# A Review of Exergy and Energy Analysis of Coal based Combined Thermal Power Plant

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## *Abstract*

*The energy supply to demand narrowing down day by day around the world, the growing demand of power has made the power plants of scientific interest, but most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only. The real useful energy loss cannot be justified by the fist law of thermodynamics, because it does not differentiate between the quality and quantity of energy. The present study deals with the comparison of energy and exergy analyses of thermal power plants stimulated by coal and gas. This article provides a detailed review of various studies on thermal power plants over the years. This review would also throw light on the scope for further research and recommendations for improvement in the existing thermal power plants.*

*Keyword:- Enegy Analysis, Exergy Analysis, Rankine cycle, co-generation.*

## 1.Introduction

In the current Situation, most of the electricity produced throughout the world is from steam power plants. Therefore, it is very important to ensure that the plants are working with maximum efficiency. Thermodynamic analysis of the thermal power plant has been undertaken to enhance the efficiency and reliability of steam power plants. Most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only. The real useful energy loss cannot be justified by the fist law of thermodynamics, because it does not differentiate between the quality and quantity of energy. The present work deals with the comparison of energy and exergy analysis of thermal power plant stimulated by coal. Generally, it is predicted that even a small improvement in any part of the plant will result in a significant improvement in the plant efficiency. Factors affecting efficiency of the Thermal Power Plant have been identified and analyzed for improved working of thermal power plant. The objective of this work is to use the energy analysis and exergy analysis based on the first law of thermodynamics and second law of thermodynamics respectively. Energy analysis helps designers to find ways to improve the performance of a system in a many way. The energy losses from individual components in the plant are calculated based on these operating conditions to determine the true system losses. In this, first law of thermodynamics analysis was performed to evaluate efficiencies and various energy losses. Exergy analysis has sparked interest within the scientific community to require a more in-depth check up on the energy conversation devices and to develop new techniques to rise utilize the prevailing restricted resources. Exergy analysis gives entropy generation, irreversibility percentage, Exergy loss and second law efficiency. The Exergy loss or irreversibility is maximum at boiler. Thus to know about actual flow of Exergy in the cycle thermodynamic analysis based on second law is desirable. In this paper Exergy analysis of operating condition of boiler has been carried out based on mass and Exergy balance. The present paper investigates the effectiveness of the power plant to offset the increasing demand of power. Energy and Exergy analysis has been carried out to determine the efficiency of each component and the overall efficiency of the plant.

## 2. A brief Review of the work already done in the field

List of SCI Journal where I read and analysis its methodology to help in my work.

| SN | Name of Title | Year | Name of Journal | Name of Author | Work Already Done |
|---|---|---|---|---|---|
| 1 | Optimization of pre combustion capture for thermal power plants using Pinch Analysis | 2016 | Science Direct (elsevier) | Saba Valiani, Nassim Tahouni | Efficiency of the power plant was increased by 8%, and the fuel consumption was decreased by 23%. |
| 2 | Performance degradation diagnosis of thermal power plants: A method based on advanced exergy analysis | 2016 | Science Direct (elsevier) | Peng Fu, Ningling Wang | Most components, the endogenous exergy destruction accounts for about 80–95% of the total exergy destruction. |
| 3 | Power Generation from Condenser Waste Heat in Coal-Fired Thermal Power Plant Using Kalina Cycle | 2016 | Science Direct (elsevier) | Goutam Khankari, Jagannath Munda | Maximum net cycle efficiency can be achieved by 2.58% for the Kalina cycle. |
| 4 | Exergy Analysis of Ultra Super-Critical Power Plant | 2013 | Science Direct (elsevier) | Sandhya Hasti,Adisorn Aroon | This proves to reduce the exergy destruction rate loss in the furnace to percent of 71%. |
| 5 | Thermodynamic analysis of 120 MW thermal power plant with combined effect of constant inlet pressure (124.61 bar) and different inlet temperatures | 2013 | Science Direct (elsevier) | Ankur Geete,A.I. Khandawal | Calculated correction factor and heat rate. |
| 6 | Energy and exergy analyses of thermal power plants: A review | 2011 | Science Direct (elsevier) | S.C. Kaushik, V. Siva Reddy | Plant component such as boiler, combustion chamber. there is optimize the irreversibilities. |
| 7 | An Approach to Analyse Energy and Exergy Analysis of Thermal Power Plants: A Review | 2010 | Scientific Research | Vundela Siva Reddy, Subhash | The first law analysis shows major energy loss has been found to occur in condenser. |
| 8 | Energy, exergy and economic analysis of industrial boilers | 2010 | Science Direct (elsevier) | R. Saidur, J.U. Ahamed | It has been found that heat exchanger and combustor are the main parts that contributed loss of energy. |
| 9 | Exergy analysis of a thermal power plant with measured boiler and turbine losses | 2010 | Science Direct (elsevier) | P.Regulagad, I. Dincer | The maximum exergy destruction is found to occur in the boiler |
| 10 | Energy and Exergy Analysis of a 348.5 MW Steam Power Plant | 2010 | Taylor & Francis Group | D. Mitrovi C, D. Zivkovic | Results show that energy losses have mainly occurred in the condenser where 421 MW is lost to the environment while only 105.78 MW has been lost from the boiler. |
| 11 | Thermodynamic analysis of a FBCC steam power plant | 2009 | Science Direct (elsevier) | Nurdil Eskin, Afsin | The increase of the excess air causes a decrease of the overall energy efficie in plant. |
| 12 | Energy and exergy analysis of a steam power plant in Jordan | 2009 | Science Direct (elsevier) | Isam H. Aljundi | The calculated exergy efficiency of the power cycle was 25%, which is low compared to modern power plants |
| 13 | Effects of operational parameters on the thermodynamic performance of FBCC steam power plant | 2009 | Science Direct (elsevier) | Nurdil Eskin, Afsin Gungor | The second law analysis reveals that the FBCC has the largest irreversibility of the total system exergy loss. |
| 14 | Understanding energy and | 2007 | Science | Mehmet | An understanding of energy and |

