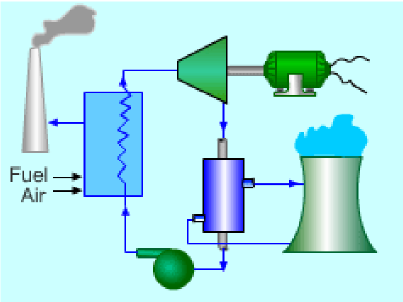
بسم الله الرحمن الرحيم

Thermal Power Stations



Kafrelsheikh University
جامعة كفر الشيخ

Faculty of Engineering
Mechanical Engineering Dept.

Lecture (3)

on

Thermal Power Stations Planning and Design Considerations

(Cost of Electrical Energy)

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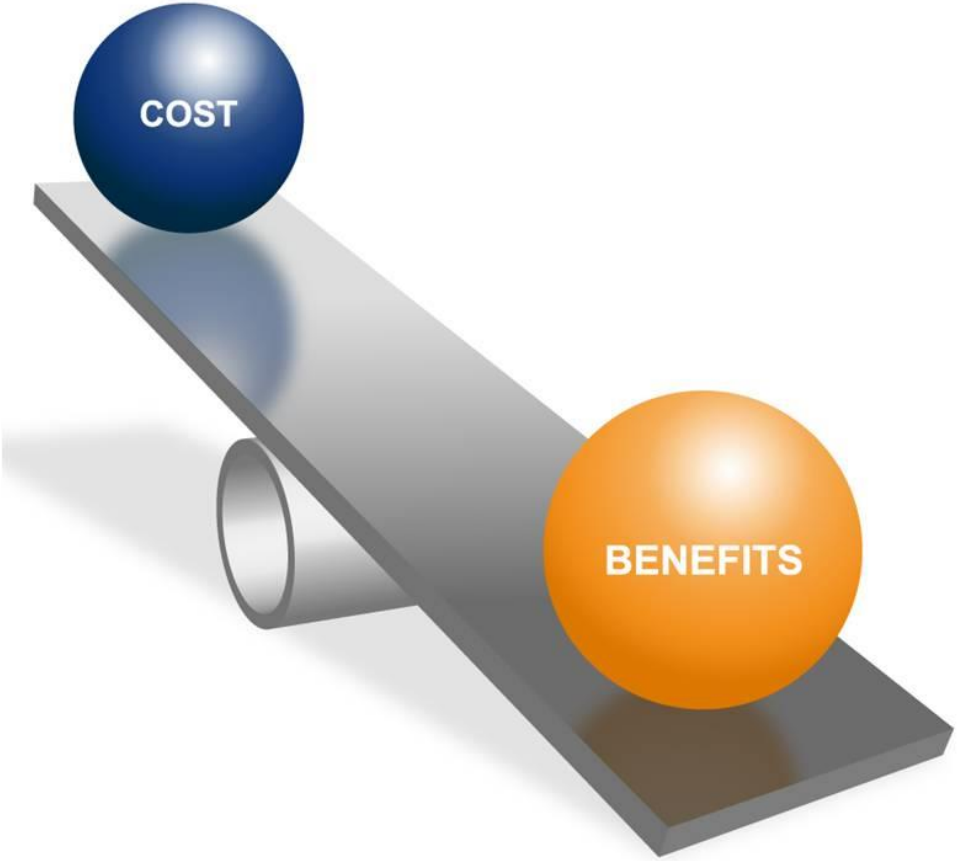
Economics of Power Generation



