Unit-VI

Economic Aspects of power generation & Tariff

→ The power demand by the consumers is supplied by the power station through the transmission and distribution networks.

→ As the consumer's load demand changes, the power supply by the powerstation changes accordingly.

→ The load on a power station varies from time to time due to certain demands as variable load on the station.

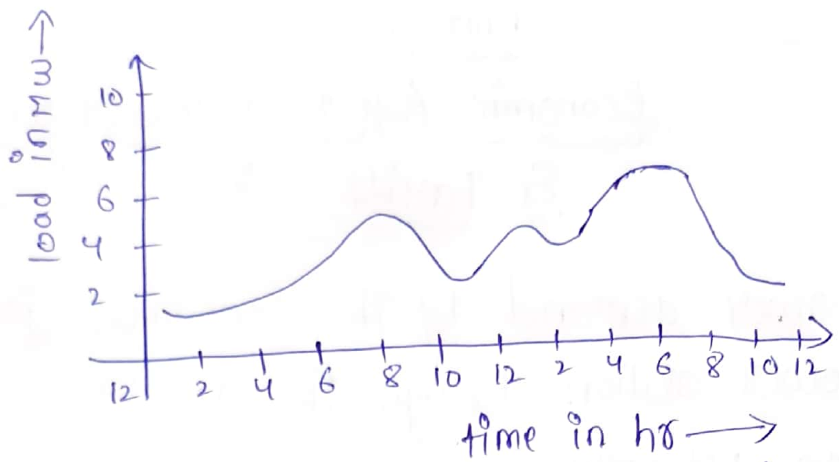
→ A power station is designed to meet the load Requirements of the consumers.

→ Due to variable loads there are some Effects i.e., Need of additional Equipment and increase in production cost.

Load curves:- The curve showing the variation of load on the power station with Respect to time is known as load curve.

→ The load on a power station is not constant, it varies from time to time.

→ The load duration during the whole day is Recorded hourly and are plotted against time then the obtained curve is known as daily load curve.



→ Fig shows variation of load w.r.t time, maximum 6 MW occur at 6 p.m

→ Monthly load curve can be obtained from daily load curves of that month, this monthly load curve is used to fix the rates of energy.

→ The yearly load curve is obtained by considering the monthly load curves of that particular year.

→ The yearly load curve is generally used to determine the annual load factor.

Importance of load curve:-

i, Daily load curve shows the variation of load on power station during diff hours of the day.

ii, The Area under the load curve gives the num of units generated in the day.

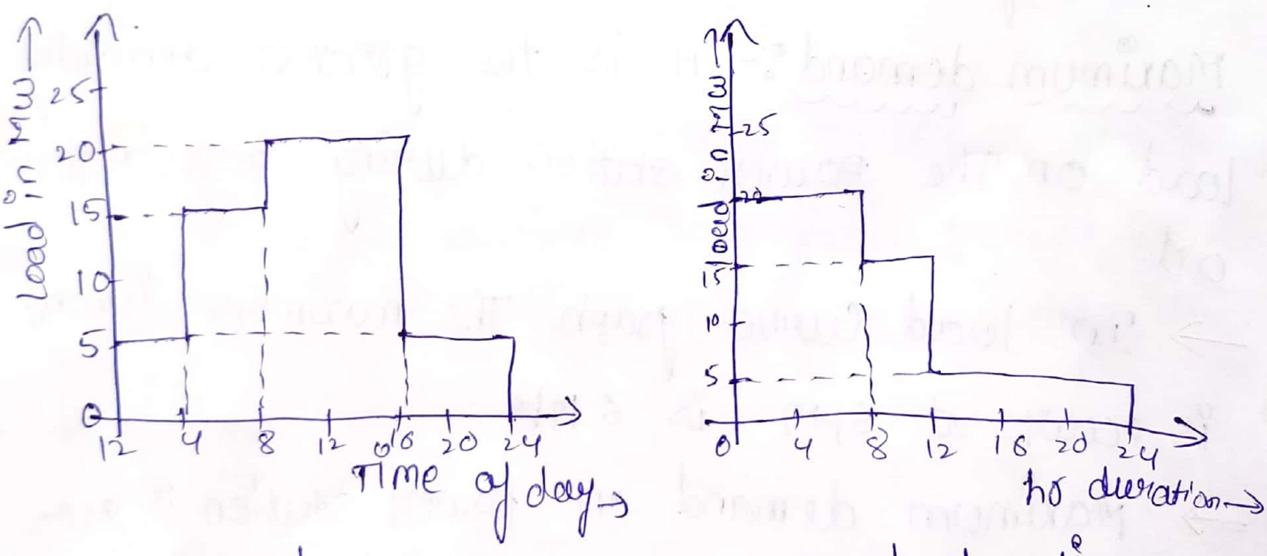
units generated/day = Area (in kwh) under daily load curve.

