

ME 419
POWER PLANT ENGINEERING
(Power Plant Economics)

Power Plant Economics

Study to provide supply of electricity at minimum cost

- ❑ The basis of the most design decisions is economic.

- ❑ Cost elements of electricity generation:
 1. **Fixed element** governed by the extent of investment
 2. **Energy element** proportional to the plant output
 3. **Customer element** related to the number of customers
 4. **Investor's profit**

Power Plant Economics

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1. The components of fixed cost

(a) Capital cost of power plant

- i. Real estate
- ii. Planning and design
- iii. Building and equipment
- iv. Cost of installation
- v. Freight and Express
- vi. Stores and storekeeping
- vii. Interest during construction

(b) Cost of primary distribution system (PDS)

- i. Cost of line
- ii. Cost of substation
- iii. Cost of right of way

Power Plant Economics

Study to provide supply of electricity at minimum cost

- c) Interest, taxation and insurance rates
- d) Deprecation upon cost of the plant and PDS
- e) Management cost
- f) General maintenance which would be required whether or not the plant were operated

2. The components of Energy element

- a) Cost of fuel
- b) Cost of labour
- c) Cost of water
- d) Oil, waste and supplies
- e) Maintenance

Power Plant Economics

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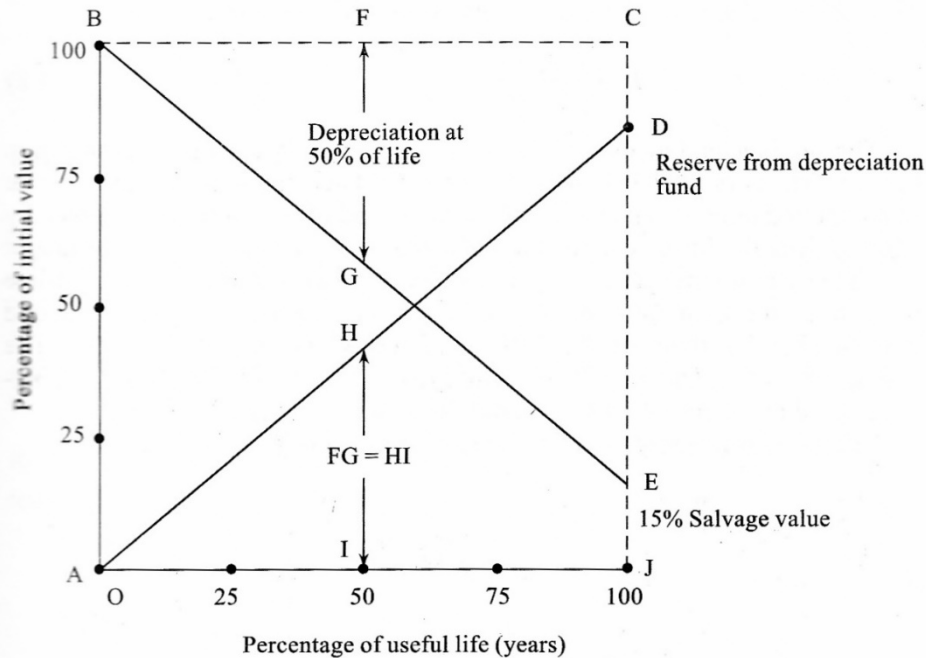
3. Customer Element

- (a) Cost of secondary distribution system
 - (i) Depreciation upon capital cost of SDS
 - (ii) Interest, taxes and insurance upon cost of SDS
 - (iii) Line/Transformer maintenance and inspection
- (b) Labour cost of collecting revenue
 - (i) Meter reading
 - (ii) Office: records, billing and accounting
- (c) Cost of franchise amortised over its life
- (d) Publicity
 - (i) Public relations
 - (ii) Advertising, etc.

