UNIT – V
ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS

1. Explain in detail the Power Tariff used for energy consumption. (or) Describe the Power Tariff types with its advantages and Disadvantages.

TARIFF DEFINITION:

The rate at which electrical energy is supplied to a consumer is known as tariff.

- Cost of Producing Electricity depends upon the magnitude of Electricity consumed by load.
- Tariff fixation has to be given to different types of consumers (*e.g.,* industrial, domestic and commercial).
- Tariff fixing for different consumers is more complicated.

Objectives of tariff.

Electrical energy is sold at such a rate so that it not only returns the cost but also earns reasonable profit. Tariff should include the following objectives:

- Recovery of cost of producing electrical energy at the power station.
- Recovery of cost on the capital investment in transmission and distribution systems.
- Recovery of cost of operation and maintenance of supply of electrical energy
- A suitable profit on the capital investment.

Characteristics of a Tariff:

(i) Proper return:

- The total receipts from the consumers must be equal to the cost of producing and supplying electrical energy plus reasonable profit.
- This will enable the electric supply company to ensure continuous and reliable service to the consumers.

(ii) Fairness:

- The tariff must be fair so that different types of consumers are satisfied with the rate of charge of electrical energy.
- A big consumer should be charged at a lower rate than a small consumer with fixed charges and thus reducing overall production cost of electrical energy.

- A consumer whose load conditions do not deviate much from the non-variable load should be charged at a lower rate than big consumers with variable load.

(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:

- The profit element in the tariff should be reasonable.
- An electric supply company is a public utility company and generally enjoys the benefits of monopoly.
- The investment is relatively safe due to non-competition in the market and the profit is to be restricted to 8% or so per annum.

(v) Attractive:

- The tariff should be attractive so that a large number 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.

1. Simple Tariff
2. Flat rate Tariff
3. Block rate Tariff
4. Two part Tariff
5. Maximum demand tariff
6. Power Factor Tariff
7. Three part Tariff

1. Simple tariff:

When there is a fixed rate per unit of energy consumed, it is called a **simple tariff** or **uniform rate tariff.**

Advantages of Simple Tariff:

- In simple tariff, the cost does not vary with increase or decrease in number of units consumed.
- The consumption of electrical energy at the consumer terminals is recorded by means of an energy meter.

- This is the simplest of all tariffs and is easily understood by the consumers.

Disadvantages of Simple Tariff:

- Every consumer has to pay equally for the fixed charges irrespective of load variation.
- The cost per unit delivered is high.
- (iii) 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 of tariff, the consumers are grouped into different classes and each class of consumers is charged at a different uniform rate.
- The different classes of consumers are made taking into account their diversity and load factors.

Advantages of Flat rate tariff:

- This tariff is more benefit to different types of consumers
- Flat rate tariff is quite simple in calculations.

Disadvantages of Flat rate tariff:

- Separate meters are required for lighting load, power load etc.
- The application of such a tariff is expensive and complicated.
- A particular class of consumers is charged at the same rate irrespective of the magnitude of 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.

- 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 the highest and it is progressively reduced for the succeeding blocks of energy.
- For example, the first 30 units may be charged at the rate of 60 paise per unit; the next 25 units at the rate of 55 paise per unit and the remaining additional units may be charged at the rate of 30 paise per unit.

Advantages of Block rate Tariff:

- The consumer gets an incentive to consume more electrical energy.
- This increases the load factor of the system and hence the cost of generation is reduced.

Disadvantages of Block rate Tariff:

- It lacks a measure of the consumer demand.
- 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 two-part tariff, the total charge to be made from the consumer is split into two components viz., fixed charges and running charges.
- The fixed charges depend upon the maximum demand of the consumer while the running charges depend upon the number of units consumed by the consumer.
- Thus, the consumer is charged at a certain amount per kW of maximum demand plus a certain amount per kWh of energy consumed i.e.

  Total charges = Rs (b × kW + c × kWh)

  where, b = charge per kW of maximum demand

  c = charge per kWh of energy consumed
- This type of tariff is mostly applicable to industrial consumers who have appreciable maximum demand.

Advantages of two part Tariff:

- It is easily understood by the consumers.
- It recovers the fixed charges which depend upon the maximum demand of the consumer.
- It is independent of the units consumed.

Disadvantages two part Tariff:

- The consumer has to pay the fixed charges irrespective of energy consumed
- There is always error in assessing the maximum demand of the consumer.

5. Maximum demand tariff.

It is similar to two-part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer.

