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Energy Based Analysis of a Thermal Power Station for Energy Efficiency Improvement

Dr. Mohammed Yunus[1], Mohammed Asadullah[2], Dr. Hamza A. Ghulman[3], Dr. J. Fazlur Rahman[4], Mohammed Irfan[5]

[1,2,4,5] Department of Mechanical Engineering, H.K.B.K.College of Engineering/ Visvesvaraiah Technological University, India

[3]Department of Mechanical Engineering, Ummul Qura University, Mekkah, Kingdom of Saudi Arabia

ABSTRACT: *Despite of growth of renewable energy stations installations like wind, solar, Tidal power, the energy for the world depends heavily on fossil fuels for electricity generation. It is also expected to continue the dependence on fossil fuels for next few decades. Therefore, given the continued reliance on the fossil fuels for some time, it is important to note these plants must reduce their environmental impact by operating fossil fuels more efficiently. Two types of analysis namely, energy and exergy analysis can be developed for the system. Energy analysis based on first law of thermodynamics cannot be applied as it cannot justify the real useful energy loss because it does not differentiate between the quality and quantity of energy within the system. Whereas, exergy analysis will characterize the work potential of a system based on the second law of thermodynamics and the maximum work that can be obtained from the system when its state is brought to the reference or dead state (standard atmospheric conditions).This technical paper presents the results of exergy and energy analysis carried out on 62 MW coal-based thermal power plant to evaluate the performance. The performance of the plant was estimated by a component-wise modeling followed by a system simulation. A parametric study is conducted for the thermal plant under various operating conditions, including different operating condenser pressures, temperatures and flow rates of cooling water across the condenser etc, in order to determine which parameter that maximizes plant performance. Energy loss distribution to find out the amount and source of irreversibilities generated in boiler and turbine in a plant so that any process in the system having largest energy destruction can be identified and that helps the designer to re design the system components.*

Keywords: *Exergy Analysis, Energy analysis, Coal based Thermal Power station, Fossil fuels, Irreversibility, Second Law of Thermodynamics.*

I. Introduction

Despite of growth of renewable energy stations installations like wind, solar and tidal power, the energy for the world depends heavily on fossil fuels for electricity generation. It is also expected to continue the dependence on fossil fuels for decades. Therefore, given the continued reliance on the fossil fuels for some time, it is important that fossil fuel plants reduce their environmental impact by operating more efficiently. The heavy dependence on fossil fuels is expected to continue for decades. Despite the depletion of fossil fuel reserves and environmental concerns such as climate change, the growth in oil demand is expected to be 60% between 2014 and 2035, 94% for natural gas and 96% for coal [24]. Since it is very clean process, it is continued to reliance on the fossil fuels for some more time. Therefore, it is important that fossil fuel plants should reduce their environmental impact by operating more efficiently.

There are two types of analysis used for thermal power plants, namely, energy and exergy analysis can be developed for the system. Energy analysis based on first law of thermodynamics cannot be applied as it cannot justify the real useful energy loss because it does not differentiate between the quality and quantity of energy within the system and also does not characterize the irreversibility of processes within the system. Whereas, exergy analysis will characterize the work potential of a system based on the second law of thermodynamics and the maximum work that can be obtained from the system when its state is brought to the reference or dead state (standard atmospheric conditions). Exergy analysis is based on the second law of thermodynamics. Past exergy studies have evaluated the performance of power plants, as a means to optimize the performance and turbine power output.

Using exergy and energy analysis, the performance of 400MW capacity coal-fired and nuclear power plants carried out successfully by Habib et. al.and Zubair et.al [17] conducted a second law analysis of regenerative Rankine power plants with reheating. Sengupta et al. [19] conducted an exergy analysis of a 210 MW thermal power plant in India. Rosen et.al.[13], [16], [20], [21] and [22] performed exergy analysis of power plants that operate on various fuels. They have also investigated capital costs involved and thermodynamic losses. Most common size of power plants in India are 100/110/200/210 MW [6]. The exergy analysis is not so popular among industries especially in India and it needs much more attention and application so that the irreversibilities can be minimized and thus the systems can be operated at much higher efficiency. The present work is to show the application of energy and exergy based analysis. The performance of the plant was estimated by a component-wise modeling followed by a system simulation (computer program) and detailed break-up of exergy losses are evaluated. For the low performance of plant, the various parameters responsible for the plant are mismatching of equipments/ components, improper maintenance, over a period of time, low performance due to deteriorated equipments, inadequate instrumentation, mismatching of equipments etc. [3].

