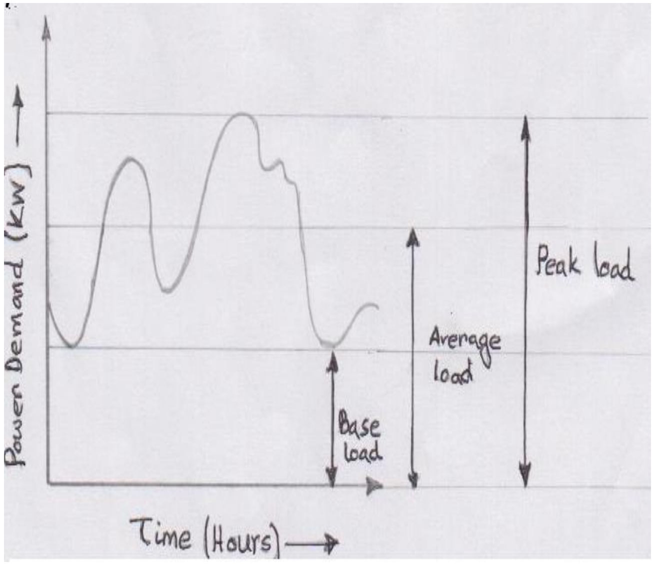
Power Plants (ME-403)

Lecture Topic: Power Plants Economics (Theory)

(8^{th} Semester B.Sc Mechanical Engineering)

MANSOOR ALI ZAHEER
Assistant Professor
Mechanical Engineering Department
University of Sargodha



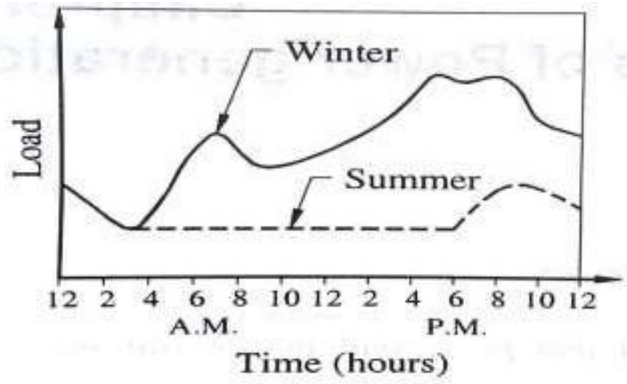
What is Economics of Power Generation?

Definition of Economics of Power Generation:

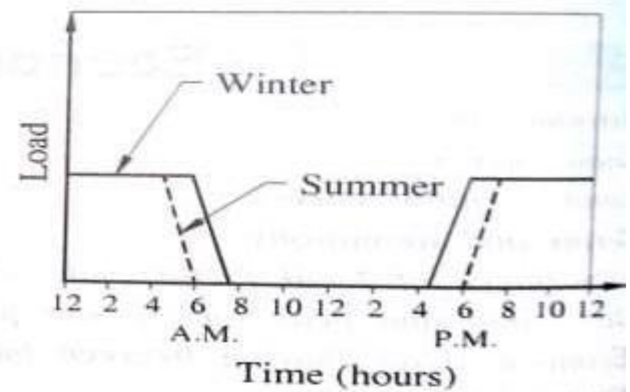
- “ The art of determining the per unit (i.e. one kWh) cost of production of Electrical Energy is known as Economics of Power Generation”.
- While designing and building a power station, efforts should be made to achieve overall economy so that the per unit cost of production is as low as possible.
- This will enable the electric supply company to sell electrical energy at a profit and ensure reliable service.

LOAD CURVES

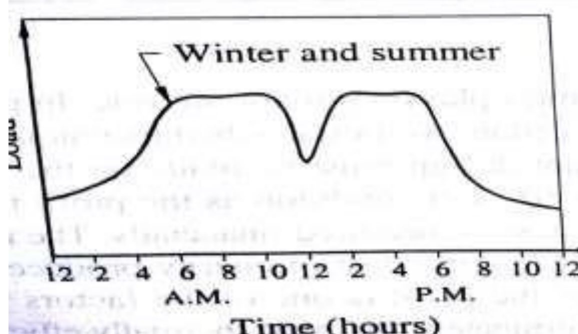
- The load on power plants will always be changing with time and will not be constant because consumer of electric power will use the power as and when required.
- Load curve is graphical representation between load in kW and time.
- It shows variation of load on the power station.
- If the time is in hours then the load curve is known as daily load curve.
- If the times is in days, the load curve is known as monthly load curve and if the time is in months, the load curve is known as yearly or annual load curve.
- The daily load curve will be different for different type of consumers and different localities. These load curves may show different pattern during summer, winter and rainy season.