Advantages of Maximum demand tariff:

- The maximum demand is assessed merely on the basis of the rateable value.

- This type of tariff is mostly applied to big consumers.

Disadvantages of Maximum demand tariff:

- It is not suitable for a small consumer.
- Separate maximum demand meter is required.

6. Power factor tariff:

The tariff in which power factor of the consumer load is taken into consideration is known as **power factor tariff**.

- A low power factor increases the rating of station equipment and line losses.
- A consumer having low power factor must be penalized.

The following are the important types of power factor tariff:

(i) kVA maximum demand tariff :

- It is a modified form of two-part tariff.
- In this case, the fixed charges are made on the basis of maximum demand in kVA and not in kW.
- A low power factor consumer has to contribute more towards the fixed charges.

(ii) Sliding scale tariff :

- This is also known as average power factor tariff.
- In this case, an average power factor, say 0·8 lagging, is taken as the reference.
- If the power factor of the consumer falls below this factor, suitable additional charges are made.
- If the power factor is above the reference, a discount is allowed to the consumer.

(iii) kW and kVAR tariff:

- In this type, both active power (kW) and reactive power (kVAR) supplied are charged separately.
- A consumer having low power factor will draw more reactive power and hence shall have to pay more charges.

7. Three-part tariff:

When the total charge to be made from the consumer is split into three parts viz., fixed charge, semi-fixed charge and running charge, it is known as a **three-part tariff**.

$$\text{Total charge} = \text{Rs}\ (a + b \times kW + c \times kWh)$$

Where, a = fixed charge made during each billing period.
b = charge per kW of maximum demand,
c = charge per kWh of energy consumed.

- It may be seen that by adding fixed charge to two-part tariff, it becomes three-part tariff.

- The principal objection of this type of tariff is that the charges are split into three components.
- This type of tariff is generally applied to big consumers.

2. Define the load distribution parameters involved in the power system economics. (or) Explain the load distribution parameters related to power distribution system.

Energy:

Energy is defined as the power consumption in the particular period of time.

- It is expressed in Kilo-Watt Hour(kWh)
- Mechanical work done over a period of time is also a form of energy like heat.

Work done:

Work done is defined as the distance travelled by the applied force.

- Its unit is Newton metre (or)Joules.
- Electrical work is the product of voltage difference and the current flows in the conductor.
- Electrical work = Power = Volt x Amp = watt = Joule/sec

Installed capacity:

Installed capacity is the designed power generation capacity of a plant.

- It is expressed in terms of energy generated per unit time (MWh).

Power:

It is the rate of work or work done per unit time.

- It is generally expressed as Joules/second or MW.
- The basic unit is watt (Joules per second).

Heat rate:

Heat rate is the amount of energy (kJ) that the fuel must supply to produce unit amount of electrical energy (kWh).

- It is expressed as kJ/kWh or kilo Calories/KWh.
- This represents the overall efficiency of a power plant.

Turbine Heat rate:

Turbine heat rate is the amount of heat steam must deliver to produce unit of heat.

- It is expressed in Kilo-Watt Hour(kWh).

Thermal efficiency:

Thermal efficiency is the amount of heat carried by the steam per unit amount of heat delivered through the fuel.

Combustion efficiency:

Combustion efficiency is defined as the ratio of the amount of energy or heat released by the fuel to the energy contained in the burnt fuel.

Availability:

- Availability is the fraction of the time a plant is available for generation.
- A plant may be partially available due to lack of operation of some components of the plant. It is called partial availability.

Outage:

Outage is another term for shut down of the plant either for planned maintenance (Planned outage) or due to unforeseen break down (forced outage).

Base Load:

The unvarying load which occurs almost the whole day on the station is called as Base load.

Peak Load:

The various peak demands of load over and above the base load of the station is known as Peak Load.

- It is also known as Peak demand

Connected load:

The sum of the continuous ratings of all the equipments connected to the power system is called connected load.

Maximum load:

Maximum load is the greatest demand on the given period during a given period.

- It is also known as Maximum demand.

Average Load:

The average of all the loads occurring at the various instants on the generating station is called **average load**. Or

The total electrical energy delivered in a given period divided by the time period is called as **average load**.

$$\text{Average load} = \frac{\textbf{kWh energy supplied in a period}}{\boldsymbol{Time\ period}}$$

$$\text{Daily average load} = \frac{\textbf{kWh energy supplied in day}}{\textbf{24}}$$

$$\text{Monthly average load} = \frac{\textbf{kWh energy supplied in day}}{\textbf{24 X 30}}$$

Variable load:

The load on a power plant varies from time to time due to uncertain demands of the consumers is known as Variable load.