Economics of Power Generation

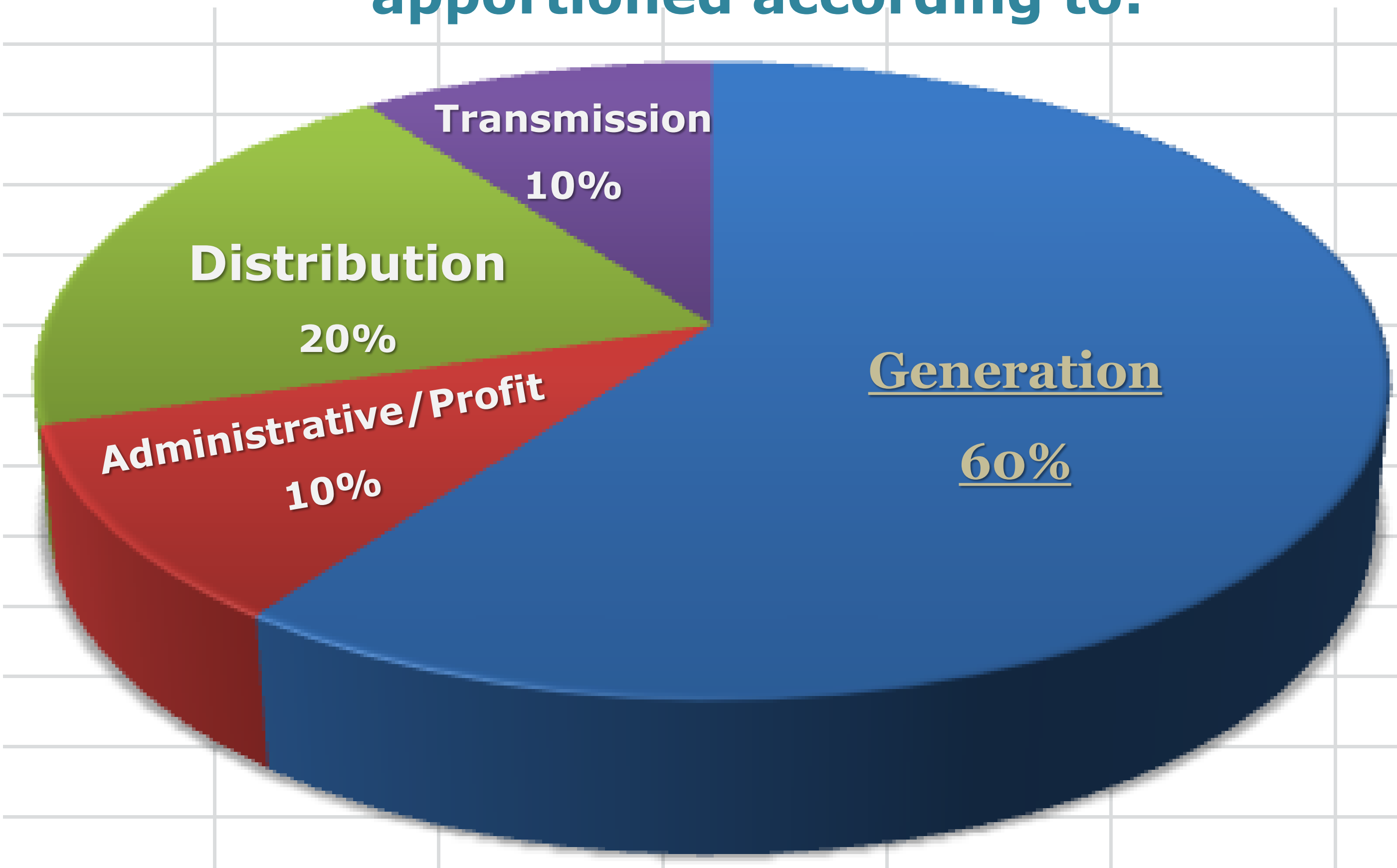
Economics of power generation: The art of determining the per unit (i.e., one kWh) cost of production of electrical energy.

Economics drives the selection of an appropriate power generation scheme for the given situation.

- The economics of power generation has assumed a great importance in this fast developing power plant engineering. A consumer will use electric power only if it is supplied at reasonable rate.
- Therefore, power engineers have to find convenient methods to produce electric power as cheap as possible so that consumers are tempted to use electrical methods.

Economics of Power Generation

The cost to the consumer for electric energy can be roughly apportioned according to:



Economics of Power Generation

Base load is that load below which the demand never falls, that is, the base load must be supplied 100% of the time.

The peaking load occurs less than about 15% of the time;

The intermediate load transpires between 15% to 100% of the time.

Economics of Power Generation

Interest: The cost of use of money.

While calculating the cost of production of electrical energy, the interest payable on the capital investment must be included. The rate of interest depends upon market position and other factors, and may vary from 4% to 8% per annum.

Depreciation: The decrease in the value of the power plant equipment and building due to constant use.

In actual practice, every power station has a useful life ranging from fifty to sixty years. From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of the plant. This reduction in the value of plant every year is known as annual depreciation. It becomes obvious that while determining the cost of production, annual depreciation charges must be included.

