Industrial Automation & Control
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Lecture - 40
Course Review and Conclusion

Welcome to lesson number 40 the last lessons of this course, so we have come to the end of the journey and it is time to recollect the places that we had seen. So, in the last lesson we will take a quick review of the course all the lessons that we have taken, and finally we will make some concluding comments.

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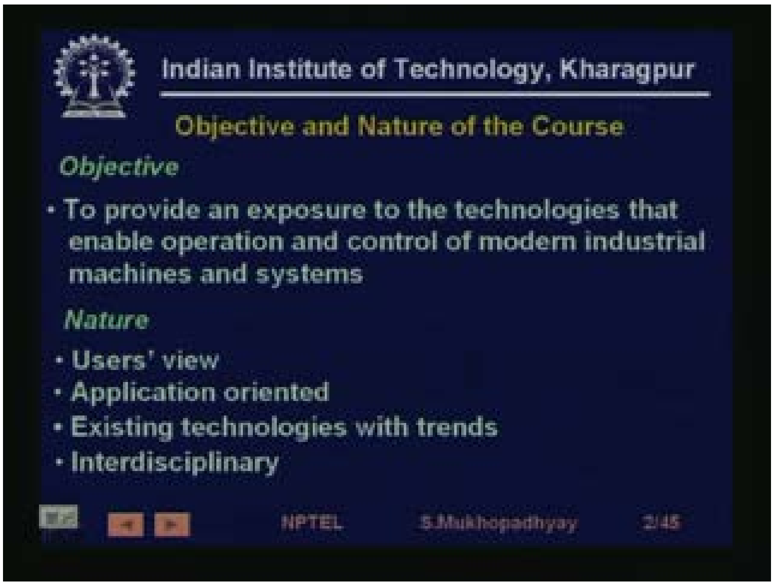

So, let us recall the objective and nature of the course as we had stated it in lesson number 1. So, the objective is to provide an exposure to the technologies is that enable operation and control of modern industrial machines and systems. So, in short I wanted it, so that if you go and visit a factory which produces something discrete manufacturing processes, steel plant, auto factory. You should be able to recognize much of the equipment and systems that you see and also be able to make out how they work, so that was the basic objective.

So, as we stated in lesson number 1 that this is essentially a user's view, so you we for a large body of technologies, is which are used in for automation. In various types of industries we want to understand basically how they work and help in producing things rather than contrasted to users view is the designer's view. So, we do not want to, this is this course is meant to be.

So, in depth that, you can start designing some of that equipment that would be an order of magnitude enhancement of depth and we have not attempted that here. We said that we will keep it application oriented, so whenever we talk about a technology we will try to make it always talking in the context of it is use, so how that does that help.

We will mainly talk about existing technologies, not very cutting edge technologies. But, some sometimes will we will also try to capture the trends that are happening in industrial automation. And, we said that this is going to be an interdisciplinary kind of course, in the sense that a lot of people, although this is predominantly electrical, in the sense that lot of the depth or the exposure that is expected in the electrical discipline is more than in the other disciplines.

But, I guess still industrial automation technology is necessarily interdisciplinary and therefore, of interdisciplinary interest. So, it should be possible for somebody from mechanical or chemical to go through this course may be with little bit of extra effort in building of the background in some of the electrical parts. So, that was the idea of the course, that to provide a view towards the breadth of automation technologies used in the variety of factories and to try to understand the basic operational issues in that.

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In that was in lesson 1, so that was the major objective of the course then in lesson 1, we started the course in a very general note and tried to define industrial automation. So, we tried to motivate we tried to basically see, how if we see that automation is, I mean an industry is a systematic economic activity. So, and it is primary objective is to make a profit, then we tried to find out, how automation helps in making profit. And then we found that we introduced the concept of economy of scale and scope that in and showed that in both respects automation helps.

We looked at the various types of production systems, the various types of factories batch processes, continuous processes, job shops, various kinds. And finally, we categorized the classes of automation, system fixed automation, flexible automation integrated automation, so tried to discuss that, which kind of automation is actually good for what kind of factories.

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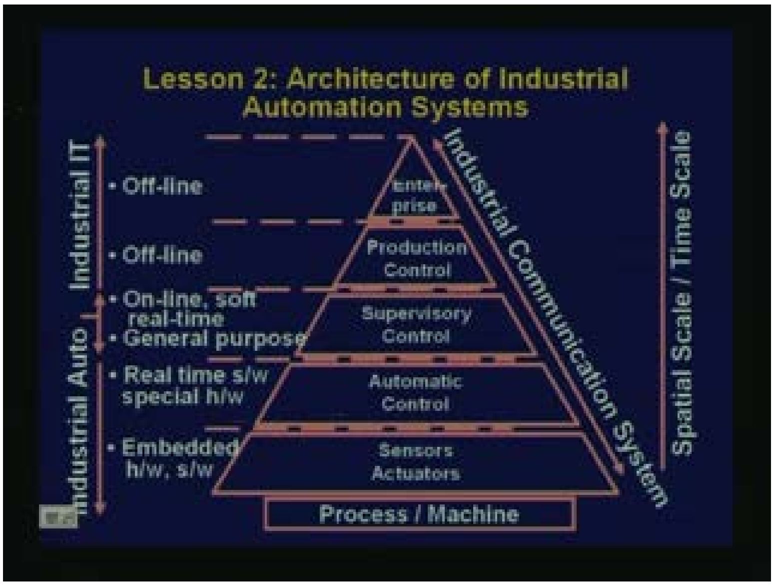

So, then we in the next lesson we took a look at the architecture of industrial automation systems. And, we introduced the automation pyramid and the levels of automation, so we talked about the levels 0 of sensors and actuators then level 1 of automatic control of various protection alarms. Then supervisory control process monitoring set point optimization then production control scheduling maintenance management inventory.

