Lecture 2.23

Turbine Control Mechanism: Governing of Steam Turbines

Agenda

- Introduction and Purpose of Turbine Governing
- Throttle Governing Principles
- Nozzle Control Governing Mechanisms
- Bypass Governing in High-Capacity Turbines
- Hydraulic vs. Electro-Hydraulic Governing Systems
- Governor Characteristics: Speed Droop and Regulation
- Emergency Overspeed Trip Mechanisms

Introduction to Steam Turbine Governing

- Governing is the process of regulating the mass flow rate of steam to match the turbine output with the generator load.
- Constant Speed Requirement: Grid-connected alternators must operate at a strict synchronous speed (e.g., 3000 RPM for 50 Hz grid).
- Load fluctuations demand immediate proportional changes in steam input to prevent frequency deviation.
- Primary components include the speed-sensing element (governor), relays/amplifiers, and the steam control valves (servomotors).

Throttle Governing Mechanism

- Mechanism: A single large throttle valve placed in the main steam line controls the entire steam flow entering the turbine.
- As load decreases, the valve partially closes, throttling the steam (isenthalpic expansion) before it enters the first stage nozzles.
- Effect on State: Throttling reduces the steam pressure (P1 to P2) at constant enthalpy, reducing the available isentropic heat drop.
- Disadvantages: Highly inefficient at part loads due to severe throttling losses; exit steam is highly superheated, wasting thermal energy.

Nozzle Control Governing

- Mechanism: The first stage (usually a Curtis wheel) nozzles are divided into groups (e.g., 4 to 6 groups).
- Each group is controlled by a separate, sequentially operated valve.
- Operation: At part load, instead of throttling all steam, one or more nozzle groups are completely shut off.
- Advantages: Steam enters the active nozzles at full boiler pressure; throttling losses are confined only to the fraction of steam passing through the actively modulating valve.

Part-Load Efficiency: Throttle vs. Nozzle Governing

- Willans Line Comparison: Plot of steam consumption (kg/h) vs. Load (MW).
- Throttle governing exhibits a linear relationship with a high no-load steam consumption intercept.
- Nozzle governing exhibits a stepped or scalloped curve, closely hugging the ideal minimum steam consumption line.
- At 50% load, nozzle governing can improve stage efficiency by 10-15% compared to pure throttle governing.

Bypass Governing for High-Capacity Turbines

- Mechanism: Used primarily for achieving peak overloads beyond the economical continuous rating.
- Steam bypasses the first one or two stages (which act as a bottleneck) and is injected directly into lower pressure stages.
- Operation: Primary valve fully opens up to economic load. For peak load, the bypass valve opens, admitting high-pressure steam downstream.
- Impact: Increases power output significantly but at a reduced efficiency, as bypassed steam does not perform work in the initial stages.

Hydraulic Governing Systems

- Traditional setup utilizes a centrifugal flyball governor driven by the turbine shaft.
- Speed changes alter the centrifugal force, moving a pilot valve piston.
- The pilot valve directs high-pressure hydraulic fluid (often fire-resistant control fluid, EHC) to a hydraulic servomotor.
- The servomotor amplifies the mechanical force to operate the massive, high-pressure steam control valves against steam pressure.

Electro-Hydraulic Governing (EHG)

- Modern standard for large thermal power plants (e.g., 500 MW - 800 MW units).
- Sensing: Magnetic pickups on the turbine shaft provide high-resolution digital speed signals.
- Processing: Microprocessor-based controllers execute complex PID control algorithms, integrating speed, load, and boiler pressure signals.
- Actuation: Electrical signals drive electro-hydraulic servo valves (EHSV) which in turn control the hydraulic actuators on the steam valves.

Governor Characteristics: Speed Droop

- Speed Droop (Regulation) is the percentage change in speed required to actuate the governor from no-load to full-load.
- Equation: Droop % = [(N_no_load - N_full_load) / N_rated] * 100
- Typical value for steam turbines is 4% to 5%.
- Necessity: A finite droop is essential for stable load sharing between multiple parallel-connected generators on a grid.

Isochronous vs. Droop Control

- Isochronous Control: Maintains absolutely constant speed regardless of load (0% droop). Only applicable to a single isolated generator or a designated grid master.
- Droop Control: Speed drops slightly as load increases. Used for all grid-tied units.
- Secondary Control (Load Reference Adjustment): The operator (or AGC) shifts the droop curve up or down to restore nominal frequency (50 Hz) after a load change.

Emergency Overspeed Trip Mechanism

- Function: An independent safety system designed to instantly shut off all steam if the turbine exceeds safe limits (typically 110% to 112% of rated speed).
- Mechanical Trip: An unbalanced spring-loaded eccentric bolt in the rotor flies out due to centrifugal force at trip speed.
- Action: Strikes a trip lever, rapidly dumping hydraulic trip fluid pressure.
- Result: Main Stop Valves (MSV) and Control Valves (CV) slam shut via heavy spring force within milliseconds.

Summary

- Turbine governing precisely matches steam input to electrical load to maintain grid frequency.
- Throttle governing is simple but inefficient at part loads; nozzle control governing significantly improves part-load efficiency.
- Bypass governing allows turbines to temporarily exceed nominal economic ratings.
- Modern plants utilize Electro-Hydraulic Governing (EHG) for superior speed, accuracy, and integration.
- A 4-5% speed droop is required for stable parallel operation, and independent overspeed trips are critical for safety.

Next Lecture Preview

- Topic: Condensers and Cooling Towers (Unit 3)
- Thermodynamics of steam condensation.
- Types of condensers: Surface and Jet condensers.
- Condenser efficiency, vacuum creation, and air extraction.