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# Heat Rate Calculation and Its Optimisation for 2x 600 Mw Thermal Power Stations and Reduction of Co2 Emission in Flue Gas

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## Abstract

In the present power system scenario major portion of the Electricity is produced from Thermal Power stations. Even though there is a penetration of renewable energy sources, the base load operation of power generation depends on the Thermal power generation. The Thermal Power plants also meets the demands when the Renewable energy sources are letting down supplying power to the Grid, and to operate in a safe mode region during the Demands. Under these scenario the thermal efficiency of the coal based Thermal power station is based on the reduction in heat rate. The heat rate of the thermal power station, otherwise the ratio of the KWh generated as output to the Kilo Calories given as input to the power plant. The reduction in heat rate and improving the Thermal power station efficiency reduces the $CO_2$ emission .The study of the Thermal power station 2X600 mw by collecting the numerical values of regenerative cycle efficiency of the power plant major equipment Steam generator and turbine with steam cycle Boiler also the Turbine with steam cycle. The study also focuses on Thermodynamic steam to power cycle. The parameters of the Thermal Power station is optimized .The study focuses light on the steam cycle thermal efficiency, fuel burnt with unit in Kwh generated , $CO_2$ emission, the furnace temperature at the firing zone in the boiler and temperatures the flue gas path. By conducting the analysis of 2X600 MW coal powered Thermal power Station, the influence of the operating parameters in the Heat rate of the plant and its $CO_2$ emission is realized .The outcome of the study reveals the optimized parameters and procedures for the power station is derived and thus reducing the $co_2$ emission.

***Keywords*:** *Heat rate, Regenerative cycle efficiency, Flue gas analysis, $CO_2$ emission*

## I. INTRODUCTION

For efficiency improvement of power systems, the thermal power generation with cost effective and lesser environmental impact is imperative for the safeguard of future energy needs. Thermal power plants loses its efficiency due to its operation parameters, aging and numerous other reasons. After commissioning of a new power plant as the age of it grows, will not be operating at optimum parameters. Efficiency deteriorates. This lowering efficiency of Thermal Power Plants causes an increase in the carbon dioxide emission, ($co_2$). The raising prices of energy and depletion power plant fuel such as coal, HFO and LDO oil resources, the management of energy and its consumption is very vital and should be optimized. The Coal based power plants works on the modified Rankine cycle principle. The energy analysis studies energy conversion and its analysis in thermal power plants where the chemical energy of coal converted in the Boiler to mechanical energy in turbine and then to Electricity in Generator. Economics of power generation starts with the good

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design and also formulating the operating procedures depending on the each equipment, and following proper operation and maintenance strategy, such that the energy efficiency conversion in power plant during its operating life of 25 years will be efficient and its life will be extended. Power generation by fossil fuel-fired power station requires the high grade of procedures in for the economic operation and reduction heat rate. The parameters of a 600 MW thermal Power Station in Chennai Tamil Nadu are taken and analyzed.

## II. PROBLEM IDENTIFICATION

1. There is a need for Increase in Thermal efficiency of the power Rankine cycle and the reduction in letting out the $CO_2$ in to the atmosphere after the combustion in the boiler in the flue gas.

2. To reduce $CO_2$ emission and conservation of coal Consumption, the optimum operating conditions of power plants is required. The process of converting chemical energy from boiler to mechanical energy in turbine and to electricity in generator configurations is necessary which leads to improved efficiency and heat rate reduction. It is imperative to study the correlation between power plant operation and its maintenance procedures and its influence on reduction of $CO_2$ emission into the atmosphere with high temperatures around 140̊C. The flue gas emissions with high temperatures is having environmental concerns and its norms and ids attracting penalty imposed from the environmental green tribunals.

3. This would also reduce the fuel consumption and on the cost basis it has the greater impact to be reduced on the fuel head.