Then finally, enterprise control where we basically finance business HRD marketing and we set that all these for today's modern efficient factories all these have to be integrated and they must continuously exchange information from the field and decisions from the various parts in both ways. And this must be enabled by some sort of a industrial communication system.

So, we also said at this point of time that in this course we are going to mainly concentrate on level 0 and 1 and we said that that is primarily industrial automation, and the higher layers are more in the realm of industrial information technology and we are not going to cover that in this course.

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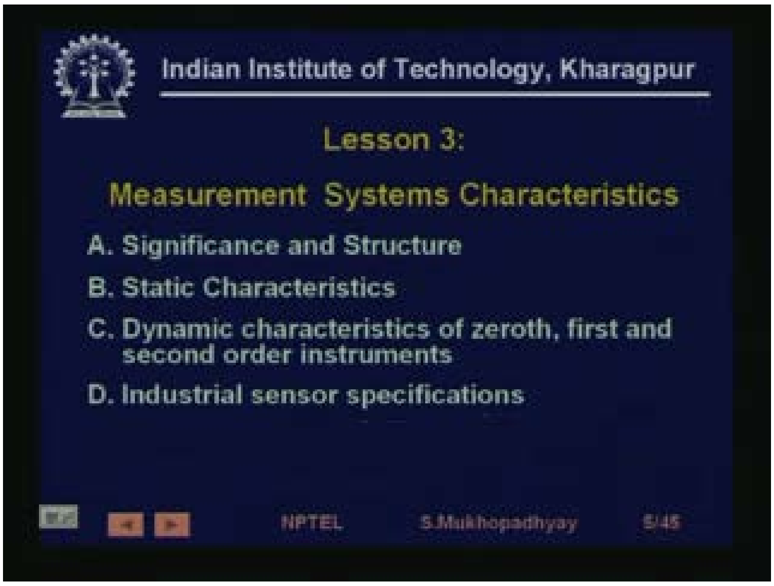

So, we started with level 0 and we first talked about the sensing system. So, we first took an abstract view of measurement systems and found, what are the typical structures, what are the typical static characteristics and dynamic characteristics by which, you can describe the performance of any abstract instrument.

We also looked at some typical sensors specifications of industrial sensors, then having done that having taken a look an abstract sensor. We started taking look at the exact I mean the individual sensors for the typical process variables which are measured and which are controlled in an industrial environment like temperature. We talked about various kinds of temperature sensors, and of course there signal processing circuits, we talked about pressure force and torque sensors. So, low pressure, high pressure, force measurement strain gauges torque measurement.

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And then we talked about position velocity and acceleration sensing, position velocity and acceleration position velocity sensing are very important for a manufacturing, because from the point of view of manufacturing accuracies So, we talked about position sensing for example, speed control is actually a very, very, very important function. So, position and velocity sense sensing, so we talked about position sensing various techniques resistive inductive capacitive, velocity sensing various electromagnetic sensing optical sensing techniques as well as acceleration sensing.

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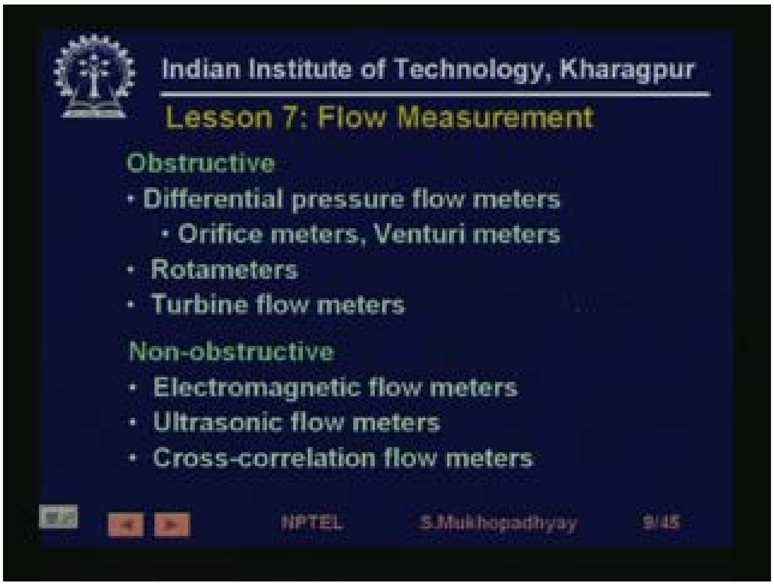

Then, we took a look at flow measurement, flow measurement is very one of the most widely measured and controlled variable in especially in process industries flow, because as we said that for temperature control you have to do flow control. For example, steam flow control for level control, you obviously have to do flow control, because level is nothing but flow integrated. So, for pressure control you also have to do flow control, because pressure is also in a way flow integrated and then flow control is obviously flow control.

So, the measure variables pressure level flow temperature, all these in many cases come back to flow control and flow control implies flow sensing. So, flow measurement is actually a very important component of process control, so we talked about various the obstructive methods of measurement including differential pressure flow meters like orifice and venturi rotameters turbine flow meters. We also talked about non obstructive methods the electromagnetic flow meter, ultrasonic flow meters, cross correlation flow meters and things like that.

