PSGT.

classmate Date Page

1. Introduction to Electrical Power Systems.

We need energy for industrial, commercial and day-to-day activities and we use energy in different forms. Out of all the forms, electric energy is the most important one as it can be generated efficiently, transmitted easily & utilised at very reasonable cost.

The ease of transmission of electric energy gives rise to a possibility of ~~gen~~ generating electric energy in bulk at a centralised place and transmit it over a long distance to the ultimate users.

When we have generation in bulk, transmission over a long distance and ~~u~~ utilisation by a number of distributed users, we need to follow systematic methodology to have reliable, efficient, economic & safe use of electric energy.

The components needed for generation, transmission and large-scale distribution of electric energy form a huge complex system termed as Electrical Power System. Power system is the branch of electrical engg. where we study in depth for its design, operation, maintenance & analysis.

Main parts of P.S. (Refer slide).

It contains a generating plant, a transmission sys, subtransmission sys, & a distribution sys. These subsystems are interconnected through transformers T_1, T_2 & T_3.

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To understand the system, let us consider some typical voltage levels.

The electric power is generated at a thermal plant with a typical voltage of 22 kV. This is boosted up to levels like 400kV through transformer T_1 for transmission. Transformer T_2 steps this vltg down to 66kV to supply power through subtransmission line to industrial loads that require bulk power at a higher voltage. The power distribution network starts with transformer T_3, which steps down the voltage from 66kV to 11kV. The distribation sys. contains loads that are either commercial types (offices, school, hotels, shops, etc) or residential types. Usually commercial customers are supplied power at a voltage level of 11kV whereas domestic consumers get power supply at 400 & 440 V.

Generating stations & a distribution sys. ~~Major Electrical Equipment in Power~~ are connected through transmission lines, which also connect one power system to another. A distribation sys. connects all the loads in a particular area to the transmission lines. For economical & technological reasons, individual p.s. are organised in the form of electrically connected areas or regional grids. Each regional grid operates technically & economically independently, but these are eventually interconnected to form a

national grid, so that each area is contractually tied to other areas in respect to certain generation & scheduling features. India is now heading for a national grid.

The national grid is the h.v. electric power transmission network in India, connecting power stations & major substations and ensuring that electricity generated anywhere in mainland India can be used to satisfy demand elsewhere. The national grid is owned, operated & maintained by state-owned Power Grid Corporation of India. Five regional grids in the country are -

1. Northern
2. Southern
3. Eastern
4. North-eastern
5. Western

Electric energy generation-

Electrical energy is generated in large hydro, thermal & nuclear power stations. In India, about 68% electricity is generated in thermal plants (including nuclear), 23% from hydro stations & 9% come from renewable & others. Coal is the fuel for most of the steam plants & rest depends upon oil/natural gas & nuclear fuels. Electric power is generated at a voltage of 11 to 25 kV which is stepped up to the range of 66 to 765 kV

For very long distances (over 600 km), it is economical to transmit bulk power by D.C. transmission. The DC voltages used are 400 kV & above, and the line is connected to the AC systems at two ends through a transformer and converting / inverting equipment. In India several HVDC transmission lines are operated.

Conventional Sources of Electrical Energy

Thermal & hydro generations are the main conventional sources of electric energy.

Thermal Power stations (steam-gas based).

The heat released during the combustion of coal, oil or gas is used in a boiler to raise steam. In India, heat generation is mostly coal based, except in small sizes.

In thermal power plants chemical energy stored in coal is transformed into electric energy.

- The coal handling plant supplies coal to the boiler.
- The heat released by the combustion of coal produces steam in a boiler at high pressure & temperature, which when passed through a steam turbine, gives off its internal energy as

mechanical energy. The axial-flow type of turbine is normally used. The steam turbine acts as a prime mover & drives the alternator.

- The ash/dust formed in the boiler is disposed off by the ash handling plant.
- Air taken from the atmosphere by the action of forced draft fan is heated in the preheater by the heat of flue gases before being fed to the boiler.
- The flue gases pass through dust collector, air preheater & economiser before being discharged to the atmosphere through the chimney.
- The exhaust steam from the turbine is condensed by the condenser and the condensate, along with make up water is fed to the boiler again.

The main equipments in a thermal plant are -

1. Coal handling plant - its function is automatic feeding of coal to the boiler furnace. A thermal plant burns enormous amount of coal. A 200 MW plant may require around 2000 tons of coal daily. In every plant there is enough storage of coal to last for nearly 15 days.

