R. C. Patel College of Engineering and Polytechnic, Shirpur

Class: SYEE (EE3K)

Course:

ELECTRICAL POWER GENERATION, TRANSMISSION AND DISTRIBUTION

(Course Code: 313333)

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Unit - II Economics of Power Generation and Interconnected Power System

- Course Outcome (CO2) - Select the relevant power generation technology based on economic operation

- **Theory Learning Outcomes (TLO's) aligned to CO's:**
- TLO 2.1 Interpret the given Load curve, Load duration curve, Integration duration curve.
  TLO 2.2 Interpret the given values of the demand factor, plant capacity factor, plant use factor.
  TLO 2.3 Interpret the given values of the diversity factor, load factor and plant load factor.
  TLO 2.4 State the causes and impact of the given grid system fault.

- **Learning content mapped with Theory Learning Outcomes (TLO's) and CO's:**

  2.1 Base load and Peak load Plants: Load curve, Load duration curve, Integrated Load duration curve. Related terms: connected load, firm power, cold reserve, hot reserve, spinning reserve.
  2.2 Cost of generation: average demand, maximum demand, demand factor, plant capacity factor, plant use factor, diversity factor, load factor and plant load factor.
  2.3 Choice of size and number of Generator units, combined operation of power station.
  2.4 Causes, Impact and reasons of Grid system fault: State Grid, National Grid, brownout and black out; sample blackouts at National and International level

* Connected load:

Defn: Connected load is the sum of continuous ratings of all the equipments, items, machines connected to the supply. The load is in killowatts (kW).

* Firm ~~load~~ Power:

Defn: Firm Power is the power which is intended to be always available for a length of period, even under emergency situations.

* Cold Reserve:

Defn: Cold reserve is the reserved generating capacity which is available for service. But cold reserve is not in operation.

* Hot reserve:

Defn: Hot reserve is the reserve generating capacity of the plant which is available in operation but it is not in service.

* Spinning Reserve:

Defn: Spinning reserve is that generating capacity which is connected to the bus-bars & it is ready to take load.

* Load curves:

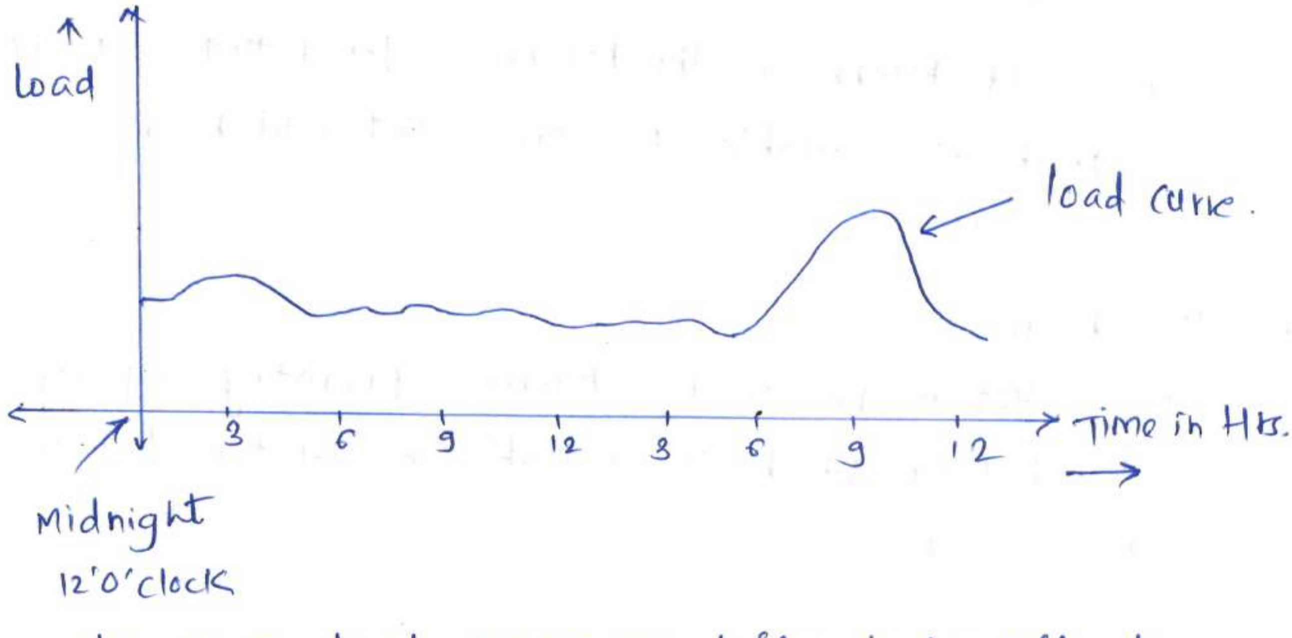
There are following types of load curves:

1. Load curve
2. Load duration curve
3. Integrated duration curve

1. Load curve:

Defn. The curve showing the load demand (i.e. variation of load) of a consumer with respect to time is called as load curve.

- For plotting the load curve time is taken on x-axis and load on Y-axis.



