Power Plant Engineering

Lecture 13

Power Plant Economy

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Lecture learning outcomes:

At the end of this lecture, you will be able to:

i. Explain the role of engineering economy in the planning, design, and operation of power plants.

ii. Utilize principles such as time value of money, interest rate, and cash flow analysis in power plant decision-making.

iii. Evaluate capital investment, operating costs, and revenue streams to assess the economic feasibility of power generation systems.

iv. Analyze key indicators such as payback period, net present value (NPV), internal rate of return (IRR), and cost-benefit ratio for different power plant projects.

v. Compare the economic performance of various power generation methods considering fuel cost, efficiency, and environmental impacts.

Content

1. Introduction to Power Plant Economy

Introduction to Power Plant Economy

- The goal of any power plant is to generate electricity reliably, safely, and at the lowest possible cost, while maintaining environmental and operational standards.
- Power Plant Economy involves the study of cost, performance, and financial optimization of power generation systems [1].
- Understanding the economy of power plants directly influences plant design, operation, investment decisions, and energy pricing.
- A poor economic decision can lead to billions of dollars in losses,

while a sound one ensures energy security and financial viability.

1. Introduction to Power Plant Economy Cont…

Importance of Power Plant Economy

- Power generation projects require large capital investments and long operating periods. Hence, understanding power plant economics helps in:
  - ✓Selecting the most economical type of power plant (thermal, hydro, nuclear, renewable, etc.)
  - ✓Reducing operational costs through improved efficiency and fuel management.
  - ✓Planning tariffs and cost recovery for power utilities.
  - ✓Guiding investment decisions for government and private investors.
  - ✓Ensuring sustainable and reliable energy supply at affordable rates.

1. Introduction to Power Plant Economy Cont…

Major Cost Components of a Power Plant

The total cost of generating electrical power includes several components:

a. Capital Cost

- The initial investment for land, building, machinery, transmission lines, and installation.
- Usually recovered over the life of the plant through depreciation and interest charges.

b. Fixed Cost

- Costs that remain constant regardless of the amount of power generated.
- Includes interest, depreciation, insurance, salaries of permanent staff, and taxes.

1. Introduction to Power Plant Economy Cont…

c. Operating (Running) Cost

- Costs that vary with the amount of power generated.
- Includes fuel, lubricants, maintenance, and wages for operating labor.

d. Maintenance Cost

- Regular expenses for upkeep and minor repairs to ensure reliability and performance.

e. Depreciation Cost

- Represents the loss in value of the plant equipment over time due to wear and tear, obsolescence, or age.

1. Introduction to Power Plant Economy Cont…

Economic Factors Affecting Power Plant Selection

- To compare different power plant options fairly, the standardized metrics used are:
  - ✓Load Factor – Ratio of average load to maximum demand; higher load factor reduces cost per kWh.
  - ✓Plant Capacity Factor – Ratio of actual energy generated to the maximum possible generation in a given period.
  - ✓Plant Use Factor – Ratio of actual energy generated to the product of plant capacity and operating hours.
  - ✓Diversity Factor – Ratio of sum of individual maximum demands to the maximum demand on the station.

1. Introduction to Power Plant Economy **Cont…**

- ✓Demand Factor – Ratio of maximum demand to connected load.
- ✓Availability and cost of fuel – Influences the operating cost.
- ✓Location and transmission cost – Affects the total investment and efficiency.
- ✓Environmental constraints – Pollution control and emission standards influence design and cost.

Principles of Power Plant Economy

- The main principle is to generate the required electrical power at the lowest total cost while ensuring reliability and sustainability.

1. Introduction to Power Plant Economy Cont…

Key guiding principles include:

1. Balancing capital and operating costs
   - A cheaper plant may have high fuel costs (e.g., diesel), while a costlier plant may have low running costs (e.g., hydro).
   - Economic optimization involves trade-offs between these costs.
2. Maximizing load factor and utilization
   - The higher the load factor, the lower the cost per unit of electricity.
3. Reducing energy losses
   - Through improved plant efficiency and modern technology (e.g., combined-cycle plants).
4. Optimizing maintenance and life-cycle cost
   - Preventive maintenance reduces unplanned downtime and total life-cycle cost.