The power plant is designed to utilize an air cooled condenser to condense the exhaust steam. This paper will identify major sources of losses and energy destruction in the power plant. It will provide ways and means to improve the system performance and reduce environment impact. Finally, it will perform a parametric study to determine how the system performance varies with different operating parameters. he introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. Experimental Methodology

A detailed process flow-sheet of a Thermal Power Station consists of a unit employs regenerative feed water heating system which is carried out in two stages of low pressure heaters and high pressure heaters along with one open de-aerating heat exchanger. Saturated steam from the boiler drum is fed to the super heater to heat it up to 500^{o}C at a pressure of 85 bars.

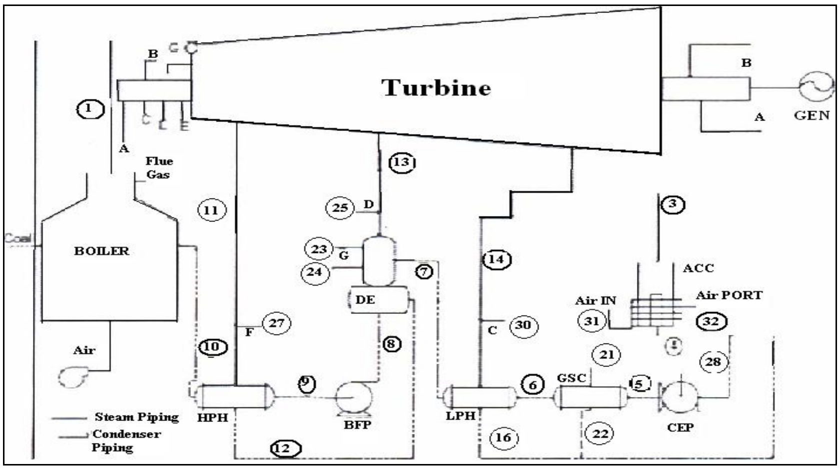

Fig. 1. Process flow diagram: ACC - air cooled condenser, BFP - boiler feed pump, CEP condensate extraction pump, DE - deaerator, GEN - generator, GSC gland steam condenser, HPH - high pressure heater, LPH - low pressure heater.

The condenser pressure is taken as 10 kPa. The extraction pressures of steams from the turbine varies at High Pressure Heater of fist stage of 30 bars to High Pressure Heater of stage of 16 bars , De-aerator of 6 bars and Low Pressure Heater of fist stage of 2.8 bars to Low Pressure Heater of 2 stage of 0.8 bar.

2.1 Composition Details

Coal available in India is the supply fuel of the power plant with the following components and the compositions of it used for coal fired thermal power plant are shown in table 1. Calorific value of Indian coal supplied to Raichur Thermal Power station has 15.5 MJ/kg.

Table 1.Composition of typical Indian coal

Components	Mass in percentage
Moisture	10
Ash	40
Hydrogen	2.68
Nitrogen	0.8
Sulphur	0.65
Oxygen	7
Carbon	38.87

2.2 Assumptions to be made for using flow sheet program method of analysis.

1. Reference temperature for water / steam is at 25^0C and incoming fuel temperature is also 25^0C.
2. Neglect the potential and kinetic exergies.
3. Environment model to calculate exergy has reference pressure and temperature are 1.013 bar and 25^0C and the composition of environment(% mole)for CO_2, H_2O, N_2, O_2, are 0.03, 3.12, 76, 21.
4. Excess air is 20%.
5. Generator efficiency is 95%.
6. Isentropic efficiency of pumps / fans and turbine are 70% and 80% respectively.

