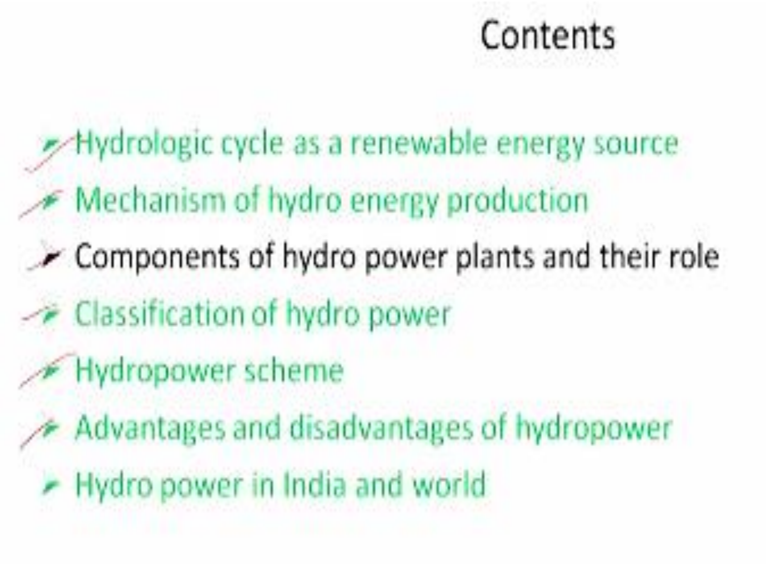
Technologies for Clean and Renewable Energy Production
Prof. Prasenjit Mondal
Department of Chemical Engineering
Indian Institute of Technology – Roorkee

Lecture - 31
Hydro Energy 1

Hi friends, now we will discuss on the topic hydro energy. Hydro means water, so hydro energy is the energy which is generated from the water. So in case of wind energy, we have discussed that the flow of air has some kinetic energy and that can be converted to electrical energy by using turbine and generator. So here also the when the water will be in flow, then the kinetic energy of that flowing water can be converted to mechanical energy in turbine which is followed by conversion in electrical energy in the generator.

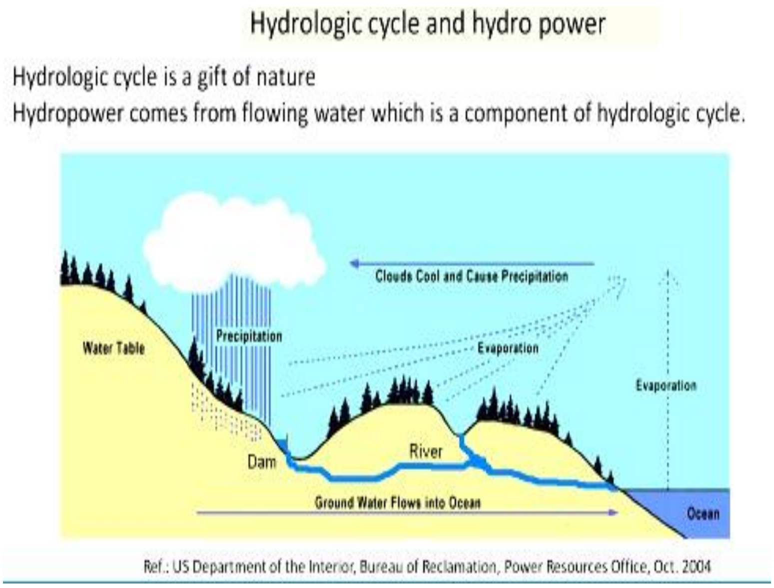
So in this case, we need the flow of water and this can be ensured by making dam or by using some river flow or canal flow, etc.

(Refer Slide Time: 01:32)



So now in this class we will discuss on hydrologic cycle as a renewable energy source, then mechanism of hydro energy production, components of hydro power plants and their role, classification of hydro power, hydropower schemes, advantages and disadvantages of hydropower, and hydropower in India and world. As we discussed that flow of water is required for hydro energy production and availability of water is also necessary for it and this is gifted by nature.