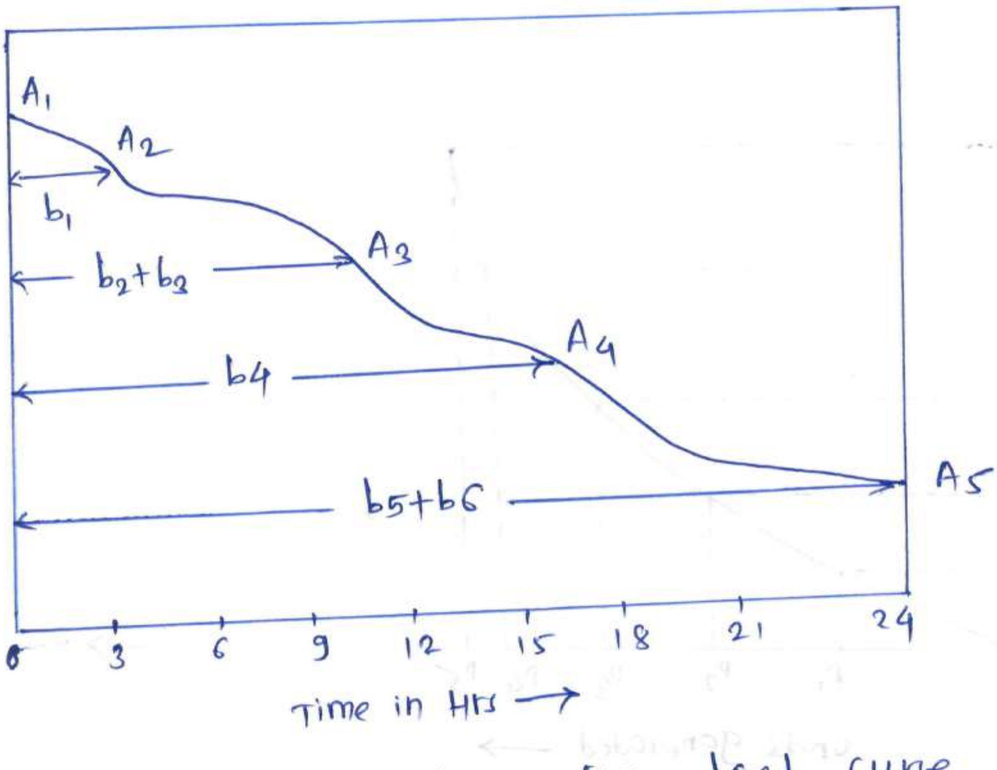
shapes of load curves are different for different consumers like residential load, commercial load, street light load, industrial load.

- Daily load curve- Time is taken in hours (For 24 hours)
- Monthly load curve- Time is taken in days (For a month)

- Annual load curve: Time is taken in Months (For 12 months)
- Area under the curve $\frac{\text{kwh}}{\text{Hrs}}$ gives the total No. of units generated in a day.
- The maximum value of load on the curve shows maximum demand (M.D.) on the station on the particular day.

* 2. Load Duration curve:

This curve represents the variation of load, but the loads are arranged in the descending order of the magnitude. Greater load at the begining at the left and lesser loads on the right, smallest load at the extreme right.



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

The area under load curve = Area under load duration Curve.

Advantages: of load duration curve:

1. It helps the engineer for capacity selection of
   i) Base load ii) Peak load plants.
2. Helps in plant design
3. Plant operation.
4. Helps in knowing cost of generation.

* 8. Integrated load curve:

Defn: The curve representing total no. of units generated for the given demand in kW is called as integrated load curve

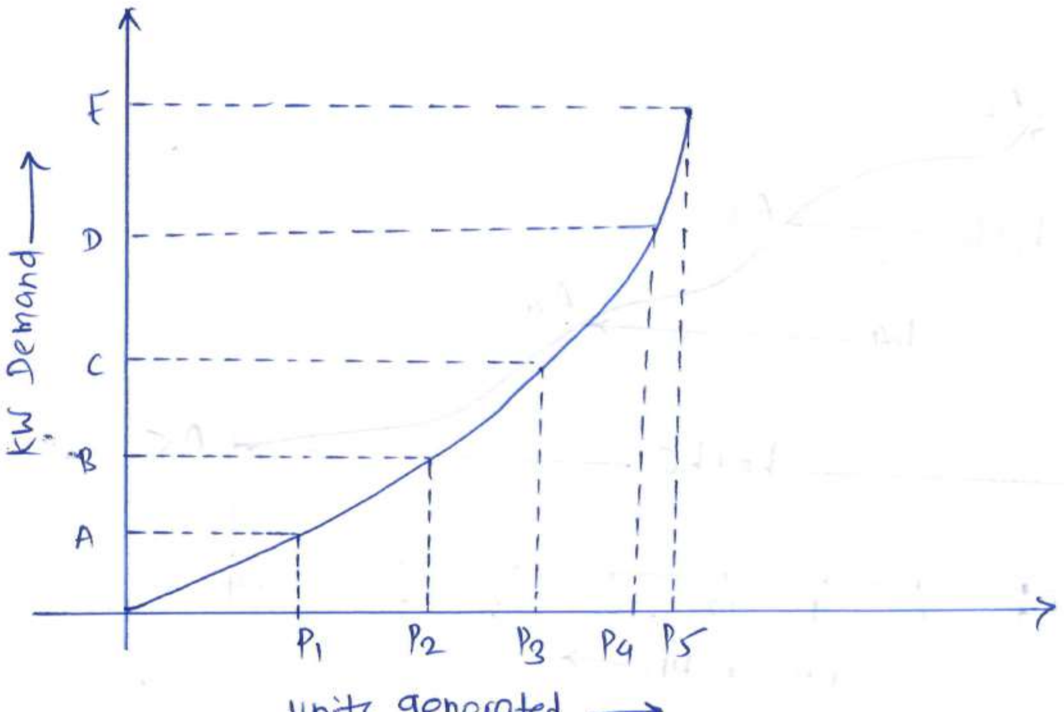


Fig: integrated load curve.