The present study has been performed using a flow-sheet program, which is a well-structured program for the thermodynamic analysis of energy systems. The ash content of Indian coal, as already mentioned is around 40 - 50% as against 5 - 10% in the coal being used in the western countries. This is one of the important factors contributing to the lower overall efficiency of the plant. Being a tropical country, the cooling water temperature in majority of the parts in India throughout the year is around 25^0C. In Europe and other western countries the cooling water temperatures are lower in the range of 5 – 10^0C, which enables the operation of the condenser at much lower vacuum pressures (5 kPa), thus resulting in higher operating efficiencies. Since, both the above factors are nature's limitation; though coal can be beneficiated to a small extent, designer's / plant operator's focus should shift to other major sites of potential improvement. Thus, the goal of this paper is to identify such sites so that the overall efficiency of the system can be improved.

III. Results and Discussion

Parametric study has been carried out in order to account the performance of the over the parameters such as gain in cooling water temperature across the condenser, Steam temperature, steam pressure, inlet air temperature, and the condenser pressure. Fig 2. shows that the reference temperature does not have an effect on the energy efficiency, but it affects then exergy efficiency. The performance of the system depends on the surroundings of the system i.e. inlet air temperature. Fig. 4. shows the variation of efficiencies (both exergy and energy) with the increase in cooling water temperature across the condenser and it is found about 0.15 – 0.20% for the temperature variation of 5^0C. As this power plant uses an air cooled condenser to condense the exhaust steam of the turbine and mainly the improvement that can be achieved by lowering the condenser pressure as shown in fig.3 due to the higher expansion of steam through the turbine, resulting in higher power output.

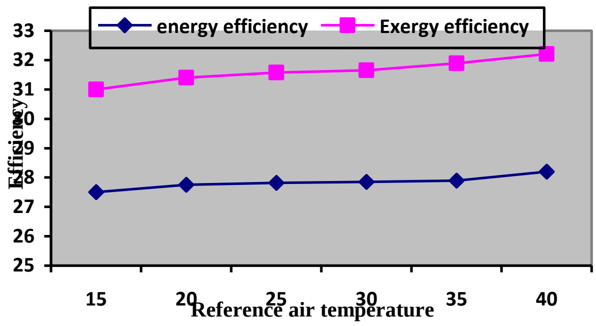

Fig.2. Variation of efficiencies v/s Reference air temperature

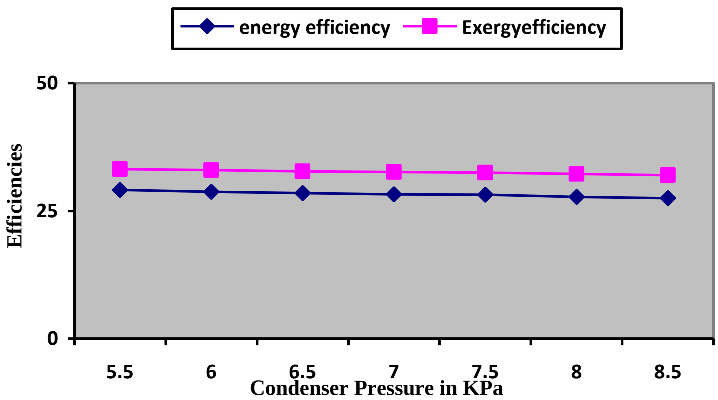

Fig. 3. Variation of efficiency vs. condenser pressure

In case of water cooled condensers, where the temperature of water can be easily controlled, but not in an air cooled condenser, the temperature at which the steam to be condensed cannot be reduced.

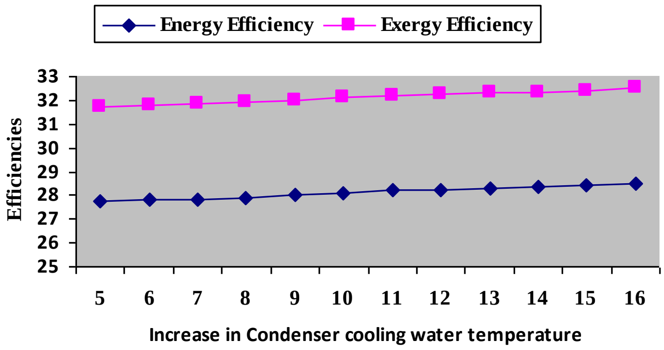

Fig. 4. Variation of efficiencies with increase in condenser cooling water temperature.