2. Pulverising plant - In modern thermal power plants, coal is pulverised, ie, ground to dust like size & carried to the furnace. Pulverisation is a means of

exposing a large surface area to the action of oxygen & consequently helping the combustion.

3. Boiler - A boiler is a closed vessel in which water under pressure is converted into steam. A boiler is always designed to absorb max. amount of heat released in the process of combustion. This heat is transferred to the boiler by all the three modes of heat transfer ie, conduction, convection & radiation.

4. Steam turbine - It converts heat energy of steam into mechanical energy and drives the generator. It uses the principle that when the steam enters through a small opening, attains a high velocity. Governors are used to maintain speed constant when load changes.

5. Ash handling plant - Coal contains a considerable amount of ash. Power plants generally use average or poor quality coal, as a result, the ash produced by a plant is pretty large. Small power stations use some conveyor arrangement to carry to dump sites directly. Large stations use more elaborate arrangements and separate systems for the ash.

6. Condenser - It does a ~~do~~ job of condensing the steam exhausted from turbine. It helps in maintaining low pressure at the exhaust, thereby permitting expansion of steam in the turbine to a very low pressure. This improves plant efficiency. The exhaust steam is condensed and used as feed water for the boiler.

The overall efficiency of the thermal power plant is poor & ~~it~~ ~~or~~ max value is about 40% because of high heat losses in the combustion and large quantity of heat rejected to the condenser.

Advantages —

Disadvantages. — Life.
fuel.
maintenance
Labour
pollution
efficiency

Hydro Power Plant

Oldest & cheapest method.

Hydro-electric projects harness water power for generation of electric energy. When water drops through a height, its energy is able to rotate turbines which are coupled to alternators.

The energy is obtained almost free of running cost & is completely pollution free.

Advantages -

1. Useful life of hydro-plant is around 50 years as compared to around 25 years of steam plant
2. No fuel requirement, hence operating cost is low
3. These plants are more robust as compared to steam plants.
4. Low maintenance.
5. Efficiency does not reduce with age.
6. Leads to conservation of coal & other fuels.
7. Operating personnel required are also small in number
8. Generally these are multi-purpose projects. In addition to generation they are also useful for irrigation, flood control, navigation, etc.
9. Pollution free.
10. Located in remote areas where land costs are low.

Disadvantages.

1. Due to high cost of civil engineering work, capital cost ~~of~~ per kW is considerably high
2. It is dependent on availability of water. In dry year, power generation is small.
3. Due to huge civil works, it requires long gestation period of about 5 to 8 years as compared to 4 to 6 years of steam plant.
4. It submerges huge areas, uproots large population & creates social & other problems.

Main parts.

1. Reservoir - Most of the ~~re~~rivers have non-uniform run offs. During ~~raini~~ rainy periods, run off is high but power requirement are low because of absence of ~~irri~~ irrigation load. It is therefore, necessary to store water during excess flow periods so that the same may be used ~~dur~~ during lean flow periods. The storage reservoirs thus help in supplying water to the turbines according to the load on the plant

2. Dam - The function of dam is to create an artificial head & storage. It diverts the flow of water so that the same could be used for generation of power. It is the most imp. & expensive part of a hydro project. The selection of type of dam for a particular location depends on topography of the site, geological & sub-soil conditions. It should be safe, economical and aesthetic in appearance

3. Surge tank.- The load on a generator keeps on fluctuating. Therefore, the water intake to the turbine has to be regulated according to the load. A reduction in load causes the governor to close the turbine gates. Sudden closure of turbine gates creates an increased pressure, known as water hammer, in the penstock. When the governor opens the turbine gates to admit more water, there is a tendency to cause a vacuum in the penstock. The function of the surge tank is to absorb these sudden changes in water requirements so as to prevent water hammer & vacuum.

The figure shows a surge tank. A decrease in load demand results in rise in water level in the surge tank. This decreases the water velocity in the penstock. An increase in demand causes water to flow out of surge tank. This increases the flow in the penstock thus preventing vacuum.

Thus surge tank helps in stabilizing the velocity & pressure in penstock & reduces water hammer & vacuum.

4. Penstock - it carries water from the water storage system to the turbine.

5. Turbines - Hydraulic turbines convert energy of water into mechanical energy which drives the alternator. They are

highly efficient, simple in construction & can be controlled easily. Different types of turbines used are:- pelton turbine, francis turbine, propellers & Kaplan turbine, etc.

