Energy and Exergy Analysis of a Thermal Power Plant

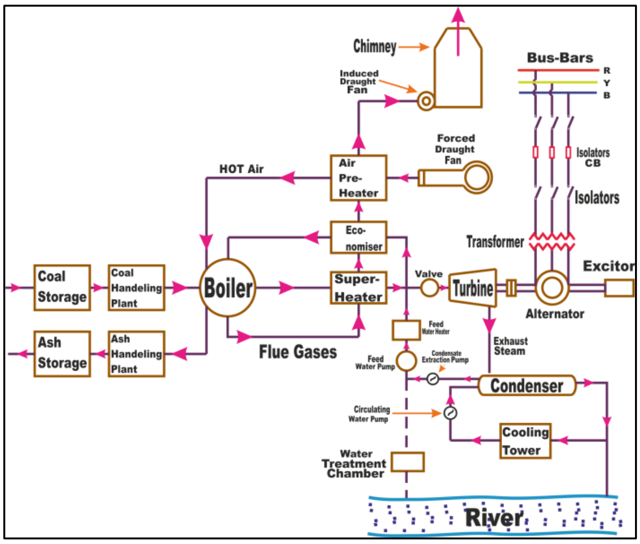
Abhishek Gupta[1] Amay Tiwari[2] Ankit Kr. Chaturvedi[3] Arpit Sachan[4] Prof. Om Prakash Umaro[5]
[1,2,3,4]Student [5]Assistant Professor
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]IMS Engineering College, Ghaziabad, India

Abstract— Increasing demand of power has made keen interest of study to improve the efficiency of power plant. The energy assessment must be made through the energy quantity as well as the quality. But the usual energy analysis evaluates the energy generally on its quantity only. However, the exergy analysis assesses the energy on quantity as well as the quality. The aim of the exergy analysis is to identify the magnitudes and the locations of real energy losses, in order to improve the existing systems, processes or components. This project carried out energy and exergy analyses of a Vijayawada Thermal Power Plant (VTPS) in order to evaluate the energetic and exergetic efficiencies and irreversibilities of units, sections and the overall system. In this study exergy analysis for different components of a 210 MW thermal power plant has been performed and the results show that the exergy destruction is more in the Low Pressure Turbine. Exergetic efficiency is compared with the thermal efficiency. Comparison of energy and exergy loss where the useful energy is loss is identified and improve the efficiency of component by making the necessary arrangements to the system components.

Keywords: Energy Efficiency, Exergetic Efficiency, Exergy Destruction, Energy Loss

I. Introduction

Given high energy cost and necessity to reduce it, as well as environmental issues, optimized use of energy and energy consumption management are very important. In fact, by accurate thermodynamic analysis of thermal systems, we can obtain results for planning and optimizing energy. For this purpose, we need data analysis instrument, which we may find in two laws of thermodynamic. The first law deals with energy analysis, and the second addresses irreversibility and exergy (work potential). The first law points to the fact that total energy in a system is constant and it is only the quality of that energy which is converted to another one, for example, conversion of thermal energy to mechanical energy. An instrument called exergy has been created analysis of energy system based on first and second thermodynamic laws. Exergy of a thermodynamic process shows efficiency or inefficiency of that process. Exergy provides us with a better understanding of processes for qualifying energy. Therefore, it would better to use exergy to locate, qualify and quantify energy destruction. Exergy can play an important role in strategic development of power plants and provision of use instructions in existing power plant. Additionally, to improve available power plants, an image of exergy destruction of power plants' components must be available, which requires exergy analysis of power plants. The energetic and exergetic analysis will provide a complete picture to improve the plant efficiency



Layout of thermal power plant

II. Literature Survey

The following literature review describes important research results regarding the thermal power plant's analysis:

Isam H. Aljundi (2009) – is studied that the energy and exergy analysis of Al-Hussein power plant (396MW) in Jordan is presented. The performance of the plant was estimated by a component wise modeling and a detailed break-up of energy and exergy losses for the considered plant has been presented. It was found that the exergy destruction rate of the boiler is dominant over all other irreversibility in the cycle. It counts alone for 77% of losses in the plant, while the exergy destruction rate of the condenser is only 9%.The real loss is primarily back in the boiler where entropy was produced. Contrary to the first law analysis, this demonstrates that significant improvements exist in the boiler system rather than in the condenser. Exergy analysis provides the tool for a clear distinction between energy losses to the environment and internal irreversibility in the process. Exergy analysis is a methodology for the evaluation of the performance of devices and processes, and involves examining the exergy at different points in a series of energy conversion steps. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e., the greatest margin for improvement) can be identified [1].

Alvaro Restrepo, Raphael Miyake, Fabio Kleveston and Edson Bazzo (2012) – are determined that the results of exergetic and environmental analysis of a typical pulverized coal power plant located in Brazil. The goal was to quantify both the exergy destruction and the environmental impact associated with a thermal power plant. According to the results, it can be noted that the exergetic and environmental models showed a similar behavior. The greater the exergy destruction, the greater the environmental impact from the power plant. The study focused only on the operation period.