It is seen that the efficiency rises with an increase in the superheated steam parameters as presented in fig. 5. Show the effects of the steam temperature on the cycle performance. It is evident the increasing the cycle steam temperature will result in a higher power output for the same mass flow rate of steam and fuel input into the boiler. Therefore steam has higher energy/exergy content, resulting in higher work output of the turbine.

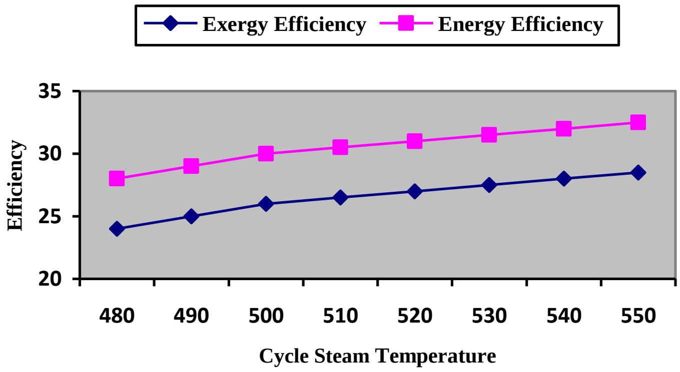

Fig.5.Illustrates the efficiency vs. Cycle steam pressure

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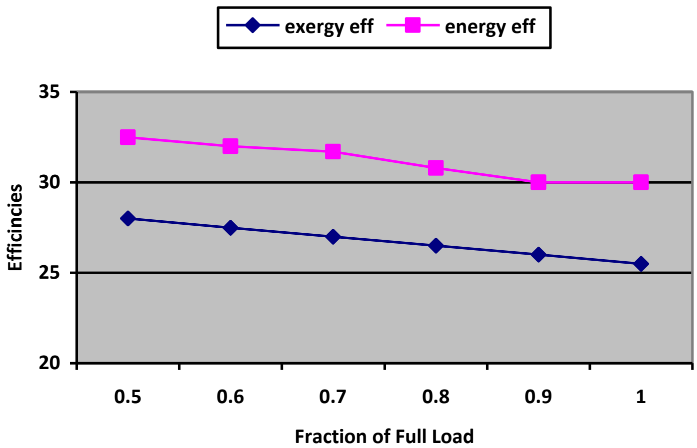

Fig. 6. Efficiency vs. Fraction of Full Load (% of generator output power)

It is evident from figs.6 and 7, that the variation of energy and exergy efficiencies with lower auxiliary power consumption, in terms of the percentage of generator output power which leads to higher system efficiencies. The operation of the plant below 50% of the designed capacity results in the significant increase of irreversibilities and indicates that when the plant is operated at its rated capacity would be more economical than operating at part loads. Figs.8 and 9 show the detailed energy and exergy balance of the considered system at the maximum operating load of 60 MW and difference in the composition of energy and exergy balances. It is noted that the exergy analysis has enabled the identification of the causes of process inefficiencies in detail when compared to the energy analysis.

