Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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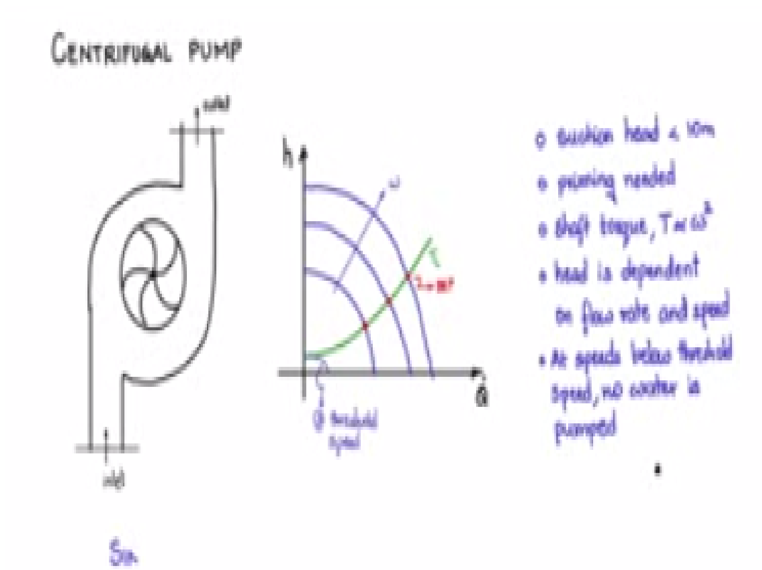

Let me discuss now important pump centrifugal pump and reciprocating pump. The centrifugal pump comes under the class of dynamic pumps, it has a set of impellers within a case, it has a suction input piper where the water is admitted in, and a delivery pipe where the water goes out it is called the discharge of the fluid of the water. The operation is based on the centrifugal force, this is rotating at high speed, the vacuum at pressure difference that is created due to the high speed rotation sucks in the water and it roots the water towards the center.

And because the centrifugal force it is pushed out into the outlet. And as a result a pressure difference is created vacuum is created which will suck in more water and so on it goes. So higher the speed impellers speed larger be pressure difference and then one of the discharge. So this is how it goes on. Let me plot on the X-axis discharge rate of the flow rate, and on the Y-axis head or the pressure.

Now the static characteristic curve in the hydraulic domain is something like this at a particular given speed. If the speed is reduced you will see the discharge static characteristic curve like this further reduction on the speed you may see something like this. So as the speed is increased in this fashion ω angular speed is increased in this fashion you will see the family of static characteristic curve is going to be pressure versus discharge rate in this fashion.

The torque felled on the shaft of the motor will be something like this and why is it like that, observe that I will mark these points here. Now these points are the best efficiency parts has indicated in the datasheets of the pumps. What it means is that when the head is 0, which means that there is no hydraulic pressure difference needed, then the hydraulic power is 0 when the flow along this axis when the flow rate is 0 even then the hydraulic power is 0 somewhere in between the hydraulic power is maximum so these are the points where you have the maximum hydraulic power and those are operating points at which the efficiency would be maximum.

So therefore it is recommended that you operate the centrifugal pump at this points of best efficiency points and therefore if you plot the locus of that the torque that should be seen the shaft of the motor will be something like this so this torque is proportional to ω^2 it is having a square angle of frequency dependency so important points suction head should be less than 10 m because by pressure suction you cannot have greater than 10m in practice less than 6m is what you may achieve because of friction losses.

Priming is need you need to fill up the centrifugal pump with water first and then switch on the motor the shaft torque has seen on the shaft of the motor is proportional to ω^2 that is this particular torque as a function of ω head e is dependent on flow rate and speed at speed is below threshold now water is pumped so what it means is that this position here this new characteristic static characteristic which are drawn.

Below this threshold everything goes into friction loss no water will be pumped so this is at threshold speed this characteristic is a threshold speed.

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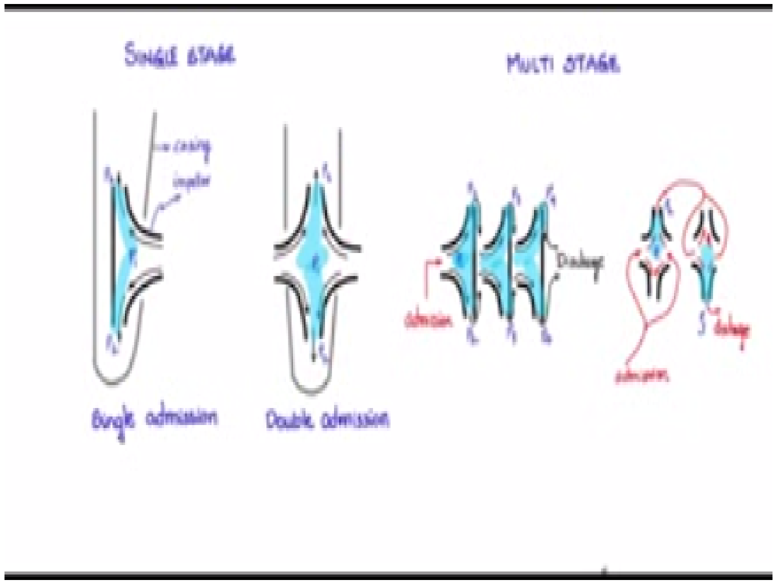

