Design of Mechatronic Systems
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Lecture 4
Elements of Mechatronic Systems – Part III

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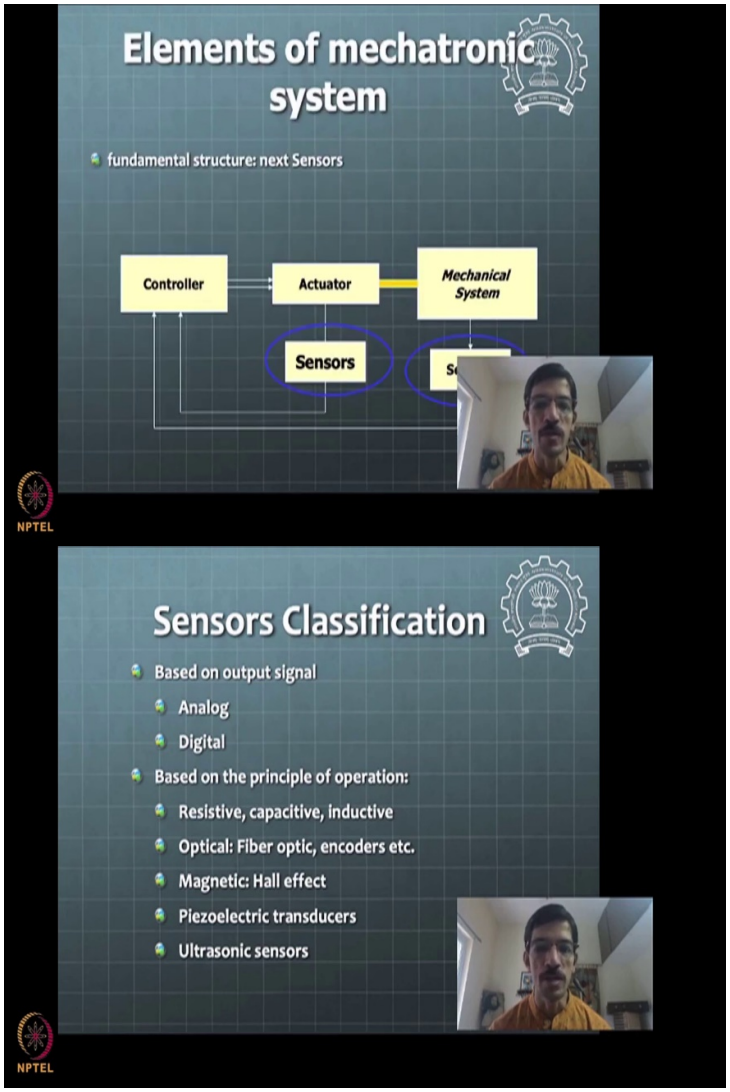

So now, we will continue our discussion on these elements of mechatronic systems. Last time we had seen some sensor elements. Remember these you can have a look at. So, let us flash through the slides and so last time we had seen these different elements of mechatronic systems and then focused on our sensors and seen some of the classifications of the sensors based on the analog and digital output and based on the principle of operation of the sensors. So, in today's class, we will continue a little bit of a discussion pending which is on the

MEMS sensors, which are which are these days more popular for many applications, because of their cost advantages.

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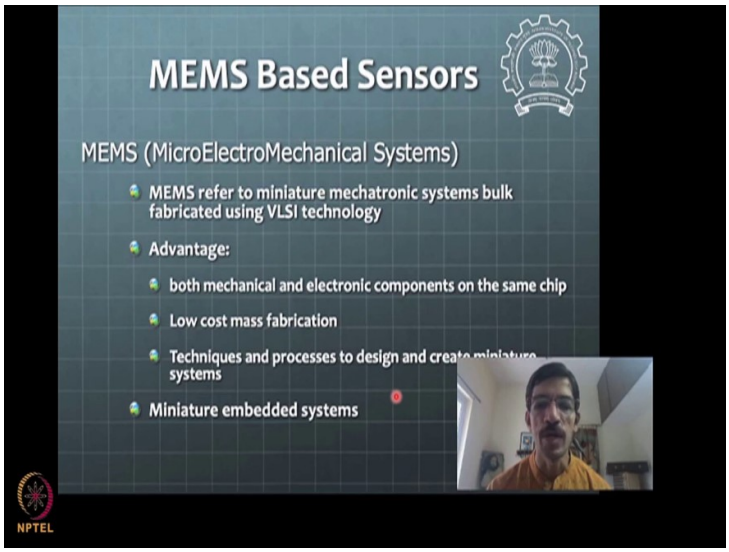