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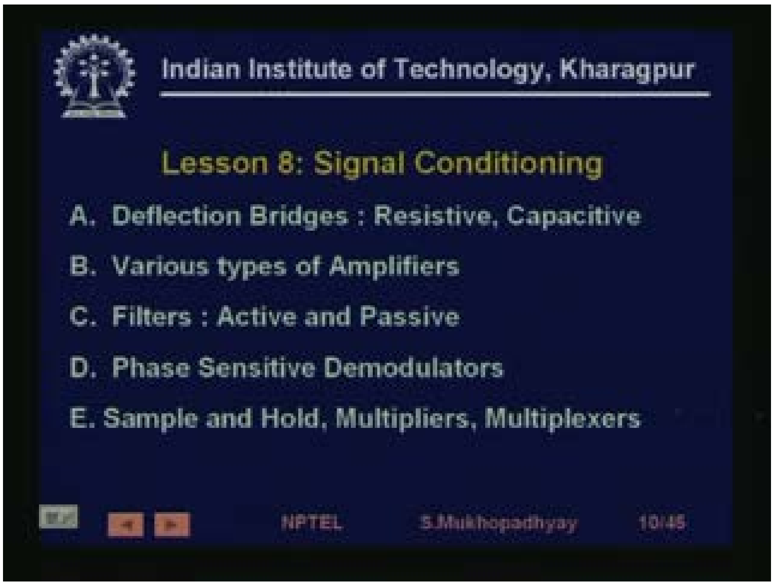

After flow measurement, we took a look at signal conditioning, because signal conditioning today is electronics is giving us. This feature that signal conditioning is a very important and there are some typical for instrumentation there are some typical signal conditions as which are used with large type of large number of sensor.

So, we talked about deflection bridges both resistive capacitive, then various types of amplifiers voltage amplifiers, current amplifiers, voltage controlled current amplifiers, charge amplifiers. So, we took looks at various kinds of amplifiers and filters are very important for removing noise, so filters active and passive filters.

And, phase sensitive demodulation demodulators, I mean in many cases the raw signal out of the sensor comes in a modulated fashion. For example LVDTs or strain gauge bridges, so it what needs to extract or demodulate the actual process variable that one is interested in, so that requires a phase sensitive demodulated circuit. So, we introduced that and various other kinds of circuits like sample and hold multipliers and multiplexers we talked about.

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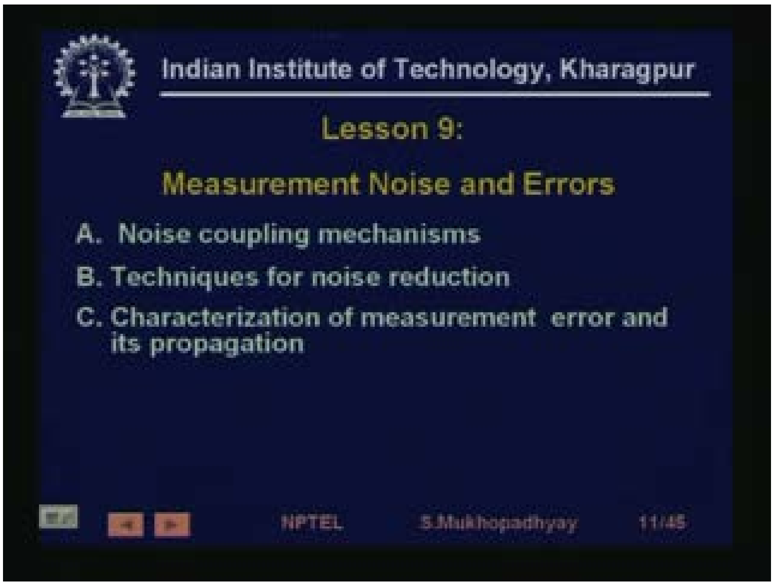

Then, we took a look at measurement noise and errors measurement noise and errors are as. So, how does noise get coupled to a sensor and as we will see that noise is actually very important, because noise reduces measurement accuracy. It also creates problems when a sensor is giving feedback to a to a process control loop, so if there is noise in the sensor, then as we have seen that the whole process control loop will start oscillating. Noise can also give you noise and errors can also give you other kinds of for example, quality control problems they can give you dimension errors. So, there we need to understand how noise gets coupled in circuits and some of the techniques and precautions to be taken.

And then still we have to live with noise and we have to we have to characterize it, so we have to know that the performance that we are getting out of our measurement systems to what extend it is certain and to what extend it is uncertain. So, we need to you know characterize, we need to build a model of models of measurement errors, so that we can specify our quality of our products.

So, we talked about measurement errors and then we talked about that each individual typically a system consist of subsystems. So, even measurement systems have various subsystems, so there can be a primary sensor, there can be a secondary sensor, then a then a signal condition and then a signal processor. Now, each of them has their individual noise characteristics. So, these noises are generated and they get propagated through the system, and so we also discussed that if noise is propagated, how does it affect the final readings of the instrument.