Effects of variable load:

- *Need of an additional equipment*
- *Increase in production cost*

Interconnected load:

The connection of two or more loads in parallel condition is known as an interconnected load.

Advantages:

- Exchange of peak loads
- Use of older plants
- Ensures an economical operation
- Increases diversity factor
- Reduces plant reserve capacity
- Increases reliability of supply.

Base load Plant:

Base load plant is a type of plant which supplies to a constant load demand in more efficient manner.

- Such plants run 100% of the time.
- Examples: Nuclear and Coal fired plants.

Peak Load Plant:

Peal load plant is a type of plant which supplies to both constant load demand as well as maximum demand.

- These plants helps over short term (15%) demand peak.
- Gas turbine, hydro plant can be used.

Interconnected grid system:

The connection of several generating stations are connected in parallel is known as an interconnected grid system.

Load Factor:

Load factor is defined as the ratio of an Average load to the Maximum load.

$$\text{Load Factor} = \frac{\textbf{Average load}}{\textbf{Maximum load}}$$

Diversity Factor:

Diversity factor is defined as the ratio of sum of individual maximum demands to the maximum demand on the power plant.

$$\text{Diversity factor} = \frac{\textbf{\textit{Sum of individual maximum demands}}}{\textbf{\textit{Maximum demand on the power plant}}}$$

Utilization factor:

Utilization factor is defined as the ratio of Maximum load to the Rated capacity of the plant.

$$\text{Utilization factor} = \frac{\textbf{Maximum load}}{\textbf{Rated capacity of plant}}$$

Plant use factor:

Plant use factor is defined as the ratio of kWh generated output to the product of rated capacity of plant and the number of hours for which the plant was in operation.

$$\text{Plant use factor} = \frac{\textbf{kWh generated output}}{\textbf{Rated capacity of plant X Number of Hours in use}}$$

Capacity factor:

Capacity factor is defined as the ratio of Average load to the Rated capacity of the plant. It is also called as **Plant capacity factor.**

$$\text{Capacity Factor} = \frac{\textbf{Average load}}{\textbf{Rated capacity of plant}} = \frac{\textbf{Total energy output in a period}}{\textbf{Rated capacity of plant}}$$

Demand factor:

Demand factor is defined as the ratio of Maximum demand on the station to the total load connected to the plant.

$$\text{Demand factor} = \frac{\textbf{Maximum demand}}{\textbf{Total connected load}}$$

Reserve Factor:

Reserve factor is defined as the ratio of Load factor to the capacity factor.

$$\text{Reserve factor} = \frac{\textbf{Load factor}}{\textbf{Capacity factor}}$$

Plant Reserve capacity:

Plant reserve capacity is defined as the difference between the Rated capacity of the plant ant the Maximum demand on the plant.

Reserve capacity = Rated capacity of the plant – Maximum demand on the plant

Coincidence Factor:

Coincidence factor is defined as the ratio of Capacity factor to the Load factor.

$$\text{Coincidence factor} = \frac{1}{\text{Reserve factor}} = \frac{\text{Capacity factor}}{\text{Load factor}}$$

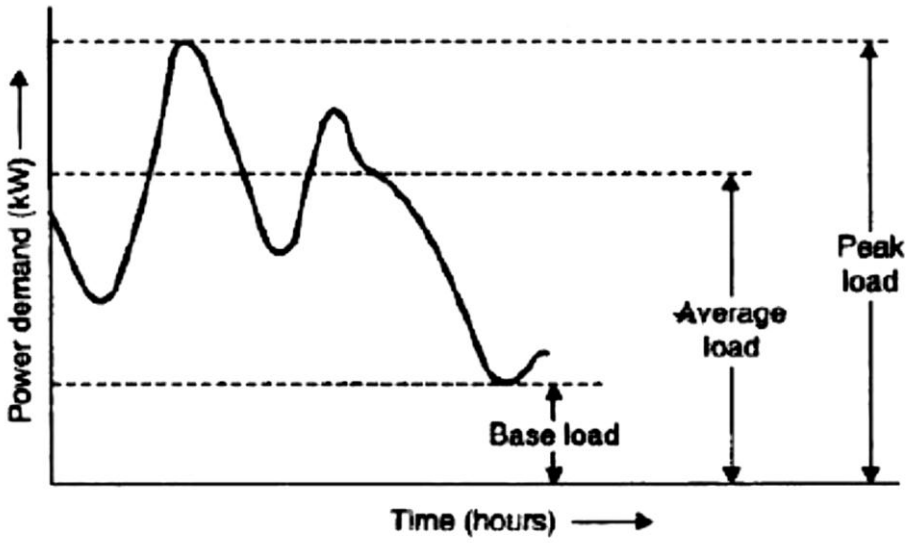
3. Explain Load curve and load duration curve with its significance. Explain the graphical representation of variable load during different time period. (or) Draw and explain the parameters related to load curve and Load duration curve.