- In integrated load curve the ordinates (i.e. Y-axis) represents demand in kW and x-axis i.e. abscissa represents units generated in kW Hrs.

* Base load and peak load plants:

i) Base load ~~Plants~~:

Defn: The unvarying load which is always present for all the 24 Hrs of a day on power plant is known as base load.

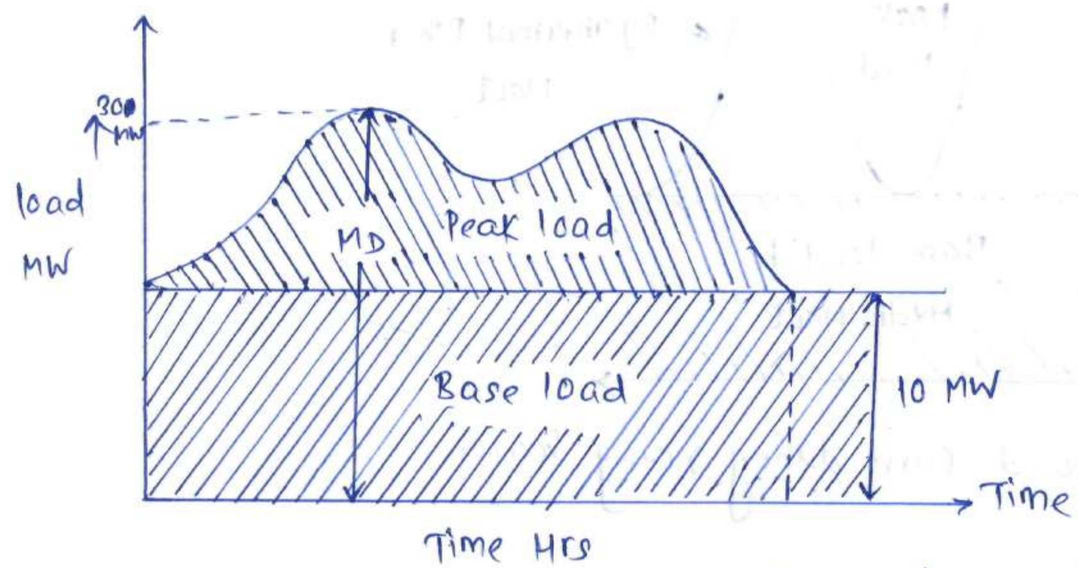


Fig: Actual load curve on a plant showing base and peak load.

ii) Peak load ~~Plants~~:

Peak load is the (variation) variable demands of load above the base load on the plant. This is shown in above fig.

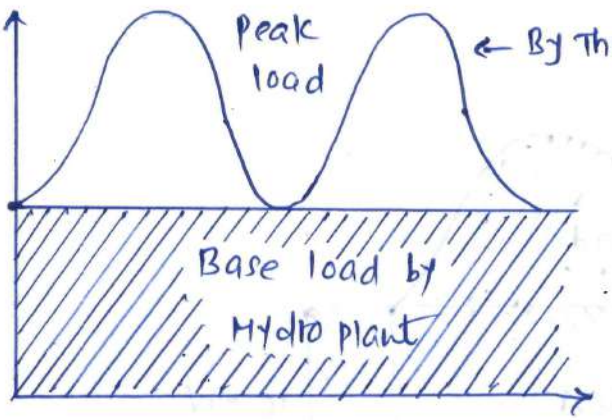
See above load curve of a particular station whose maximum load (MD) is say 300 MW. If this load is to be supplied by this only one station, then its installed capacity shall be 300 MW.

See the above curve of a particular station whose maximum load (MD) is say 30 MW. If this load is to be supplied by this only one station, then its installed capacity shall be 30 MW. But peak load curves are for short period in a year so 30 − 10 = 20 MW remain idle on the generating plant for period of year. Generator will work under loaded for much of the period at lower efficiency which is not desirable.

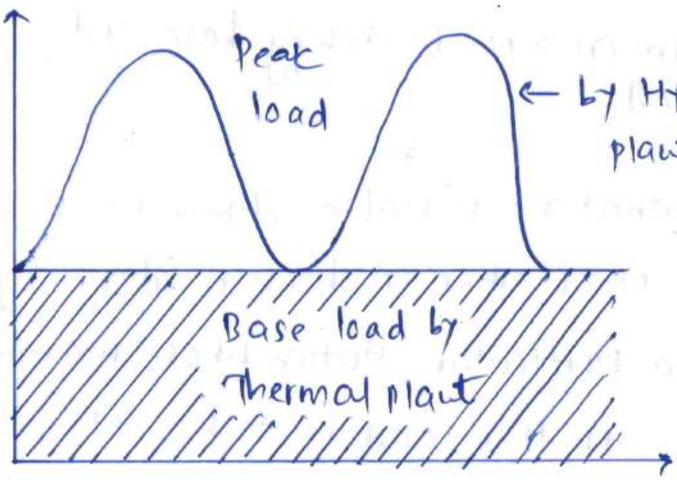
Moreover due to big capacity, the capital cost will also be more.

So it is advisable and planed to Co-ordinate two stations together.. One station will be base load power station and in its Coordination the other will be peak load power station.