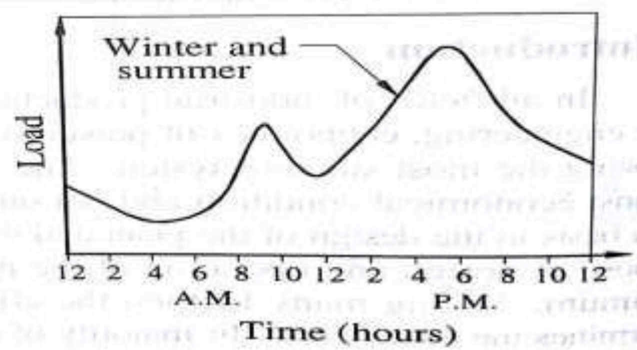
(a) Residential load curve



(b) Street lighting load curve

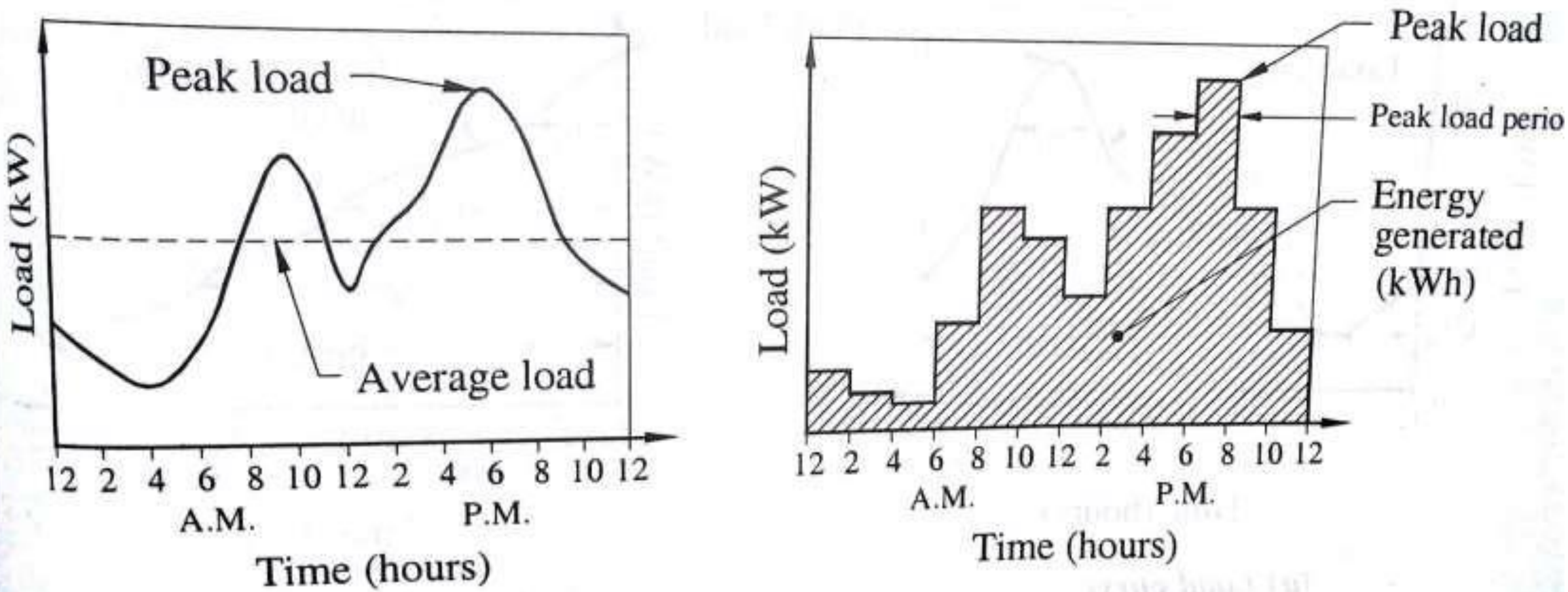


(c) Industrial load curve



(d) Urban traction load curve

- The combined daily load curve for all types of consumers is shown in figure (a) and the approximated curve for simplicity is shown in figure (b).



