Lecture 5.43

Comparative Analysis: Diesel Engine Vs Gas Turbine Power Plants

Agenda

Topics Covered

- Introduction and Basis of Comparison
- Thermodynamic Cycle Differences
- Space and Layout Requirements
- Capital Cost and Installation Time
- Efficiency and Part-Load Performance
- Fuel Flexibility and Water Requirements
- Maintenance, Lubrication, and Lifespan
- Environmental Impact and Summary

Introduction to Comparative Analysis

Overview

Both Diesel and Gas Turbine plants are internal combustion prime movers used extensively for decentralized power generation.

- Selection criteria depend heavily on site-specific constraints: space availability, water scarcity, fuel supply logistics, and capital budget.
- Primary applications for both include peak load shaving, emergency standby power, and isolated grid power supply.

Why Compare?

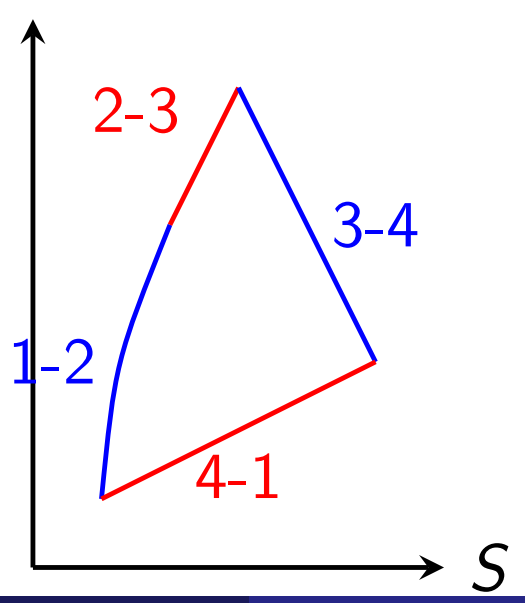
Understanding their comparative advantages is crucial for power systems engineers when designing independent power producer (IPP) setups or captive power plants.

Basic Cycle Differences

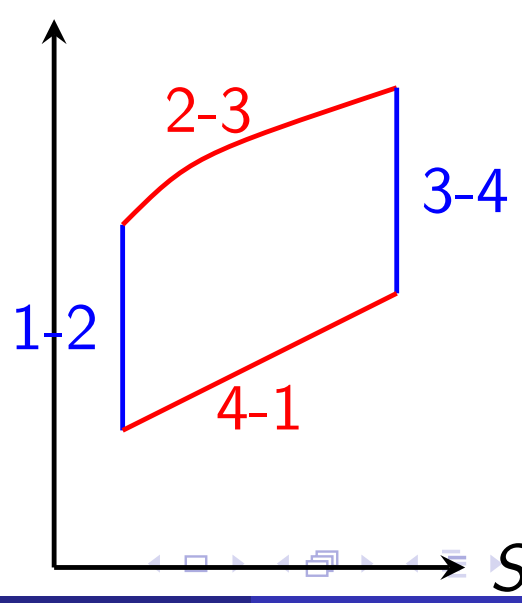
Cycles of Operation

- **Diesel Plants:** Dual/Diesel Cycle (Compression of air, constant pressure heat addition, isentropic expansion, and constant volume heat rejection).
- **Gas Turbines:** Brayton Cycle (Isentropic compression, constant pressure heat addition in combustion chamber, isentropic expansion, and constant pressure heat rejection).

Diesel (Dual) T-S



Brayton T-S

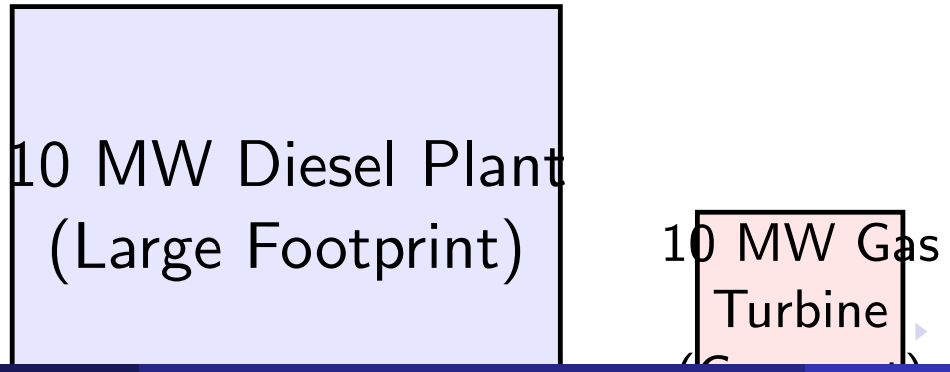


Plant Layout and Space Requirements

Footprint Comparison

Gas Turbine Plants have a significantly higher power-to-weight and power-to-volume ratio compared to diesel engines. For a given capacity, a gas turbine plant requires approximately 1/3rd to 1/4th the floor space of a comparable diesel plant.