Take the case of Hydro power station and Thermal power station.



i) Load curve during rainy season.



ii) Load curve during summer season.

If a power plant to be employed as base load power plant then

i). It must be capable of working continuously for long periods.

ii) Its operating cost must be very low

iii) Their repairs and maintenance should be speediy and economical.

iv) Their repairs and maintenance should be speediy and economical.

iv) operating / supervisory persons be minimum required.

→ If a power plant to be employed as peak load power plant then

i) It should have capability of quick-start

ii) It should give quick response to load variations

iii) It should respond to synchronising in shorter period.

* Cost of Generation:

* Average Demand:

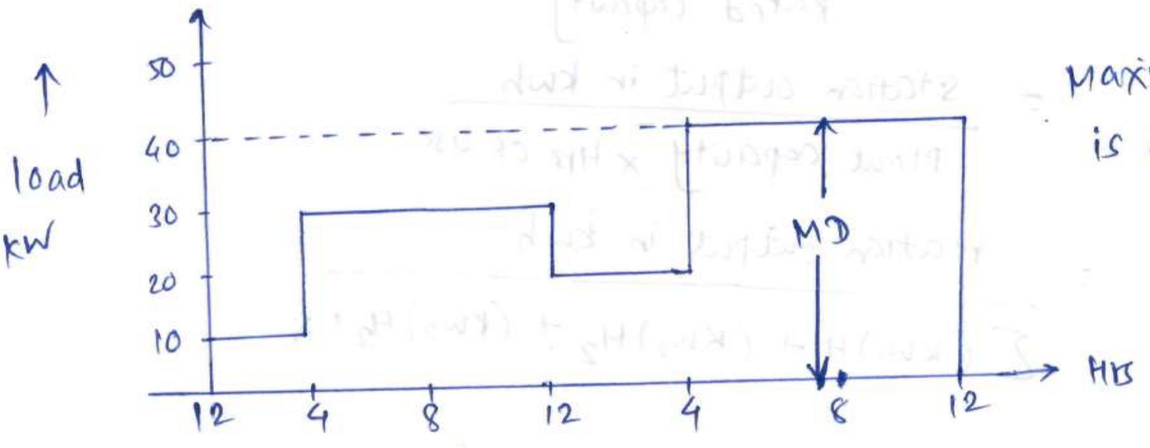
- Daily Average demand $= \dfrac{\text{Total kwh units delivered in a day}}{24 \text{ (Hrs of day)}}$

- Monthly average demand $= \dfrac{\text{kwh units delivered in a month}}{24 \times \text{days of month}}$

- Annual average demand $= \dfrac{\text{kwh delivered in a year}}{24 \times 365 \text{ (i.e. 8760)}}$

* Maximum Demand:

Maximum demand is defined as the largest demand of load on the generating power station during a given period. Load on the station is never constant. It varies time to time. At a particular duration of period it is maximum.



Maximum demand is 40 kW at 8 pm.

Fig: Load curve

* Demand Factor:

Defn: Demand Factor is defined as the ratio of maximum demand on the system to the total connected load of the system.

$$\text{Demand Factor (DF)} = \frac{\text{Maximum Demand (MD)}}{\text{Connected load}}$$

* Plant capacity Factor:

Defn: It is defined as the ratio of actual energy generated in a given period to the maximum energy that could have been generated during the same period.

$$\text{plant capacity Factor} = \frac{\text{Actual energy generated}}{\text{maximum energy that could be produced.}}$$

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

* Plant use Factor:

It is defined as the ratio of average demand to rated capacity.

$$\therefore \text{plant use Factor} = \frac{\text{Average demand}}{\text{Rated capacity}}$$

$$= \frac{\text{station output in kWh}}{\text{Plant capacity} \times \text{Hrs of use}}$$

$$= \frac{\text{station output in kWh}}{\Sigma (KW_1)H_1 + (KW_2)H_2 + (KW_3)H_3 + \cdots}$$

∴ It is also given by

$$\text{Plant use Factor} = \frac{\text{Actual energy produced}}{\text{plant capacity} \times \text{Time (Hr)}}$$

* **Diversity Factor:**

It is defined as the ratio of the sum of individual maximum demands to the maximum demand on power station.

$$\text{Diversity Factor} = \frac{\text{sum of individual maximum demands, of}}{\text{maximum demand of the station.}}$$

* **Load Factor:**

Defn: It is defined as the ratio of no. of units generated actually in a given period to the no. of units which could have been generated with the same maximum demand.

$$\text{load Factor} = \frac{\text{Average demand}}{\text{maximum demand}}$$

$$= \frac{\text{Energy generated in a given Period}}{\text{maximum demand} \times \text{Hrs of operation in the given period.}}$$

* **Plant load Factor:**

Defn: It is defined as the ratio of average demand to the rated capacity.

$$\therefore \text{plant load } \cancel{\text{Capacity}} \text{ Factor} = \frac{\text{Station output in kWh}}{\Sigma (kW_1) H_1 + (kW_2) H_2 + (kW_3) H_3 \ldots}$$

$$\text{plant use Factor} = \frac{\text{Actual energy produced}}{\text{plant capacity} \times \text{Time (Hr)}}$$

* Problems on Cost of Generations:

① A plant having load factor of 0.6 has a peak load of 110 MW. Calculate the energy generated by this plant in one month of 30 days.