So now let me just discuss with you about 2 important aspect there is something called the single stage and motile stage most of the pumps especially for low heads we use a single stage pump which means the impeller is the single impeller so if this is the casing the impeller is housed in the casing like this is where the water admitted and we call this one has admission and the water exits like this, so when the water is a routed admitted through this routed like through at this through this impeller the impeller is rotating at high speed and the centrifugal forces force the water out through this outlet, so if I draw the direction it look something like this so this is the casing and this is the impeller now water is admitted only from one side it is called the single admission.

You also have double admission so it will look this the impeller looks like this if I draw the casing it look like in this fashion so water can be admitted this way and this way and then water comes out because of the pressure difference between this center and the outer Perry ferry water is pushed out by the centrifugal force now the direction of flow will be like this, this is double admission now double admission of course is more advantages because the water getting admitted through this port and water admitted getting admitted through this port balance the impeller wheel.

So therefore the double admission is more advantages from that point of view it has reduced impact on the barring there is also multi stage than your how very deep well very wells and then in the case of submersible pumps where you have to pump to a very great had especially from bore wells like the bore well examples that we discussed multi stage impellers or normally used in the pump so then it is called a multi stage pumps, let me just show you how the schematic looks like this is a single stage.

Impeller this is the single stage impeller I will place one more impeller set like this place one more impellers set like, so if I keep on placing impellers like this, this becomes multi stage so this is the admission point this is the single admission point where water is admitted routed in and it is routed as it goes in and it is rotating centrifugal force, forces the water to the out let of the impeller so it goes out of the impeller like that and then water is routed by a diffuser and it comes in into the second impeller it is admitted into the second impeller.

And from here it again through centrifugal force goes out and then it is admitted to the third impeller and so on and finally to the discharge point. Like the single admission multi stage you have the double admission multi stage let me show you two stage double admission, so if I say this is it is admitted it will go in on both sides then it will come out through this it is rooted and then goes into the double admission impeller of the next stage goes out so on.

So in this way the double admission multi stage impeller works, now actually if you see there is a pressure P1 at this point and then P2 at the periphery of the impellers so P1-P2 is what is focusing the water to the periphery likewise here also you have P1 and P2 and the pressure P1-P2 the ΔP is forcing the water because of their rotation and the centrifugal force. Now here in the multi stage you see the pressure starts adding up, so there is P1 and this P2 and here at P2 it is admitted into the next impeller stage, P3 must be great, P2 will force into P3.

P3 is the pressure at the admission of the third stage, P4 so on, so actually the ΔP is keep adding up likewise in the case of the double admission you have P1, P2,P3 so on. So because of the addition and the power addition the pressure there is sufficient differential pressure from the first to the last stage which will pump the water to much greater heights, so that is how the multi stage pumps start working and generally used in submersible pumps in bore wells a type of applications.

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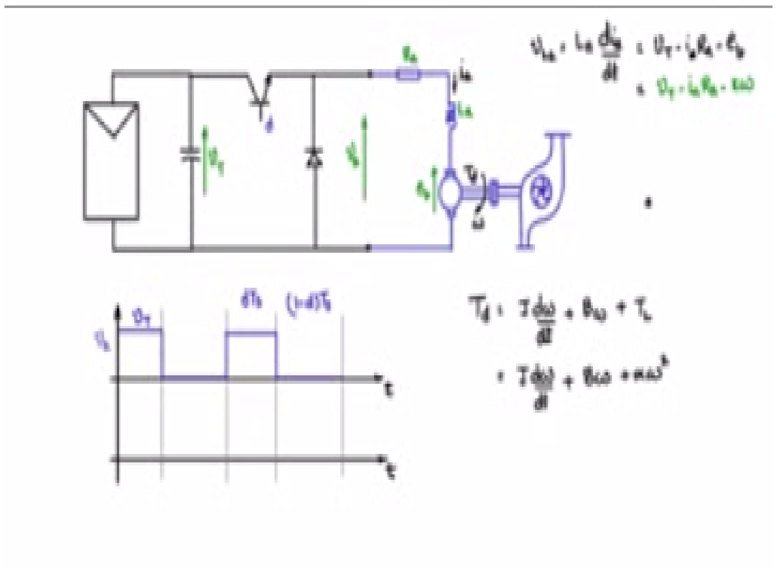

Let us now see how we interface the PV to the pump, so we have the PV and at the output thumbnails of the PV we have CT that is a buffer capacitor and from the terminal I will make the chopper which means there is a switch and the diode that is it I am not putting the dc, dc convertor remaining and the inductance and the capacitance I am just having the chopper to switch.