So, the MEMS refers to microelectromechanical systems. They are fabricated by IC technology, you might have seen foundries where, these people wear this kind of a dust free cloth and then you know enter the foundry and then fabricated chips. So, that chips usually like computer chips will have only electronic components. Now, if you can imagine if you are a computer chip will have some a mechanical kind of components then it refers to this MEMS technology of bulk fabrication of many many sensors at a time on the surface of a wafer.

So, because you can fabricate maybe 1000s of sensors in one kind of a process, its manufacturing is very easy. Manufacturing cost is very low, manufacturing may not be so easy because it undergoes VLSI processes which are based on the equipment which are costly equipments. So, the advantages here are you can have integrated fabrication of sensors with both mechanical and electronic components on the same sensor.

Then low cost of fabrication. Low costs due to mass fabrication and the techniques and processes can be designed to create really really small systems. So, this is a very interesting area of application or area of research also.

There are many interesting systems that can be developed based on this MEMS technology and one should be aware about this. So, somehow maybe we can reserve some separate lecture on this actually, at some point in the future classes. So, where we can demonstrate

some interesting sensors and actuators also in the MEMS based technologies. For now, we will go forward with other kind of topics that we would like to see here.

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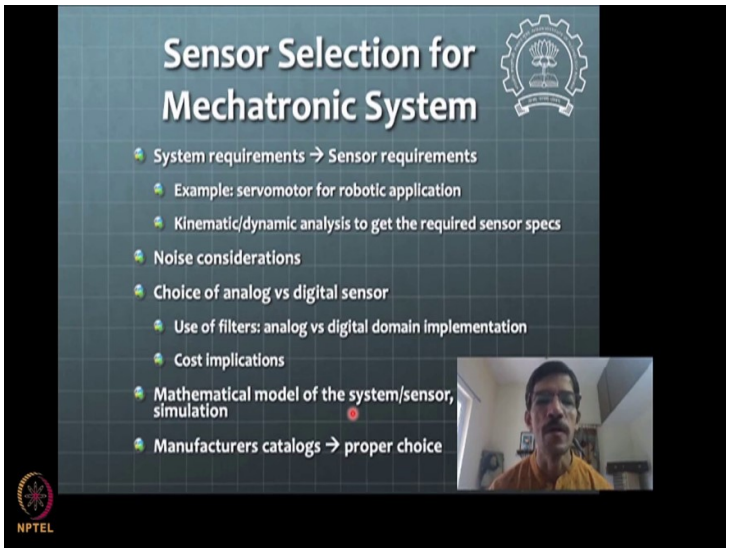

So, this sensor selection again, we will come to this topic later on also, but we need to have some a common sense understanding for sensors selections. For example, if you want to get sensor selected for a given mechatronics system. See, this is like evolving, design processes iterative and evolving. So, you cannot immediately come up with the specifications of the sensor, but you will have some kind idea then you change the, start developing first kind of design then with the analysis you find well, we need to fine tune some specifications.

Like that a design is evolving process for mechatronic systems. So, we will have to go through this evolving process. We may not have all the details at one go. But as we start thinking about applications we will get to know more and more details and then we can incorporate them into the requirements and the development selection of the sensors and things that.

So, from the systems requirement perspective, you need to get to the sensor requirements. So, that process is maybe somewhat based on prior experience or maybe based on some mathematical analysis. There are many different ways we can do that and again, iterative way it will go.

So, we will go through this kind of a process sometime later, but these are some issues that were needs to be looking at for selection of sensors, then second one is a noise consideration. So, if you are doing the analog sensing versus digital sensing, you need to worry about the

noise in that way. So, you may need to filter or you may need to take care of the noise in analog domain or in the digital domain.

So, for example, if the wire or the sensor is already giving some kind of a noise before even getting into digital domain, you may pass a sensor output through some analog filter, some simple RC circuit will take care of that. Then you of course, you will have a cost implications with this. Then mathematical modeling is going to be important for simulations to kind of come up with precise specifications for your sensor.

