Industrial Automation & Control
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Lecture - 31
Energy Savings with Variable Speed Drives

Welcome to lesson of Industrial Automation and Control. In this lesson which is entitled Energy Savings with Variable Speed Drives. We are going to explain demonstrate that for a kind of application which is very predominant in the industry very common how what are the, firstly we are going to see what are the various kinds of flow control applications that is the application that we are trying to consider.

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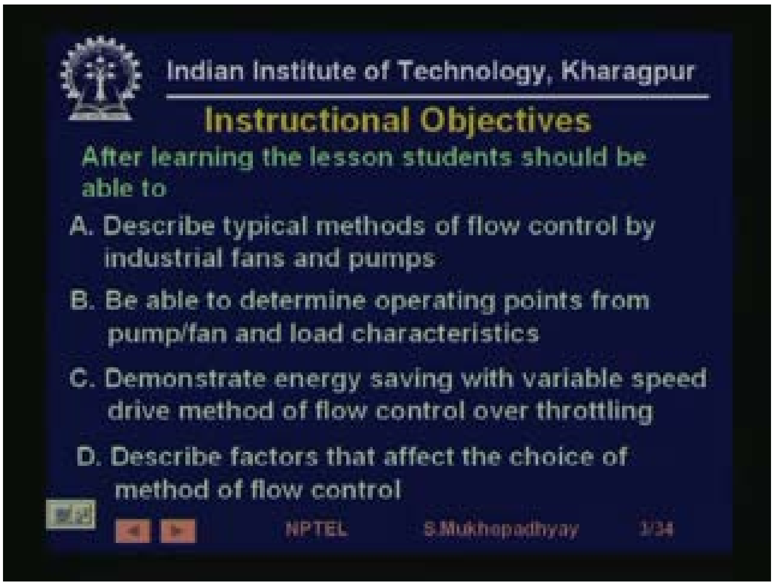

So, it flow can be of gas or liquid, so accordingly we have either what are known as fans or blowers or we have pumps, fans blowers and pumps constitute an enormous very significant fraction of the loads which are driven by motors and motors which consume a large amount of electrical power in the industry. So, they are very common and common applications and very significant from the energy point of view.

So, we are going see that in such applications how flow is to be controlled and, then we are also going to see that if you flow is typically controlled by driving a pump by a motor, but if you drive a pump by a motor then it will drive a certain amount of air. Let us say, if you have pump it could be water now the demand for this air or water it is not the same all the time.

So, that flow has to be controlled now there are so firstly, how do we when we connect a machine to the pump, what is the amount of flow that is established that depends on the pump characteristics that depends on the machine characteristics. So, we are going to see that, how when you connect a pump or a fan with a, so called load how is the operating point established what will be the pressure what will be the flow, it is actually much like you know establishing an operating point when you connect a battery with a circuit or a load right.

So, we are going to see that and we will see that depending on how we can vary this operating points we have to vary this operating point, because we need to vary the flow. Now, this flow can be varied by various ways of varying the operating point and it is, so some of these ways are may be very simple, but may be may not be efficient in from an energy operating point of view.

While others may involve more complex technology, but possibly would be more energy saving, so we are going look at two of the most common techniques and show that how their energy characteristics are going to be different. In fact, that will motivate the next few lessons in this course that we are going to have an industrial drives probably this lesson would show why industrial drives are I mean show at least one side of the story that why variables speed drives are such an important thing. I mean such an important technology in industrial automation control, so finally we would also see in this in the course of discussion that when to choose what type of flow control or drive right, it is not that you always energy saving is the all important criteria, so we will discuss little bit on that.

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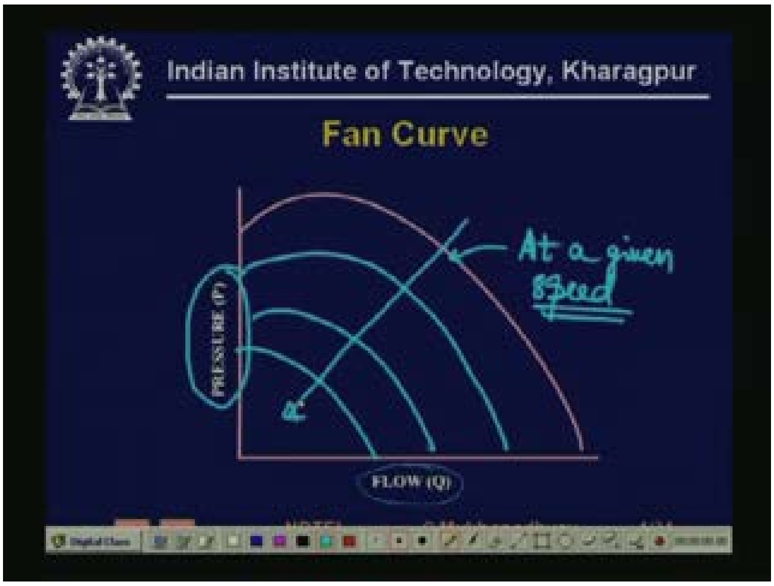

So, let us look at a basic characteristic of fan right, so here we are the fan is this is the intrinsic characteristic of the fan itself irrespective of what the load is, so the fan actually develops a pressure at its outlet and also develops a certain flow and this in develops when the fan is rotated at a certain speed. So, when we have plotted this curve which is on one axis is flow and the other axis is pressure, so it shows the pressure is you know somewhat like voltage and flow is somewhat like current.

So, in that sense it is like since we are many of us are electrical engineers, so this is somewhat like VI characteristics of a battery or an energy source and we must remember that is curve is drawn at some speed at a given speed of rotation. So, if the speed of rotation will is changed then the, then this characteristic will shift up and down actually you will get a family of characteristics with decreasing speed.

So, this is the characteristics of the fan as such now if this fan is now connected to a load, the load means that it could be various things for example, typically fans are used in furnaces. So, in the furnace typically if you go to the power station you will find that you have big boilers and these boilers are heated by furnaces and these furnaces have two huge fans one is called an induced draft fan another is called a forced draft fan.

So, these are you know like I mean furnaces like a Chula, so you need to flow water blow air into it for combustion, so these fans actually blow that air and the induced draft fan actually I mean sucks out, the after combustion air most from full of carbon dioxide. So, these are. So, these are, so it is the furnace which is the load, so if you connect the fan to the furnace then at a certain speed of the fan a certain operating point or certain pressure flow will be established, so basically how do we get that.

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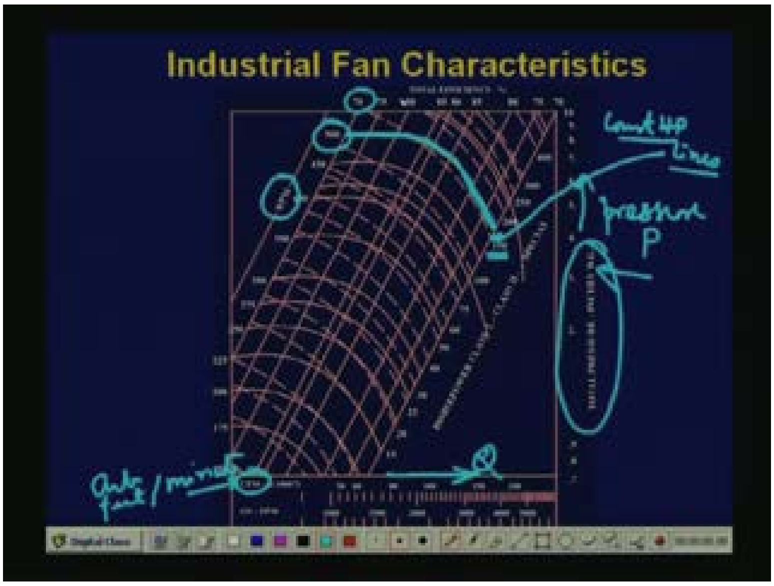

So, we this is a fan characteristics which will come back to the a little later this is a little complicated actually basically let us have look at it, basically what it being done is that this is this actually gives a family of curves. So, on this axis you have this CFM means Cubic Feet which is a unit of volume per minute, so this is nothing, but volume flow rate, so this axis is Q and this is total pressure in inches of in inches of water column.

