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Heat Rate Improvement in Utility Power Plants through Steam Turbine Performance Optimization

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This paper describes the performance enhancement of steam turbines. Various energy conservation measures, such as steam path audit, vacuum improvement in condenser, turbine retrofits, feed heater performance improvement, etc. are discussed. Study results show that the improvement in operating turbine efficiency will lead to a quantum improvement in unit heat rate from 25 kcal/kWh to 225 kcal/kWh.

1.0 INTRODUCTION

The present installed capacity of power generation in India is 200 GW (31-03-2012), out of which 65.44 % is through thermal generation [1]. The national average plant load factor is 77.68 % [2]. National weighted average operating overall station heat rate (SHR) is 2618.2 kcal/kWh against the design SHR 2347.9 kcal/kWh [3].

The observed deviation in the operating SHR from design SHR is mainly due to deviation in the operating performance of

- Turbine
- Boiler
- Auxiliary system
- Steam consumption
- Other external parameters such as deteriorating coal quality, ambient conditions, etc.

2.0 TURBINE AND ASSOCIATED SYSTEM

Study was carried out on turbines of capacity ranging from unit size of 30 MW to 500 MW. The performance analysis of various system is given in the following sections.

2.1 Turbine

Typical design and operating turbine efficiency distribution with different unit sizes, are given in Table 1. Variation of turbine efficiency with plant load is shown in Figure 1. Turbine efficiency increases with the unit size. The variation in operating efficiency from design turbine

TABLE 1
TURBINE EFFICIENCY IN UTILITY COAL-FIRED THERMAL POWER STATIONS

Particular	30–55 MW units		110–140 MW units		210 MW units		500 MW units	
	Design	Operating	Design	Operating	Design	Operating	Design	Operating
Maximum	38.19	35.87	42.25	39.31	46.06	44.67	44.21	42.28
Minimum	34.47	31.03	41.69	32.16	41.55	39.11	41.53	39.49
Average	36.33	33.14	41.92	35.04	43.15	40.53	43.06	41.03

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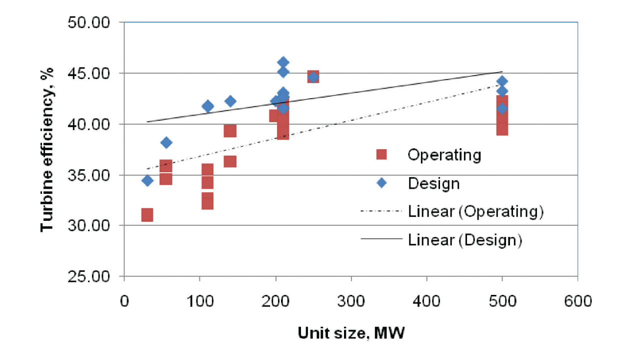

FIG. 1 VARIATION OF TURBINE EFFICIENCY WITH PLANT LOAD

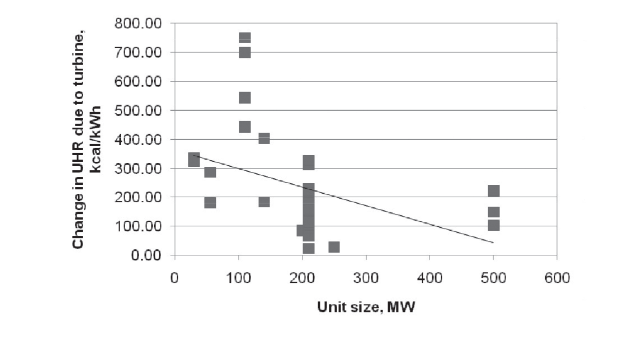

FIG. 3 VARIATION OF CHANGE IN UHR DUE TO TURBINE-RELATED LOSSES WITH UNIT SIZE

efficiency is large in smaller units of capacity 30–110 MW units, moderate in 210–250 MW units and minimal in 500 MW units. The trend shows the advances made in the design and due to aging of old smaller capacity units.

The turbine specific steam consumption (SSC) variation with unit size is given in Figure 2. The design SSC of 210 MW units varies from 2.96 t/MWh to 3.17 t/MWh. The operating SSC for 210 MW units varies from 3.01 t/MWh to 3.40 t/MWh. The design SSC of 500 MW units varies from 3.05 t/MWh to 3.29 t/MWh. The operating SSC of 500 MW units varies from 3.02 t/MWh to 3.16 t/MWh.

