# Energy, Exergyand Energy Audit Analysis of Vijayawada Thermal Power Station

**B. Sairamkrishna, P. Vijaya Kumar, Y.Appala Naidu**

*Abstract:Vijayawada 210MW coal-based thermal power plant's energy and exergy analyses were conducted to assess the energetic and exegetic efficiencies and losses of various parts and the plant's general scheme. This coal-fired power plant, which consumes approximately 2,000 metric tons of coal, produces approximately 170 MW to 180 MW of electricity every day against installation ability of 210 mw the supply of energy to demand is declining throughout the world day by day. The increasing demand for energy has made power plants of science concern, but most power plants are built solely by the vigorous performance criteria based on the First Thermodynamics Law. The actual useful loss of energy cannot be justified by thermodynamics ' First Law because it does not distinguish between the quality and amount of energy. Thus, this current research deals with the comparison of coal-based thermal power plants electricity and exergy analyses. For calculation purposes, the entire plant cycle was divided into three areas: (1) only the turbo-generator with its inlets and outlets, (2) turbo-generator, condenser, feed pumps and regenerative heaters, (3) the entire cycle of boilers, turbochargers, condensers, feed pumps, regenerative heaters and auxiliary plants. The analyses were carried out considering information on this power plant's layout (50 percent, 80 percentand 100 percent) and operation information (57 percent and 67 percent loading condition). The plant's general energy efficiencies are 35.48 percent, 56.77 percent, 70.96 percent and 75.67 percent, and the general exergy efficiencies are a44.25 percent, 33.31 percent, 30.78 percent, and 30.21 percent, 50%, 80 percent, 100 percent of the design information. But the power plant's general energy and exergy efficiencies in operational information are 39.2%, 46.6% and 27.9%, 27.2% for 57% and 67% loading lower than the design value Specific CO2, SOx, NOx and particulates are also used to study the environmental impactof power plants. To find the irreversibility of the method, the distribution of exergy losses in power plant parts was evaluated. The comparison between the energy losses and the exergy losses of the plant's individual parts indicates that the highest power losses of 49.92% happen in the condenser, while the maximum exergy losses of 68.27% happen in the boiler. The analyses were also carried out one by one by inactivating the heater. Exergy assessment can be particularly efficient in defining methods to optimize the efficiency of current activities and plant design while energy equilibrium transfers heat between the device and its environment. Exergy-based operating and maintenance choices have been shown to be more efficient in decreasing inefficiencies in working power plants*

*Index Term: energy analysis, exergy analysis, power plant flow scheme, energy and energy effectiveness, mass energy and exergy equilibrium equation, thermodynamics second law*

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## I.INTRODUCTION

High energy expenses and the need to reduce them, as well as environmental issues, make optimized energy use and energy consumption management very important. Indeed, by accurate thermodynamic evaluation of thermal systems, we can obtain results for energy planning and optimization. To this end, we need a tool for data analysis, which can be found in two thermodynamic laws. The first law deals with the assessment of energy, while the second deals with irreversibility and exergy (job potential). The first law points to the fact that total energy is constant In a system, and converting thermal energy into mechanical energy, for example, is only the quality of that energy.A tool called exergy was developed based on first and second thermodynamic laws to analyse the energy system. Thermodynamic process exergy demonstrates that process's effectiveness or inefficiency. Exergy gives us a better knowledge of energy qualification processes. Therefore, to find, qualify and quantify energy destruction, it would be better to use exergy. Exergy can play a significant part in the strategic growth of power plants and in providing directions for use in current power plants. In addition, a picture of exergy destruction of the parts of power plants must be accessible to enhance the accessible power plants, which involves exergy assessment of power plants. The energy and exergy assessment will provide a full image to enhance the effectiveness of the plant Boiler: Boiler is an enclosed vessel that heats and circulates water until at the necessary pressure the water is transformed into steam. Water tube boilers are being used.
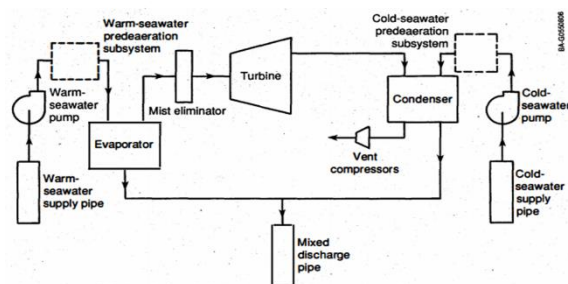


**Fig.1 basic line diagram of power plant**

Super heater: The purpose of the super heater is to heat the steam from the boiler cabinet before it enters the turbine.Re-heater: vapor from high-pressure turbine is re-heated before entering intermittent and low pressure turbines Economizer:

The flow gas from the boiler carries a lot of heat.

