Steam and Gas Power Systems
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Module No # 05
Lecture No # 21
Steam Turbine

Hello I welcome you all in this course on steam and gas power systems. Today we shall start with the steam turbines. Steam turbines are a sort of prime movers which are used to convert heat energy into the work.

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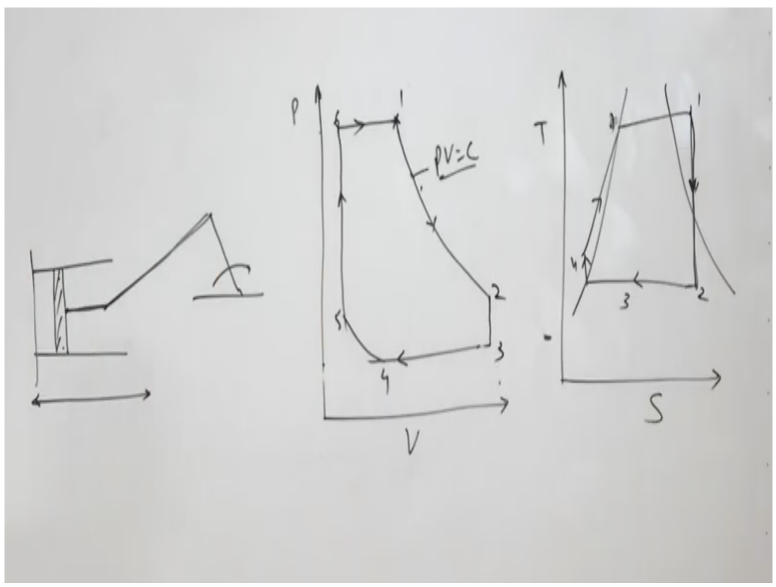

If you look at the Rankine cycle on temperature interpreted diagram, 1 to straight 2 and straight 2 to 3 to 4 and 4 to 1. Now in this diagram this isentropic expansion of steam takes place inside the steam turbine, in fact it was the consistent effort during 18 to 19 century. It started in 17 century to convert heat into the useful work and steam engine was the first device which was used to convert heat into the useful work.

If we depict the cycle in a steam engine on a PV diagram it is going to be like this, steam admitting the steam engine because steam engine works on (()) (1:42) like petrol engine or diesel engine. So it has a cylinder and cylinder is fitted with piston and a unique thing here is piston rod which auto this petrol engine, diesel engine do not have the piston rod.

So it is fixed with piston and the piston rod is connected to the connecting rod and connecting rod connects the piston rod to the crane shaft which rotates with a certain ampoule. So reciprocation motion of piston is converted to rotary motion with this mechanism as in the case of petrol and diesel engine as well. Here this piston rod is taken because the length of this stroke is quite large in a steam engine.

If you compare length of the stroke in petrol or diesel engine it is quite large, so if you do not use this piston rod then it will obstruct the movement of this connecting rod that is why piston short piston rod is provided in a steam engine and there are other advantages of having a piston rod. So if we transform this process of power development on PV diagram, is going to be like this- one, two, and three in an ideal case.

It means that the steam is admitting this cylinder a cut off of steam supply takes place at a certain pressure then steam expands in the steam engine up to the state 2 and again it comes back to state three through condensation or it is expanded to the surroundings. If you look at this point because this curve almost follows the process PV = C. So this curve tends to be flatter at the end and if you look at this end this stroke the power or the useful work gained during this stroke is not very significant.

So normally instead of expanding its team at constant pressure at a certain pressure higher than constant pressure, the steam is extended to the surrounding so that the size of the stroke or size of the cylinder is restricted at the sacrifice of a very insignificant power development during this stoke. Now if you want to have because in this case we are not taking the clearance volume into the picture because for actual engine to work there has to be clearance between the piston and the cylinder head.

So some clearance is provided in that case the diagram is going to be modified like this. So it is going to be 1, 2, 3, 4, 5 and 6. Now in this steam engine in fact the pressure energy of the steam is converted into the useful work. Now we will discuss about the Turbines in turbines, the dynamic action of steam causing the work.