Ans: Given: load factor = 0.6

M.D = 110 MW

Hrs = 24 × 30.

$$\text{load factor} = \frac{\text{Energy generated in given Period}}{\text{max. demand} \times \left[\text{Hrs of operation in the given period}\right]}$$

$$\therefore 0.6 = \frac{\text{Energy generated in 30 days}}{(110 \times 10^3) \times (24 \times 30)}$$

$\therefore$ Energy generated = 47520000 kW Hr.

② A generating station has connected load of 43 MW and maximum demand of 20 MW. The units generated are 61.5×10^6 per year. Calculate:

i) Demand Factor ii) load Factor.

Soln: Given: Connected load = 43 MW

Max. demand (MD) = 20 MW

Generated Energy = 61.5×10^6 units/year

Using formula,

$$\text{Demand Factor} = \frac{\text{Max. Demand}}{\text{connected load}} = \frac{20}{43}$$

Demand Factor = 0.465

$$\text{load Factor} = \frac{\text{Avg load}}{\text{MD}}$$

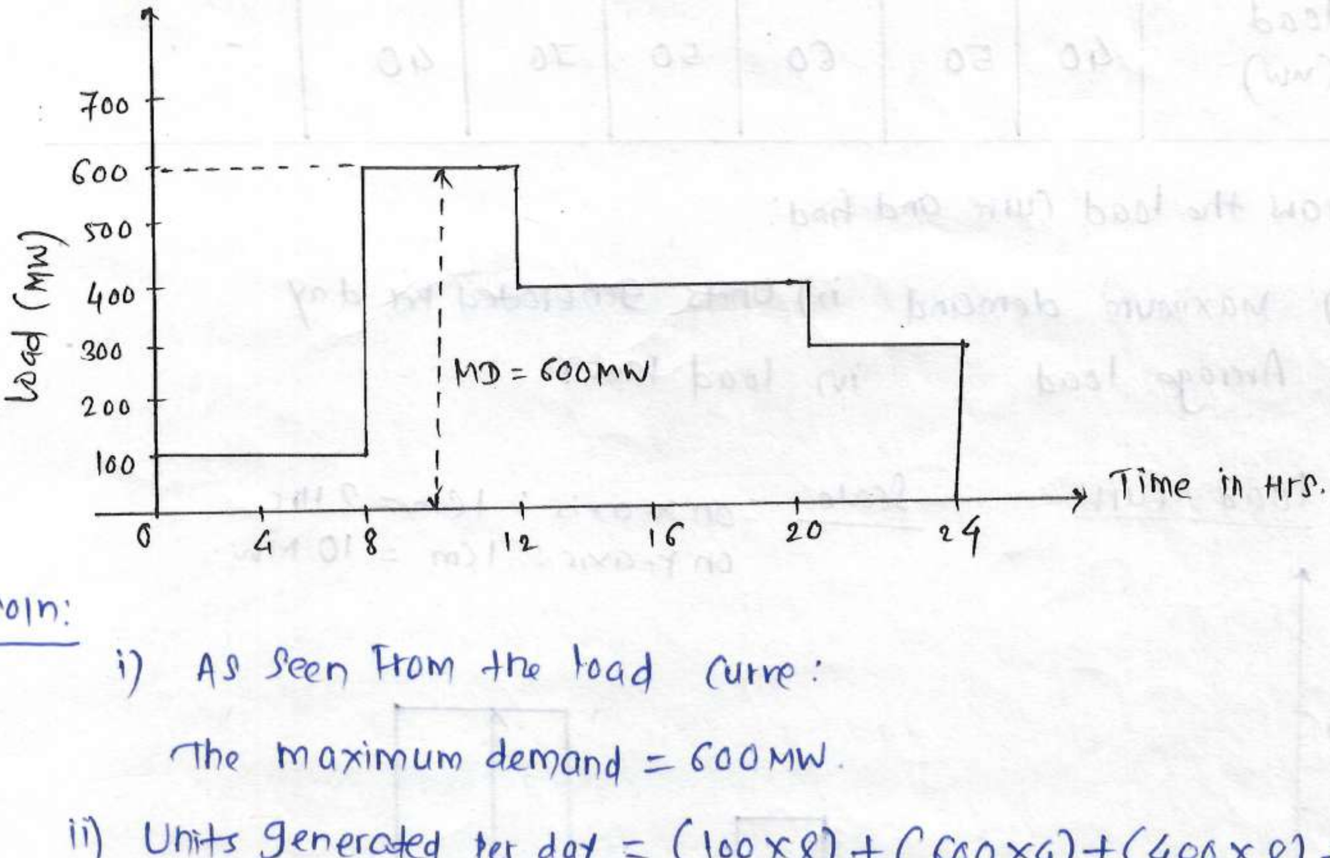
$$= \frac{61.5 \times 10^6}{20 \times 8760}$$

$$= 0.35 \qquad \underline{3.51 \times 10^{-4}} \text{ \_ Ans}$$

(3) The daily load of a power station is shown in Fig: find from it

i) M.D. on power station ii) units generated per day

iii) Average load iv) load factor.



Soln:

i) As seen from the load curve:

The maximum demand = 600 MW.

ii) Units generated per day $= (100 \times 8) + (600 \times 4) + (400 \times 8) + (300 \times 4)$

$= 7600$ MWh.

iii) Average load $= \dfrac{\text{Energy consumed in 24 Hrs}}{\text{Hours of a day}}$

$$= \frac{7600}{24} = \underline{316.66 \text{ MW}}.$$

iv) load Factor = $\frac{\text{Average load}}{\text{Maximum demand}}$

$= \frac{316.66}{600}$

load Factor = 0.5277.