The economizer function is to retrieve some of the heat from the heat conducted up the chimney in the flue gases and to use it to heat up the feed water to the boiler. It is positioned between the boiler outlet and the chimney entrance in the passage of flue gases. The savings in coal consumption and elevated boiler effectiveness result from the use of economizer. Turbines: A turbine is a mechanical tool that extracts and converts fluid flow power into useful work. In V.T.P.S. there are 3 turbines, namely high-pressure turbine (HPT), low-pressure turbine and medium-pressure turbine. Super heater steam with a temperature of 535 OC and a pressure of 128 bars is the inlet to the HPT. Deaerator: The purpose of the deaerator is to remove oxygen from feed water and other materials dissolved. Because if there are any traces of oxygen and other dissolved gasses, there is a serious affect of corrosion that damages the wall of the pipes. Spray type deaerator is used in V.T.P.S condenser: turbine steam enters the condenser. In heat energy plants, shell and tube heat exchangers (or surface condensers) are usually installed at the steam turbine outlet. These condensers are heat exchangers that transform steam from their gaseous, also acknowledged as phase transition, into their liquid state. In this manner, the latent steam heat is released inside the condenser. Feed water heaters use the surface condenser feed water heaters are the heaters used in power plants before they enter the boiler to heat the feed water. Working cycles, heat and work are the basic types of energy mainly associated with thermal stations. Heat creates work and this is an extra task

LITURATURE SURVEY

Rosen [1] provided a comparison between coal-fired power plants and nuclear steam power plants based on electricity and exergy. The findings are recorded from comparisons of coal fired and nuclear power generating stations based on energy and exergy. A version of software for process simulation, earlier improved for exergy assessment by the writer, is used. Overall energy and energy efficiencies are 37% and 36% respectively for the coal-fired method and 30% for the nuclear process Rudra et al. atomic process [2] examined to improve the effectiveness of coal-fired steam power plants by advance steam parameters. This article introduces heat energy plant-based coal research using subcritical, supercritical and ultra-supercritical vapour circumstances. Kiran and Karuna [3] examined heat energy plant size, place and source of thermodynamic inefficiencies. It is expected that this examination will provide fresh perspectives into the efficiency of the steam power plant as it contains both energy and exergy analyses. Exergy assessment can be particularly efficient in defining ways of optimizing the efficiency of current activities and plant design while energy equilibrium provides heat transfer between the structure and its surrounding Bejan [4] describes the basics of exergy assessment techniques and minimizing entropy generation (or thermodynamic optimization-minimizing exergy destruction). The article starts with a review of irreversibility, entropy generation, or destruction of exergy. Examples demonstrate the accounting for exergy flows and accumulation in closed systems, open systems, heat transfer procedures, and energy and cooling plants Tapan et al. [5] submitted a 500 MWe steam turbine cycle to define parts that deliver important prospective job savings. Performance criteria are developed that are applicable to the individual parts. Exergy flows, exergy consumption owing to irreversibility and rational performance parameters for the turbine cycle and its elements are calculated using information on plant operation under various conditions Kaushik et al. [6] provided a comparison of energy and exergy analyses of coal and gas-stimulated thermal power plants. This paper offers a thorough overview over the years of various researches on thermal power plants. This review would also shed light on the scope for further studies and improvements in current thermal power plants

## II. METHODOLOGY

INTRODUCTION TO EXERGY AND ENERGY

3.1. Energy: In 1807 THOMAS YOUNG used the word energy from the Greek term "energy." Is it a point function and can a system property appear for the first moment in the work of A in the 4th century? Energy is defined as the feature of a substance in the context of chemistry because of its atomic, molecular or aggregate structure.

3.2. Exergy: the German engineer Rant used the term "exergy" for the first time in 1956. Exergy is a property that is connected to the state and environment of the scheme. The maximum amount of work an engine can do from the source

3.2.1 Exergy needs:
• Exergy analyses have started to be used in the last several centuries to optimize the system.
• We can see where we should focus our attempts to enhance system effectiveness by evaluating the exergy lost by each element in a method. Comparing parts or systems can also be used to assist create informed design choices.