The motor dc motor itself ahs in built and which is storage has in built inductance which electric may see what happens now the motor ahs the series winding resistance or a is the small value than the series inductance La magnetizing inductance all the inductances lump together and put it as La and the motor itself which is at control voltage source like that.

Now this motor a is the permanent magnet dc motor so you need a dc drive the shat of the motor is compelled one another shat this shat of the central fuel pump like this so this central fuel pump has inlet and the outlet and this is the with the way in slight this so this is the system we have vt here terminal voltage and across the R matured of the motor having the a this is Ra La this sir back mm Ev or the mechanical side.

I have developed term Td that is ω of the shat now we know that Td is equal to Td the develop supply overcome j dω/dt any inner shat reflected up to this point on the shat into dω/dt change in speed+ there is varying on this side on this side there will be varying friction d* ω + the low term the hydrolic load of the centre fuel pump we saw in the characteristics just before TL and what is TL okay.

Let me put it down the $d\omega/dt$ + d ω+ some $\alpha\ \omega^2$ we said TL was proper control ω^2 now this is the kind of load that dc motor will see and then it has to develop the shat to overcome all these compress now how does this operator and were let us see this is switching on off, on off which means the voltage here will the either connected to vt or it will be 0.

Because it will be free wheel so when it is on there will be a current flow like this through this and then it will start driving the motor it will have orbital current orbital current will produce the torque in the DC motors proportional to the orbital current and this torque will cause the sharp to rotate and this ω will cause pressure difference head and which will cause the flow of water and therefore the discharge rate of the flow rate comes. And because of this ω you will have a mm of induced here and this back mm is going to oppose the flow of the current and it will all settle at some state.

Let me just draw the important wave forms so that we get an idea of inside into the operation, so this is time axis I will see 2 wave forms V_a and current I_a through the motor. So let me divide them into time zones now this is during the on time, off time. During the on time V_t will comes directly at this point, so V_a is V_t during the off time V_a 0 because and the current flowing through this and the inductor will prevail like that.

So it comes period of period, next we have this duty cycle that is the starts of BJT or IBGT is switching on for DTS time period and switching off for a 1- DTS time period. And the average value of V_a here is V_t x d. now let us see the current here, the current here the equation the governing equation V_{la} the voltage across this la dia/ dt paratile equation. Now what is V_a potential at this point – the potential at this point V_a – Ira V_a would be either 0 or V_t so let us when this is on.

It will be $V_t - I_a R_a$ on the one side and the other side it is E_b, so I can write as V_t – Ia Ra – e_b is proportional to ω, so is the k ω. So this would be the relationship integrating this would be giving me i_a. Now let us say R_a is very small then it will $V_t - k\omega$, $V_t - e_b$. As ω is rotating with mechanical time constant where it is initially J this is not going to vary quickly as quickly as electrical parameters like the current because electrical time constant is very fast.

So VT is parallel constant EB is also parallel constant for the period TS so therefore VT-kω is sufficient constant and also this is right the current IA will rise with the slope of VT-EB/OLA ω I am taking it as varying very slowly compared to the electrical parameters and RI is almost negotiable so during the time when it is off this is 0 it is only EB which is coming across LA so it is –eb/la so this one is –eb/la so it is slope it goes.

So let us say this is the current the armature current that is flowing through the motor so this current value I can adjust up and down by controlling the duty cycle so the duty cycle is small and then the IA value will be small the IA value will be high so this can go up and down so by controlling IA I am controlling because tok is proportional to IA in DC mode and by adjusting IA I have adjusted TD so if you adjust TD then the speed gets modified as the speed gets modified the pressure difference are called the inlet or the outlet gets modified and therefore the flow rate so this is how you control.

The flow rate by adjusting the duty cycle here and we EB is proportional to ω as I told here so the ω is actually acting as in opposition to IA and this steady stage we try to do some value and VT-EB we are taking that into account vt-eb/la is what will determine the current so in this way adjusting is duty cycle will adjust the average value of VA which is will become DVT which in term will adjust the value of IA flowing through this IA flowing through this will affect DT which will affect ω and so on the ω will affect the pressure difference across the pump which will affect the flow rate so this is how this enter people is interfaced PV cell or PV module and this is how it operates.