Lecture 1.4

Classification of Power Generating Stations

Agenda

- Broad Classification Criteria
- Classification by Energy Source
- Thermal, Hydro, and Nuclear Stations
- Classification by Load Type
- Base Load vs. Peak Load Plants
- Plant Characteristics and Selection

Broad Classification Criteria

Overview

Power plants can be classified based on several key criteria to understand their role and operational mechanics.

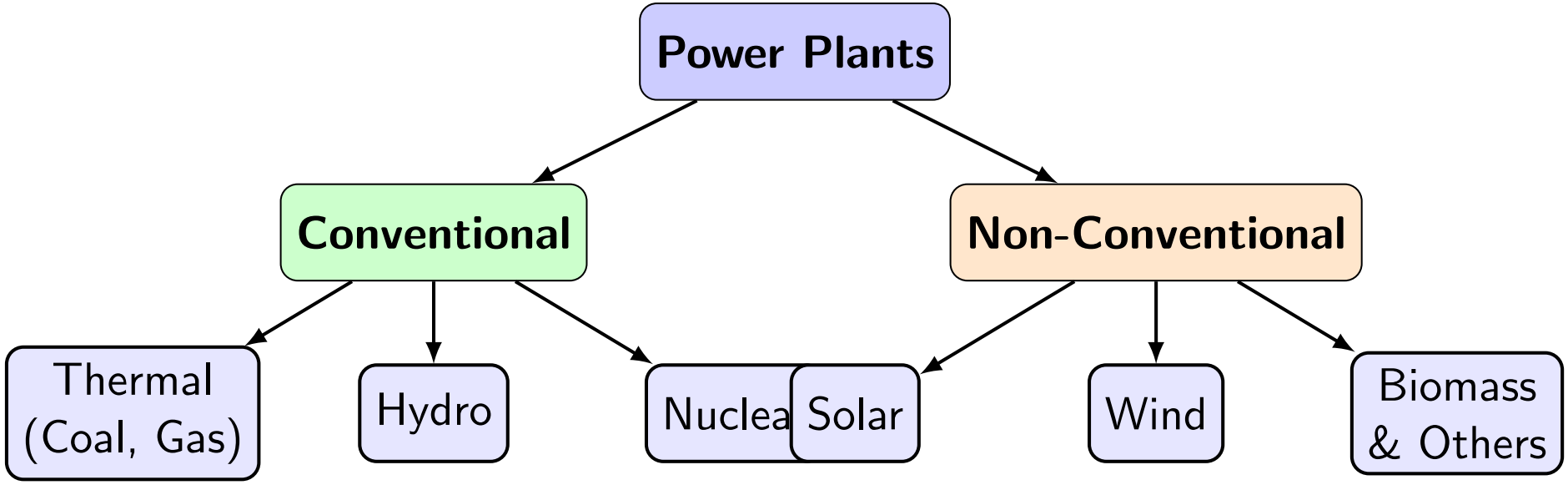
- **Primary Energy Source:** Conventional (fossil fuels, hydro, nuclear) vs. Non-conventional (solar, wind, biomass).
- **Nature of Load:** Base load, Peak load, and Intermediate load stations.
- **Location:** Pit-head (near fuel source) vs. Load-center (near consumers).
- **Thermodynamic Cycle:** Steam cycle (Rankine), Gas cycle (Brayton), Combined cycle.

Classification by Energy Source

Conventional Sources	**Non-Conventional Sources**
Traditional, widely used sources with established technologies.	Emerging or heavily promoted sources for sustainable generation.
Examples: Coal, Natural Gas, Nuclear, Large Hydro.	Examples: Solar PV/Thermal, Wind, Tidal, Geothermal, Biomass.

- The choice of energy source dictates the entire plant architecture, from handling equipment to environmental control systems.
- **Transition Trends:** Modern grids are seeing a steady shift from conventional fossil fuels to non-conventional renewable sources to reduce carbon footprint.

