IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 46-51

A Study on Plant Exergy Analysis

Mahalingesh Bagali[1], Dr. V. Mariappan[2], Devendra Gowda[3]
[1]Assistant Professor,Mechanical Engineering Department, Agnel Institute of Technology and Design Assagao, Bardez-Goa, [2]Professor,& Principal, Agnel Institute of Technology and Design Assagao, Bardez-Goa, [3]Assistant Professor EEE Department, SanjayGhodawatUniversity, Kolhapur

Abstract: *In today's modern world, energy is one of the most essential requirements for the existence of human society.The energy demand especially in form of high-grade electricity and low-grade fossil fuels like petrol, diesel, gas and coal has been increasing exponentially day by day. So, there is an crucialrequirement to discover for solutions related to energy generation based on fossil fuels. This paper based on the application of 2nd law of thermodynamics for energy efficient design and operation of the conventional coal fired power generating station.The energy calculationnecessity be made over the energy quantity as well as the quality. But the usual energy studyassesses the energy generally on its quantity solitary. However, the exergy analysis measures the energy on quantity as well as the quality. The primary aims of in this paperis to analyze the system machineries separately to recognize and calculate the locations having major exergy losses. In addition, the effect of changing the reference atmosphere state on this study will also be presented.*
Keywords: *Thermal Power Plant, Exergy, Second law efficiency*

I. Introduction

Indian Energy Scenario: The worldwide economic development has enhanced energy demand consequently pressurizing conventional energy sources that have become not able to encounter the world energy demand. The developing countries owing to population imbalances substantial sectors do not have a continuous availability of electricity able it to grid presence at the location apart from remote locations where economics does not permit grid extension. India had an connected capacity of 233.91 GW of networkenergy amounting to 967 TWh energy generations (May 2014 data) excluding the 39.375 GW Captive power. The total energy generated in country has been accounted at 1102.9 TWh from all sources. [1] As per January 2012 data per principal energy consumption in India was reported to be 778 kWh owing to network technical losses of 23.65% as compared to world average of less than 15% (2013 data).

The electric energyperformances as solitary of the mainagents in the overall development of the nation through its support to basic necessities of lighting, water pumping, and comfortable living conditions, essential health care, educational aids, communication and transport. It also fuels creativeactionsalong withcultivation, business, industry manufacturing, and mining. In a emergingnation like India globalization and urbanization have enhanced the existing standards of the public, lead to surge in domestic power demand. At current the gap in between source and demand is about 10.5 percent. Most of the energy is supplied from thermal power plant andhydroelectric power plants. [2]

II. Thermodynamic Concepts Of Energy And Exergy

The idea of energy is so used to us today that it is naturally obvious, yet we are facing difficulty in describing it precisely. Energy is a scalar quantity that cannot be taken directly but can be documented and estimated by secondary measurements. The total value of energy of system is tough to measure, whereas its energy change is slightly easy to estimate.. The sun is the most important source of the earth's energy. It emits a spectrum of energy that travels across space as electromagnetic radiation.

Energy is also associated with the structure of matter and can be released by chemical and atomic reactions. Throughout history, the emergence of civilization has been characterized by the discovery and effective application of energy to society's needs.

However, the exergy analysis assesses the energy on quantity as well as the quality. The main 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.

III. Energy And Exergy Analysis

Umit Unver et al., (2007), analyzed thermo economics of combined cycle power plants considering the effects of atmosphere temperatureand load variations based on second law of thermodynamics. The effects of load and ambient temperature influenced generated energy costs that were 29 to 32$ per MWh without considerations on load effect. The cost of irreversibility accounted for 40–45% of power cost while cost segment in reversible power amounted to 55–60% of the total cost. [1] Souman Rudra et al., (2008) reported exergetic analysis of coal fired subcritical, supercritical and ultra-supercritical steam power plants through simulation based on mathematical models. The exergy loss of steam generator reduced to 12% from 18% as the steam parameters were increased from sub-critical to supercritical. Decreasing the condenser pressure by 100 mbar l increased power output by 2.5%. [2]