iii, The highest point in this curve shows maximum demand on the station.

iv, This curve gives Average load, Load factor and helps in selecting the size and num of generating units.

v, This curve helps in preparing the operation schedule of the station.

Load Duration curve:- When the load elements of a load curve are arranged in the order of descending magnitude, the curve thus obtained is called as load duration curve.



load curve. load duration curve.

→ In load duration curve maximum demand is represented to the left and decreasing loads are represented to the right in the descending order.

→ The Area under two curves are equal.

Connected load:- It is the sum of continuous rating of all the Equipments connected to supply system.

→ A Power station supplies load to thousands of consumers. Each consumer has certain Equipment installed.

→ Example is a consumer has five 100-w lamps and a power point of 500w, then the connected load of the consumer is [5×100+500]=1000w.

Maximum demand:- It is the greatest demand of load on the power station during a given period.

→ In load curve graph the maximum demand is occur at 6pm is 6 MW.

→ Maximum demand on power station is generally less than connected load.

→ Maximum demand helps in determining the installed capacity of the station. E station must be capable of meeting the maximum demand.

iii, Demand factor :- It is the Ratio of maximum demand on the power station to its connected load.

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Connected load.}}$$

→ The value of demand factor is always less than 1. because connected load is always greater than maximum demand.

→ It helps in determining the capacity of plant equipment.

iv, Average load :- The average of loads occuring in the power station in a given period is (day or, month or, year) known as average load or average demand.

$$\text{Daily average load} = \frac{\text{No. of units (kWh) generated in a day}}{24 \text{ hrs}}$$

$$\text{Monthly average load} = \frac{\text{No. of units (kWh) generated in a month}}{\text{No. of hr's in a month.}}$$

yearly Average load = $\frac{\text{No. of units (kwh) generated in a year}}{8760 \text{ hr's}}$

Load Factor:- The Ratio of Avg. load to the max. demand during a given period is known as load factor i.e.,

$$\text{load factor} = \frac{\text{Avg. load}}{\text{max. demand}}$$

* If the plant is in operation for T hr's

$$\text{load Factor} = \frac{\text{Avg. load} \times T}{\text{max. demand} \times T}$$

$$= \frac{\text{units generated in T hr's}}{\text{max. demand} \times T \text{ hr's}}$$

→ It is always less than '1' because Avg. load is smaller than max demand.

→ load factor is important in determining the overall cost per unit generated.

→ Higher the load factor lower will be the cost per unit generated.

Diversity factor:- The Ratio of sum of individual maximum demands to max. demand on power station.

$$\text{Diversity factor} = \frac{\text{sum of individual max. demand}}{\text{max. demand on power station}}$$

→ Diversity factor is always greater than '1' because maximum demand on power station is always less than sum of individual maximum demands of the consumers.