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| | exergy efficiencies for improved energy management in power plants | | Direct (elsevier) | Kanoglu, Ibrahim Dincer | exergy efficiencies is analyzing, optimizing and improving energy systems through appropriate energy policies and strategies. |
| 15 | Effect of altering combustion air flow on a steam power plant: Energy and exergy analysis. | 2007 | Wiley inter Science | Marc A. Rosen, Raymond Tang | An efficiency increase of about 5% can be significant, if it can be achieved economically. The results could lead to improved designs of steam power plants. |
| 16 | Exergy analysis on combustion and energy conversion processes. | 2005 | Science Direct (elsevier) | Hiroshi Taniguchi, Kunihiko Mouri | The exergy value is shown to have the fundamental equations of thermal energy, heat transfer, throttling and combustion. |
| 17 | Energy, exergy, and Second Law performance criteria. | 2005 | Science Direct (elsevier) | Noam Lior, Na Zhang | some of the magnitude differences of exergy and Second Law efficiencies and the errors that can be made if the equations and systems are not defined carefully. |
| 18 | Exergetic and thermoeconomic analyses of power plants | 2003 | Science Direct (elsevier) | H.Y. Kwak, D.J. Kim | The computer program that was developed which shows that the exergy and the thermoeconomic analysis presented here. |
| 19 | Combined cycle plant efficiency increase based on the optimization of the heat recovery steam generator operating parameters | 2002 | Science Direct (elsevier) | Alessandro Franco, Alessandro Russo | This method it seems possible to reach overall combined cycle efficiencies near to 60% on existing plants, just by optimizing the heat recover and the steam cycle. |

National Journal where I read and analysis its methodology to help in my work.

| SN | Name Of Title | Year | Name Of Journal | Name Of Author | Work Already Done |
|---|---|---|---|---|---|
| 20 | Energy & Exergy Analysis of Thermal Power Plant at Design and Off Design Load. | 2016 | IARJSET | Rakesh Dang, S.K. Mangal | The boiler has the highest amount of exergy destruction, so the great attention should be paid towards boiler in terms of design or technical change. |
| 21 | Thermoexergetic analysis of Steam Power Plant. | 2016 | IJES | Rajat Pardal, B. B. Arora | In order to achieve significant improvement of energy efficiency the boiler and turbine systems need to be redesigned. |
| 22 | Energy and Exergy Analysis of Coal Fired Power Plant | 2016 | IJIRTS | H Ravi Kulkarni, Prof P.P.Revankar | From ultimate analysis of boiler we can see that complete combustion taking place but due to upward pressure of air, fuel contains fines which flue gas. |
| 23 | Thermal Performance of Reheat, Regenerative, Inter Cooled Gas Turbine Cycle | 2015 | IJRMET | Milind S Patil, Datta B.Pawase | About 50% increase in thermal efficiency is observed at a pressure ratio of 4 when t decrease from 0.33 to 0.23. |
| 24 | Analysis of Efficiency At a Thermal Power Plant | 2015 | IRJET | Anjali T H, Dr. G Kalivarathan | The efficiency of components in the power plant is found out by using energy and exergy calculation. We can see that the efficiency loss in boiler and turbine is more. |
| 25 | Exergy Analysis Of Thermal | 2014 | IJESR | Yamini | The use of feed water heater reduces |