Al-Ghandoor A. et al., (2009), performed the assessment of energy and exergy efficiencies of power generation sub-sector in Jordan that mainly constituted of steam-based power plants, combined cycle plants and gas turbine plants.T. Ganapathy et al.,(2009) carried out work on exergy analysis of Lignite fired Thermal Power Plant with the aim to identify real energy losses and to improve existing systems, processes or components using mass, energy and exergy balance equations. The first law efficiency of the plant was 27% and hence the Exergy analysis located the system or component where in the necessary attention could to be paid to improve the plant performance. [3]

Vundela Siva Reddy et al., (2010) performed exergy analysis of thermal power plants based upon the Rankine cycle and Brayton cycle for comparison between coal fired and gas fired thermal power plants the first law analysis showed major energy loss to occur in condenser while the second law (Exergy) analysis showed that combustion chamber in both steam and gas turbine thermal power plants are main source of irreversibility. The Irreversibility in condenser is insignificant, because in the condenser the low-quality energy is lost. [5]

The plant exergy efficiencies improved by 0.37% for decrease of excess air from 0.4 to 0.15 and 2.3% for stack-gas temperature decrease from 137oC to 90oC. The improvement for measures applied simultaneously was less than sum of improvement predicted when separately applied. [8]Padma Dhar Garg et al., (2013) investigated exergy and efficiency of combined cycle Power Plant accounting for operating conditions on combined efficiency, cogeneration efficiency and power output and exergy destruction were investigated.At 1400°C turbine inlet temperature and 10pressure ratio, 35% exergy losses occurred in gas turbine combustion chamber, while losses in other plant components were between 7% and 21%. [10]

Sarang j gulhane et al., (2013) studied exergy analysis of boiler in cogeneration thermal power plant based on second law of thermodynamics.The study found that heat loss reducing measures like boiler insulation did not prevent exergy destruction that amounted to 83.35% and 76.33% respectively at the load of 1.1 MW and 5.6 MW [14]The energy and exergy efficiencies of boiler were found to be 84.39 % and 42.09 % respectively with Combustor being the major contributor for exergy destruction in boiler. [16]

IV. Exergy Analysis

Exergy input to the boiler= $m_1 \times [1-\frac{T_o}{THR}] \times q_{in}$ -------(1)

Exergy added to the working fluid= $m_1 \times \{[h1-h23]-T_o \times [S1-S23]\}$ ---------(1.1)

$\dot{I}_{Boiler} = \dot{X}_{in} - \dot{X}_{working\ fluid}$ --------(2)

$\eta_{II\ Boiler} = 1-\frac{\text{Exergy destroyed}}{\text{Exergy Supplied}}$ ---------(3)

The exergy balance for the high-pressure turbine is given by

$W_{HP\ Turbine} = m_1 \times [h_1-h_2] + [m_1-m_2] \times [h2-h4]$ ---------(4)

$\dot{I}_{HP\ Turbine} = \dot{X}_{in} - \dot{X}_{out} - W\ HP\ Turbine$ -------(5)

$\eta_{II\ HP\ Turbine} = 1-[\frac{\dot{I}_{HP\ Turbine}}{\dot{X}_{in} - \dot{X}_{out}}]$ -------(6)

The exergy balance for LP turbine is given by

$W_{LPT} = (m_5-m_6-m_8) \times (h_{31}-h_{10}) + (m_{31}-m_{10}) \times (h_{10}-h_{12})) + (m_{31}-m_{10}-m_{12}) \times (h_{12}-h_{14}) + (m_{31}-m_{10}-m_{12}-m_{14}) \times (h_{14}-h_{16})$ ---------(7)

$\dot{I}_{LP\ Turbine} = \dot{X}_{in} - \dot{X}_{out} - W_{LPT}$ ----------(8)

$\eta_{II\ LP\ Turbine} = 1-[\frac{\dot{I}_{LP\ Turbine}}{\dot{X}_{in} - \dot{X}_{out}}]$ ----------(9)

The exergy balance for Condenser

$\dot{I}_{Condenser} = m_{16} \times \{[h_{16}-h_{29}] - T_o[S_{29}-S_{16}]-([1-\frac{T_o}{T_{29}}] \times m_{16} \times [h_{16}-h_{29}])\}$ -------(10)

$\eta_{IICondenser} = 1-(\frac{\dot{I}_{Condenser}}{m_{16} \times (\Psi_{16}-\Psi_{29})})$ ------(11)

The exergy balance for Boiler feed Pump

$W_{BFP} = m_{30} \times (h_{21}-h_{30})$ ---------(12)