So, basically this is pressure or P, now so the, so you see part of the fan characteristic is shown and you can see that a family of curves are shown, so what are these family of curves. So, basically the various operating point. For example, these are if you see these constant lines I will draw it here, so for example these lines, this line it starts with this number 500 and here it is written RPM, so which means that this is the if the fan is made to rotate at 500 RPM, then the pressure flow characteristic will follow this curve.

Similarly, you have a family of curve for various speeds on the other hand look at these doted lines, so this dotted line this dotted line it says 150, so this is these are constant horse power lines, so these are constant horse power lines. So, if you operate it along this curve, then you have a you always spend 150 horse power. Similarly, you have a number of curves, similarly you can have efficiency constant efficiency characteristics, say this is 70 percent line this is the 80 percent line, and so on.

So, basically this curve shows that if the fan is operated at various speeds what are going to, so basically pressure flow characteristics with something constant either the speed is constant or the energy is constant, so that you can conveniently find the operating point and in fact, we will use this curve later on. To find out to actually compute the energy savings, so having understood this let us move on and we will come back to this curve in a while.

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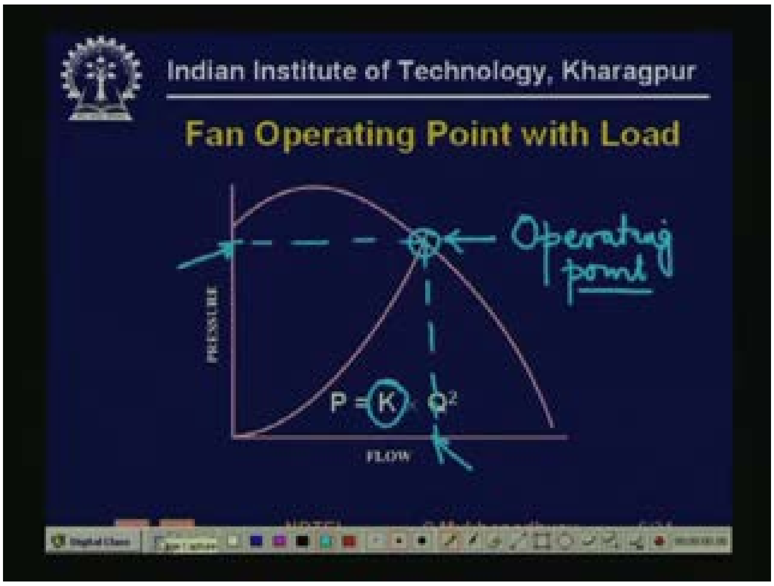

Yes, so here now we come back to how an operating point is established, so you see just like remember that when we computed operating points in our circuit courses, we drove what is known as the load line, so on the other hand you have a load has a certain characteristic means, that if you want to create a certain amount of flow through that load. In this case may be through the furnace, you need to create a certain amount of pressure difference, suppose you take a pipe then to be able to create a certain amount of flow through the pipe you need to create a certain of amount of pressure difference across the two ends of the pipe.

So, that is the characteristic of the pipe that to create a given amount of flow how much pressure difference is needed and typically turns out that it follows a square law, basically that occurs because of Bernoulli flows when you have what is known as turbulent flow that means, when the flow velocity is high then there is a law called Bernoulli's law which we are not going to now. From which you can drive that the pressure flow relationships through any constriction if the flow velocity is sufficiently high that is if the Reynolds number is so high that the flow can be called turbulent, then typically the pressure flow relationship is quadratic.

So, the load typically follows such an equation with some constant K, so it is a narrow constriction this value of K is going to be high if it is the open constriction value of K is going to be low and so on. So, if you connect such a load across the pump, then they will intersect and this is the operating point, so this is the operating point, so immediately if you connect this is the flow and this is the pressure which will be which are going to be a established.

So, the pressure which will be established if you connect this pump with this load this flow will be established and this pressure will be established, so now let us talk about varying the flow, because we need to depending on the load characteristics. For example if your electrical energy demand decreases then you need to reduce the rate of combustion, so you need to reduce the flow air flow into the furnace, so how do you do that.

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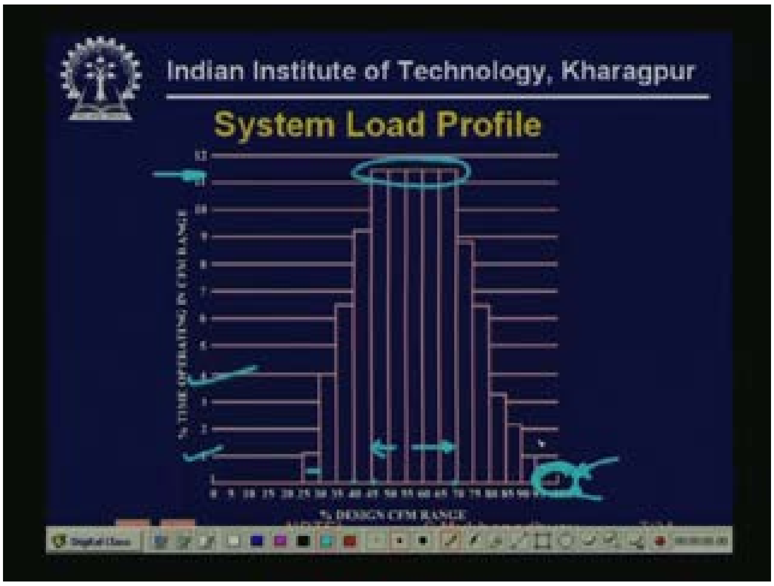

So, typically it happens this is a typical case it is we have we are calling it a system load profile which means that the system is to which we have connected the load how do we what do you mean by the load we mean by the load we mean flow rate. So, you see that this is the demand a typical demand profile, so it says that this is let us say that this is the maximum flow is 100 that can that we are calling 100 percent, so since we must have kept some amount of safety margin.

So, probably maximum flow hardly ever occurs may be does not occur at all or may be occurs at very small time, so most of the time that is the flow is actually between you see about 45 to 70 percent. So, this maximum time the flow stays within 45 to 70 percent of the design flow range, similarly it stays at it stays between 40 and 45 percent for, so that is about you know 11.something percent of the time.

So, 1 2 3 4 5, so about more than 50 percent of the time is stays within this flow range and similarly it stays within 25 to 30 percent for 1 percent of time and 30 to 35 percent of about 4 percent of time and so on. So, this basically shows that in the of the total operational times let us say a day, what I mean what is the loading if you take a loading of say 40 to 45 or 50 to 55, a particular loading level for how much does it stay, what percent of the time.

So, there are some things which are important to note here, firstly note that the fan size must be selected based on the 100 percent continuation, so because the fan for; however, small time the 100 percent demand comes if you select the equipment such that the demand will be met, then the fans of a size will be selected by the 100 percent, but most of the time it will not operate at it will not operate at that level.

So, rather it will operate most of the time at half level and it will also operate at very low levels for a very small amount of time. So, this is the typical load characteristic now let us see what happens, so we need to shift this operating point all the time, so let us see now what happens if shift the operating points.

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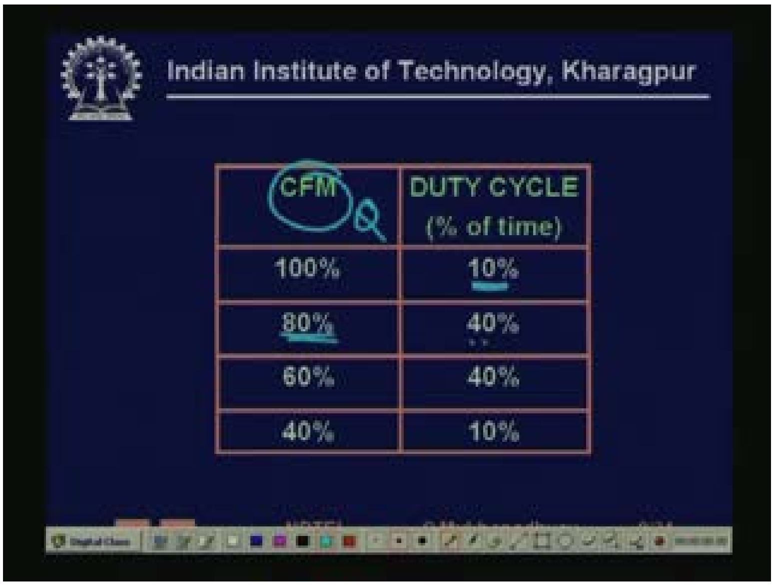

CFM	DUTY CYCLE (% of time)
100%	10%
80%	40%
60%	40%
40%	10%

So, this is summarized, so it says that it this is like you know roughly suppose, because we are going to see an example, so suppose in our example 100 percent CFM means again basically flow Cubic Feet per Minute, this is a CFM means Q. So, 100 percent flow stays for 10 percent of the time, 80 percent flow stays 40 percent of the time 60 percent for 40 percent of the time and 40 percent 10 percent of the time, imagine such a case then.