1. Introduction to Power Plant Economy

Economic Performance Indicators

- To assess and compare different power plants, several economic indicators are used:

Indicator	Formula	Description
Cost per kWh	Total annual cost ÷ Annual energy generated	Unit cost of electricity
Load Factor	(Average Load ÷ Maximum Load) × 100	Measures plant utilization
Capacity Factor	(Actual Output ÷ Maximum Possible Output) × 100	Indicates effective use of capacity
Plant Heat Rate	(Input energy / Output energy)	Lower values indicate better efficiency
Return on Investment (ROI)	(Net Profit ÷ Investment) × 100	Financial performance measure
Payback Period	Investment ÷ Annual Profit	Time required to recover investment

1. Introduction to Power Plant Economy Cont…

Cost Optimization Strategies

- To achieve minimum cost of generation, the following strategies are employed:
  1. Efficient plant design and selection of modern technology
  2. Fuel management and diversification (e.g., co-firing, natural gas blending)
  3. Preventive and predictive maintenance
  4. Automation and control systems to reduce manpower cost
  5. Load management and demand-side optimization
  6. Integration of renewable sources and cogeneration systems

2. Engineering Economy and Principles of Engineering Economy

- Engineering economy is the application of economic techniques to evaluate alternatives in engineering projects, aiming to minimize cost and maximize economic benefits [2].
- In the context of power plants, engineering economy helps determine:
  - The most economical type of plant to build,
  - The optimum capacity,
  - The most efficient operating conditions, and
  - The financial feasibility of proposed projects.

2. Engineering Economy and Principles of Engineering Economy Cont…

- In power plants, engineering economy focuses on:
  - ✓Investment planning
  - ✓Cost analysis
  - ✓Revenue estimation
  - ✓Financial feasibility
  - ✓Decision-making under uncertainty

2. Engineering Economy and Principles of Engineering Economy Cont…

Scope in Power Generation

- Selection of type and size of power plant.
- Determination of capital investment and operating costs.
- Estimation of electricity tariff or selling price.
- Economic life determination of equipment.
- Replacement analysis for aging or inefficient units.
- Evaluation of renewable vs. non-renewable energy systems.

2. Engineering Economy and Principles of Engineering Economy Cont…

Fundamental Principles of Engineering Economy

- The principles of engineering economy guide economic decision-making.
- The following are the key ones relevant to power plant economics:

Principle 1: Develop alternatives

- Economic decisions require feasible alternatives — such as comparing a thermal plant vs. a hydro plant, or upgrading an old system vs. installing a new one.

Principle 2: Focus on differences

- Only the differences in cost, revenue, or performance between alternatives matter.
- This principle avoids evaluating irrelevant data that are common to all alternatives.

2. Engineering Economy and Principles of Engineering Economy

Principle 3: Use a consistent viewpoint

- All costs and benefits must be evaluated from the same perspective — usually the investor, utility, or government.
- For power projects, this ensures that costs, taxes, and revenues are analyzed consistently.

Principle 4: Consider the time value of money

- Money today is worth more than the same amount in the future due to interest or inflation.
- Hence, all cash flows must be adjusted to a common time base (present, annual, or future value).

2. Engineering Economy and Principles of Engineering Economy Cont…

Principle 5: Use a common unit of measure

- All costs and benefits should be expressed in monetary terms (e.g., USD per kWh).
- This allows fair comparison of different technical options.

Principle 6: Consider all relevant criteria

- Besides direct costs, include:
  - ✓Maintenance and operating costs,
  - ✓Environmental impacts,
  - ✓Social or regulatory costs, and
  - ✓Residual (salvage) values.