Here in this case the pressure of a steam which is exerted on the piston which is used for overcoming the inertia and the friction is used for developing the work through this (()) (5:26) in case of steam turbine. Now we have discussed the steam engine, let us come to the steam turbine, now in case of steam turbine there is a derivic action of steam derivic action means there is change in momentum.

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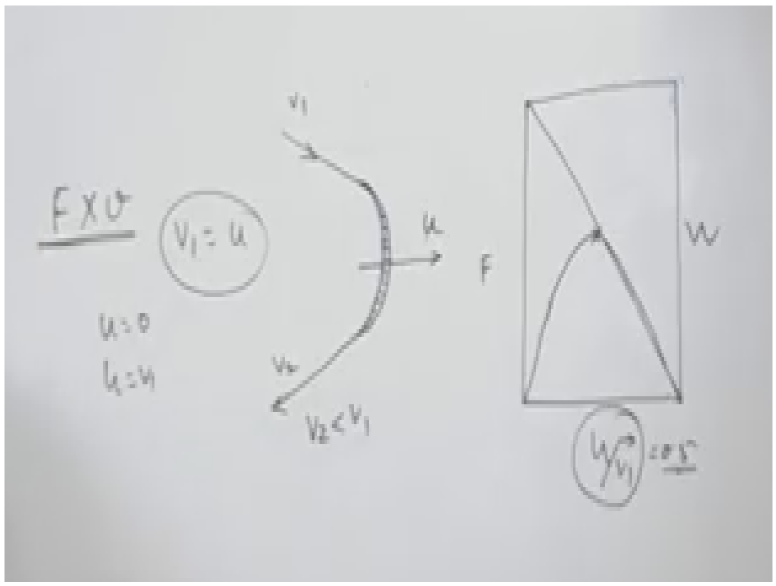

If we change in momentum of the steam right and the rate of changing this momentum of steam will exert force, it is from the Newton second law of mission. Now suppose we take a plate a curled blade and steam strikes with a certain velocity to this blade, not it strikes it glides over the plate it does not strike but glides over the blade and leave from other side of the blade with certain velocity V1 it is coming to the blade gliding over the surface of the blade.

This is the blade surface, this is the cross section of the blade, so there is no confusion and it leaves with a velocity V2, from other side right because there is a change in the direction of the velocity. Momentum will be there and is going to be change in the momentum, and this change in momentum will exert force on the blade. But blade is not moving, we have considered that the blade is fixed but certain amount of force will be exerted on this curled blade.

Now in second case suppose this curled plate is moving with a certain velocity U, initially the magnitude of V1 is going to be the magnitude of V2 when U = 0. But now the blade is also moving with certain velocity in that case V2 is going to be less than V1. But will get certain amount of work because force is being exerted and if we multiply force with the velocity that is the amount of work we are going to get.

Or there is amount of output we are going to get now we keep on increasing the value of U the force the work will keep on increasing. Suppose V1 becomes = U in that case there is not going to be any output. So output is 0 when U = 0 output is 0 when V = V1. Now if we draw a characteristic curve between force and the velocity, now this is U or U by V1 and this is force.

So U by V1 when it is zero when the force is maximum and when this = 1 then force is 0. So this is going to be like this but output because we are concerned we are not concerned with the force we are concerned with the output of the turbine. So when the U and V1 will increase initially the output that is work will increase will attain some maximum value and then it will reduce.

So at maximum output or maximum work force may not be maximum. So this ratio = 0.5 this will discuss later on in subsequent lectures. Now we will start with advantages of steam turbine over advantages of steam turbine over steam engine.