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|---|---|---|---|---|---|
| | Power Plant | | | Verma, Kalpit P. Kaurase | the amount of heat required to generate the superheated steam in the boiler. |
| 26 | Second Law Analysis Of Gas Based Thermal Power Plant To Improve Its Performance. | 2014 | IJSRM | M.K.Pal, H.Chandr, A.Arora | The analysis made in this paper gives the idea of impact of the inlet temperature of the turbine on the exegetic competence. |
| 27 | Review on Waste Energy Recovery Systems | 2014 | IJIRSET | M. Dubey, A. Arora, H. Chandra | The use of Rankine cycles with low-grade thermal sources offers significant potential for energy productivity. |
| 28 | Exergy Analysis For 120 MW Thermal Power Plant With Different Inlet Temperature Conditions | 2014 | IJRET | Ankur Geete ,A. I. Khandwaw ala | Different seven case studies have been done on 120MW thermal power plant to analyze exergy outlet from different components. |
| 29 | Exergy Analysis of A Combined Gas/ Steam Turbine Cycle with A Supercharged Boiler | 2013 | AJER | Sayed A.Abdel-Moneim | Exergy destruction ratio, ranges from 31% to 43%, was found for SBCC, while values from 43% to 52% were obtained for the conventional combined cycle. |
| 30 | Energy and Exergy Analysis of Extraction cum Back Pressure Steam Turbine | 2013 | IJMER | A.H.Rana, J.R.Mehta | Turbine exergy efficiency is lower than its energy efficiency as utilization of heat is at lower temperature than inlet. |
| 31 | Energy And Exergy Analysis Of A Geothermal Power Station With Two-Phase Closed Thermosyphon System In An Organic Rankine Cycle | 2013 | IJAET | Milad Khorami, Bahram Mehrasa | In this paper, an enhanced Fortran code was combined with the EES software to develop thermodynamic model and exergy analysis |
| 32 | Performance and Exergy Analysis of the Boiler | 2013 | IJSR | Krishan Kumar, Dharmendr a Patel, | In the present work a exergy analysis of operating condition of boiler has been carried out based on mass and exergy balance. |
| 33 | Energy Analysis of Thermal Power Plant | 2012 | IJSER | Raviprakas h kurkiya, Sharad chaudhary | Energy analysis of a thermal power plant is reported in this paper. It provides the basis to understand the performance of a fluidized bed coal fired boiler, turbine and condenser. |
| 34 | Thermodynamic Analysis of Power Generating Units Based On First and Second Law: A Review | 2012 | IJEIT | M.K.Pal, Anil Kumar | The worldwide concern about cost, environment and quick availability to meet continuous load growth will continue to enhance the adoption of gas and steam turbine engines in power systems. |
| 35 | Exergy analysis for combined regenerative Brayton and inverse Brayton cycles | 2012 | IJEE | Zelong Zhang, Lingen Chen | The effects of the effectiveness of the regenerator and other parameters on the exergy performances of the combined cycle are analyzed, and the exergy performances are optimized. |

## 3. Methodology:-

Methodology Case study on thermal power plant, major components of power plant of are listed, points are selected carefully such that it measure the temperature, mass flow rate, pressure is noted down at each inlet and outlet of components of the system. At full load condition parameter reading is noted down. For these points enthalpy and entropy value is noted from the steam table. Individual energy and exergy analysis is calculated for each components of the system. The Exergy destruction at each point is calculated and the loss is determined with location and magnitude. The energy and exergy efficiency is also calculated and to identify the loss occurring in power plant component.

## 4. Thermodynamic Analysis

Engineers and scientists have been traditionally applying the First law of thermodynamics to calculate the enthalpy balances for more than a century to quantify the loss of efficiency in a process due to the loss of energy. The exergy concept has gained considerable interest in the thermodynamic analysis of thermal processes and plant systems since it has been observed that the First law analysis has been insufficient from an energy performance standpoint. Energy analysis is based on the first law of thermodynamics, which is related to the conservation of energy. Second law analysis is a method that uses the conservation of mass and conservation of energy principles together with the entropy for the analysis, design and improvement of energy systems. Second law analysis is a useful method to complement, but not to replace energy analysis.

In an open flow system, there are three types of energy transfer across the control surface, namely working transfer, heat transfer and energy associated with mass transfer or flow. The temperature from the heat source and the work developed by the system are used for the analysis of open flow systems and to analyze plant performance whilst kinetic and potential energy changes are ignored. The energy or first law efficiency of a system is defined as the ratio of energy output to the energy input to the system.