Principle 7: Make uncertainty explicit

- Future costs (e.g., fuel prices or inflation) are uncertain.
- Sensitivity analysis and risk evaluation help test the impact of varying these assumptions.

Principles of Power Plant Economics

- Power plant economics integrates engineering economy with operational and technical considerations to ensure least-cost generation [3].
- Basic economic principle is achieved by:
  - ✓Optimizing capital and running costs,
  - ✓Maintaining high load factor, and
  - ✓Using efficient conversion systems.

2. Engineering Economy and Principles of Engineering Economy Cont…

Key Economic Factors

1. Capital Cost vs. Operating Cost Trade-off
   - High initial cost may yield low running cost (e.g., hydro plants).
2. Plant Efficiency
   - Higher efficiency reduces fuel cost.
3. Load Factor
   - The higher the load factor, the lower the cost per kWh.
4. Plant Capacity Utilization
   - Ensuring continuous operation reduces fixed cost burden.
5. Maintenance and Reliability
   - Downtime increases cost due to loss of generation.

Cost Components in Power Plant Economics

Cost Type	Description	Examples
Fixed Cost	Independent of energy generation	Interest, depreciation, taxes
Variable Cost	Proportional to output	Fuel, lubricants
Semi-variable	Partly fixed and partly variable	Maintenance, operator wages

2. Engineering Economy and Principles of Engineering Economy Cont…

Cost of Energy (Generated Cost) can be calculated:

$$\text{Cost per kWh} = \frac{\text{Annual Fixed Cost} + \text{Annual Operating Cost}}{\text{Annual Energy Generated}}$$

Decision-Making in Power Plant Economy

- The decision-making process involves:

1. Defining objectives (e.g., minimize cost or emissions).
2. Developing feasible alternatives.
3. Estimating cash flows (investment, O&M, revenues).
4. Applying economic evaluation methods.
5. Selecting the best alternative.

3. Financial Analysis and Indicators of Financial Performance

- Financial analysis in power plant economics involves evaluating the costs, revenues, and profitability of a power generation project [4].
- It helps determine whether investing in a particular power plant—be it thermal, hydro, nuclear, or renewable—is financially viable and sustainable over its lifetime.
- Financial performance indicators are helpful to evaluate the economic viability, profitability, and long-term sustainability of power generation projects.
- They form the foundation for investment decisions, plant design, tariff setting, and policy analysis.

3. Financial Analysis and Indicators of Financial Performance Cont…

- Financial indicators allow comparison between alternative technologies (coal, gas, hydro, renewable).
- They are used in feasibility studies, financing negotiations, and project performance monitoring.
- Helps identify cost drivers, profit margins, and payback periods.
- The major components of financial indicators include:
  1. Capital (investment) cost
  2. Operating and maintenance (O&M) costs
  3. Fuel costs
  4. Internal rate of return (IRR)

3. Financial Analysis and Indicators of Financial Performance Cont…

Major Components of Financial Analysis

1. Capital (Investment) Cost

- These are one-time costs required to build and commission the plant.
- The components of capital costs include:
  - ✓Land acquisition and site preparation
  - ✓Plant and equipment costs: boilers, turbines, generators, reactors, etc.

3. Financial Analysis and Indicators of Financial Performance Cont…

- ✓Civil works and infrastructure: buildings, foundations, cooling towers, roads
- ✓Transmission connection cost
- ✓Engineering, procurement, and construction services
- ✓Interest during construction
- ✓Capital cost is usually expressed as $/kW of installed capacity.

3. Financial Analysis and Indicators of Financial Performance Cont…

2. Operating and Maintenance (O&M) Costs

- These are recurring annual costs incurred to operate the plant.
- Fixed O&M costs: salaries, insurance, administrative expenses
- Variable O&M costs: fuel, lubricants, consumables, water treatment, waste disposal
- Maintenance costs: scheduled and unscheduled repair and replacement
- O&M costs are typically expressed in \$/kWh or \$/MW-year.

