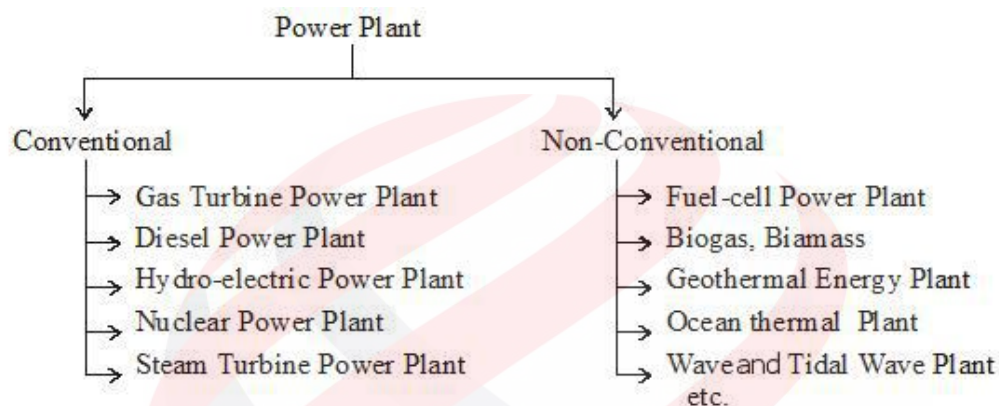


## INTRODUCTION TO POWER PLANT ENGINEERING

**Concept of Power Plant:** A power plant is assembly of system to generate electricity *i.e.* power with economy and requirements.

### Classification of Power Plant



**Note:** The Steam Power Plant, Diesel Power Plant, Nuclear Power Plant, Gas Power Plant are called Thermal Power Plant; because these convert heat into electrical energy.

### Classification of Power Plant Cycle:

(i) **Vapour Power Cycle: Example.** Carnot cycle, Rankine cycle, Reheat cycle, etc.

(ii) **Gas Power Cycle: Example.** Otto cycle, Diesel cycle, Gas turbine cycle etc.

**Economics of power plant engineering:** As there is an exponential growth of production of electricity. Then the rate of change of electricity production per year.

$$\therefore \frac{dE}{dt} = Ei \quad \dots(i)$$

Where, E= fractional increases rate in electricity production each year.

$$\text{And } \ln \frac{E}{E_0} = i(t - t_0)$$

$$\text{Or } E = E_0 e^{i(t-t_0)} \quad \dots(ii)$$

Where  $E_0$ =electricity production in the base year  $t_0$

Equation (ii) gives the exponential behavior called doubling time

$$\text{Or } \frac{E_2}{E_1} = e^{i(t_2-t_1)} \quad \dots(iii)$$

If  $t_d$ = doubling time  $=t_2-t_1$  then

$$\therefore \frac{E_2}{E_1} \Rightarrow 2$$

Therefore  $(1+i)^{t_d} = 2$

$$\text{Or } t_d = \frac{0.693}{i} \quad \dots(iv)$$

From (iv), if  $i=62\%$  then  $t_d=11.2$  year

**Note:-** The demand of electricity has a linear relation with the gross national product (GNP) of a country. Thus with the increases in economic growth the consumption of electricity also increases

#### **Power plant planning parameters:**

- (i) Total power output to be installed ( $\text{kW}_{\text{inst}}$ )
- (ii) Size of the generating units.

#### **Determination of the total installed capacity:**

- (i) First demand ( $\text{kW}_{\text{inst}}$ ) estimated
- (ii) Growth of demand
- (iii) Reserve capacity required.

#### **Size of the generating units depend on:**

- (i) Variation of load (load Curve) during 24 hours.
- (ii) Total capacity of units connected to the electric grid
- (iii) Minimum start up and shut down periods of the units
- (iv) Maintenance schedule
- (v) Plant efficiency V/s size of unit
- (vi) Price and space demand per kW V/s size of unit

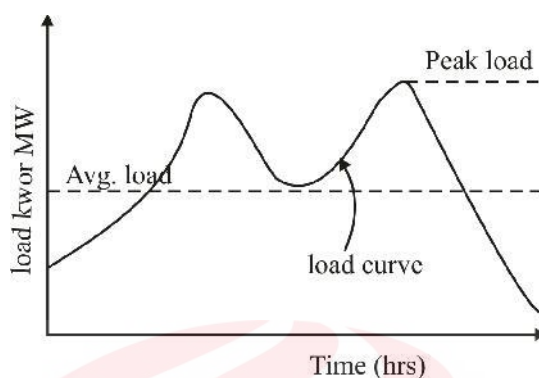
$$\therefore \text{Load Factor } = m = \frac{\text{Average load Over a given time interval}}{\text{peak load during the same time interval}} \quad \dots(i)$$

$$\text{Or } m = \frac{\text{kWh(Avg)in a year}}{\text{kW}_{\text{max}} \text{ in a year}}$$

if  $m < 1$  then plant capacity remains unutilized for major part of the year and electricity production cost would be high or vice-versa.

