Technologies for Clean and Renewable Energy Production
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Lecture - 32
Hydro Energy 2

Hi friends, now we will discuss on the second part of hydro energy.

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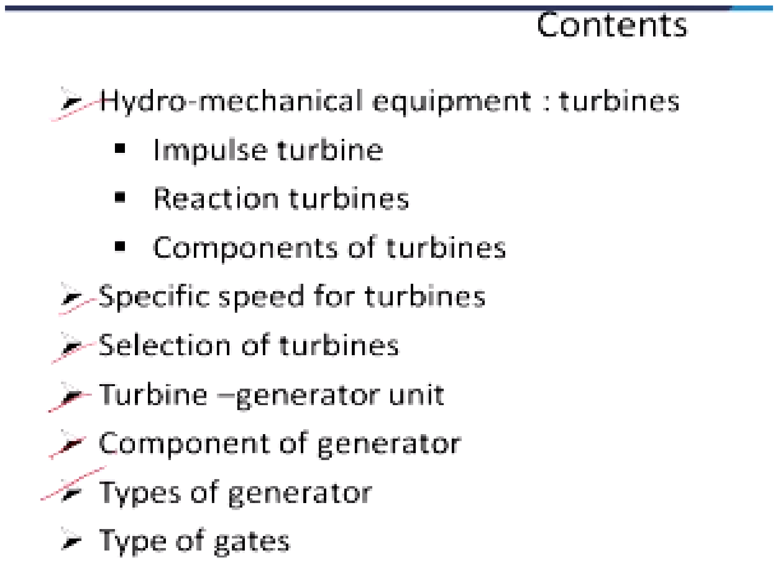

In this part, we will concentrate on hydro mechanical equipment that is turbines and different types of turbines we will discuss that is impulse turbine, reaction turbine, and components of these turbines and then specific speed for turbines, then selection of turbines, turbine generator unit, component of generator, then types of generator and type of gates.

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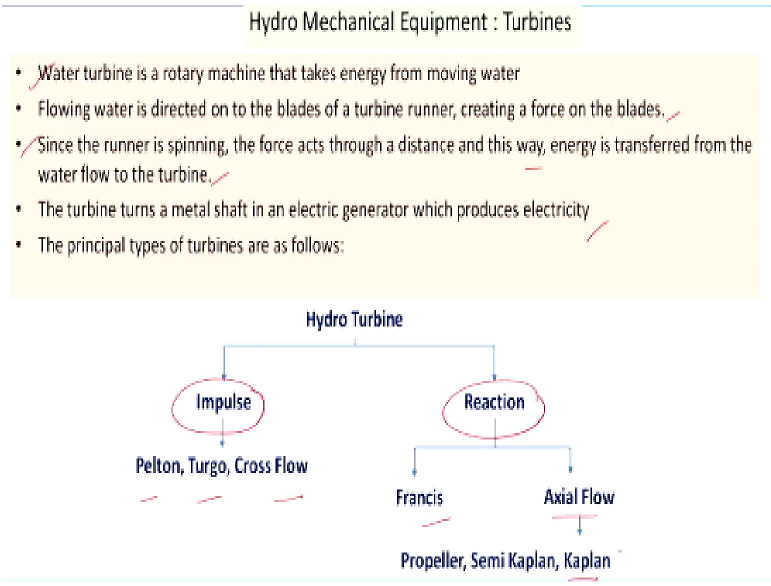

Hydro mechanical equipment. As you have discussed in this equipment this type of equipment, kinetic energy of water is converted to mechanical energy and turbine is the major part of it. In this case, when water falls on the turbine blade, it rotates which is connected to the shaft and the shaft is coupled with the generator for electricity production, we have already discussed it.

Then water turbine is a rotary machine that takes energy from moving water and flowing water is directed on the blades of a turbine runner creating a force on the blades and since the runner is spinning, the force acts through a distance and this way energy is transferred from the water flow to the turbine. The turbine turns a metal shaft in an electric generator which produces electricity. The principal types of turbines are basically impulse and reaction type.

So impulse may be some examples are Pelton, Turgo and Cross Flow whereas reaction it is Francis and Kaplan, this Kaplan is basically axial flow turbines propeller, semi Kaplan and Kaplan these are types of turbines.