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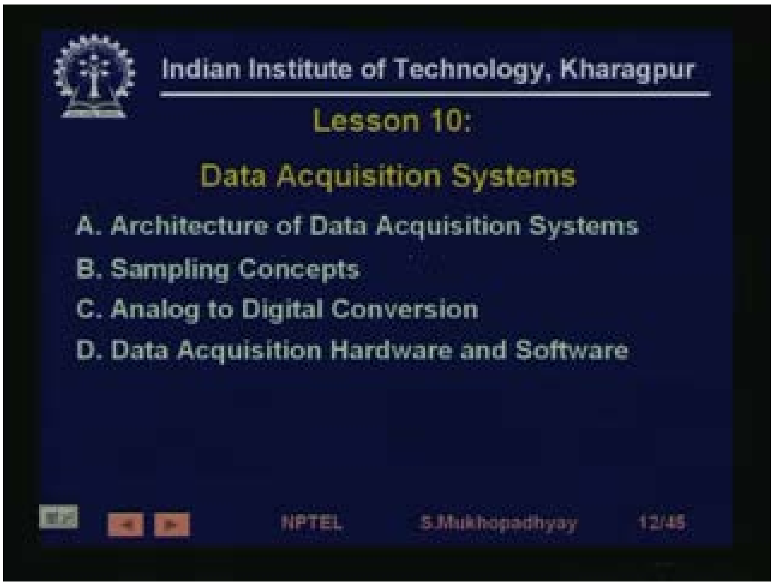

Finally, in today's automated environments the sensors are typically connected to the data acquisition systems which are connected to the computers, so that these process variables which is the final reality in the field and which is the real story about the production process. So, that one can measure it sense it analyze it monitor it control it, so all that is today done by computers. So, one of the first things is to get these process level signals into the computer and that is done through data acquisition systems. So, we took a look at the architecture of the data acquisition system, what they are made of and how they get the data into the computer. So, we started with sampling, then we talked about analog to digital conversion and finally, we talk to about the interface with the computer and the software which lets a human being or a computer program see the data analyze the data for control purposes.

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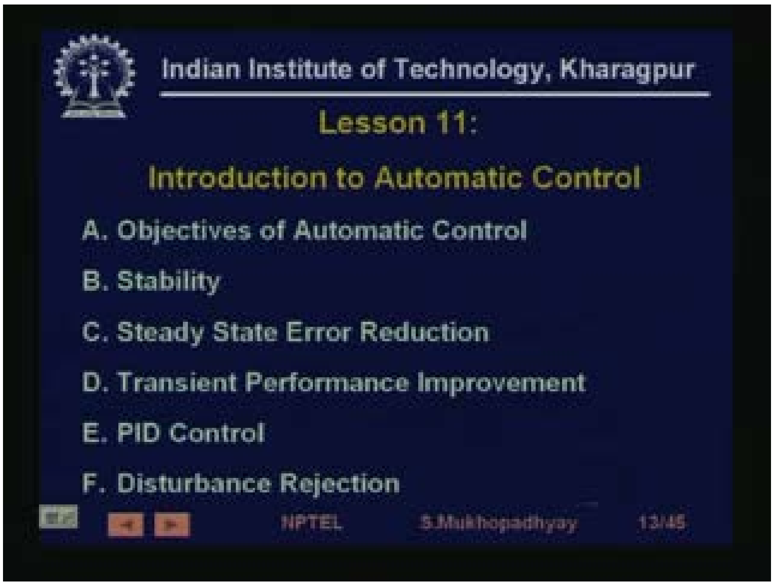

This is completed, so that we started with an abstract measurement system, then we took looks at some specific the major process variables of measurement. Then, we took a look at the typical signal processing circuits that are used for instrumentation and measurement. Then, we took at a look at the noises and the uncertainties and the measurement errors and finally, we took look at the data acquisition systems which gets the data into our computer. So you have after that now once the data is in the computer, we need to we came to the second module of the course which is on which is on automatic control.

So, we have come first we have covered sensing, then we have come to automatic control. And, in automatic control the first in the beginning we talked about the basic purpose of control and the what are its typical performance issues like stability like steady state error like transient what is a goal of a controller, and then we talked about the sources which create problems in control like you know disturbance.

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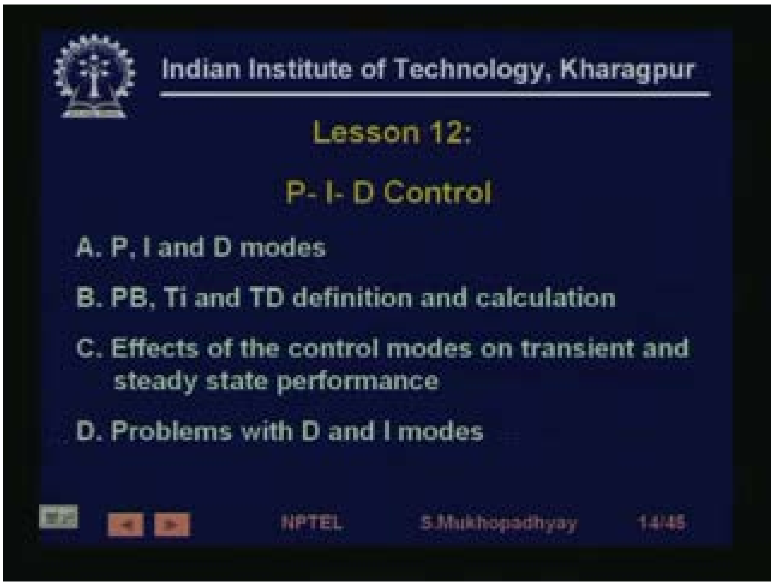

So, having understood these general concepts, we first took up PID control which is the still people say that even with. So, much advance controls about 80 to 90 percent of all industrial control has a PID, so it is important that PID controllers are looked at thoroughly. So, we talked about the basic PV, PI and D modes, then the various parameters like process proportional band integral time and derivative times. The effects of these changing these parameters on the transient performance on the plant and the steady state performance there are some problems with D and I modes and how to circumvent them.