4. Investor's profit

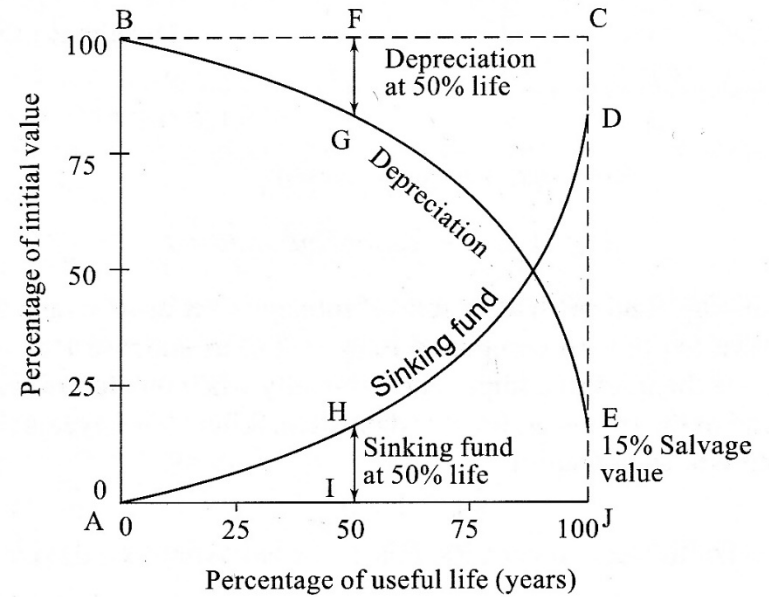
- 8% or less for public limited Co.

Depreciation Methods



Straight-Line Depreciation

$$D = (A - G)/N$$



Sinking-Fund Depreciation

$$P = \frac{A' i}{(1 + i)^{N-1}}$$

Depreciation Methods

Table 3-1. LEGALLY APPROVED DEPRECIATION RATES AND THE USEFUL LIFE THEY REPRESENT

(From *Standard Handbook for Electrical Engineers*, McGraw-Hill Book Co., Publishers)

Property	Depreciation (Straight-line) Per Cent	Life, Years
Air compressors.....	4 to 5	20 to 25
Boilers, fire tube.....	6.7 to 10	10 to 15
Boilers, water tube.....	5	20
Breechings.....	3.5 to 10	10 to 28.5
Buildings.....	2	50
Coal and ash machinery.....	5 to 10	10 to 20
Condensers.....	5	20
Conduits.....	2	50
Steam engines.....	3 to 7.5	13.3 to 33.3
Gas engines.....	6.7	15
Foundations, machinery.....	same as its machine	same as its machine
Fuel oil handling machinery.....	4	25
Generators.....	3 to 5	20 to 33.3
Steam turbogenerators.....	5 to 10	10 to 20
Feed water heaters, closed.....	3.3	33
Feed water heaters, open.....	3.5	28.5
Electric meters.....	5 to 8	12.5 to 20
Piping and covering.....	4 to 6.67	15 to 25
Pumps.....	5 to 6.7	15 to 20
Stacks.....	3 to 10	10 to 33.3
Stokers, fixed parts.....	5	20
Stokers, moving parts.....	20	5
Storage batteries.....	5	20
Switchboard and wiring.....	3 to 8	12.5 to 33.3
Transformers, station service.....	5 to 6.7	15 to 20
Turbines, steam.....	5 to 6.7	15 to 20
Turbines, hydraulic.....	3.33	30
Wire, weatherproof.....	6.25 to 7.5	13.3 to 16
Motors.....	5	20

Problem-1

A 7500-kw steam plant is erected at a cost of \$125 per kw. Assume that bonds in the amount of the total cost were sold. They are to mature in 15 years, which is also the estimated life of the plant. Salvage value is estimated at 5% of first cost. Interest on bonds is 4%; on sinking fund deposit 3_1/2%. The amount of annual payment on the investment, also the sinking fund accumulation after 5 years, will be computed.

Solution

$$\text{Sinking fund factor} = \frac{0.035}{(1.035)^{15} - 1} = 0.052$$

$$\text{Sinking fund payment} = 0.052(125 \times 7500 \times 95\%) = \$46,312.50$$

$$\text{Annual interest payment} = 0.04(125 \times 7500) = \$37,500.00$$

$$\text{Total} = \$83,812.50$$

$$\text{Five-year accumulation factor} = \frac{0.035}{(1.035)^5 - 1} = 0.186$$

$$\text{Accumulated amount} = \frac{46,312.50}{0.186} = \$248,991.93$$

Cost of Electricity, Problem-2

It is proposed to supply a load with a maximum demand of 500 MW and load factor of 70%. Choice is to be made from a nuclear power plant, a hydraulic power plant and a steam power plant. Calculate the overall cost per kWh in case of each scheme as given below:

<i>Cost</i>	<i>Steam power plant</i>	<i>Hydroelectric power plant</i>	<i>Nuclear power plant</i>
1. Capital cost per MW installed	Rs 3 crore	Rs 4 crore	Rs 5 crore
2. Interest	6%	5%	5%
3. Depreciation	6%	4%	5%
4. Operating cost (including fuel) per kWh	30 paise	5 paise	15 paise
5. Transmission and distribution cost per kWh	2 paise	3 paise	2 paise

Cost of Electricity

Steam power plant:

- Capital cost

$$= \text{Rs } 3 \text{ crore} \times 500 = \text{Rs } 1500 \times 10^7$$

- Interest

$$= 0.06 \times 1500 \times 10^7 = \text{Rs } 90 \times 10^7$$

- Depreciation

$$= 0.06 \times 1500 \times 10^7 = \text{Rs } 90 \times 10^7$$

- Annual fixed cost (interest + depreciation)

$$= \text{Rs } 180 \times 10^7$$

- Energy generated per year = average load \times 8760

$$= \text{Load factor} \times \text{maximum demand} \times 8760$$

$$= 0.7 \times 500 \times 10^3 \times 8760$$

$$= 306.6 \times 10^7 \text{ kWh}$$

Depreciation Methods

- Running cost/kWh = (operating cost / kWh) + (transmission and distribution cost/kWh)

$$= 30 + 2$$

$$= 32 \text{ paise}$$

- Overall cost/kWh = fixed cost/kWh + running cost/kWh

$$= \frac{\text{Rs } 180 \times 10^7}{306.6 \times 10^7 \text{ kWh}} + 0.32$$

$$= 0.59 + 0.32 = 0.91 \quad \text{or} \quad 91 \text{ paise}$$

Theory of Rates

- Consumers of electricity are charged for their maximum demands (kW) as well as the energy (kWh) consumed
- Few requirements for the tariff are, it should –
 - be easy to understand
 - provide low rates for high consumption
 - encourage the consumers having high load factors
 - take into account maximum demand charges and energy charges
 - avoid the complication of separate wiring and metering connections

Theory of Rates

- Now-a-days, there are three elements in calculating total electricity charge:
 - **Demand charge:** Recovers fixed element of cost and a portion of profit
 - **Energy charge:** Recovers energy element of cost
 - **Service charge:** Recovers customer element of cost and a portion of the profit.

Theory of Rates

There are various types of tariffs in use, these are

- Flat demand rate
- Straight line meter rate
- Step meter rate
- Block rate tariff
- Two part tariff (Hopkinson Demand Rate)
- Three part tariff (Doherty Rate)

Theory of Rates

- The various types of tariffs can be derived from the following general equation

$$Y = DX + EZ + C$$

- where

- Y = Total amount of bill for the period considered
- D = Rate per kW of maximum demand
- X = Maximum demand in kW
- E = Energy rate per kWh
- Z = Energy consumed in kWh during the given period
- C = Constant amount to be charged from the consumer during each billing period

Flat Demand Rate

- It is based on the number of lamps installed and a fixed number of hours of use per month or per year
- The rate is expressed as a certain price per lamp or per unit of demand (kW) of the consumer
- Can be expressed as: $Y=DX$
- This energy rate eliminates the use of metering equipment
- Customers have no urge to conserve energy.

Straight Line Meter Rate

- The amount to be charged from the consumer depends upon the energy consumed in kWh which is recorded by a means of a kilowatt hour meter.
- It is expressed in the form
$$Y = EZ$$
- This rate suffers from a drawback that a consumer using no energy will not pay any amount although he has incurred some expense to the power station due to its readiness to serve him.
- Secondly, since the rate per kWh is fixed, this tariff does not encourage the consumer to use more power.

Step Meter Rate

- The charge for energy consumption changes as the energy consumption becomes more
- No energy, no bill/tariff
- Customer element of cost is not recovered.
- This tariff is expressed as follows:

$$Y = EZ \text{ If } 0 \leq Z \leq A$$

$$Y = E_1 Z_1 \quad \text{If } A \leq Z_1 \leq B$$

$$Y = E_2 Z_2 \quad \text{If } B \leq Z_2 \leq C$$

- And so on
- Where E , E_1 , E_2 are the energy rate per kWh and A , B and C , are the limits of energy consumption

Block Rate Tariff

- A certain price per units (kWh) is charged for all or any part of block of each unit and for succeeding blocks of energy the corresponding unit charges decrease
- No energy, no bill/tariff
- Customer element of cost is not recovered.
- It is expressed by the expression
 - $Y = E_1Z_1 + E_2Z_2 + E_3Z_3 + E_4Z_4 + \dots$
 - where E_1, E_2, E_3, \dots are unit energy charges for energy blocks of magnitude Z_1, Z_2, Z_3, \dots respectively

Two Part Tariff (Hopkinson Demand Rate)

The total charges are based on the maximum demand and energy consumed

It is expressed as

$$Y = D \cdot X + EZ$$

A separate meter is required to record the maximum demand

Customer element is not recovered.