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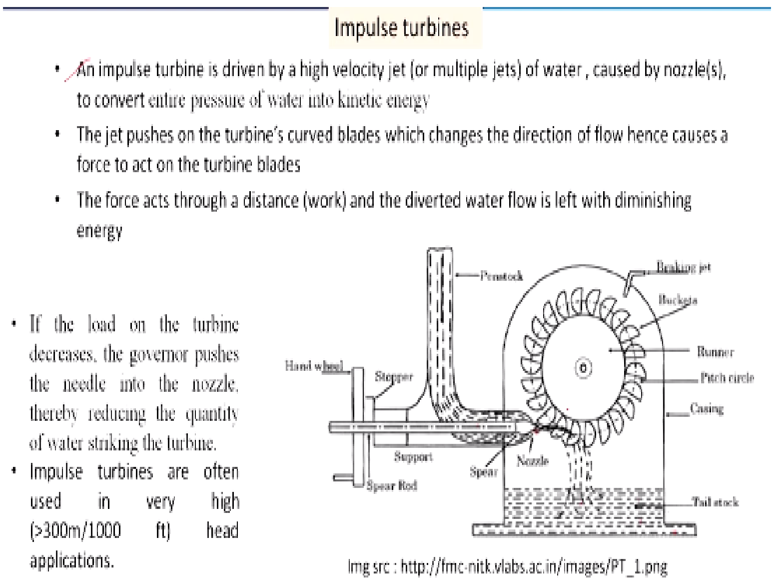

Now we will see impulse turbines. What is this type of turbines? Here we see this is your penstock, so water is coming and entering through this, so this nozzle is there, so through this nozzle the water is coming and getting entry into the turbine casing. We also see here so the governor can place the needle in the nozzle, so depending upon the nozzle position, the flow of water can change. So the main feature of impulse turbine is that an impulse turbine is driven by a high velocity jet or multiple jets of water caused by nozzles.

So this nozzle is creating jets, to convert entire pressure of water into kinetic energy. This is the main feature of this impulse turbine. The jet pushes on the turbines curved blades, so these are the curved blades, this jet pushes on these curved blades which changes the direction of flow hence causes a force to act on the turbine blades. So here, the flow is going this direction and we are changing this direction the water is at the same time the blades are forced to move and get some circulatory movement to the rotor.

The force acts through a distance and the diverted water flow is left with diminishing energy. So this water which is getting out that is called tailrace then that that loses its energy, which was available in the upstream of it. If the load on the turbine decreases that means I need some less electricity, the load on the turbine is decreased, then we have to reduce the water flow and that is done by the governor by pushing this needle into the nozzle. These impulse turbines are often used in very high heat applications.

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This Pelton turbine, an example of this impulse type turbine is Pelton turbine, you see here. Here the blades are mounted in this rotor in the runner, both sides we see the blades are attached and half of the blades it is shown so it consists of a wheel with a series of split buckets set around its rim, so this is our rim, so series of buckets are connected to this rim. A high velocity jet of water is distributed tangentially at the wheel, so the wheel will tangentially just like densely distributed to this wheel and the jet hits each bucket and is split in half.

So jet is hitting this bucket and two half it is split so that each half is turned and deflected back almost through 180 degree, and nearly all the energy of the water goes into propelling the bucket and the deflected water falls into a discharge channel below, just like this which is shown here it is falling here in the discharge channel. So this is the figure photograph of Pelton turbine.

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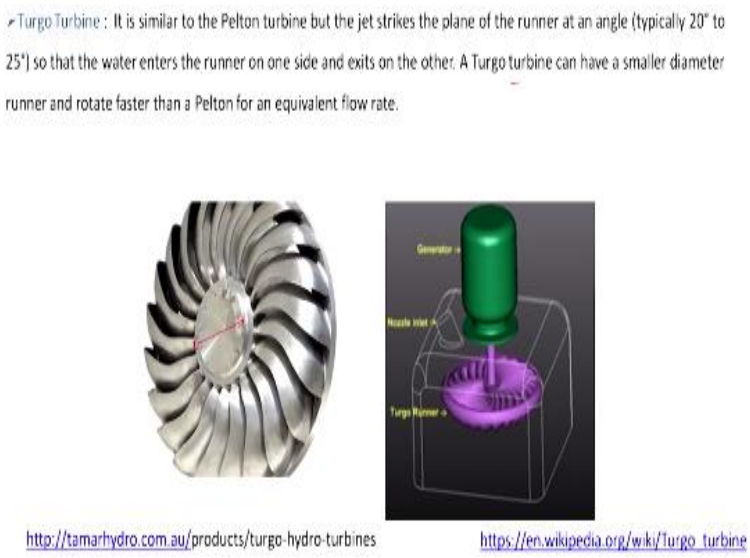