The Exergy Method is an alternative, comparatively fresh method based on the notion of exergy, loosely defined in relation to a specified setting as a universal measure of the capacity for job or quality of distinct types of energy. An application for exergy equilibrium to a process or entire plant informs us how much of the usable job capacity or exergy provided as the system input was eaten irretrievably lost by the process. The loss of exergy, or irreversibility, usually offers quantitative inefficiency measurement of processes. Analysis of plant multiple parts shows the general distribution of plant irreversibility among plant parts, identifying those that contribute most too general plant inefficiency. The notion of irreversibility is strongly based on the two-primary legislation of thermodynamics, unlike the traditional performance criteria. Combining the continuous stream power equation {first law} with the expression for entropy production rate {second law} derives the exergy equilibrium for a control. Although the second law is not explicitly used in the Exergy technique, the practical consequences of the second law are demonstrated by its implementation to process evaluation. Therefore, the research of different kinds of irreversibility and its effect on plant performance offers a better and more useful understanding of the second law than the research of its statements and corollaries Mass, energy and exergy balance can be articulated for any steady state control volume with negligible potential and kinetic energy shifts.

Specific boiler exergy is provided by

$$= (h-h_o)-T_o(s-s_o)........ (1)$$

Where $h_o$, $s_o$, reflects the point of reference (normal environment)

Total energy is provided by $X_o = m_o$

$$= m_o [(h-h_o)-T_o(s-s_o)].............. (2)$$

The following equation evaluates the particular physical exergy of the stream

$$e_i= (h_i-h_o) - T_o (s_i- s_o) = \Delta h-T_o\Delta s......... (3)$$

Destruction of exergy $(I) = E_{xin} – E_{xout} - W ------- (4)$

Percentage Exergy Destruction= (Exergy destruction/Total exergy destruction of the power cycle) * 100............ (5)

Second law efficiency or Exergy efficiency is defined as the

= exergy output ÷exergy input................ (6)

## 4. OBSERVED AND CALCULATED DATA

Overall power plant energy and exergy efficiencies are obtained from information summarized in Table 4.1 and shown in Figure. 4.1 as a feature of 100%, 80% and 50% as a condition of charging. The evaluation shows an improvement in overall energy efficiency with load percentage increase and reduced exergy efficiency. Fig.4.1 shows that the operation of the plant below 56 percent of the designed capacity outcomes in a substantial rise in the effectiveness of the exergy and the energy and exergy efficiency is the same at that stage. A decrease in exergy efficiency is attributed to the loss of exergy in the steam generation unit (Boiler) and turbine. The structure of the energy and exergy balances depicted is strikingly different. It is observed that the exergy assessment has made it possible to determine in detail the causes of process inefficiencies relative to the energy analysis

**Table 4.1 Energy and exergy efficiency of overall power plant at design data**

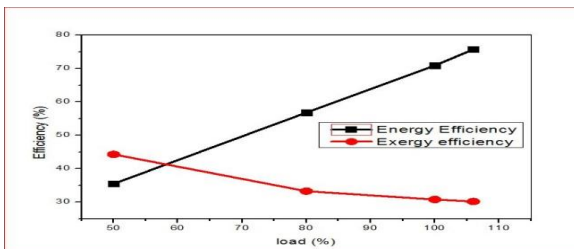| %loading | Energy efficiency | Exergy efficiency |
|----------|-------------------|-------------------|
| 50 | 35.5 | 44.3 |
| 80 | 56.8 | 33.3 |
| 100 | 70.9 | 30.8 |



**Fig 4.1 Energy and exergy efficiency of overall power plant at design data**

## 4.1 OPERATING DATA

Overall power plant energy and exergy efficiencies are based on operating information summarized in Table 4.1.1 and shown in Figure. 4.1.1 As a function of the charging condition of 57% and 67%. From the overall power plant's design and working information comparison for the energy and exergy efficiencies, it is discovered that the working condition's effectiveness is lower than the design condition. These can be discovered on two distinct dates from the site visit. There are only two information points accessible.

