Lecture 1.5

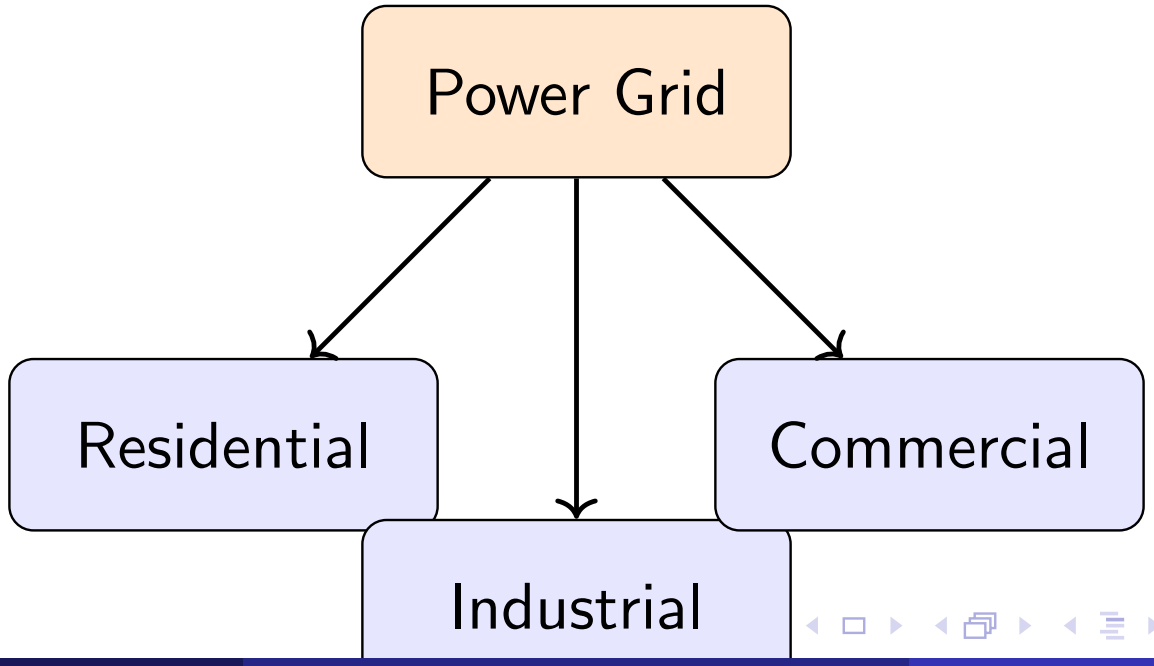
Power Plant Load and Performance Parameters

Agenda

- Understanding Power Demand: Connected Load, Base Demand, and Maximum Demand
- Graphical Representations: Load Curves and Load Duration Curves
- Performance Parameters: Average Load and Load Factor
- Utilization Metrics: Plant Capacity, Use, and Utilization Factors
- Diversity Factor and its Economic Impact
- Summary and Q&A

Introduction to Power Demand

- **Connected Load:** The sum of the continuous ratings of all energy-consuming apparatus connected to the system.
- System demand is never constant; it fluctuates based on time of day, weather, and industrial schedules.
- Understanding demand characteristics is critical for determining the required size and number of generator units.
- Generation must instantaneously match demand, necessitating accurate forecasting and performance metrics.



Base Demand vs. Maximum Demand

- **Base Demand (Base Load):** The unvarying, minimum load that occurs on the power station throughout a given period (e.g., 24 hours).
- Base load plants operate continuously at high capacity factors (e.g., Nuclear, large Coal/Thermal plants).
- **Maximum Demand (Peak Load):** The greatest demand of load on the power station during a given period.
- Maximum demand dictates the installed capacity of the station to ensure reliability without supply interruption.
- Peak load plants (e.g., Gas turbines, pumped storage hydro) are designed for quick start-up to handle these surges.