And then you typically go through manufacturer catalog and match the requirements whatever you have generated the sensor requirements; you need to be matching with manufacturer's catalog and getting, selecting a proper sensor. So, that is a kind of process that goes on for the sensors election. So, we will do this process sometime later, but you should be aware about these parts here.

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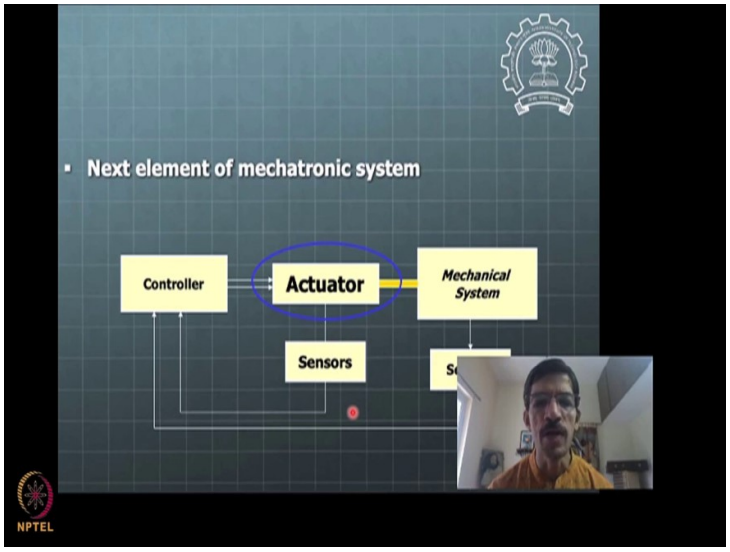

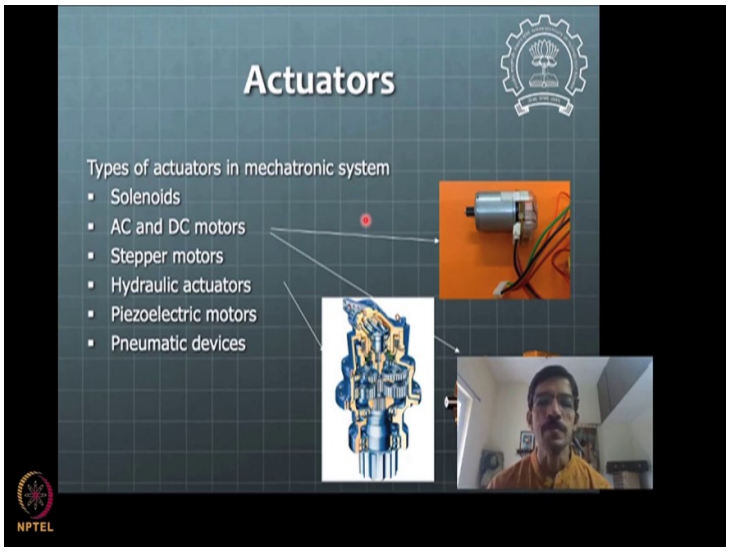

Then, we have a next element, which is actuator in the system. Now, for actuator we have lots of different kind of choices. So, from the mechatronics perspective, now I am not really talking about only techno many kinds of different kinds of actuators that are found in the literature. We can have actuators which are like, I would say servo controllable, that is what is important here.

So, there are many, many actuators, they can make servo controllable possibility, but these are some of the most popular kind of actuators. So, solenoids is one of the important class. They are used in mainly push button, they are not servo usually, so solenoids are not a servo actuators, but they are digital ON or OFF kind of actuator.

So, they are used in many kind of mechatronic systems, especially the process industries and things like that, where you want to do suddenly open a valve or close a valve which is not, it is a digital opening and closing or you need to remove the articles or parts from the conveyor belt, which are not really suiting the, you need to reject the parts of the conveyor belt.

That actuation one can do by solenoid. So, many many different places they have applications, then AC or DC motors, these are very important class because they are most popular actuators in mechatronic systems. Then you can have stepper motors also big class and then for the systems which are very heavy, you will have, which have very high power requirements, we will have hydraulic actuators and nowadays very precise application piezoelectric motors for example, autofocus cameras or DSLR cameras will have this piezoelectric motors, for moving for the motion of the lens.