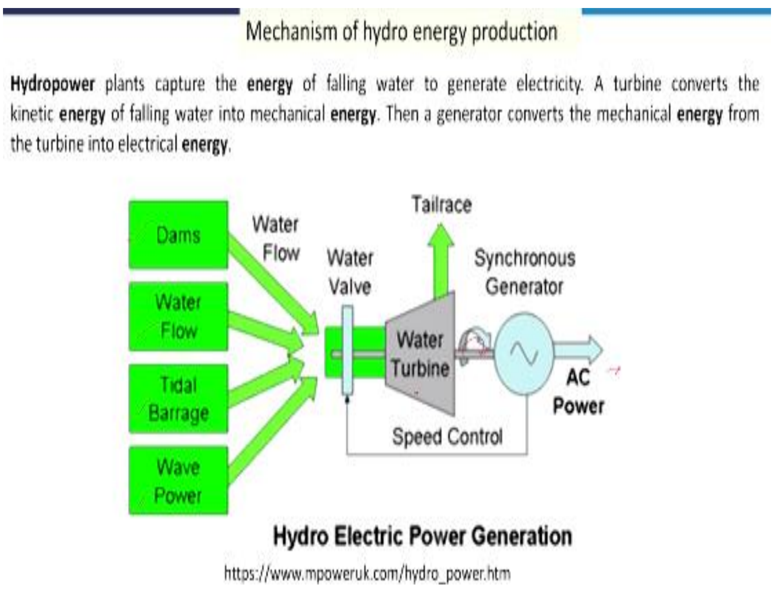
(Refer Slide Time: 02:15)



So in terms of hydrologic cycle, you see here the water which is evaporated from the ocean it is converted to cloud and again precipitates. We know it very well that the water cycle and then when it precipitates on the land or in the water, then from the land the water is flooded and it comes to the river stream, in the mountain, it comes to the dam and dam to river stream and the water gets velocity in this river and in this dam.

So the velocity of the water will be used to rotate a turbine, in fact the kinetic energy of this flowing water will be used to rotate a turbine blade, a turbine rotor, and that will be connected to a generator for electricity production.

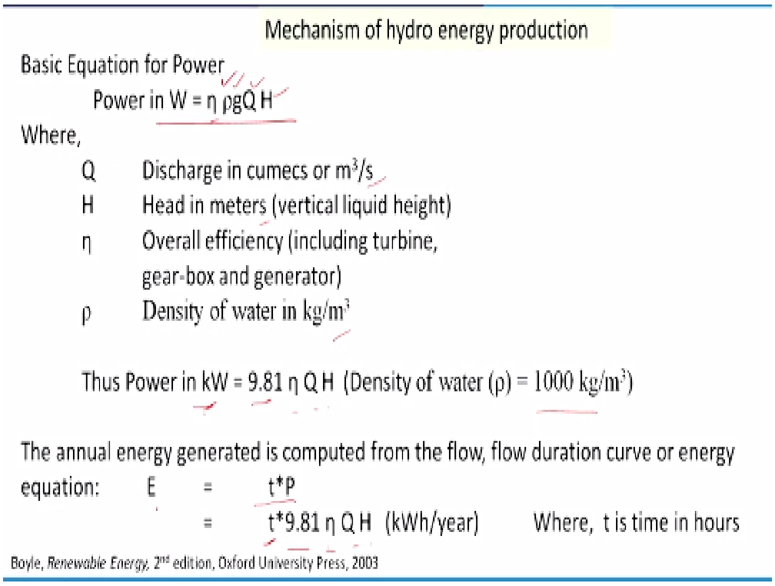
(Refer Slide Time: 03:11)



So you see this figure shows us that for the production of electricity, hydroelectricity we need the flow of water that can be done by dams, that can be river flow, water flow, tidal barrage, or water wave power. So these different sources which can be used to ensure the velocity of the water or the flow of the water and that the water flow will come to the water turbine and then turbine rotor will be there and blades will be attached to this rotor and it will be rotating and the shaft will get some circular movement here, which is coupled with the generator and then AC power we will get.

The water which is coming to the turbine that will lose its velocity and it will go to or in terms of the kinetic energy, the kinetic energy will be lost here of this water stream and that will go as tailrace.

(Refer Slide Time: 04:13)



This is the mechanism of hydroenergy and now what will be the power we can achieve through this hydro turbine, that will depend upon some factors that what is the flow of head, what is the difference in the head from dam to turbine or so that we have to determine and the power determination can be done by using this formula that power in watt that is equal to ρgQH into efficiency of the system.