Plant capacity factor:- It is the Ratio of actual Energy produced to the maximum possible Energy that could have been produced during a given period.

$$\text{Plant capacity factor} = \frac{\text{Actual Energy produced}}{\text{max. energy that could have been produced}}$$

$$= \frac{\text{Average demand} \times T}{\text{plant capacity} \times T}$$

$$= \frac{\text{Average demand}}{\text{plant capacity}}$$

→ If the considered period is one year

Annual plant Capacity Factor

$$= \frac{\text{Annual kwh o/p}}{\text{Plant capacity} \times 8760}$$

→ Plant capacity factor is an indication of the Reserve capacity of the plant.

→ Power station is so designed that it has some Reserve capacity for meeting the increased load demand in Furture.

→ Installed capacity is greater than the max. demand.

Reserve capacity = plant capacity − max. demand.

Plant use Factor :- It is Ratio of kwh generated to the product of plant capacity and the num of hours for which the plant was in operation i.e.,

$$\text{Plant use factor} = \frac{\text{station o/p in kwh}}{\text{Plant capacity} \times \text{hr's of use}}$$

units generated per Annum :-

$$\text{load factor} = \frac{\text{Average load}}{\text{Max. demand}}$$

Average load = max. demand × L.F

∴ units generated / Annum = Avg. load (in kW) × Hr's in a yr

= max. demand (kW) × L.F × 8760.

1. A generating station has a max. demand of 25 MW, a load factor of 60%, a plant capacity factor of 50% and a plant use factor of 72%. Find i, The Reserve capacity of the plant. ii, The daily energy produced and iii, max. Energy that could be produced daily if the plant while running as per schedule, were fully loaded.

Sol :- i,
$$\text{Load Factor} = \frac{\text{Average demand}}{\text{Max. demand}}$$

$$0.60 = \frac{\text{Average demand}}{25}$$

Average demand = 25 × 0.60 = 15 MW.

Plant capacity factor = $\frac{\text{Average demand}}{\text{plant capacity}}$

$\therefore$ plant capacity = $\frac{\text{Average demand}}{\text{plant capacity factor}}$

$= \frac{15}{0.5} = 30\,MW$

$\therefore$ Reserve capacity of plant

= plant capacity − max. demand

$= 30 - 25 = 5\,MW$.

ii, Daily energy produced = Avg demand × 24

$= 15 \times 24 = 360\,MWh$

iii, Max. energy that could be produced.

= $\frac{\text{Actual energy produced in a day}}{\text{plant use factor}}$

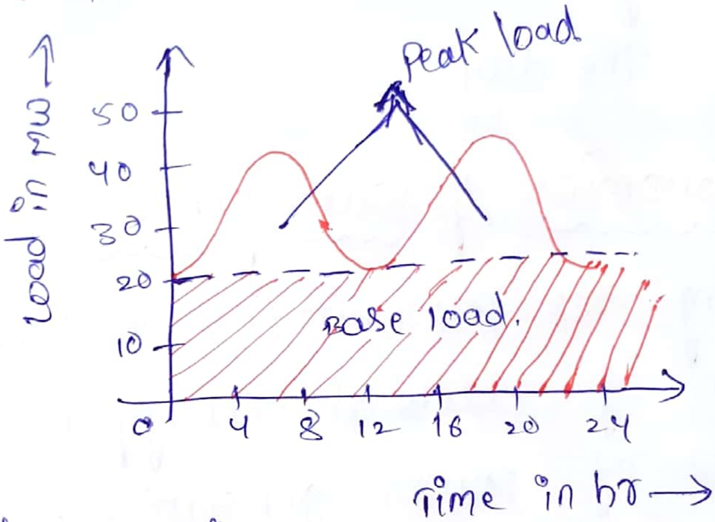
$= \frac{360}{0.72}$

$= 500\,MWh/day$.

Base load and Peak load on power station:-

→ Load on the power station varies from time to time, it can be considered in two parts,

i, Base load. ii, Peak load.



i, **Base load**:- The unvarying load which occurs almost the whole day on the station is known as base load.