**Table 4.1.1 Energy and exergy efficiency of overall power plant at operating data**

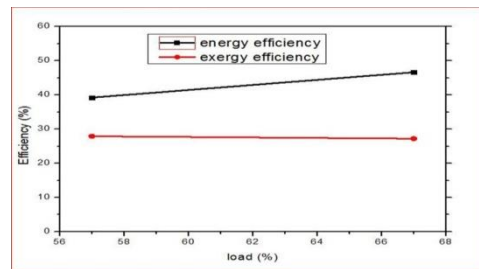| % Loading | Energy efficiency | Exergy efficiency |
|-----------|-------------------|-------------------|
| 57 | 39.2 | 27.9 |
| 67 | 46.6 | 27.2 |



**Fig 4.1.1 Energy and exergy efficiency of overall power plant at operating data**

## 4.2 ENERGY AND EXERGY EFFICIENCY OF TURBINE

Due to a large quantity of condenser energy, the energy efficiency of the turbine cycle is low (47.25% at 100% load). But the derivative exergy efficiency of the turbine is high (83.14% at 100% load), because a tiny exergy linked with turbine exhaust vapour enters the condenser, part of which is returned to CW and partly consumed due to irreversibility.

## 4.3 EXERGY, ENERGYANALYSISOF EACH COMPONENT AT DIFFERENT LOAD

**Table4.3 Different Component Energy and Exergy efficiency for 50% Load**

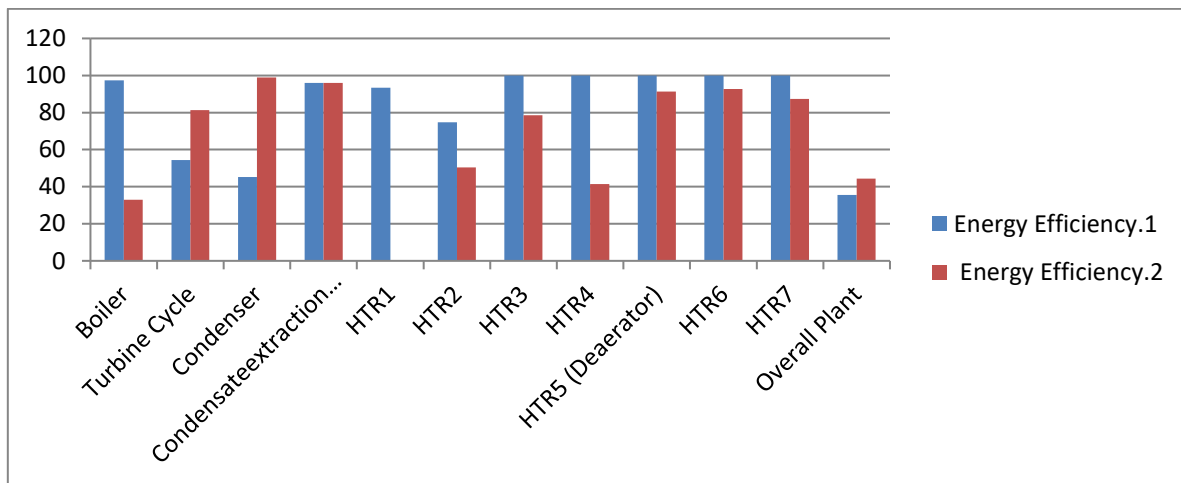| Components | Energy Efficiency, η1 | ExergyEfficiency η2 | Energy loss | Exergy loss |
|---|---|---|---|---|
| Boiler | 91.6 | 31.7 | 8.4 | 68.3 |
| Turbine cycle | 59.3 | 82.7 | 40.7 | 17.3 |
| Condenser | 50.1 | 99.8 | 49.9 | 0.2 |
| Condensate extraction pump | 91.4 | 91.4 | 8.6 | 8.6 |
| HTR1 | 100 | 79.5 | 0 | 20.5 |
| HTR2 | 70.3 | 79.8 | 29.7 | 20.2 |
| HTR3 | 100 | 69.4 | 0 | 30.6 |
| HTR4 | 100 | 97.3 | 0 | 2.7 |
| HTR5(Deaerator) | 100 | 98.2 | 0 | 1.8 |
| HTR6 | 100 | 80.8 | 0 | 19.2 |
| HTR7 | 99.9 | 99.9 | 0.1 | 0.1 |
| Overall plant | 71 | 30.8 | 29 | 69.2 |