A) <u>Load curve:</u>

- The curve showing the variation of the load on the power station with respect to time is known as **Load curve**.
- The load on a power station is never constant because it varies time to time.

<u>Types of load curve:</u>

- The load variations during the whole day is plotted against the time is called as **Daily load curve.**
- The load variations during the whole month is plotted against the time is called as **Monthly load curve**. This can be obtained from the daily load curve of that month.
- The load variations during the whole year is plotted against the time is called as **Yearly load curve**. This can be obtained from the monthly load curve of that particular Year.



Graphical representation of Load (Load curve)

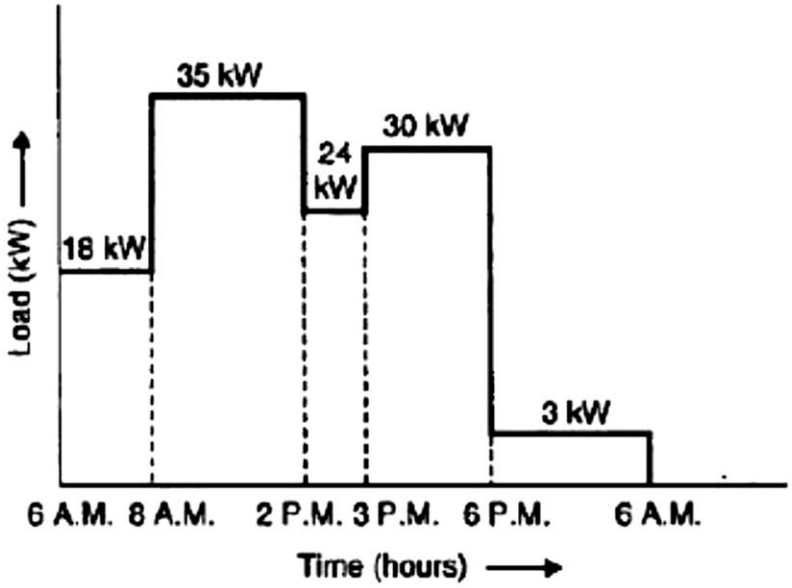
<u>Significance of load curve:</u>

- The area under the load curve represents the energy generated in the period considered.
- The area under the curve divided by the total number of hours gives the average load on the power station.

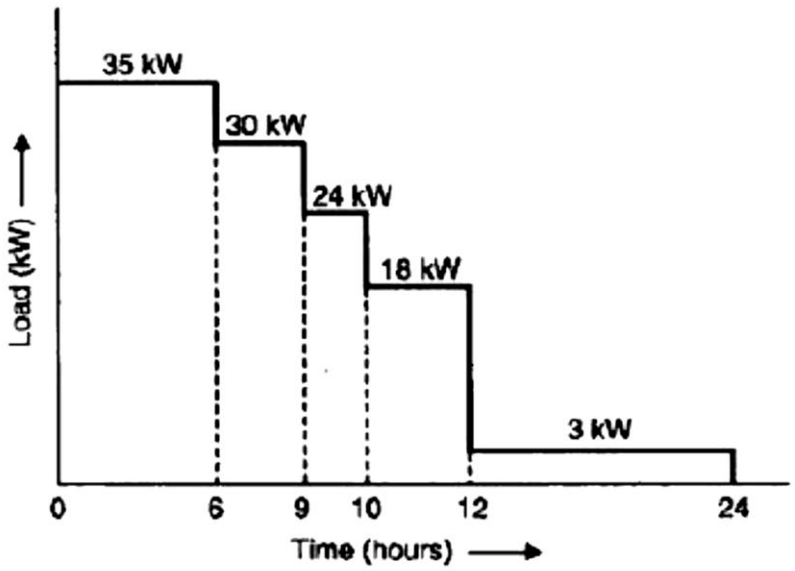
- The peak load indicated by the load curve is the graph represents the maximum demand of the power station.
- Load curve helps in selecting the size and number of generating units of the power station.
- Load curves give full information about the incoming load.
- Load curve helps in deciding the operation schedule of the station.
- Load curves also help to estimate the generating cost.