$\dot{I}_{BFP} = (\dot{X}_{in} - \dot{X}_{out})$ ---------(13)

$\eta_{II\ BFP} = \frac{(\dot{X}_{21} - \dot{X}_{30})}{W_{BFP}}$ ----------(14)

The exergy balance for Condenser extraction pump

$W_{CEP} = m_{29} \times (h_{17} - h_{29})$ -------(15)

$\dot{I}_{CEP} = (\dot{X}_{in} - \dot{X}_{out}) + W_{CEP}$ --------(16)

$\eta_{II\ CEP} = 1 - [\frac{(\dot{X}_{30} - \dot{X}_{21})}{W_{CEP}}]$ ------------(17)

The exergy balance for high pressure Feed water heater 1

$\dot{I}_{HP\ FWH\ 1} = m_7(\Psi_7 - \Psi_{25}) - m_{21}(\Psi_{22} - \Psi_{21})$ -------------(18)

$\eta_{II\ HP\ FWH1} = 1 - [\frac{\dot{I}_{HP\ FWH\ 1}}{m_7(\Psi_7 - \Psi_{25})}$ -----------(19)

The exergy balance for high pressure Feed water heater 2

$\dot{I}_{HP\ FWH\ 2} = m_3(\Psi_3 - \Psi_{24}) - m_{22}(\Psi_{23} - \Psi_{22})$ -----------(20)

$\eta_{II\ HP\ FWH2} = 1 - [\frac{\dot{I}_{HP\ FWH\ 2}}{m_{22}(\Psi_{23} - \Psi_{22})}]$ -------(21)

The exergy balance for Low pressure Feed water heater 1

$\dot{I}_{LP\ FWH\ 1} = m_{15}(\Psi_{15} - \Psi_{28}) - m_{17}(\Psi_{18} - \Psi_{17})$ -----------(22)

$\eta_{II\ LP\ FWH1} = 1 - [\frac{\dot{I}_{LP\ FWH\ 1}}{m_{17}(\Psi_{18} - \Psi_{17})}]$ ---------(23)

The exergy balance for Low pressure Feed water heater 2

$\dot{I}_{LP\ FWH\ 2} = m_{13}(\Psi_{13} - \Psi_{27}) - m_{18}(\Psi_{19} - \Psi_{18})$ --------(24)

$\eta_{II\ LP\ FWH2} = 1 - [\frac{\dot{I}_{LP\ FWH\ 2}}{m_{13}(\Psi_{13} - \Psi_{27})}]$ ---------(25)

The exergy balance for Low pressure Feed water heater 3

$\dot{I}_{LP\ FWH\ 3} = m_{11}(\Psi_{11} - \Psi_{26}) - m_{19}(\Psi_{20} - \Psi_{19})$ ------------(26)

$\eta_{II\ LP\ FWH2} = 1 - [\frac{\dot{I}_{LP\ FWH\ 3}}{m_{11}(\Psi_{11} - \Psi_{26})}]$ ---------(27)

The exergy balance for Deaerator or Feed water heater 4

$\dot{I}_{DEAERATOR} = (m_{21}S_{11} - m_{25}S_{25} - m_9S_9 - m_{20}S_{20})T_o$ - ----------(28)

$\eta_{II\ DEAERATOR} = 1 - [\frac{\dot{I}_{DEAERATOR}}{m_{25}\Psi_{25} \times m_9\Psi_9 \times m_{20}\Psi_{20}}]$ -----------(29)

V. Results

High Pressure Components in Thermal Power Plant

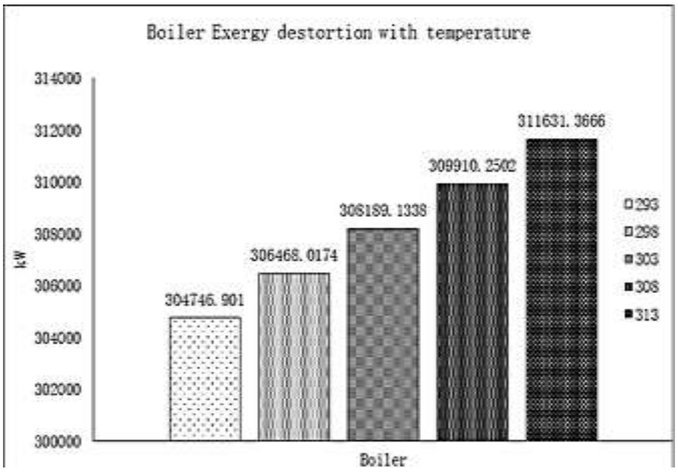

Fig. 1. Variation of Boiler Exergy destruction with temperature.