So, you can see that very interesting sound that comes when you when the lens is focusing in your SLR camera. That is because of these piezoelectric motors, then you may have pneumatic actuators are also a possibility. So, we will go briefly through each of them and not so many details, but as we go along we will get into more and more details.

So, this is a motor which is DC motor along with the encoder here, so this is what we will probably use for our programming or learning the practical parts of the of the system. So, with the TIVA board, we will use this motor with the encoder attached to it for that understanding some of the fundamentals of control that this course has to offer.

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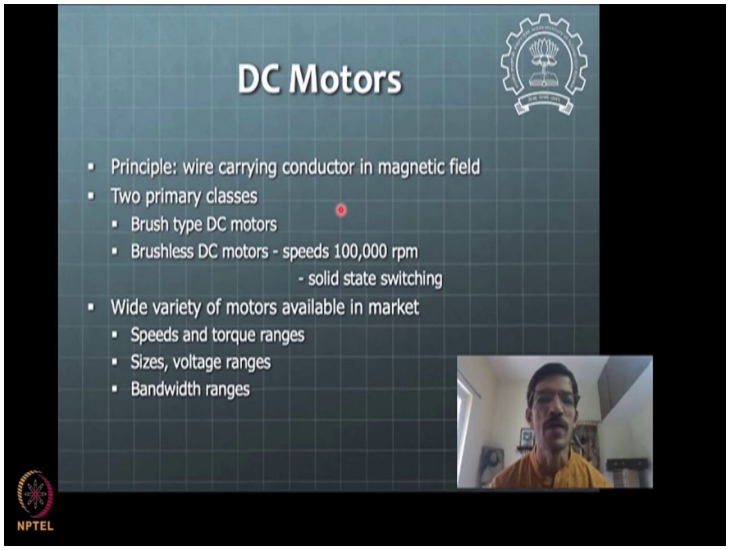

Now, coming to the DC motors, this you know this you know the principle, there are two primary classes which is brush type in brushless type. So, brushless types are where you use it for the applications where you need a high speed and then wide variety of these motors are available in the market. The very high precision manufacturing or very high quality motors will find from the companies Maxon or Faulhaber.

Those kinds of companies will produce these motors which are very, very good quality motors, but otherwise also, there are many, many companies in the market where these motors can be available and speed, torque ranges, size voltage ranges, you will have lot of variety you will find with the DC motor.

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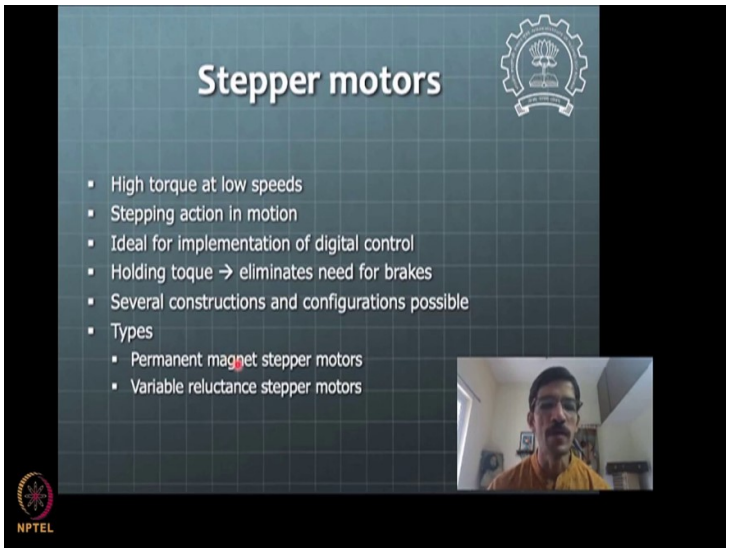

Then stepper motors are another popular actuators for mechanical mechatronic systems, we will see some of the applications soon. They are used in the places where you do not need a sensor. So, you can rely on the steps, making sure that the steps are not missed in the drive way based on the capacity.

So, you choose a motor of a capacity that the steps should not be missed and you are simply give so many number of steps and the application will be running smoothly. If there are external loads, which will prevent the steps to be slipped then these actuators are not really good.

