Lecture 2.17

Plant Auxiliary Systems and Circuits

Agenda

- Introduction to Auxiliary Systems
- Fuel and Ash Handling Systems
- Air Supply and Flue Gas Circuits (Draft Systems)
- Feedwater and Steam Circuits
- Condensers and Cooling Water Systems
- Steam Turbine Lubrication Systems

Introduction to Plant Auxiliary Systems

- **Definition:** Subsystems required to operate the main energy conversion equipment (boiler, turbine, generator).
- **Key Functions:** Material transport (coal, water, air), waste removal (ash, exhaust gases), and equipment protection (lubrication, cooling).
- **Auxiliary Power Consumption (APC):** Typically 6-8% of total gross generation in modern coal-fired plants.
- **Reliability Dependency:** Failure in any major auxiliary (e.g., Boiler Feed Pump) leads to immediate unit trip or deration.

Fuel Handling System (FHS)

- **Purpose:** Receive, prepare, store, and transport coal to the boiler bunkers.
- **Coal Unloading & Storage:** Wagon tipplers, track hoppers, stacker-reclaimers for stockpile management (dead and live storage).
- **Coal Preparation:** Magnetic separators remove tramp iron; primary and secondary crushers reduce coal size to ~20 mm.
- **Conveying:** Extensive belt conveyor networks equipped with dust suppression, fire protection, and belt weighers.
- **Milling:** Final pulverization in coal mills (bowl mills or ball mills) to fine powder (70% passing through 200 mesh) before conveying to burners.

Ash Handling System (AHS)

- **Bottom Ash Handling:** Heavy ash falling to the furnace bottom. Handled via water-impounded hoppers, clinker grinders, and hydraulic sluicing or mechanical drag chain conveyors.
- **Fly Ash Handling:** Fine ash carried by flue gas, collected in Electrostatic Precipitators (ESP) or baghouses (accounts for ~80% of total ash in pulverized coal).
- **Pneumatic Conveying:** Fly ash is transported dry using vacuum or pressure pneumatic systems to storage silos.
- **Ash Utilization:** Dry fly ash is dispatched for cement manufacturing and construction; residual slurry is pumped to ash ponds.

Air Supply Circuit: Draft Systems

- **Balanced Draft System:** Maintains furnace pressure slightly below atmospheric (-10 to -20 mmWC) to prevent hot gas leakage.
- **Forced Draft (FD) Fan:** Supplies ambient air for combustion. Forces air through the Air Preheater (APH) into the windbox.
- **Primary Air (PA) Fan:** Supplies high-pressure air to dry coal in the pulverizer and transport pulverized coal to the burners.
- **Air Preheater (APH):** Recovers heat from flue gas to preheat incoming combustion air, improving thermal efficiency and aiding coal drying.

Flue Gas System & Emission Control

- **Induced Draft (ID) Fan:** Extracts flue gas from the furnace and exhausts it to the chimney, maintaining the negative furnace pressure.
- **Gas Path Sequence:** Furnace \ensuremath{\rightarrow} Superheaters/Reheaters \ensuremath{\rightarrow} Economizer \ensuremath{\rightarrow} Air Preheater (APH) \ensuremath{\rightarrow} Electrostatic Precipitator (ESP) \ensuremath{\rightarrow} Flue Gas Desulfurization (FGD) \ensuremath{\rightarrow} ID Fan \ensuremath{\rightarrow} Chimney.
- **Electrostatic Precipitator (ESP):** Uses high DC voltage to ionize and collect fly ash particles with up to 99.9% efficiency.
- **Flue Gas Desulfurization (FGD):** Wet limestone scrubbers remove SO2 emissions before the gas reaches the stack.

Feedwater and Steam Circuit Overview

- **The Closed Loop:** Demineralized water is continuously cycled through phase changes. Condenser \ensuremath{\rightarrow} Feed Pumps \ensuremath{\rightarrow} Heaters \ensuremath{\rightarrow} Boiler \ensuremath{\rightarrow} Turbine \ensuremath{\rightarrow} Condenser.
- **Condensate Extraction Pump (CEP):** Pumps condensed water from the condenser hotwell through low-pressure (LP) heaters.
- **Deaerator:** An open heater that mechanically removes dissolved oxygen and non-condensable gases from the feedwater by heating it to saturation temperature with extraction steam.
- **Chemical Dosing:** Hydrazine and ammonia are added for oxygen scavenging and pH control to prevent corrosion.