B) <u>Load duration curve:</u>

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



Daily load Curve



Load duration curve

Significance of Load Duration curve:

- The area under the load duration curve and the corresponding chronological load curve is equal.
- Load duration curve represents total energy delivered by the generating station with optimized operating units.
- Load duration curve gives a clear analysis of generating power economically.
- Proper selection of base load power plants and peak load power plants becomes easier.

C) Important definitions for Load Curve:

Base Load:

The unvarying load which occurs almost the whole day on the station is called as Base load.

Peak Load:

The various peak demands of load over and above the base load of the station is known as Peak Load.

- It is also known as Peak demand

Connected load:

The sum of the continuous ratings of all the equipment connected to the power system is called connected load.

Maximum load:

Maximum load is the greatest demand on the given period during a given period.

- It is also known as Maximum demand.

Average Load:

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Cold reserve:

Cold reserve is that reserve generating capacity which is not in operation but can be made available for service.

Hot reserve:

Hot reserve is that reserve generating capacity which is in operation but not in service.

Spinning reserve:

Spinning reserve is that reserve generating capacity which is connected to the bus and is ready to take the load.

D) Types of loads:

- **Residential load**: This type of load includes domestic lights, power needed for domestic appliances such as radios, television, water heaters, refrigerators, electric cookers and small motors for pumping water.
- **Commercial load:** It includes lighting for shops, advertisements and electrical appliances used in shops and restaurants etc. This load occurs for some hours during the day time.
- **Industrial load:** It consists of load demand of various industries. The magnitude of this type of load depends on the type of industry.
- **Municipal load:** It consists of street lighting, power required for water supply and drainage purposes. This pumping process occurs at the night time only.
- **Irrigation load**: This type of load includes electrical power needed for pumps driven by electric motors to supply water to fields. This type of load is supplied for night 12 Hours.
- **Traction load:** It includes trams, cars, trolley, buses and railways. This type of load has wide variation depends on time.

4. Explain the factors to be considered for site selection of power plant. (or) Describe the site selection factors considered for different power plant construction and operation.

In general, both the construction and operation of a power plant requires the existence of some conditions such as water resources and stable soil type. Some factors such as population centers and protected areas will be affected by either the construction or operation of the plants.

Factors for power plant site selection:

Area size:

- Before any other consideration, the minimum area size required for the construction of power plant should be selected.

Transportation network:

- Reduced transportation is needed from the availability of fuel
- Easy and enough access to transportation network is required in both power plant construction and operation periods.

Gas pipe network:

- Area to the gas pipes reduces the required expenses on the space required.
- If underground pipes are used there is no need of

Power transmission network:

- To transfer the generated electricity to the consumers in reduced cost.
- The plant should be connected to electrical transmission system with profitable manner.
- The plant should be located nearer to the electric network to distribute power.

Geology and soil type:

- The power plant should be built in an area with alternate soil and rock layers
- This combination of soil can withstand the weight and vibrations of the power plant.

Earthquake and geological faults:

- Even weak and small earthquakes can damage many parts of a power plant intensively.
- Therefore the site should be away enough from the faults and previous earthquake areas.

Topography (Slope Areas):

- Changing of a sloping area into a flat site for the construction of the power plant needs extra budget.
- Therefore, the parameters of elevation and slope should be considered.

Rivers and floodways:

- **T**he power plant should have a reasonable distance from permanent and seasonal rivers and floodways.

Water resources:

- For the construction and operating of power plant more volume of water are required. This could be supplied from either rivers or underground water resources.
- Enough water supplies in defined area can be a factor in the site selection.

Environmental resources:

- Operation of a power plant has important impacts on environment.
- Priority will be given to the locations that are far enough from national parks, wildlife, protected areas, etc.

Population centers:

- The waste from the power plant has adverse effects on the environment and population.
- The site should have an enough distance from population centers.

Need for power:

- In general, the site should be near the areas that there is more need for generation capacity.
- More power near the power plant is to decrease the amount of power loss and transmission expenses.

Climate:

- The productivity of a power plant depends on parameters such as temperature, humidity, wind direction and speed.
- The environmental conditions should be always taken into site selection criteria.

Land cover:

- Some land cover types such as forests, agricultural land, etc. are sensitive to the pollutions caused by a power plant.
- The effect of the power plant on such land cover types surrounding it should be considered.
- Proper waste disposal systems are to be designed in addition to construction of power plant.