Another type of impulse turbine is Turgo turbine. So here also very similar but some design is different, so you see that this diameter is lesser than this which is having here. So it is similar to the Pelton turbine, but the jet strikes the plane of the runner at an angle that is typically 20 degree. So this is made some 20 degree angle, the water which is coming here that is that is tracking the plane of the runner at 20 degree to 25 degree angle, so that the water enters the runner on one side and exits on the other.

The Turgo turbine can have a smaller diameter runner and rotate faster than a Pelton turbine, just I have discussed this diameter is less and this design is also different now there is some angle 20 to 25 degree, so it can rotate with a faster speed.

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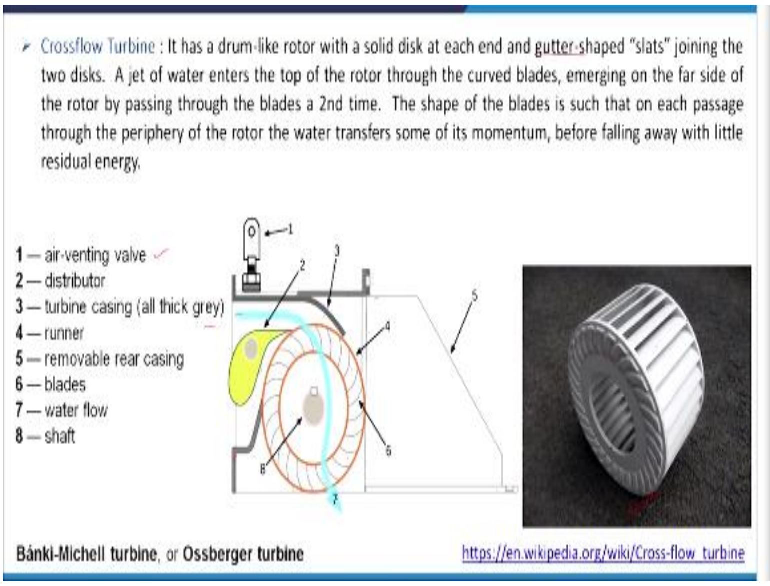

Then crossflow turbine, so this is showing a crossflow turbine. So what we see here it is a drum like rotor with a solid disc at each end, so each end we have some solid disc, here is one solid disc, here is one solid disc. So these two solid discs are attached to these slats so that is gutter shaped slats so these are giant and a jet of water which is getting into here, a jet of water enters the top of the rotor through the curved blades, these are the curved blades emerging on the far side of the rotor by passing through the blades a second time.

So water is going there and one time again it is going through. The shape of the blades is such that on each passage through the periphery of the rotor, the water transfer some of its momentum so when the water is passing through this, it transfer some momentum and before falling away with the little residual energy, so when it is falling from this rotor, the water loses its energy. So here we see these are the different parts of this turbine.

Here air-venting valve is shown here, then distributor so this is distributor, 3 turbine casing, so all these are casing of the turbines and gray color these are the casing, and 4 is our runner, so this is our runner, this is the case, we are having the runner. Then removable rear casing 5, this is your removable rear casing; blades, these are the blades which are attached with this runners; and then water flow, it entering here and it is going to this side, so this is very important here the water is coming and it is going so here it is going through the blades again it is going to the blades, so it is going that way and then 8 is our shaft.

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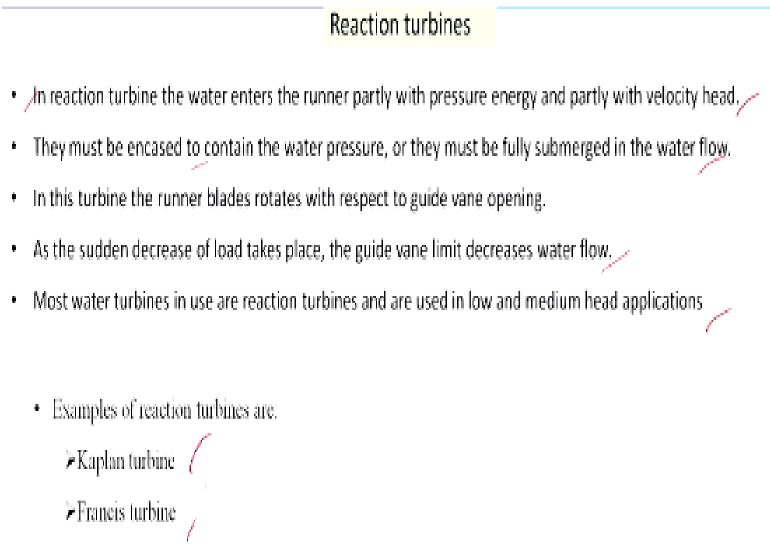