(4) A generating station has the following daily load curve:

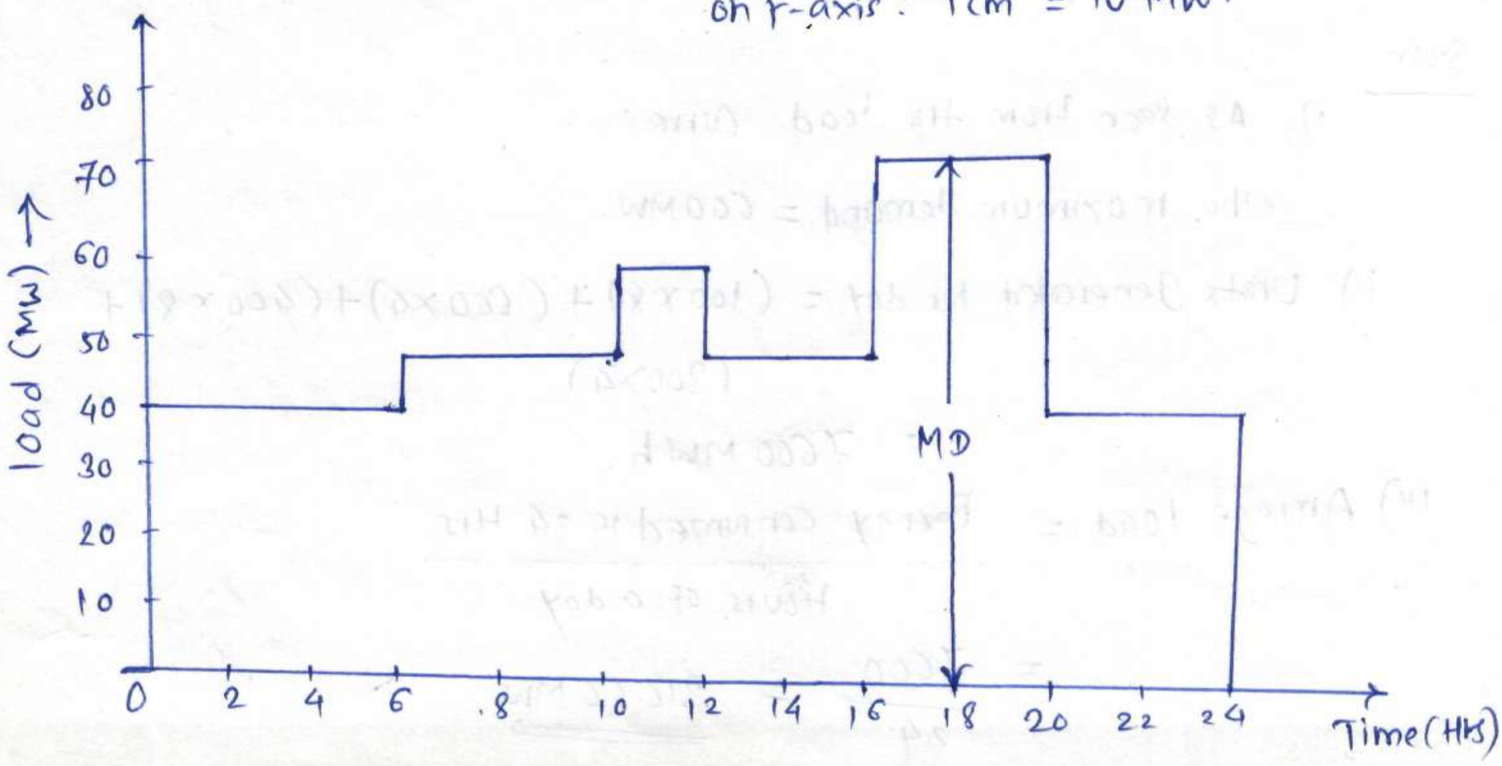
Time (Hrs)	0-6	6-10	10-12	12-16	16-20	20-24	-
load (MW)	40	50	60	50	70	40	-

Draw the load curve and find:

i) Maximum demand ii) Units generated per day

iii) Average load iv) load Factor:

Soln: load Curve: Scale: on x-axis : 1cm = 2 Hrs
on y-axis : 1cm = 10 MW.



i) Maximum demand = 70 MW

ii) Units generated per day :

$$= (40\times6)+(50\times4)+(60\times2)+(50\times4)+(70\times4)+(40\times4)$$

$$= 240+200+120+200+280+160$$

$$= 1200\ \text{MWh}$$

iii) Average load :