## 5. Energy analysis

Exergy is the maximum theoretical useful work attainable from an energy carrier under the conditions imposed by an environment at given pressure Po and temperature to, and with given amounts of chemical elements. The purpose of an EA is generally to identify the location, source, and magnitude of true thermodynamic inefficiencies in process plants such as power plants (Chao and Yan, 2006). Disregarding kinetic and potential energy changes, the specific flow Exergy of a fluid at any cycle state is given by

$$e = (h - h_0) - T_0( s - s_0) \tag{1}$$

The reversible work as a fluid goes from an inlet state to an exit state is given by the Exergy change between these two states, as follows (Kotas, 1995; Kwak, 2003):

$$e_{OUT} = e_{IN} - (h_{OUT} - h_{IN}) - T0(s_{OUT} - s_{IN}) \tag{2}$$

The SPP consists of two major components: one is the heat transfer system and the other is the turbine system. The chemical energy in the fuel provides the total Exergy for the plant, which is the original exergy source (Rosen and Dincer, 2003). Part of the exergy from the fuel is lost in the heat transfer system, including the boiler, the bleeds heat exchangers, the economizer and the condenser. The rest of the exergy goes into the turbine system as the exergy input for generating power. Some of the exergy input is lost in running the turbines and pumps. The amounts of these losses are defined by their machine efficiency. Also, a certain amount of the exergy is lost with the exhausted gas. The remaining exergy gives the shaft work, which is received by the electrical generators, which become the final exergy sink (Sanjay et al., 2007). the exergy loss and exergy efficiency for each of the Rankine cycle components can be calculated as follows:

### 5.1 Boiler

The Exergy loss in the boiler can be calculated as follows (Kotas,1995)

$$El_{boiler} = E_{in} - E_{out} = \sum(me)_{IN} - \sum (me)_{OUT} \tag{3}$$

$E_{IN}$ is the sum of the fuel Exergy and air Exergy that is input to the boiler. $E_{OUT}$ is Exergy of the combustion that produces in the boiler.

### 5.2 Steam turbine

The Exergy loss in the steam turbine is defined as follows (Sanjay et al., 2007)

$$El_{\ TURBINE} = \sum(me)_{IN} - \sum(me)_{OUT} - W_{OUT} \tag{4}$$

Where, $W_{OUT}$ is the actual produced shaft work.The maximum shaft work of the steam turbine is equal to the difference of the input and output steam enthalpies. Accordingly, the exergetic efficiency of the turbine is defined as the ratio of the

$$€ = \frac{W\ out}{\sum(me)in - \sum(me)out}$$

### 5.3 Heat exchangers

Feed-Water Heaters (FWHs) and condensers are essentially heat exchangers designed to perform different tasks. An Exergy balance written on the heat exchanger should express the Exergy destroyed in the system as the difference of Exergies of incoming and outgoing streams, as follows (Chao, 2006

$$el_{FWH} = E_{in} - E_{out} = \sum(me)\text{in}-\sum(me)\text{out} \quad (6)$$

The exergetic efficiency of a heat exchanger (HEX) is defined as the ratio of the increase in the exergy of the cold fluid to the decrease in the exergy of the hot fluid.

$$€ = \frac{\sum[me\ out - me\ in]cold\ stream}{\sum[me\ in - me\ out]hot\ stream}$$
(7)

### 5.4 Pump

The Exergy loss in the pump can be expressed as follows (Chao, 2006)

$$el_{pump} = \sum(me)\text{in}- \sum(me)\text{out} + W_{in} \quad (8)$$

*W*in is the actual power consumed in the pump, as shown in Figure 1. The Exergetic efficiency of the pump can be defined as the ratio of the minimum work input to the actual work input, using the following equation:

$$€ = \frac{\sum(\text{me})\text{out} - \sum(\text{me})\text{in}}{\text{Win}} \quad (9)$$

### 5.5 Rankine cycle

The total exergy loss in the Rankine cycle is simply the sum of exergy losses in the boiler, steam turbines, heat exchangers, and pump. The overall exergetic efficiency of the cycle can be calculated as follows (Kwak, 2003)

$$€\text{cycle} = \frac{Wnet}{Efuel} \quad (10)$$

Where *W net* is Net workdone.

$$W_{NET} = W_{OUT} - W_{IN} \quad (11)$$

### 5.6 Pinch analysis (PA)

PA has become a general methodology for the targeting and design of thermal and chemical processes, and associated utilities. When considering the energy efficiency of a process, pinch-based approaches target the identification of the possible energy recovery by heat exchange, and define the Minimum Energy Requirement (MER) of the process. The energy targeting in PA set by the CC and GCC are only in terms of heat loads. However, to deal with systems involving heat and power, the concepts of both the CC and the GCC should be extended.