Tree Diagram of Power Plants



Thermal Power Stations

Function

Convert heat energy from fuel combustion into electrical energy.

- **Steam Power Plants:** Utilize coal, oil, or gas to produce high-pressure steam, driving a steam turbine (Rankine Cycle). Known for high capacity and continuous operation.
- **Gas Turbine Power Plants:** Use natural gas or liquid fuels. Air is compressed, heated by fuel, and expanded through a gas turbine (Brayton Cycle). Quick starting, often used for peak loads.
- **Combined Cycle Power Plants (CCPP):** Integrate gas and steam cycles. Exhaust heat from the gas turbine is used to generate steam, significantly boosting overall thermal efficiency (up to 60%).

Hydroelectric Power Stations

Function

Convert potential and kinetic energy of water into electrical energy.

- **Classification by Head:** High head (Pelton turbines), Medium head (Francis turbines), Low head (Kaplan turbines).
- **Classification by Facility Type:** Run-of-river (limited storage), Reservoir/Storage (large dams), Pumped-storage (acts as a massive battery by pumping water back up during low demand).
- **Characteristics:** Zero fuel cost, high initial capital cost, long gestation period, extremely quick starting capabilities making them ideal for grid frequency regulation.

Nuclear Power Stations

Function

Utilize the heat generated from nuclear fission (e.g., Uranium-235) to produce steam.

- **Core Components:** Nuclear reactor, control rods, coolant, heat exchanger (steam generator), and steam turbine.
- **Reactor Types:** Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Pressurized Heavy Water Reactor (PHWR), Fast Breeder Reactor (FBR).
- **Characteristics:** Extremely high energy density fuel, zero greenhouse gas emissions during operation, complex safety and waste management requirements. Strictly operated as base load due to inflexibility in rapid power changes.

