Lecture 1.10

Simple Numericals on Load, Cost, and Tariff

Agenda

- Review of Key Formulas (Load Factors)
- Numerical Problem 1: Load and Demand Factors
- Review of Key Formulas (Power Generation Costs)
- Numerical Problem 2: Cost of Electrical Energy
- Review of Key Formulas (Tariff Structures)
- Numerical Problem 3: Two-Part Tariff Calculation
- Numerical Problem 4: Comprehensive Mixed Problem
- Summary and Q&A

Formula Recap: Load and Demand

Term	Formula	Typical Range
Demand Factor	Max Demand / Connected Load	< 1
Average Load	Total energy / Hours	–
Load Factor	Avg Load / Max Demand	< 1
Diversity Factor	Sum of individual max demands / Simultaneous max demand	> 1
Plant Capacity Factor	Actual Energy / (Capacity $\times$ hours)	< 1
Plant Use Factor	Actual Energy / (Capacity $\times$ actual operating hours)	< 1

Problem 1: Load Factors

Problem Statement

A generating station has a connected load of 43 MW and a maximum demand of 20 MW.
The units generated being 61,500,000 per annum.

Calculate:

1. The demand factor.
2. The load factor.

Assume a non-leap year (365 days).

Solution 1: Load Factors

Given:

Connected Load $= 43$ MW, Maximum Demand $= 20$ MW, Annual Energy $= 61.5 \times 10^6$ kWh

1. Demand Factor Calculation

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Demand Factor = Maximum Demand / Connected Load
              = 20 MW / 43 MW = 0.465 or 46.5%
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2. Load Factor Calculation