**Fig 4.3 Comparison of efficiency in the plant and components at 50 % load**

**Table 4.3.1Different Component Energy and Exergy efficiency for 80% Load**

| Component | Energy Efficiency, η1 | Exergy Efficiency, η2 | Energy loss, % | Exergy loss, % |
|---|---|---|---|---|
| Boiler | 92.8 | 32.2 | 7.2 | 67.8 |
| Turbine cycle | 58.4 | 82.4 | 41.6 | 17.6 |
| Condenser | 49.1 | 99.6 | 50.9 | 0.4 |
| Condensate extraction pump, CEP | 95.4 | 95.4 | 4.6 | 4.6 |
| HTR1 | 99.7 | 0 | 0.3 | 0 |
| HTR2 | 72.2 | 63.6 | 27.8 | 36.5 |
| HTR3 | 100 | 49.8 | 0 | 50.2 |
| HTR4 | 100 | 66.4 | 0 | 33.6 |
| HTR5 (Deaerator) | 100 | 95.4 | 0 | 4.6 |
| HTR6 | 100 | 79.9 | 0 | 20.1 |
| HTR7 | 99.9 | 90.2 | 0.1 | 9.8 |
| Overall Plant | 56.8 | 33.3 | 43.2 | 66.7 |

*Retrieval Number F8916088619/2019©BEIESP*
*DOI: 10.35940/ijeat.F8916.088619*
*Journal Website: www.ijeat.org*

4311

*Published By:*
*Blue Eyes Intelligence Engineering*
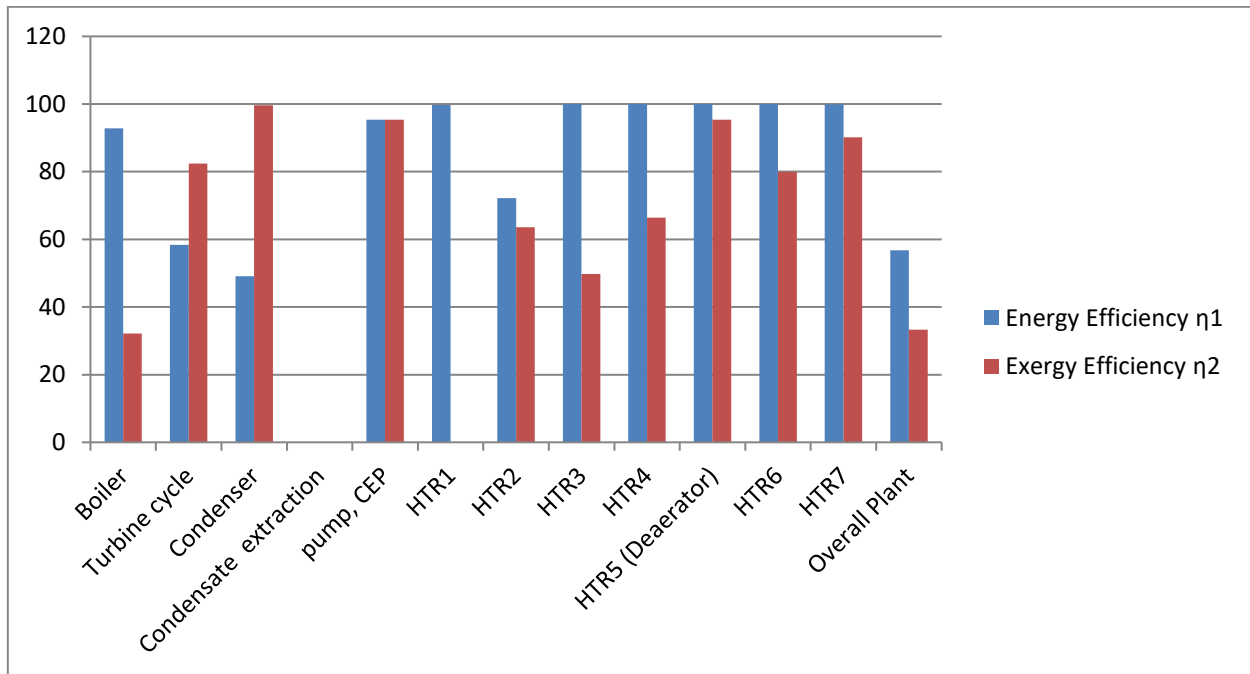*& Sciences Publication*