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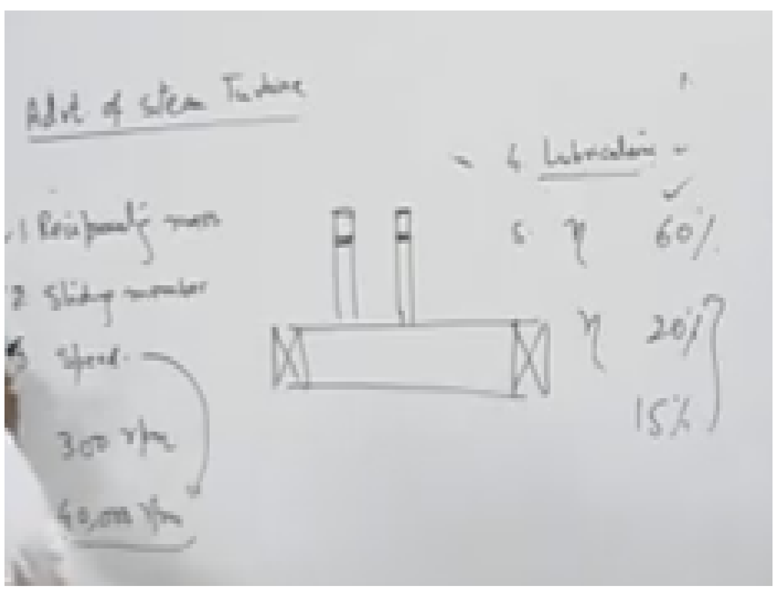

Advantage of steam turbine, now in steam turbine what happens there is a rotor, I should explain you the basic working of the steam turbine. In steam turbine there is a rotor right and over a rotor there are number of blades in this direction there are number of blades. So there is a rotor, on the rotor there are number of blades fixed on the turbine surface extensively as well as circumferentially.

So there will be a circumferentially arrangement of the curled blades fixed at a different certain inch over the circumference and along the excess of the turbine, when the steam glides over this blades. When steam glides over these blades the force is exerted in this direction and these blades starts moving like this in a rotation manner and that is how the RPMS are important to the rotor and the rotor is connected to the generator and that is how the electricity is generated.

Now advantages of steam turbine are first of all there is no reciprocating mass. Steam turbines are rotary machines, so there is no reciprocating mass or there is no linkage to convert reciprocating motion to rotary motion as in the case of steam engine. So there is no unbalance force in steam turbines, so balancing is not a problem. Second thing is wear and tear is less and we can directly couple steam turbine shaft to the generator.

There is no sliding member in reciprocating system there are sliding members which causes loss due to friction. So there in steam turbine there is no sliding member. Third thing is speed in reciprocating engine, the limiting speed is approximately 300 rpm, is very low but if you compare this with the steam turbine, speed in steam turbine the single stage steam turbine we can go up to 40,000 rpm.

But forty thousand rpm is not very useful for us if it is directly available. We have to reduce it to 3000 rpm because all generators set or the electricity generators they work on 3000 rpm how it is reduced for 40,000 to 3000 we will discuss later on, it is not appropriate to discuss it here in the steam turbine.

Internal lubrication is not required in reciprocating engines, the lubrication is required in steam turbine, internal lubrication is not required though some hybridizing were in solved different type of variants are required for when to support the rotating shaft for not much lubrication is required in the steam turbine. And then the most important thing is efficiency of steam turbine is approximately 60 %.

Efficiency of steam engine, maximum efficiency can go up to 20% otherwise it is 15 %, 15 to 20 %. So efficiency of steam turbine is quite high. Third thing is in steam engines the steam is send to the surroundings or you have seen in the PV diagram even the exhaust wall is opened above the constant pressure if you look at the PV diagram.

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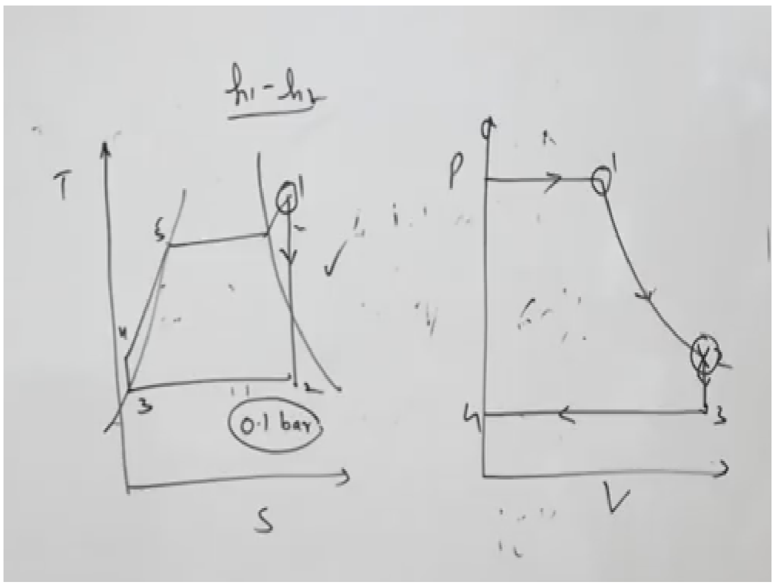

