PERFORMANCE ENHANCEMENT OF COMBINED CYCLE POWER PLANT

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Abstract
Energy demand is increasing day by day. Power plants produces electricity by different means amongst combination of Gas turbine unit with steam turbine unit are being used widely in all over the world. It should be noted here that while producing electricity thermal efficiency of the power plants are quite poor. They are also the major polluters of the environment. Any conventional power plant receives fuel energy (F), produces work (W) and rejects 'non-useful' heat (QA) to a sink at low temperature. As per capita electricity consumption is increasing, pollution from these plants are serious issues to the society. In order to have good control on environmental pollution and to minimize the fuel input for a given work output some methods should be adopted which will lead the power plants to better efficiencies. This will clearly give economic benefit in the operation of the plant, minimizing fuel costs. Main benefit of the cogeneration power plant is increased efficiency due to better utilization of heat energy from the flue gases. Further there are more chances by which one can improve the performance of the power plant like reheating, regenerative heating and inter cooling. These three methods has been suggested for better performance and increased thermal efficiency. After suggesting the methods various calculations have been done and graphs are plotted which shows the comparison between simple cycle and methods given.

Keywords— Performance enhancement, Cogeneration, Reheating, Regenerative heating Inter cooling, Combined Cycle power plant.

I. Introduction

Power plants are considered as a heart of any country's growth because unless electrical power any country can't develop. Power generation scenario is different in different country in all over the world. India has majority of thermal power plants which are running on coal. 55% TO 58% of power produced is produced from coal based power plant. Every power plan is having two types of equipment. (1) Main (2) Auxiliary. Main equipments are like boiler and turbine while auxiliary equipments are like feed water pumps, condensate extraction pumps, air compressors etc. Main components are power producing device while auxiliary equipments are power consuming devices. While producing the power these auxiliaries requires some power which is known as auxiliary power consumption. Net power generation is reduced with high value of auxiliary power consumption. To increase net power generation efforts should be done either by increasing the performance of turbine and produce high amount of power or decreasing the auxiliary power consumption. Fig. 1 shows the power generation scenario of India. Majority of power generation is done with coal base power plant.

The auxiliary power consumption fall in the range of 2 to 5 % of actual generating capacity in combined cycle power plants.[1]

Auxiliaries are enlisted here which plays a key role in power consumption.

- Boiler feed pumps
- Condensate extraction pumps
- Compressors
- Cooling towers
- Water treatment systems Cooling water pumps
- Air conditioning systems etc.

In order to increase the performance of the power plant energy conservation should be done in various auxiliaries like pumps, compressors, air conditioning systems etc.

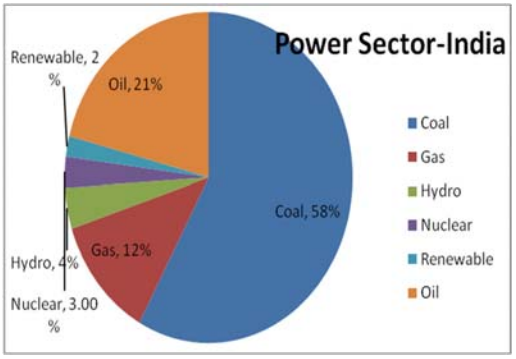

Fig. 1 Power Generation Scenario in India

II. Observations & Findings

When power plants are running on part load performance of the auxiliaries is very poor due to part load behavior. This makes the auxiliary power consumption considerably high. To reduce auxiliary power consumption efficiency of all those auxiliaries needs to be focused so that net power output of the power plant can be increased. In this paper mainly focus is given to pumps only as they are consuming large amount of power. Behavior of Boiler feed pumps and condensate extraction pumps is recorded.

For performance analysis design data are taken and actual data like discharge pressure, flow and current taken by the motor for driving the pump is recorded which is expressed in following table I. [2]

TABLE I

Pump Operational Parameters- Design and Actual

Parameter	Boiler Feed Pump		Condensate Extraction Pump	
	Design	Actual	Design	Actual
DISCHARGE PRESSURE (kg/cm^2)	173	88	26	26
DISCHARGE FLOW (m^3 /hr)	185	168	285	230
CURRENT (Amp.)	155	92	33	29

It was found that motor input power is considerably high even at less power output. After this some possible reasons are listed out due to which efficiency of the pump may be lower. Due to selection of oversized pump, faulty operation of combination of pumps, throttling, not accurate impeller diameter and more discharge pressure than required performance of pump may be poor.

III. Results & Discussion

For improving performance of pump two suggestions were given as (i) Trimming of Impeller (ii) Reducing the stages of pump.

