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Research Article

An Energy Analysis of Condenser

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Abstract

*The conventional steam power plant working under, the Rankine Cycle and the steam condenser as a heat sink and the steam boiler, as a heat source have the same importance for the power plant operating process. Energy efficiency of the coal fired power plant strongly depends on its turbine-condenser system operation mode. Operating the condenser at optimum circulation water flow rate is essentially important to ensure maximum efficiency and minimum operating cost of the plant. To control the condenser variables like cooling water flow rate, condenser pressure, condenser temperature having vital importance on entire plant performance. For the given thermal power plant configuration, cooling water temperature or/and flow rate change generate alterations in the condenser pressure. Those changes have great influence on the energy efficiency of the plant. This project focuses on the influence of the cooling water temperature and flow rate on the condenser performance, and thus on the specific heat rate of the coal fired plant and its energy efficiency. Variations in condenser backpressure about design can impact the economic operation of a turbo generator unit in terms not only of heat rate, but also of the cost of chemicals used to compensate for the dissolved oxygen concentration in both the condensate and feed water. These effects can be adjusted by employing means to control condenser backpressure and this paper examines how the costs of these effects can be evaluated and suggests some approaches for the active control of backpressure. Reference plant Rayapati Power Generation Pvt. Ltd., Rajnandgaon working under turbine follow mode with a close cycle cooling system having capacity of 7.5 MW situated at Thakurtola village near Rajnandgoan district under state of Chhattisgarh, India. The study revealed that when plant runs at full load, the parameters like condenser pressure, heat rate, fuel consumption and cycle efficiency affected by cooling water flow rate. i.e. operating the condenser at optimum cooling water mass flow rate 1800m^3/h instead of current flow rate 1536.45 m^3/h and plant input decreases as **7326048 Rs./year**.*

Keywords: *cooling water flow rate, condenser pressure, condenser temperature, heat rate, vacuum, cycle efficiency*

Introduction

The need for electrical energy will certainly continue to grow, and it has become imperative to lower the cost of electricity and enhance the operational economy of the turbine unit. Heat losses from the steam power plant cycle are mostly due to heat rejection through the condenser. Operating condenser at optimum variables is essentially important to ensure maximum efficiency and minimum input of the plant. The condenser operating conditions are of the great influence on the maximum generated power and the heat rate value. In the same time, the operating conditions of the cooling water system determine the operating conditions of the condenser (Milan V. Sanathara et al, 2013) Energy exploration and exploitation, capacity additions, clean energy alternatives, conservation, and energy sector reforms will, therefore, be critical for energy security. Energy conservation has also emerged as one of the major issues in recent years. Conservation and efficient utilization of energy resources play a vital role in narrowing the gap between demand and supply of energy. Improving energy efficiency is one of the most desirable options for bridging the gap in the short term.

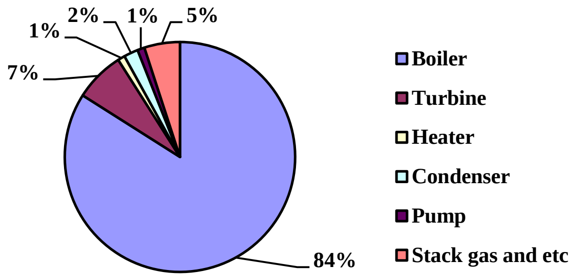

Figure 1 Present ratio irreversibility in power plant component

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The total potential for renewable power generation in the country as on 31.03.12 is estimated at 89774 MW. This includes wind power potential of 49130 MW (54.73%), SHP (small-hydro power) potential of 15399 MW (17.15%), Biomass power potential of 17,538 MW (19.54%) and 5000 MW (5.57%) from bagasse-based cogeneration in sugar mills.