→ In fig 20MW of load has to be supplied by the station at all times of day & night i.e., throughout 24 hr. So, 20MW is the base load of the station.

ii, **Peak load**:- The various peak demands of load over and above the base of load of the station is known as peak load.

→ In fig. There are peak ~~dean~~ demands of load excluding base load.

→ This peak demand generally form a small part of the total load and may occur throughout the day.

Economics of power generation:- The art of determining the per unit (i.e., one kwh) cost of production of electrical energy is known as Economics of power generation.

→ consumer will use power only if it supplied at Reasonable rate. so, Engineers have to find convenient methods to produce electric power as cheap as possible

→ There two terms which are used in this Economics of power generation.

i. Interest:- The cost of use of money is known as interest.

→ Investement on power station should borrowed from banks, so. company should pay the annual interest for amount.

→ While calculating the cost of production of electrical energy, the interest payable on the capital investement must be included.

→ The rate of interest depends upon the market position and other factors,

iii, Depreciation :- The decrease in the value of the power plant equipment and building due to constant use is known as depreciation.

→ The equipments of power station is steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of plant this is known as annual depreciation

→ Due to this equipments should be replaced, so there will be a extra investement i.e., cost of Replacement.

Cost of Electrical Energy :- Total cost of electrical energy generated can be divided into three parts

i, Fixed cost :- It is the cost which is independent of max. demand, units generated, salaries of high officials.

→ In this annual expenditure, salaries of officials, capital investment on land are fixed and it should met whether the plant has high or low max. demand.

ii, **Semi fixed cost** :- It is the cost which depends upon max. demand but is independent of units generated.

→ It is directly proportional to max. demand, on account of annual interest and depreciation on capital investment of building & equipment, taxes, salaries of management and clerical ~~[illegible]~~ staff

→ max. demand determines its size and cost of installation.

iii, **Running cost** :- It depends only upon the num of units generated.

→ The Running cost is on account of annual cost of fuel, lubricating oil, maintenance, Repairs and salaries of operating staff.

→ These charges depends upon the energy o/p. The running cost is directly proportional to the num of units generated by the station.

Expressions for cost of Electrical Energy:-

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

i) **Three part form:-** In this overall annual cost of electrical energy generated is divided into three parts i.e., Fixed cost, semi-fixed cost & running cost

Total annual cost of energy = fixed cost + semi-fixed cost + Running cost.

= Constant + proportional to max-demand + proportional to kwh generated

$= Rs\ (a + b\,kw + c\,kwh)$

where a = annual fixed cost independent of max. demand, energy o/p.

b = Constant which when multiplied by max. kw demand on the station gives the annual semi fixed cost

C = a constant which when multiplied by kwh o/p per annum gives the annual running cost.

ii, Two part form:- It is sometimes convienient to give the annual cost of energy in two part form.

→ the annual cost of energy is divided into two parts ie, a fixed sum per kw of max. demand plus a running charge per unit of energy.

∴ Total annual cost of energy = Rs (A kw + B kwh)

A = a constant which when multiplied by max 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.

Tariff:- The Rate at which Electrical energy is supplied to a consumer is known as tariff.

→ It includes total cost of producing and supplying electrical energy plus the profit, it cannot be same for all consumers.

→ **Objective of tariff:-** Like other commodities, electrical energy is also sold at such a rate so, that it not only returns the cost but also Earns Reasonable profit.

i, Recovery of cost of producing electrical energy as the power station.

ii, Recovery of cost on the capital investment in transmission and distribution systems.

iii, Recovery of cost of operation and maintenance of supply of electrical energy Eg.. metering equipment, billing etc.,

iv, A suitable profit on the capital investment.

Desirable characteristics of a Tariff:-

i, **Proper returns:-** The tariff should be Ensure

The proper returns from each consumer.

→ The total returns must be equal to cost of producing and suppling electrical energy plus profit.