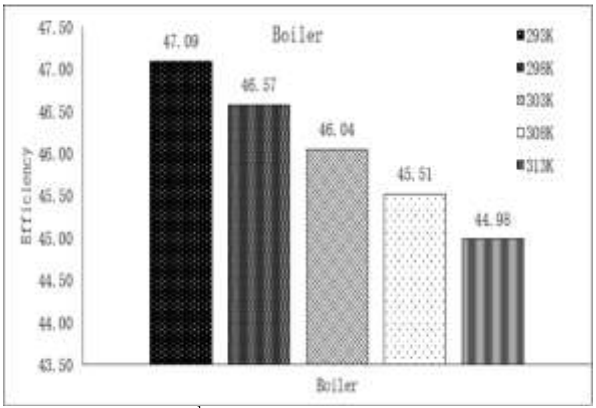

Fig. 2. Variation of 2nd law Boiler efficiencies with temperature

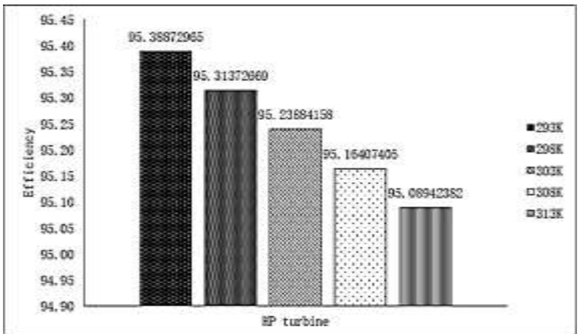

Fig. 3. Variation of 2nd law HP Turbine efficiencies with temperature

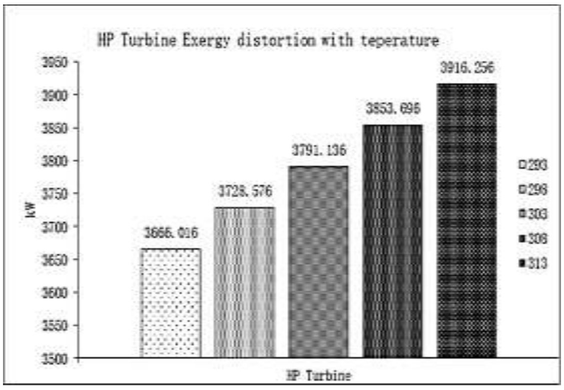

Fig. 4. Variation of HP Turbine Exergy destruction with temperature

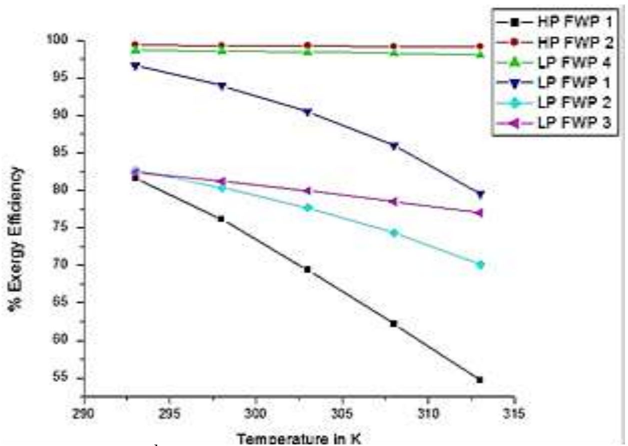

Fig. 5. Variation of 2nd law efficiency of various Feed Water Heaters with Temperature