Steam engine the exhaust is opened slightly above the atmospheric pressure, but in the case of steam turbine and we will draw the temperature interpretive diagram for the steam turbine. The steam can expand pressure below the atmospheric pressure and normally the pressure in the condenser is approximately 0.1 bar, 0.1 to 0.2 bar and output of the turbine depends upon 1, 2, 3, 4, 5 output of the turbine depends upon H1 – H2.

So definitely higher vacuum, we are maintaining here more output we are getting from the turbine. However in the case of steam engine we are sending steam out at outside atmosphere at pressure slightly above the atmospheric pressure or definitely we are drawing more energy from the same amount of level energy at state 1 in the case of steam turbine.

So and last but not the least they are suitable for the generator because output in is form of rotary motion and so it can be directly coupled to the generators. Now the second thing these are the advantages of steam turbine. Now we go for the classification of the steam turbine.

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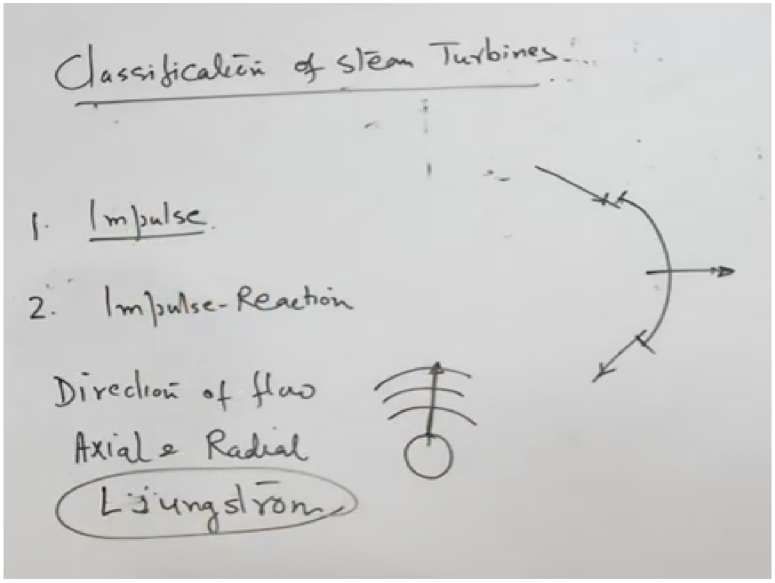

Classification of steam turbines, we lead us two types of turbines, impulse turbines and impulse reaction turbines. Now in impulse turbines the steam high velocity steam which is coming from the nozzle. Actually what happens the steam available in the boiler which is coming from the boiler it passes through the nozzle. So this high pressure steam the energy or enthalpy of this high pressure steam.

Part of this enthalpy is converted into the kinetic energy and this high velocity steam glides over the blade surface and that is how the output is generated in a steam turbine or the power is generated in a steam turbine. Pressure drop takes place only in the nozzle in impulse turbine, there is no pressure drop during this passage. Pressure remains constant and the output is by virtue of change only rate of change of momentum.

So this type of turbine is known as impulse turbine. Now second is reaction turbine or impulse reaction turbine because pure reaction turbine is not practical. So we take impulse reaction turbine, now in impulse reaction turbine the pressure drop takes place in this passage as well, so in impulse reaction turbine the pressure drop takes place inside the nozzle and inside the or through the blade passage as well.