6. Governor - The function of governor is to keep the speed of alternator constant when the load changes. To maintain the freq. of electric supply constant, the speed of alternator must remain constant. A good speed regulating governor should be quite sensitive to the changes in shaft speed and should be rapid in action. However, it must not close the pipe so quickly so as to cause water hamm in the penstock.

Major hydro-electric plants in India.

1. Koyna (Maharashtra)

Pumped storage plants.

It is a special type of plant meant to supply peak loads. During peak load period, water is drawn from the head water pond (upper reservoir) through the penstock & generates power for supplying the peak load.

During the off-peak period, the same water is pumped back from the tail water pond (lower reservoir) to the upper reservoir, so that this water may be used to generate energy during the next peak load period. Generally pumping of water from lower to upper reservoir is done at night when loads are low. The reservoir capacity should be such that the plant can supply peak load for 4 to 11 hours.

The earlier pumped storage installations used a separate pump for pumping the water back. A recent development is a reversible turbine pump. During low loads, the alternator runs as a motor & drives the turbine which now works as a pump. This arrangement reduces the capital cost of the plant. The power for driving the motor is taken from the system.

Nuclear Power Stations.

The energy needs of a country cannot be met from a single source. Hydro electric stations produce cheap power but need a thermal backing to increase the capacity. The coal reserves of the world are fast depleting. The nuclear power is the only source which can supply the future energy demands of the world.

Advantages:-

1. Amount of fuel is small, hence fuel cost is low.
2. Plant needs less area
3. Leads to conservation of coal

A nuclear plant consists of a nuclear reactor (for heat generation), heat exchanger (for converting water into steam by using the heat generated in the reactor), steam turbine, alternator, condenser, etc. Thus it is similar to steam power plant except that the nuclear reactor & heat exchanger replace the boiler.

Moderator — to slow down initial high speed of neutrons. — Graphite, heavy water, water

Control rods — To control the fission rate of the nuclear fuel - uranium.

Boron, cadmium, indium are capable of absorbing many neutrons.

Chain reaction is slowed down.

Combined operation of various types of power stations.

In an interconnected power system which has a number of power stations of different types operating in parallel, it is necessary to co-ordinate the different stations for best possible economic operation. In deciding the type of plant to be used & allocation of load to the plant factors such as availability of fuel & other resources in country, types of plants with their cost & economics of generation have to be studied.

The types of stations that are usually available are — ~~hyd~~ hydro-electric, steam, gas, diesel & nuclear. These have to be used either as peak load plants or base load plants (or sometimes both) for co-ordinated operation.

Base load plants run throughout the year. The economic characteristics of base load plants should be such that they supply power at high capital costs but have low cost of operation.

Peak load plants run for few hours in the year. They should supply power at low capital costs though their cost of operation may be high. Peak load stations should be capable of quick starting & should be inexpensive in starting & shutting down operations.

Nuclear power stations are used as base load stations operating at high load factors of over 80%. These meet the "block loads" at the bottom of the load ~~curve~~ curves.

Hydro-electric stations with ample storage are also used for base load operation. Hydro-electric stations with limited storage are used to meet the peak loads. Pumped storage plants are always used as peak load plants.

Steam stations are capable of operation as both - peak & base load, depending on co-ordination required with other types of stations in the system. These can operate at load factors varying from 40% to 80%.

Diesel & gas-turbines plants are also used as peak load plants only. These work at low ~~pow~~ load factors of 25% or so. If the load factors are lower than 25%, then gas plants are preferred.

Diesel plant is useful as a peak load, standby or emergency plant.

Interconnection of power stations.

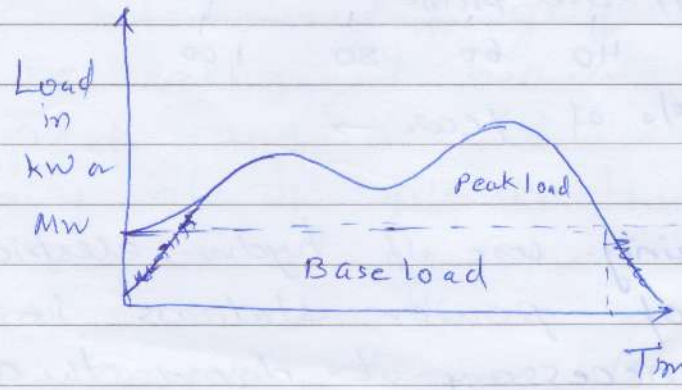
The connection of various generating stations in parallel is called interconnection of power stations or also called as interconnected grid system.

Before studying advantages of grid system, first know the concept of base load & peak load.