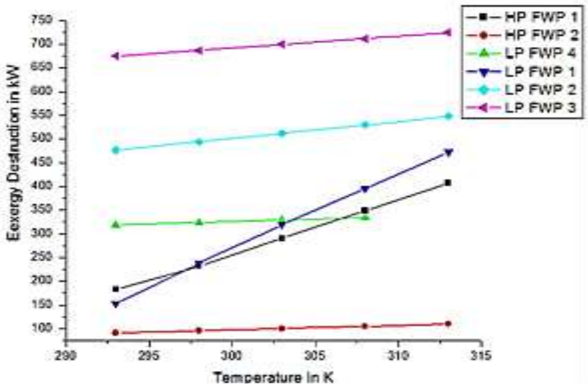

Fig. 6. Variation of Exergy Destruction of various Feed Water Heaters v/s temp

Exergy Analysis of Thermal Power Plant

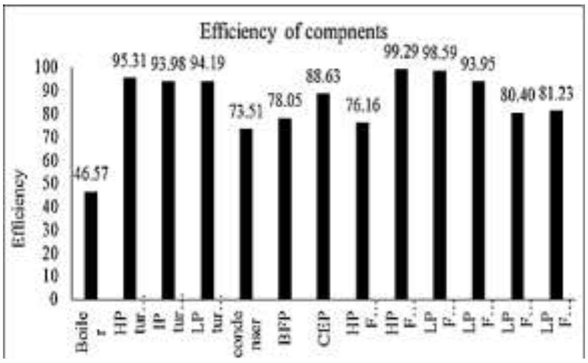

Fig.7. Efficiencies of various components of power plant

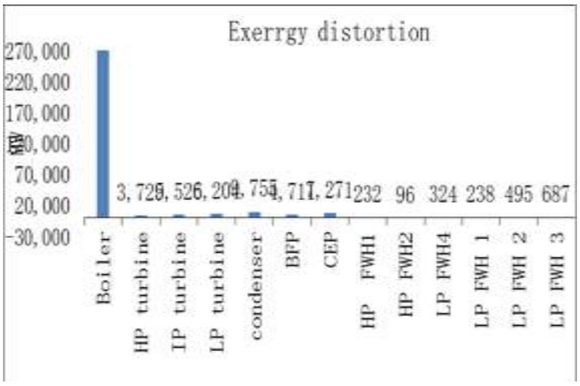

Fig. 8. Exergy destruction of various components of power plant

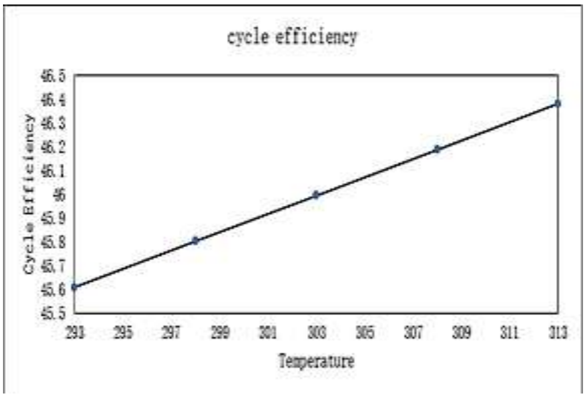

Fig. 9. Variation of cycle efficiency of power plant with temperature

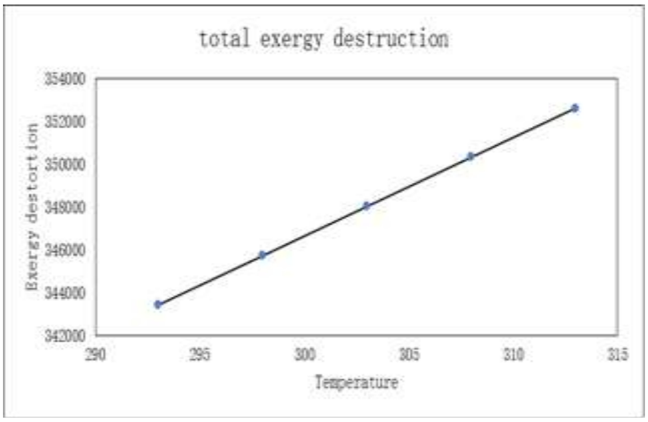

Fig. 10. Variation of Total Exergy destruction with temperature

VI. Conclusions

The second law analysis shows 88% of energy loss occurred in the combustion chamber of thermal power plant. Preheating the reactants is the most common way of reducing the energy loss of a combustion process. The first law efficiency analysis shows, major energy loss was found to be in condenser. But in the exergy analysis the boiler is found to be the highest energy loss area. Compared to the boiler (88.6%) the condenser has lesser energy loss (2.62%). The feed water heaters are having less energy loss of 0.6% as compared to the boiler (88.6%).