Generated Electrical Energy Costs

The total cost of electrical energy generated can be divided into three parts, namely;

Fixed cost: **It is the cost which is independent of maximum demand and units generated.**

The fixed cost is due to:

1. **Annual cost of central organization,**
2. **Interest on capital cost of land**
3. **Salaries of high officials**

Generated Electrical Energy Costs

Semi-fixed cost: It is the cost which depends upon maximum demand but is independent of units generated.

The semi-fixed cost is due to:

1. Capital investment of building and equipment,
2. Taxes,
3. Salaries of management and clerical staff

Generated Electrical Energy Costs

Running cost: It is the cost which depends only upon the number of units generated.

The running cost is on account of annual cost of:

1. Fuel,
2. Lubricating oil,
3. Maintenance and repairs
4. Salaries of operating staff

Generated Electrical Energy Costs

Since costs are expressed on a per kWe·hr basis, a high capacity factor is desired so the capital cost is spread out.

The capital and operating (including fuel) costs generally dictate how a plant is used on the grid (hydroelectric units are an exception to the following):

Loading	Capital Costs	O&M and Fuel Costs	Example Plants
Base	High	Low	Coal, Nuclear
Peak	Low	High	Oil, Old natural gas units

Generated Electrical Energy Costs

The plant selection for various load demands can be summarized as:

Loading	Power Plants	Economics	Capacity Factor*
Base	Large coal and nuclear units	Large capital outlay is acceptable, but must have reasonable operating and maintenance costs	CF > 57%
Intermediate	Old coal, oil or gas units with low thermal efficiency and combined cycle plants	Have mid range operating and maintenance costs	23% < CF < 57%
Peak	Combustion turbines and diesel engines; and hydroelectric	Need to minimize capital costs, but fuel costs can be high	CF < 23%

Generated Electrical Energy Costs

The overall annual cost of electrical energy generated by a power station can be expressed in two forms; three part form and two part form.

Three part form. In this method, the overall annual cost of electrical energy generated is divided into three parts *via* fixed cost, semi-fixed cost and running cost *i.e.*

Total annual cost of energy = Fixed cost + Semi-fixed cost + Running cost

= Constant + Proportional to max. demand + Proportional to kWh generated.

= $a + b$ kW $+ c$ kWh

a = annual **fixed cost** independent of maximum demand and energy output

b = constant which when multiplied by maximum kW demand on the station gives the annual **semi-fixed cost**.

c = a constant which when multiplied by kWh output per annum gives the annual **running cost**.

Generated Electrical Energy Costs

Two part form: It is sometimes convenient to give the annual cost of energy in two part form. In this case, the annual cost of energy is divided into two parts; a fixed sum per kW of maximum demand plus a running charge per unit of energy. The expression for the annual cost of energy then becomes:

Total annual cost of energy = A kW + B kWh

A = a constant which when multiplied by maximum kW demand on the station gives the annual cost of the first part.

B = a constant which when multiplied by the annual kWh generated gives the annual running cost.

Methods of Determining Depreciation

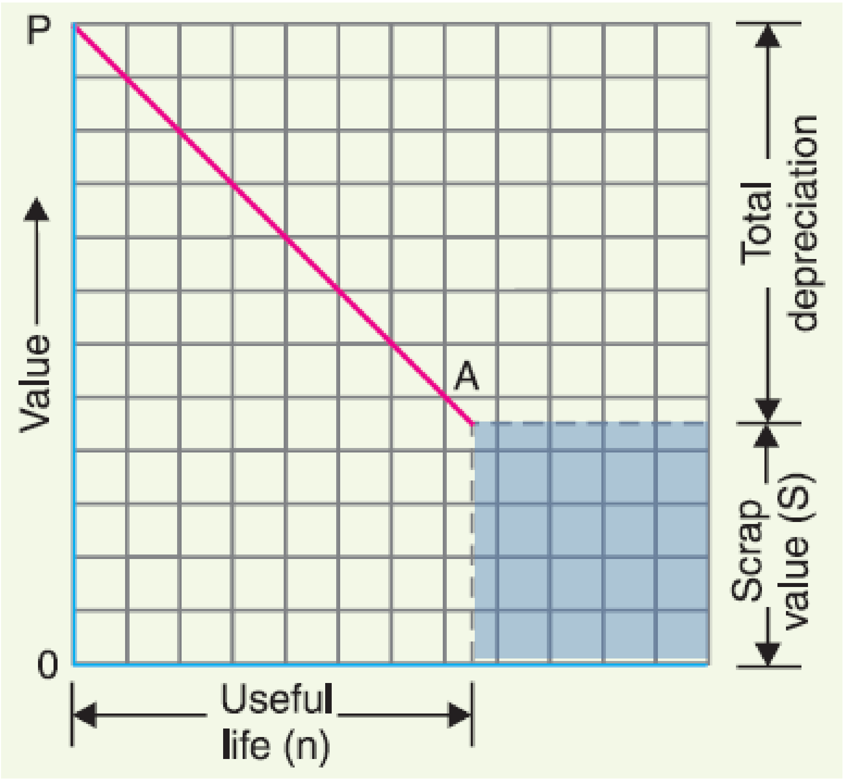
The following are the commonly used methods for determining the annual depreciation charge :