So then we are coming to reaction turbine. So what we have seen in case of impulse turbine. the water flow passes through nozzles and hits the blades of the turbine. In reaction turbine, the water enters the runner partly with pressure energy and partly with velocity head. So they must be encased to contain the water pressure or they must be fully submerged in the water flow, so there may be the possibilities in this case.

In this turbine, the runner blades rotate with respect to guide vane. There are some guide vanes which controls the flow and that flow controls the speed of the blade. As the sudden decrease of load takes place means the turbine needs some less rpm of the turbines blade, then the guide vane limit decreases the water flow. Most water turbines in use are reaction turbines and are used in low and medium head applications. Some examples are Kaplan turbine and Francis turbine.

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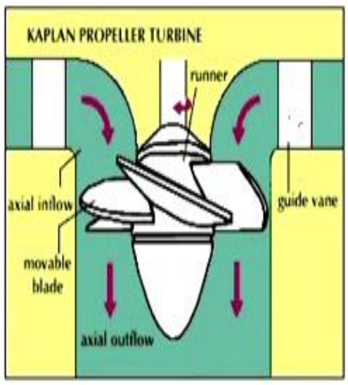
- Propeller type turbines : They are similar in principle to the propeller of a ship, but operating in reversed mode.
- A set of inlet guide vanes admits the flow to the propeller and these are often adjustable so as to allow the flow passing through the machine to be varied.



http://ruahaenergy.com/wp-content/uploads/2016/06/turbine-kaplan.jpg

So propeller type of turbines that is Kaplan turbines, so propeller type turbines that is Kaplan. They are similar in principle to the propeller of a ship, but operating in reversed mode, how it operates. We see here we have guide vane, so these are the guide vanes, so water will come through it. These guide vanes will allow the water to come to the blade and it will give some movement to the runner.

So as a set of inlet guide vanes admits the flow to the propeller and these are often adjustable so as to allow the flow passing through the machine to be varied, so the flow is varied by the guide vane.

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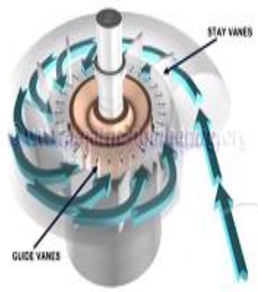
- Francis turbine : It is essentially a modified form of propeller turbine in which water flows radially inwards into the runner and is turned to emerge axially. For medium-head schemes, the runner is most commonly mounted in a spiral casing with internal adjustable guide vanes.



http://www.mechanicalbooster.com/2018/01/francis-turbine.html

Now Francis turbine. So it is essentially a modified form of popular turbine in which water flows radially. So here water is coming radially inwards into the runner and is turned to emerge axially, then it is going this direction it is going there, so this is flow of the Francis turbine. For medium head schemes, the runner is most commonly mounted in a spiral casing with internal adjustable guide vanes, so these are the guide vanes, internal adjustable guide vanes. So these are the different types of turbines which are used in hydropower production.

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Specific speed for various types of hydro-turbines

Specific Speed, $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

N = Turbine speed in RPM

P = Rated power in kW

H = Head in m

Types of Runner	Specific Speed , N_s
Pelton	12 – 30
Turgo	20 – 70
Crossflow	20 – 80
Francis	80 – 400
Propeller and Kaplan	340 – 1000

The specific speed value for a turbine is the speed of a geometrically similar turbine which would produce unit power (one kilowatt) under unit head (one meter). The specific speed of a turbine is given by the manufacturer and refers to the point of maximum efficiency.

Now we will see how to get the information about the different types of turbines. So we have some parameter that can be compared to guess the performance or efficiency of the turbines, so that is called specific speed. So that specific speed for various types of hydro turbines we will see here. So what the specific speed is, so specific feed as per the expression it is Ns = N root of P/H to the power 3/4, so N is the rpm of the turbine, P is the rated power in kilowatt, and H is the head in meter.