References

[1]. Umit Unver, Muhsin Kilic, Second Law Based Thermo Economic Analysis of Combined Cycle Power Plants Considering the Effects of Environmental Temperature and Load Variations, International Journal of Energy Research, 2007; 31:148–157

[2]. Souman Rudra, Hyun Min Shim, Hyung Taek Kim, Exergetic Analysis of Coal Fired Thermal Power Plants Based Advance Steam Parameters, Proceedings of the 4th BSME-ASME International Conference on Thermal Engineering, 27-29 December, 2008, Dhaka, Bangladesh

[3]. Al-Ghandoor J.O. Jaber, I. Al-Hint., Assessment of "Energy and Exergy Efficiency of Power Generation Sub-Sector in Jordan" Volume 3, Number 1, March. 2009, Pages 1 – 8

[4]. T. Ganapathy, N. Alagumurthi, R. P. Gakkhar, K. Murugesan., Exergy Analysis of Operating Lignite Fired Thermal Power Plant, Journal of Engineering Science and Technology Review 2 (1) (2009) 123-130

[5]. Rashad, A. El Maihy, Energy and Exergy Analysis of a Steam Power Plant in Egypt, ASAT- 13, May, 26 – 28, 2009

[6]. Vundela Siva Reddy, Subhash Chandra Kaushik, Sudhir Kumar Tyagi, Naraya Lal Panwar, An Approach to Analyse Energy and Exergy Analysis of Thermal Power Plants: A Review, Smart Grid and Renewable Energy, 2010, 1, 143-152

[7]. S. C. Kaushik, V. SivaReddy, S. K. Tyagi, Energy and exergy analyses of thermal power plants, Renewable and Sustainable Energy Reviews 15 (2011), 1857–1872

[8]. Amirabedin Ehsan, M. Zeki Yilmazoglu, Design and Exergy Analysis of a Thermal Power Plant Using Different Types of Turkish Lignite, international Journal of Thermodynamics (IJoT) Vol. 14 (No. 3), pp. 125-133, 2011

[9]. Vosough Amir, Improving Steam Power Plant Efficiency through Exergy Analysis, Ambient Temperature, 2nd International Conference on Mechanical, Production and Automobile Engineering (ICMPAE'2012) Singapore April 28-29, 2012

[10]. Ankit Patel, Energy and Exergy Analysis Of A Boiler With Different Fuels like Indian Coal, Imported Coal And L.S.H.S. Oil, International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 8, October – 2012

[11]. Padma Dhar Garg, SatenderDehiya, Ankit Barasiya, Aditya Rahangdale, Vijay Shankar Kumawat, Exergy and Efficiency Analysis of Combined Cycle Power Plant, International Journal of Scientific & Engineering Research, Volume 4, Issue 12, December-2013

[12]. Yong Li, Lei Liu, Exergy Analysis of 300MW Coal-Fired Power Plant, 2012 International Conference on Future Electrical Power and Energy Systems, Energy Procedia 17 (2012) 926 – 932

[13]. R. Jyothu.Naik, T. Rekha Madhuri, Md. Altaf Hussian, K. Mohan Sai, V. Chinni, Exergy Analysis of 120 MW Coal Based Thermal Power Plant, International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 4, April – 2013

[14]. M. K. Pal, Anil Kumar, H. Chandra, Energy and Exergy Analysis Of Boiler And Turbine Of Coal Fired Thermal Power Plant, International Journal of Engineering Research & Technology, Vol. 2 Issue 6, June – 2013

[15]. Sarang j gulhane, Amit kumar Thakur, Exergy Analysis of Boiler In cogeneration Thermal Power Plant, American Journal of Engineering Research (AJER), Volume-02, Issue-10, pp-385-392, 2013

[16]. Sahil Suryvanshee, Alok Chaube, Exergy Analysis of Thermal Power Plant; A Review, International Journal of Engineering Research & Technology, Vol. 2 Issue 7, July – 2013

[17]. LalatenduPattanayak, Steady State Energy and Exergy Analysis of Pulverized Coal Fired Boiler, International Journal of Engineering Research & Technology, Vol. 3 Issue 2, February – 2014

[18]. Darshan H Bhalodia, Sanjeev Yadav, Energy and Exergy Analysis of Coal Fired Cogeneration Power Plant, International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 2, February – 2014