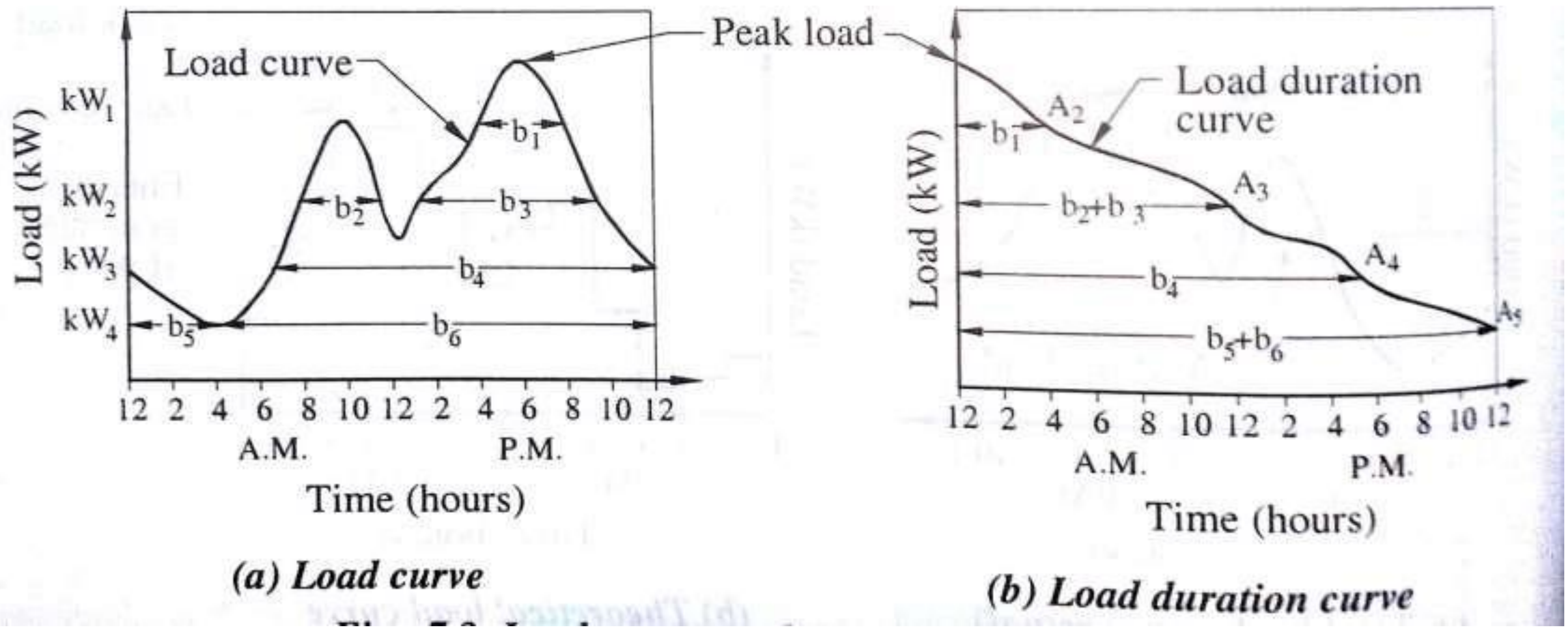
(a) Total load curve (actual)

(b) Theoretical load curve

Fig. 7.2 Daily load curve for all types of consumers.

LOAD DURATION CURVES

- Load duration curve is simply a re-arrangement of daily load curve with loads set up in descending order of magnitude.
- The load duration curve indicates for how many hours a certain load is required in a day.



TERMS AND DEFINITIONS

1. Connected load:

Connected load is the sum of ratings in kilowatts (kW) of equipment installed in the consumer's premises.

The connected loads in the premises of a consumer are shown in figure.

Total load connected in the consumer's premises:

= 40 + 1000 + 60 + 40 + 20 + 500 + 25 + 60 = 1745 W

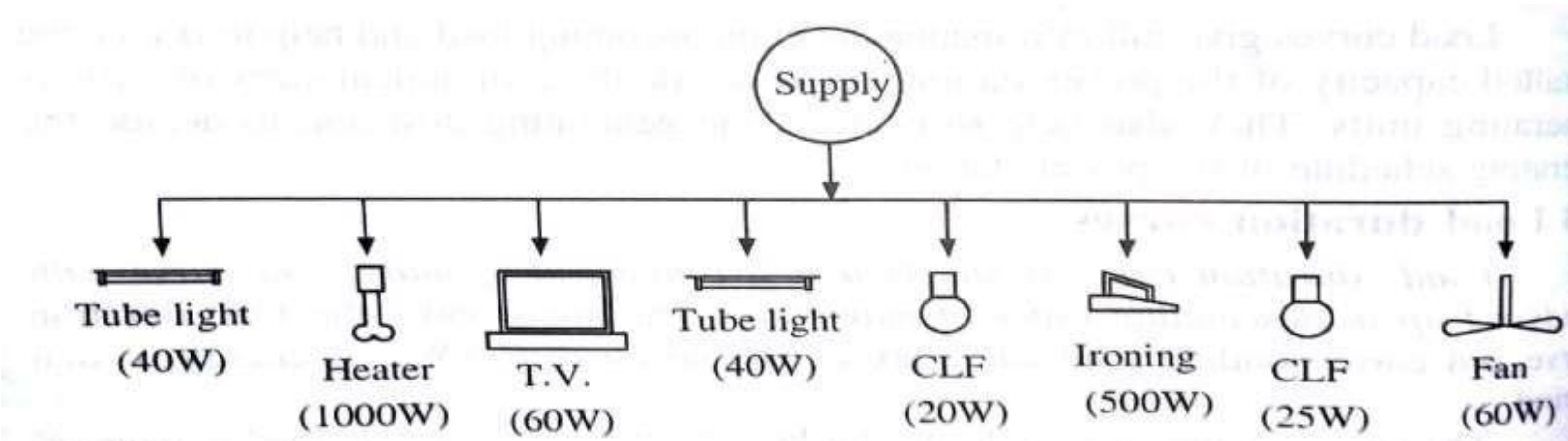


Fig. 7.4 Load in a consumer's premises

2. Demand:

The demand of an installation or system is the load that drawn from the source of supply at the receiving terminals averaged over a suitable and specified interval of time. Demand is expressed in killowatts (kW) or other suitable units.

3. Maximum demand or Peak load

It is the maximum load which a consumer uses at any time. It can be less than or equal to connected load.

If all the equipment fitted in consumer’s premises run to their fullest extent simultaneously then the maximum demand will be equal to connected load. But generally the actual maximum demand is less than the connected load because all the devices never run at full load at the same time.

(4) Demand factor:

It is defined as the ratio of maximum demand to connected load.

(5) Average load:

The average load is calculated dividing the area under the load curve (energy in kWh) by the time period (24 hours) considered to draw the load curve.

$$\therefore \text{Average load} = \frac{\text{Area under load curve}}{24} = \frac{\text{Energy consumed 24 hrs}}{24}$$

(6) Load factor:

It is defined as the ratio of average load to maximum or peak load. Load factors and demand factors are always less than unit.

Load factor play an important part on the cost of generation per unit. The higher the load factor the lesser will be the cost of generation per unit for the same maximum demand.

$$\therefore \text{Load factor} = \frac{\text{Average load}}{\text{Maximum load}}$$

7. Diversity factor:

The diversity factor is the ratio of the sum of the maximum demands of the individual consumers and simultaneous maximum demand of the whole group during a particular time.

$\therefore$ Diversity factor

$$= \frac{\text{Sum of individual maximum demands}}{\text{Simultaneous maximum demand at a given time}}$$

Diversity factor is always greater than unity.

8. Plant Capacity factor:

It is defined as the ratio of actual energy produced in kilowatt hours (kWh) to the maximum possible energy that could have been produced during the same period.

$$\therefore \text{Plant capacity factor} = \frac{\text{Average load x 24}}{\text{Plant capacity x 24}} = \frac{\text{Average load}}{\text{Plant capacity}}$$

The difference between load and plant capacity factors is an indication of reserve capacity.

The capacity factor shows how near the plant runs to its full ratings.

The high values of demand factor, load factor, diversity factor and capacity factor are always desirable for economic operation of the plant and to produce energy at a cheaper rate.

9. Plant use factor:

It is defined as the ratio of energy produced in a given time to the maximum possible energy that could have been produced during the actual number of hours the plant was in operation.

It shows the extent to which the plant capacity is used to meet the peak demand.

Plant use factor =

$$\frac{\text{Annual energy produced}}{\text{capacity of plant} \times \text{No. of hours plant is in operation during year}}$$