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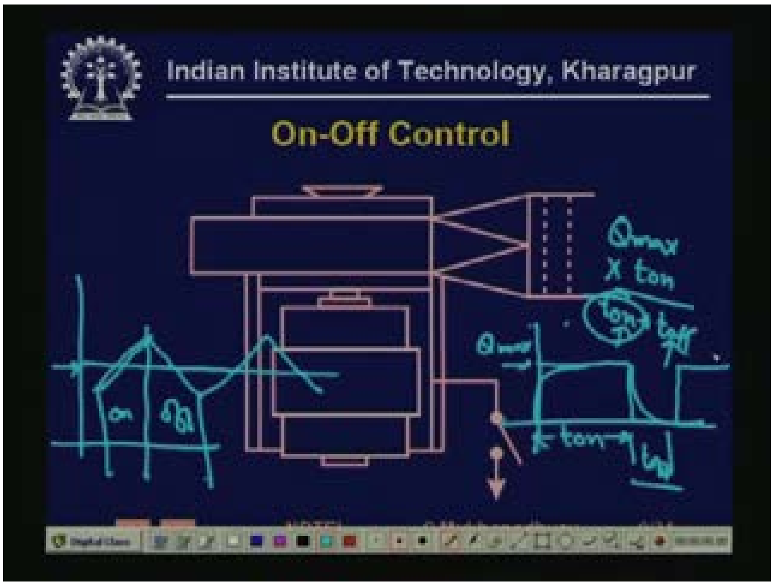

Now, let us see that what are the various ways of controlling one of the easiest ways of controlling air flow is to switch on and switch off a fan you know this happens regularly, if you see a if you see home air conditioner, you must have notice that the fan I mean the in that case the compressors which is on and off. So, it is a kind on-off control, so in a similar way if you want to control flow, then you can also switch off and switch on the fan.

So, what will happen if you do that, so you see if you switch on the fan suppose the flow rate will raise for relay time, then it will fall again and you will switch it on and then switch it off. So, you will be able to establish an average flow and this average will actually depend on what is known as the duty ratio, so this is on this is off, so basically the average value will be or rather actually what will happen if that if you it will not raise slowly, because the time constant will be fast enough rather it will be like this.

So, for the moment you switch it on some flow will be establish the moment you switch it off that flow will fall, this is an approximation actually the flow will raise fast and you will flow fall fast, so if you approximate it as at a square wave, so again if you switch it on and switch it off. So, basically if this is the flow rate Q max then the average flow rate will be given by Q max into t on by t on plus t off, very easy to know this is t on and this is t off, so the average flow you can change by simply increasing t on by simply changing t on and t off.

These are this problem is the simplest way you need nothing you need you only need the motor and the motor and the fan you anyway need, but as far as equipment for driving the motor is concerned, you need nothing you just need switch on the motor switch off the motor at certain frequency or say certain rate for that also you need some equipment, but that is very simple, but this is hardly ever used.

Because, of the fact that there will be flow pulsations and you know these kind of fans are typically used for industrial processes we need we use them for cooling, for things like combustion, so what will happen in the furnace for sometime suddenly a lot of air will come. So, when a lot of air will come if there is, see what we want to do is we when we want to have we are giving fuel and we are giving air.

So, for to get the maximum thermal efficiency from the fuel we need to have a fuel air ratio, perfect fuel air ratio such that full combustion of the fuel will take place, so if you put more air then also air is wasted and if you put less air, then the fuel will not burn. So, in other words that pulsating value of flow is not good for combustion flow control, so similarly another major application for flow control is for cooling, so it is not good too. So, if you sometimes if you send coolant and sometimes if you do not send it, then the temperature on the equipment will be pulsating and this temperature may affect reaction rates, it may cause thermal stress on the equipment. So, in general for industrial flow control problems we cannot tolerate such pulsations, so therefore, this on-off control method is not good, so we go for other methods.

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So, what are the other methods another very simple method is, so on-off control is the simplest of control that is that is going to be temperature fluctuation, basically the flow fluctuation will cause may cause temperature fluctuation, sometimes for home application it is used when you have less load and you have a large volume. So, if you, so there is a lot of you know you thermal capacitance, so little bit of flow variation will not be felt because of large volumes of room, so but sometimes for home applications ventilation HVSC applications these kind of control is used, but generally not use industrially.

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The next control which is used is called the outlet damper control for the fan, so outlet damper means basically a damper means you know is like a set of veins, you know just like say sometimes on the you must have seen what is what are these called there, when you put something on the windows to keep out the sun. So, you know there you can change gaps you can move them either you can keep them like this or you can keep them like this, so that some air can flow.

So, basically dampers are also similar things, so what you do is you put a damper at the outlet of the fan, so basically the damper puts a resistance and does not allow air to flow clearly. So, by that you try to reduce the flow that is a very it is a relatively simple method of flow control, because the controls required for creating a particular resistance in the damper or creating a particular damper angle is actually very simple.

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But, what is the third method the third method and which is the very energy saving method is variable speed fan control, so you do not put any damper, but you rather change the speed of the fan and reduce it when you require less flow, but for that you require a variable speed drive of the motor and that is much more sophisticated technology is required especially when the motor is large. Compared to you know dampers and or valves, but as we shall see that they can save considerable amount of energies.

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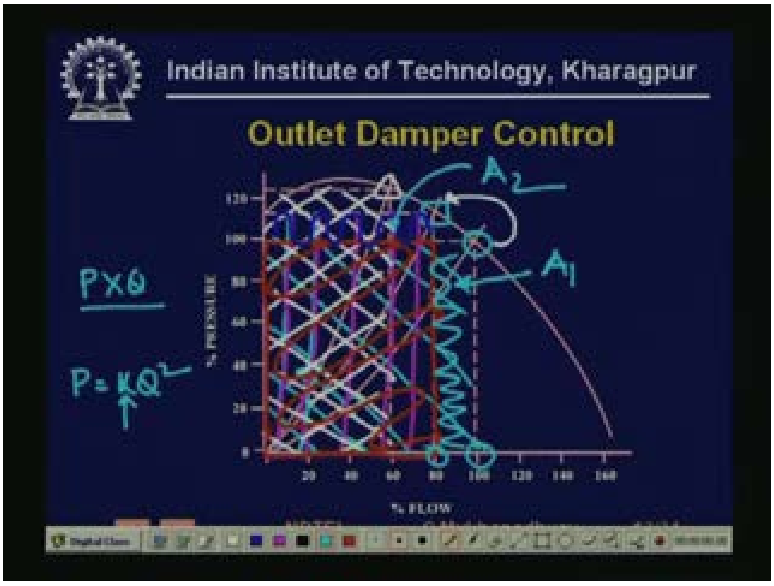


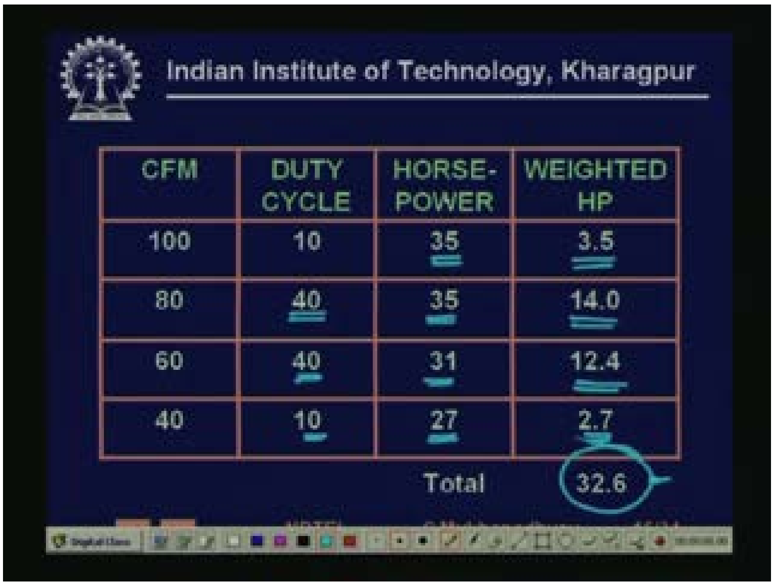
So, let us see, so now let us look at what happens to the operating characteristics when you have damper control, so here is the fan curve you can see that now a damper is essentially actually puts a resistance. So, basically we had this, so it you can consider the damper to be part of the load, so as you are closing the damper this load characteristic of P equal to K Q square, this K value is gradually increasing which means that as the damper is the closing more and more pressure is required to drive a given flow that is natural.