**Fig 4.4 Comparison of efficiency in the plant and components at 80% load**

**Table 4.3.2 Different Component Energy and Exergy efficiency for 100% Load**

| Components | Energy Efficiency, η1 | Exergy Efficiency η2 | Energy loss | Exergy loss |
|---|---|---|---|---|
| Boiler | 91.6 | 31.7 | 8.4 | 68.3 |
| Turbine cycle | 59.3 | 82.7 | 40.7 | 17.3 |
| Condenser | 50.1 | 99.8 | 49.9 | 0.2 |
| Condensate extraction pump | 91.4 | 91.4 | 8.6 | 8.6 |
| HTR1 | 100 | 79.5 | 0 | 20.5 |
| HTR2 | 70.3 | 79.8 | 29.7 | 20.2 |
| HTR3 | 100 | 69.4 | 0 | 30.6 |
| HTR4 | 100 | 97.3 | 0 | 2.7 |
| HTR5 (Deaerator) | 100 | 98.2 | 0 | 1.8 |
| HTR6 | 100 | 80.8 | 0 | 19.2 |
| HTR7 | 99.9 | 99.9 | 0.1 | 0.1 |
| Overall plant | 71 | 30.8 | 29 | 69.2 |



**Fig 4.5 Comparison of efficiency in the plant and components at 100% load**

## 4.4 ENERGY AND EXERGY HEATER'SEFFICIENCE

Extraction of steam from LP heaters (HTR1 to HTR4) is low pressure and low exergy. Deaerator has a high exergy effectiveness as it has a powerful exergy flow relative to all other heaters and a large thermal transfer and deaeration region also reduces irreversibility (exergy consumption) shown in table 4.4.1. Higher exergy consumption in HTR6 is due to higher irreversibility due to higher differences in temperature between hot 217 ° C and cold 164.9 ° C in HTR

**Table 4.4.1: Exergy flows and exergy efficiencies at 100% Heater charging**

| Component | Net exergy input rate | Useful exergy output rate | Exergy cons. Rate | EXERGY efficiency |
|---|---|---|---|---|
| | (MW) | (MW) | (MW) | % |
| HTR1 | 0.3 | 0.2 | 0.1 | 79.52 |
| HTR2 | 2.2 | 1.8 | 0.5 | 79.77 |
| HTR3 | 3.6 | 2.5 | 1.1 | 69.36 |
| HTR4 | 2.3 | 2.3 | 0.1 | 97.29 |
| HTR5 (Deaerator) | 9.8 | 9.7 | 0.2 | 98.18 |
| HTR6 | 10.2 | 8.2 | 2 | 80.84 |
| HTR7 | 5.33 | 5.32 | 0.01 | 99.9 |

**Table 4.4.2 Overall power plant energy and exergy efficiencies by inactivating heater**

| 50 % Loading | Energy efficiency | Exergy efficiency |
|---|---|---|
| All heaters are active | 35.48 | 44.25 |
| HTR3 inactive | 31.49 | 41.97 |
| HTR3 ,4 inactive | 29.75 | 40.71 |
| HTR3,4,6 inactive | 26.66 | 38.42 |
| HTR3,4,6,7 inactive | 25.34 | 37.45 |

It is discovered from the evaluation of the model scenario that energy efficiency is reduced by 10 percent and exergy efficiency is reduced by 7 percent from the active condition of all heaters to the inactive condition of four heaters. Energy efficiency is therefore reduced more than effectiveness of exergy
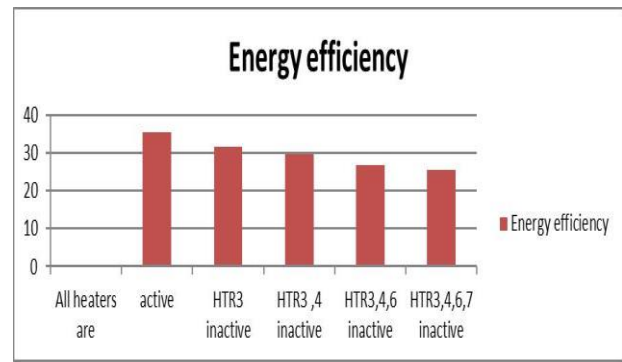