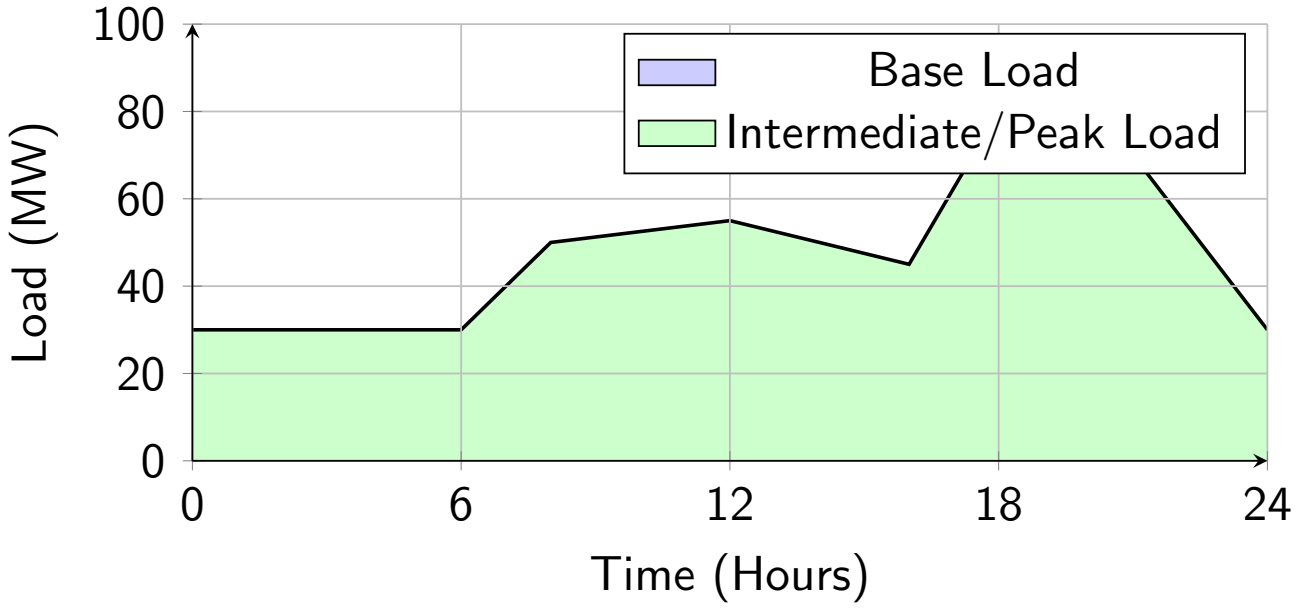
Parameter	**Base Load Plants**	**Peak Load Plants**
Start-up Time	Slow	Fast
Capital Cost	High	Low
Operating Cost	Low	High

The Load Curve

- A **Load Curve** is a graphical plot of the load (in kW or MW) on the power station against time (in hours).
- **Chronological Representation:** Shows the exact time sequence of load variations.
- **Area Under the Curve:** Represents the total energy generated (in kWh or MWh) during the specified period.
- **Highest Point on the Curve:** Indicates the Maximum Demand.
- **Types of Load Curves:** Daily (24 hours), Monthly, and Annual (8760 hours).