So this is the mathematical relationship of specific speed. So what the specific speed is, so that we will see now. So the specific speed value for a turbine is the speed of a geometrically similar turbine which would produce unit power that is 1 kilowatt under unit load that is 1 meter, unit head, under unit head that is 1 meter. So this is our specific speed, so this specific speed is given by the manufacturer of the turbines and we can say this is the maximum capacity of the turbine to perform, the maximum efficiency of the turbine.

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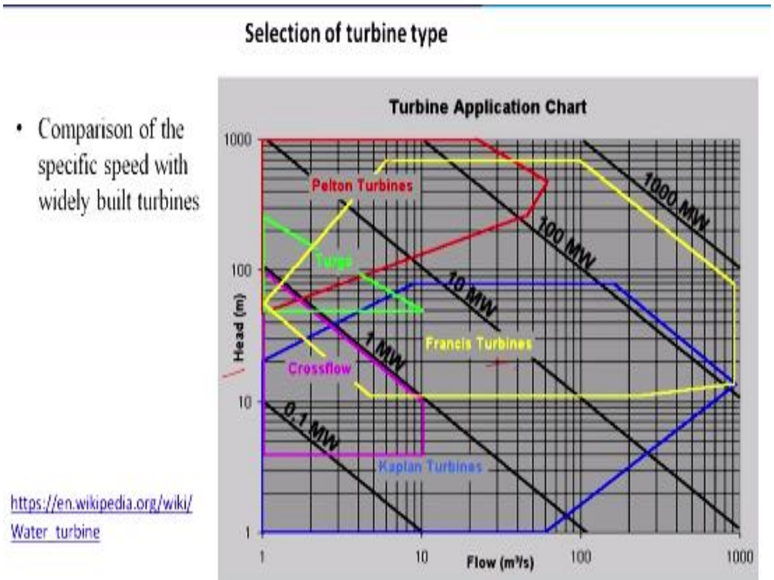

Now we will discuss how the turbine can be selected. So turbine selection depends upon some factors, one is your head requirement and another is your what is the requirement of the power productions, what is the capacity of the power plant, what is the head available and what is the flow available. What is the flow available, what is the head available and what is the capacity we are expecting from the plan, so that will help us to decide what type of turbine can be chosen. So this graph shows us some information.

So this is your say this yellow line yellow area this indicates Francis turbine, so here we have head in y axis in meter, flow meter cube per second in x axis, and these black lines indicates the capacity of the plant. So 0.1 megawatt, 1 megawatt, 10 megawatt, 100 megawatt, 1000 megawatt. This is the zone where we can recommend Francis turbines, this is the zone the blue color when we can go for Kaplan turbines, this is the zone for which you can go for Pelton turbines and this is the zone for which you can go for Turgo turbines.

So these are the different informations which help us to select a turbine type for our particular application.

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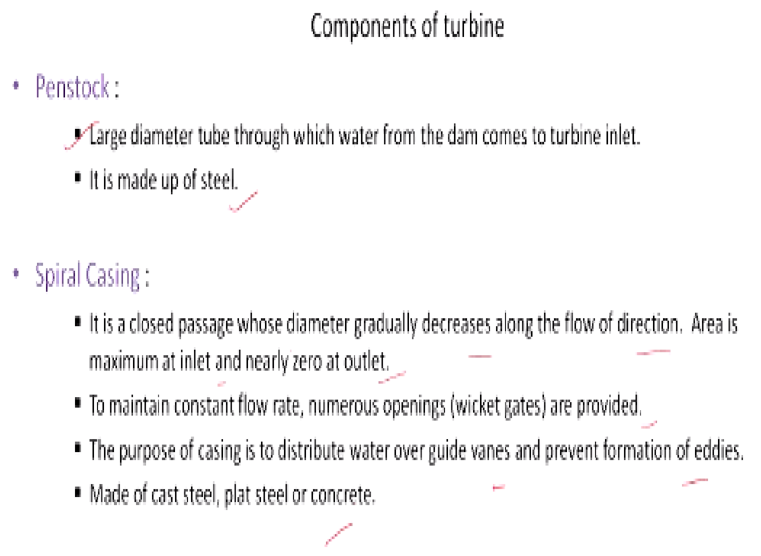

Now we will see the components of turbines. What are the components of turbines, now we have seen that it is attached to the penstock, so penstock that is the large diameter tube through which water from the dam comes to the turbine inlet and it is made of steel. Then spiral casing that is it is a closed passage whose diameter gradually decreases along the flow of direction. Area is maximum at inlet and nearly 0 at outlet, so this is your spiral casing.