So, as the damper is closing this curve is shifting this way, because this is increasing K now what is happening to the energy, the energy in a fan the energy being delivered is P into Q, so in other words it is the area of this rectangle at any operating point. At this operating point, it is the area of this rectangle this is the area, when you are at this operating point, operating point number 2 then this is the actually I could have taken a different color let me take this color.

So, at the other operating point this is the and when you take the third operating point which is this then this is the area energy demand, so you can very well see that what is the difference if you move from this operating point to this operating point, what is the difference in energy, the difference in energy is actually this part is common, this part is common between that can you see that, so this is common, so this is gone on the other hand this is gone and this is added.

So, the energy saving is actually comes down to the difference between this area A 1 and this area A 2 which is very low, so you see that even if you have moved from this operating point you have come from 100 percent to 80 percent flow, the energy has not fallen by that much amount the energy has fallen only by the amount of difference between these two areas, in fact the same, so the energy fall is not so much.

So, in fact you can see the energy curves, so you see that in damper control as we are going from 100 to 80, the energy fall will be only this much, very low, so here, so that the 20 percent flow reduction, but there is probably a 5 percent energy reduction fall in action. This is not a pressure this is a power, so that is why this method is not so energy efficient you are not saving energy though it reduces it, you are not flowing it, but it is the very simple method you do not require much, you require either a valve or a damper used to close and open, then what happens if u do vehicles.



CFM	DUTY CYCLE	HORSE-POWER	WEIGHTED HP
100	10	35	3.5
80	40	35	14.0
60	40	31	12.4
40	10	27	2.7
		Total	32.6

Now, this is that particular case, so if you want to see this we can come to we can let us come to the if you want to see this figure, so what was it say, it says that for our example and for the fan curve that we have seen if you take 100 percent CFM 100 percent flow the horse power requirement becomes 35, we will see how it comes 35 from those curves. If you have 80 percent the horse power requirement is also 35 hardly any reduction, if you have 60 percent it falls to 31 if you have 40 percent it falls 27 and from the load characteristics we have seen that 100 percent loads stays 10 percent time.

So, per hour per percent is3.5 is the weighted horse power, so 35 horse power levels stays 10.10 percent of the time, so therefore, weighted horse power is 3.5 we are trying to calculate the average horse power. Similarly, 35 percent again 35 stays 40 percent of the time that is 14 and 31 stays 40 percent of the time that is 12.4 and 27 stays 10 percent of the time that is 2.7, so the average horse power requirement is 32.6 remember this figure we will come back and see that you do a variable speed drive what it what for the same pump and for the same load profile, if we have a variable speed drive what would have been this figure.

So, we have 32.6 horse power average horse power requirement for the load and the pump, so just we would also like to see how this 35 35 and 31 figures are located, because otherwise you may not believe me. So, let us go back and how do we close this, can I go back to the side, so I will I am going back to the fan curve just to show you all.

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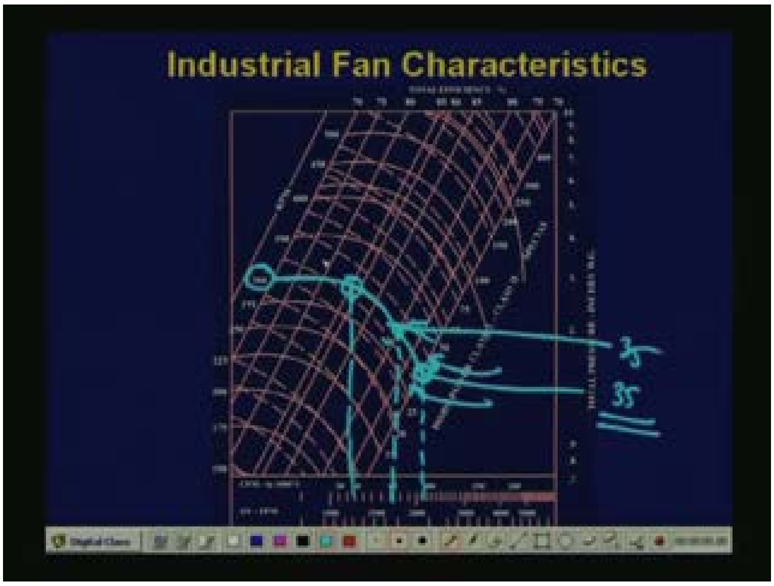

So, we have the fan curve, so let us see that is actually this has been calculated with the fan RPM of about 300, so this is the 300 curve, so we are looking at this curve this is the constant RPM 300 curve and we are at 100 percent. So, this is somewhere over here, so you see that it is somewhere over here can you see that, so it is somewhere over here now you see what is the power requirement here, look at these curves this is 30 this is the constant 30 curve this is the constant 40 curve 40 horse power, so where are we are at 35.

Now, what happens when you are 80 percent flow that is when you are here, so when you are here you are roughly here, so you are at 80 percent curve now you see that where are you, this curve this curve and this curve are moving in parallel. So, if it is 35 here it is going to be 35 here also that is why this is also 35, this is also 35 if you do 60 percent that is here where are we, you are 60 percent would be somewhere over here, so you are here.

So, that is a little reduced you see this is the 30 curve this is the 40 curve this is the 40 curve, so therefore, and this it is actually a non-linear variation, because 50 to 60, 60 to 70 its gradually getting closer, so there is something like 31 32 its slightly reduced actually. So, this is how you get those figures from an actual pump characteristics, so now we go forward quickly again and gone to the variable gone to the variable speed drive case and see what happens, so that is the case.

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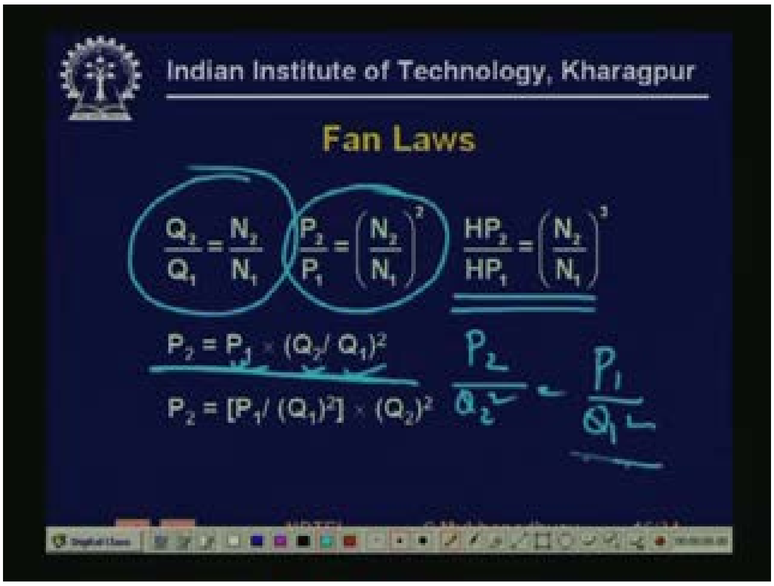

Now, here before we discuss that we need to understand what are known as the fan laws, so what are the fan laws the fan laws say that in a fan roughly Q 2 by Q 1 equal to N 2 by N 1. If you operate if you change the speed the curve shifts in such a manner that on the Q axis you are going to get proportional to these things and P 2 by P 1 equal to N 2 by N 1 square, so the horse power variations are going to be into by goes to vary as N 2 by N 1 Q.