3. Financial Analysis and Indicators of Financial Performance Cont…

3. Fuel Costs

   - Dominant cost component for thermal power plants (coal, gas, oil, biomass).
   - Determined by fuel price, calorific value, and plant efficiency.

4. Depreciation and Taxation

   - Depreciation: allocation of plant cost over its useful life (straight-line or declining balance).
   - Purpose: reflects equipment wear and tear; affects taxable income.
   - Taxation: corporate income tax on net profit after depreciation and interest deductions.

3. Financial Analysis and Indicators of Financial Performance Cont…

Indicators of Financial performance

1. Net Present Value (NPV)

- It is the difference between the present value of all cash inflows and the present value of all cash outflows over the lifetime of a project.

$$\text{NPV} = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+i)^t}$$

Where:

$\mathrm{R_t}$ = revenue in year t

$\mathrm{C_t}$ = cost in year t

i = discount rate

n = project lifetime

- Positive NPV→economically viable project
- Negative NPV→ Unprofitable project

3. Financial Analysis and Indicators of Financial Performance Cont…

2. Internal Rate of Return (IRR)

- It measures the rate of return a project is expected to generate over its lifetime, considering all cash inflows and outflows.
- It is the discount rate at which the Net Present Value (NPV) of all cash flows (both inflows and outflows) of a project becomes zero.
- The discount rate that makes NPV=0, i.e.,

$$\mathrm{NPV} = 0 = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+i)^t}$$

- Indicates the expected profitability of the investment.
- Higher IRR→more attractive project.

3. Financial Analysis and Indicators of Financial Performance Cont…

3. Benefit-Cost Ratio (BCR)

- It measures the economic worthiness of a project by comparing its total expected benefits to its total expected costs — both expressed in present value terms.
- It is the ratio of the present value (PV) of all benefits to the present value (PV) of all costs associated with a project.

$$\text{BCR} = \frac{\text{Present Value of Benefits}}{\text{Present Value of Costs}}$$

- BCR>1 →Project is economically justified

4. Payback Period (PBP)

- It measures how long it takes for an investment to recover its initial cost from the net cash inflows generated by the project.
- It is the time required for the cumulative cash inflows from a project to equal the initial investment.

$$\text{PBP} = \frac{\text{Initial Investment}}{\text{Annual Net Cash Inflow}}$$

- Shorter payback = faster recovery, lower risk.

3. Financial Analysis and Indicators of Financial Performance Cont…

5. Capacity Factor (CF)

- Used to evaluate the efficiency and utilization of a power plant — whether it's thermal, hydro, nuclear, solar, wind, or biomass.
- It is the ratio of the actual energy produced by a power plant during a specific period to the maximum possible energy it could have produced if it operated at full (rated) capacity for the same period.

$$\text{CF} = \frac{\text{Actual Energy Output}}{\text{Maximum Possible Output}} \text{x}100\%$$

  - High CF indicates better financial performance

3. Financial Analysis and Indicators of Financial Performance Cont…

6. Levelized Cost of Electricity (LCOE)

- Represents the average cost per kWh of energy generated over the plant's lifetime, taking into account all costs — from construction to operation, maintenance, fuel, and decommissioning.
- It is the present value of total lifetime costs of building and operating a power plant divided by the present value of the total electricity generated over its lifetime.

$$\text{LCOE} = \frac{\text{Total Lifetime Costs}}{\text{Total Lifetime Electricity Generation}}$$

- Used to compare technologies on a consistent cost basis.

3. Financial Analysis and Indicators of Financial Performance Cont…

7. Profitability Index (PI)

- It measures the relative profitability of a project by showing how much value is created per unit of investment.
- The Profitability Index (PI) is the ratio of the present value of future cash inflows to the present value of cash outflows (initial investment).

$$\text{PI} = \frac{\text{Present Value of Future Cash Flows}}{\text{Initial Investment}}$$

- If PI>1→Acceptable Project

4. Economics of Power Generation

- The primary objective of power plant engineering, from an economic standpoint, is to generate electrical energy at the lowest possible cost while ensuring reliability and meeting environmental standards.
- The economic viability of a power plant depends on various factors, including capital costs, operating costs, maintenance expenses, fuel prices, and plant performance metrics.
- It's must to balance the trade-offs between high-efficiency, high-cost equipment and lower-efficiency, low-cost options to minimize the total expenditure over the plant's life.

