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Steam System Optimization in coal-fired Thermal Power Plant

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Abstract— **T Industrial studies reveal that the poorly sustained steam systems waste around 15% to 30% of the steam energy generated. Energy is wasted in leakage in failed traps, radiation loss through bare pipes and the condensate losses which in-turn reduces boiler load contributing to fuel savings. Proper insulation reduces distribution losses leading to the optimum use of fuel burnt to generate the steam for the design load. Fixing the traps reduces considerable amount of condensate waste This involves huge unwanted cost for fuel burning, water treatment involved in make-up water consumption every year.**

Keywords— **Steam, Optimisation, Conservation, Efficiency**

I. INTRODUCTION

The industrial world invades a significant role of global energy consumption and in emissions of Carbon di-oxide as the steam systems play an important role in heating systems and in power sector. According to the International Energy Agency (IEA), the industry operates at only half of its potential energy efficiency: "The energy intensity of most industrial processes is at least 50 % higher than the theoretical minimum determined by the laws of thermodynamics" [1]. The objective of this paper is to analyse steam system of a coal fired thermal power plant and evaluate their system efficiencies by invading the inefficiencies involved in the process pathway conversion. This paper focuses on the energy saving measures involved in a boiler system related to combustion, heat transfer process, and the quality of working fluid used in the steam system.

II. STEAM SYSTEM: THE ENGINE OF THERMAL POWER PLANT

Steam system in a thermal power plant converts water into steam using heat from burning coal by the process of combustion in the furnace of the boiler. The schematic of a thermal power plant is shown below in Figure 1.

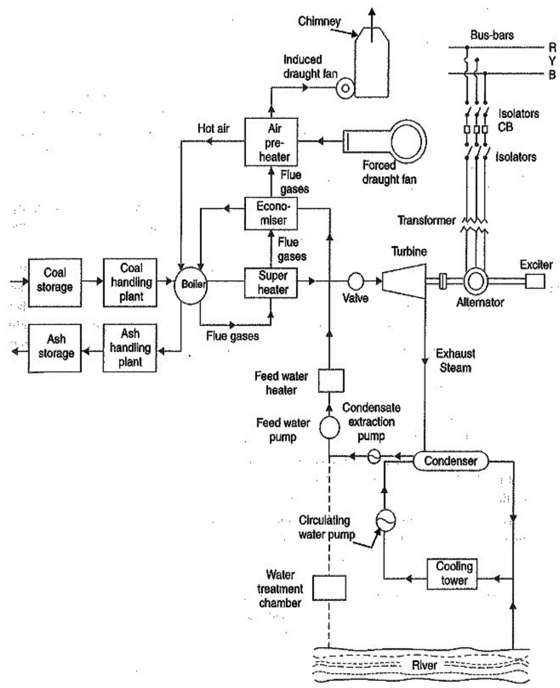

FIGURE .NO.1 SCHEMATIC OF A THERMAL POWER PLANT

A. The Process of Steam Generation

The High pressure steam is generated by the process of converting high pressure water in to high pressure steam by the process of combustion through the four series discussed below:

Preheating in an Economiser :

Water entering the boiler in preheated in a heat exchanger by hot flue gases which otherwise will be released to atmosphere. Thus the heated water entering boiler saves the fuel to be burnt otherwise.

Evaporation in the Water Walls and Drum:

The thermal energy generated by burning coal turns the liquid hot water into saturated steam inside the tubes, which are the water walls of a boiler.

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Superheating in a Super-heater:

The saturated steam formed the water tubes are heated well above the saturated temperature and thereby the saturated steam gets converted to superheated steam.

Turbo-generator:

The high pressure steam form the super heater flows in the tubes to spin the steam turbine and thus mechanical energy produced gets converted to electricity.

B. The Power Expansion Process

The thermal energy stored in the steam is converted to mechanical energy. The following Closed Loop pathway of steam is accounted for water and steam circuit : Boiler-Super-heater – valve- Turbine-Condenser- Condensate Extraction Pump- Feed Water Pump- Feed Water Heater-Economiser- Boiler shown in Figure 2.

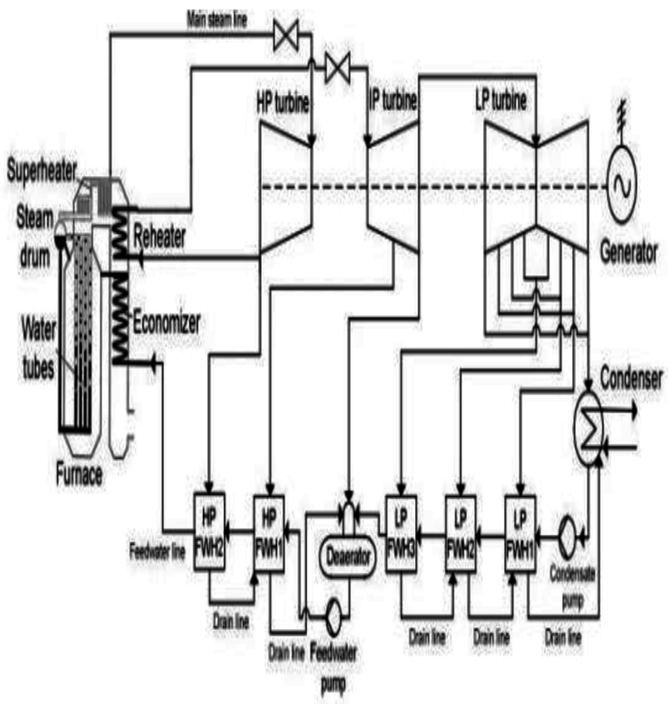

FIGURE NO.2 WATER AND STEAM CIRCUIT

High-Pressure Turbine:

High Pressure steam expands rapidly against the turbine blades and the shaft rotates at high speed.