And combined of effect of these pressure drops cause exerts pressure on the blades and that is how the power is generated. Now the second is on the basis of direction of flow most of the turbine axial flow turbine. So axial flow turbine means this is water and direction of flow of steam in the axial of water blades are fixed circumferentially and excessively as well and steam glides over the blades and it exerts pressure tangent to the water.

And that is how the rotor is transmuted. So this type of top type of turbine are known as axial flow turbines. There are radial flow turbines also, axial radial while in radial turbine the movement of the steam is in radial direction. And the most very popular turbine is radial turbine is Jungstrom turbine. In this turbine there is a glide of moving plates in opposite direction and when the steam flow in the radial direction the output is produced.

There is tangential flow turbines also tangential flow means the steam strikes the plate in the tangential direction but steam turbines are rarely tangential type of turbines. Some of the application they are used for running the auxiliary is for its small capacity power generation or for running the auxiliary in the power plants. They can be used but normally most of the turbines are axial flow turbines.

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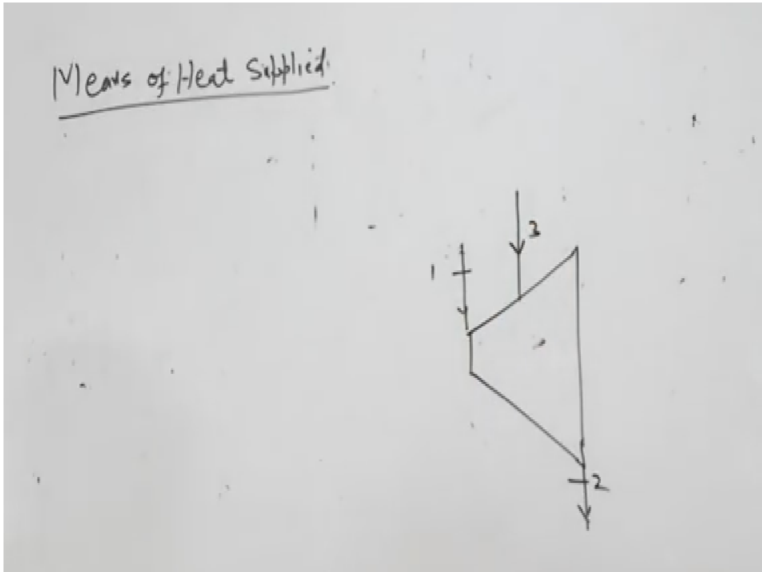

Now another classification is means of heat supply by mean, how the heats is supplied means of heat supplied now in a turbine is denoted like a diverging section, a diverging passage like this is high pressure side and this is low pressure side. So 1 is single pressure turbine, single pressure turbine means steam is entering from one and leaving at 2. That is single pressure turbine mixed ordeal pressure turbine in which turbine at some intermediate space.

There is also an entry of the steam that is I mean instead of having at entry at one pressure the entry of steam is at different pressure. So this is known as mixed ordeal pressure turbine and as we discussed earlier also there is a reheating arrangement also in the turbine, in reheating arrangement

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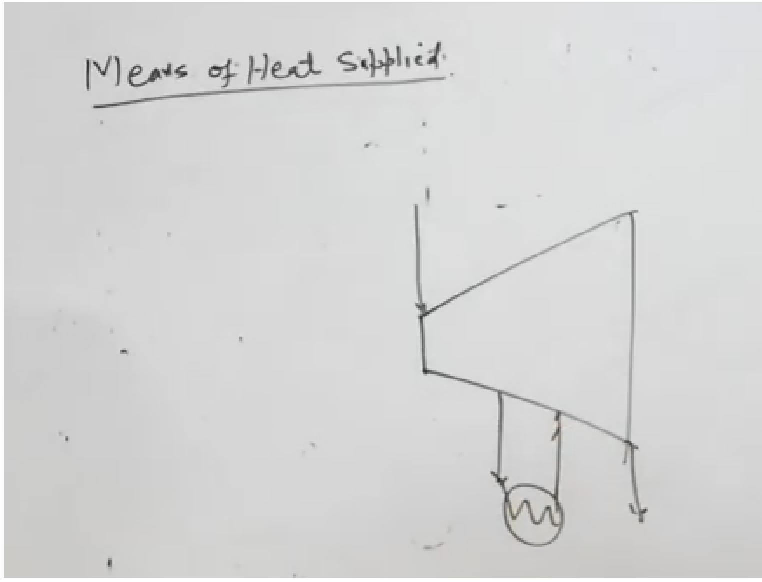

