ENERGY, EXERGY AND ENVIRONMENTAL IMPACT ANALYSIS OF 125 MW COAL FIRED THERMAL POWER PLANT

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Abstract

Power generation plays a most important role in the development of country and the living standards. About 80% of electricity produced from fossil fuels and 20% from renewable resources but now a day we are facing a problem of lacking of fossil fuels for long time use as per demand generating. So we need to customize its use and enhance the output efficiency of power plant. Therefore in this paper we present how to improve the efficiencies and whether a further inspection required of 125 MW coal fired power plant. So Energy and Exergy analysis have been carried out in order to evaluate the energetic and exergetic efficiencies of the plant and its components at 100% loading condition, but most of the power plants are designed on the basis of energetic performance and is based on the First Law of Thermodynamics only. The real useful energy loss cannot be justified by the First Law of Thermodynamics because it does not differentiate between the quality and quantity of energy. Energy analysis presents only quantity based result while Exergy analysis presents quality along with quantity based results of the power plant and is based on the principle of Second law of thermodynamics. This paper presents that how the Exergy analysis is more useful as Energy analysis for coal fired thermal power plants.

Key Words: *Energy analysis, Exergy analysis, Flow system of power plant, Exergy destruction, Energy and Exergy efficiency, Mass energy and exergy balance equation, Second Law of Thermodynamics.*

1. INTRODUCTION

Energy consumption plays an important role in the development of any country and the living standards of human being [1]. So the energy supply needs to improve the utilization of energy resource. Therefore, the complexity of power generating units has increased and this requires thermodynamic calculations with high accuracy. Therefore Energy and Exergy analysis has increasingly attracted the interest for the achievement of the goal. Generally, we evaluate the performance of thermal power plants through energy analysis criteria which is based on the principle of First Law of Thermodynamics. But currently we use Exergy analysis which is based on the principle of Second Law of Thermodynamics has found a useful method in the design process, evaluation, optimization and improvement of thermal power plants. The exergetic performance analysis does not determine only magnitudes, location and causes of irreversibility in the power plant but also provides more meaningful assessment of plant individual component efficiency. Therefore it can be said that utilizing exergetic and energetic analysis together can give a complete analysis of the power plant system.

Energy is always conserved in every device or process while Exergy does not conserved but it destroyed. The Second Law analysis of a power cycle gives us to identify the major sources of loss and shows avenues for further performance improvement [2]. With the help of exergy analysis we are able to identify the location of degradation of energy and rank them in terms of their significance. The exergy consumption during a process is proportional to entropy creation due to irreversibility. Exergy consumption or order of destruction is the form of environmental damage. By preserving Exergy we can increase the efficiency and can be reducing the environmental damage up to limit [3].

1.1 Energy and Exergy

Total energy creates with the sum of available energy plus unavailable energy. Total energy is simply called Energy and available energy is called Exergy. Exergy flows to and from components however do not balance indicating a disappearance or consumption of exergy. This disappearance is really a conversion from available energy to unavailable energy. Consumption shows the amount of loss of available energy. Components consume exergy by virtue of the ineffectiveness of their ability to transfer available energy. In order to compare on basis of quality levels of various energy carriers [4], e.g. fuels, it is necessary to determine the equivalents of each energy quantity at a particular grade level. This can be done by using exergy concept because which overcomes the limitations of the first law of thermodynamics.

An exergy analysis is a useful concept of ecology and sustainability because it can use at a common measure of resource quality along with quantity [5]. In order to perform the exergy analysis of the plant, the detail steam properties, mass, energy and exergy balances for the unit were conducted. The exergy values of each component are calculated by assuming that the component is in an open system and there are only physical exergy associated with the material streams.

2. POWER PLANT CONFIGURATION

The power plant has three turbines; High, Intermediate and Low pressure turbine (HP, IP and LP) and is connected to the generator. It has also seven heaters in which four are low pressure heaters and three are high pressure heaters.

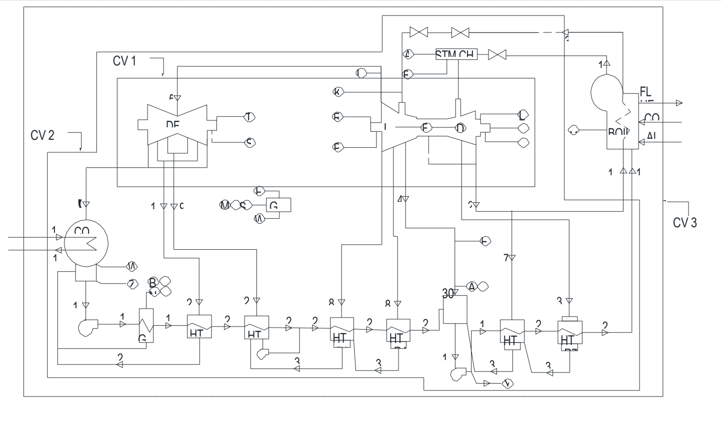

Figure -1: Flow system of coal fired power plant

2.1 Overall Energy Efficiency

Rate of Energy entering the control volume 3 with fuel is:

$$En_t^f = m_{in}^f * LHV$$

And, Total energy flow rate entering the control volume 3 is written as [6]

$$En_{in} = En_{in}^f + En_{13}$$

The composition of coal which has been considered for the analysis are as:

82.5% C, 5.09% H2, 9.2% O2, 1.66% N2, Ash 12.2%, H2O 10%

Now, Energy flow rate leaving the control volume 3 with flue gas is expressed as

$$En_{out}^g = \sum m_j^g h_j^g$$

And, Total energy flow rate leaving the control volume 3 including that with circulating water

$$En_{out} = En_{out}^g + En_{14}$$

The net power output from the control volume 3 is calculated as:

$$P_{net} = G - P_{aux}$$

Therefore, the energy efficiency (The First Law efficiency) of the control volume 3 is written as follows

$$\eta_1 = \frac{P_{net}}{En_{in} - En_{out}}$$

2.2 Overall Exergy Efficiency

Rate of Exergy entering the control volume 3 with fuel [7]:

$$Ex_{in}^f = m_{in}^f n_c \frac{e_{in}^{-f}}{M_c}$$

And, Total Exergy flow rate entering the control volume 3 is

$$Ex_{in} = Ex_{in}^f + Ex_{13}$$

Now, Exergy flow rate leaving the control volume 3 with flue gas is

$$Ex_{out}^g = \sum m_j^g e_j^g$$

And, Total Exergy flow rate leaving the control volume 3 including that with circulating water

$$Ex_{out} = Ex_{out}^g + Ex_{14}$$

Therefore, the net power output from the control volume 3 is

$$P_{net} = G - P_{aux}$$

The Exergy efficiency (The Second Law efficiency) of the control volume 3 is evaluated by using the following Equation,

$$\eta_2 = \frac{P_{net}}{Ex_{in} - Ex_{out}}$$

3. RESULT PARAMETERS

The design data of the plant components of 125 MW coal fired thermal power plant have been used for the present energy and exergy analysis to calculate the energy flow and exergy flow at different stages. The energy and exergy efficiencies of the components have been determine using the equations [8]. Energy and exergy flows rate for the complete power cycle are computed from the plant design data at 100% loading condition and the results are tabulated as:

Table-1: Energy and Exergy efficiency of plant and its component.

Component	Energy Efficiency	Exergy Efficiency	Energy Loss %	Exergy Loss %
Overall plant	63.93	27.87	38.4	72.13
Boiler	92.15	31.9	7.85	68.1
Turbine Cycle	56.08	82.75	43.92	17.25
Condenser	24.17	70.2	75.83	29.8
Condensate extension pump	100	100	0	0
HTR1	100	79.73	0	20.27
HTR2	72.2	78.1	27.8	21.9
HTR3	99.8	98.99	0.2	1.01
HTR4	99.9	97.12	0.1	2.88
HTR5 (Deaerator)	100	98.17	0	1.83
HTR6	99.9	80.8	0.1	19.2
HTR7	99.8	99.89	0.2	0.11

The analysis shows that increase in overall energy efficiency and decrease in exergy efficiency at 100 percentage loading condition. The decrease in exergy effiency is shows that the loss of exergy in the steam generation unit (Boiler) and turbine. There is striking difference in the composition of the represented energy and exergy balances. It is noted that the exergy analysis has been utilized for process inefficiencies in detail and compared to the energy analysis.