## III. THERMAL POWER STATION REGENERATIVE SYSTEM

The system consist of firing of raw coal in bowl mills to the order of 15 microns which is carried by the Primary Air (PA) fans. The carried coal is fed in to the Boiler through tangential fired coal nozzles. And the Forced draft (FD) fans which supplies the excess air into the boiler through the re generative Air pre heater. The Boiler is designed with wet bottom ash hopper with negative draught furnace with the VFD controlled Induced draft (ID) fans with forced circulation BHEL with the boiler Circulation Pumps (BCW) in high pressure Boiler. The steam produced is fed in the Turbine as the prime mover for the generator with the capacity of 705 MVA

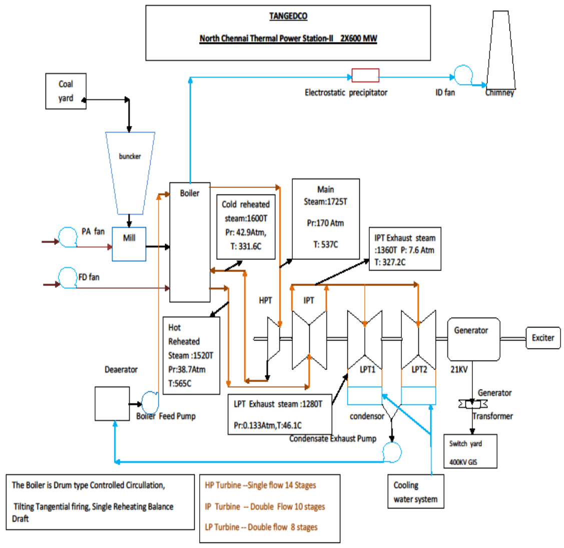


**Fig No: 1**

## PROBLEM SOLUTION

1. Boiler Efficiency

The boiler parameters are collected on full load condition and its efficiency is calculated as

Boiler efficiency η= (M fw-Mb).(Hw+0.98ΔH-hfw)

Boiler load factor LF = 100 {(M fw-Mb)/(M fw max)}

Where

mb =boiler blow down rate = 1930 T/Hr

M fw= feed water rate =2200 T/Hr

Hf calorific value of fuel =3500 Kj/kg

Mfl Fuel Consumption =350 T/Hr



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M fw maximum feed water rate = 2300 T/Hr

ΔH latent heat of steam = 184.021Kj /Kg

Hwa specific saturated water enthalpy = 598.711kj/kg

Hfwa specific feed water enthalpy = 414.69Kj/Kg

The boiler efficiency is 72%

The real time values taken in the furnace are:

The furnace to wind box DP =64 mmWC

Gross calorific value Indian coal=3141 Kcal/Kj

Gross calorific value of imported

Coal =5003 Kcal/Kj

Furnace Draft = -9 mmwc

PA header pressure = 802 mmwc

The $O_2$ in the flue gas =3.7%

PA flow = 840 T/Hr

FD flow =1200 T/Hr

Flew gas outlet temperature = 151/165°C

Drum pressure = 178 Kg/Cm²

Apart from other parameters the furnace temperatures in real time are measured in all the elevations and corners of the boiler and tabulated

The furnace temperature taken in real time

| | Corner 1 | Corner 2 | Corner 3 | Corner 4 |
|---|---|---|---|---|
| AB Elevation | 965°C | 856 C° | 957°C | 830°C |
| CD Elevation | 1085°C | 1108°C | 992°C | 730°C |
| EF elevation | 1131°C | 1025°C | 940°C | 1065°C |
| HJ elevation | 641°C | 755°C | 760°C | 825°C |

**Table: 1 Furnace temperatures**

## STEAM TURBINE EFFICIENCY CALCULATION

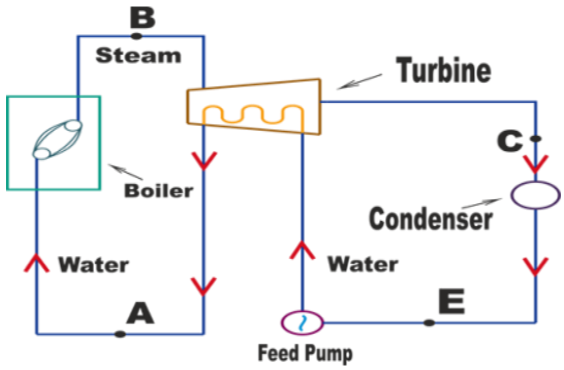


**Fig: 2**

For the turbine efficiency calculation the various enthalpy of the regenerative[ fig2] system at various points are calculates as

hA = Enthalpy of steam at a point A.

hB,hC,hD = Corresponding values at B,C and D.

hfd = Enthalpy or sensible heat of water at D.