Re-heater:

The exhaust from the high pressure turbine is routed back to re-heater to increase the temperature of the steam.

Intermediate-Pressure Turbine:

The steam from the re-heater axially flows to the intermediate turbine inner casing from above and below through two inlet nozzles flanged to the midsection of the outer casing. This opposed double flow in these two sections compensates axial thrust.

Low-Pressure Turbine:

The exhaust steam form the Intermediate turbine continue expanding across the low pressure turbine and exit at a very low pressure to the condenser.

C. The process of Steam Distribution:

An efficient steam distribution system is important to distribute steam properly at the right quality and quantity through the steam distribution system.

The Super heated Steam generated in the boiler is conveyed through the main steam line to the inlet of the High pressure turbine where it expands in stages and mechanical work is obtained in the shaft. There are branch pipes which distribute the steam to other equipments in the power plant.

III. STEAM SYSTEM OPTIMIZATION

The major scope for improving efficiency in a steam system is in the utilisation of steam. The improvement on the combustion efficiency in generation side [2],[3],[4],[5],[6],[7] is done using optimizing end-user with heaters and enhancing heat recovery through an economizer. The various factors during operation of a boiler and a steam turbine are discussed below:

A Factors during operation of Boiler

Excess Air Impacts Boiler Efficiency:

Sufficient air is needed to ensure stable combustion. Uncontrolled air leads to increase in boiler heat loss and thereby reduced boiler efficiency. The challenge for every boiler operator is to maintain the optimised air for complete combustion of fuel. Complete combustion occurs when fuel completely gets oxidised. Perfect air-fuel mixing is not always possible due to variations in fuel quality and quantity with various operating load conditions. A small increase in excess air in boiler operation can reduce overall efficiency by 1–2%.

Combustion Air Preheat:

An air pre-heater is used to preheat the air entering the boiler for combustion. The heat exchange is by the heat of the flue gases which otherwise would be wasted.

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The incoming air if raised to 20OC increases the thermal efficiency by 1%.

Incomplete combustion:

In-complete combustion happens when fuel does not burn fully and unburned carbon remains. It is easily identified by smoke and actions can be taken immediately to ensure complete combustion of fuel.

Control of fineness of pulverised fuel:

Optimising the coal pulveriser mill system includes adjusting classifier speeds and managing air to coal ratios with proper maintaining of particle size distribution. This minimizes the unburned carbon and thereby the use of auxiliary power consumption.

Ensure Soot blowing:

Wall blowers should be used periodically to remove molten slag directly from water-wall tubes. Long retractable soot blowers are used in high temperature convection zones to avoid damage from heat. 3mm build up of soot can increase fuel consumption around 2.5%. Cleaning water walls reduce the furnace exit gas temperature.

Minimising Air leakage:

Air leakage into furnace changes the stoichiometric ratios leading to unburned fuel. Lowering the air leakage conserves energy by prevention of cooling of hot gases and thereby reduces auxiliary power consumption.

Stack Temperature:

High stack temperature leads to escape of sensible heat through the chimney. Hence lowering of the same is to be monitored. An optimal balance of the temperature avoids acid dew-point corrosion at the chimney.

B Factors during operation of Turbo-Generator

Controlling the throttle losses:

By adoption of sliding pressure operation, the throttle losses are controlled. The pressure drop occurs when steam drops through the partially closed throttle valve without doing useful work.

Optimising condenser performance:

The condenser performance if optimised by maintaining a proper vacuum saves enormous amount of energy, which improves the overall heat rate. Tube cleaning should be done periodically to remove debris and algae growth. The debris filters should be cleaned in order to maintain the differential pressure across the cooling system.

Optimising feed heaters performance:

The performance of Feed water heater if optimised conserves energy as it directly involves in reducing the fuel consumption. The overall cycle heat rate is improved as the feed water temperature during its travel form the condenser to the steam drum gets raised.

Reduction in make-up water consumption:

The leakage in the pipes and valve should be arrested regularly. 0.1% rise in Demineralised make-up water increases the generation costs of the thermal power plant. Mass balance should be done periodically to find the hidden losses in the steam-water cycle.

IV. CONCLUSION

This study throws a light towards optimisation of steam systems, stressing the need of energy conservation at all junctures and the cumulative increase in overall efficiency of the thermal power plant. By adopting a systematic approach towards steam optimization, substantial savings could be obtained.

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