1. **Straight line method ;**
2. **Diminishing value method ;**
3. **Sinking fund method.**

Methods of Determining Depreciation

Straight Line Method

In this method, a constant depreciation charge is made every year on the basis of total depreciation and the useful life of the property. Obviously, annual depreciation charge will be equal to the total depreciation divided by the useful life of the property.



$$\text{Annual depreciation charge} = \frac{P - S}{n}$$

P = Initial cost of equipment

n = Useful life of equipment in years

S = Scrap or salvage value after the useful life of the plant.

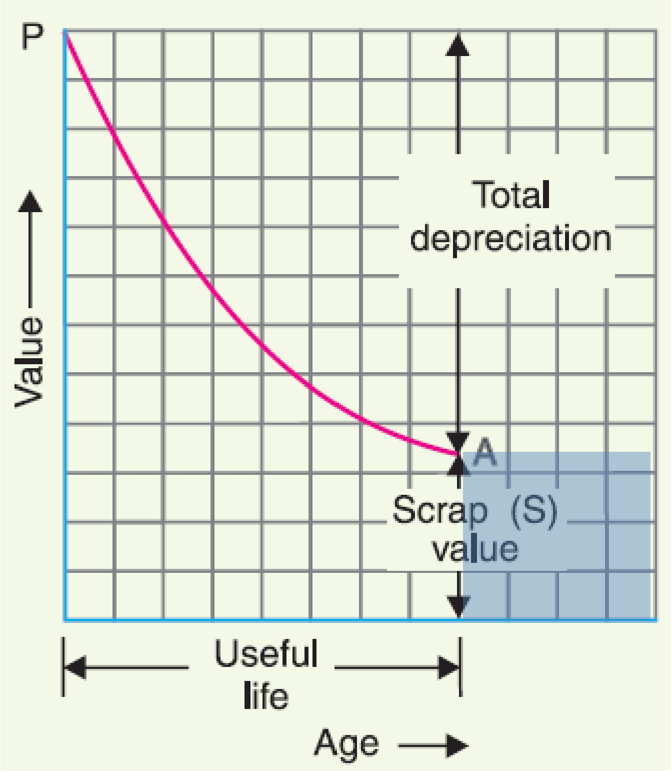
As an example, if the initial cost of equipment is $ 1,00,000 and its scrap value is $ 10,000 after a useful life of 20 years, then,

$$\text{Annual depreciation charge} = \frac{\text{Total depreciation}}{\text{Useful life}} = \frac{1{,}00{,}000 - 10{,}000}{20} = \$\,4{,}500$$

Methods of Determining Depreciation

Diminishing value method

In this method, depreciation charge is made every year at a fixed rate on the diminished value of the equipment. In other words, depreciation charge is first applied to the initial cost of equipment and then to its diminished value.



$$\text{Annual unit depreciation, } x = 1 - (S/P)^{1/n}$$

$$\text{The value of equipment after } n \text{ years} = P(1 - x)^n$$

P = Capital cost of equipment

n = Useful life of equipment in years

S = Scrap value after useful life

Methods of Determining Depreciation

Sinking fund method

In this method, a fixed depreciation charge is made every year and interest compounded on it annually. The constant depreciation charge is such that total of annual instalments plus the interest accumulations equal to the cost of replacement of equipment after its useful life.

$$\text{Value of plant after } N \text{ years} = P - \text{Total fund after } N \text{ years} = P - \frac{q(1+r)^n - 1}{r}$$

$$\text{Annual deposit in the sinking fund is} \quad q = (P-S)\left[\frac{r}{(1+r)^n - 1}\right]$$

Where $N \leq n$

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Methods of Determining Depreciation

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Importance of High Load Factor

The load factor plays a vital role in determining the cost of energy. Some important advantages of high load factor are listed below :

1. **Reduces cost per unit generated:** A high load factor reduces the overall cost per unit generated. The higher the load factor, the lower is the generation cost. It is because higher load factor means that for a given maximum demand, the number of units generated is more. This reduces the cost of generation.