Distance from airports:

- The power plant has high towers and chimneys and large volumes of gas.
- For security reasons, they should be away from airports.

Archeological and historical sites:

- The vibrations of power plant should not affect the historical building because they are fragile and at same time very valuable.
- The site should have an enough distance from historical building areas.

5. Write the advantages and disadvantages of various power plants.

Thermal Power Plant:

Advantages of Thermal Power Plant:

- They can respond to rapid1y changing loads without difficulty.
- A portion of the steam generated can be used as a process steam in different industries.
- Can be located very conveniently near the load centre.
- As these plants can be set up near the industry transmission costs are reduced.
- Steam engines and turbines can work under 25 per cent of overload continuously.
- Fuel used is cheaper.
- Less space is required in comparison with that for hydro-electric plants.
- Cheaper in production cost in comparison with that of diesel power stations.
- Cheaper in initial cost in comparison with that of diesel power stations.

Disadvantages of thermal power plant:

- Maintenance and operating costs are high.
- The cost of plant increases with increase in temperature and pressure.
- Long time required for erection and putting into action.
- A large quantity of water is required.
- Great difficulty experienced in coal handling.

- The plant efficiency decreases rapidly below about 75 per cent load.
- Presence of troubles due to smoke and heat in the plant.

Diesel turbine Power Plant:

Advantages of Diesel Power plant:

- The advantages of diesel power plants are listed below.
- Very simple design also simple installation.
- Limited cooling water requirement.
- Standby losses are less as compared to other Power plants.
- Low fuel cost.
- Quickly started and put on load.
- Smaller storage is needed for the fuel.
- Layout of power plant is quite simple.
- There is no problem of ash handling.
- Less supervision required.
- For small capacity, diesel power plant is more efficient as compared to steam power plant.
- They can respond to varying loads without any difficulty.

Disadvantage of Diesel Power Plant:

- High Maintenance and operating cost.
- Fuel cost is more, since in India diesel is costly.
- The plant cost per kW is comparatively more.
- The life of diesel power plant is small due to high maintenance.
- Noise is a serious problem in diesel power plant.
- Diesel power plant cannot be constructed for large scale.

Gas turbine Power plant:

Advantages of Gas turbine Power plant:

- It is smaller in size and weight as compared to an equivalent steam power plant.
- The initial cost and operating cost of the plant is lower than an equivalent steam power plant.
- The plant requires less water as compared to a condensing steam power plant.
- The plant can be started quickly and can be put on load in a very short time.
- There are no standby losses in the gas turbine power plant
- The maintenance of the plant is easier and maintenance cost is low.
- The lubrication of the plant is easy.
- The plant does not require heavy foundations and building.

- There is great simplification of the plant over a steam plant due to the absence of boilers with their feed water evaporator and condensing system.

Disadvantages of Gas turbine power plant:

- Major part of the work developed in the turbine is used to derive the compressor.
- Network output of the plant is low.
- Temperature of the products of combustion becomes too high
- Service becomes complicated even at moderate pressures.

Nuclear Power Plant:

Advantages of Nuclear Power Plant:

- Nuclear reactor have long life.
- Breeder reactors create more usable fuel than they use.
- A nuclear aircraft carrier can circle the globe continuously for 30 years on its original fuel.
- Reprocessing of nuclear material creates the nuclear fuel for hundreds of years.
- Nuclear power plant can be located almost anywhere far away from the cities.
- Very low greenhouse gas emissions due to shielding of reactor.
- Nuclear power plants requires less space.
- Nuclear power plants already exist and are available worldwide.
- More nuclear power can be produced in large quantities over short periods of time.
- The contribution of nuclear power to global warming is relatively little.

Disadvantages of Nuclear Power Plant:

- Nuclear disaster changes the living land to Non- living land for more number of years.
- Nuclear research has created large contamination problems.
- Nuclear plants are more expensive to build and maintain.
- Lack of nuclear fuels needed for nuclear power plants.
- Nuclear plant workers may be exposed to high levels of radiation causes diseases.
- Breakdown of nuclear reactor are costly to replace.
  High risk power supply is needed for nuclear power plant.
- Nuclear meltdown can release massive amounts of radiation.
  Nuclear energy can create more problems than they solve.
- These plants also consume large amounts of water.
- Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.
- Nuclear power plants are not well suited for varying load conditions.
- Maintenance cost of the plant is high.
- It requires trained personnel to handle nuclear power plants.