Figure 1 shows that the boiler has the most exergy losses in power plant and figure.2 shows that the condenser has the most energy losses in power plant. These figures illustrate the difference between energy and exergy analyses

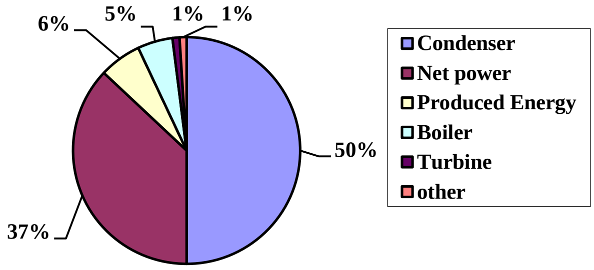

Figure 2 Present ratio of heat balance in power plant component

There are two principal modes for operating boiler/turbo-generator units designed according to the Rankine Cycle, namely (1) the turbine-follow mode and (2) the boiler-follow mode. In the turbine-follow mode the turbine governor is set to control the generator load while the boiler control system adjusts the fuel firing rate and other parameters so as to maintain, as close as possible to their design values, the pressure and temperature of the live steam at the turbine throttle. Fossil –fired units that are centrally dispatched usually operate in this mode.

On a unit controlled in this way, a rise in condenser backpressure will tend to cause the end point enthalpy to rise, resulting in a reduction in generated power. However, the governor will respond and increase both the throttle and, consequently, the exhaust flows so as to restore the generated power to the preset level. The rise in unit heat rate caused by the increased fuel flow will be only partly offset by the rise in condensate temperature at the hot well. On a fall in condenser backpressure, the reverse will occur; but if it falls below the point where the exhaust annulus become choked, then excessive condensate sub-cooling will result, establishing a limit to the improvement in heat rate resulting from the lower backpressure.

In the boiler-follow mode, the fuel-firing rate or, in the case of a nuclear power plant, the steam generator reaction rate, are set at a fixed value. The turbine governor now adjusts the throttle valve (and therefore generated power) so as to maintain the steam pressure at the throttle valve inlet at its design value. In this mode, a rise in condenser backpressure will, by also raising the Usable Energy End Point (UEEP), because a drop in power for the same net heat input to the system; while the reverse will occur when the backpressure falls.