The efficiency of the power plant is the main parameter to be considered, since is closely related to the consumption of coal and therefore with the CO2 release. The study considered an extended boundary following the entire coal route and the associated processes. The exergy analysis showed that the highest irreversibility was associated with the power plant. This result was expected due to the high level of entropy generation in the combustion process. A sensitivity analysis was also conducted, showing that an improvement of the power plant efficiency leads to a meaningful improvement of the exergy and environmental performance [2].

Naveen Shrivastava, Seema Sharma and Kavita Chauhan (2012) – are presented that the efficiency assessment and benchmarking of thermal power plants in India. Performance improvement of very small amount can lead to large contribution in financial terms, which can be utilized for capacity addition to reduce demand supply gap. With this view, relative technical efficiency of 60 coal fired thermal power plants (being main source of electricity in India) has been evaluated. In India, total energy shortage and peaking shortage were recorded as 11.2% and 11.85%, respectively in 2008–09 (Central Electricity Authority, 2009a,b,c,d), reflecting non-availability of sufficient supply of electricity. According to National Perspective Plan for R&M, Central Electricity Authority (Central Electricity Authority, 2009c), and some power plants have completed or about to complete their economic life. Replacement of over aged power plants with latest technology power plants is also recommended in order to improve overall efficiency [3].

Mohammad Ameri and Nooshin Enadi (2012) – are presented that complete thermodynamic modeling of one of the gas turbine power plants in Iran based on thermodynamic relations. The exergy analysis results revealed that the combustion chamber (CC) is the most exergy destructive component compared to other cycle components. Also, its exergy efficiency is less than other components, which is due to the high temperature difference between working fluid and burner temperature. Both thermodynamic modeling and exergy analysis of a gas turbine cycle were performed as part of this research study. The results from the exergy analysis show that the combustion chamber is the most significant exergy destructor in the power plant, which is due to the chemical reaction and the large temperature difference between the burners and working fluid [4].

P. Regulagadda, I. Dincer and G.F. Naterer (2010) – are performed that a thermodynamic analysis of a subcritical boiler–turbine generator for a 32 MW coal-fired power plant. Both energy and exergy formulations are developed for the system. A parametric study is conducted for the plant under various operating conditions, including different operating pressures, temperatures and flow rates, in order to determine the parameters that maximize plant performance. The maximum exergy destruction is found to occur in the boiler. As a result, efforts at improving the performance of the power plant should be directed at improving the boiler performance, since this will lead to the largest improvement to the plant's efficiency [5].

Marc A. Rosen, Ibrahim Dincer and Mehmet Kanoglu (2008) – are studied that the use of exergy is described as a measure for identifying and explaining the benefits of sustainable energy and technologies, so the benefits can be clearly understood and appreciated by experts and nonexperts alike, and the utilization of sustainable energy and technologies can be increased. Exergy can be used to assess and improve energy systems, and can help better understand the benefits of utilizing green energy by providing more useful and meaningful information than energy provides. Exergy clearly identifies efficiency improvements and reductions in thermodynamic losses attributable to more sustainable technologies. Exergy clearly identifies efficiency improvements and reductions in thermodynamic losses attributable to green technologies. Exergy can also identify better than energy the environmental benefits and economics of energy technologies. Thus, exergy has an important role to play in increasing utilization of green energy and technologies [6]

III. METHODOLOGY

A. Introduction to Exergy:

Energy the word energy derives from the Greek term "energy" was used by THOMAS YOUNG in 1807. is a point function and a property of the system possibly appears for the first time in the work of A the 4th century. Energy is defined as the In the context of chemistry, energy is an attribute of a substance as a consequence of its atomic, molecular or aggregate structure.

Exergy The German Engineer Rant first used the term "exergy" in 1956. Exergy is a property and is associated with the state of the system and the environment. The maximum amount of maximum work that can be done from the source for a engine. 3.3 Need for Exergy: In the last several decades, exergy analysis has begun to be used for system optimization. By analyzing the exergy destroyed by each component in a process, we can see where we should be focusing our efforts to improve system efficiency. It can also be used to compare components or systems to help make informed design decisions. The Exergy Method is an alternative, relatively new technique based on the concept exergy, loosely defined as a universal measure of the work potential or quality different forms of energy in relation to a given environment. An exergy balance application to a process or a whole plant tells us how much of the usable work potential, or exergy supplied as the input to the system under consideration has been consumed {irretrievably lost} by the process. The loss of exergy, or irreversibility, provides generally applicable quantitative measure of process inefficiency. Analysing multiply components plant indicates the total plant irreversibility distribution among the plant components, pinpointing those contributing most to overall plant in efficiency. Unlike the traditional criteria of performance, the concept of irreversibility is firmly based on the two main laws of thermodynamics. The exergy balance for a control be derived by combining the steady flow energy equation {First law} with the expression for the entropy production rate {second law}. Although the second law is not used explicitly in the Exergy method, its application to process analysis demonstrates the practical implications of the second law. Thus studying different forms of irreversibility and their effect on plant performance, gives a better and more useful understanding of the second law than studying its statements and corollaries Mass, energy, and exergy balances for any control volume at steady state with negligible potential and kinetic Specific exergy.