So, similarly, so if you know you know if you know this Q 2 by Q 1 and you know P 1, you can calculate P 2 by this formula, because P 2 by P 1 equal to Q 2 by Q 1 whole square if you eliminate N and N from these 2, then you get basically P 2 by Q 2 square equal to by P 1 by Q 1 square. So, P 2 by Q 2 square is equal to P 1 by Q 1 square these are this is at speed N 2 and these two are at speed N 2 and these two are at speed N 1, so now having known that we come back.

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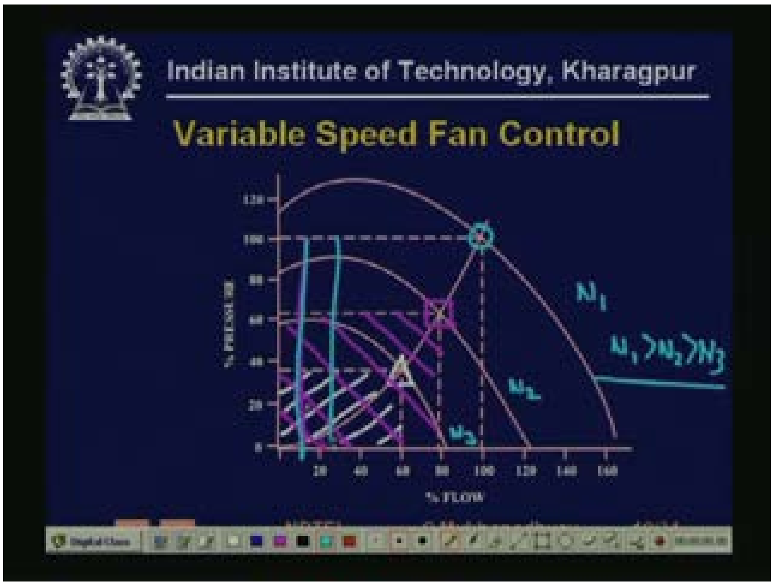

So, we see this variable speed fan control, so now what happens is that if you want to reduce the speed, we are not going to put any damper or any valve in other words the characteristic of the system remains unchanged. Now, we are changing the speed of the fan, so the fan characteristic shifts, so this is let us say N 1 this is N 2 and this is N 3 and N 1 is greater than N 2 is greater than N 3.

So, now what happens is that now the operating point will change along this, this is the first one then this is the second one and this is the third one, so what happens to the power requirements now, so the power requirement for the last one is this. See previously as we were reducing flow pressure was going up, so the power was not falling now, as we are reducing this speed it is not just that the flow is reducing, it is the pressure is also falling and very rapidly too.

So, what happens, so this is the area required this is the it is the energy and similarly for this case second operating point this is the energy and for the third operating point this is the energy, so for the third operating point this is the energy. So, you can very well understand that energy falls very sharply, so that is why you are going to get a huge benefit in terms of energy savings, so you can now see that the power curve how sharply it falls compare to what you had seen in the case of the outlet damper control. So, this is the essence of energy, so this shows that how energy saving variable speed drive can be and just to you know drive the point home, we are going to show you.

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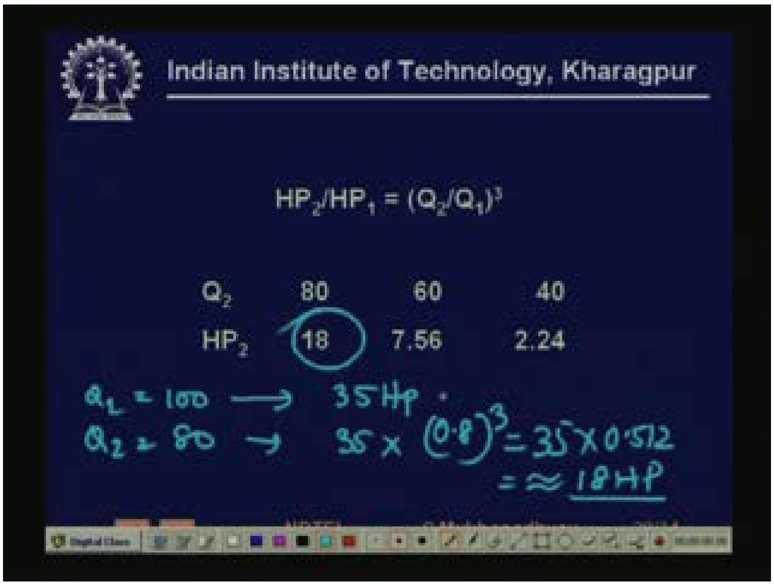

That you know we are just applying that same formula that, what happens is that remember that at Q 1 equal to 100 we had HP requirement of 35 HP, so with Q 1 equal to 80 Q 2 equal to 80 HP requirement will be 35 into 0.80 whole cube which is equal to 35 into 0.512 which is almost equal to 80 horse power. So, this is 80 similarly if you multiply this by 0.6 whole cube, then you will get 7.56, similarly 2., so these are the horse power requirements now applying the fan laws and you can get very similar figures if you see the fan curves, because the fan curves obey the fan laws, so here we are.

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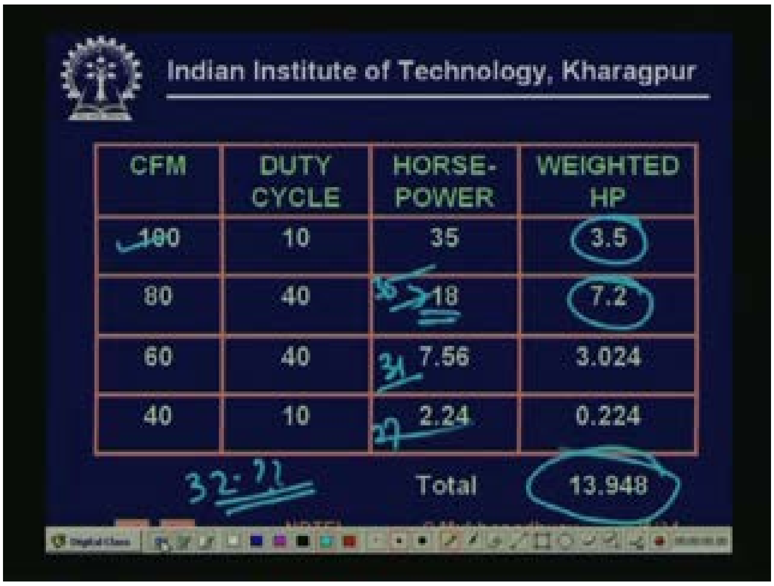

So, now let us see the energy average horse power requirements when you are varying the speed the 100 percent case is the same 33.5, 80 percent case is now totally different this was 35 remember this was 31 and this is was 27. So, now the average horse power requirement is 32 where the previous one 13 the previous one was some 32.something, so you can imagine that what amount of power saving has been achieved almost 20 horse power which is 1400 kilohertz, 14000.

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So, this is you know this is the little calculation this is this Dollar figure is because of the source from which this is taken, but this turns out to be almost equivalent to hour, if you take about 45 Rupee per Dollar. So, this becomes about 2.5 Rupees which is a kind of an average rate not exactly, it vary from state to state it varies on various energies labs and industrial energy rates are anyway not just depends on the kilowatt it also depends on the maximum demand.

So, approximately speaking if you take 2.5 Rupees and if you take 2.5 Rupees here then you have you can enquire roughly you have 10000 kilowatt hour per month, 10000 kilowatt hour per month saving at 2.5 Rupees per kilowatt hour that comes to be a 25000 Rupees saving per month on a single fan. Now, the question whether this is justified, so whether it is justified will depend on see apart from the conservational aspect of energy that we need to be energy efficient, we need to because facial fuel is not going to last forever etcetera.

Even, if you ignore those things then people are going to look at money, so if you it all depends on it is again remember that in the early lessons of the course we talked about capital cost and we talked about variable cost, so energy is a variable cost. So, whether people are going to resort to simple a damper type of control or whether they will actually buy this variable speed drives depends on how much money is required to buy these drives and how much money is required to maintain them against how much savings these drives give.

So, it is all this is basically because of this comparative, these comparative figures which will decide practically speaking whether a particular industry is going to adopt this technology or the other and so it happens that you know, why the outlet damper technology was more common is, because the variable speed drive technology was not so developed it was not robust.