4. Economics of Power Generation

Cont…

- The economics of power generation deals with the study of cost, efficiency, and financial aspects of producing electricity from various energy sources [5].
- It aims to determine the most cost-effective and reliable method for generating power while ensuring sustainability and meeting demand.
- While designing and building a power station, efforts should be made to achieve overall economy so that the per unit cost of production is as low as possible.

Objectives of Economic Analysis

- To determine the total and unit cost of power generation.
- To compare the economic viability of different power plants.
- To aid in investment and operational decision-making.
- To ensure optimal utilization of resources.

4. Economics of Power Generation

Economics of Major Power Plants

1. Thermal Power Plant (Coal/Gas/Oil Based)

   - High fuel cost – major recurring expense (up to 60–70% of total cost)
   - Moderate capital cost
   - High maintenance cost
   - Short construction time

The economic features of thermal power plants are:

- Best for base-load operation.
- High load factor required for profitability.
- Economically viable where fuel supply is abundant and transport is easy.

4. Economics of Power Generation

2. Hydroelectric Power Plant

- High capital cost (due to dam, reservoir, and civil works)
- Low operating cost (no fuel)
- Long life span (50–100 years)

Its economic features are:

- Suitable for peak-load and base-load.
- Dependent on site topography and hydrology.
- Very low cost per kWh after capital recovery.

4. Economics of Power Generation

Cont…

3. Nuclear Power Plant

- Very high capital cost
- Low fuel cost but requires expensive handling and waste disposal
- High safety and regulatory costs

The economic features include:

- Best for continuous base-load operation.
- Low running cost and high reliability.
- Economically viable for large-scale generation.

4. Economics of Power Generation

4. Solar Power Plant

- High capital cost for PV modules, inverters, and land.
- Negligible fuel cost (sunlight is free).
- Low O&M cost.

The economic features of solar power plant are:

- Best for distributed and off-grid applications.
- Intermittent generation → Requires storage or hybridization.
- Cost per kWh declining rapidly due to technology advancement.

4. Economics of Power Generation

Cont…

5. Wind Power Plant

- High capital cost (turbines and installation)
- No fuel cost
- Low O&M cost

The economic features include:

- Suitable for areas with consistent wind speeds.
- Capacity factor ranges from 25–40%.
- Payback period: 5–8 years typically.

4. Economics of Power Generation

Cont…

6. Biomass Power Plant

- Moderate capital cost
- Fuel cost depends on biomass availability
- Higher O&M cost due to handling and combustion systems.

The economic features are:

- Useful for rural electrification.
- Can utilize agricultural and organic waste.
- Provides carbon-neutral electricity.

4. Economics of Power Generation

Cont…

Environmental and Social Cost Considerations

- Economic analysis must include external costs such as:
  - ✓Air and water pollution
  - ✓Land degradation
  - ✓Greenhouse gas emissions
  - ✓Public health impacts
  - ✓Waste disposal costs
- Renewable plants, though costly initially, are more economical in the long term due to low externalities and policy incentives.

Summary

- Power plant economy studies the costs, efficiency, and financial viability of electricity generation.
- Engineering economy applies economic principles to evaluate and optimize engineering projects.
- Principles of engineering economy, such as NPV, IRR, and payback period, guide investment and operational decisions.
- Financial analysis uses performance indicators like profitability, capacity utilization, and benefit-cost ratio to assess power plants.
- Economics of power generation compares costs, revenues, and efficiency across different energy technologies to support informed decisions.

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Thank you !