Nomenclature:

h = enthalpy (kj/kg)
ho = dead state enthalpy (kj/kg)
To = dead state temperature (K)
s = entropy(kj/kgk)
so = dead state entropy(kj/kgk)
Ein = energy input(kj)
Eout = energy output(kj)

for boiler is given by = (h-ho)-To(s-so)........(1)

Where h_o, s_o, To represents the reference state point (standard environment)

Total Exergy is given by Xo = m o [(h-ho)-To(s-so)]..............(2)

the specific physical exergy of the stream was evaluated from the following equation

ei= (hi-ho) - To (si- so) = Δh-ToΔs.........(3)

Exergy Destruction (i) =Exin – Exout- 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)

ic energy changes can be expressed, respectively.

IV. CONCLUSION

Following conclusions can be drawn from this study;

1) The first law analysis shows major energy loss has been found to occur in condenser. The second law (exergy) analysis shows that combustion chamber in both steam and gas turbine thermal power plants are main source of Irreversibility. An exergy method of optimization gives logical solution improving the power production opportunities in thermal power plants.
2) The first law analysis shows major energy loss has been found to occur in condenser. The second law (exergy) analysis shows that combustion chamber in both steam and gas turbine thermal power plants are main source of Irreversibility.
3) The major energy destruction occurs in the heat recovery system which leads to inefficient heat transfer between hot stream (flue gas) and cold stream (water & air). It indicates heat exchanger system need to be carefully inspected.
4) Preheating the reactants is the most common way of reducing the irreversibility of a combustion process. The preheating is usually carried out using product of combustion after they have performed their main heating duty and before they are discharged into atmosphere.
5) The exergy analysis showing that an improvement of the power plant efficiency leads to a meaningful improvement of the overall performance. .
6) In every plant component such as a boiler, combustion chamber there is some intrinsic irreversibility which cannot, owing to the present state of technological development, be eliminated.
7) The maximum exergy destruction is found to occur in the boiler. As a result, efforts at improving the performance of the power plant should be directed at improving the boiler performance, since this will lead to the largest improvement to the plant's efficiency.

V. RESULT AND DISCUSSION

Analysis is done on NTPC Dadri on 1 unit of 210MW.

From the analysis it is found that exergy efficiency is much lower than the energy efficiency based on first law. It is also concluded that the Air preheater Superheater and economizer are main components which contribute to exergy loss. It is depicted from the analysis that nearly 47% exergy loss takes place in combuster that suggest that combuster is not working adiabatically and combustion is not complete. It is due to irreversibility involved in combustion process, therefore combustor design require some modification to improve plant performance. The major energy destruction occurs in heat recovery system which leads to poor heat transfer rate between flue gas and water and air. Exergy destruction in low pressure turbine is more as compared to high pressure and intermediate pressure turbine and require modification in design or proper maintenance.

components	Exergy destruction (MW)	Percent exergy destruction	Percent exergy efficiency
Boiler	120.540	76.75	43.9
Turbine	20.407	12.99	73.4
Condenser	13.738	8.75	26.3
Boiler pumps	.220	.15	82.6
CRT pump	0.331	.20	28.5
HPH1	.438	.26	97.7
HPH2	.359	.24	97.3
Deaerator	.355	.24	95.4
LPH4	.377	.22	89.5
LPH5	.295	.20	67.3
Power cycle	157.059	100.0	24.8

Table1.1: Exergy destruction and exergy efficiency of the power plant components:

At, To =298.15 K, Po = 101

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REFERENCES

[1] Book on "THERMODYNAMICS An engineering approach" 2008 by Yunus A. Cengel & Michael A Boles 6th Edition, McGraw Hill Companies,Inc,New York.
[2] NTPC Dadari, www.ntpc.co.in
[3] P.k Nag (2008) "Power Plant Engineering",by Tata McGraw-Hill Publishing Company Ltd. 7 West Patel Nagar , New Delhi 110008

[4] Isam H. Aljundi, Energy and exergy analysis of a steam power plant in Jordan. Applied Thermal Engineering 29 (2009) 324–328 technologies for the power cycle of a thermal power plant. Energy 36 (2011) 1966–1972
[5] Alvaro Restrepo, Raphael Miyake, Fabio Kleveston and Edson Bazzo. Exergetic and environmental analysis of a pulverized coal power plant. Energy 45 (2012) 195–202
[6] P. Regulagadda, I. Dincer and G.F. Naterer, Exergy analysis of a thermal power plant with measured boiler and turbine losses. Applied Thermal Engineering 30 (2010) 970–976
[7] Marc A. Rosen, Ibrahim Dincer and Mehmet Kanoglu, Role of exergy in increasing efficiency and sustainability and reducing environmental impact. Energy Policy 36 (2008) 128–137 Applied Thermal Engineering 51 (2013) 787–800
[8] Central electricity Authority(CEA) of india.