→ This will enable the supply company to ensure continuous and reliable service to consumers.

ii, **Fairness:-** The tariff should be fair so that different types of consumers are satisfied with the rate of charge of electrical energy.

→ A consumer whose load conditions do not deviate much from the ideal should be charged at a lower rate than the one whose load conditions change appreciably from the ideal.

iii, **Simplicity:-** The tariff should be simple so that an ordinary consumer can easily understand it.

→ A complicated tariff may cause an opposition from the public which is generally distrustful of supply companies.

iv, **Reasonable Profit:-** There should be a reasonable profit.

→ electric supply company is a public utility company and generally enjoys the benefits of monopoly.

→ The profit is Restricted to 8% or so per annum.

V. Attractive :- The tariff should be attractive so that a large num of consumers are encouraged to use electrical Energy.

→ Efforts should be made to fix the tariff in such a way so that consumers can pay Easily.

Types of tariff :- There are several types of tariff. The commonly used type of tariff are.

1. simple tariff :- when there is a fixed rate per unit of energy consumed, it is called a simple tariff or uniform rate tariff.

→ In this type, the price charged per unit is constant i.e., it does not vary with increase or decrease in num of units consumed.

Disadvantages :-

→ There is no discrimination b/w different types of consumers since every consumer has to pay equitably for the fixed charges.

→ The cost per unit delivered is high

→ It does not encourage the use of electricity.

2. Flat rate tariff:- When different types of consumers are charged at different uniform per unit rates, it is called a flat rate tariff.

→ In this type, The consumers are grouped into different classes and each class of consumers is charged at a different uniform rate.

→ Ex:- The flat rate per kwh for lighting load may be 60 paise, where it may less for power load i.e., 55 paise / kwh

→ Advantage with this type is more fair to different types of consumers and is simple in calculations.

Disadvantage:-

→ This Tariff varies according to the way of supply, separate meters are required for lighting load, power load etc., so, this tariff is expensive & complicated.

→ A particular class of consumers is charged at the same rate irrespective of magnitude Energy consumed.

3. Block rate tariff:- when a given block of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively Reduced rates, it is called a block rate tariff.

→ In this, the energy consumption is divided into blocks and the price per unit is fixed in each block.

→ The price per unit in the first block is highest i.e., Ex:- First 30 units may charged at the rate of 60 paise per unit, and it reduced for the succeeding blocks i.e., next 25 units is at 55 paise per unit and Remaining units charged at 30 paise per unit.

→ This will increases the load factor of the system and hence the cost of generation is reduced.

→ This type of tariff is being used for majority of Residential and small commercial consumers.

4. Two part tariff :- When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed it is called a two-part tariff

→ In this total charge is split into two components i.e., fixed charges & running charges.

→ Fixed charge depends upon the max. demand of the consumer, running charges depends on num of units consumed by consumer.

→ Total charges = Rs (b×kw + c×kwh)

b → charge per kw of max. demand

c → charge per kwh of energy consumed.

→ This type is most applicable to Industrial consumers.

Advantages :- It is easily understood by the consumers.

→ It recovers the fixed charges which depends upon the max. demand of consumers. but independent of units consumed.

Disadvantages:- consumers has to pay fixed charges whether they consumed the electrical energy or not consumed.

→ There is always error in assessing the max. demand of the consumer.

5. Maximum demand tariff:- It is similar to two-part tariff but the difference is in this max. demand was measured by using seperate max. demand meters at consumers.

→ This type of tariff is mostly applied to big consumers, it is not suitable for small consumers because separate max. demand is required.

6. Power factor tariff:- The tariff in which p.f of the consumer's load is taken into consideration is known as power factor tariff.

→ In A.C system p.f is very important. A low p.f increases the rating of station equipment and line losses.

→ A consumer having low p.f must be penalised there are three types p.f tariff.

i, **KVA Max.demand tariff:-** It is modified form of two part tariff.

→ In this fixed charges are made on the basis of max.demand in "KVA" not in kw.