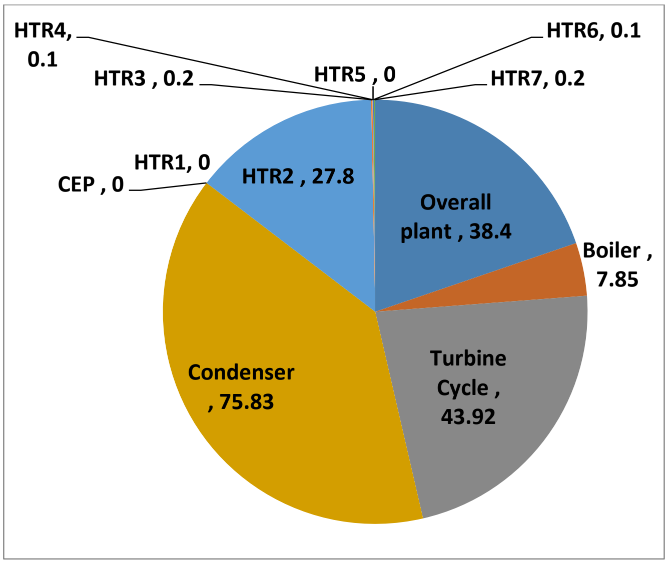

Chart-1: Percentage of Energy loss

From chart it can be seen that the maximum energy loss occurred in condenser. So The First law analysis directs to make our attention towards the condenser improvement and for the plant performance improvement. About 75% of the total plant energy losses occur in condenser only and these losses are useless for the generation of electric power.
Thus the analysis of the plant based only on the First Law principles may mislead to the point that the chances of improving the electric power output of the plant. Hence the First Law analysis cannot be used to pin point prospective areas for improving the efficiency of the electric power generation.

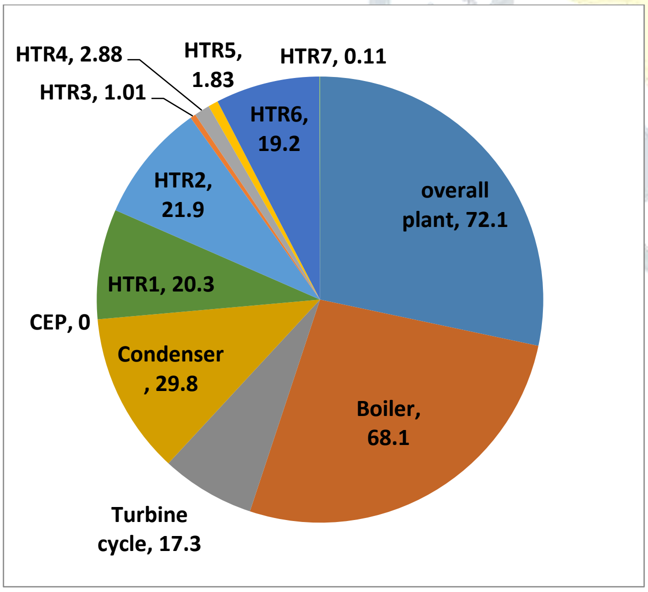

Chart-2: Percentage of Exergy loss

Here in chart 2 we can easily seen that how the exergy being losses in the components of the plant and overall plant. It can be observed that the maximum exergy loss occurs in the Boiler component and that may be due to the irreversibility of the combustion process in the boiler. On another side the exergy destruction rate of the condenser is only 29%.So the real losses in the boiler where entropy was created. Hence Exergy analysis (Second law of Thermodynamics) shows that the boiler section has need to further inspection for the improvement of performance of power plant not in the condenser. The calculated exergy efficiency of the overall power cycle is 28% at 100% load. It means that we have a improvement chance about 72% i.e. are available for improvement [9].

4. CONCLUSIONS

Energy and Exergy analysis here concluded that, this study proves more useful because it easily shows that which analysis is more efficient for the improvement of power plant and where the further inspection required throughout the steam generation. It gives a logical and practical solution to achieve the goal of more efficient output. From the data considered and the frequent analysis gives the following conclusions:

- From the analysis it is found that exergy efficiency is lower than energy efficiency.
- It has been observed that 68% exergy loss occur in boiler which shows boiler is not fully adiabatic and the combustion may not be complete properly. This large exergy loss occurs due to the combustion reaction and the large temperature difference during heat transfer between gas and steam. When we compare it with overall plant output, we found more exergy loss occurs in boiler.
- The maximum energy destruction occurs in the condenser which guides to inefficient heat transfer between hot stream and cold stream.
- A poor load energy efficiency is aspects to higher relative energy rejection. On the other hand, bad poor load exergy efficiency is not due to higher relative exergy rejection but caused by higher relative exergy consumption.
- Results show that a little deviation in performance of HP heaters will have greater impact on cycle efficiency because HP heaters deals with higher temperature difference between feed water and extraction steam consume i.e larger quantity of exergy.
- When First Law of Thermodynamics analysis does not indicate performance deterioration while exergy analysis pinpoints inefficiencies and indicate avenues for improvement.
- Energy analysis results lead to erroneous conclusion that major loss is associated with the heat rejection at the condenser, while exergy analysis quantitatively demonstrates that only a very small amount of work potential is lost in the condenser *(since the heat is rejected nearly at the ambient temperature).*
- Operation and maintenance decisions based on exergy analysis of the power plants proved more effective.
- Exergy based approach of performance monitoring in operating power plants helps in better management of energy resources and environment.

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