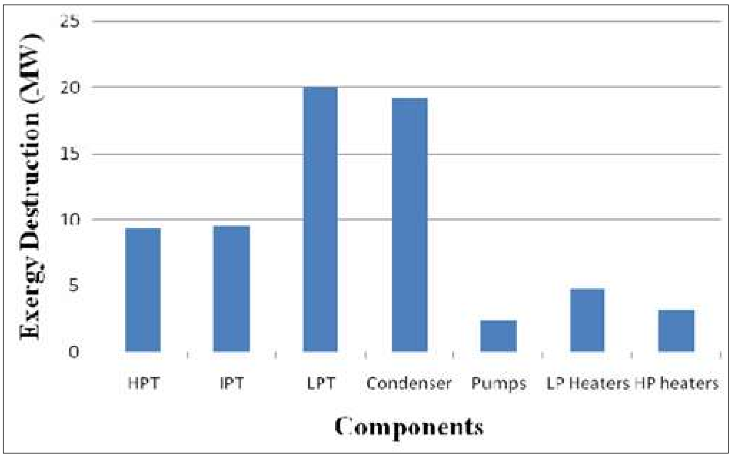
In this study the exergetic analysis of 210 MW plant of Dr. N.T.T.P.S is performed. With the obtained values which are shown in the tables 1, 2 and 3. The exergy destruction percentage, 2nd law efficiency and the destruction of exergy is calculated and are shown in the table 4. All the calculations are done at 95% condition and the graphs are plotted and are shown below.

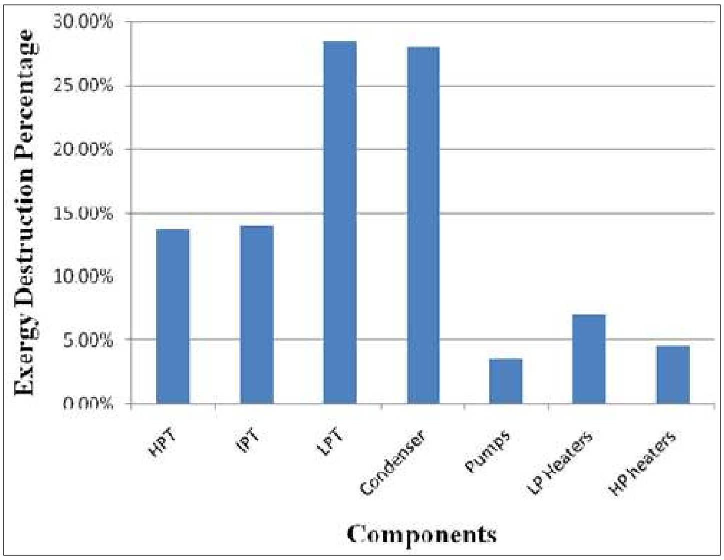
The second law efficiency is more for High Pressure Heater and can be observed from graph 4.In the power generating components it is found to be high for intermediate pressure turbine and Low Pressure Turbine is having low efficiency. This shows both these components are having higher entropy generation rate and there is room for improvement. The destruction in exergy is more in condenser the reason is it runs at low temperature and so as the work capacity. Even the amount of losses in the exergy is more we will not consider because of its quality of energy which is low.

**Table 4**

| Loading | | @ 95% loading | | |
|---|---|---|---|---|
| Components | | Exergy destruction(MW) | Percentage exergy destruction (%) | 2nd Law efficiency (%) |
| High Pressure Turbine | Stage 1<br>Stage 2 | 6.76<br>2.64 | 9.99<br>3.90 | 89.03<br>68.39 |
| Intermediate Pressure Turbine | Stage 1<br>Stage 2<br>Stage 3<br>Stage 4<br>Stage 5 | 2.91<br>3.886<br>0.339<br>1.158<br>1.11652 | 4.30<br>5.74<br>0.50<br>1.71<br>1.65 | 90.28<br>84.07<br>98.99<br>93.76<br>80.79 |
| Low Pressure Turbine | Stage 1 | 19.29 | 28.52 | 62.14 |
| **Total** | | **38.09** | | 77 |
| Condenser | | 19.22 | 28.42 | 21.45 |
| Pumps | | 2.41 | 3.56 | 60.25 |
| LP Heaters | LPH 2 | 2.77 | 4.09 | 63.69 |
| | LPH 3 | 0.74 | 1.09 | 91.62 |
| | LPH 4 | 1.26 | 1.86 | 91.78 |
| HP Heaters | HPH 5 | 0.662 | 0.97 | 97.59 |
| | HPH 6 | 0.06 | 0.08 | 99.84 |
| | HPH 7 | 2.413 | 3.56 | 94.89 |
| **Total** | | **7.905** | | |
| Power Cycle | | 67.625 | | |






## 6. Conclusion

The Exergy destruction for a 210 MW plant of V.T.P.S has been performed and it can be seen that the condenser is having the highest exergy destruction rate and there is scope for improvement but practically its feasibility is low because of its Physical and environmental factors.

## Nomenclature

h =Specific enthalpy (kJ/kg)
s =Specific entropy (kJ/kg K)
$h_0$ =Specific enthalpy at ambient condition (kJ/kg)
$s_0$ =Specific entropy at ambient condition (kJ/kg-K)
$\dot{I}$ =Exergy destruction rate (MW)
T =Temperature (°C)
$\dot{m}$ = Mass flow rate (kg/s)
W= Work done rate or power done by the system (MW)
P= Pressure (bar)
=Specific exergy (kJ/kg)
$\dot{X}$ =Total energy rate (MW)
$\eta_{II}$ = Second Law Efficiency

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