### 5.7 Combined pinch and exergy analysis (CPEA)

By allowing the comparison of the quality of the different forms of energy, exergy is a rigorous way of analyzing energy conversion systems such as SPPs. In the context of process integration analysis, the exergy concept is combined with pinch analysis for reducing the fuel requirement and optimizing the Rankine cycle in SPPs. The Exergy Composite Curve (ECC) and Exergy Grand Composite Curve (EGCC) concepts have been introduced by Feng and Zhu (1997) for this purpose. For each linear segment in the CC, the heat Exergy delivered (e) by a stream delivering a heat load (Q) from the inlet temperature (Tin) to the outlet temperature (Tout) is computed by Equation 12 (Feng and Zhu, 1997):

$$e = Q(1 - \frac{T0}{Tlm}) \quad (12)$$

Where, Tlm is the logarithmic mean of temperatures computed by Equation 13 (Polley et al., 1990):

$$Tlm = \frac{TIN - TOUT}{IN(\frac{TIN}{TOUT})} \quad (13)$$

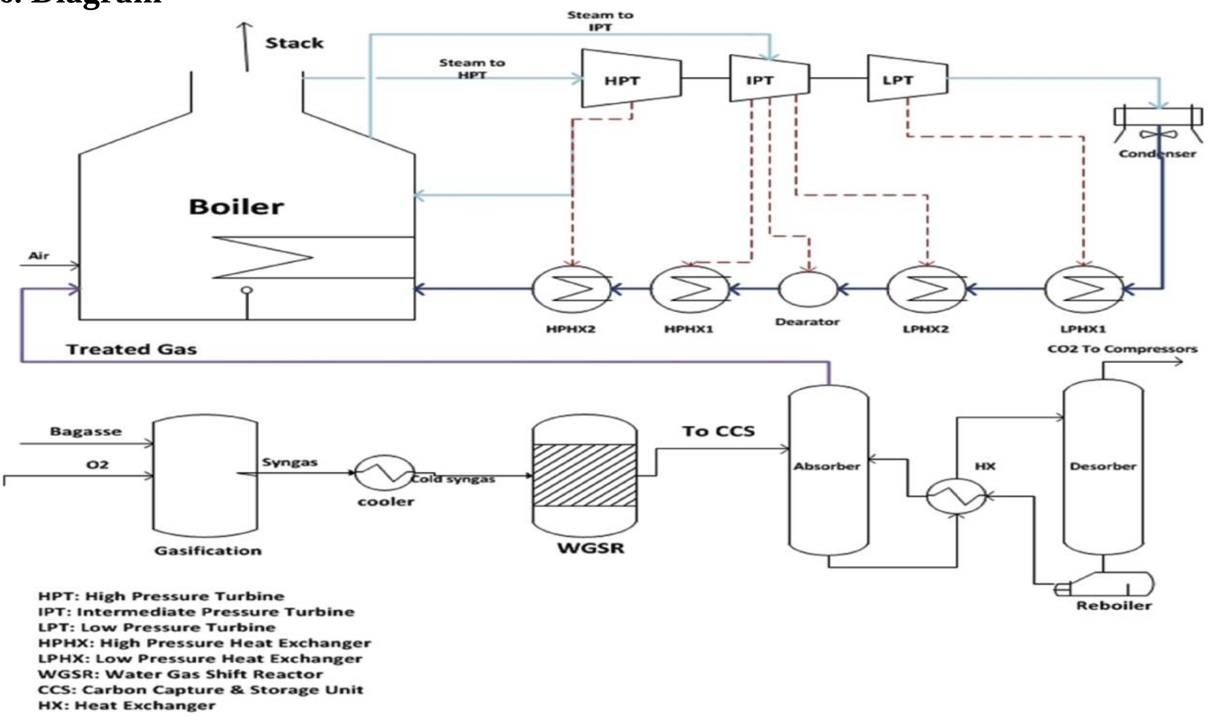
When considering the hot CC, the heat delivered is represented by the T-H diagram; the exergy delivered is computed by replacing the temperature axis by the Carnot factor, as expressed in Equation 14. It then corresponds to the area between the CC and the enthalpy axis (Feng and Zhu, 1997). The same procedure is followed for the cold streams, to define the Exergy required by the cold streams (Kotas, 1995).