To maintain constant flow rate, numerous openings are provided to this and the purpose of casing is to distribute water over guide vanes and prevent formation of eddies in the turbines. Made of cast steel or concrete.

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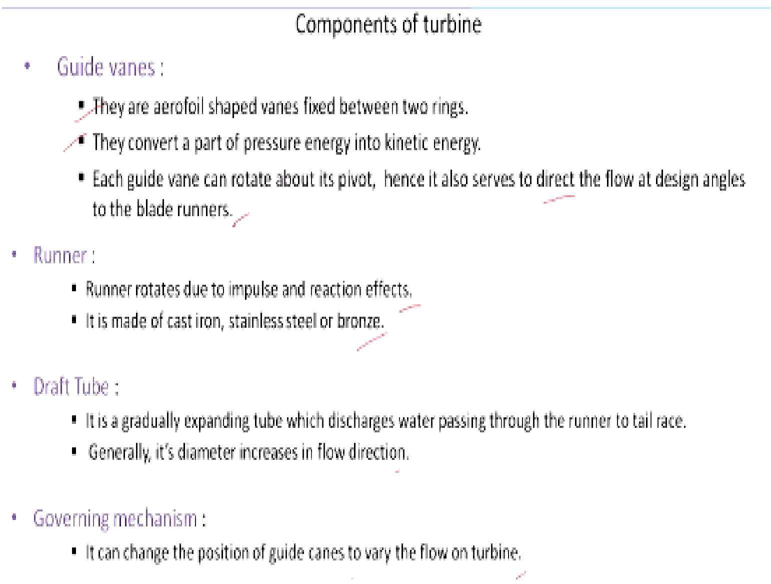

Then guide vanes, those are also very important to control the flow of water into the turbines plate. So they are aerofoil shaped vanes fixed between two rings, they convert a part of pressure energy into kinetic energy, and each guide vane can rotate about its pivot and hence it also serves to direct the flow at design angles to the blade runners. The runner rotates due to impulse and reaction effects and it is made of cast iron, stainless steel or bronze. Draft tube, it is gradually expanding tube which discharges water passing to the runner to tail race and generally its diameter increases in flow directions.

Governing mechanism are that just we have seen that if the needle in the nozzle will be placed to reduce the velocity in case of impulse turbine. So here the it shows governing mechanism, it can change the positions of guide vanes to vary the flow on turbine it, either guide vanes' position or the positions of the needle in the nozzle, so that way for in impulse turbine so this helps.

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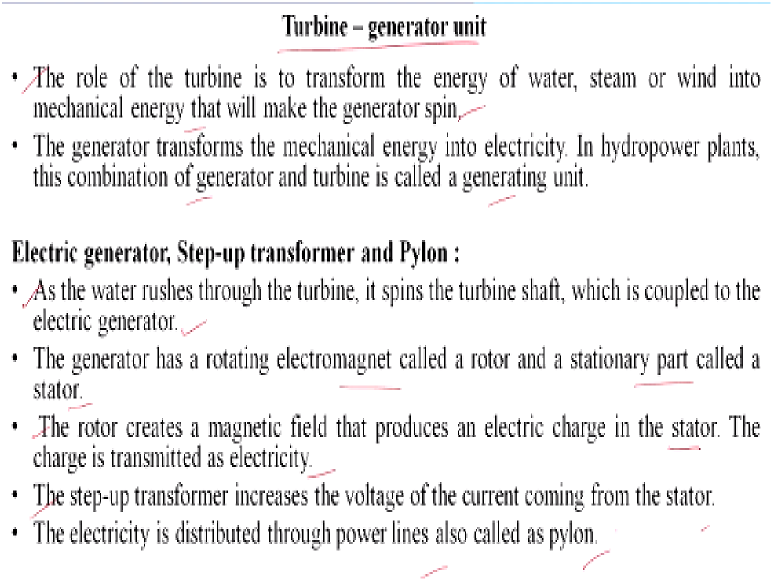

So these are the different parts of the turbine which helps to perform it in a most effective way. Now in the turbine, the mechanical energy which is produced that has to be converted to electrical energy, so turbine generator unit or coupling of turbine in generator is very very important. So the role of the turbine is to transform the energy of water a steam or wind that we have discussed in the previous classes also to mechanical energy that will make the generator spin.