The steam entering the turbine is taken at certain point heated and then it is resent to the turbine for its pressure. So this is a reheating we have applied and discussed reheating and regeneration. In case of regeneration the field water is heated with the help of exhaust from the turbine. So that is a regenerative arrangement in the turbine now another classification of the turbine can be

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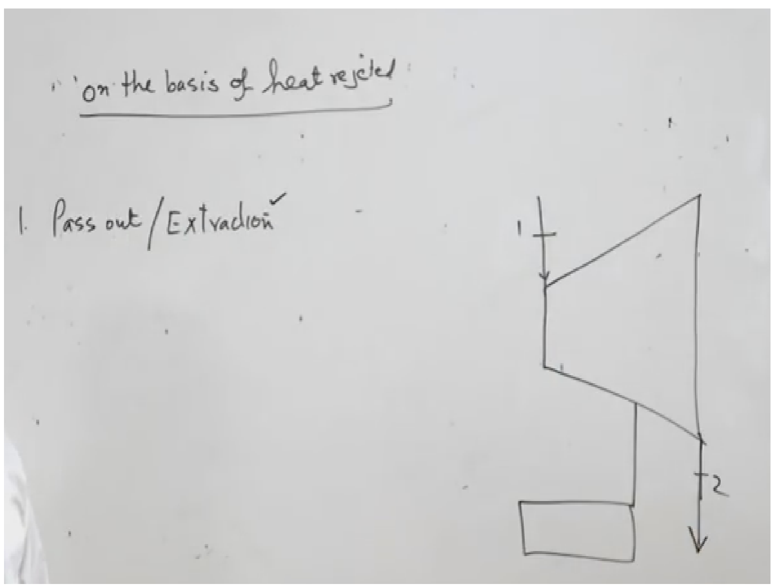

On the basis of heat rejected how the heat is rejected from the turbine, the first is pass out turbine or extraction both are same. Pass out or extraction turbine during expansion with the turbine starting from state 1 and this is state 2 at some intermediate place the steam is trapped and steam is used for some chemical process or some process in the industry.

So this type of turbine is known as this type of heat rejection turbine having this type of heat rejection system is known as pass out or extraction turbine. Regenerative turbine we have discussed in earlier lectures about what is regeneration. Condensing turbines is a normal type of turbine where condensation of flow take place. I mean there is a condenser turbine and condenser pump and boiler normal arrangement that is known as condensing turbine.

Because steam gets condensed in a condenser. Now non condensing turbine I mean that steam is sent to the surroundings. So steam does not get condensed in the close cycles. So that is non condensing turbine. Back pressure or topic turbine the steam coming out of the steam is extended up to the lowest possible pressure and this steam coming from the turbine is used for and the exit of the turbine not intermediate state.

But the exit of the turbine is used for the some industrial process. For example in sugar industries the power is generated and the exhaust of the turbine the steam is available at very low pressure and temperature. This low temperature, low pressure steam is used for processor in the sugarcane industries. Now the number of cylinders is turbine in say the expansion of steam need not take place in a single entity it can take place in different turbines.