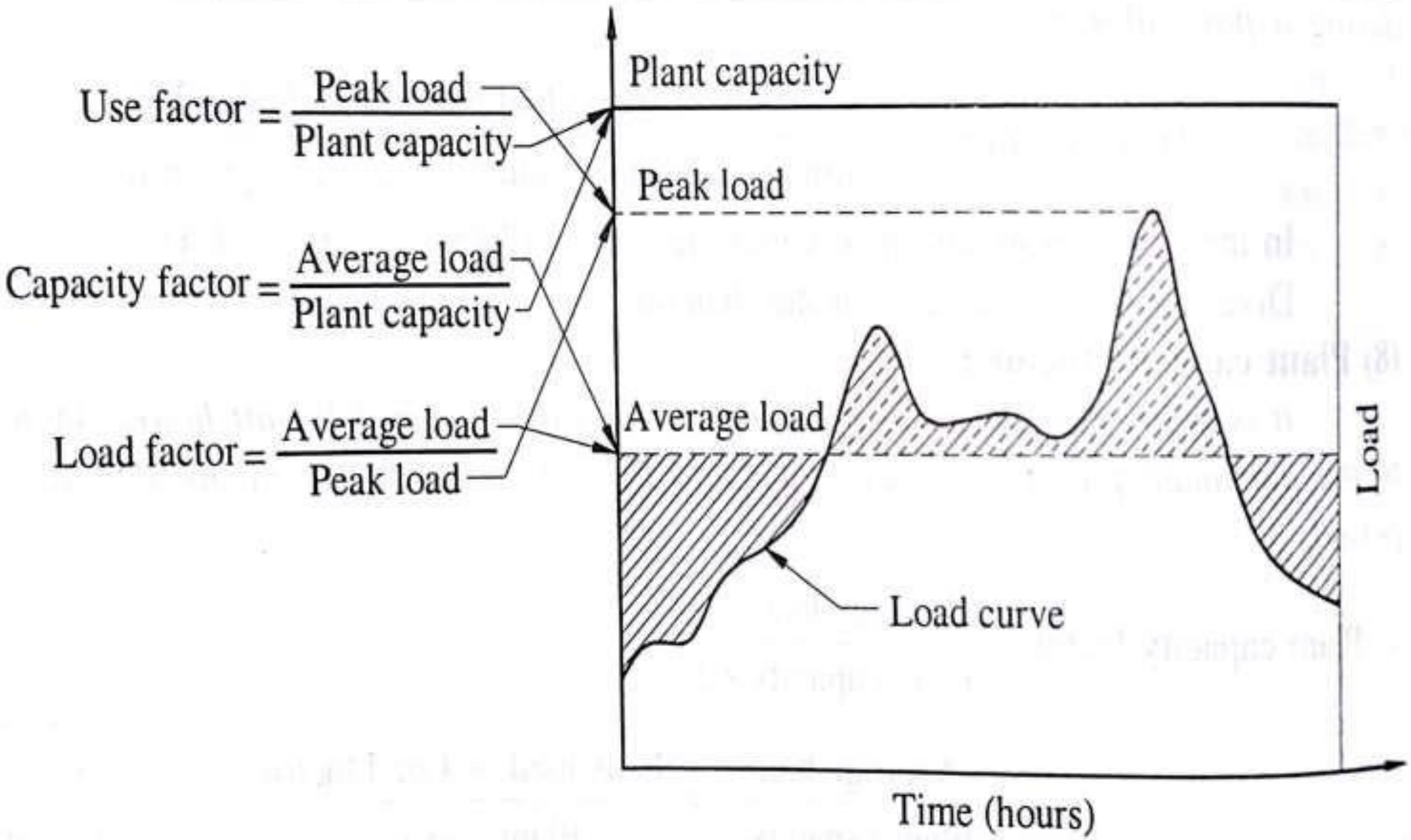


Fig. 7.6 Representation of different factors

IMPORTANCE OF LOAD FACTOR AND DIVERSITY FACTOR

(1) Load factor

- Load factor is the ratio of average load to maximum load on the power plant.
- The load factor will increase if the average load increases without the increase in maximum load. Thus, the total number of units of energy generated (kWh) at higher load factor would increase.
- But the annual fixed charges per unit of energy generated would reduce with the increase in load factor.
- Hence, the annual fixed charges per unit of energy generated would reduce with the increase in load factor. As a result the overall cost per unit of energy generated reduces.