So the generator transforms the mechanical energy into electricity. In hydropower plants, the combination of generator and turbine is called a generating unit, so this is the generating unit. We will see some terms here, that is say electric generator, we will say this is a transformers and pylon. So as the water rushes to the turbine, it spins the turbine shaft which is coupled to the electric generator. The generator has a rotating electromagnet called a rotor and stationary part called a stator, so rotor and stator are the main part of the generator.

The rotor creates magnetic field that produces an electric charge in the stator. The charge is transmitted as electricity, but this electricity voltage may not be that high. So the setup of transformer increases the voltage of the current coming from the stator. The electricity is distributed through power lines that is called as pylon. These are the parts of turbine generator unit.

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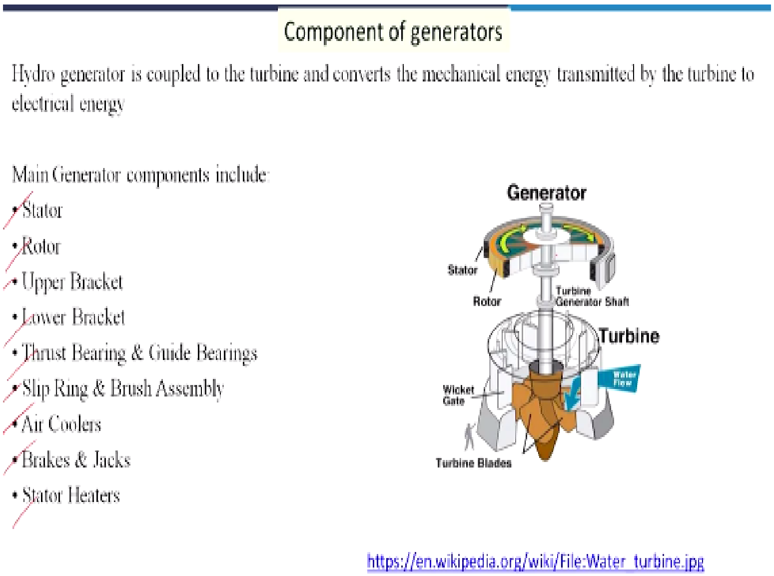

The component of generators if you see, then major components are the stator, rotor, upper bracket, lower bracket, thrust bearing and guide bearings the bearing is required, slip ring and brush assembly, air coolers, brakes and jacks, and stator heaters. So these are the parts. So here the turbine and this is stator and this is rotor.

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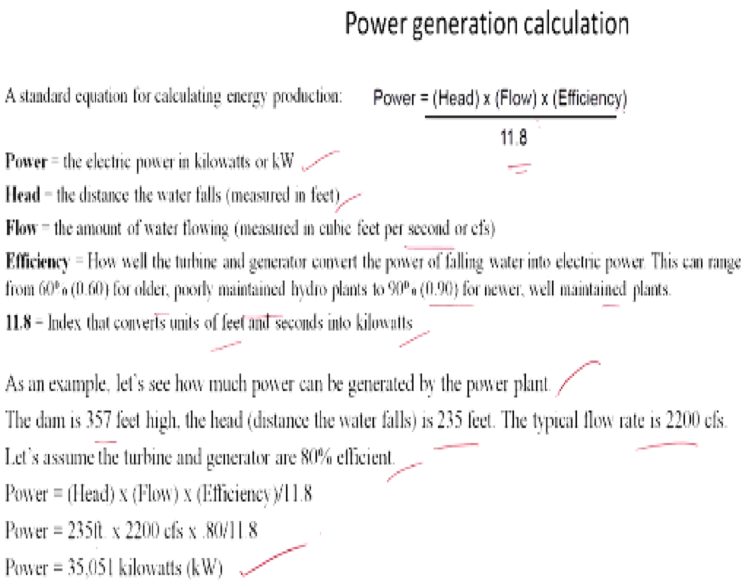

Now how can we calculate the power generation, if it is the data available in FE system, the power generation can be head x flow x efficiency/11.8. So power electric power in kilowatt, then the distance the water falls in feet, and then flow is in cubic feet per second, so then this formula is used. Efficiency, then this term efficiency, efficiency how well the turbine and generator convert the power of falling water into electric power, so basically it will be having combined one, so turbines and generator,.