So, it was it was too way too expensive, so therefore people always opting even if there was they were not energy efficient people opted for this damper and valve control kind of techniques. But now with the these variable speed drive drives really becoming robust and cost effective it shows that it makes a lot of sense to acquire variable speed drives for such equipment.

So, this, so basically it is the cost and it is the capital cost of purchasing the equipment and the cost of the cost of maintenance which decide whether these technologies are going to be adopt it. So, you see this shows that how important it is to make a technology cheap and to make a technology robust; otherwise it is not going to be adopted, so we go move over to in the case of pumps.

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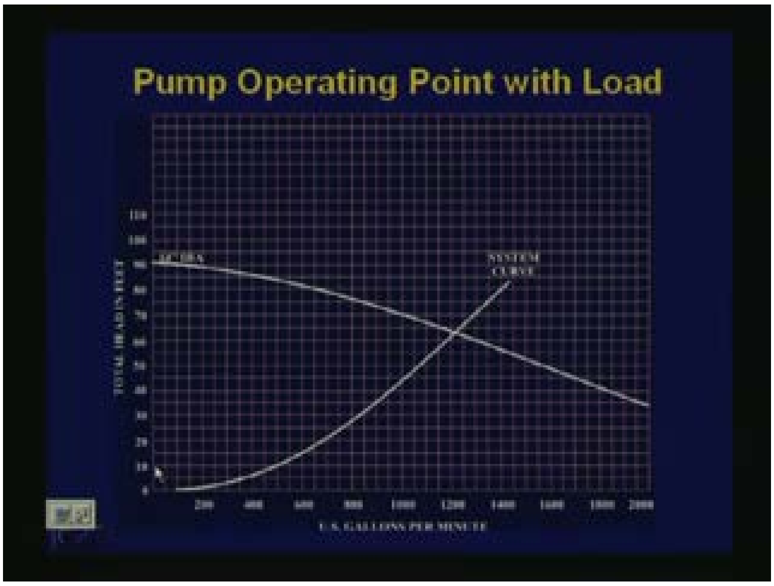

For pumps this is a pump characteristic again the same thing basically is same thing, so we are going to do this little bit fast, so this is the pump characteristic and this is the system curve, which is again you know… Of course, there is a little difference in the sense that fans drive gases, which are compressible and pumps drive liquids, which are generally incompressible.

So, there is a slight difference there, but it looks essentially the principle is all the same this side you have total head in feet of water cover previously you had inches, because that was gas this is liquid. And you have this is given in you can have you have to choose an unit, because this is from an American reference, so this is gallons per minute.

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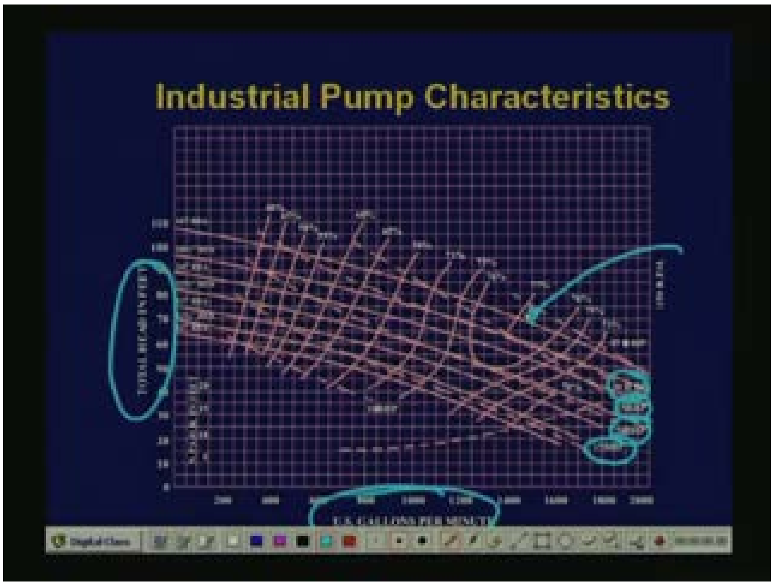

So, similar to the fan characteristic you can have a pump characteristic where again you have the pressure up evidence take, where will we back now to damps, so this is going to be tricky now that I taken from this. So, again you have this pressure and this side you have flow and this side you have you know various RPM you see that, so you have this constant horse power lines and the various speeds also. So, you see that then and this constant these lines are the various speed lines and these doted lines as before are the these doted lines and the constant power lines, so it is like the old curve itself.

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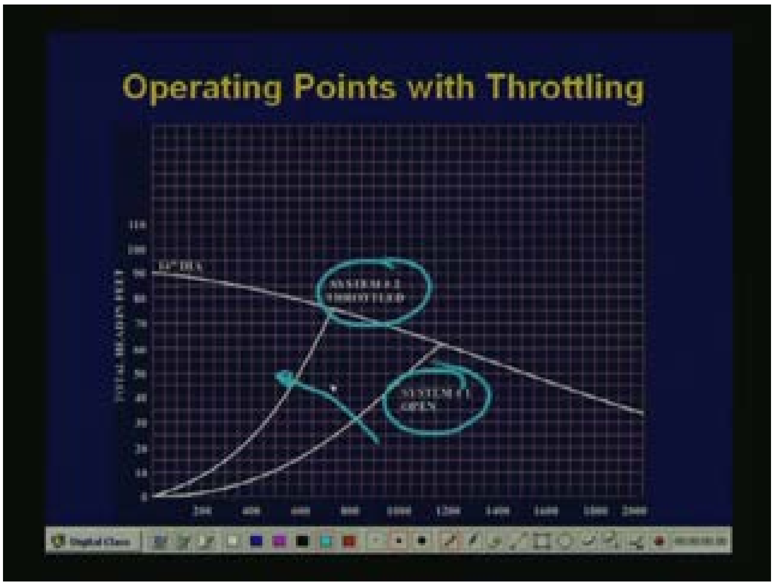

So, again in this case previous in the case of fans you put dampers in the case of pumps you put valves, flow control valves which we have already seen in our earlier lesson, so that kind of when you close the valve it is generally called throttling. So, this shows how the operating point shifts if you have one system which is open, one system which is open another system which is throttled. So, again you see that the load curve changes and the operating point will shift from this to this, so the same thing happens here again for pumps.

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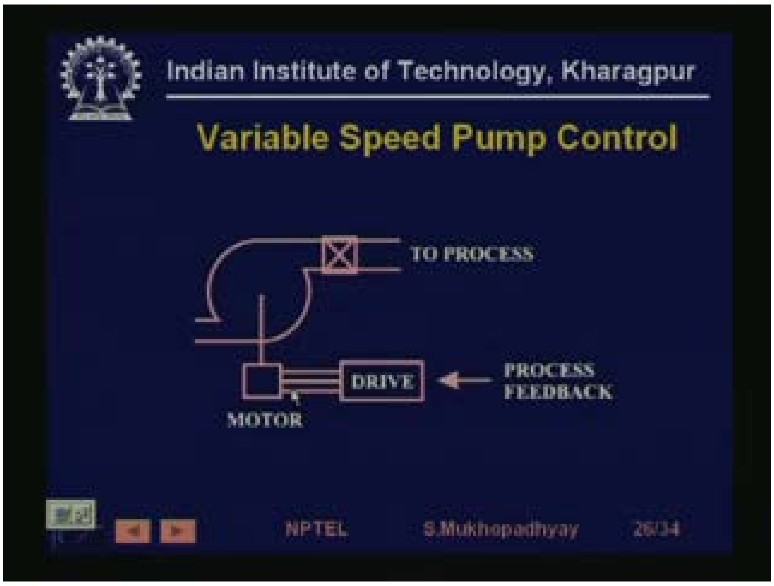

This is a variable speed pump control, so you have you have a constant speed drive one we are controlling is either you have a constant speed motor drive and you have a valve or you have a variable speed drive of the pump, depending on the feedback depending on the load. Basically, that the drive has to be controlled and some speed reference has to be given, we will see in our future lectures as in detail as to how these how the speed of a motor and a pump can be controlled next.