The overall efficiency including turbine, gearbox and generator and H is here head water head in meters, Q is discharge in meter cube per second, and ρ is the density of water in kg per meter cube. Now if we know as the density of water is equal to one 100 kg per meter cube and if we use this one 100 kg per meter cube for water then this watt in terms of kilowatt will be converted to 9.81 which is for g and Q into H into efficiency and this 1000 here so that will be converted in kilowatt.

So in kilowatt 9.81 x Ƞ x Q x H that is the formula which can be used to determine the power productions in the hydropower plant, if we know the head and if we know the flow. Then annual production can be calculated by the formula that power x the time, so what is the power we have 9.81 x Ƞ x Q x H and then we can multiply it to the time, if it is time it is in hour, then that will be in kilowatt hour, so that unit of electricity can be produced from the thermal power plant and we can calculate in any hydropower plant what will be the energy generated in a year or during any span of time.

(Refer Slide Time: 06:28)

A mountain stream flows over a terrain where micro-hydro power plant is possible where an effective head of 50 m be built and a flow rate of 0.6 m^3/sec can be maintained. How much power can the hydro plant generate? Assume plant efficiency (η) of 83%.

- $H = 50$ m
- $Q = 0.6\ m^3/s$
- $\eta = 0.83$
- $P = 9.81\eta QH = 9.81(0.83)(0.6)(50) = 244$ kW
- $= 0.244$ MW

How much energy (E) will the hydro plant generate each year?

E = Pxt

= MWh annually

= 0.244MW × 24 hrs/day × 365 days/yr

= 2137 MW

- What is the number of population that can be supported by this energy? Assume per capita electricity consumption in India as 780 kWh annually?

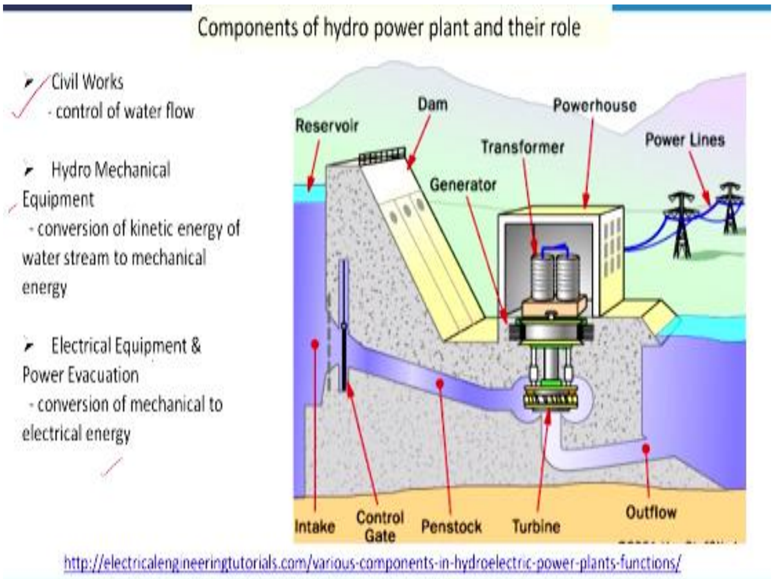
- People = E÷780 = 2137 * 10^3/780 = 2740

Now we will see one problem statement, say a mountain stream flows over a terrain where micro-hydro power plant is possible where an effective head of 50 meter be built and a flow rate of 0.6 meter cube per second can be maintained. How much power can the hydro plant generate, this is the question. So assume plant efficiency is 83%. So in this case, we have the formula that is equal to P = 9.81 x Ƞ x Q x H, here H is given that is equal to 50 meter, Q is given that is equal to 0.6 meter cube per second, and efficiency is given 0.83.

So we can calculate the value of P in kilowatt hour that is equal to 9.81 x 0.83 x 0.6 x 50, so it is coming to 244 kilowatt, so in terms of megawatt that will be 0.244 megawatt. So then, how much energy will be produced in each year that will be say this power 0.244 megawatt x 24 hours per day x 365 days per year, so that will be that total 2137 megawatt. Then if we want to know what is the number of population that can be supported by this energy, then that can also be calculated if we know the consumption of energy per capita.

So assuming per capita electricity consumption India as 780 kilowatt hour annually, then the number of population that can be served by this energy is this how much energy we are producing divided by 780 kilowatt hour, then we are getting this much equal to 2740 people, so this much of people can be served by this hydropower plant.