(2) Diversity factor

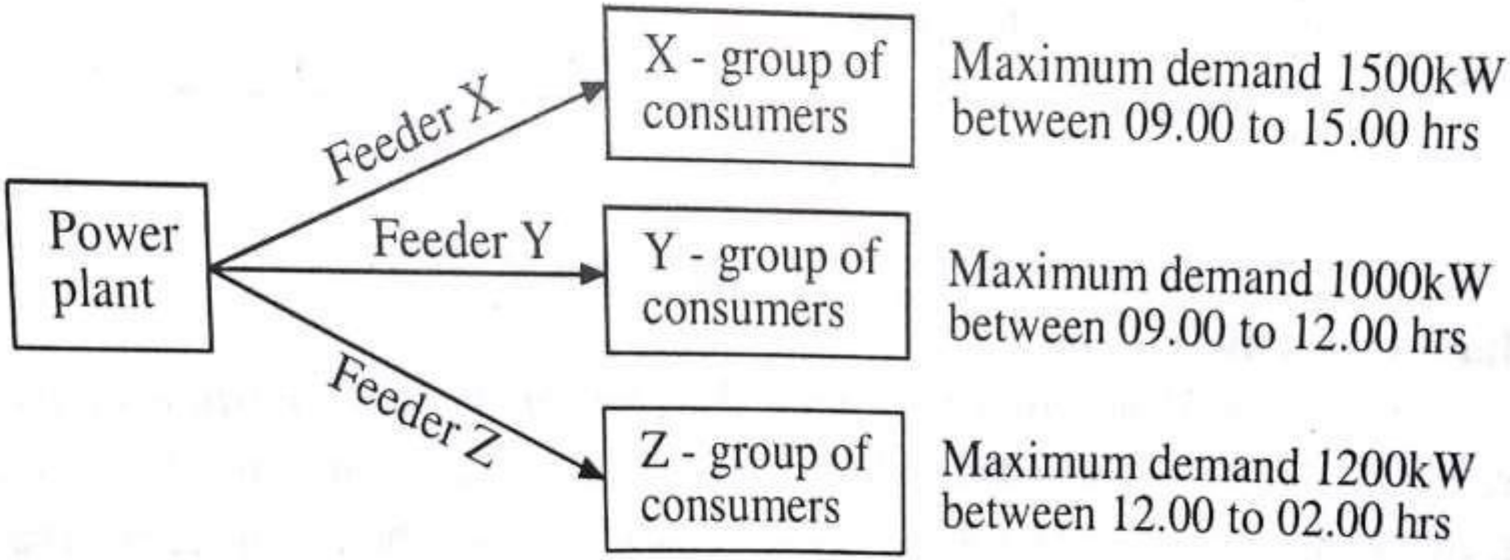


Fig. 7.8 Maximum load demand by various group of consumers

BASE LOAD AND PEAK LOAD POWER PLANTS

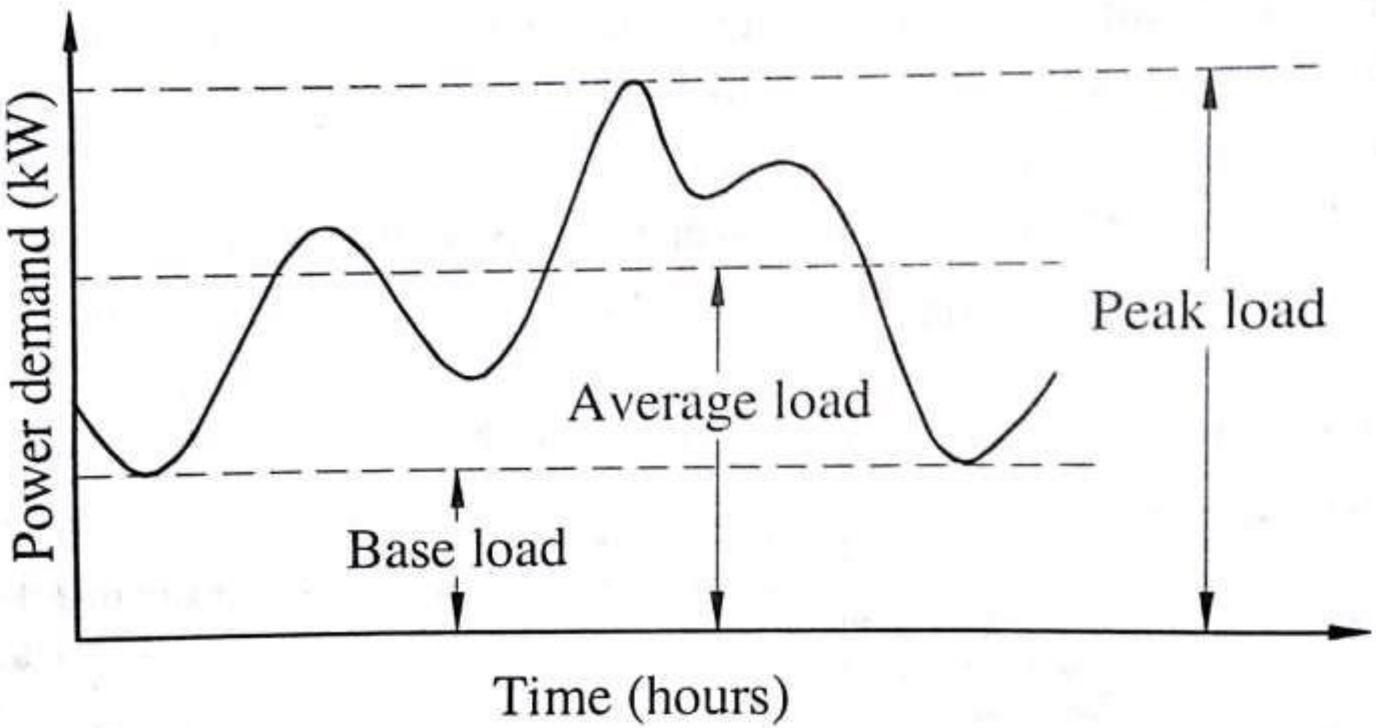


Fig. 7.9 Load curve

COST OF POWER PLANT

- The cost analysis of power plant includes fixed cost and running cost.

1. Fixed cost:

(i) Land, building and equipment cost:

- Cost of land and building will depend upon the location of the plant. If the plant is situated near the cities, the land will be costlier than the case if it is located away from the cities.
- The cost of equipment or the plant investment cost is usually expressed on the basis of kW capacity installed.

(ii) Interest:

- All the enterprises need investment of money and this money may be obtained as loan, through bonds and shares, or from owners of personal funds.
- The interest on the capital investment must be considered because otherwise if the same amount was not invested in power plant, it would have earned an annual interest.
- A suitable rate of interest must be considered on the capital invested.

(iii) Depreciation cost:

- Depreciation accounts for the deterioration of the equipment and decrease in its value due to corrosion, weathering, and wear and tear with use.
- It also covers the decrease in value of equipment due to obsolescence. It is required to replace the generating plant machinery after its expiry of useful life.
- Therefore, a certain amount is kept aside every year from the income of the plant to enable the replacement of plant at the end of its useful life. This amount is called depreciation amount.

(iv) Insurance:

The costly equipment and the buildings must be insured for the fire risks, riots etc. A fixed sum is set aside per year as insurance charges. The insurance charge depends upon the initial cost of the plant and the insurance coverage.

(v) Management cost:

This includes the salaries of management, security and administrative staff, etc. working in the plant. This must be paid whether the plant is working or not. Therefore, this is included in fixed charges of the plant.

2. Running cost:

The running cost or operating cost of the power plant includes the cost of fuel, cost of lubricating oil, direct labour cost, cooling water and number of consumable articles required. The wages required for supplying the above material are also included in the operating cost of the power plant.