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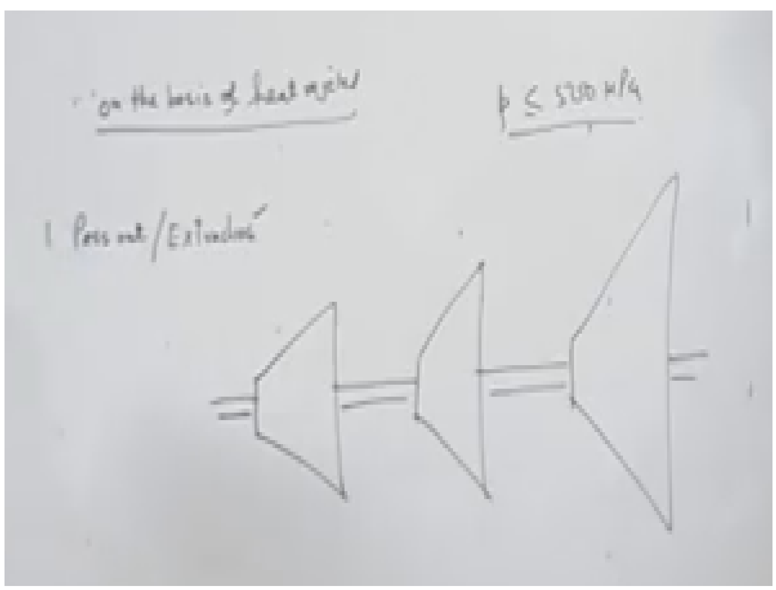

So in a power plant normally there is a high pressure turbine it has intermediate pressure turbines and it has low pressure turbines. The power plant can have two three low pressure turbines, two three intermediate pressure turbines, they are known as LP, LP1, LP2, LP 3 normally it is considered when the inlet pressure in the turbine is 5 bar or less than 5 bar or 500 kilowatt.

The pressure is less than or = 500 kilopascal, then it is known as low pressure turbine and by visual inspection you can judge which is high pressure turbine which is low pressure turbine because high pressure turbine, the specific volume of the speed steam is less. So it is going to be small in size as the pressure of the steam reduces specific volume of the steam is increases and that is how the size of the turbines keeps on increasing.

They can be tandem turbine. There is another classification tandem is output is coming to the common shaft right or there is tandem type of arrangement and there is a cross compound type of arrangement where output from each turbine is sent to an individual shaft. So that is known as cross compound type of arrangement. The turbine can be a single flow or double flow type of turbine single flow means

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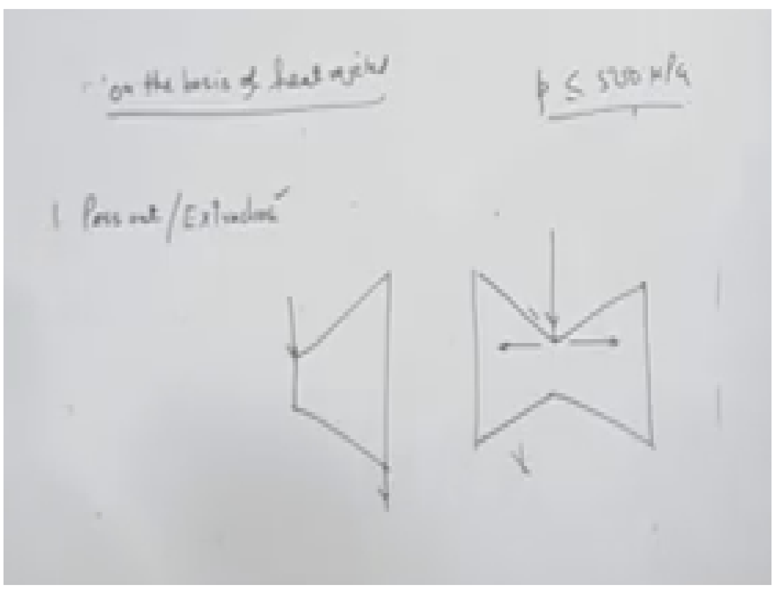

Steam is entering from one side and leaving from another side this is single flow double flow normally double flow arrangement is done in high low pressure turbine because the size of the low pressure turbine is big they are bigger in size so in that case steam enters in the middle and it moves axially in both the directions.