High-Pressure Feedwater System

- **Boiler Feed Pump (BFP):** The heart of the feedwater system. Boosts feedwater pressure significantly above boiler drum pressure (e.g., to 200-300 bar in supercritical plants).
- **BFP Drives:** Often driven by dedicated auxiliary steam turbines (BFP-T) rather than electric motors to save auxiliary power consumption.
- **High-Pressure (HP) Heaters:** Closed heat exchangers downstream of the BFP. Utilize high-pressure extraction steam from the turbine to further preheat feedwater.
- **Economizer Entry:** Feedwater enters the boiler economizer near saturation temperature, minimizing thermal shock and latent heat requirements in the furnace.

Condenser Systems

- **Function:** Condenses exhaust steam from the Low-Pressure (LP) turbine, creating a high vacuum (down to 0.1 bar absolute) to maximize turbine expansion work.
- **Surface Condensers:** Shell and tube heat exchangers. Steam condenses on the outer surface of tubes while cooling water flows inside.
- **Vacuum Maintenance:** Steam Jet Air Ejectors (SJAE) or mechanical vacuum pumps continuously remove non-condensable gases leaking into the condenser.
- **Condenser Tube Materials:** Typically titanium or stainless steel to resist corrosion and erosion from cooling water and high-velocity steam.

Cooling Water System

- **Cooling Water (CW) Pumps:** Massive vertical pumps supplying enormous volumes of water to the condenser to absorb the latent heat of condensation.
- **Once-Through Cooling:** Uses river or sea water directly, discharging warmer water back. High environmental impact.
- **Closed-Loop Cooling Towers:** Warm water from the condenser is sprayed into cooling towers (Natural Draft or Induced Draft).
- **Evaporative Cooling:** Heat is rejected to the atmosphere primarily through the evaporation of a small fraction (1-2%) of the circulating water.
- **Make-up Water:** Required to compensate for evaporation, drift, and blowdown losses in the cooling tower circuit.

Steam Turbine Lubrication System

- **Purpose:** Provides clean, cooled oil to turbine and generator journal and thrust bearings to prevent metal-to-metal contact and dissipate heat.
- **Main Oil Pump (MOP):** Driven directly by the turbine shaft during normal operation to supply lubricating oil.
- **Auxiliary and Emergency Pumps:** AC motor-driven Auxiliary Oil Pump (AOP) for startup/shutdown. DC motor-driven Emergency Oil Pump (EOP) for safe coast-down during total AC power failure.
- **Oil Coolers & Purifiers:** Shell-and-tube heat exchangers cool the hot return oil. Centrifuges continuously remove moisture and particulate contaminants.
- **Jacking Oil System:** High-pressure oil injected under the bearings to lift the heavy rotor during low-speed barring (turning gear) operation, preventing boundary lubrication wear.

Summary

- **Fuel and Ash Systems:** Handle massive bulk material flows, preparing coal for combustion and managing dry/wet ash disposal.
- **Draft Systems:** FD, PA, and ID fans manage the air and flue gas paths, ensuring safe furnace pressure and driving flow through emission controls (ESP/FGD).
- **Feedwater/Steam Circuit:** Cycle efficiency relies heavily on high-pressure BFP, regenerative feed heating, and effective deaeration.
- **Cooling Systems:** Condensers create essential vacuum, while cooling towers reject enormous latent heat to the atmosphere.
- **Lube Oil Systems:** Critical mechanical protection for high-speed rotating equipment, featuring redundant AC/DC pumping architectures.

Next Lecture Preview

- Topic: Plant Performance and Efficiency Optimization
- Understanding Heat Rate and Plant Load Factor.
- Thermodynamic losses in the steam cycle.
- Methods to improve overall plant efficiency and reduce auxiliary power consumption.