So, you need to make sure that the torque that is required for the application is not higher than what your choice of the motor. So, motor should be delivering higher torque than the application needs, then they should be fine and it, the stepper motors also have this a holding torque which eliminates the need for brakes if at all the application requires that. Again, there are several constructions and configurations possible. So, we will get into some of some more details but if you have some idea about how they work for example here.

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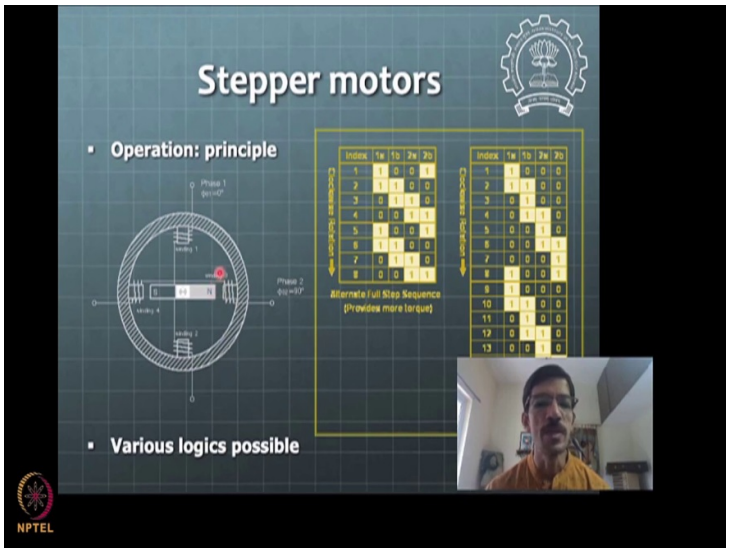

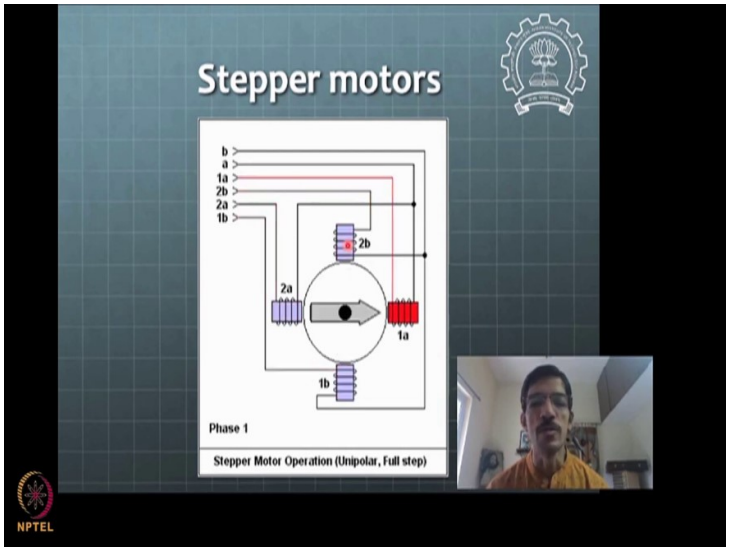

So, this operation principle is very simple here you excite one coil and then are you excited the next coil the rotor will move to the next position and then you will have sequence of excitation of different different coils. There are typically four coils in the stepper motor 1A, 1B, 2A, 2B, there are a standard terminology that is used that. And these operate in a very different many different logics that can be possible. So, for example, in this case, maybe I will show you the animation of the logic. So, you have only one single excitation happening at a time now. So, this is one mode of operation, it is called full step operation.

Then if you see, if you want only half of this step to be happening. So, what we can do can you think about? For example, one of the ways to get to these micro stepping modes there are different these micro stepping modes can be possible. One of the ways to get to that is, you

control the voltage itself on each of the coils. So, I tell you how we can control the voltage and do that when we see this half step mode, you may understand things better. So, half step mode, you will see this is the thing that will happen this is going to happen. Can you see that? So, you excite one coil and other coil next to it both together.

So, we will make the position of the rotor into some kind of a middle position here. Now, if I want to change this middle position to do either side of this coil or side of that coil, I can excite these two windings differentially, are you with me? So, we should think about how can we have some multiple steps possibility between the two half steps?

So, this is one half step up here and other half step or within one full step, how can have, how can I have more steps than half step possibility? So, think about that it is very interesting way you can see that, we can operate stepper motors to give you really really high resolution although the steps are designed or the motor is designed to give only this single step or half step or something.