A. *Trimming of Impeller*

Size of impeller matters a lot in pump performance. If impeller diameter is higher than what is required than it will require more power to run it as well as it will produce more head which is more than its required value. To overcome this difficulty diameter of impeller can be reduced by machining and desired value of head and discharge can be attained. [3]

It should be noted that after trimming of pump impeller geometric and kinematic similarity conditions may not completely preserved. Impeller width to outlet diameter ratio or impeller inlet to outlet diameter ratio may get change so there is possibility of not matching the geometric similarity as prior to impeller trimming. There are also chances of not matching the kinematic similarity as the blade angle varies with radius of impeller outlet diameter. In contrast to this some similarity conditions are satisfied also in many elements like shape of impeller, disposition and number of impeller blades etc. In affect to this authors have suggested trimming up to about 75% of a pump's maximum impeller diameter. [4] Trimming more than that amount results mismatching of impeller and casing. It was also found that with decrement of impeller diameter clearance between the impeller and the fixed pump casing increases. Due to which internal flow recirculation will increases considerably which is the main reason for head loss and the lower pumping efficiency. [5]

B. *De- staging of Pump*

For reducing the energy added to the system fluid pump stages should be reduced. In pump de-staging one or more impeller from the multistage pump is generally removed. By pump destaging useful correction of pumps can be achieved through changes in system loads which are oversized for their application. Pump de-staging offers the performance curve to be moved upward, achieving roughly the same effects as modification of the diameter. In de-staging of pump number of stages reduces, which in turn directly lowers the amount of energy imparted to the system fluid and lowers both the flow and pressure generated by the pump in stages.

After looking above data calculation were done. It was found that boiler feed pumps and condensate extraction pumps are not running at their design efficiency operating at far from its best efficiency point.[6]

Boiler Feed Pump output power,

Po = □ * g * Q * H

= [910.74 (kg/m3)*9.8 (m/s2)*168 (m3/hr) *700(m)] = 292 KW

Boiler Feed Pump input power,

Pi = 1.73* V * I * COS ϕ

= 1.73 * 6600(V) * 92.07(Amp.) * 0.9

= 946 KW

Condensate Extraction Pump output power,

Po = □ * g * Q * H

= 991 (kg/m3) * 9.8 (m/s2) *230 (m3/hr) *260.3(m)

= 162 KW

Condensate Extraction Pump input power,

Pi = 1.73* V * I * COS ϕ

= 1.73 * 6600(V) * 29 (Amp.) * 0.9

= 297KW

After calculating the pump input power and hydraulic output power it was found that pumps are running far from its best efficiency points (BEP) and performance of the pump were poor. It can be seen in following table II.

TABLE II
Performance Analysis - Design and Actual

Parameter	Boiler Feed Pump		Condensate Extraction Pump	
	Design	Actual	Design	Actual
Power (KWh)	1024	292	260	162
Efficiency (%)	73	32	73	58

Suggestions are implemented and pumps are modified according to that in order to achieve high efficiency. In boiler feed pump impeller was trimmed and in condensate extraction pump de staging was adopted. It is also necessary to check whether these modifications are viable or not. In order to check economic viability some indices like Simple Payback Period (SPP) and Annual Savings have been calculated. After looking to the results it was found that Simple payback period was very less almost near to 6 months in both impeller trimming and de staging.

After implementation of impeller trimming and de staging annual savings are again calculated with existing parameters.

In Boiler feed pump impeller trimming was done.

Energy saving after Impeller trimming = 46 kW

Energy savings per Year = saving per hour *hours per day *total day* availability factor* unit cost

= 46 * 24 * 365 * 0.85* 3

(Considering 3 Rs. as selling prize of 1 unit)

= 1,027,548 INR

While in condensate extraction pump de staging of multi stage pump was carried out.

Energy saving after de staging = 154

kW Energy savings per Year =

saving per hour *hours per day *total day* availability factor* unit cost

= 154 * 24 * 365 * 0.85* 3

(Considering 3 Rs. as selling prize of 1 unit)

= 3,440,052 INR

Simple payback period (SPP) was also calculated for both of the pumps. In case of impeller trimming it was about 4 months and de staging it was merely 1.5 months. Looking to the above values both suggestions are found feasible.

However it was found that values of annual savings before and after implementation are not exactly matching. But overall we are getting the benefits of considerable amount of annual savings and hence whole work is practically viable.

I. Conclusion

After study of operating parameters of pumps it was found that main reason behind poor performance of the pumps is off design operating conditions.

Part load efficiency of the pumps are considerably low. Throttling, bed operational combination of pumps or selection of oversized pump may be the reason for poor performance.

For improving efficiency of pumps impeller trimming and de staging of multi stage pump is suggested. Based on economic analysis both suggestions were found suitable and practically Implemented.

References

[1] A. Franco, C. Casarosa, (2003). On some perspectives for increasing the efficiency of combined cycle power plants, Applied Thermal Engineering 22 (13), 1501–1518.

[2] Tejas N Raval, Nirma University, Ahmedabad,(2010). Thesis on Optimization of Auxiliary Power Consumption of a Combined Cycle power plant.

[3] G. Singh, J.W. Mitchell, (1998) Energy savings from pump impeller trimming, ASHRAE Journal 40 (4), 60–63.

[4] A.Y. Maurice, I. Weybourne,(2001) Improving the energy efficiency of pumping systems, J. Water SRT - Aqua 50, 101–111

[5] L.M. Tsang, 1992. Theoretical account of impeller trimming of the centrifugal pump.Proc. of the Institution of Mechanical Engineers, Part C, J. Mech. Eng.Sci.206(3). [6] Fact sheet. Energy efficiency in air pumps (2004) Department of energy.