(Refer Slide Time: 08:29)

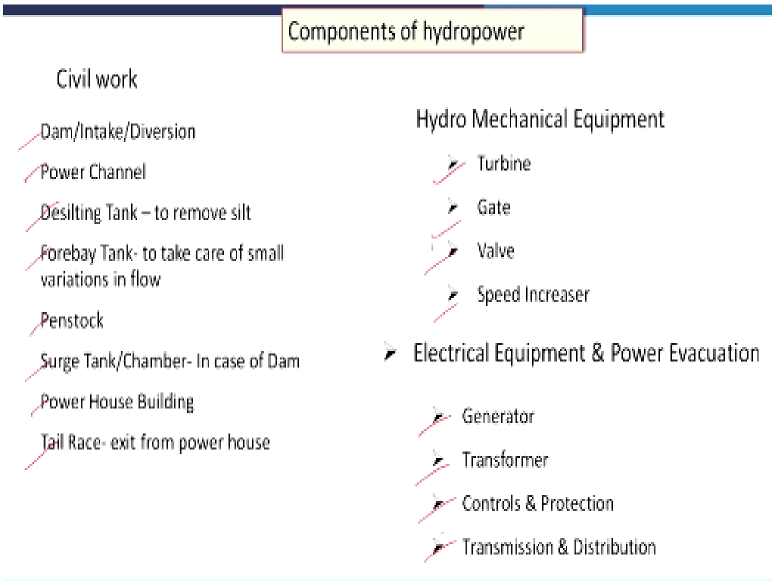


Now we will see the components of hydropower plant and their role. So this figure shows us schematically one thermal power plant, so here we see some civil structures are there, these are the civil structures. This is our reservoir, water is stored here, and then water is passed through this penstock to this turbine and then turbine casing etc is there and then generator electricity is produced.

So basically if we classify this different parts of it, so 1 is civil work, that is civil works control of water flow the main role of this, then here the kinetic energy of water is converted to mechanical energy here, the turbine shaft will be rotating, will give some rotatory movement and that is done by the flow of water. So that hydro mechanical equipment is important that is the heart of this whole plant and then conversion of kinetic energy of water stream to mechanical energy that is the main role of this part.

Then third is electrical equipment, so this mechanical energy in the shaft will be converted to electrical and then for distribution etc, we need some dedicated system. So then conversion of mechanical to electrical energy it is done by electrical equipment and power, so that is the different parts of it.

(Refer Slide Time: 09:53)



Now we will see the civil work contents dam or intake or diversion in some cases, we will discuss and we will see some figure which will explain these things. Then power channel, then desilting tank for removing the silts and forebay tank to take care of small variations in flow, so during that time if variation in the flow, so forebay water will be stored and it will maintain the continuous flow of the water. Then penstock through which the water will come to the turbine.

Then surge tank or chamber in case of dam it is available, power house building so one building is also required, and the tail race that is exit from the power house. So these are the civil work we need. Then hydro mechanical equipment we need turbine, we need gate, we need valve, and we need speed increaser. Electrical equipment and power evacuations include generator, transformer, controls and protections, and transmissions and distribution. It is going to grid or it is off-grid, both options may be available.

(Refer Slide Time: 11:03)

Classification of hydro power

- **Generation Based**

Pico	IC* ≤ 5 kW
Micro	5 kW < IC ≤ 100 kW
Mini	100 kW < IC ≤ 2000 kW
Small	2 MW < IC ≤ 25 MW
Medium	25 MW < IC ≤ 100 MW
Large	IC > 100 MW

- **Head Based**

High	75 m & above
Medium	30-75 m 300
Low	3-30 m
Ultra low	below 3 m

*IC: Installed Capacity

So now we will see how the hydro power plants can be classified. So that can be classified depending upon the capacity; so pico, micro, mini, small, medium, and large. So pico means that is install capacity less than 5 kilowatt, micro 5 kilowatt to 100 kilowatt, mini 100 to 2000 kilowatt, and small 2 megawatt to 25 megawatt, medium 25 to 100 megawatt, and large greater than 100 megawatt. So these are the typical range which is used for the classification.

Then on the based of head also that is your ultra low, low, medium, and high head hydro power are classified. So ultra below 3 meter, low 3 to 30 meter, medium 30 to 75 meter, and high 75 and above. Somewhere in some reference, it is given as 75 is given as 300 meter.