Total heat supplied to the steam is the summation of total heat at a point A and the heat supplied during the reheating between B and C .So, total het supplied =Total heat at A + Heat supplied between B and C

TURBINE WORK DONE (APPROX.) by HPT- 30%,

IPT- 45%, LPT- 25%

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DESCRIPTION: BHEL 600MW Turbine

M.S. Press 173 Kg/CM²

M S Temp 540°C

M.S. Flow 1930 T/H

FW Flow 2100 T/H

Turbine efficiency η = Work done / Total heat supplied

= (hA – hB) + (hC -hD)/ hA + {(hC- hB) – hFD }

On calculation of the

Turbine Efficiency = 35%

## IV. THE THERMAL EFFICIENCY OPTIMIZATION

1. For designing the optimum operating conditions the heat rate of the power plant under study by collecting the data are calculated

Heat rate =Heat energy supplied for a particular period (MJ)/Energy output for the particular period (Kwhr)

The Design Heat rate is 2252.44 Kcal /Kwhr

The gross actual Heat rate isGross heat rate (Kcal/Kwh)

= (Total coal consumption X coal Calorific value of that particular grade of coal) (HSD consumption *SpGravity * Calorific value)/Gross Generation in MU (Eq No1)

= (5003X3141) + (2774 X 4756) + 0 (since no oil used)/ (11.707 X 1000)

= 2469.25 Kcal /Kwhr

Decreasing the heat rate of the power plant will lead to the cost reduction and also decrease in the emissions of Sox Nox and $CO_2$

2. The designed value of the Thermal power station under study has the heat rate of 2252.44Kcal /Kwhr in order to achieve the reduced heat rate, finding the energy losses in the system will help to utilise the energy supplied to the boiler and the turbine is calculated and the energy conversion rate is calculated.

3. For calculation of the energy conversion losses and the useful energy conversion the thermodynamic model of the Thermal power station with the steam parameters and details of mass flow with real time data is collected [Fig3] and the flow chart of the power plant of 600 MW is prepared as in fig no1. The enthalpy and entropy in each point of the steam flow in the regenerative system is found. From the details the boiler turbine Energy and the useful work exergy is calculated in all the steam flow points of the system.

## V. BOILER ENERGY CONSERVATION

1. The steam generator in a thermal power station largest exergy destruction equipment .So in order to achieve the energy conservation and heat rate reduction technical attention in the operation maintenance [9] and also in design the boiler and its auxiliaries is required. The losses accounts for around 37 % of total coal supplied .In our study of the 600 MW Power plant the total coal fed per hour accounts for around 370 T/Hr. In total around 10500 T/Day is supplied, and the exergy of boiler is 40 % of energy destruction .Hence more concentration on the steam generator is carried out

2. Apart from the exergy analysis the practical nameplate design parameters are adjusted for achieving the optimized boiler efficiency. The primary air flow reduced 840 T/Hr to 770 T/Hr. The wind box DP has been raised from 64 mmwc to the design value of 70 mmwc by raising the Secondary air flow and also the flue gas $O_2$ has been raised from 3.7 to 4.2% since the lower $O_2$ in the flue gas indicated that the excess air is not sufficient and this causes the combustion problem hence for complete combustion the $O_2$ level has been adjusted [7]. The soot blowers operation from one sequence to times



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decreased the Flue gas outlet temperatures 151/ 163̊C to 145/156̊C

