Lecture 5.42

Auxiliary Systems of Gas Turbine Plant

Agenda

- Introduction to Gas Turbine Auxiliaries
- Starting System Operation and Types
- Ignition System Mechanics
- Fuel System and Conditioning
- Lubrication System Layout
- Cooling and Sealing Systems
- Air Intake and Exhaust Systems
- Summary and Key Takeaways

Introduction to Gas Turbine Auxiliaries

- Auxiliary systems are vital support subsystems required for the safe, reliable, and efficient operation of the main gas turbine.
- They do not generate power themselves; rather, they consume a fraction of the plant's parasitic load.
- Key systems include: Starting, Ignition, Fuel, Lubrication, Cooling, and Intake/Exhaust systems.
- Failure or malfunction of any single auxiliary system will typically result in a turbine trip (shutdown) to prevent catastrophic damage.

Starting System: Purpose and Mechanics

- Unlike steam turbines, a gas turbine cannot self-start. The compressor must be rotated to provide sufficient airflow for combustion.
- The starting system accelerates the rotor from rest to a speed where the turbine produces enough work to drive the compressor (self-sustaining speed).
- Self-sustaining speed is typically around 30% to 50% of the rated synchronous speed.
- The starting device must overcome rotor inertia, bearing friction, and aerodynamic drag in the compressor.

Starting System: Types of Prime Movers

- Electric Motor Starters: Common in smaller or industrial units. Connects via a clutch that disengages once self-sustaining speed is reached.
- Diesel Engine Starters: Used for black-start capability or in remote areas without a reliable grid connection.
- Pneumatic (Air/Gas) Starters: Uses high-pressure air or natural gas expanded through a small starting turbine.
- Static Frequency Converters (SFC): Uses the main generator as a synchronous motor during startup by supplying it with variable frequency AC power. Common in large heavy-duty frame machines.

Ignition System

- Initiates combustion of the air-fuel mixture during the startup sequence.
- Utilizes high-energy, high-voltage spark plugs (igniters) located in specific combustion cans (typically two redundant igniters).
- Once ignition is established in the primary cans, flame propagation tubes (cross-fire tubes) carry the flame to the remaining combustion chambers.
- The ignition system is retracted or de-energized once combustion is confirmed via flame scanners (UV or IR detectors).

Fuel System: Liquid and Gas

- Responsible for delivering fuel to the combustors at the precise flow rate and pressure required by the load demand.
- Gas Fuel System: Includes knock-out drums (to remove moisture), gas scrubbers, heaters (to prevent condensation and ensure superheat), and gas control valves (SRV and GCV).
- Liquid Fuel System: Includes low-pressure forwarding pumps, filters, high-pressure primary pumps, flow dividers (to ensure equal flow to all nozzles), and atomizing air systems.
- Dual-Fuel capability requires complex valving to allow on-the-fly transfer between gas and liquid fuels.

Lubrication Oil System: Functions

- Provides hydrodynamic lubrication to the journal and thrust bearings of the turbine and generator.
- Acts as a primary coolant for the bearings, removing frictional heat and heat conducted from the turbine rotor.
- Supplies high-pressure hydraulic fluid for the actuation of control valves (e.g., fuel valves, Inlet Guide Vanes).
- Operates continuously during run-down (coasting) and on turning gear to prevent rotor bowing and bearing damage after shutdown.

Lubrication Oil System Layout

- Main Lube Oil Pump (MLOP): Usually shaft-driven, provides pressure during normal operation.
- Auxiliary Lube Oil Pump (ALOP): AC motor-driven, used during startup, shutdown, and as backup.
- Emergency Lube Oil Pump (ELOP): DC motor-driven from batteries, critical for safe coast-down if AC power fails.
- Lube Oil Coolers and Filters: Shell-and-tube or fin-fan coolers remove heat; duplex filters remove particulates (typically 10-25 microns).

Cooling and Sealing Air System

- Gas turbine firing temperatures (1200\ensuremath{^\circ}C - 1600\ensuremath{^\circ}C) far exceed the melting point of the turbine blade metallurgy.
- Cooling air is extracted from intermediate and discharge stages of the compressor.
- This air is routed through internal passages in the rotor and stator to cool the turbine nozzles and buckets (blades) via film and internal convection cooling.
- Sealing air prevents hot combustion gases from escaping into the bearing cavities and prevents lubricating oil from leaking into the gas path.

Air Intake and Filtration System

- Gas turbines consume enormous volumes of ambient air. Any particulates can cause compressor blade erosion or fouling, degrading efficiency.
- Intake systems typically feature multiple stages: weather louvers, coalescer pads (moisture removal), pre-filters, and high-efficiency particulate air (HEPA) filters.
- Anti-icing systems bleed hot compressor discharge air into the intake to prevent ice formation on the Inlet Guide Vanes (IGVs) in cold climates.
- Inlet chillers or evaporative coolers may be used to increase air density and thus increase turbine power output in hot weather.

Exhaust System

- Directs the hot exhaust gases (usually 500\ensuremath{\^\circ}C - 600\ensuremath{\^\circ}C) safely away from the turbine and operating personnel.
- Exhaust diffusers recover dynamic pressure and reduce exhaust velocity.
- Silencers are installed in the exhaust stack to mitigate the high-decibel, low-frequency noise generated by the turbine.
- In combined cycle or cogeneration plants, the exhaust is routed to a Heat Recovery Steam Generator (HRSG) via a diverter damper.

Summary

- Auxiliary systems are the life-support systems for the gas turbine.
- Starting systems accelerate the rotor to self-sustaining speeds using external power or SFCs.
- Fuel and Ignition systems coordinate to initiate and maintain controlled combustion.
- Lubrication systems protect bearings and actuate valves, with critical redundant DC pumps for emergencies.
- Cooling, Intake, and Exhaust systems manage thermal limits, air quality, and environmental noise.

Next Lecture Preview

- Next Topic: Cogeneration Power Plants
- Concept of Combined Heat and Power (CHP).
- Utilization of gas turbine exhaust in Heat Recovery Steam Generators (HRSG).
- Overall plant efficiency improvements through cogeneration.