- Diesel plants require massive concrete foundations to dampen low-frequency vibrations generated by reciprocating masses.
- Gas turbines, being rotary, are practically vibration-free, allowing for lighter foundations and modular, containerized packaging (plug-and-play).



Capital Cost and Installation Time

Investment Overview

- **Capital Cost:** Gas turbine plants typically have a lower initial capital cost per kW of installed capacity than diesel plants of the same rating.
- **Installation Time:** Gas turbines are highly modular and skid-mounted; installation and commissioning can be completed in a matter of months.

Exceptions

- Diesel engines, especially large low-speed ones, require on-site assembly, extensive civil works for foundations, and longer commissioning periods.
- However, for very small capacities (below 1-2 MW), high-speed diesel generator sets often have lower initial costs due to mass production economies.

Starting Time and Load Response

Diesel Plants

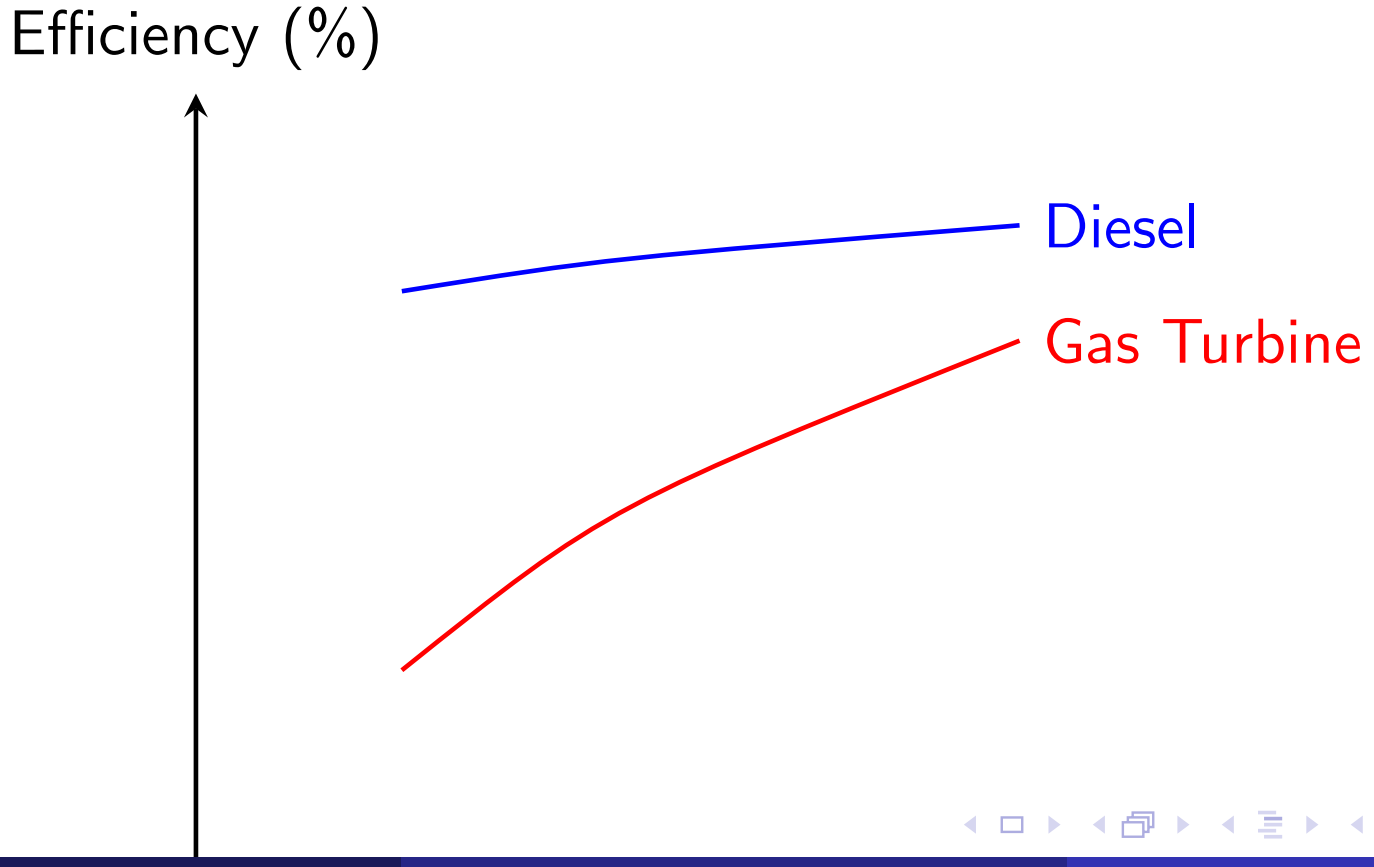
Diesel Plants can be started from cold and synchronized to the grid at full load within 1 to 2 minutes, making them excellent for emergency black-start. They respond almost instantaneously to load fluctuations due to direct mechanical governing of fuel injection.

Gas Turbine Plants

Gas Turbine Plants require a longer starting sequence (purging, cranking, ignition, acceleration) typically taking 5 to 15 minutes to reach full load. They have a slightly slower transient response due to the thermal inertia of the combustion process and compressor dynamics (risk of compressor stall).