2. **Reduces variable load problems:** A high load factor reduces the variable load problems on the power station. A higher load factor means comparatively less variations in the load demands at various times. This avoids the frequent use of regulating devices installed to meet the variable load on the station.

Example 1: Cost per product unit

A generating station has a maximum demand of 50,000 kW. Calculate the cost per unit generated from the following data :

Capital cost = Rs 95×10^6 ; *Annual load factor = 40%*

Annual cost of fuel and oil = Rs 9×10^6 ; *Taxes, wages and salaries etc. = Rs $7{\cdot}5 \times 10^6$*

Interest and depreciation = 12%

Solution :

Units generated/annum = Max. demand × L.F. × Hours in a year

$= (50{,}000) \times (0{\cdot}4) \times (8760)$ kWh $= 17{\cdot}52 \times 10^7$ kWh

Annual fixed charges

Annual interest and depreciation = 12% of capital cost

$=$ Rs $0{\cdot}12 \times 95 \times 10^6 =$ Rs $11{\cdot}4 \times 10^6$

Annual Running Charges

Total annual running charges = Annual cost of fuel and oil + Taxes, wages etc.

$=$ Rs $(9 \times 10^6 + 7{\cdot}5 \times 10^6) =$ Rs $16{\cdot}5 \times 10^6$

Total annual charges $=$ Rs $(11{\cdot}4 \times 10^6 + 16{\cdot}5 \times 10^6) =$ Rs $27{\cdot}9 \times 10^6$

$\therefore$ Cost per unit $=$ Rs $\dfrac{27{\cdot}9 \times 10^6}{17{\cdot}52 \times 10^7} =$ Re $0{\cdot}16$

Example 2: Determine the depreciated value

The equipment in a power station costs Rs 15,60,000 and has a salvage value of Rs 60,000 at the end of 25 years. Determine the depreciated value of the equipment at the end of 20 years on the following methods :

(*i*) Straight line method ;

(*ii*) Diminishing value method ;

(*iii*) Sinking *fund method at 5% compound interest annually.*

Solution :

Initial cost of equipment, P = Rs 15,60,000

Salvage value of equipment, S = Rs 60,000

Useful life, n = 25 years

(*i*) *Straight line method*

$$\text{Annual depreciation} = \frac{P - S}{n} = \text{Rs } \frac{15{,}60{,}000 - 60{,}000}{25} = \text{Rs } 60{,}000$$

Value of equipment after 20 years

$$= P - \text{Annual depreciation} \times 20$$

$$= 15{,}60{,}000 - 60{,}000 \times 20 = \textbf{Rs 3,60,000}$$

Example 2: Cost per product unit

(ii) Diminishing value method

Annual unit depreciation, $x = 1 - (S/P)^{1/n}$

$$= 1 - \left(\frac{60{,}000}{15{,}60{,}000}\right)^{1/25} = 1 - 0{\cdot}878 = 0{\cdot}122$$

Value of equipment after 20 years

$$= P(1 - x)^{20}$$

$$= 15{,}60{,}000\ (1 - 0{\cdot}122)^{20} = \textbf{Rs 1,15,615}$$

(iii) Sinking fund method

Rate of interest, $r = 5\% = 0{\cdot}05$

Annual deposit in the sinking fund is

$$q = (P - S)\left[\frac{r}{(1+r)^n - 1}\right]$$

$$= (15{,}60{,}000 - 60{,}000)\left[\frac{0 \cdot 05}{(1 + 0 \cdot 05)^{25} - 1}\right]$$

$$= \text{Rs } 31{,}433$$

∴ Sinking fund at the end of 20 years

$$= q\,\frac{(1+r)^{20} - 1}{r} = 31{,}433\ \frac{(1 + 0 \cdot 05)^{20} - 1}{0 \cdot 05} = \text{Rs } 10{,}39{,}362$$

Value of plant after 20 years = Rs (15,60,000 – 10,39,362) = **Rs 5,20,638**

Thank you