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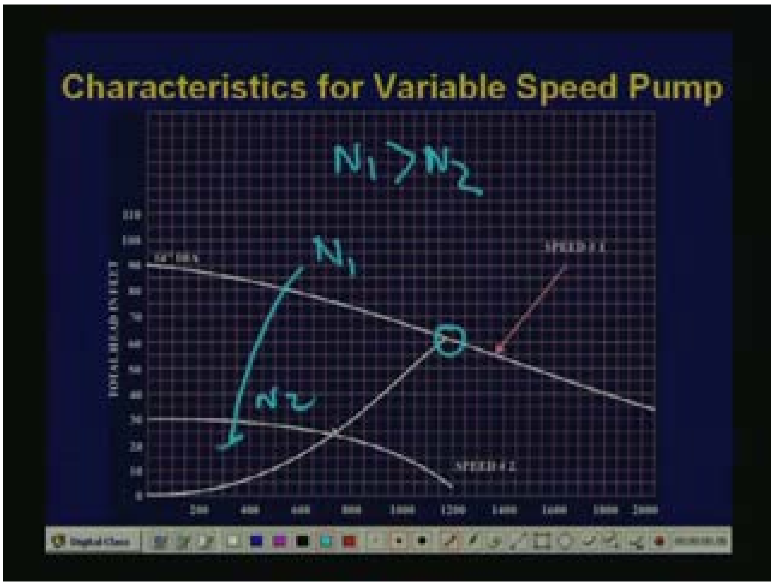

Now, if we control the speed as before the pump characteristic will now come down, this is N 1, this is N 2, and N 1 is greater than N 2, so the operating points will now shift from this to this, just like a previous case.

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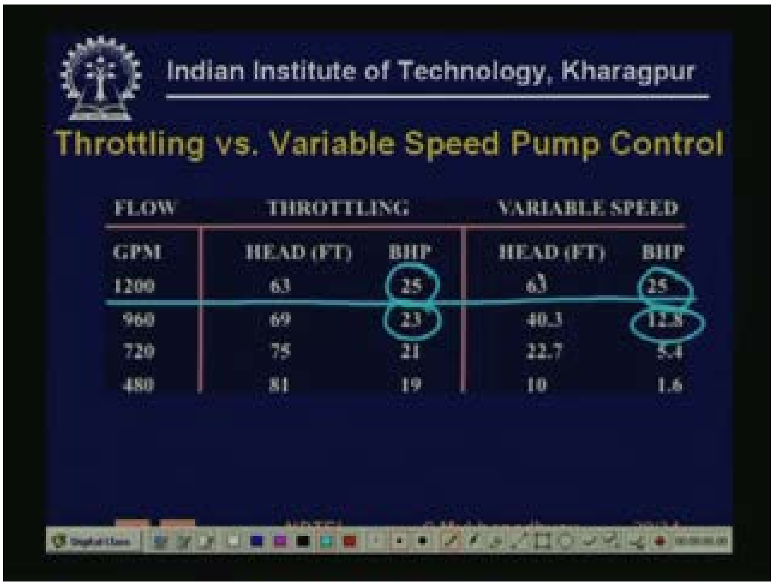

So, if you do the similar analysis on this pump a similar thing comes out that is see a 1200 the head requirement is and the BHP requirement is 25 25 at 960 throttling its 23 hardly reduced, but for variable speed drive it is much more reduce again because of the fan and the pumps laws, so a similar saving will result that is what?

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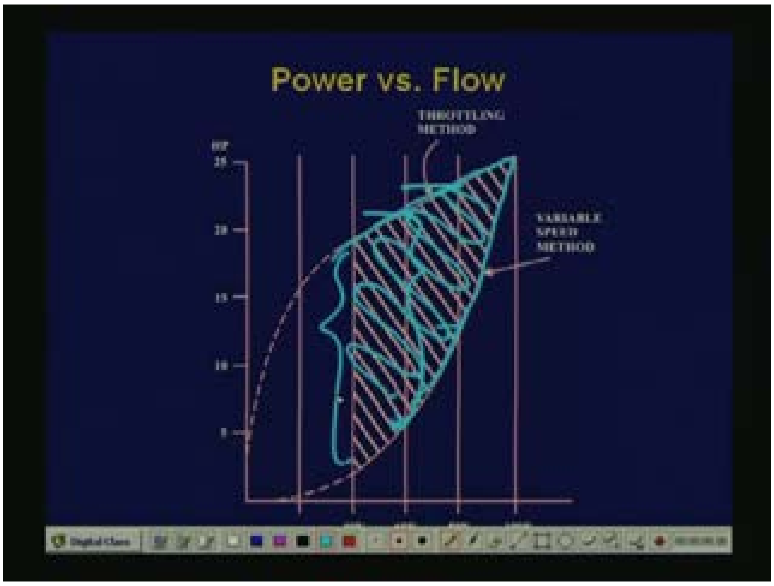

So, we come back, so this is just another depiction that if you have a shows that if you had a throttling method, then the energy would have fallen along this path if you have a variable speed method it will fall along this path. So, this is the energy saving that you are getting rather these input at any load this is the energy saving that we are getting that is the difference between these two which is substantial.

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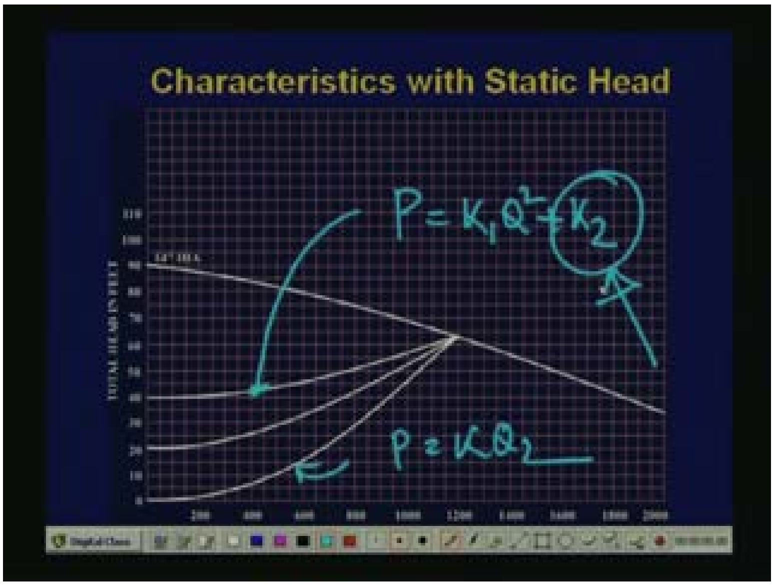

So, only thing is that in the case of the pump there is a there is sometimes pumps operate with a static head, so if you have a static head then the load characteristic can be this is one with without static head where P is equal to K Q square type of characteristic, but a pump can also operate with the static head where the characteristic is P equal to K 1 Q square plus K 2.

So, this K 2 is the static pressure which is there at the pump inlet sometimes, there may be the pump may be elevated you know, so in such a case it has a for example, the load the pump may be below and the load may be at a vertical height. So, even if there is no flow there is the valve in the constant pressure on the pump, so for driving such loads as we shall see that the energy saving is reduced.

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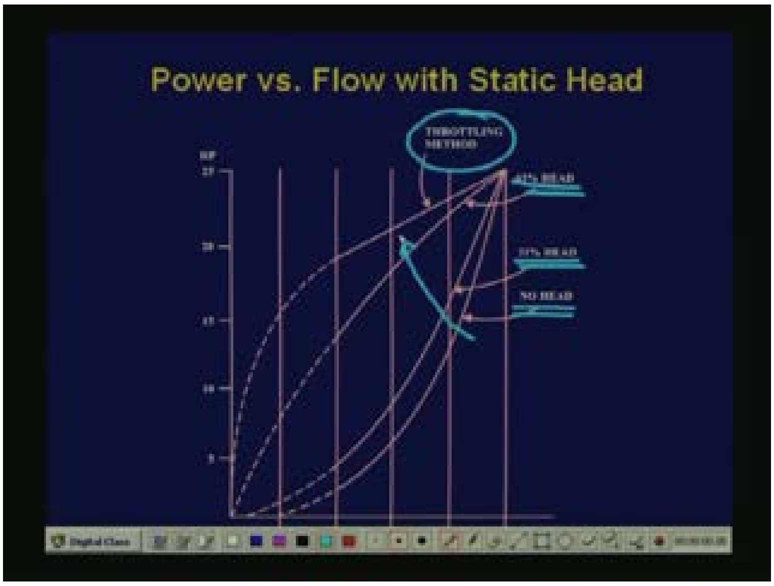

It turns out that with static head this is the throttling method, so and this is the variable speed drive method with no head this is for 31 percent head this is 63 percent. So, as the head increases the energy saving actually reduce moves towards the throttling method.