So this can range from 60% percent for older and poorly maintained hydro power to 90% for newer and well maintained plants. The 11.8 is index that converts the units of heat and seconds into kilowatts. So this is the formula which can be used for the power calculation. One example, as an example let us see how much power can be generated by the power plant. The dam is 357 feet high, the head is 235 feet, and the typical flow rate is 2200 cfs that is cubic feet per second.

So let us assume the 80% efficiency of the turbine. So in this case power = head x flow x η/11.8. So here head is 235 feet, then flow is 2200 cfs, and efficiency is 80% that means 0.80, so divided by 11.8, so that is equal to 35,051 kilowatts. So that is equal to this much is the power generation capacity of the plant.

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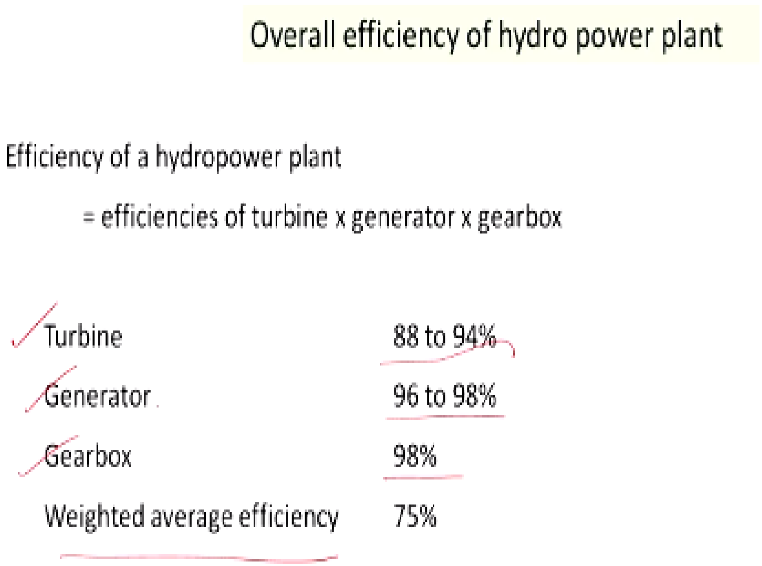

Then as you told that efficiency of the system depends upon the efficiency of the turbine, depends on the efficiency of the generator, efficiency of gearbox and weighted average efficiency is the multiplication of this this and this. So for example 88 to 94 for turbine efficiency, 96 to 98% for generator efficiency, gearbox is 98%, so weighted average efficiency we get 75%.

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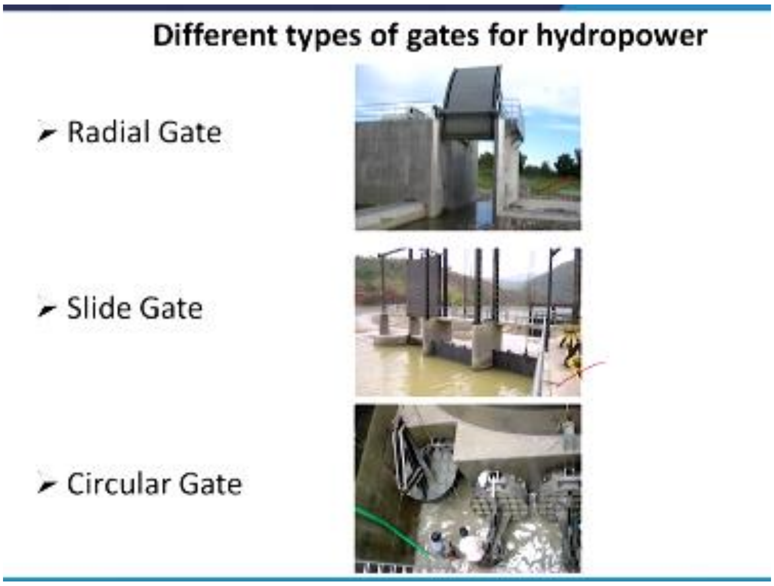

There are different types of gates for hydropower, so that is radial gate and slide gate and circular gate that help the flow of water through the gates. So this is the radial gate, this is slide gate, these are the circular gates. So there are different types of gates. Different types of valves also used in this plant. So, up to this on hydro energy production. Thank you very much for your patience.