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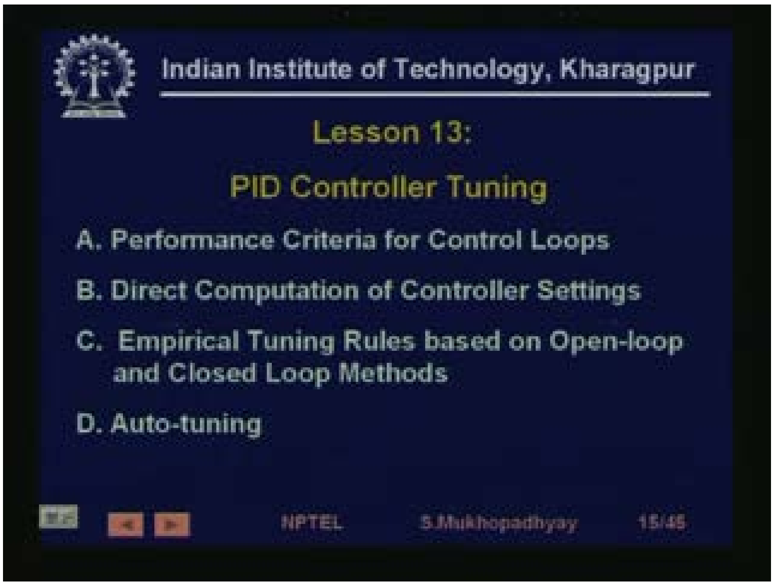

Then, we talked about PID control auto tuning, so this gains have to be properly set. So, that you have good response and because the response of the control loop is as we have said is directly related to a number of quantities like mainly product quality, the energy efficiency, raw materials that you are consuming and things like that. So, it is very important to have control loops well tuned, so that efficiency of production can be achieved. So, we looked at various methods of tuning starting from direct computation, I mean analytical computation based on modules, then empirical tuning which are based on experimental results.

And finally, we took a look at auto tuning, so auto tuning is that the controller itself examines the input output signal and then decides and then and from there it decides the best controller parameters for this process. And then downloads it into the controller I mean basically sets the PID control a parameter as those value. So, without human intervention and we described the method using relay control systems.

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So, after PID controller tuning, we took we took a look at various different control structures which give great advantages in certain system very common industrial situation and control like we started with feed forward and ratio control feed forward control is typically it can give you a very good performance in the face of disturbance, if disturbance is measurable. We also looked at ratio control which is a kind of feed forward control.

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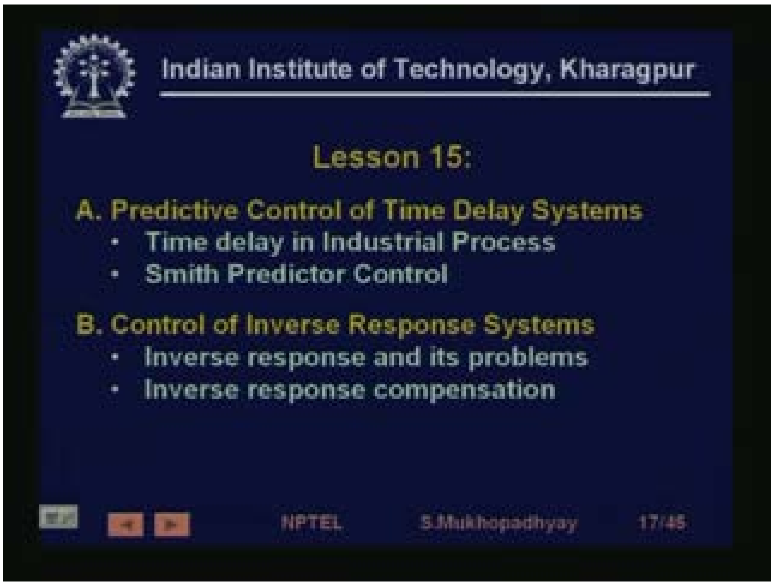

Then, we took a look at typical techniques to control process time delays which are very common, because of material flow time's etcetera in process systems and also non minimum phase systems where which are also some not uncommon and for example, in a drum level control. So in such situations, some special control structures are actually required for effective control of the processes. So, we looked at these two particular kinds of processes namely time delay systems and inverses response processes and then found introduced some particular control structures which are use are controlling these.

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Then, we looked at some special control structures, which use multiple sensors that is multiple measurements in a loop or multiple actuation points. So, in particular first we looked at cascade control and explained that, how it can give you much improved performance than in no cascade control if some intermediate variables can be measured.

Similarly, we took a look at selective controls selective control is a control where you typically used for controlling spatially distributed equipments something like in a boilers or furnaces. Similarly, multi actuator control where the same there is only one variable being controlled, but that may be controlled using several actuators.

So, typical case will be let us saying HVAC control that is heating ventilation air conditioning control where the same room temperature is controlled. But, when it is below ambient it is controlled using different equipment or the or some kind of chiller or air conditioning, while if it is to be maintained above ambient then you use heaters.

Similarly, we can use split range control and so that this is splint range control and then we can use override control sometimes you operate a plant for let us say I mean from to time your plant operational policy can change. So, sometime you can operate for maximizing production, sometimes you can operate for minimizing some energy condition some emergency condition or for from the point view of safety. So, there can be various ways of controlling.

So, I mean sometimes you can control using there may be two valves and you can operate either one of them sometimes. So, in such a case I mean the when one control policy actually at times overrides the other and then rides a different actuator, but the same control variable is being controlled in such case we have override control. So in other words, we first looked at PID in depth, then we looked at certain very special control structures which gives significant benefit.