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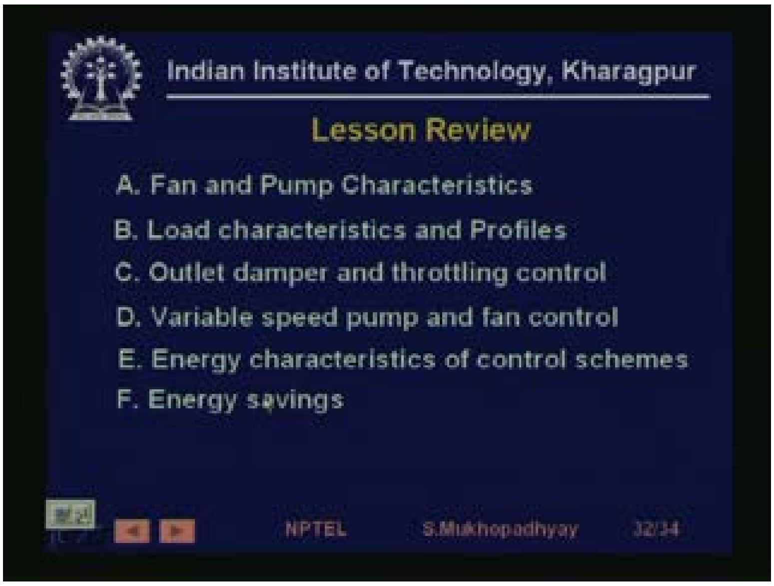

Anyway those are fine points we have what we have done in this lesson is that we have seen the fan and the pump characteristics, we have seen the load characteristics and typical load profiles. And we have seen two kinds of control for fans outlet damper and for pumps throttling control and for pumps, and fans we have seen the variable speed control and we have seen the energy characteristics of this control schemes, and we have I have got an idea of the energy savings.

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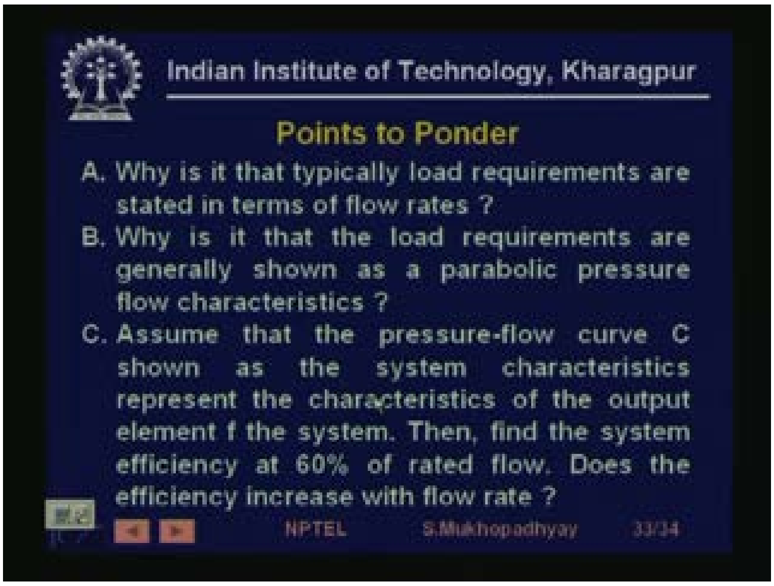

So, here are the few questions for you why is it that the typically load requirements have stated in terms of flow rates why you have to look at the applications and we have discuss this, why is it that load requirements are generally shown as parabolic pressure flow characteristics again. And, the third is that from these characteristic it will be interesting if you can find how the efficiency varies does it increase does it decrease as flow is reduced, so these are the few questions on which you can ponder.

Thank you very much.

Industrial Automation & Control

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Lecture – 32

DC Motor Drives

Welcome to lesson number 32 of the course on industrial automation and control, in this lesson we will mainly be looking at not mainly solely be looking at DC motor drives. Now, we have seen that actually drives are very, very important components of automation, because they create motion and creating motion is extremely important for industrial operations both in the process industry as well in the manufacturing industry.

For example, if you take the manufacturing industry then you need see the whole of manufacturing operation we have just we have done in the previous lecture, some given you some exposure to CNC machines which are various kinds of metal cutting machines. You have seen that very precise motion is to be created in those machines, the either the block or the tool either the job or the tool have to be moved in precise precisely from one coordinate to the other.

So, that is one kind of example then there is a big example of material handling, so all material handling devices require you to create motion, similarly in the process industry you require pumps which will create flow, you require control valves. So, for their operation also you need to create motion, so creating of motions is very important, so we will we are in most cases motion is generally rotational motion is created by a motor, because it is very convenient in a small space you can create that motion and, then using various kinds of mechanisms this motion is converted in to various other kinds of motions like linear motions etcetera.

So, we are going to look at creation of basically creation of rotational motion using motors and we start with DC motors, because they are still widely used and they are the simplest kinds of motors which are used to create motion and lot of application was there, now some of the applications are being replaced by AC motor drives, but still a lot of them exists and it is a proper point to start the discussion on drives.

So, in this we will mainly be considering we will first we have an introduction like we are having now and, then we will look at two kinds of you know we are basically in this lesson we are basically going to see what is the technology how exactly what is the engineering of the drives how exactly these motors are rotated sometimes, they are accelerated sometimes they have to be decelerated they have to stop start, they have to move clockwise counter clockwise. So, how all these motions are basically created the technology part of it not the analysis part of it.

You have all ready seen some part of analysis of DC motor control in the context of a CNC machine in a previous lesson, so in this lesson we are mainly concerned with seeing how in a motor you can create various kinds of motion. So, we look at two kinds of this creation of motions since these are electric motors, so they create, so they require various kinds of electronics power electronic devices and circuits. So, we are going to look at two broad classes of circuits one are line frequency converters and switch mode DC-DC converters which are which will show you two different ways of controlling DC motors, so having said that let us look at the main instructional objectives of this course.

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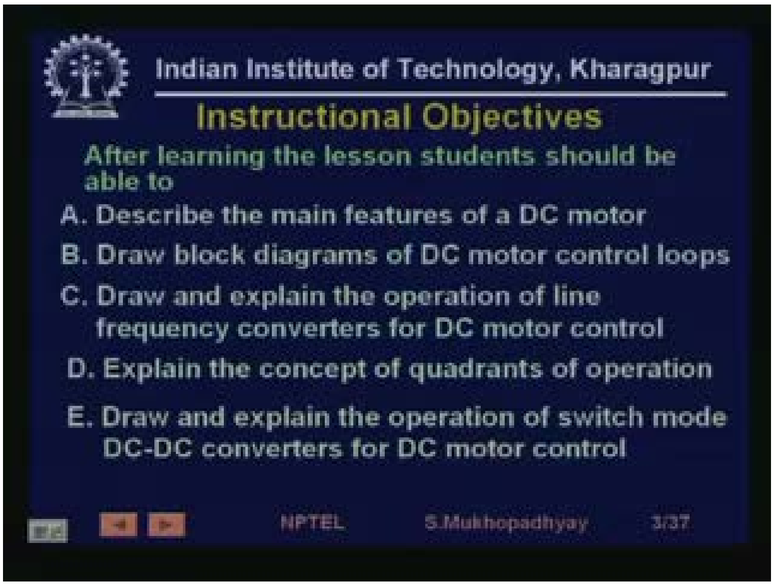

So, after learning the lesson the student should be able to describe the main features of a DC motor, basically should be able to understand how it works, then should be able to draw a block diagrams of various DC motor control, loops to be able to identify how the DC motor is excited how feedback is obtained etcetera. And, then they will be able to explain the basic ways in which a line frequency controlled basically, line frequency AC to DC converters for how they are used for DC motor control. And finally, they will they will also understand the aspect of you know the, there is a concept of four quadrant operation of motors, so that is very important in for drives to understand. Then, lastly they will be able to explain the operation of a switch mode DC-DC converter based DC motor control.