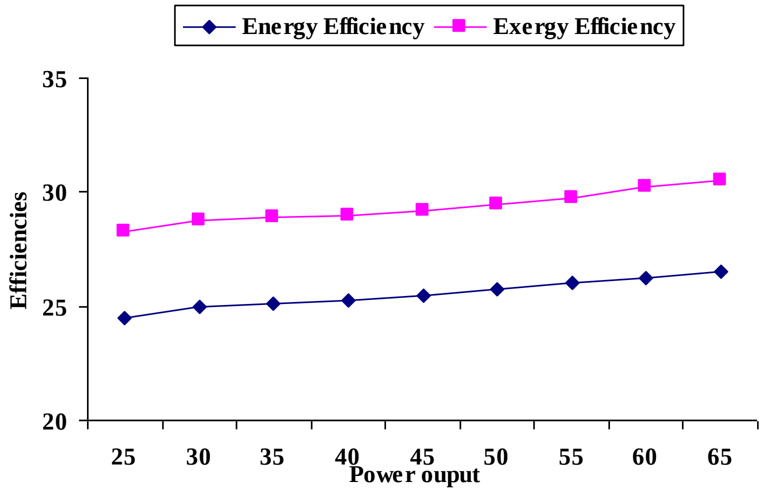

Fig.7. Variation of efficiencies vs. power output of Turbine

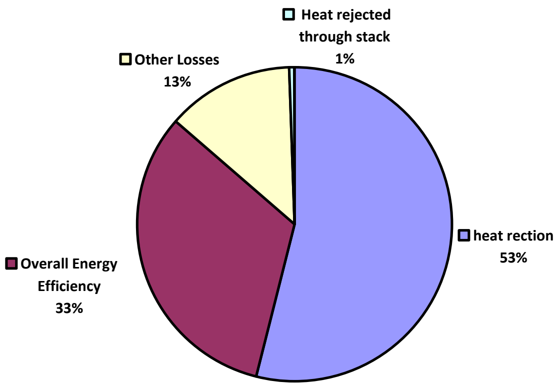

Fig. 8.Energy balance of 62 MW thermal power plant

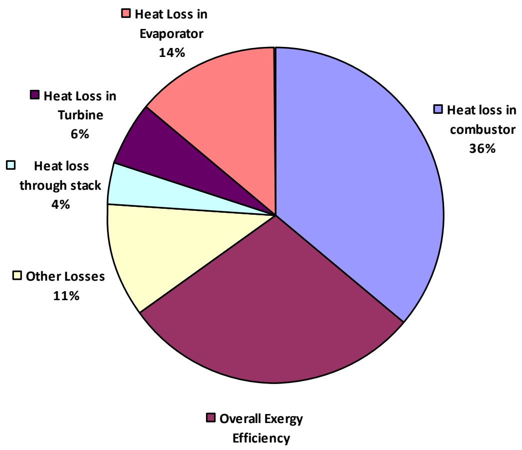

Fig. 9.Exergy balance of 62 MW thermal power plant

In order to utilize non-renewable sources more effectively like fossil fuels without damaging the environment, so that it can achieve better environmental sustainability. This will enable us to maximize its use of limited resources and make existing resources last longer. Fig. 10 shows the effect of exergy efficiency on the sustainability index.

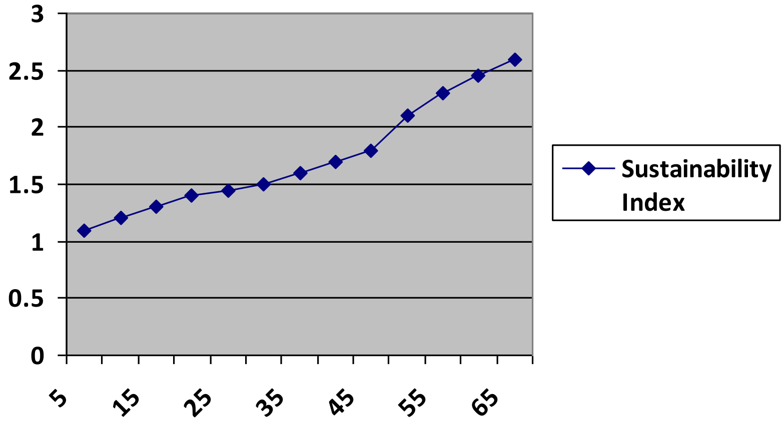

Fig.10. Sustainability index vs. exergy efficiency.

IV. Conclusion

Energy analysis of a thermal power plant based on a second law analysis has been presented and a detailed parametric study considering the effects of various parameters on the system performance has been performed to identify and quantify the sites having largest energy and exergy losses. The power plant's energy and energy efficiency is determined to be 32.5% and 27.5% for the gross generator output. The maximum exergy loss is found to occur in the boiler and turbine and if the performance of a boiler and turbine are improved, plant performance will also be improved. Hence the largest improvement the power plant efficiency. The exergy analysis of the plant showed that lost energy in the condenser is thermodynamically insignificant due to its low quality.

REFERENCES

[1] T. J. Kotas, "Exergy Criteria of Performance for Thermal Plant: Second of Two Papers on Exergy Techniques in Thermal Plant Analysis," International Journal of Heat and Fluid yongping yang “comprehensive exergy based evaluation and parametric study of a coal fired ultra super critical power plant.

[2] Mali Sanjay D, Dr. Mehta N S, " Easy Method Of Exergy Analysis For Thermal Power Plant", International Journal of Advanced Engineering Research and Studies,Vol. I, Issue III, April-June, 2012, PP-245-247

[3] P Regulagadda “energy analysis of a thermal power plant with measured boiler and turbine losses” applied thermal engineering vol 30-[2010], PP.970-976.