$$\eta = 1- \frac{TO}{T} \quad (14)$$

Figure 3 shows how the CC (T-H diagram) for a heat transfer system can be converted into the ECC and the EGCC. The shaded areas in Figure 3 indicate the Exergy loss associated with the heat transfer process. The graphical representation of process units involving energy in terms of heat and power has been made possible with the introduction of a variable referred to as energy level (Ω) defined as follows (Feng and Zhu, 1997):

$$\Omega = \frac{EXERGY}{ENERGY} \quad (15)$$

## 6. Diagram




Dia 1: Different component of Boiler

## 7. Exergy Analysis:-

The Thermodynamic analysis of any power plant considers the balance of mass, energy, entropy and exergy [4]. It is important to determine the amount of work potential that can be attained from the system. The work potential derived from the system is often referred to as useful work "Exergy".

Table1. Exergy destruction rate and exergy efficiency formula used for Exergy analysis

| S.N | Components | Exergy destruction (MW) | Exergetic efficiency (%) |
|---|---|---|---|
| 1 | Boiler System | E Feed - E Product + H heat in | E Product - E Feed / H heat in |
| 2 | Turbine | E Feed - E Product - W workout | E Product- E Feed / W workout |
| 3 | Condenser | E Feed - E Product - H heat out | E Product- E Feed / H heat out |
| 4 | Pump | E Feed - E Product + W workout | E Product- E Feed / W workout |
| 5 | Furnace | E Fuel in + E Feed - E Product | E Product - E Feed / E Fuel in |
| 6 | Heaters | E Feed - E Product | E Product / E Feed |
| 7 | Steam Cycle | Sum of all components | W Net out / E Fuel in |

Table 2. Power plant model validation case analysis

| S.N | Description | Aljundi, 2009[12] | SandhyaHasti 2013[4] | This Study |
|---|---|---|---|---|
| 1 | Net power output MW | 56 | 54.4 | |
| 2 | Thermal efficiency % | 26 | 24.4 | |
| 3 | Net efficiency % | - | 35.96 | |
| 4 | Fuel consumption rate Kg/s | 5.6 | 5.24 | |
| 5 | Flue gas temperature C | 1700 | 1710 | |

In Table 1, it is seen that the percentage of excess air used in the data [13] is in the range of 18%. If the percentage of moisture content is high, the net efficiency is low. The reason is that the presence of the moisture will reduce the amount of energy released during coal combustion. As a result of this, there is a reduction in the temperature of the combustion products. Increasing the temperature of the air used in the air pre-heater can increase the net efficiency of the power plant. This external air supplied will raise the temperature of the coal combustion; As a result, the net efficiency of the system increases. The main steam temperature was maintained in the range between 600 to 650 $^0$C for the plant operating in the Ultra super critical condition. An increase in the main steam temperature will increase the enthalpy of the steam used inside the steam cycle. This will result in the additional work done which enhances the net efficiency of the power plant.

Table 3. Exergy model validation case analysis [46].

| S.N | Components | Exergy destruction (MW) Reference | Exergy destruction (MW) This model | Exergy efficiency Refer. | Exergy effici. This model |
|---|---|---|---|---|---|
| 1 | Boiler | 120 | 115 | 43.8 % | 46 % |
| 2 | HPT | 32 | 29 | 73.5 % | 77 % |
| 3 | IPT | 13.5 | 12 | 63 % | 61 % |
| 4 | LPT | 15.6 | 13.5 | 86 % | 87 % |
| 5 | Condenser | 13.7 | 11.3 | 26.5 % | 29 % |
| 6 | LPHX1 | 11.21 | 10.1 | 45 % | 49 % |
| 7 | LPHX2 | 12.15 | 10.9 | 54 % | 57 % |
| 8 | Dearator | 9.35 | 8.2 | 90.4 % | 96 % |
| 9 | HPHX1 | 8.35 | 7.3 | 85.3 % | 81 % |
| 10 | HPHX2 | 7.41 | 6.76 | 80.3 % | 75 % |

After validation, the developed model was used for simulating the performance of an ultra supercritical plant under conditions listed in Table 1. The simulation results can be found in Table 3. The distribution of exergy destruction across the power plant was plotted in. Apparently, furnace is the major source of exergy losses followed by the turbines.