We know that the load on the power station is never constant, but keeps on changing with time. This load can be divided into two parts - i) base load & ii) peak load.

The fixed load which occurs almost whole day on the plant is called base load. The loads which are over & above the base load of the power plant is called peak load.

Consider the load curve with base load & peak load shown below.-

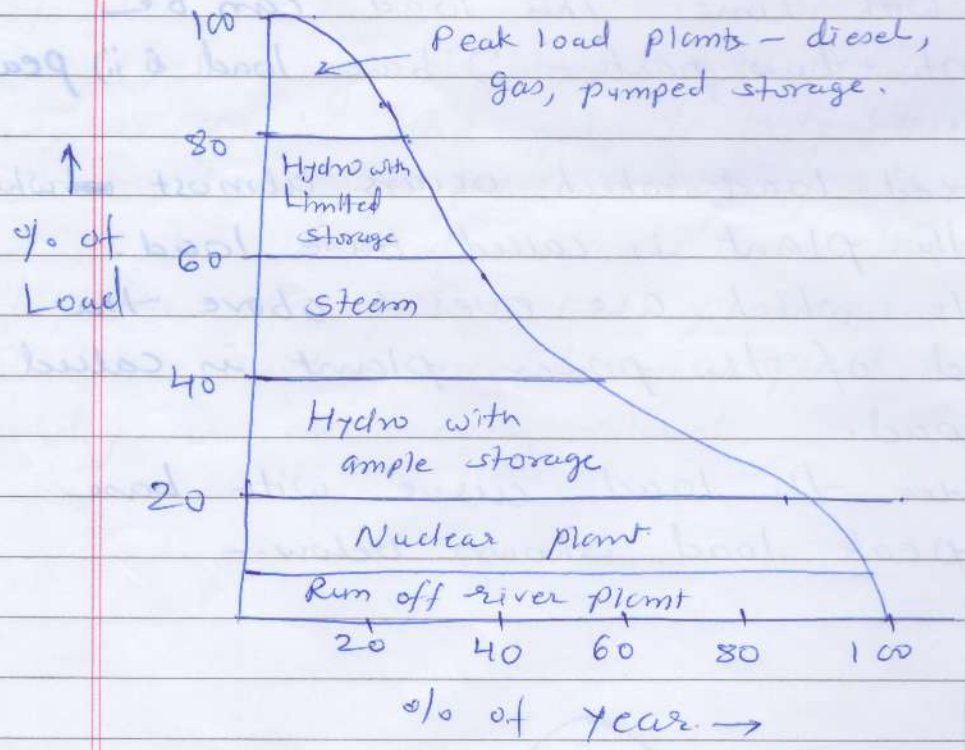


If such load curve is to be met by a single unit (power plant), then its installed capacity should be equal to

peak load demand or more. But peak load occurs for short duration, hence such solution is not economical.

The other way is to divide the load into base load & peak load. By interconnection of various power stations of different types, some station will supply base load while some other stations will supply peak load.

~~The~~ A typical load allocation to various plants is shown below:-



While considering use of hydro-electric, steam & other types of power stations in a system, it is necessary to draw the annual load duration curve of the system & fit the various types of plants into the area under the curve.

The power plants which are working as

base load should be capable of working continuously for long periods, should have low operating cost and its repair should be economical & speedy.

The peak load power plants should be capable of quick start, fast synchronisation and should have fast response to load variations.

The hydro-power plant with run-off river water serves as base load. They are normally employed as base load plants as their capital cost is high but running cost is comparatively low. But when water is not abundently available, they are used as peak load plants.

The cost of per unit generation in steam plant is minimum, hence it can be employed as base load. Nuclear power plants are also used as base load. Diesel, gas and pumped storage plants are used as peak load plants.

Advantages of interconnected system.

1. With interconnected grid system, peak loads can be exchanged between generating stations. If peak load demand is more than capacity of the plant, then excess load can be shared by other interconnected stations.
2. It is possible to use the old and inefficient plants in the grid system for short duration to supply peak demands.
3. With interconnected grid sys., the economical operation of the plant is possible. The total

load is arranged such that more efficient plants can be used as base load stations which can work throughout the year at high load factor.

4. Load curves of two different stations are not identical. The peak loads may occur at times different by few minutes. Thus the maximum demands of individual stations are not occuring simultaneously. Hence it is ~~not~~ possible to work with lesser installed capacity.

5- The reliability & continuity of the supply is improved with interconnected grid system. If fault condition occur at any one station, supply can be maintained with the help of other stations.