(Refer Slide Time: 12:04)

Classification of hydro power

Classification based on purpose

a) Single purpose project
b) Multipurpose project: Tehri (irrigation + power generation + drinking water)

Classification based on hydraulic features

a) Conventional hydropower plants
   - Utilize the available hydraulic energy of the flowing water- all the existing plants are of this cateogry in India
b) The pumped-storage plants
   - Recycling of water for supplying peak load
c) Tidal power plants

Classification on the basis of operation

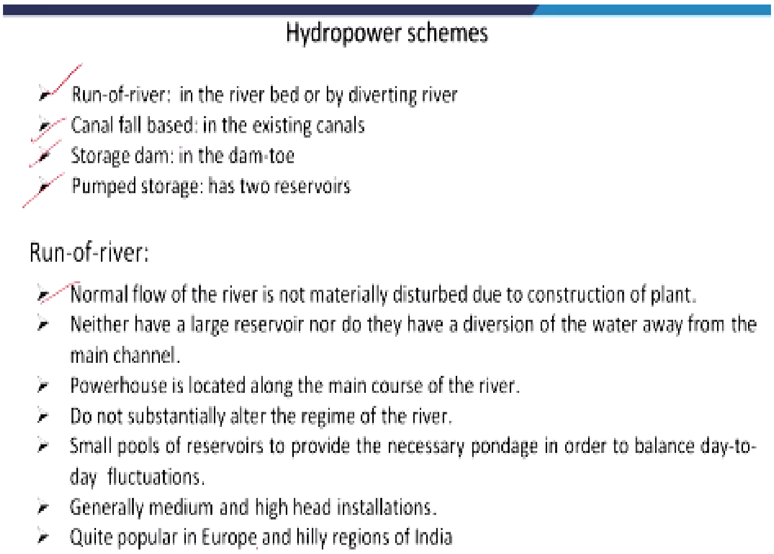
a) Isolated plant: not connected with a grid system and directly meets the demand. Example: Khopoli hydro-electric project for Bombay only.
b) Grid connected plant: feeds into national/state grid, common hydro-electric project

So classification of hydro power on other basis is also based on purpose whether it is for single purpose, only for electricity production, or it is have some other purpose also, like say

Tehri damn, it is irrigation plus power generation plus drinking water that way you can classify. Classification based on hydraulic features, so what are the hydraulic features that means conventional hydro power plants that means only it is the dams or rivers are used to produce the electricity or pumped storage plants that means recycling of water for supplying peak load.

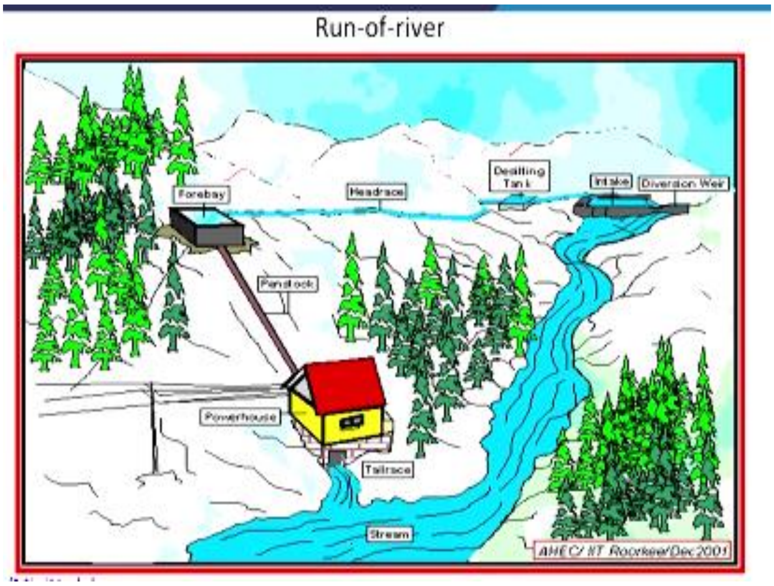
So from the bottom tank the water will be sent to the top tank so that way also it is possible, but normally it is not used in the country, and the tidal power plants is also another type of power plants. Then we may classify on the basis of operation that is your isolated plant or grid connected plants, that may be the energy produced in the plant can be connected to the grid or it may be used off grid for the permitting the local need. There is Khopoli hydroelectric power for Bombay only.