→ As KVA is inversely proportional to p.f, so, a consumer having low p.f has to contribute more towards the fixed charges.

→ It encourages the consumers to operate their appliances, machinery at improved p.f.

ii, **sliding scale tariff:-** This is also known as avg. p.f tariff.

→ In this Avg p.f like 0.8 lag is taken as reference. If the p.f of consumer is below the Ref then additional charges are made.

→ If p.f of consumer is above the Ref. p.f then discount is allowed to consumer.

iii, **kw & KVAR tariff:-** In this both active power (kw) and Reactive power (KVAR) supplied are

are charged seperately.

→ A consumer having low p.f will draw more Reactive power and hence shall have to pay more charges.

7. Three part tariff :- The total charge is split into three parts i.e., fixed charges, semi-fixed charges and running charges, it is known as three part tariff.

∴ Total charge = Rs(a + b × kw + c × kwh).

a → Fixed charge during each billing period. It includes interest and depreciation on the cost of secondary distribution & labour cost of collecting Revenues.

b → charge per kw of max. demand.

c → charge per kwh of energy consumed.

→ This type is applicable for big consumers.

1. The max. demand of a consumer is 20A at 220V and his total energy consumption is 8760 kwh. If the energy is charged at the rate of 20 paise per unit for 500 hours use of the max. demand per annum plus 10 paise per unit for additional units. Calculate
i, Annual bill ii, Equivalent flat rate.

sol:- Assume the load factor and power factor to be unity.

$\therefore$ max. demand $= \frac{220 \times 20 \times 1}{1000} = 4.4$ kW

i, units consumed in 500 hrs $= 4.4 \times 500$
$= 2200$ kWh.

charges for 2200 kWh $=$ Rs 0.2×2200
$= 440$

Remaining units $= 8760 - 2200$
$= 6560$ kWh.

charges for 6560 kWh $=$ Rs 0.1×6560
$= 656$

$\therefore$ Total annual bill $= (440 + 656) = 1096$

ii, Equivalent flat rate $= \frac{1096}{8760} = 0.125$
$= 12.5$ paise.

2. Calculate annual bill of a consumer whose max. demand is 100 kW, P.f $= 0.8$ lag and load factor $= 60\%$. The tariff used is Rs 75 per kVA of max. demand plus 15 paise per kWh consumed.

sol:- units consumed 1yr $=$ max. demand $\times$ L.F $\times$ Hr in a year
$= (100) \times (0.6) \times (8760)$ kWh
$= 5.256 \times 10^5$ kWh.

max. demand in kVA = 100/p.f = 100/0.8
= 125

Annual bill = max. demand charges + Energy charges.

$= (75 \times 125) + (0.15 \times 5.256 \times 10^5)$

= 9375 + 78840

= 88,215.

3. The monthly readings of a consumer's meter are as follows. max. demand = 50kW; Energy consumed = 36,000 kwh; Reactive Energy = 23,400 kVAR, If the tariff is Rs 80 per kw of max. demand plus 8 paise per unit plus 0.5 paise per unit for Each 1% of p.f below 86%, calculate the monthly bill of the consumer.

sol:-

$$\text{Avg load} = \frac{36,000}{24 \times 30} = 50\text{kw}$$

$$\text{Avg. Reactive Power} = \frac{23,400}{24 \times 30} = 32.5\text{kVAR}$$

suppose ϕ is the p.f angle

$$\tan\phi = \frac{\text{kVAR}}{\text{Active power}} = \frac{32.5}{50}$$

$= 0.65$

$\phi = \tan^{-1}(0.65)$

$= 33.02^\circ$

Then $\cos\phi = 0.8384$.

P.f surcharge = Rs $\frac{36{,}000 \times 0.5}{100} \times (86 - 83.84)$

= 388.8.

Monthly bill = $(80 \times 50 + 0.08 \times 36000 + 388.8)$

= $(4000 + 2880 + 388.8)$

= 7268.8 Rs.