**Figure: 4.6 Energy efficiency of the Overall power plant by inactivating feed water heater**
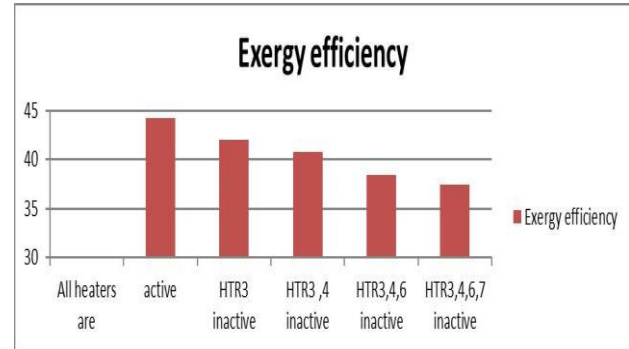


**Figure: 4.7 Exergy efficiency of the Overall power plant by inactivating feed water heater**

**Table 4.4.3 Difference between Energy and energy efficiencies by inactivating heater**

| 50% Loading | Energy efficiency | Differences between energy efficiency |
|---|---|---|
| All heaters are active | 35.48 | |
| HTR3 inactive | 31.49 | 3.99 |
| HTR3,4 inactive | 29.75 | 1.74 |
| HTR3,4,6 inactive | 26.66 | 3.09 |
| HTR3,4,6,7 inactive | 25.34 | 1.32 |

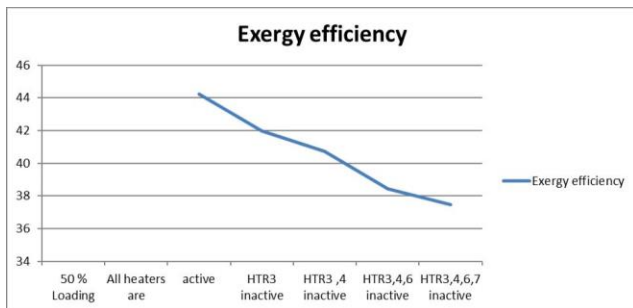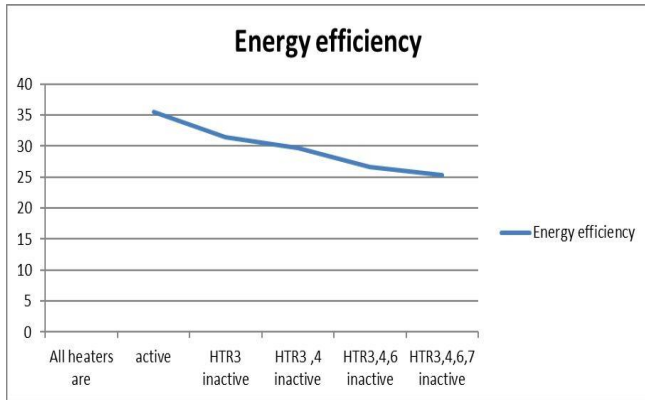| 50% Loading | Exergy efficiency | Differencebetween exergy Efficiencies |
|---|---|---|
| All heaters are active | 44.25 | |
| HTR3 inactive | 41.97 | 2.28 |
| HTR3 ,4 inactive | 40.71 | 1.26 |
| HTR3,4,6 inactive | 38.42 | 2.29 |
| HTR3,4,6,7 inactive | 37.45 | 0.97 |

**Figure: 4.8 Difference between Exergy and energy efficiencies by inactivating heater**

It is discovered from Table 4.5 and Fig 4.8 that when the low-pressure heater HTR3 is inactivated, the effectiveness of the energy is reduced by 2.28%. But when both HTR3 and HTR4 low pressure heaters are inactivated, the effectiveness of Exergy is only reduced by 1.26 percent. Later, when HTR3, HTR4 and HTR6 are inactivated, the effectiveness of Exergy is reduced by 2.29%. But when four heaters (two low-pressure heaters HTR3, HTR4 and two high-pressure heaters HTR6, HTR7) are inactivated, then only 0.97 percent of energy

4.5 Energy audit

The method of energy audit we have used in this thesis is "DETAILED ENERGY AUDIT". The method of audit used here is the most detailed and time consuming one. This contains the use of devices to calculate the energy consumptions of all the equipment's in the thermal power plant. This energy audit exercise is a method to find out the wastage of energy in the thermal power plant and finding out the methods to rectify them