We can possibly by changing the control or by changing the amount of energization of one coil versus other coil; one can have like many many different possibilities. So, we look at those possibilities again in the future, we may deal with more details about actuators. There are these different applications of stepper motor; dot matrix printers, nowadays, these are extinct now.

You might not have even heard of this name of dot matrix printers, floppy drives also are extinct. We used to be in the past, you have a magnetic disk and you can drive things by I mean store the data on the disk, which is nowadays all replaced by pen drives. Then, lot of robots we have many many different applications. So, we will see some of them, CD ROM drives, there are some interesting ways stepper motors have been used.

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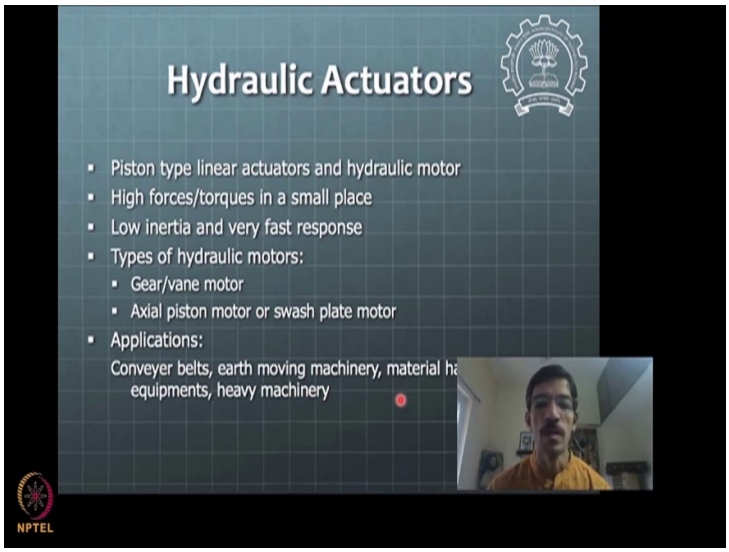

Now, we look at little bit of hydraulic actuators. So, in hydraulics you can have two possibilities; one is a linear actuators or you can have a hydraulic motor is also possible. So, we can see how hydraulic motors can be made to work actually. So, we will see that. Hydraulic actuators would be useful in the places where you need a very high force and you need very high torque in very small kind of compact environment.

However there as the name suggests, you need some fluid that can be given this pressurized fluid which can be given this actuation. So, you need this entire system of, oil tank and oil pressurization and things like that. So, that entire system needs to be there together. Then you will have very high forces and torques in a small place that can be possibility.

Because of the high torques naturally they will be very fast in having relatively low inertia and very fast response. There are many different hydraulic motors possible with the principles, the vane motors is one of the ways that you can have hydraulic motors created or you have axial piston motor or swash plate motor.

So, you just Google about this and you will see how these motors, these hydraulics are working. Their applications will be mainly in the conveyor belts or earth moving machinery, in big machinery, where you want to dig out some things and those very high forces are needed, that is where you use these hydraulic actuators.

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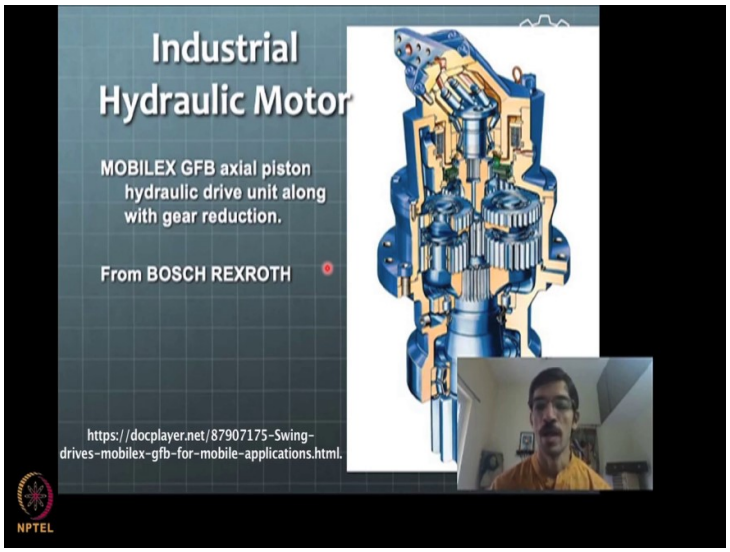

So, this is one of the open up picture of hydraulic axial piston motor. So, you can see that pistons are up here and they are operating this swash plate here, the swash plate is a rotary plate with pistons which are coming at an angle. So, you can imagine when this piston is pushed here, the torque which will be created will push the shaft it will rotate the shaft in this direction.