(i) Fuel cost:

In a thermal power plant, fuel is the heaviest item of operating cost. The selection of the fuel and the maximum economy in its use are, therefore, very important consideration in thermal power plant design. The cost of fuel includes not only its price at the site of purchase but its transportation and handling cost also.

(ii) Oil, Grease and Water cost:

The cost of various consumables like oil, grease, etc. and water cost are also proportional to the amount of power generated. These costs increase with an increase in life of the plant as the efficiency of the power plant decreases with the age.

The total cost of power generated is the sum of fixed charges and operating charges.

ECONOMICS IN PLANT SELECTION

•Selection of the design and size of the equipment is primarily based upon economic consideration and a plant that gives the lowest unit cost of production is usually chosen.

•The working efficiency is generally higher with larger sizes of plants and with high load factor operation.

•Also, the capital cost per unit installation reduces as the plant is increased in size.

•Bigger size of plant would require greater investment and possibilities of lower than optimum, load factor usually increase with larger size of the plant.

Steam Power Plants

- As pressure and temperature of steam power plants are raised the capital cost increases but the cycle efficiency is increased. The advantages of higher pressures and temperatures is generally not apparent below capacity of 10,000 kW unless fuel cost is very high.

- Heat rates may be improved further through reheating and regeneration, but again the capital cost of additional equipment has to be balanced against gain in operating cost.

- The use of heat reclaiming devices, such as air pre-heaters and economisers, has to be considered from the point of economy in the consumption of fuel.

Internal Combustion Engine Plants

•The efficiency of the engine improves with compression ratio but high pressures necessitate heavier construction of equipment which increases cost.

•The choice may also have to be made between four-stroke and two-stroke engines, the former having higher thermal efficiency and the latter lower weight and cost.

•The cost of the supercharger may be justified if there is a substantial gain in engine power which may balance the additional supercharger cost.