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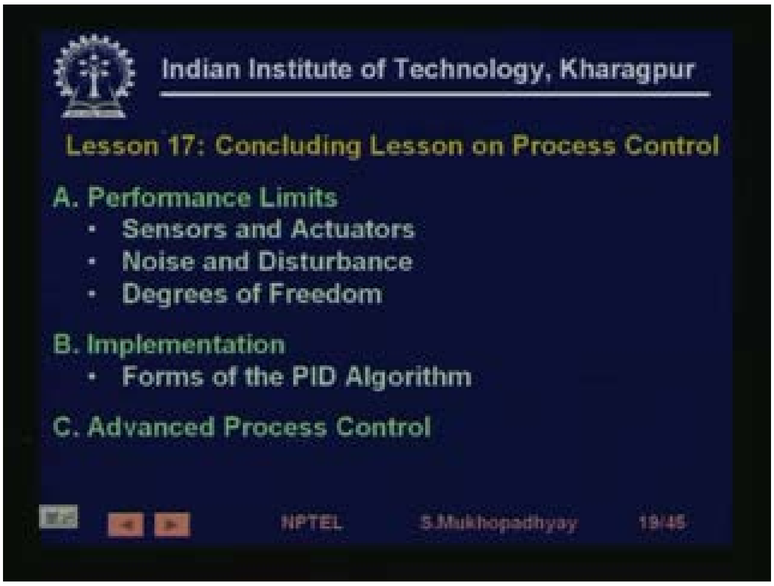

And finally, we took a look at some the factors which limit performance typically the characteristics of sensor, the characteristics of actuators all actuators have their rate limits as well as position limits. So, I mean if you think a very large input can be given to a plant it actually cannot be given for actuator limitation and it is for these reasons that the. So, called theoretical responses cannot be obtained.

So, these constraints put a limit on the performance on the control loop and similarly we have we have limitations on sensors and we also have limitations on the process dynamics or in other words degrees of freedom that is things are related and we cannot have we cannot all the time it is not possible to have absolutely independent control.

So that is, how much how much of independent control you can actually achieve depends on the degrees of freedom, so these are some of the factors that actually limit control performance of industrial systems. Then, we talked about the implementation and in specifically we talked about, how the PID algorithm can be implemented in various ways and how they are practically implemented in the commercial industrial controllers. And finally, we talked about little about advance process control that is in fact, we have not in this control module we have not talked about some of the advanced process controls that are slowly being introduced.

So for example, we have not talked about module predictive control or non-linear module predictive control we have not talked about internal module controls or others other kinds of control like state feedback controls. We have not talked about decoupling say there are several topics we have not talked about, but still we talked about the major common control structures.

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Having talked in terms of the continuous controls we shifted to logic controls which are also equally important and equally prevalent in industrial manufacturing which basically control sequence of operations of machines and generate they are often sometimes used for protection. Sometimes used for supervisory control where several sequences of control modes are executed, sometimes they are used for generating alarms they are more commonly used in discrete manufacturing.

So, we first took a brief look at the theory of any control is actually based on models, so we took a look at some discrete event system models which and then tried to introduce and capture some of the industrial sequence control problems in terms of this discrete event systems model. Then, we introduced the programmable logic controller or the PLC it is a class of equipment which sell in the market which carry out most of the sequence control, and then we introduced the programming languages for this logic control which are used as used in PLCs, so in namely the relay ladder logic.

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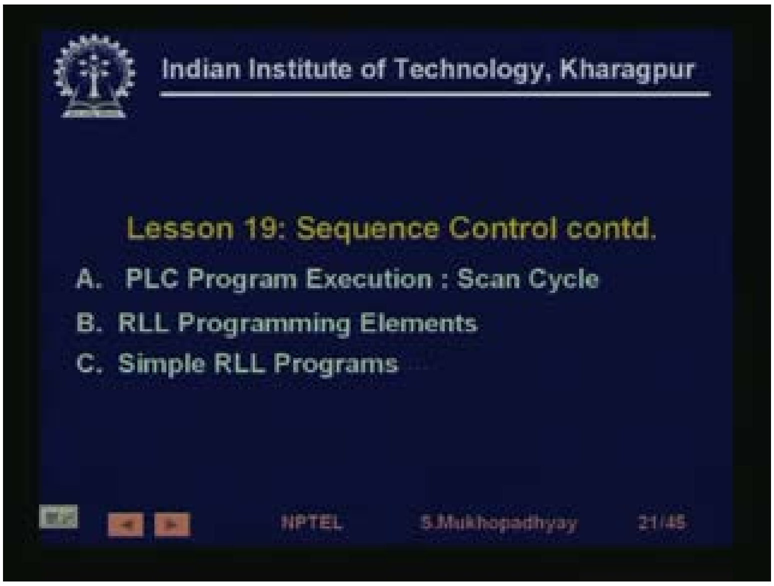

Then, we explained how PLCs work, how they get data compute outputs and then finally, download into the field. We also introduced the RLL programming elements that is the basic programming elements and started discussing simple RLL programs.

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Then, we talked about other RLL program features various kinds of statements arithmetic data move and program control operations and some other I mean macro operations which are basically a collection of I mean a fixed collection of elementary operations.

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Finally, we introduced a systematic method by which this PLC controllers can be written for some industrial control problems. So, we modeled the process as a state machine and then based on that state machine we discussed how we can write a relay ladder logic program.