Variation of change in unit heat rate due to turbine-associated losses for different unit size is shown in Figure 3. The deviation varies from 23 kcal/kWh to 750 kcal/kWh for unit size from 30 MW to 500 MW. The trend shows that the deviation is more in the old smaller capacity units. The overall average deviation in UHR due to turbine-associated loss is accounting to 235 kcal/kWh.

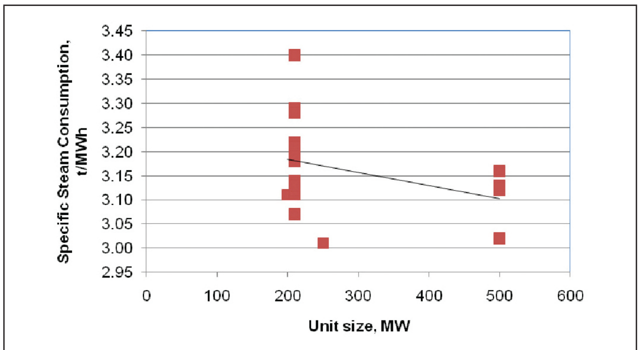

FIG. 2 VARIATION OF SPECIFIC STEAM CONSUMPTION OF TURBINE WITH UNIT SIZE

The estimated improvement in turbine cylinder efficiency is 6–7 % points and 2.5–3.0 % overall turbine efficiency due to adaption of 3D design blading in turbines [4,5].

Common problems observed in turbines are the poor performance of the turbines due to deteriorated internal conditions, deposits in blades and flow paths, etc. The recommended measures to improve the performance of the turbines are:

(a) regular study of temperature and pressure profile across the turbine.

(b) steam path audit to quantify deterioration in heat rate at every stage of the turbine.

(c) retrofits wherever necessary.

(d) adapting changes to the existing blade profiles with advanced 3D stage specific blades and 3D modeled exhaust diffuser.

(e) improved turbine sealing.

(f) endoscopy examination of blading without opening the turbine casing.

(g) control of reheat spray quantity, etc.

2.2 Condenser

Condenser-related problems observed are:

(a) poor vacuum.

(b) higher TTD.

(c) uncontrolled cooling water flow.

(d) higher differential pressure in cooling water side between passes of condenser, etc.

The recommended measures to improve the performance of the condenser are:

(a) online condenser cleaning,

(b) scale and biological control dozing of cooling water (CW),

(c) improving the cooling tower performance to maintain the CW water temperature at par with the design value at entrance of condenser,

(d) performing condenser vacuum drop test.

(e) acid cleaning of condenser tubes.

2.3 Feed Water Heaters

In feed water heaters, the common problems observed are:

(a) sub-optimal performance of HP heaters.

(b) poor TTD.

(c) higher degree of super heat steam entering HP heaters, etc.

Normally, the design TTD of HP heaters varies from 0 to –2 °C and in most cases, it will be negative. The negative TTD indicates that the entering steam is at super heat. Few of the 210 MW and 500 MW units studied showed a higher negative TTD value. This indicates that the extraction steam to that particular heater enters at a very high degree of super heat than its design condition. This high negative TTD calls for critical examination of turbine stages, as the work is not getting converted usefully as it is indented for and leaving the steam at higher temperature and pressure than its design condition.

Recommended measures to improve the performance of the feed water heaters are:

(a) periodic cleaning of the tube nests.

(b) critically monitoring the performance of each feed heaters and conducting regular performance audit.

(c) proper venting of heaters to avoid air blanketing, etc.

2.4 Other Performance Improvement Options

Other energy efficiency improvement options are:

(a) valves such as main steam, hot reheat turbine inlet valves, bypass valves, high-energy drain valves, etc., need to be critically examined during overhaul/shutdown for any internal damages, etc.

(b) changing over the auxiliary steam header charging from cold reheat line instead from mains steam line.

(c) providing temperature sensors with indicators at downstream side of high-energy drains is an option to control any valve passing in such lines.

(d) routine condition assessment of main steam, reheat steam piping, valves, main steam flow paths and sealing passages, governing system, condenser, feed water heaters, etc.

3.0 CONCLUSION

Turbine efficiency plays a vital role in the unit heat rate. A very marginal change in the turbine efficiency affects the unit heat rate. Various performance improvement options such as steam path audit, vacuum improvement in condenser, turbine retrofits, feed heater performance improvement will lead to overall heat rate improvement ranging from 25 to 225 kcal/kWh.

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