Literature Survey

Milan V.Sanathara, Ritesh P.Oza and Rakesh S.Gupta in 2013 focused on the influence of cooling water flow rate and temperature on the condenser performance, and thus on the specific heat rate of the coal fired plant and its energy efficiency using Parametric Analysis Method. As cooling water flow decreases the vacuum inside the condenser. This increased condenser pressure will decrease the power output of LP turbine which is not advisable. From mathematical model and analysis author proved that energy efficiency of condenser reduces when cooling water inlet temperature increases. Amir vosough, Alireza falahat, Sadegh vosough, Hasan nasr esfehani,Azam behjat and Roya naseri rad in 2011 to identify and quantify the sites having largest energy and exergy losses at cycle Using Energy and Exergy Analysis Method . In addition, the effect of varying the condenser pressure on this analysis will also be presented with the limits of turbine & condenser temperature and design, the minimum allowable condenser pressure should be chosen to produce maximum efficiency and output power. This pressure should be always controlled during the power plant operation. The maximum energy loss was found in the condenser where 60.86% of the input energy was lost to the environment. The exergy destruction in the condenser was 13.22% and thermal and exergy efficiency 38.39 %, 45.85. Ajeet Singh Sikarwar , Devendra Dandotiya and S.K. Agrawal in 2013 Study about the factors or parameters which reduced the efficiency of condenser Using Analysis of ATPS and finalizes three causes which affecting the performance of condenser are deviation due to inlet temperature of cold water , deviation due to cold water flow, deviation due to air ingress /dirty Tube, particular in this study the efficiency of a power plant will reduce to 0.4% by these deviation in condenser. Ankur Geete and A.I. Khandwawala in 2013 using Exergy Analysis Method for create relation between correction Curves for power & heat rate are generated for different condition of condenser back pressure. A.H.Rana and J.R. Mehta in 2013 Detail study about energy efficiency, exergy destruction, exergy efficiency and turbine heat rate are evaluated at 70 % and 85 % maximum continuous rating (MCR) of steam turbine Using Energy and Exergy Analysis Method. Turbine exergy efficiency is lower than its energy efficiency as utilization of heat is at lower temperature than inlet. Turbine exergy loss is 12.32 % and 12.56 % at 70 % and 85 % MCR. When Turbine MCR is increased from 70 to 85%, coal consumption is reduced by 16.46 kg/h and ash handling plant load is reduced by 41.47 kg/day. CO_2 emission is reduced by 26.89 kg/h, while SO_2 emission is reduced by 0.62 kg/h. Vosough Amir and Sadegh vosough in 2011 focused on Energy and Exergy Method for power plant Efficiency In the considered power cycle, the maximum energy loss was found in the condenser. Next to it was the energy loss in the boiler system. The major source of exergy destruction was the boiler system where chemical reaction is the most significant source of exergy destruction in a combustion chamber. Exergy destruction in the combustion chamber is mainly affected by the excess air fraction and the temperature of the air at the inlet. Jinsong Tao, Huanbin Liu etc in 2010 using the Optimization Analysis Method for steam turbine and condenser for effect of cooling water temperature in thermal efficiency of power plant Condensers increase the enthalpy drops and turbine work by lowering the turbine outlet pressure. The lower the pressure, the higher the efficiency and power are. The optimization for turbines, condensers and cooling water tower can increase the paper mill power plant electricity generation, and obtain good economical result through adjusting some operation parameters without capital investments. Mirjana, S LAKOVIC and Dejan D. MITROVIC in 2010 focused on impact of cooling water temperature on energy efficiency of power plant, increasing pressure in the condenser of 1 kPa, efficiency decreases to 1.0-1.5% using Simulator based on IAPWS-IF97 .considering that in this particular case the reduction is 1.2%, dependence of the energy efficiency in the function of the cooling water temperature rise is obtained. The condenser heat transfer rate and pressure in the condenser are given for variable cooling water temperature and flow rate, the specific heat rate change due to the change of condensing pressure, and the specific heat rate change due to the cooling water temperature change. Finally, the energy efficiency for the reference plant is given as the function of the change in condensing pressure. A.Dutta and A .K. Das in 2013 had worked upon the Loss factor and Efficiency of surface condenser and result found out At a particular load and condenser pressure, with the decrease in temperature rise in cooling water the condenser efficiency decreases. Similarly, at higher temperature rise in cooling water the condenser offers higher efficiency. At a particular load and condenser pressure, Loss Factor (LF) increases with decrease in temperature rise in cooling water. At a particular load and condenser pressure, Loss Factor decreases with increase in efficiency. It has been also noted that the efficiency is maximum when the Loss Factor equals to one. Hardik.B.Patel and N.S. Mehta Using the Exergy Method for inlet cooling water for condenser using MAT Lab program decrease of condenser pressure from 0.18 bar to 0.10 bar optimum cooling water temperature is also decrease from 34ºC to 21ºC, and exergy destruction at 21ºC decreases from 41755 kW to 30263 kW. So it is better to operate the condenser at as low as possible pressure.

Prashant Sharma, SPS Rajput and Mukesh Pandey in 2011 focused on Exergetic Optimization of Inlet Cooling Water Temperature of Cross Flow Steam Condenser, It is found that optimum cooling water temperature decrease with decrease of condenser pressure Using Exergoeconimic Analysis Method for minimized the using the Exergy method. As the upstream mass flow rate increase, the optimum coolant temperature and exergy efficiency decreases, Pressure drop is also increased with increase of cooling water flow rate using MAT Lab program. With decrease of condenser pressure from 0.18 bar to 0.10 bar optimum cooling water temperature is also decrease from 34 to 21, and exergy destruction at 21 decreases from 41755 kW to 30263 kW. Operating temperature of cooling water cannot be increased more than 34. At this temperature, exergy destruction is 27350kW and exergy efficiency is 37.1%,Richard E. putman and Dr. Joseph W.harpster study the Economical effect of condenser backpressure on Heat Rate, condensate sub cooling and feed water dissolved oxygen, Using Simple Unit Performance Modeling Techniques, it is possible to evaluate the economic benefits which would result from varying the backpressure, taking account of any associated increase in condensate sub cooling, possible choking of the low pressure turbine exhaust annulus and any changes in the cost of feed water treatment chemicals.