**6. Conclusion:-**

Energy analysis of a thermal power plant is reported in this paper. It provides the basis to understand the performance of fluidized bed coal fired boiler, feed pump, turbine and condenser. The

energy balance sheet shows that theoretical losses in various component of boiler. It provides information for selection of the components which has maximum losses so, that optimization techniques could be used to make it more efficient. The various energy losses of plant, through different components are calculated which indicates that maximum energy losses occur in turbine.
Following conclusions can be drawn from this study:
1. The coal type affects the first law efficiency of the system considerably.
2. It has been also analyzed that a part of energy loss occurs through flue gases.
3. The presence of moisture has an effect on overall efficiency.
4. If we use the heat recovery system to recover the heat losses through flue gases then it will be more useful for us.

The efficiency of components in the power plant is found out by using energy and exergy calculation. From the above table we can see that the efficiency loss in boiler and turbine is more. Hence, we should improve the efficiency of boiler and turbine by proper maintenance. There are many factors, which influence the efficiency of the thermal power plant. The fuel used for combustion, type of boiler, varying load, power plant age, they lose the efficiency. Most of the loss in efficiency due to mechanical wear on variety of components, resulting heat losses. Therefore, it is necessary to check all the equipments periodically. Moreover, it is noticed that the overall efficiency of any thermal power plant depends upon the technical difficulties under unpredictable conditions. So that efficiency of the thermal power plant is increased by 3 to 5 %.

## References

[1] Saba Valiani , Nassim Tahouni, “Optimization of pre-combustion capture for thermal power plants using Pinch Analysis”, Science Direct (elsevier),(2016) ,pp.1-11.
[2] Peng Fu, Ningling Wang, “Performance degradation diagnosis of thermal power plants: A method based on advanced exergy analysis”, Science Direct (elsevier),(2016), pp.219-229.
[3] Goutam Khankari, Jagannath Munda,”Power Generation from Condenser Waste Heat in Coal-Fired Thermal Power Plant Using Kalina Cycle”, Science Direct (elsevier),(2016), pp. 613-624.
[4] Sandhya Hasti,Adisorn Aroonwilas,”Exergy Analysis of Ultra Super-Critical Power Plant”, Science Direct (elsevier),(2013), pp.-2544-2551.
[5] Ankur Geete, A.I. Khandwawala, “Thermodynamic analysis of 120 MW thermal power plant with combined effect of constant inlet pressure (124.61 bar) and different inlet temperatures”,Science Direct (elsevier), (2013), pp.-17-25.
[6] S.C. Kaushik, V. Siva Reddy,”Energy and exergy analyses of thermal power plants: A review”, Science Direct (elsevier),(2011), pp.-1857-1872.
[7] Vundela Siva Reddy, Subhash Chandra Kaushik,”An Approach to Analyse Energy and Exergy Analysis of Thermal Power Plants: A Review”, Scientific Research, (2010), pp.143-152.
[8] R. Saidur , J.U. AhamedEnergy, exergy and economic analysis of industrial boilers, Science Direct (elsevier) ,(2010), pp.2188-2197.
[9] P. Regulagadda, I. Dincer ,“Exergy analysis of a thermal power plant with measured boiler and turbine losses”, Science Direct (elsevier),(2010),pp.970-976.
[10] D. Mitrovi C,D. Zivkovic,”Energy and Exergy Analysis of a 348.5 MW Steam Power Plant”, Taylor & Francis Group ,(2010), pp.1016-1027.
[11] Nurdil Eskin , Afsin Gungor,”Thermodynamic analysis of a FBCC steam power plant”,Science Direct (elsevier),(2009), pp.2428-2438.
[12] Isam H. Aljundi,”Energy and exergy analysis of a steam power plant in Jordan”, Science Direct (elsevier) ,(2009), pp.324-328.
[13] Nurdil Eskin, Afsin Gungor,”Effects of operational parameters on the thermodynamic performance of FBCC steam power plant”, Science Direct (elsevier),(2009), pp.54-66.
[14] Mehmet Kanoglu, Ibrahim Dincer, “Understanding energy and exergy efficiencies for improved energy management in power plants”, Science Direct (elsevier), (2009), pp.3967-3978.

[15] Marc A. Rosen, Raymond Tang,”Effect of altering combustion air flow on a steam power plant: Energy and exergy analysis”, Wiley interScience,(2007), pp.219-231.
[16] Hiroshi Taniguchi, Kunihiko ,”Exergy analysis on combustion and energy conversion Processes”, Science Direct (elsevier),(2005),pp.111-117.
[17] Noam Lior, Na Zhang,”Energy, exergy, and Second Law performance criteria”, Science Direct (elsevier),(2005), pp.281-296.
[18] H.Y. Kwak, D.J. Kim,”Exergetic and thermoeconomic analyses of power plants”, Science Direct (elsevier), ,(2003), pp.343-360.
[19] Alessandro Franco, Alessandro Russo,”Combined cycle plant efficiency increase based on the optimization of the heat recovery steam generator operating parameters”, Science Direct (elsevier),(2002), pp.843-859.
[20] Rakesh Dang, S.K. Mangal,”Energy & Exergy Analysis of Thermal Power Plant at Design and Off Design Load”, IARJSET, ,(2016), pp.29-36.
[21] Rajat Pardal, B. B. Arora,”Thermoexergetic analysis of Steam Power Plant”, IJES,(2016), pp. 11-19.
[22] H Ravi Kulkarni,Prof P.P.Revankar,”Energy and Exergy Analysis of Coal Fired Power Plant”, IJIRTS ,(2017), pp.53-57.