Three Part Tariff (Doherty Rate)

- The customer pays some fixed amount in addition to the charges for maximum demand and energy consumed
- It is expressed by the expression

$$Y = DX + EZ + C$$

Three Part Tariff (Doherty Rate)

- The customer pays some fixed amount in addition to the charges for maximum demand and energy consumed
- It is expressed by the expression

$$Y = DX + EZ + C$$

Annual cost of operating an electric system are:

- Coal: \$300,000
- Franchise and Publicity : \$70,000
- Station Depreciation : \$190,000
- Station Supplies: \$30,000
- Primary Line Depreciation: \$190,000
- Interest, Taxes and Insurance
 - On plant and primary line: \$50,000
 - On secondary line: \$85,000
- Secondary line depreciation: \$120,000
- Plant maintenance: fixed \$1000, variable \$2000
- Secondary line maintenance: \$50,000
- Labor: Generation \$105,000
 - Distribution: \$80,000
 - Accounting: \$150,000
- Superintending and Management \$50,000
- Dividends and Stockholders: \$350,000
- Annual station output 70×10^6 kWh, 10% line loss
- Peak load 20,000 kW, diversity factor 3.33
- No. of customers 100,000

Compute a three-charge rate in which one-half of the dividends are in service charge, the other half is the demand charge

Annual Cost Elements

1. Fixed Element

- ❑ Station Depreciation : \$190,000
- ❑ Primary Line Depreciation: \$190,000
- ❑ Interest, Taxes and Insurance
 On plant and primary line: \$50,000
- ❑ Plant maintenance: fixed: \$1000
- ❑ Superintending and Management: \$50,000

Total: \$481,000

Annual Cost Elements

2. Energy Element

- Cost of fuel : \$300,000
- Cost of Labor (generation) : \$105,000
- Station Supplies : \$30,000
- Plant maintenance (variable): \$2000

Total: \$437,000

Annual Cost Elements

3. Customer Element

<input type="checkbox"/> Secondary line depreciation	: \$120,000
<input type="checkbox"/> Interest, Taxes and Insurance On secondary line	: \$85,000
<input type="checkbox"/> Secondary line maintenance	: \$50,000
<input type="checkbox"/> Labor distribution	: \$80,000
<input type="checkbox"/> Accounting	: 150,000
<input type="checkbox"/> Franchise and Publicity	: \$70,000

Total: \$555,000

Annual Cost Elements

4. Investor's Profit

☐ Dividends to Stockholders	: \$350,000

	Total: \$350,000

Station output	: 70×10^6 kWh
Line loss	: 10%
Energy delivered to Customers	= $90\% \times 70 \times 10^6$ kWh
	= 63×10^6 kWh

Diversity factor = 3.33 = Individual customer max demand / Station Peak load
 Individual customer max demand = $3.33 \times 20,000$ kW
 = 66,600 kW

$$\begin{aligned}\text{Annual demand charge} &= \text{fixed element} + 50\% \text{ of dividends} \\ &= \$ 481,000 + \$ 175,000 \\ &= \$ 656,000\end{aligned}$$

$$\begin{aligned}\text{Annual unit demand charge} &= \frac{\text{annual demand charge}}{\Sigma \text{ individual maximum demand}} \\ &= \$ 656,000 / 66,600 \\ &= 9.85 \text{ \$/kW}\end{aligned}$$

$$\begin{aligned}\text{Unit demand charge per month} &= 9.85 \text{ \$/12} \\ &= 0.82 \text{ \$/kW} \\ &\sim 1 \text{ \$/kW}\end{aligned}$$

$$\begin{aligned}\text{Energy charge} &= \frac{\text{Energy element cost}}{\text{kWh consumed}} \\ &= \$ 437,000 / 63 \times 10^6 \text{ kWh} \\ &= 0.7 \text{ ¢/kWh}\end{aligned}$$