Methodology

To Analysis the effect of this back pressure in power plant efficiency and yearly fuel saving in terms of rupees, we using parametric analysis method for better and accurate analysis & comparison of parameter.

Following data are analysis in this method:-

- Plant Evaluation such as plant specification, operating range, PLF, Efficiency etc.
- Performance Analysis:-
  A. surface condense
  B. cooling Tower
- To analysis cooling water flow rate and condenser pressure
- To analysis condenser pressure and power output
- To analysis Heat rate & Energy efficiency
- Effect on plant economy

Result and Discussion

Comparison of design and operating parameter show in table No 1 its show the various key value which effecting performance of condenser.

Table No 1 Comparison between Designing & operating parameter

Parameter	Design	Operating
Condenser vacuum	694mmhg	612mmhg
Condenser TTD	4.8°C	19.8°C
Condenser Effectiveness	62.50%	30.76%
C.T. Range	8°C	8.8°C
C.T. Approach	6°C	5.5°C
Effectiveness	57%	61%
Evaporation losses	21.33 m^3/h	20.03 m^3/h
Make up water consumption	4.2666 m^3/h	4.006 m^3/h
Cooling water rate	1800 m^3/h	1536.45 m^3/h
Turbine back pressure	0.1bar	0.21bar
Turbine work	952.6kW	884.9kW
Cycle Efficiency	36.70%	34%
Specific steam consumption	28.08TPH	30.53TPH
Steam Rate	3.77 kg/kWh	4.068 kg/kWh
Heat rate of turbine	9718.3 kJ/kWh	10566.22 kJ/kWh
fuel consumption	5805 kg/h	6300 kg/h