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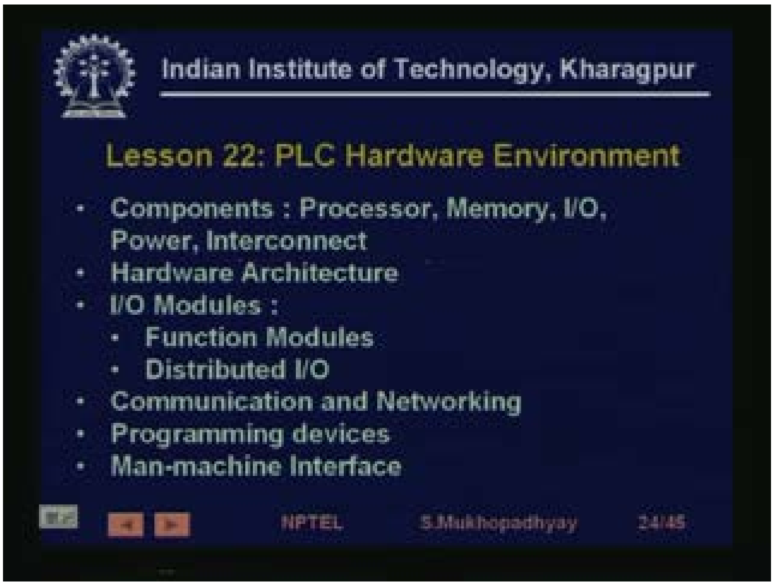

In the last lesson, we talked about the PLC hardware environment the exact the kinds of processors the specific typical specifications of processor memory IO. The bus extension various kinds of special purpose IO modules like function modules, distributor IO modules, various kinds of communication and networking modules like industrial internet. Then, the devices that are used for programming PLCs I mean developing programs and then downloading and finally, man machine interfaces like which can be connected with PLCs. So, this completes our logic control module.

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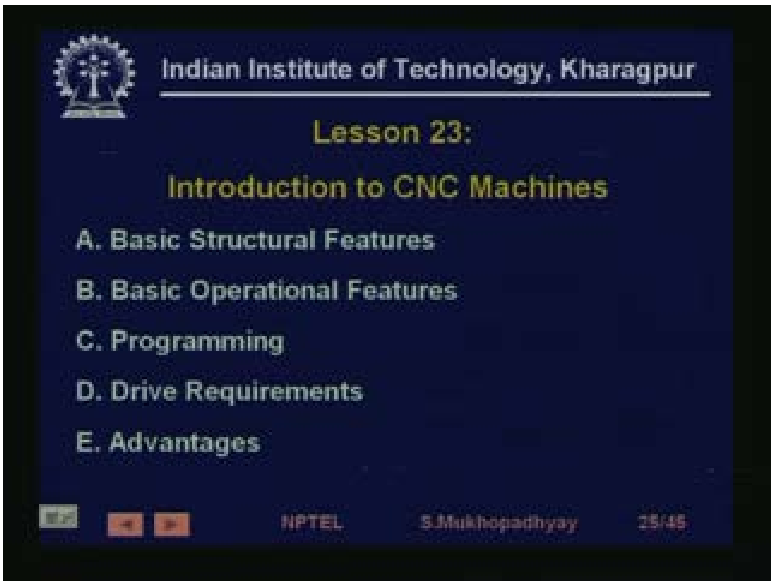

And, we come to one of the applications area namely CNC machines which are typically used for discrete manufacturing all over the world. So, we looked at the basic structural features and the basic operational features of the CNC machines and how they are programmed that is how the various cutting operations can be specified. So, that he machine can operate by itself. We also looked at the typical kinds of actuation requirements for these machines, and also took a look at the huge advantages that these machines can sometimes give you.

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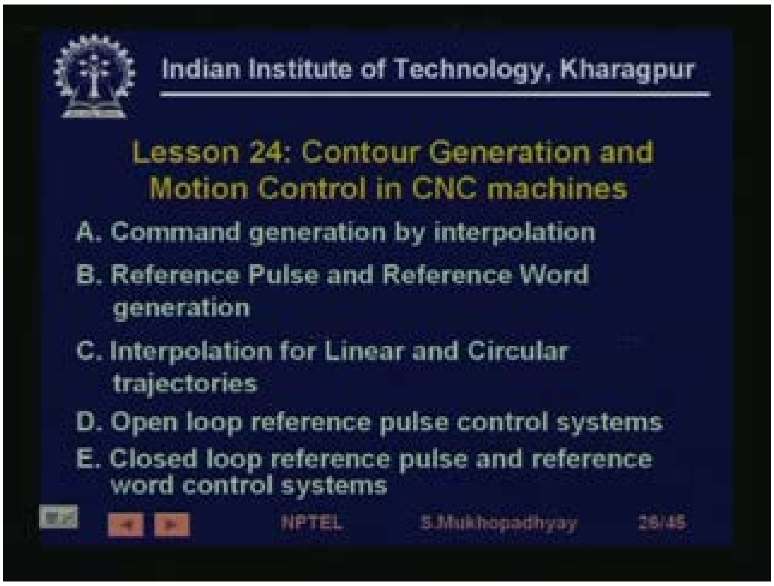

In the next lesson, we took more detailed look at how in CNC machine there are basically you have to create when you have to have when you are doing manufacturing actually removing metal by this shearing. So, relative motion between the job and the tool has to be created, so for that the job has to move and the tool also has to move. So, typically what happen is that one of these motions is rotational and the other motion is translational.

So in any case, there are precise position control speed control requirements on these on these actuations are on this ride, so that the part dimensions are good and the part surface finishes are good. So, to understand how these motion commands are generated and how the motion control is actually carried out this precision control in the CNC machines.

In lesson 24, we looked at various kinds of command generations strategies like by interpolation when we took basically two kinds of control system called reference pulse and reference word systems and how to generate them. And, we actually took at took a look at one open loop reference pulse control and closed loop reference pulse and reference word control system.