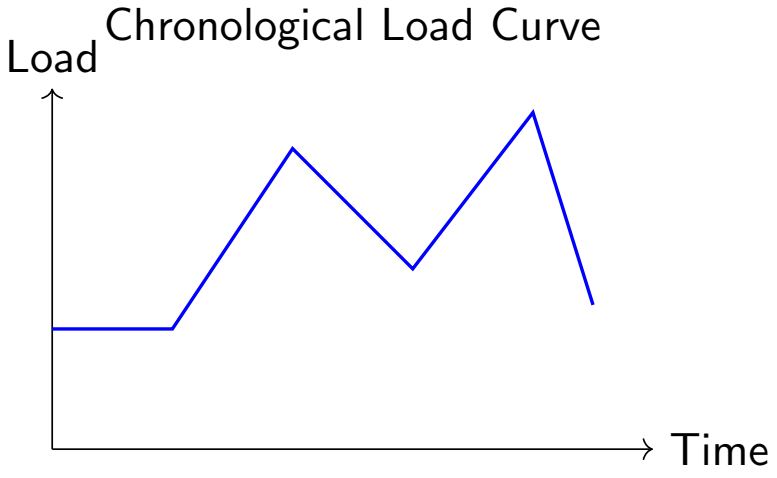
Anatomy of a Daily Load Curve

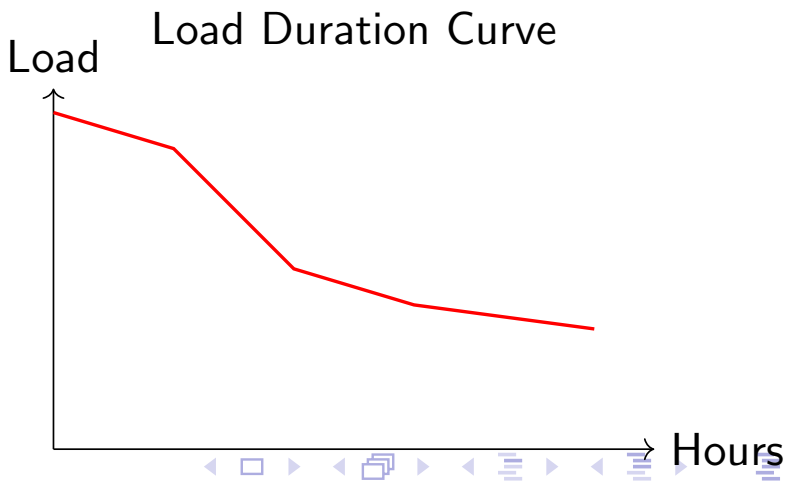
- X-axis: Time from 00:00 to 24:00 hours.
- Y-axis: Load in Megawatts (MW).
- Lower shaded region: **Base Load**, constant across 24 hours.
- Middle region: Intermediate load variations.
- Upper spikes: **Peak Loads**, typically occurring in morning and evening hours.



Load Duration Curve

- Derived from the chronological load curve by rearranging the load elements in descending order of magnitude.
- The highest load is plotted on the left, decreasing towards the minimum load on the right.
- X-axis represents the number of hours (or percentage of time) a particular load or higher is demanded.
- Area under the load duration curve equals the area under the chronological load curve (total energy).
- Provides a clearer picture of how long specific generation capacities must be operated.





Average Load and Load Factor

- Since average load is always less than maximum demand, Load Factor is always less than 1 (or 100%).
- **Significance:** A higher load factor means the power plant's installed capacity is being utilized more efficiently.
- **Economic Impact:** Higher load factor reduces the fixed cost per unit of energy generated, lowering the overall tariff.

Average Load

$$\text{Average Load} = \frac{\text{Area under the load curve}}{\text{Total time in hours}}$$

Load Factor

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Maximum Demand}}$$

Plant Capacity and Plant Use Factors

- **Plant Capacity Factor:** Measures how much energy the plant actually generated compared to what it could have generated if running at full capacity continuously.
- **Plant Use Factor:** Accounts for periods when the plant is shut down for maintenance or lack of demand.

Plant Capacity Factor

$$\text{Capacity Factor} = \frac{\text{Actual Energy Produced}}{\text{Installed Plant Capacity} \times \text{Total Time}}$$

Relationship

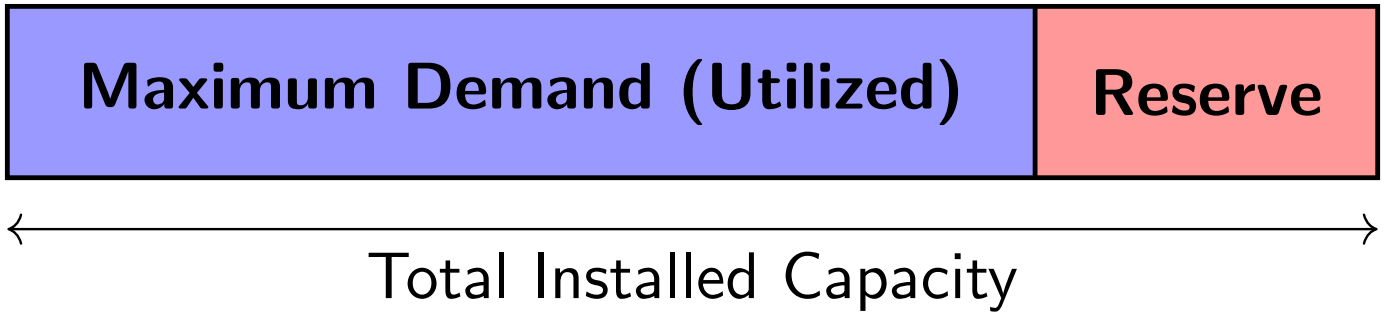
$$\text{Capacity Factor} = \text{Load Factor} \times \frac{\text{Maximum Demand}}{\text{Installed Capacity}}$$

Plant Use Factor

$$\text{Use Factor} = \frac{\text{Actual Energy Produced}}{\text{Installed Plant Capacity} \times \text{Actual Operating Hours}}$$

Plant Utilization Factor

- **Plant Utilization Factor** = Maximum Demand on the station / Rated Installed Capacity of the station.
- Also known as the Plant Equipment Factor.
- Indicates the extent to which the installed capacity is being utilized during peak demand conditions.
- **Reserve Capacity** = Installed Capacity - Maximum Demand.
- A Utilization Factor of 1.0 means there is zero reserve capacity, which poses high risks during equipment failure.