Hydro-electric Power plant:

Advantages of Hydro-electric Power plant:

- The plant is highly reliable
- Maintenance and operation charges are very low.
- The plant can be run up and synchronized in a few minutes.
- The load can be varied quickly
- The rapidly changing load demand can be met without any difficulty.
- The plant has no stand-by losses.
- No fuel charges.
- The efficiency of the plant does not change with age.
- The cost of generation of electricity varies little with the passage of time.

Disadvantages of Hydro-electric Power plant:

- The capital cost of the plant is very high.
- The hydro-electric plant takes much longer in design and execution.
- These plants are usually located in hilly areas far away from the load center.
- Transformation and transmission costs are very high.
- The output of a hydro-electric plant is never constant due to vagaries of monsoons and their dependence on the rate of water flow in a river.

Magneto-Hydro Dynamite Power Generation:

Advantages of MHD Generation:

- Here only working fluid is circulated, and there are no moving mechanical parts.
- Mechanical losses are very low and makes the operation more dependable.
- The temperature of working fluid is maintained the walls of MHD.
- It has the ability to reach full power level almost directly.
- The cost of MHD generators is much lower than conventional generators.
- MHD has very high efficiency.

6. Write the comparison of capital and operating cost for various power plants. (or) Explain in detail about the capital and operating cost of different power plants from the basics of Power plant economics.

A power plant should provide a reliable supply of electricity at minimum cost to the consumer is generally called as Power plant Economics.

The cost per kilo-Watt hour(kWh) is determined by three different costs:

1. Fixed cost
2. Variable cost (Operation and Maintenance cost)
3. Fuel cost·

Fixed cost(FC) or Capital cost:

- Fixed cost is the installation cost which mainly includes interest, depreciation, insurance, taxes.
- This cost is depending on the capital invested on the plant construction including the cost of the land.

Variable cost:

- Variable cost is the combination of Operating and Maintenance cost of the power plant.
- Operation cost includes the cost of wages for workers and servicing of equipment.
- Maintenance cost includes the cost of repairs including spare parts, water, lubricating oil, chemicals and miscellaneous expenses.

Fuel cost:

Fuel cost is the cost which depends on the amount of electricity generated in kWh of electricity sent out per year.

Total annual cost of power plant:

The total annual cost (C_i) in a power plant can be calculated from

$$C_I = \left(\frac{I+D+T}{100}\right) C_c + (W + R + M) + Cr$$

Where, I = interest in %; D = Depreciation in %; Taxes and insurance in %;
Cc = Construction cost; W = Cost of wages and salaries; R = Repair cost;
M = Miscellaneous cost ; Cr = fuel cost.

- In order to calculate the electric power cost to a consumer, the power outage cost (which includes transmission cost, distribution cost, administrative expenses, and return or profit on the investment).is also considered in addition to the production cost.
- A measure for the reliability of a power plant is the forced outage rate is defined by the annual ratio.

$$\text{Forced outage rate} = \frac{\textbf{Forced outage hours}}{\textbf{Service hours} + \textbf{Forced outage hours}}$$

- In general, central station generators has a tradeoff between capital and operating costs.

- Those types of plants that have higher capital costs tend to have lower operating costs.
- Further, generators which run on fossil fuels tend to have operating costs that are extremely sensitive to changes in the underlying fuel price.

- Typical capital and operating costs for different power plants

Type of Power plant	**Capital Cost ($/kW)**	**Operating Cost ($/kWh)**
Coal-fired combustion turbine	$500 — $1,000	0.20 — 0.04
Natural gas combustion turbine	$400 — $800	0.04 — 0.10
Coal gasification combined-cycle (IGCC)	$1,000 — $1,500	0.04 — 0.08
Natural gas combined-cycle	$600 — $1,200	0.04 — 0.10
Wind turbine (includes offshore wind)	$1,200 — $5,000	Less than 0.01
Nuclear	$1,200 — $5,000	0.02 — 0.05
Photovoltaic Solar	$4,500 and up	Less than 0.01
Hydroelectric	$1,200 — $5,000	Less than 0.01

- Depends on capital and operating cost, the direct comparison of overall costs of different power plants is not possible.

- Power plant installation cost is based on a measure called the "Levelized Cost of Energy"(LCOE).

- LCOE is the measure of cost which is the average price per unit of output needed for the plant to break even over its operating lifetime.

$$\mathrm{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where,

LCOE = Levelized cost of electricity
I_t = Investment expenditures in the year t
M_t = Operations and maintenance expenditures in the year t
F_t = Fuel expenditures in the year t
E_t = Electricity generation in the year t
r = Discount rate

n = Life of the system

- Irrespective of technology, all generators share the following characteristics which influence the plant operations:

  Ramp rate: This variable influences how quickly the plant can increase or decrease power output in percentage of capacity per unit time.

