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Effect of water side deposits on the energy performance of coal fired thermal power plants

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Abstract

This paper presents the effects of water side deposits in the 210 MW coal fired thermal power plant components (viz., boiler, turbine, feed water heaters, condensers and lube oil coolers) on the energy efficiency of these components and that of the overall system at 100% maximum continuous rating (MCR). The origin, composition and rate of build up of deposits on the water side are presented. A linear growth rate of deposits is assumed for simplicity. The effects of the reduction in heat transfer, increased pressure drop and increased pumping power/reduced power output in the components are quantified in the form of curve fits as functions of the deposit thickness (μm). The reduction in heat transfer in the boiler components is in the range of 0.2–2.0% under normal scaling. The increased pumping power is of the order of 0.6–7.6% in the boiler components, 29% in the BFP circuit, 26% in the LPH circuit, 21% in the HPH circuit and 18% in the lube oil cooler circuits. The effects on the overall coal fired plant is quantified through functional relations between the efficiencies and the notional deposit thickness. The sensitivity indices to the notional deposit thickness are: boiler efficiency: −0.0021% points/μm, turbine circuit efficiency: −0.0037% points/μm, auxiliary power efficiency: −0.00129% points/μm, gross overall efficiency: −0.0039% points/μm and net overall efficiency: −0.0040% points/μm. The overall effect of scale build up is either increased power input of ∼68 kW/μm (at a constant power output) or decreased power output ∼25 kW/μm (at a constant power input). Successful contaminant control techniques are highlighted. Capacity reduction effects due to water side deposits are negligible.

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1. Introduction

Contamination control in thermal power plants is a stringent operational requirement that is essential for managing the power plant assets optimally. The main water contamination (demineralized water, bearing cooling water and auxiliary cooling water) results from:

(a) Inadequately treated water streams originating from poor quality of input stream, operation/maintenance problems of water purifying/transferring/pumping equipment, inability to handle transients, damaged moisture separators/deaerator/spray nozzles etc.
(b) In leak of condenser cooling water into demineralized water stream.
(c) In leak of raw water into auxiliary cooling water stream.
(d) Boiler carryover (physical entry of chemicals into steam during evaporation).
(e) Boiler hideout (deposition of chemicals used for contaminant control).
(f) Corrosion products of copper alloys from the pre-boiler systems (feed water heaters and condenser).
(g) Injection of main and reheat sprays into steam for attemperation.

Water contamination results in scaling (crystallization of dissolved substances from the flowing fluid onto the flow surfaces) on internal surfaces of the water/steam pressure parts of the boiler, turbine, regenerative feed water heaters, condenser, lube oil coolers etc. Deposit build up primarily depends on the water/steam composition, flow velocities (optimal velocities [1]: 0.5–4.0 ms^{-1} for water, 20–50 ms^{-1} for saturated steam and 40–80 ms^{-1} for superheated steam), tube substrate and the temperature of operation. As a rule of thumb, in power plant practice, deposits up to 100 μm are considered as inconsequential. Deposits in the range 100–300 μm are designated as moderate. Deposits in excess of 300 μm are viewed as desirous of attention for clean up for sub-critical boilers. For supercritical boilers, the upper limit between clean up intervals is 150 μm [2].

The characteristic properties of water side deposits can be represented by the ratio [3],

$$\phi = [\text{volume of deposit/volume of metal destroyed}]$$

If $\phi < 1$, the deposit is porous and useless. If $\phi > 2$, internal stresses tend to rupture it, causing uneven deposition with no benefit towards corrosion protection. If $1 < \phi < 2$, it is capable of providing corrosion resistance, but the effect is offset by the reduction in heat transferring capacity.

The effects of deposition can be quantified as follows:

- Decreased heat transfer in the boiler, feed heaters, turbines, condenser, auxiliaries and secondary cooling circuits. The thermal conductivity of heat exchanger tubing of thermal plants [4] is as follows:
  - Carbon steels: 28–32 $W\,m^{-1}\,K^{-1}$.
  - Alloy steels: 24–30 $W\,m^{-1}\,K^{-1}$.