And once that piston is in the end position, then that the hydraulic force will be removed here and then the next piston will be operated and then the next person in this position will be again pushing this to the end position. And again this operation continues with multiple pistons that are there and the way this motor is rotated.

So, very high force can be applied here with the high pressure of the oil that is there in the piston and then that can be controlled in by using some hydraulic servo valves. So, that is another element that will be needed in the system to that is our electromechanical interface to this actuators.

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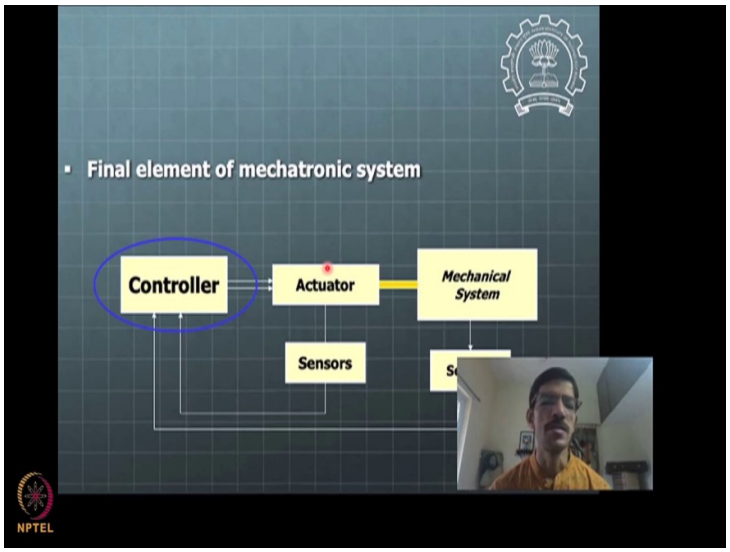

Some applications here; then last element is controller, so we will talk briefly about controller again, I am just giving you some somewhat brief overview of things where we have to talk a lot more details as we go along the in the course. So, but this is some a, brief idea you should have in your mind to slowly start understanding more and more details about.

So, or you may, there is a questions based on these to think about and then, we will take up these questions as we as we go along. Let us that that would be a good way to understand things better.

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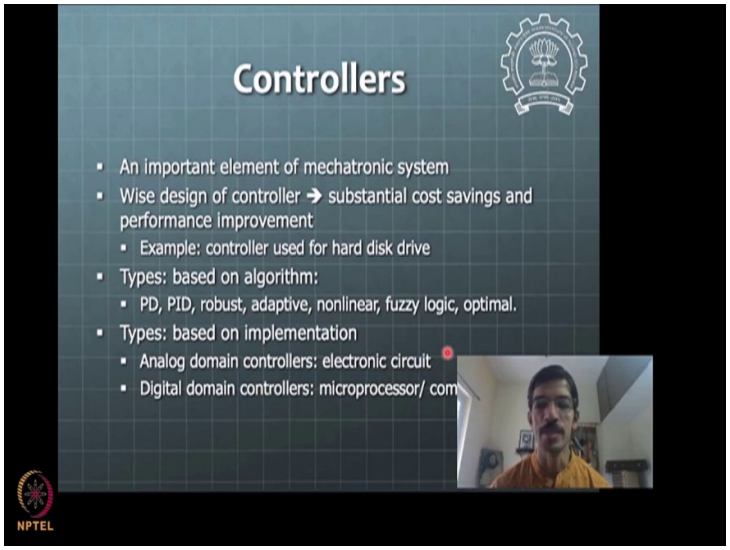

So, controller is also very important element of the mechatronic system. So, why is controller design can lead to substantial savings in the cost? So, I will we will see some examples and understand this part. This is very very important point that we need to be aware about that, know the way you design control, would have a lot of cost implications.