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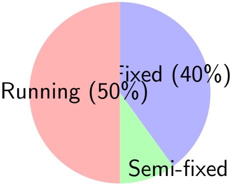
Average Demand = Total Annual Energy / Hours in a
year
               = 61,500,000 kWh / (365 × 24) h
               = 61,500,000 / 8760 kW
               = 7020.5 kW = 7.02 MW
Load Factor    = Average Demand / Maximum Demand
               = 7.02 MW / 20 MW = 0.351 or 35.1%
```

Formula Recap: Power Plant Economics

- **Total Annual Cost:** Sum of Fixed Costs, Semi-fixed Costs, and Running (Operating) Costs.
- **Fixed Costs:** Independent of generation (e.g., interest on capital, depreciation, taxes).
- **Running (Operating) Costs:** Proportional to the units generated (e.g., fuel cost, maintenance).
- **Cost of Generation per Unit:** Total Annual Cost / Total Annual Energy Generated (in kWh).
- **Depreciation:** Straight Line method, Sinking Fund method, or Diminishing Value method.



Problem 2: Cost of Electrical Energy

Problem Statement

A 100 MW power station has the following parameters:

- Capital cost: Rs. 1500 per kW installed.
- Interest and depreciation: 10% on capital.
- Annual load factor: 40%.
- Annual capacity factor: 30%.
- Annual running charges: Rs. 20×10^6.

Calculate:

1. The cost of power generation per kWh.
2. The reserve capacity.

Solution 2: Cost of Electrical Energy

Calculations

Total Capital Cost $=$ 100,000 kW $\times$ Rs. 1500/kW $=$ **Rs.** 150×10^7
Annual Fixed Charges (10%) $= 0.10 \times 150 \times 10^7 =$ **Rs.** 15×10^6
Total Annual Cost $=$ Fixed (15M) $+$ Running (20M) $=$ **Rs.** 35×10^6

Energy Generated

Avg Load $=$ Capacity $\times$ Capacity Factor $=$ 100 MW $\times$ 0.30 $=$ **30 MW**
Units Generated/year $=$ 30,000 kW $\times$ 8760 h $= 262.8 \times 10^6$ **kWh**

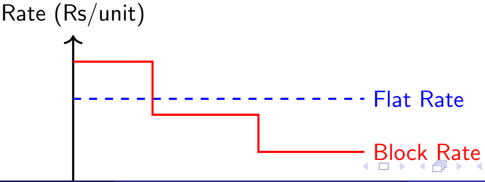
Results

Cost per kWh $=$ Total Cost / Units $=$ 35,000,000 / 262,800,000 $=$ **Rs. 0.133 (13.3 Paise)**

Reserve Capacity $=$ Plant Capacity - Max Demand
Max Demand $=$ Avg Load / Load Factor $=$ 30 MW / 0.40 $=$ **75 MW**
Reserve Capacity $=$ 100 MW - 75 MW $=$ **25 MW**

Formula Recap: Tariff Calculations

- **Simple Tariff:** Cost per unit = Total cost / Total units supplied.
- **Flat Rate Tariff:** Different consumer classes (lighting, power) are charged at different fixed rates per unit.
- **Block Rate Tariff:** Energy is divided into blocks (e.g., first 50 units), with the price per unit decreasing for successive blocks.
- **Two-Part Tariff (Hopkinson Demand Rate):** Total Bill = Rs $(A \times \text{kW} + B \times \text{kWh})$
  - A = Rate per kW of maximum demand (Fixed charge)
  - B = Rate per kWh of energy consumed (Running charge)
- **Power Factor Tariff:** Often incorporates a kVA maximum demand charge or penalties for low power factor.



Problem 3: Two-Part Tariff

Problem Statement

A consumer has a maximum demand of 200 kW at 40% load factor. The tariff is Rs. 100 per kW of maximum demand plus 10 paise per kWh consumed.

Calculate:

1. The total energy consumed in a year (8760 hours).
2. The annual electricity bill.
3. The overall cost per kWh.

Tariff Equation: $\textbf{Bill} = (100 \times \text{MD}) + (0.10 \times \text{Energy})$

Solution 3: Two-Part Tariff

1. Energy Consumed

Average Load = Maximum Demand × Load Factor = 200 kW × 0.40 = **80 kW**

Annual Energy = Average Load × 8760 = 80 × 8760 = **700,800 kWh**

2. Annual Bill Calculation

Maximum Demand Charge = Rs. 100 × 200 kW = **Rs. 20,000**

Energy Charge = Rs. 0.10 × 700,800 kWh = **Rs. 70,080**

Total Annual Bill = 20,000 + 70,080 = **Rs. 90,080**

3. Overall Cost per kWh

Overall Cost/kWh = Total Annual Bill / Total Energy

Overall Cost = 90,080 / 700,800 = **Rs. 0.1285 or 12.85 paise/kWh**

Problem 4: Comprehensive Mixed Problem

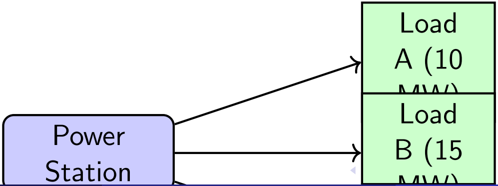
Problem Statement

A power station supplies three distinct loads:

- Load A: Max demand 10 MW, LF 40%
- Load B: Max demand 15 MW, LF 50%
- Load C: Max demand 20 MW, LF 60%

The diversity factor of the station is **1.5**.
The tariff for the station is **Rs. 150 per kW of station maximum demand + 5 paise per unit generated.**

Calculate: The overall cost of generation per unit (kWh).



Solution 4: Comprehensive Mixed Problem

1. Station Maximum Demand

Sum of individual max demands = 10 + 15 + 20 = **45 MW**
Station Max Demand = Sum of MDs / Diversity Factor = 45 / 1.5 = **30 MW**

2. Total Energy Generated Annually

Units A = 10,000 kW × 0.40 × 8760 = 35.04×10^6 kWh
Units B = 15,000 kW × 0.50 × 8760 = 65.70×10^6 kWh
Units C = 20,000 kW × 0.60 × 8760 = 105.12×10^6 kWh
Total Units = 205.86×10^6 **kWh**

3. Total Cost and Cost per Unit

Demand Charge = Rs. 150 × 30,000 kW = Rs. 4.5×10^6
Energy Charge = Rs. 0.05 × 205.86×10^6 = Rs. 10.293×10^6
Total Cost = Rs. 14.793×10^6
Cost per Unit = 14.793×10^6 / 205.86×10^6 = **Rs. 0.0718 (7.18 Paise)**

Summary

- **Load Metrics:** Load factor, capacity factor, and demand factor are crucial for assessing plant utilization.
- **Diversity Factor:** A higher diversity factor reduces the required station capacity and lowers the cost of generation.
- **Costing:** Total cost comprises fixed (capital-dependent) and running (generation-dependent) components.
- **Tariffs:** Two-part tariffs effectively split costs, charging for maximum demand (kW) and energy consumption (kWh) separately.

Next Lecture Preview

Unit 2 Preview: Thermal Power Plants

- Site selection criteria for steam power plants.
- General layout and working principle of modern thermal power plants.
- Coal handling, ash handling, and dust collection systems.
- Introduction to thermodynamic cycles (Rankine cycle).