**Load Curve:** the average load is calculated by dividing the area under daily load curve by the considered time period.

$$\text{Average load} = \frac{\text{Area under load curve (kwh)}}{24 \text{ hours}} \quad \dots(ii)$$



**Capacity factor or plant factor**

$$n = \frac{\text{Average load}}{\text{rated capacity of the plant}} = \frac{\text{kWh generated in a year}}{kW_{inst} \times 24 \times 365} \quad \dots(iii)$$

If rated capacity = peak load

Then load factor = capacity factor

**Reserve capacity = load factor – capacity factor** ...(iv)

$$\text{Reserve factor } r = \frac{kW_{inst}}{kW_{max}}$$

$$\text{Or } r = \frac{m}{n} \quad \dots(v)$$

**Connected load:** Each Consumer has a connected load which is the sum of the continuous ratings of all the equipment and output on the consumer's circuits

**Maximum demand:** It is the maximum load which a consumer uses at any time it is always less than or equal to the connected load.

$$\therefore \text{Demand factor} = \frac{kW_{max} \text{ (Actual)}}{kW_{conn} \text{ (total)}} \quad \dots(vi)$$

**Diversity factor:** It is the time distribution of maximum demands of similar types of consumers.

$$div = \frac{\text{sum of individual consumer groups}}{\text{Actual peak load of the system}} \quad \dots(vii)$$

**Note:** High value of demand factor, load factor capacity factor required for economic operation of the plant and to produce electricity at least cost

$$\therefore \text{Plant use factor } = u = \frac{\text{kWh}_{\text{gen}}}{\text{kW}_{\text{inst}} \times \text{operating hours}} \quad \dots(viii)$$

If operating hour = 1 year = 8760 hour Then  $u = n$

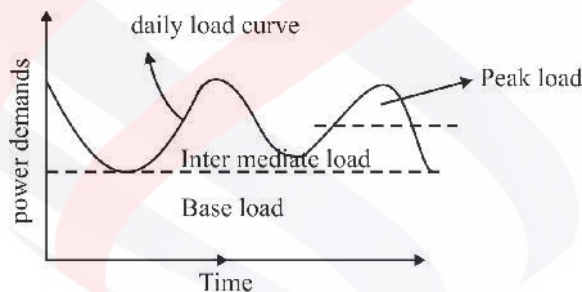
As  $u = 1$  then need of additional capacity of the plant. Hence the plant capacity is always designed to be greater than the peak load to take extra loads coming in future.

$$m \text{ Load factor} \times \text{use factor} = \text{capacity factor} \quad \dots(ix)$$

$$\therefore kWh = \int_0^{24} kW dt \quad \dots(x)$$

The Area under the annual load duration curve gives the total energy supplied by the utility generating system during the year and it is divided as

- (i) **Base load:** it is the load below which the demand never falls and is supplied 100% of the time
- (ii) **Peak load:** it occurs about 15% of the time
- (iii) **Inter mediate load:** it is the remaining load region.



### Economics calculations:

A power plant should provide a reliable supply of electricity at minimum cost to the consumer.

The cost per  $\text{kW}_{\text{net}}$  is determined by

- (i) Fixed costs, interest, depreciation insurance, taxes capital cost.
- (ii) Operation and maintenance cost including salaries and wages
- (iii) fuel cost
- (iv)  $\text{kWh}_{\text{net}}$  sent out per year.

### m Total annual cost

$$C_t = \frac{I + D + T}{100} \times C_c + W + R + M + C_f \quad \dots(i)$$

Where

I= interest (%)

D= depreciation (%)

T= taxes (%) and insurance (%)

$C_c$ =construction or capital cost

W= wages

R= Repairs or maintenance

M= miscellaneous

$C_f$ = Fuel cost

m kWh<sub>net</sub> =rated or installed output of generators

$L_{Aux}$  = power consumption by Auxiliaries (%)

n= plant capacity factor

**Annual Ratio:** A measure of reliability of a power plant

$$= \frac{\text{force outage hours}}{\text{servicehours} + \text{forced outagehours}} \quad \dots(ii)$$

m **Economy scale of construction cost**

$$C_{c,1} = C_{c,2} \left( \frac{R_2}{R_1} \right)^k \quad \dots(iv)$$

Where

$C_{c,1}$  and  $C_{c,2}$  are for parts with rated output of  $R_1$  and  $R_2$  and  $k < 1$ .