See controllers for example used in hard disk drives; they have been designed to perform really really well in with also which will not demand a lot of investment into the sophisticated nature of the arm that is there for the hard disk drive to, see this arm positioning on the surface of hard disk drive is extremely precision, high precision application is required there.

But the way the controllers and inherent mechatronic system is develop, you can have that at a very low cost that can be possible. Maybe we will have some chance of looking at hard disk drive a little more in detail as we go along. Then there are different kinds of algorithms that can be possible.

So, some of the algorithms are listed here, but there are not the complete list, you have you will have lots of lot of possibilities in this domain tons up papers and some literature is published on the control algorithms for many different applications. Then you can have types of algorithm based on the implementation class.

So, you can have analog domain implementation or digital domain implementation and that you can have controller developed in different domains. Mostly when we talk about mechatronics system will chiefly consider this digital domain implementation by using microcontroller or microprocessor and analog domain also is possibility but we will see whenever we have some simple controllers implemented then analog domain can be okay.

Some kind of PD PID controllers we can implement by using this op-amps basically op-amp circuitry, but then we cannot change the gains on the fly. There are some disadvantages to the system but as long as we know that this is what we want finally and is fixed it is not going to change ever then analog domain controllers are not a problem.

But digital domains nowadays are available at very low cost of people I do not think are going to do the analog domain kind of circuits these days. Only advantage analog domain will give is the continuous domain implementation or application, which is not possible digital domain. We need to have some sampling done for getting the digital domain implementation in place.

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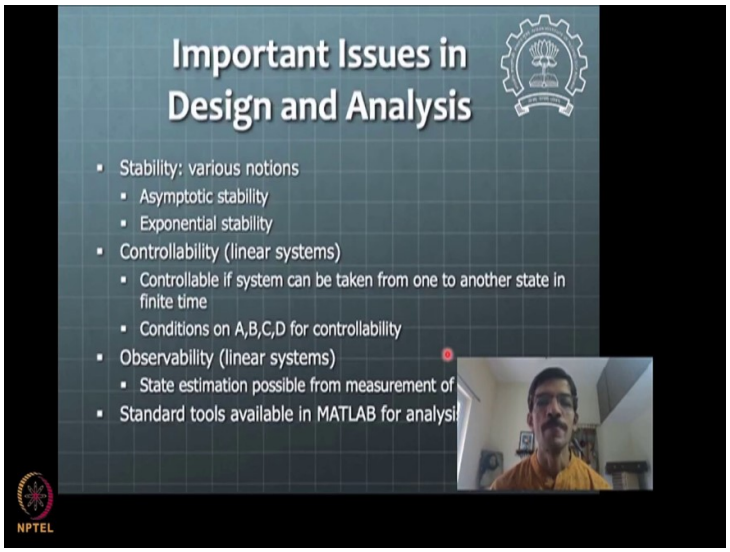

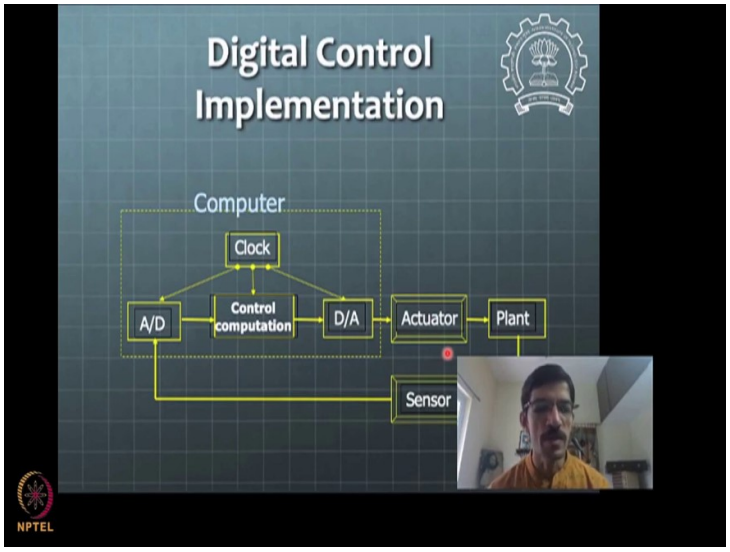

So, there are some design and analysis issues for controllers which we have to again deal with anyway in the great details later. So, I think maybe we will stop here.