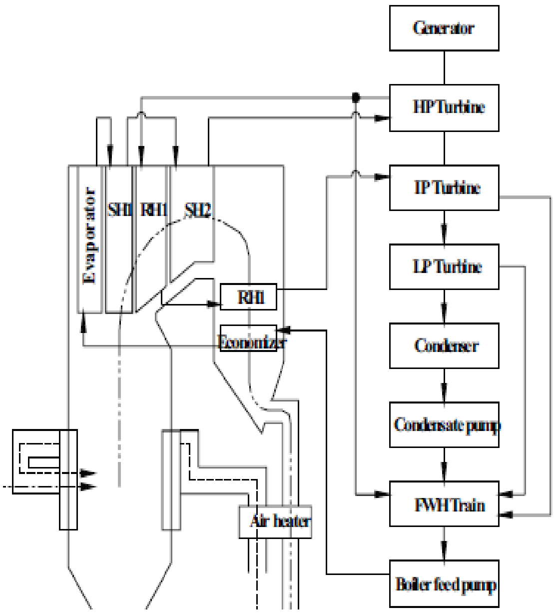
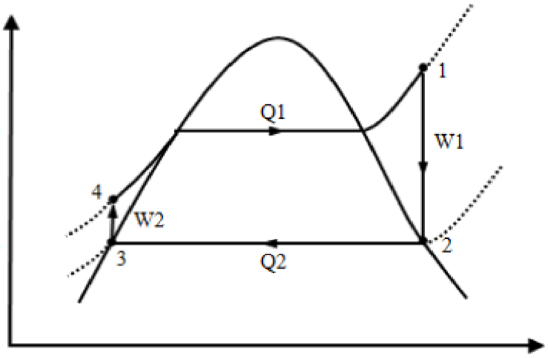



**Fig 3: Steam Path**

## VI. TURBINE EFFICIENCY IMPROVEMENT

The energy loss in the condenser which is high [5] in this power plant as much as calculated as 74%, this is the heat reduction stage of the Rankine cycle,[4] which is entropy against the Temperatures of the steam changes of steam undergoes in Thermal power station system . The loss in the condenser [19] has also has the correlation and , which is attributed with the cooling water inlet temperatures variations due to sea water current nature, high during the summer around 33.8̊ C and to the minimum of 26.3°C .The condenser vacuum efficiency also depends on the Vacuum pumps efficiency, and air ingression in the vacuum systems. The air tightness test revels the passing in the vacuum system. After arresting of the leakages of air in the vacuum system the vacuum improved from 0.11/0.12 Ksc to 0.9/0.94 Ksc on left and right side of the condenser




**Entropy Kj/KgK**

**Fig: 3 Rankine Cycle**

## VII. ENERGY SAVING POTENTIAL

1. Energy saving potential on Exergy analysis with the first law of efficiency is (Fig no2) Boiler 82% as the energy cracked in the boiler is the highest and so the energy saving potential is also high with 75%. In case of Turbine it is the condenser which is heat rejection stage of the modified Rankine cycle is 75% and condenser energy saving potential is 25%. The overall plant energy saving potential is 39% and the exergy. The useful energy cracked in different components are measures from the fig no1 shows the values as (fig no:2) boiler 58% turbine 91% condenser 82% deaerator 51% BFP 79% LPH1 70% LPH2 61% LPH3 29% HPH5 82% HPH6 69% and HPH7 52%.