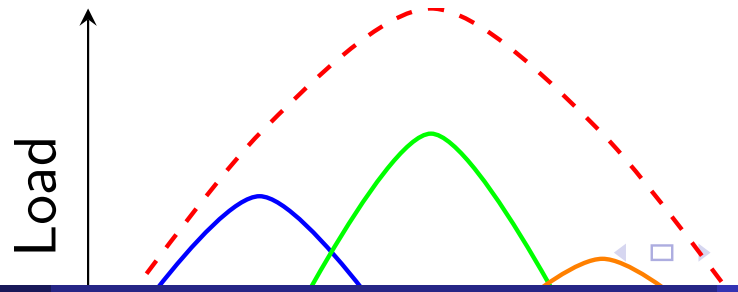


Diversity Factor

- Individual consumers do not experience their maximum demands simultaneously.
- Because of non-simultaneous peaks, the **Simultaneous Maximum Demand** is always LESS than the sum of individual demands.
- Therefore, Diversity Factor is always **GREATER than 1**.
- **Significance:** A higher diversity factor reduces the required maximum demand on the station, lowering capital costs.

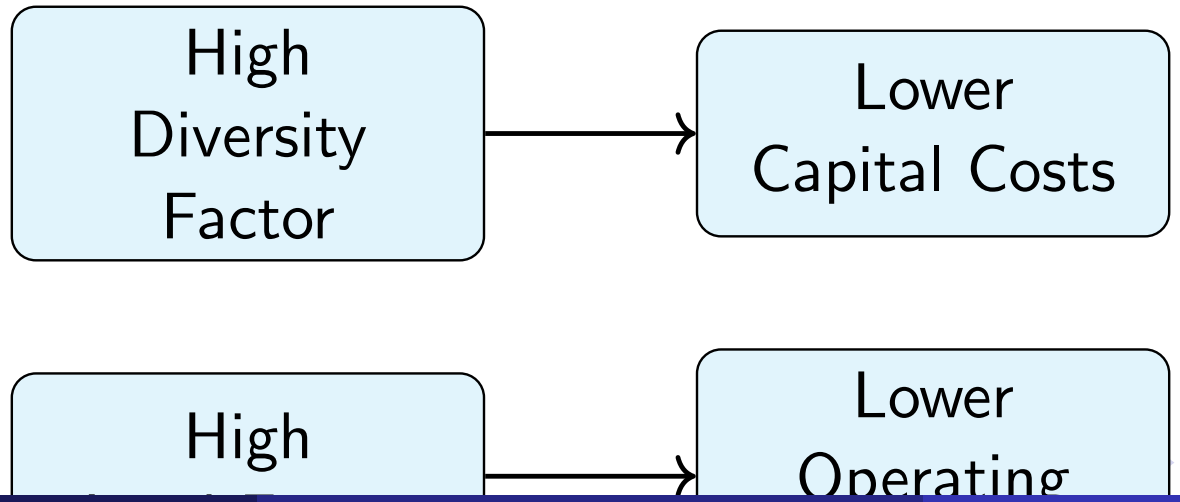
Diversity Factor

$$\text{Diversity Factor} = \frac{\text{Sum of Individual Maximum Demands}}{\text{Simultaneous Maximum Demand on the Power Sta}}$$



Economic Implications of Performance Parameters

- **Capital Cost Optimization:** Higher Diversity Factor minimizes the installed capacity required, directly cutting capital investment.
- **Operational Efficiency:** Higher Load Factor ensures base load units run continuously at their peak efficiency point.
- **Tariff Design:** Customers with high load factors are generally offered cheaper tariffs because they use grid infrastructure more steadily.
- **Grid Stability:** Forecasting these parameters accurately prevents grid collapse during extreme peak events.



Summary

- **Base Demand** is constant; **Maximum Demand** dictates installed capacity.
- **Load Curves** and **Load Duration Curves** are essential for visualizing and analyzing energy generation patterns.
- **Load Factor** (Average/Max) and **Capacity Factor** measure utilization efficiency and are always < 1.
- **Diversity Factor** accounts for non-coincident peaks, is always > 1, and significantly reduces required capital investment.

Next Lecture Preview

- Economics of Power Generation: Capital, Fixed, and Operating Costs.
- Depreciation Methods: Straight Line, Sinking Fund, and Diminishing Value.
- Tariff Structures for Electricity Billing.
- Please review the formulas for Load Factor and Diversity Factor, as we will use them in cost calculation problems.

See you next time!