(Refer Slide Time: 13:19)



Then we will see the schemes for hydro power. So we have run-of-river, we have canal based, we have storage dam, we have pump storage. So run-of-river we will see in this case normal flow of river is not materially disturbed due to the construction of the plan.

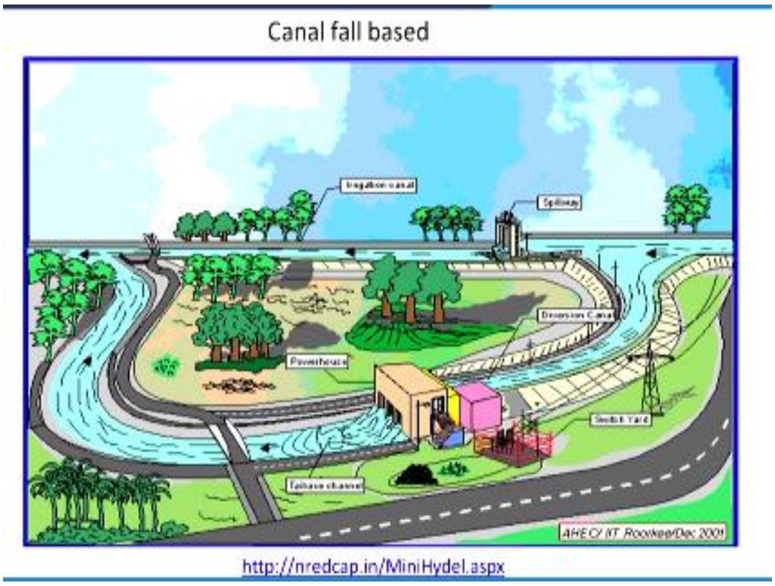
(Refer Slide Time: 13:36)



At first we see the figure. Here the river is there, so this river some diversion is there here, so desilting tank for the silt separation, then it is coming to forebay, the main objective is to ensure the constant flow of water here through the penstock to the turbine and then in the turbine the water is coming and electricity is generated and this is your tailrace and again it is coming to the main river stream. So this is with small diversion of water without affecting the main stream of the river, this hydro power plant can be established and this is called run-of-river power plant.

These are the some features, neither have a large reservoir nor do they have a diversions of the water away from the main channel. Power house is located along the main course of the river and do not substantially alter the regime of the river, small pools of reservoirs to provide the necessary pondage in order to balance day to day fluctuations, generally medium and high head installations, and then quite popular in Europe and hilly regions of India. So these are some features of this run-of-river.

(Refer Slide Time: 14:48)

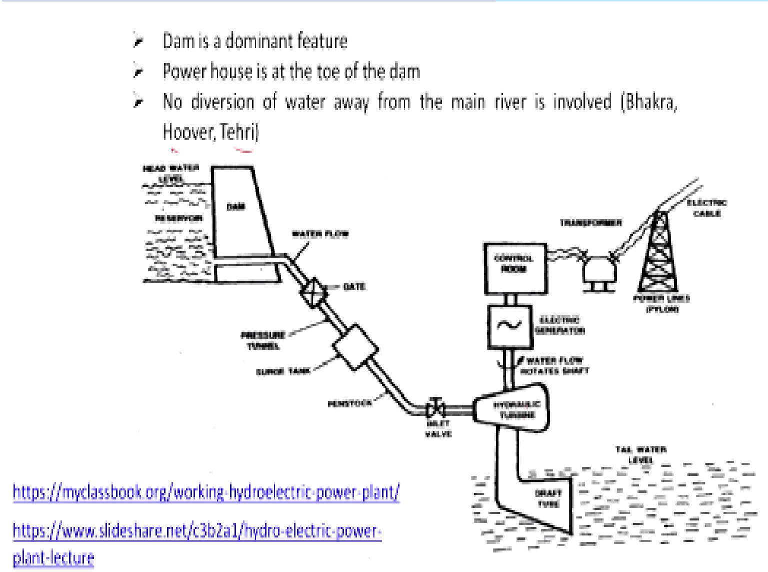


Then canal based plants are also available. So here these are the main stream here, so here we are getting powerhouse, so this is our powerhouse, water is coming through, this is the diversion canal, so this is your canal and this is diversion canal, so this water is coming here electricity is produced and again it is going and meeting there.