4.5.1 BENEFITS OF USING ENERGY AUDIT (REFERED FROM NTPC)

- Drastically lowers consumption fees.
- It is possible to mention the impact of operational improvements.
- Reduces power usage and operating costs.
- Energy losses identified for corrective behavior.
- Improves general system efficiency and efficiency and profitability.
- Prevents failure of the machinery.
- Estimates the economic effect of projects for power usage.
- There is no comprehensive training or calculation required

4. 5.2 OBJECTIVE OF ENERGY AUDIT (REFERED FROM NTPC)

- Tominimize wastage without affecting production and quantity.
- To minimize investment.
- To go to sustainable development.
- Reduce idling time.
- To check power factor and correction factor possibilities.
- To explore possibilities of using chemicals for reduction in water spray.
- To maximizing mechanical handling minimizing bulldozing.
- To decrease the equipment failure rate.

| Cost estimate of air losses | 1605000 /- |
|---|---|
| Cost estimate of losses owing to coal transport | 96300 /- |
| Cost estimation of losses in the track hopper scheme owing to non-opening of doors | 321000 /- |
| Cost assessment of losses owing to engine idling time | 2920 /- |
| Cost estimation of losses owing to opaque walls and excessive electricity consumption | 1800/- |
| Energy waste by Boiler's second law assessment | 112210.78 /- |
| Energy waste by Economizer's second law assessment | 2499.068 /- |
| Energy waste costs by APH's second law assessment | 1072/- |
| Loss in CV to pulverize from the marshal yard | 115898/- |
| Q cost due to 1% of the blow down | 36052.92/- |
| cost of Q due Soot blowing losses | 222514.56 / - |

## IV. CONCLUSION

In this study, energy and energy analyzes are shown to support the efficiency of coal-fired heat energy plants and to acknowledge future improvements in design efficiency. It provides a logical solution to improve the chances of power generation in thermal power plants. Following findings can be drawn from the information submitted and the later analysis:

1. Exergy efficiency is discovered to be smaller than energy efficiency from the evaluation. Boiler is the primary component that has helped to reduce the effectiveness of exergy.

2. It has been noted that the exergy loss of 68.27 percent occurs in combustor (Boiler), which demonstrates that combustor is not fully adiabatic, and that combustion may not be complete...

3. In the condenser, significant energy destruction occurs, resulting in inefficient heat transfer between warm flow (flue gas) and cold flow (water and air). It demonstrates the need for the heat exchanger system to be carefully inspected

4...A higher rejection of relative energy is attributed to poor energy efficiency with part load. On the contrary, poor part-load efficiency is not caused by higher refusal of relative exergy, but by higher relative exergy consumption

5.Results indicate that feeding heaters with greater variations in temperature between feed water and extraction steam consume more exergy and HP heaters cope with greater amounts of exergy. A small deviation in the performance of HP heaters will therefore have a greater effect on cycle efficiency and therefore more attention is needed

6. Considering flue gas emissions, stack height is calculated. From the site visit stack height is discovered to be about 100 m which meets Environmental Energy Conservation Regulations requirement.

7. When traditional analysis of First Law does not show deterioration of performance, the assessment of exergy identifies inefficiencies and demonstrates ways to improve.

8. Thus, the energy analysis results lead to the erroneous conclusion that important loss is linked to condenser heat rejection, while quantitative exergy evaluation demonstrates that only a very small amount of work ability is wasted in the condenser (because heat is almost rejected at ambient temperature).

9. Decisions on operation and maintenance based on the energy plants ' exergy assessment was more efficient. Power station equipment includes elevated exergy transfer density and therefore, in such systems it is essential to minimize exergy destruction. Exergy-based efficiency surveillance strategy in running power plants helps improve energy resource and environment management.

10. Use of economizer instead of air preheater

Q of air preheater= 25830 kW

Q of economizer= 4857 kW

Rate of air preheated heat transfer is very big than Economizer. Therefore, we need to create 3100 pipes instead of 544 pipes to create an Economizer of the same heat transfer rate. Therefore, the cost of making economizer is 6 times the cost of building an economizer, so we don't use economizer instead of APH. This calculation is performed in MATLAB program. We are using air preheater instead of this large economizer because it will occupy very large space and construction expenses are very high, but it is one-time investment. And the engine responsible for the air preheater rotation is 11 kW, 415 V, 3 moving stages at 1460 rpm, but this engine's maintenance and operating costs are much smaller than those of such a large economizer.

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