So these two types of arrangements illustrative arrangements are also possible in steam turbine. Now there is another classification because that is based on rotational speed, now rotational speed of a turbine here we supply 50 hertz or electricity supply is 50 hertz

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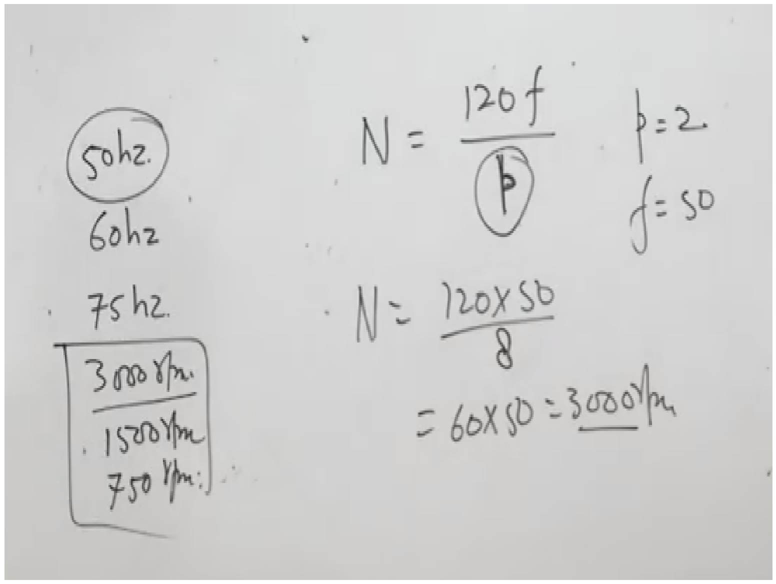

In some of the countries like it is 60 hertz, some of the countries it is 75 hertz. I will focus on this 50 hertz now. For 50 hertz supply if you want to have 50 hertz supply then rpm of the motor is going to be 120 F by P. P is number of poles because if you go to the market you will not find what is motors you will find motors for 3000 rpm.

Like for example, you this small capacity generator petrol running with the petrol this of capacity 1 kilowatts one and half kilowatts. The one you will find it is running at 3000 rpm or you will find machines running on 500 rpm or you will find machines running on 7050 rpm. So in market the electrical machines are not available for all rpms.

There are certain rpms only for those, only you will get the machine. Now how this rpms are decided, suppose I take two poles motor if you are take two poles P = 2F is 50 hertz it is fixed. So N is going to be 120 into 50 divided by 2. So it is going to be how much this 60 into 50 = 300 rpm.

Suppose we can go for four poles also, if you go for four poles this will be reduced to 1500 rpms. If we go for eight poles this will be reduced to 750 rpms. Right now I want to have output of 60 hertz, now again we will use the same

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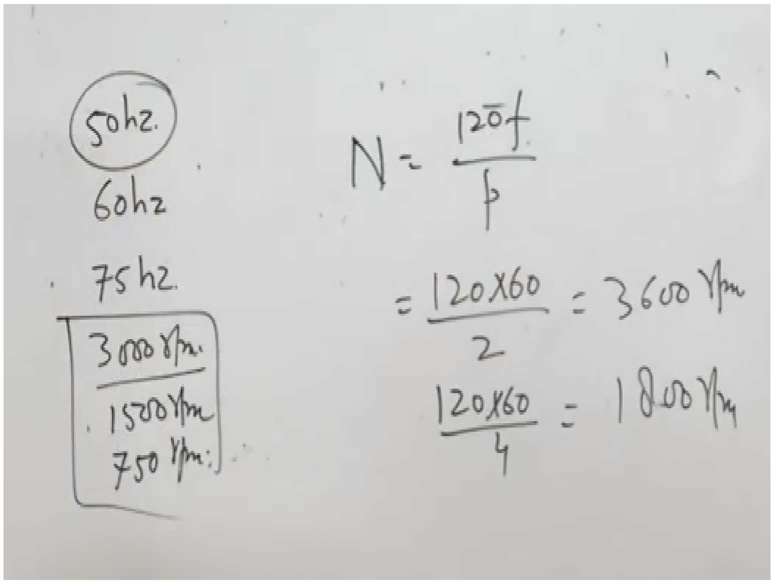

Formula N = 120 F by P. So if F is equal to 60, 120 into 60 divided by 2 it is going to be 3600 rpm. In some of the countries this electricity supply is sixty hertz. So 3600 rpm again if we go for four pole then it is going to be 1800 rpm and similarly if you go for the eight poles it is going to be 900 rpm. I think this is all for the classification of steams right sorry classification of steam turbine and in the next class we will start with the compounding of steam turbine thank you.