[4] T. Ganapathy, N. Alagumurthi, R. P. Gakkhar and K. Murugesan, "Exergy Analysis of Operating Lignite Fired Thermal Power Plant," Journal of Engineering Science and Technology Review, Vol. 2, No. 1, 2009, pp. 123-130.

[5] S. C. Kamate and P. B. Gangavati, "Exergy Analysis of Cogeneration Power Plants in Sugar Industries," Applied Thermal Engineering, Vol. 29, No. 5-6, 2009, pp. 1187-1194.

[6] A. Datta, S. Sengupta and S. Duttagupta, "Exergy Analysis of a Coal-Based 210 mw Thermal Power Plant," International Journal of Energy Research, Vol. 31, No. 1, 2007, pp. 14-28.

[7] I. H. Aljundi, "Energy and Exergy Analysis of a Steam Power Plant in Jordan," Applied Thrmal Engineering, Vol. 29, No. 2-3, 2009, pp. 324-328.

[8] Ankit patel “energy and exergy analysis of boiler with different fuels like Indian coal ,imported coal and L.H.H.S oil vol 8 oct 2012.

[9] A. Rashad, and A. El Maihy, "Energy And Exergy Analysis Of A Steam Power Plant In Egypt" 13th International Conference on Aerospace Sciences & Aviation Technology, ***ASAT- 13,*** May 26 – 28, 2009.

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

[11] R saidur “energy and exergy economic analysis of industrial boiler” Vol 38(2010)2188-2197

[12] R. Jyothu naik “exergy analysis of 120MWcoal based thermal power plant ’’vol 2 4 apil 2013 issn 2278-0181.

[13] M. A. Rosen, "Energy- and Exergy-Based Comparison of Coal-Fired and Nuclear Steam Power Plants," Exergy, Vol. 1, No. 3, 2001, pp. 180-192.

[14] M.K. pal "energy and exergy analysis of boiler and turbine of a coal fired thermal power plant '' vol 2. Issue 6, June 2013.

[15] H. Erdem, A. V. Akkaya., A. Dagdas, S. H. Sevilgen, B. Sahin, I. Tek, C. Gungor and S. Atas, "Comparative Energetic and Exergctic Performance Analyses for Coal-Fired Thermal Power Plants in Turkey." International Journal of Thermal Sciences, Vol. 48, No. 11, 2009, pp. 2179-2186.

[16] M.A. Rosen, Energy and exergy-based comparison of coal-fired and nuclear steam power plants, Exergy - International Journal 1 (3) (2001) 180-192.

[17] M.A. Habib, S.M. Zubair, 2nd-law-based thermodynamic analysis of regenerative-reheat Rankine-cycle power plants, Energy, vol. 17, Pergamon- Elsevier Science Ltd., 1992. pp. 295 301.

[18] Tapan K. Ray, Amitava Datta, Amitava Gupta, Ranjan Ganguly, Exergy-based performance analysis for proper O&M decisions in a steam, Energy Conversion and Management 51 (2010) 1333–1344.

[19] S. Sengupta, A. Datta, S. Duttagupta, Exergy analysis of a coal-based 21 OMW thermal power plant, International Journal of Energy Research 31 (2007) 14-28.

[20] M.A. Rosen, 1. Dincer, Exergoeconomic analysis of power plants operating on various fuels, Applied Thermal Engineering 23 (2003) 643-658.

[21] M.A. Rosen.. I. Dincer, On exergy and environmental impact, International Journal of Energy Research 21 (1997) 643-654.

[22] M.A. Rosen. 1. Dincer, M. Kanoglu. Role of exergy in increasing efficiency and sustainability and reducing environmental impact, Energy Policy 36 (2008) 128-137.

[23] M.J. Moran, H.N. Shapiro, Fundamentals of Engineering Thermodynamics, sixth ed., John Wiley & Sons, Inc., 2006.

[24] S.C. Kaushika, V. Siva Reddya, S.K. Tyagib. Energy and exergy analyses of thermal power plants: A review, Renewable and Sustainable Energy Reviews 15(2011) 1857–1872.