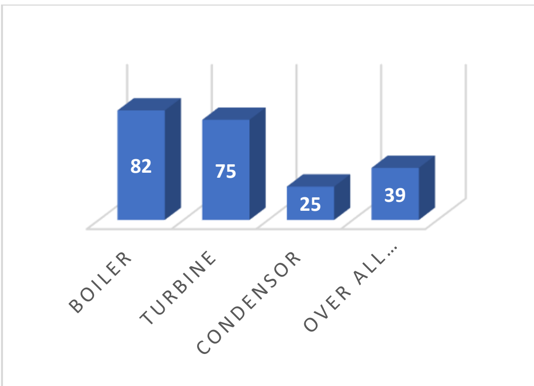



**Fig No: 3**



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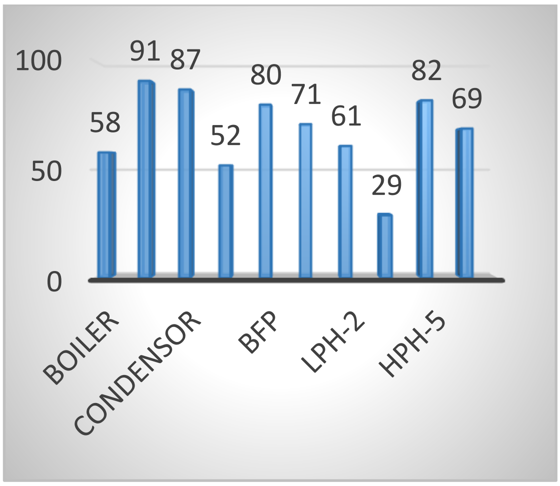


Fig No: 4

As single kWH of electricity is equivalent to 3.6 MJ the overall Thermal efficiency is calculated from the Heat calculated from Heat rate TE =100X3.6/ Heat rate which in the case of the 600 MW power plant under study is 36.56%

## VIII. THE POTENTIAL FOR IMPROVEMENT

The improvement potential is calculated with the value of exergy loss in money M in c, I the cost of investment in c, E is the exergy economic factor and IP is the improvement Potential, which calculated as 229080.58 in Boiler system, 6595 in turbine system and in condenser system 14261 all in corers.

Improvement in heat rate

The improvement system of the potential losses makes improvement in the heat rate as, the readings are taken in real time which reveals

Before improvement the heat rate is calculated as = 2469.25 Kcal /Kwhr

After the improvement the heat rate is reduced to = 2340.26 Kcal/Kwhr

$CO_2$ emission reduction by improving heat rate.

The $CO_2$ t/MW before Heat rate reduction= 0.928 ton/ MW

The $CO_2$ t/MW after heat rate reduction = 0.890 ton / MW

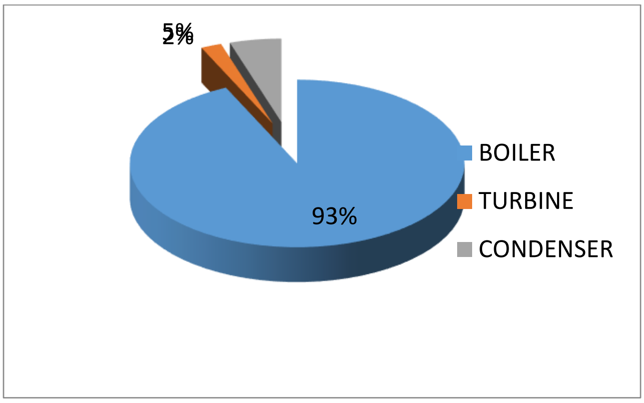


Fig No: 5

## IX. CONCLUSION

In this paper 600 MW thermal power plant main equipment of Boiler and turbine efficiency are calculated .The heat rate of the power plant is calculated .The improvement potential of the heat rate is analyzed from the useful and wasted energy and the main areas of heat loss in the heat rejection stage of turbine the condenser the various factors are carried to improve the regenerative cycle efficiency and condenser efficiency. The other major equipment the boiler efficiency also improved suggesting heat losses in the furnace by varying the existing parameters into name plate designed parameters and exergy analysis. After suggestion are implemented in the operation improved heat rate the $CO_2$ emission is calculated. This $CO_2$ in the flue gas before the improvement is compared with the $CO_2$ emissions after the improvement in the Heat rate. All these readings are taken in the real time data in the 600 MW power plant.

The boiler has the high exergy destruction, the design and technical change will save the larger energy where 40 % of exergy supplied is lost in boiler. In condenser exergy destruction but in condenser is around 9.96%. .Maximum Improvement is in the boiler. In percentage term, from the overall plant, the improvement potential for the boiler is 93%. Which means boiler is the components which has the major scope of


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improvement. The maximum amount of irreversibility occurs in the boiler.

The study analysis not only confined to the thermal power stations but can also extended to the other energy conversion station as utility boilers ,smelters ,and other chemical energy conversion in to heat is the major part of the process.

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