[23 Milind S Patil, Datta B.Pawase,"Thermal Performance of Reheat, Regenerative, Inter Cooled Gas Turbine Cycle", IJRMET,(2015), pp.28-33.
[24] Anjali T H, Dr. G Kalivarathan, "Analysis Of Efficiency At A Thermal Power Plant", Irjet, (2015) pp.1112-1119
[25] Yamini Verma, Kalpit P. Kaurase,"Exergy Analysis Of Thermal Power Plant", IJESR,(2014), pp.940-945.
[26] M.K.Pal, H.Chandra, A.Arora,"Second Law Analysis Of Gas Based Thermal Power Plant To Improve Its Performance", IJSRM ,(2014), pp.688-692.
[27] M. Dubey , A. Arora , H. Chandra,"Review on Waste Energy Recovery Systems", IJIRSET ,(2014), pp.18335-18367.
[28] Ankur Geete & A. I. Khandwawala,"Exergy Analysis For 120mw Thermal Power Plant With Different Inlet Temperature Conditions", IJRET ,(2014),pp.21-30.
[29] Sayed A.Abdel-Moneim,"Exergy Analysis of A Combined Gas/ Steam Turbine Cycle with A Supercharged Boiler", AJER,(2013), pp.321-333.
[30] A.H.Rana, J.R.Mehta,"Energy and Exergy Analysis of Extraction cum Back Pressure Steam Turbine", IJMER ,(2013), pp.626-632.
[31] Milad Khorami,Bahram Mehrasa,"Energy And Exergy Analysis Of A Geothermal Power Station With Two-Phase Closed Thermosyphon System In An Organic Rankine Cycle", IJAET ,(2013), pp.52-62.
[32] Krishan Kumar, Dharmendra Patel,"Performance and Exergy Analysis of the Boiler", IJSR, (2013), pp.3011-3015.
[33] Raviprakash kurkiya, Sharad chaudhary," Energy Analysis of Thermal Power Plant", IJSER, (2013), pp.1-7.
[34] M.K.Pal, Anil Kumar,"Thermodynamic Analysis of Power Generating Units Based On First and Second Law: A Review", IJEIT,(2012), pp.349-356.
[35] Zelong Zhang, Lingen Chen,"Exergy analysis for combined regenerative Brayton and inverse Brayton cycles", IJEE,,(2012), pp.715-730.
[36] Satish Raghuvanshi, Govind Maheshwari,"Analysis of Ammonia –Water (NH3-H2O) Vapor Absorption Refrigeration System based on First Law of Thermodynamics", IJSER ,(2011), pp.1-7.
[37] Mohammad Ameri, Saman Amanpour,"Energy and exergy analysis and optimization of a double flash power plant for Meshkin Shahr region", World Renewable Energy Congress, Sweden,,(2011), pp.1297-1304.
[38] Abtin Ataei, ChangKyoo Yoo,"Combined pinch and exergy analysis for energy efficiency optimization in a steam power plant", IJPS, ,(2010), pp.1110-1123.
[39] T.Ganapathy,R.P Gakkhar,"Energy And Exergy Analysis Of Operating Thermal Power Plant At 50 MW Grid Load", I-MANAGER JFET, ,(2009), pp.34-40.
[40] Mohammad Ameri, Pouria Ahmadi,"Energy, exergy and exergoeconomic analysis of a steam power plant:A case study", IJER, ,(2009), pp.499-512.
[41] T. Ganapathy, N. Alagumurthi,"Exergy Analysis of Operating Lignite Fired Thermal Power Plant", JESTR, ,(2009), pp.123-130.
[42] R K Kapooria, S Kumar,"An analysis of a thermal power plant working on a Rankine cycle: A theoretical investigation", Journal Of Energy In Southern Africa, (2008), pp.77-83.
[43] M. Ameri, P. Ahmadi,"Exergy analysis of a 420MW combined cycle power plant", Wiley Interscience,(2007), pp.175-183.