(Refer Slide Time: 15:13)

This is one example of say canal fall based system that is Ganga canal, 10,500 cusec capacity, then Pathri powerhouse 3 x 6.8 megawatt capacity, and Mohammadpur 3 x 3.1 megawatt, so 3 units are there for 3.1 megawatt capacity.

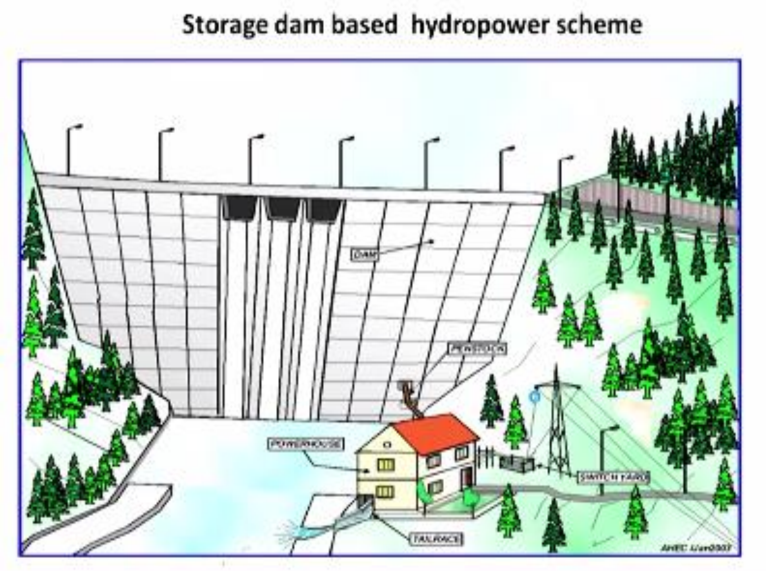
(Refer Slide Time: 15:41)



Then storage dam based hydropower scheme, so this is also very important one and widely used like the Tehri dam. So storage dams, so this is our dam here, so water will come from this penstock and this is our powerhouse, and then water is going at the tailrace it is meeting the mainstream of the water here, what do we do, that dam is a dominant feature of this in case of storage dam based, so dam is necessary and power house is at the toe of the dam and that no diversion of water away from the main river is involved.

So this is the basic features of this type of hydropower plant like say Bhakra, Hoover, and Tehri are of this type.

(Refer Slide Time: 16:34)



So here it is coming the penstock and it is turbines, just I have mentioned in this case this is one.

(Refer Slide time: 16:35)

1. Generation capacity: 1000 MW
2. Surface of impoundment: 52 km^2
3. Water storage: 4 km^3
4. Irrigation potential: 270,000 hectare
5. Drinking water: 1.2 X10^6 m^3 per day

Tehri hydel project

So this is the photograph of Tehri hydel project at a generation capacity 1000 megawatt. Then surface of impoundment on 52 kilometer square, water storage 4 meter cube, irrigation potential 270,000 hectare and drinking water 1.2 x 10 to the power 6 meter cube per day.

(Refer Slide Time: 17:18)

Pump storage power plant

- Electricity is not amenable to direct storage, the primary aim being to generate power to the tune of demand in the grid at all the times.
- PSPP is indirect way of storing electrical energy.
- Essential Requirements: Two reservoirs with a high difference in water levels between the two.
- Various arrangements are possible for the higher and lower reservoirs:
  - Both the reservoirs on the same river
  - Two reservoirs on two different rivers
  - Higher reservoir an artificially constructed pool and lower reservoir on a natural river.
  - The lower reservoir is a natural lake while the higher reservoir is artificial.

Then pump storage power plant. This power plant as you have mentioned that the water will be sent from lower head to upper head at the high elevation to ensure the flow of water to meet the peak load, and in this case it is the indirect way of storing electrical energy and 2 reservoirs with the high difference in water levels between the two is very essential. These 2 reservoirs may be both the reservoirs on the same river, may be on 2 different reader rivers.

Higher reservoir and artificially constructed pool and lower reservoir on a natural river that can be possible, but the lower reservoir is a natural lake while the higher reservoir is artificial. So that way different types of options can be produced.