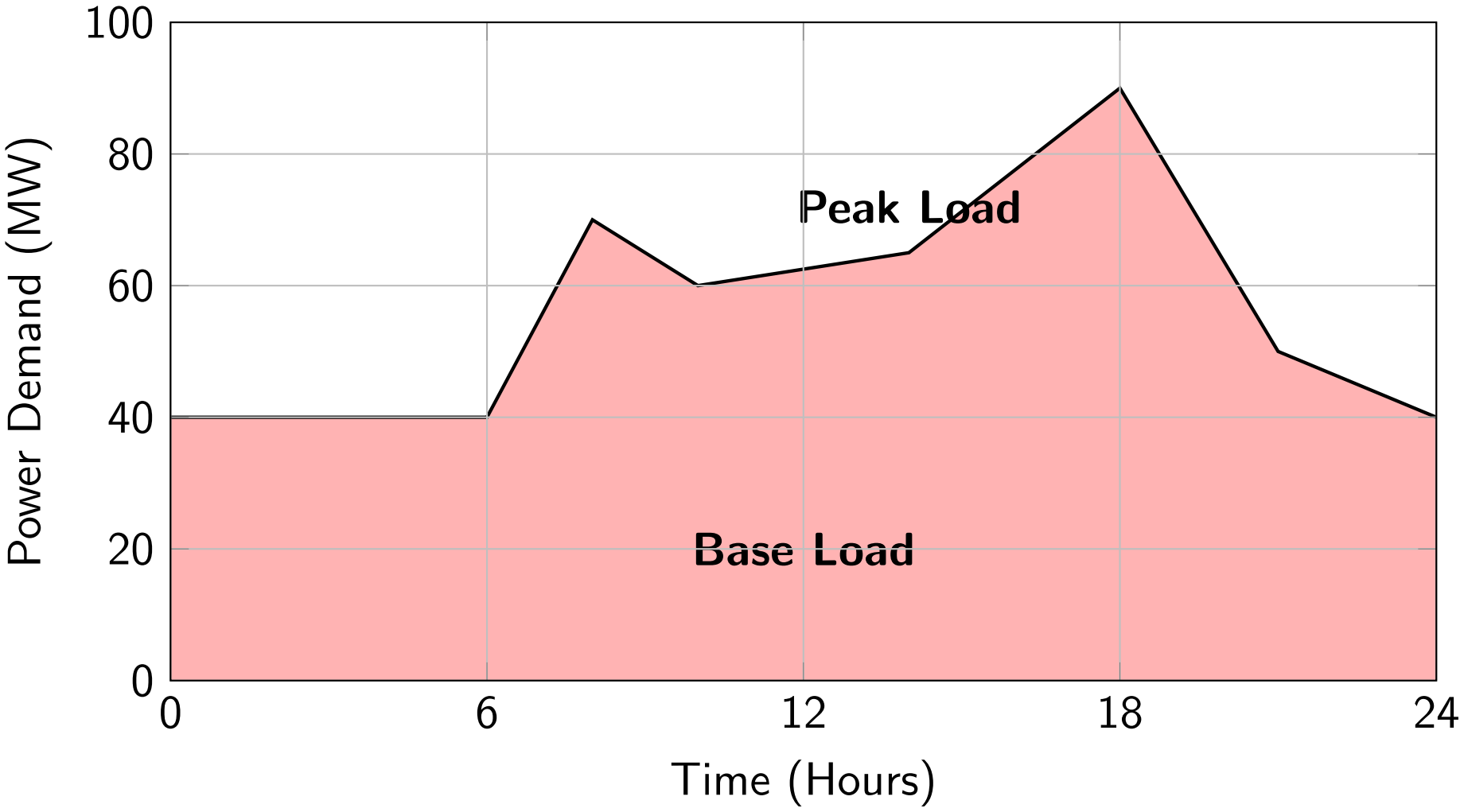
Classification by Load Type

Overview

Power demand fluctuates throughout the day and year. Plants are classified by how they meet this demand.

- **Base Load Demand:** The unvarying, continuous minimum demand on the electrical grid over a given period.
- **Peak Load Demand:** The variable, temporary maximum demand that occurs during specific times (e.g., evenings when lighting and appliances are used).
- **Intermediate Load:** The demand level that falls between base and peak, requiring plants that can adjust output relatively well.

Understanding the Load Curve



Base Load Power Plants

- **Role:** Operate continuously at close to their maximum capacity (high plant capacity factor) to supply the constant background grid demand.
- **Key Requirements:** Must be highly reliable, have low operating/fuel costs, and be capable of continuous, steady-state operation.
- **Examples:** Nuclear power plants, large Coal-fired thermal plants, Run-of-river hydro plants, and large Geothermal plants.
- **Drawback:** Generally slow to start up and shut down; poor at ramping power output quickly to follow fluctuating load.

Peak Load Power Plants

- **Role:** Dispatched only during periods of high demand. They operate for fewer hours (low plant capacity factor).
- **Key Requirements:** Must have ultra-fast start-up times, rapid ramp rates (ability to change output quickly), and low capital cost (since they sit idle often).
- **Examples:** Open-cycle Gas Turbines, Diesel generator sets, Pumped-storage hydro, and increasingly, large-scale Battery Energy Storage Systems (BESS).
- **Drawback:** Often have higher operating and fuel costs (e.g., natural gas or diesel) and lower overall efficiency compared to base load plants.

Summary

Key Takeaways

- Power plants are primarily classified by energy source (Conventional vs. Non-Conventional) and their role in the grid (Base vs. Peak load).
- Thermal, Hydro, and Nuclear plants form the core of conventional generation.
- Base load plants operate continuously with low running costs. Peak load plants are highly responsive but have higher operational costs.
- Thermal, nuclear, and large hydro are typical base load plants. Gas turbines and pumped hydro are typical peak load plants.

Next Lecture Preview

Topic: Major Power Plants in India and Load Curves

- We will look at specific case studies of major power installations across the country.
- We will dive deeper into load curves, load duration curves, and understand mathematical terms like connected load, maximum demand, and average load.