Efficiency and Part-Load Performance

- **Full Load Efficiency:** Large diesel engines can achieve thermal efficiencies of 40-45%. Simple cycle gas turbines typically achieve 30-38%.
- **Part-Load Efficiency:** Diesel engines maintain a relatively flat efficiency curve down to 50% load, while Gas turbines suffer a drastic drop.



Fuel Flexibility and Preparation

Diesel Engines

Can burn a wider variety of liquid fuels, including Heavy Fuel Oil (HFO) and Light Diesel Oil (LDO), which are cheaper.

Gas Turbines

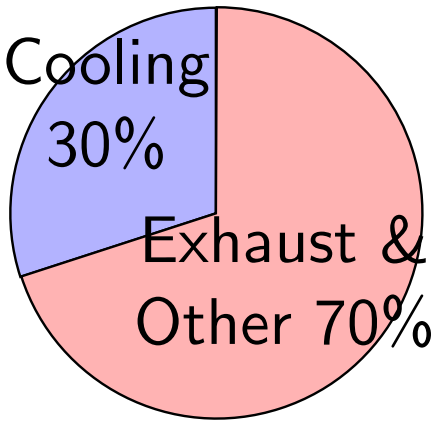
Require cleaner fuels like Natural Gas or high-grade distillate oils to prevent hot corrosion of turbine blades by vanadium and sodium.

- Using HFO in a gas turbine requires extensive, costly fuel treatment plants (washing and vanadium inhibition).
- Gas turbines are exceptionally well-suited for gaseous fuels directly from pipelines, whereas gas-fired reciprocating engines are more complex.

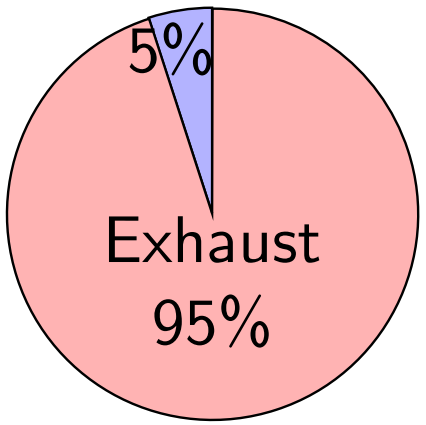
Cooling Water Requirements

- **Diesel Plants:** Require a substantial amount of cooling water to maintain engine block, lube oil, and charge air temperatures within safe limits. Typically, 25-30% of the fuel energy is rejected to the cooling water system.
- **Gas Turbine Plants:** Reject the vast majority of their waste heat directly to the atmosphere through the exhaust gases. Total water demand is negligible compared to diesel.

Diesel Heat Rejection



Gas Turbine Heat Rejection



Maintenance, Lubrication, and Operating Life

Maintenance & Lubrication

- **Diesel engines:** Involve many moving, sliding parts (pistons, valves, cams) requiring frequent maintenance and part replacement. Consume a significant amount of expensive lubricating oil.
- **Gas turbines:** Have fewer moving parts (primarily just the rotor assembly), resulting in longer intervals between major overhauls. Lube oil consumption is virtually zero.

Operating Life

Large, low-speed diesel engines typically have a longer overall operational lifespan than high-temperature gas turbine components.

Environmental Impact and Emissions

Emissions Profile

- **Gas turbines:** (especially dry low NOx designs firing natural gas) have significantly lower NOx, SOx, and particulate matter emissions.
- **Diesel engines:** Running on heavy fuel oils require massive, expensive exhaust gas cleaning systems (scrubbers, SCR) to meet modern environmental regulations.

Noise and Footprint

- Gas turbines produce high-frequency aerodynamic noise, easier to attenuate using acoustic enclosures and silencers.
- Diesels produce low-frequency structural noise that is harder to block.
- Gas turbines generally have a much smaller environmental footprint, making them easier to permit in urban environments.

Summary of Comparison

- **Base Load Applications:** Large low-speed diesels (using HFO) or Combined Cycle Gas Turbines.
- **Peak Load/Emergency Applications:** High-speed diesels for instant power, Simple Cycle Gas Turbines for larger capacity peaking where space is limited.

Parameter	**Diesel Engine**	**Gas Turbine**
Capital Cost	Higher	Lower
Efficiency (Part Load)	High	Low
Water Requirement	High	Low
Space Requirement	High	Low
Starting Time	Very Fast (1-2 min)	Fast (5-15 min)

Final Verdict

Neither is universally better. The 'best' choice is a direct function of fuel price and availability, load profile, and physical site constraints.

Next Lecture Preview: Cogeneration

Combined Heat and Power (CHP)

In our next lecture, we will introduce the concept of Cogeneration. We will explore how utilizing the waste heat from both diesel and gas turbine exhausts can dramatically increase overall plant thermal efficiency.

- Topics will include topping and bottoming cycles, and thermodynamic principles of heat recovery.
- Please review the basic concepts of heat exchangers and the Rankine cycle before the next class.