$$\text{Average load} = \frac{\text{No. of units generated in one day}}{24}$$

$$= \frac{1200\times10^3}{24}$$

$$\text{Average load} = 5000\ \text{kW}$$

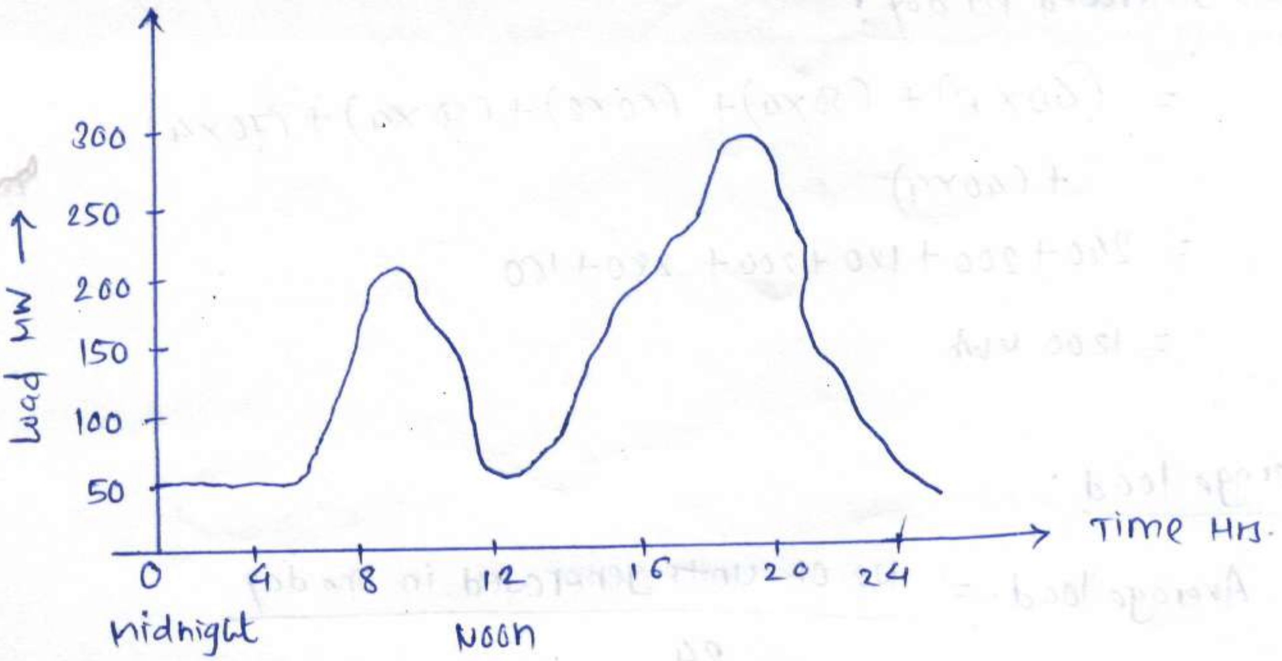
iv) load Factor:

$$\text{load Factor} = \frac{\text{No. of units generated in one day}}{24\times \text{M.D.}}$$

$$\text{load Factor} = \frac{1200\times10^3}{24\times70\times10^3}$$

$$\text{load Factor} = 0.7142$$

* choice of size and number of Generator units:



The load demand is Fluctuating in a day of 24 Hours. load is not constant. As seen the peaks load (M.D.) is ~~the~~ in the evening period. Here M.D. (Maximum demand) is 300MW.

There are two ways of deciding the generators:

A) One is a generator unit (single unit) to meet the load including maximum demand. In this case M.D. is 300MW, so generator capacity should be 300MW. More over in case of maintenance, repairs, Failures, this units has to be shut down. Also, as a standby unit we must install another 300MW unit.

Drawbacks:

1. load is Fluctuating from 50MW to 300MW. For few hours it is Fully loaded and For most of the period it is under loaded. It is expected that the generator shall be loaded near to its F.L. capacity as it gives maximum efficiency running at such loads. This is economical. but actually it runs at low load, so efficiency is less.
2. Second drawback is one more same capacity generator is to be installed as stand by unit.

3. standby unit of same capacity requires much more area. It increase the overall capital cost of the plant.

(B) The other way is instead of big size single unit and standby unit, select variable no. of units of different capacities to suit to the load at different periods of a day. No. of units can be run at a time, added or switched off as per load conditions during the various period of a day.

Advantage:

- In this case reserve capacity required is very less in comparison with type A.
- This gives better plant capacity factor and plant use factor.
- Also reliability and continuity of supply is maintained.
- Units can be taken for maintenance, repairs, without disturbing the continuity of supply.

* Combined operation of power stations:

* Need of combined operation of power stations:
- For getting most economic operation and to ensure optimum utilization it becomes necessary to combine the operation of various power plants located in the region.

* Integrated system: connecting all power plants together of the region for supplying power, the system is known as integrated system.

* Advantages of Integrated system (Grid):

1. leads to considerable saving.
2. Can run at good load factor
3. Total generating capacity to be reduced since less space capacity is required.

4. It allows the system to be planned to find maximum size of generating unit instalation which results in less cost per kw.
5. Minimum amount of fuel is required as a whole.
6. Generator unit can be run at a load to give maximum efficiency.

* Advantage of combined operation of power plants:

1. Ensure flexibility of operation.
2. Ensure reliability of supply.
3. Reserve capacity required is reduced.
4. There are so many economic benefits.
5. Co-ordination of base load and peak load is beneficial.

* Limitations of interconnected power stations:

1. Suffer from cascade tripping and overall blackouts in the large region.
2. May not be full co-operation with master control center by regional centers.
3. Much investments in large interconnection for control centers and automatic mechanism of control.
4. In planning, operation and control technical problems may arise.
5. Overall disturbance may be created due to synchronous ie. frequency disturbance of one area is transferred to adjacent areas.

