Lecture 5.40

Configuration of Diesel Power Plant

Agenda

- Introduction to Diesel Power Plants
- General Layout of a Diesel Power Plant
- Working Principle (Thermodynamic Cycle)
- Fuel Supply System
- Air Intake and Exhaust Systems
- Engine Cooling System
- Lubrication System
- Starting System
- Electrical Systems and Control
- Summary and Q&A

Introduction to Diesel Power Plants

- Diesel power plants use a diesel engine as the prime mover to drive an alternator.
- They operate on the Diesel cycle (compression-ignition), utilizing liquid fuel such as High-Speed Diesel (HSD) or Light Diesel Oil (LDO).
- Typically used for small to medium scale power generation (2 to 50 MW).
- Primary applications: Standby/emergency power, peak load plants, off-grid or remote location power generation, and mobile power units.
- Characterized by quick starting capability and high thermal efficiency compared to small steam plants.

General Layout of a Diesel Power Plant

- The core is the Diesel Engine coupled directly to the Generator (Alternator).
- Surrounding the prime mover are essential auxiliary systems:
- 1. Fuel Supply System (storage, filtration, injection)
- 2. Air Intake System (filters, superchargers/turbochargers)
- 3. Exhaust System (silencers, heat recovery)
- 4. Cooling System (water jackets, radiators/cooling towers)
- 5. Lubrication System (oil pumps, coolers, filters)
- 6. Starting System (compressed air or battery/electric)

Working Principle: The Diesel Cycle

- Diesel engines operate on a 4-stroke or 2-stroke compression-ignition cycle. Power generation typically uses 4-stroke engines for better efficiency.
- 1. Suction Stroke: Pure air is drawn into the cylinder.
- 2. Compression Stroke: Air is compressed to a high ratio (14:1 to 22:1), raising its temperature significantly above the auto-ignition temperature of the fuel (e.g., 500-700\ensuremath{\^\circ}C).
- 3. Power Stroke: Atomized fuel is injected at the end of compression. It auto-ignites, rapidly expanding and driving the piston down.
- 4. Exhaust Stroke: The exhaust valve opens, and the rising piston pushes out the burnt gases.

Fuel Supply System Configuration

- Function: To store, filter, and deliver fuel to the engine cylinders in exact quantities and at high pressure.
- Components: Main storage tank, day tank, transfer pump, strainers/filters, fuel injection pump, and atomizing injectors.
- Flow: Storage Tank -¿ Transfer Pump -¿ Filter -¿ Day Tank -¿ Injection Pump -¿ Injector -¿ Engine Cylinder.
- The Day Tank holds a daily supply of fuel and allows impurities to settle.
- Injection pressure must be extremely high (often ¿1000 bar) to ensure fine atomization for rapid and complete combustion.

Air Intake and Exhaust Systems

- Air Intake System:
- - Supplies clean air for combustion. Requires approximately 15-20 kg of air per kg of fuel.
- - Uses dry or oil-bath filters to remove dust, preventing cylinder wear.
- - Often includes a Turbocharger (driven by exhaust gases) to compress intake air, increasing power output and efficiency.
- Exhaust System:
- - Removes burnt gases safely from the plant.
- - Includes a Silencer/Muffler to reduce low-frequency noise.
- - Exhaust gases exit at 400-500\ensuremath{^\circ}C. Waste heat recovery boilers (cogeneration) can be used to generate low-pressure steam or hot water.

Engine Cooling System

- Purpose: To maintain the cylinder head, block, and pistons at safe operating temperatures, preventing thermal failure and maintaining oil viscosity.
- Only about 35-40% of fuel energy converts to shaft power; much of the rest is heat.
- Components: Water jackets around cylinders, water pumps, cooling towers or radiators, and raw water/soft water heat exchangers.
- Closed-loop system: Treated (demineralized) soft water circulates through the engine to prevent scaling.
- Secondary loop: Raw water cools the soft water via a heat exchanger and then rejects heat via a cooling tower.

Lubrication System

- Functions: Reduces friction and wear between moving parts (pistons, bearings), cools internal components, cleans surfaces, and provides a piston ring seal.
- Type: Typically a pressurized, forced-feed lubrication system.
- Components: Lube oil sump, gear-driven main oil pump, oil cooler, primary and secondary oil filters, and pressure relief valves.
- Lube Oil Cooler: Crucial for maintaining oil viscosity. Oil is typically cooled by the engine's main water cooling system.
- Oil purifiers or centrifuges are often used in large plants to continuously remove sludge and carbon deposits.

Starting Systems

- Diesel engines cannot start themselves; they require external power to overcome initial friction and compression resistance.
- Electric Starting: Used for small to medium sets (up to ˜2 MW). Employs DC starter motors powered by heavy-duty lead-acid battery banks.
- Compressed Air Starting: Used for large industrial diesel engines. High-pressure air (20-30 bar) is directly injected into specific cylinders during their power stroke to turn the engine.
- Auxiliary Engine Starting: A small petrol or diesel engine is temporarily coupled to the main engine (less common in modern plants).
- Pre-lubrication pumps are often run before starting large engines to ensure bearings are lubricated.

Electrical Systems and Control

- Alternator: Directly coupled to the engine flywheel. Usually a 3-phase synchronous generator.
- Exciter: Provides DC current to the alternator rotor field.
- Governor: An electro-hydraulic or electronic speed controller that adjusts the fuel rack position to maintain constant engine speed (and thus AC frequency) despite load variations.
- Control Panel: Monitors critical parameters (oil pressure, water temperature, exhaust temp, voltage, frequency).
- Automatic Voltage Regulator (AVR): Maintains constant terminal voltage.

Plant Layout Considerations

- Vibration Isolation: Massive concrete foundations with anti-vibration mountings (springs or rubber pads) are essential to prevent structural damage.
- Ventilation: The engine room requires massive airflow to remove radiated heat and supply combustion air.
- Acoustic Enclosures: Critical for noise compliance, especially in urban environments.
- Fire Safety: Diesel fuel storage requires strict adherence to fire codes, including bunding (containment walls) around tanks and foam suppression systems.

Summary

- Diesel power plants offer flexible, quick-start power generation based on the compression-ignition cycle.
- The complete configuration involves the prime mover and six critical auxiliary systems.
- Fuel, Air/Exhaust, Cooling, Lubrication, Starting, and Electrical control systems must all function perfectly in tandem.
- Proper plant layout must address vibration, noise, heat dissipation, and fuel safety.
- While capital costs are relatively low, high operating fuel costs restrict their use mainly to peak load and emergency backup roles.

Next Lecture Preview

- Topic: Performance and Testing of Diesel Power Plants
- Calculation of Indicated Power (IP) and Brake Power (BP).
- Mechanical, Thermal, and Volumetric Efficiencies.
- Heat Balance Sheet for a Diesel Engine.
- Methods to improve plant performance and cogeneration possibilities.