Lecture 2.24

Turbine Control Mechanism: Governing of Steam Turbines

Agenda

- 1. Introduction to Turbine Governing
- 2. Purpose and Requirements of Control Mechanisms
- 3. Throttle Governing Mechanism
- 4. Nozzle Control Governing
- 5. Bypass Governing
- 6. Comparative Analysis of Governing Types
- 7. Emergency Governing and Safety
- 8. Summary and Next Lecture Preview

Introduction to Turbine Governing

- Governing is the process of regulating turbine speed and power output in response to varying load conditions.
- Generators connected to the grid must operate at a strict synchronous speed (e.g., 3000 RPM for 50 Hz, 3600 RPM for 60 Hz).
- As electrical load decreases, turbine speed tends to increase; as load increases, speed drops.
- The governing system dynamically adjusts the mass flow rate or pressure of steam entering the turbine to balance mechanical power generation with electrical demand.

Essential Components of a Governing System

- Speed Sensor / Flyball Governor: Detects variations in turbine shaft speed using centrifugal force.
- Relay / Servomotor Mechanism: Amplifies the weak mechanical signal from the governor into hydraulic force capable of moving massive steam valves.
- Control Valves: Regulate the physical flow or pressure of the steam entering the high-pressure turbine casing.
- Feedback Loop: Ensures stability by preventing over-correction (hunting) of the valve positions.

Throttle Governing Mechanism

- Operates by throttling (restricting) the steam before it enters the first stage of the turbine.
- Throttling is an isenthalpic (constant enthalpy) process. It reduces the steam pressure and thus the available enthalpy drop (work output).
- The mass flow rate of steam is directly controlled by the position of a single large throttle valve.
- At part loads, severe throttling occurs, leading to significant thermodynamic losses and reduced efficiency.

Characteristics of Throttle Governing

- Willans Line: The relationship between steam consumption (kg/h) and power output (kW) is linear for a throttle-governed turbine.
- Equation: $m = m_0 + k * P$ (where m = mass flow, P = power, m_0 = no-load flow).
- Advantages: Simpler construction, fewer control valves, suitable for small turbines where efficiency at part load is not a dominant concern.
- Disadvantages: High throttling losses at low loads; the steam state entering the turbine has lower availability.

Nozzle Control Governing

- Steam is admitted to the first stage (usually a Curtis wheel) through multiple, separate nozzle groups.
- Each group is controlled by its own dedicated valve. Governing is achieved by completely opening or closing individual nozzle groups.
- By avoiding partial throttling across the entire steam flow, the steam enters active nozzles at nearly full boiler pressure.
- This significantly reduces throttling losses at part loads compared to pure throttle governing.

Performance of Nozzle Governing

- The Willans line for nozzle governing is not a single straight line but a series of slightly curved segments.
- At the exact point where a valve is fully open (valve point), there is zero throttling loss for that nozzle group.
- Between valve points, minor throttling occurs through the valve that is actively modulating.
- Primarily used in impulse turbines; reaction turbines generally require full-arc admission and thus rely on throttle or bypass governing.

Bypass Governing

- Used when the turbine must generate power exceeding its normal economical continuous rating (maximum continuous rating - MCR) for short durations.
- Under maximum load conditions, the main throttle valve is fully open, but more steam is needed.
- A bypass valve opens, admitting fresh, high-pressure steam directly into later stages of the turbine (skipping the first few high-pressure stages).
- The later stages have larger flow areas capable of accommodating the increased specific volume and mass flow.

Comparative Analysis of Governing Methods

- Efficiency at Part Load: Nozzle Governing ¿ Throttle Governing.
- Mechanical Complexity: Nozzle Governing (high, multiple valves) ¿ Throttle Governing (low, single valve).
- Application: Nozzle governing is standard for high-capacity impulse turbines. Throttle governing is used in reaction turbines and smaller units.
- Overload Handling: Bypass governing is exclusively used for handling overload conditions beyond the capacity of the first stage nozzles.

Emergency Governing and Protection Systems

- An independent, fail-safe mechanism designed to shut down the turbine completely if normal governing fails.
- Overspeed Trip: Typically activates at 110% to 115% of rated speed. An unbalanced spring-loaded ring or bolt on the shaft flies out due to centrifugal force, striking a trip lever.
- Action: Instantly dumps hydraulic control oil, causing massive, heavy main stop valves to slam shut via powerful springs.
- Other trip conditions: Low lube oil pressure, high exhaust temperature, excessive rotor vibration, or generator electrical faults.

Summary

- Governing is essential for matching turbine power output to electrical load while maintaining synchronous speed.
- Throttle governing controls total flow via a single valve, causing high efficiency losses at part loads due to isenthalpic expansion.
- Nozzle governing uses multiple valves to control segments of the first stage, maintaining high pressure and efficiency across varying loads.
- Bypass governing allows for overload operation by admitting high-pressure steam to lower stages.
- Emergency governing systems provide critical protection against catastrophic overspeed events.

Next Lecture Preview

- Topic: Steam Condensers and Cooling Systems
- Understanding the critical role of the condenser in closing the Rankine cycle.
- Types of condensers: Surface vs. Jet condensers.
- Condenser efficiency, vacuum creation, and air extraction methods.
- Introduction to cooling towers and environmental thermal discharge.