* Regional Grid, state Grids, National Grid, Reasons of Grid system fault:

* Grid system:

An electrical grid is an interconnected network. It consist of generating stations, high voltage transmission lines, distribution lines, utility (customers).

i) Regional grid: It is formed by interconnecting different transmission systems of a particular area through transmission line.

ii) State grid: This grid is formed by interconnecting power stations existing in a particular state in transmission system.

iii) National grid: It is formed by interconnecting different regional grids.

* Causes/Reasons of a Grid System Faults:

Reasons / Causes are as follows:

i) Failure of equipments:

If any of the element in power system fails completely or partially, the load on that element gets shifted to the nearby elements in the system hence that element gets overloaded.

These elements again tend to shift their load on other nearby element and so on. This is cascading effect which leads to system failure.

ii) power suppliers drawing excessive power from the grid:

- This happens due to increase in demand supply gap. i.e. demand more than supply, causes over draining of grid system.
- The generators connected in grid tend to run slow i.e. their speed falls down causing frequency to be less than specified limits. (Specified limits is 49.5 Hz to 50.2 Hz).
- This causes tripping of grid. Thus there will be sudden power loss. This is known as grid failure or blackout.

* Impact of Grid Fault (Failure):

Following are the impacts of grid failure:

1) Impact on industries:

Due to power cut the production system comes to halt for industries like- Metalluray, pharmaceuticals, biochemical etc.

2) Impact on health care:

The health care facilities are hospitals, dispensaries etc. have many life supporting systems powered by electricity.

3) Impact on transportation:

The electrical transport systems like electric traction, trains, trams etc. comes to stop.

4) Communication System:

All communication systems are powered by electricity through batteries. But battery/UPS backup is for limited time. So, entire communication system may stop functioning due to power failure.

5) Water Supply system:

The drinking water, irrigation water pumping system is affected and water supply will be interrupted.

6) Elevator System:

The occupancies with multistory building will be affected. Lifts will comes to stop.

7) Impact on power stations:

If the grid is to be restored, it will take considerable time to start because thermal power plant required large time to restart.

* Difference beth Blackout and brownout:

Sr. No	point of Comparison	Blackout	Brown out
1.	Nature of suppry interruption	Complete interruption	suppry not interrupted
2.	Intentional or untentional	Unintentional	Intentional or unintentional
3.	Causes	Major Fault in power system, Cascade tripping of grid.	voltage sag, increased power demand.
4.	Functioning of derices in the system	All derices come to hart	Devices are functioning, some may be affected due to under voltage
5.	Damage to the equipment	probability is rery less	Sensitive instruments are damaged due to voltage Fluctuations.
6.	Supply Continuity	Nil	Continuity is present at reduced voltage.
7.	System resume process	Tedious and Complicated	Comparatively less Complicated.
8.	Economic loss	Huge	Comparatively less.

* Blackout and Brownout:

* Blackout:

- It is complete interruption of electrical power over a large area for an extended period of time.
- The blackout occurs due to major fault in power system or cascade tripping of grid system.
- The blackout occurs suddenly i.e. without any warning or indication etc.

* Brown out:

- Brownout is intentional or unintentional drop in the supply voltage.
  - Intentional means the supply voltage is reduced to prevent the blackout.
  - Untentional drop includes voltage sag on line which causes voltage dip for small duration of time.
- The devices which are sensitive to voltage fluctuations are affected.

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Question Bank

ProgramName:Electrical Engineering	Class: EE3K	Academic Year: 2026-27
CourseName:ELECTRICAL POWER GENERATION,TRANSMISSION AND DISTRIBUTION	Sub Code:313333	Date-29/05/2026

Unit – II Economics of Power Generation and Interconnected Power System (10 Marks)

1. Define the terms :-
   i) Cold reserve
   ii) Hot reserve capacity. (Winter-24)
2. Define the terms :-
   a. Load curve
   b. Load factor
   c. Connected load
   d. Diversity factor (Winter-24)
3. A generating station has following duty load cycle :-

Time (Hrs)	0–6	6–10	10–12	12–16	16–20	20–24
Load (MW)	40	50	60	50	70	40

   Draw the Load curve and find :-
   i) Maximum Demand
   ii) Average Load
   iii) Units generated per day
   iv) Load factor
4. Explain following terms related to grid system :
   i) National grid
   ii) State grid
   iii) Blackout
   iv) Brownout
5. Define –
   i) Plant capacity factor
   ii) Diversity factor (Summer-2025)
6. Draw and explain: Load curve. (Summer-2025)
7. The peak load on a power plant is 50 mw. The loads having maximum demands of 30 mw, 10 mw and 17 mw are connected to the power station. The annual load factor is 50%. Calculate –
   i) Average load on the power station
   ii) Demand factor

iii) Diversity factor
iv) Energy supplied per year. (Summer-2025)

8. State the advantages of combined operation of power station. (Summer-2025)
9. Define the following terms :–
   i) Cold reserve
   ii) Spinning reserve. (Winter-2025)
10. Define Maximum Demand and Demand Factor. (Winter-2025)
11. Draw and explain load duration curve used in power system operation.
12. The load generating station charges as recorded in the following table during 24 hours of a day :–

Time (Hours)	0-6	6-10	10-16	16-20	20-24
Load (MW)	40	80	60	70	60

    Draw the daily load curve and load duration curve.

13. Define: i) Average Demand ii) Maximum Demand iii) Plant Capacity Factor iv) Plant Use Factor
14. Define: i) Diversity Factor ii) Load Factor
15. Define: i) Connected Load ii) Firm Power

SubjectTeacher **HOD EE** **Principal**

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