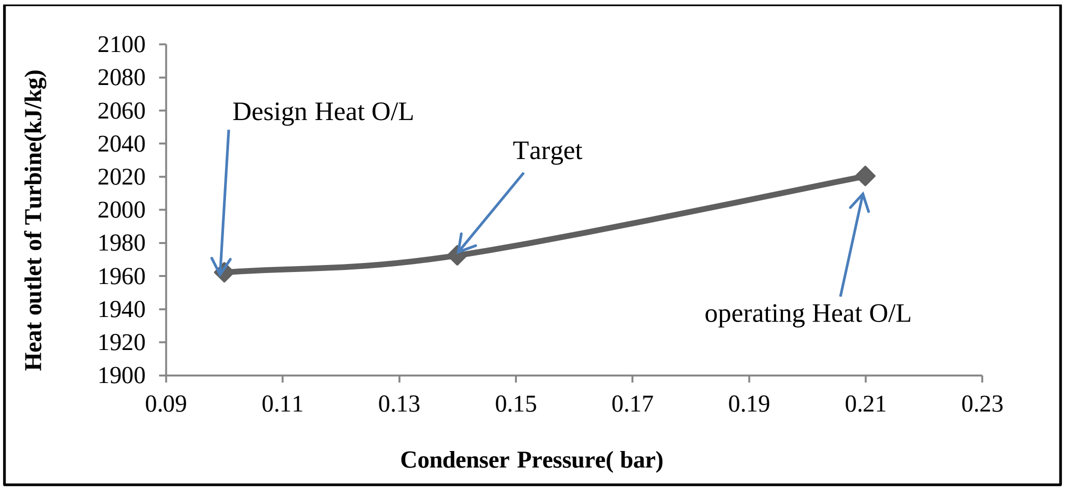

Figure 3 Turbine output v/s Condenser Pressure

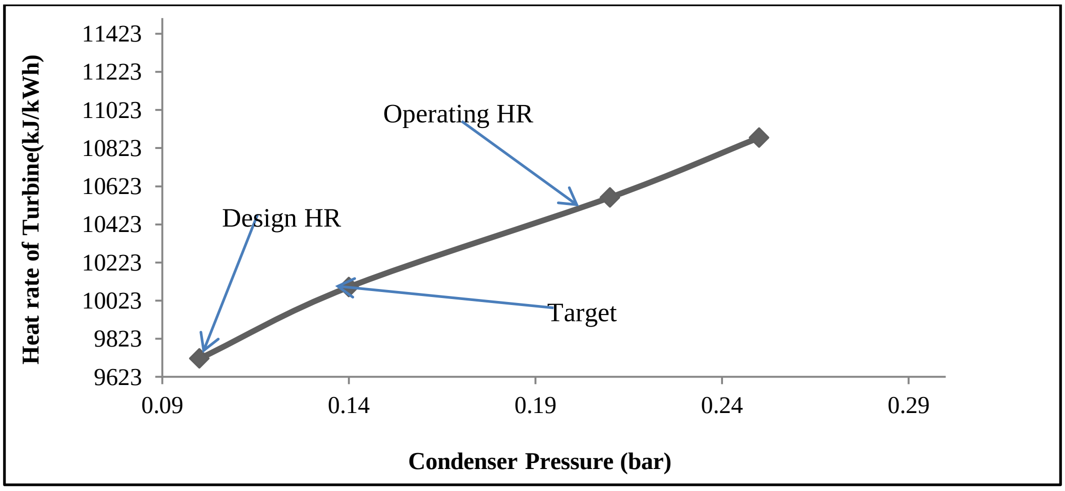

Figure 4 Condenser Pressure v/s Heat Rate

Fig. 5 show the effect of condenser pressure on the fuel consumption and heat rate performance .it is evident that the fuel consumption increases with an increase in the heat rate parameter and fig 6 shows the effect of fuel consumption on cycle efficiency of plant both parameter effecting by condenser pressure.