  Ramp time: The amount of time taken from the moment a generator is turned on for providing energy to the grid at its lower operating limit.

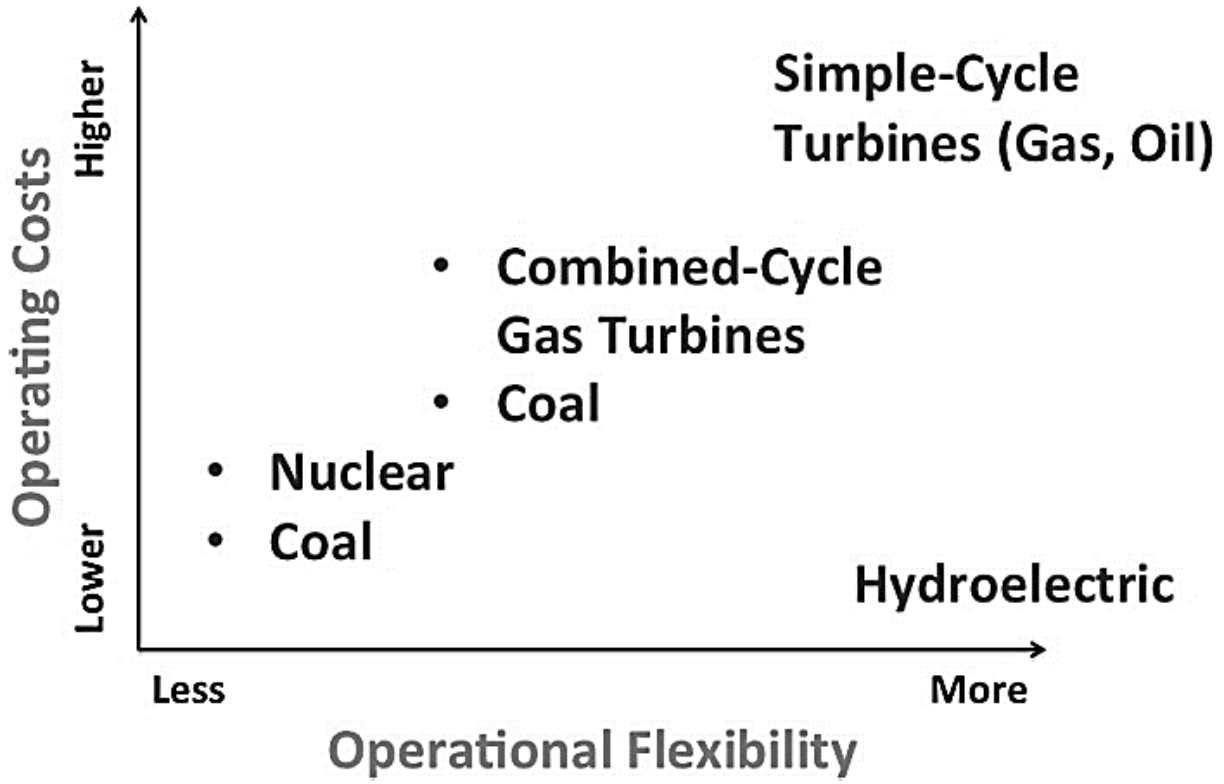
  Capacity: The maximum output of a plant in megawatt.

  Lower Operating Limit (LOL): The minimum amount of power(in MW) is generated in a plant once it is turned on.

  Minimum Run Time: The shortest amount of time required for a plant to generate minimum amount of electricity once it is turned on.

  No-Load Cost: The no-load cost is the fixed cost of operation without any power generation in the power plant.
  Start-up and Shut-down Costs:

  These are the costs involved in turning the plant on and off, in Dollars/MWh.



Comparison of operating cost and operational flexibility for different power plant

- The cost structure for transmission and distribution is different than for power generation.
- There is basically no fuel cost involved with operating transmission and distribution wires (and their associated balance-of-systems, like substations).

Typical Ramp and Run times for power plants.		
Type of Power plant	**Ramp Time**	**Minimum Run Time**
Simple-cycle combustion turbine	minutes to hours	minutes
Combined-cycle combustion turbine	hours	hours to days
Nuclear	days	weeks to months
Wind Power plant	minutes	none
Hydro-electric power plant	minutes	none