Gas Turbine Power Plant

- The cost of the gas turbine power plant increases as the simple plant is modified by inclusion of other equipment such as *intercooler, regenerator, re-heater, etc.*

- *But the gain in thermal efficiency and thereby a reduction in operating cost may justify this additional expense in first cost.*

Hydro-electric Power Plant

•As compared with thermal stations an hydro-electric power plant has little operating cost and if sufficient water is available to cater to peak loads and special conditions for application of these plants justify, *power can be produced at a small cost.*

• ***Plant Economy :-***

•The capital cost per unit installed is higher if the quantity of water is small.

•Also, the unit cost of conveying water to the power house is greater if the quantity of water is small.

•The cost of storage per unit is also lower if the quantity of water stored is large.

•An existing plant capacity may be increased by storing additional water through increasing the height of dam or by diverting water from other streams into the head reservoir.

FACTORS AFFECTING ECONOMICS OF GENERATION AND DISTRIBUTION OF POWER

- The economics of power plant operation is greatly influenced by :

(a) Load factor

(b) Demand factor

(c) Utilisation factor

Load Factor :-

•In a *hydro-electric power station with water available and a fixed staff for maximum output, the cost per unit generated at 100% load factor would be half the cost per unit at 50% load factor.*

•*In a steam power station the difference would not be so pronounced since fuel cost constitutes the major item in operating costs and does not vary in the same proportion as load factor. The cost at 100% load factor in case of this station may, therefore, be about 2/3rd of the cost 50% load factor.*

•*For a diesel station the cost per unit generated at 100% load factor may be about 3/4th of the same cost at 50% load factor.*

• *From the above discussion it follows that :*

(a)Hydro-electric power station should be run at its maximum load continuously on all units.

(b)Steam power station should be run in such a way that all its running units are economically loaded.

(c) Diesel power station should be worked for fluctuating load or as a stand by.

Demand Factor and Utilisation Factor:-

- A higher efficient station, if worked at low utilisation factor, may produce power at high unit cost.

- The time of maximum demand occurring in a system is also important. In an interconnected system, a study of the curves of all stations is necessary to plan most economical operations.

- The endeavour should be to load the most efficient and cheapest power producing stations to the greatest extent possible. Such stations, called “base load stations” carry full load over 24 hours, i.e. for three shifts of 8 hours.

- The stations in the medium range of efficiency are operated only during the two shifts of 8 hours during 16 hours of average load.

- The older or less efficient stations are used as peak or standby stations only, and are operated rarely or for short periods of time.

•Presently there is a tendency to use units of large capacities to reduce space costs and to handle larger loads.

•However, *the maximum economical benefit of large sets occurs only when these are run continuously at near full load.*

•*Running of large sets for long periods at lower than maximum continuous rating increase cost of unit generated.*

Effect of Variable Load on Power Plant Design and Operation

The necessity of supplying a variable load influences the characteristics and method of use of power plant equipments. The generation of power must be regulated according to the demand followed by governing to achieve the same. Another requirement of a power plant is a quick response to the load.

In all variable load problems, the major problem is that the generator (and prime mover) must be able to take varying load as quick as possible without the change in voltage and frequency. When the load on the generator increases, the rotor and prime-mover speed decreases, thereby reducing the frequency. With the decrease in speed of the prime mover which is due to the increase in load on generator, the governor must act, admitting more fuel in case of thermal plants and more water in case of hydel plant, enough to bring the speed back to normal and pick up the load. The frequency stabilizers are used to maintain the frequency constant which may change due to response of the equipments.

The raw materials used in thermal power plant are fuel, air and water and to produce variable power according to requirement by varying the raw material. With an increase in load on the plant, the governor admits more steam and maintains the turbine speed. The governor response to this point has followed rapidly the change of load but beyond this point, changes are not so rapid. Because, the steam generator operates with unbalance between heat transfer and steam demand long enough to suffer a definite decrease of steam pressure. With fluctuating steam demand, it becomes very difficult to secure good combustion and steady steam pressure because efficient combustion requires the co-ordination of so many services. The co-ordination between the different components and processes is not as simple as supplying of more raw materials, but the reason being that there is certain time lag present in combustion and heat transfer that is not present in electrical generators.

The design of thermal plants for variable loads is always more difficult than diesel or hydraulic plants, and it is always desirable to allow the thermal plant to operate as base load plant.

It is always necessary in case of power plants to keep the reserve capacity in order to meet the peaking loads. This reserve is particularly required for an individual or isolated plant. This reserve capacity always increases the charges of electrical energy supplied. Therefore, it is always desirable to keep the reserve capacity as small as possible.