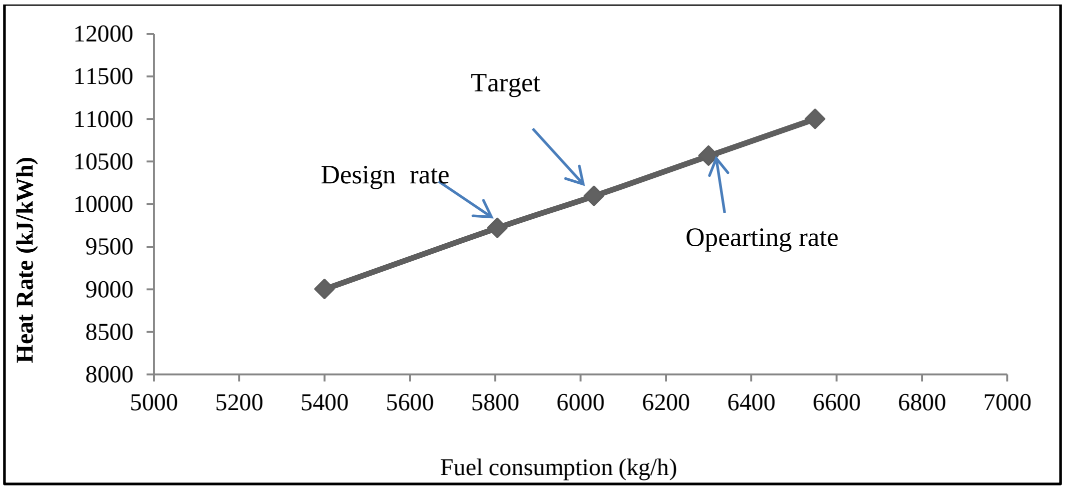

Figure 5 Fuel Consumption v/s Heat Rate

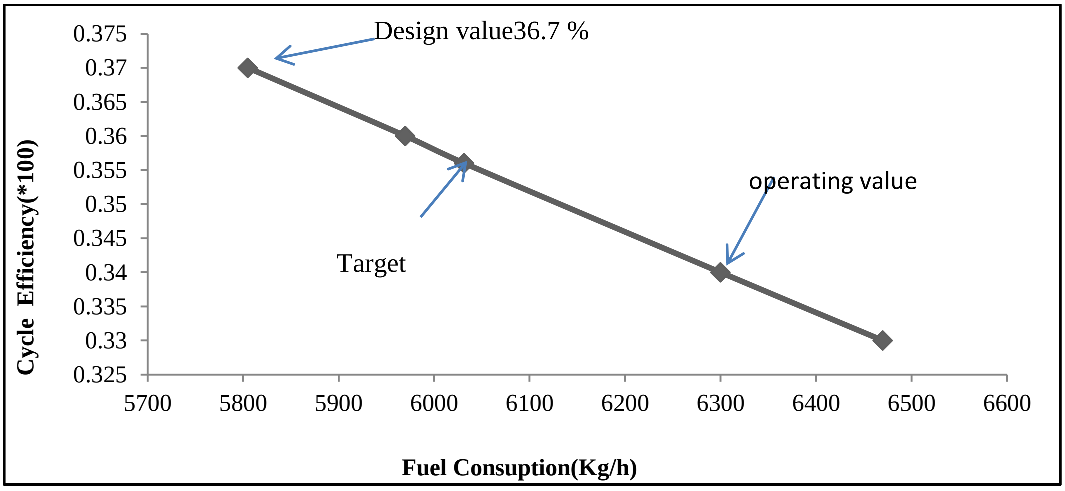

Figure 6 Cycle Efficiency v/s fuel consumption

It is not possible to achieve design parameter of condenser but target close to design parameter. When condenser pressure increase from its design valve, then outlet enthalpy of turbine also increase from its optimum value show in fig 3 and fig 4 indicate the relation between condenser pressure and heat rate of turbine. So it is clear the graph when increase the condenser pressure, heat rate also increase.

Table No 2 Comparison between operating & target parameter

Parameter	Operating	Target
Condenser vacuum	612mmhg	661mmhg
Turbine back pressure	0.21bar	0.14 bar
Turbine work	884.9kW	925.7kW
Cycle Efficiency	34%	35.60%
Specific steam consumption	30.53TPH	29.16TPH
Steam Rate	4.068 kg/kWh	3.88kg/kWh
Heat rate of turbine	10566.22 kJ/kWh	10094.5kj/kWh
fuel consumption	6300 kg/h	6031.6kg/h

Effect on Plant Economy

Reduction in fuel consumption = 6300-6032 = 268 kg/h
Fuel price rate = Rs. 3400/tone = Rs. 3.4/kg
Therefore,
Reduce input cost = fuel Consumption × Price
= 268× 3.4
= 911.2 Rs/hr = 21868.8 Rs/day
= 21868.8×335 days
= 7326048 Rs/ year

Conclusion

Steam power plant strongly depends on its cold end operating conditions, where the condenser is the key of the heat exchange system. The pressure in the surface condenser will depend on condenser design, the amount of latent heat to be removed, cooling water temperature and flow rate, maintenance of the condenser and air removal system. In this paper influence of cooling water flow rate & condenser pressure is considered for power plant thermodynamic system .A Parametric and numerical calculation was done and if we increasing of cooling water flow rate to maintain the same heat transfer rate at higher vacuum in the condenser, and thus, to increase energy efficiency of the plant, is a good way in optimizing plant operation and 5% fuel saving and approximate 73 lacs /year. So it is essential to operate the condenser variable at their optimum level for better performance of entire power plant and it is clear that:

- Lower flow rate leads to increase the condenser pressure than design value & poor heat transfer will occur.
- Lower the condenser pressure tends to decrease power output of turbine.
- Lower the turbine output, higher the heat rate and higher the heat rate means lower the plant efficiency.

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