$$\begin{aligned}\text{Annual service charge} &= \text{Customer element} + 50\% \text{ of dividends} \\ &= \$555,000 + \$175,000 \\ &= \$730,000 \text{ for } 100,000 \text{ customers}\end{aligned}$$

$$\text{Per Customer annual service charge} = \$7.3 \text{ per year}$$

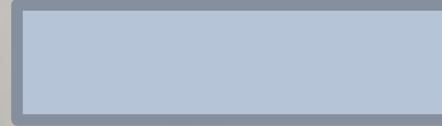
$$\text{Service charge per month} = \text{¢ } 61$$

Three-charge rate:

$$Y = D X + E Z + C$$



BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
OFFICE OF THE CHIEF ENGINEER
ELECTRICITY BILL FOR THE MONTH OF AUGUST/2022
24/09/2022



Electricity rate & other Charges

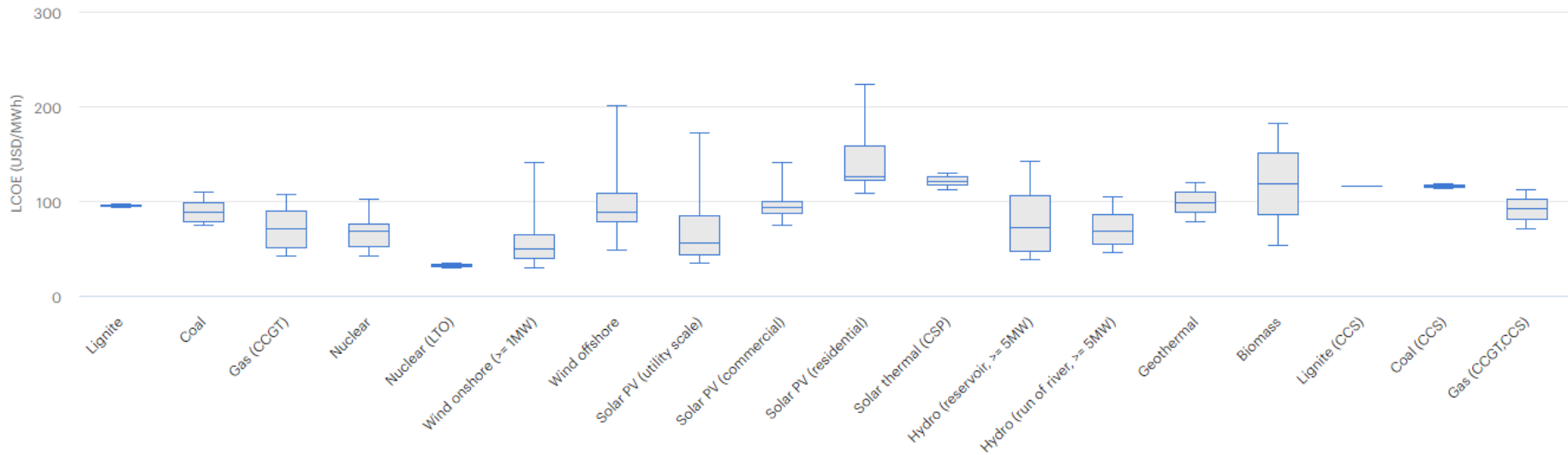
Starting Unit	Ending Unit	Unit Charge
1	75	4.19
76	200	5.72
201	300	6.00
301	400	6.34
401	600	9.94
601	Above	11.46

Demand Charge: TK.30.0 /month
VAT: 5% of bill amt
Service Charge: Tk.10.0 /month
Minimum Charge: Tk.115.0

Meter reading for the month of AUGUST = 43355
Meter reading for the month of JULY = 43066
KWH consumption = 289
Arrears = TK. 0.00
Amount payable as Electricity Bill = TK. 1683

The levelized cost of electricity (LCOE) in electrical energy production is the present value of the price of the produced electrical energy, considering the economic life of the plant and the costs incurred in the construction, operation & maintenance and the fuel costs.

LCOE by technology, discount rate of 7%



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The levelized cost of electricity (LCOE) in electrical energy production is the present value of the price of the produced electrical energy, considering the economic life of the plant and the costs incurred in the construction, operation & maintenance and the fuel costs.