**Depreciation fund calculation:**

(i) **Straight line method:**

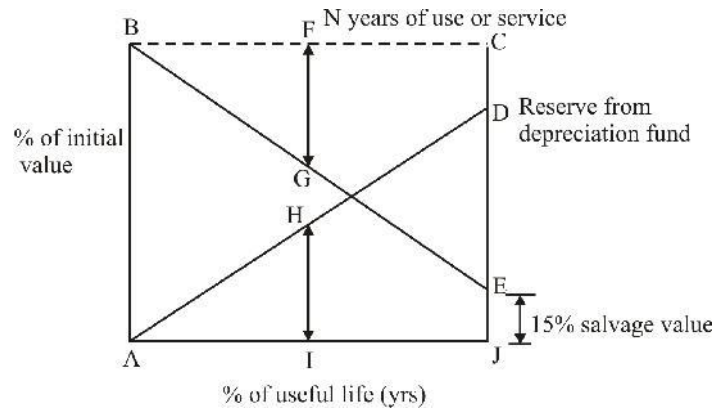
Assumption: the depreciation occurs uniformly every year as per the straight line law and the money saved neglects any interest then

$$\therefore \text{Depreciation change per year} = D = \frac{(A - G)}{N} \quad \dots(i)$$

When A= capital cost of equipment

G= salvage value after

N= years of use or service



(ii) **Sinking found method:** A sum of money is set aside every year for N years and invested to earn compound interest.

Let  $P$  = Annul deposit (for 1<sup>st</sup> year)

$I$  = interest compounded annually when the deposit is invested

After  $(N-1)$  years the worth of equipment (compounded annually)

$$\therefore Rs = P(1+i)^{N-1} \quad \dots(i)$$

$$\text{And net worth} = P + P(1+i) + P(1+i)^2 + \dots + P(1+i)^{N-1} \quad \dots(ii)$$

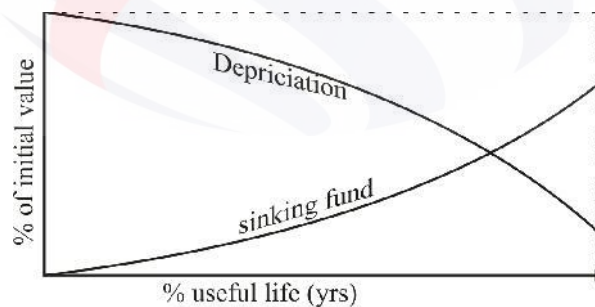
i.e a geometric progression with common ratio  $r = (1+i)$

$$\therefore \text{Sum, } S = \frac{P(1+i)^{N-1}}{i} \quad \dots(iii)$$

$$\text{Or } S = A(\text{capital cost}) - G(\text{salvage cost}) \quad \dots(iv)$$

If  $P$  = annual payment to sinking found

$$= [(\text{initial value}) - (\text{salvage value})] \times \frac{i}{(1+i)^{N-1}} \quad \dots(iv)$$



**Incremental heat Rate:** the performance of a plant is given by

$$\therefore \text{Plant net heat rate } (P_{NHR}) = \frac{\text{heat input}}{\text{net kW output}} \text{ kJ / kWh} \quad \dots(i)$$

**Economic scheduling principle:**

Let  $I_c$  = combined input to units 1 and 2

$L_c$  = Combined output of units 1 and 2

When  $I_c$  is at a maximum it must hold

$$\frac{dI_c}{dL_1} = 0 \dots (i)$$

Since  $I_c = I_1 + I_2$

$$\frac{dI_1}{dL_1} + \frac{dI_2}{dL_2} = 0$$

$$\frac{dI_2}{dL_1} = \frac{dI_2}{dL_2} \times \frac{dL_2}{dL_1}$$

Since  $L_c = L_1 + L_2$

$$\frac{dL_2}{dL_1} = -1$$

$$\frac{dI_2}{dL_1} = (-) \frac{dI_2}{dL_2} \dots (ii)$$