(Refer Slide Time: 18:01)

Advantages and disadvantages

Advantages	Disadvantages
Emissions-free, with virtually no CO_2, NO_X, SO_X, hydrocarbons, or particulates	Frequently involves impoundment of large amounts of water with loss of habitat due to land inundation
Renewable resource with high conversion efficiency to electricity (80+%)	Variable output – dependent on rainfall and snowfall
Dispatchable with storage capacity	Impacts on river flows and aquatic ecology, including fish migration and oxygen depletion
Usable for base load, peaking and pumped storage applications	Social impacts of displacing indigenous people
Scalable from 10 KW to 20,000 MW	Health impacts in developing countries
Low operating and maintenance costs	High initial capital costs
Long lifetimes	Long lead time in construction of large projects

Now we will see the advantage and disadvantage of this hydropower production. So it has obviously more advantages because it does not create any pollution, emission free with virtually no carbon dioxide, no SOx, and no NOx. Renewable resource with high conversion efficiency, the conversion efficiency is very high in this case, it is greater than 80% efficiency, but whatever other thermal conversion methods we have discussed in case of combustion or gasification base or IGCC all are having lower efficiency than this.

Then dispatchable with storage capacity, usable for base load peaking and pumped storage applications, scalable from 10 kilowatt to 20,000 megawatt, low operating and maintenance cost, and long lifetimes. These are the advantages of the system of this power plant, but it has some these advantage also like frequently involves impoundment of large amounts of water with loss of habitat due to land inundation, variable output dependable on rainfall and snowfall, so rainfall and snowfall affects the availability of water and disturbs the continuous flow of it.

Impacts on river flows and aquatic ecology including fish migrations and oxygen depletion, then social impacts of displacing indigenous people that is also one major issue, health impacts in developing countries, high initial capital cost, and long lead time in constructions of large projects. So these are the disadvantage of this hydel power plant and there is many times we see the debate whether such and such state should go for hydel power or not.

(Refer Slide Time: 19:50)

World's largest dams and hydropower generation

Name	Country	Year	Max Generation
Three Gorges	China	2009	18,200 MW
Itaipú	Brazil/Paraguay	1983	12,600 MW
Guri	Venezuela	1986	10,200 MW
Grand Coulee	United States	1942/80	6,809 MW
Sayano Shushenskaya	Russia	1983	6,400 MW
Robert-Bourassa	Canada	1981	5,616 MW
Churchill Falls	Canada	1971	5,429 MW
Iron Gates	Romania/Serbia	1970	2,280 MW

"Hydroelectricity," Wikipedia.org

These are some examples of world's largest dams and hydropower generation. So we see hydro power is used in different countries like China, Brazil, Venezuela, United States, Russia, Canada, and Romania/Serbia. Some examples are given here. Out of these, the Three Gorges that is 2009 it is established, it has 18,200 megawatt the largest capacity in the world.

(Refer Slide Time: 20:16)

Macro hydro-power projects in India

S.No.	Project	River / State	Installed Capacity
1	Bhakra	Sutlej & Beas/ Himachal Pradesh	1325 MW
2	Dehar	Sutlej / Himachal Pradesh	990 MW
3	Kalinadi Stage-I	Kalinadi	910 MW
4	Sharavathy	Sharavathy / Karnataka	891 MW
5	Koyna	Koyna / Maharashtra	880 MW
6	Nagarjuna-Sagar	Krishna / Andhra Pradesh	810 MW
7	Idduki stage-I	Idukki, Kalavu & Cheruthan / Kerala	780 MW
8	Srisailam	Krishna / Andhra Pradesh	770 MW
9	Salal	Chenab / Jammu & Kashmir	690 MW
10	Ranjit Sagar	Ravi / Punjab	600 MW
11	Chamera – I, II, III	Ravi / Himachal Pradesh	1071 MW
12	Tehri	Bhagirathi/ Uttarakhand	1400 MW

In India, we have many hydel power like say Bhakra, Dehar, Kalinadi stage I, Sharavathy, Koyna, Nagarjuna Sagar, Idduki stage I, Srisailam, Salal, Ranjit Sagar and Chamera I, II, III. So these are different projects and these are the rivers on which these power plants have been installed and these are our installed capacity. So these are the overall discussion and informations on the hydel power plant, and we will discuss in the next class on different mechanical equipment and electrical equipments used for the production of electricity.

Thank you very much for your patience.