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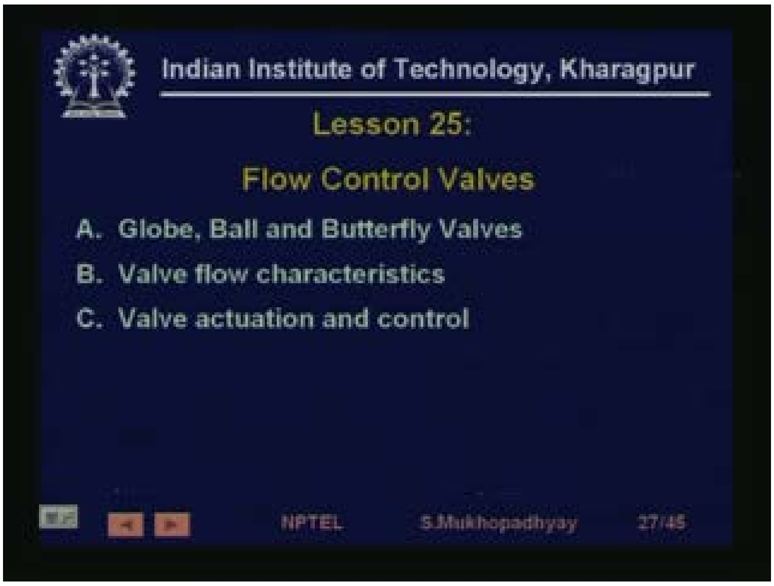

So, after that we took a look at flow control valve flow control valves are very very common and important elements in factories. So, we looked at three major kinds of valves globe ball and butterfly valves and we took a look at a flow characteristics their constructions and how the valves are moved and how the valves are moved precisely. For example we took a look at valve positioners and what advantage these positioners give you.

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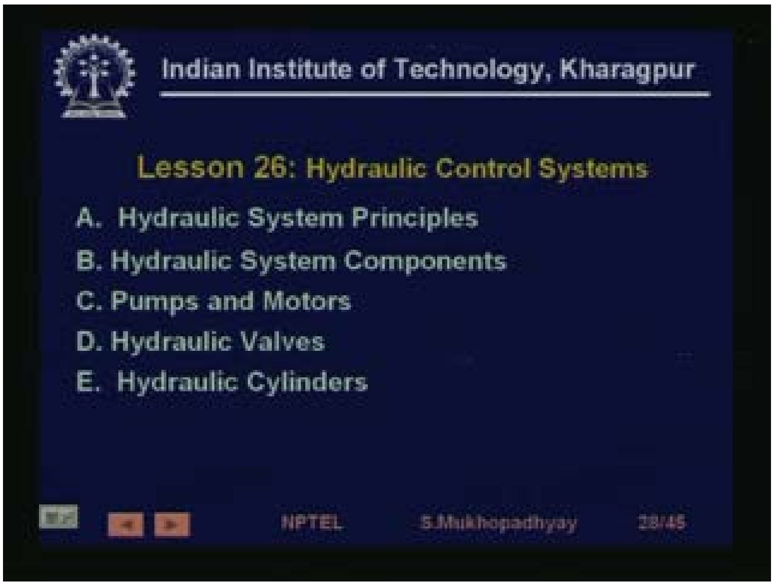

After flow control valves, we took started taking a look at hydraulics and pneumatics. So first, we took a look at hydraulics were we understood the basic principles Pascal's law then major hydraulic system components. And then we took look took a look at the components one by one that is we took a look at pumps and the motors we took a look at the hydraulic valves both direction control valves, as well as servo valves. And then we finally, look at the final actuator control element or hydraulic cylinders.

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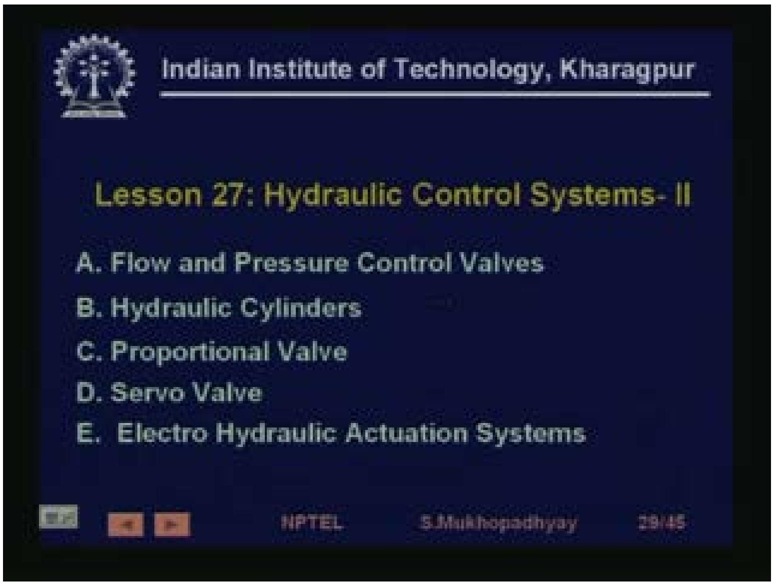

Then in the next lesson, we actually continued this and we took a look at flow and pressure control valves and previously we mainly took a look at direction control valves. Now, we took flow and pressure control valves hydraulic cylinders, then two kinds of valves which are used very much in controls that is an analog flow control, so they are the proportional valves and the servo valve. So, and then finally, we took a look at an electro hydraulic actuation system.

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In lesson 28 we took we took a look at various typical industrial hydraulic circuits and saw how these techniques can be applied for industrial purposes.

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Then, we came to pneumatics, pneumatics is very similar to hydraulics, but there are slight differences. So, we took a look at system components again compressors pneumatic valves and their accessories.

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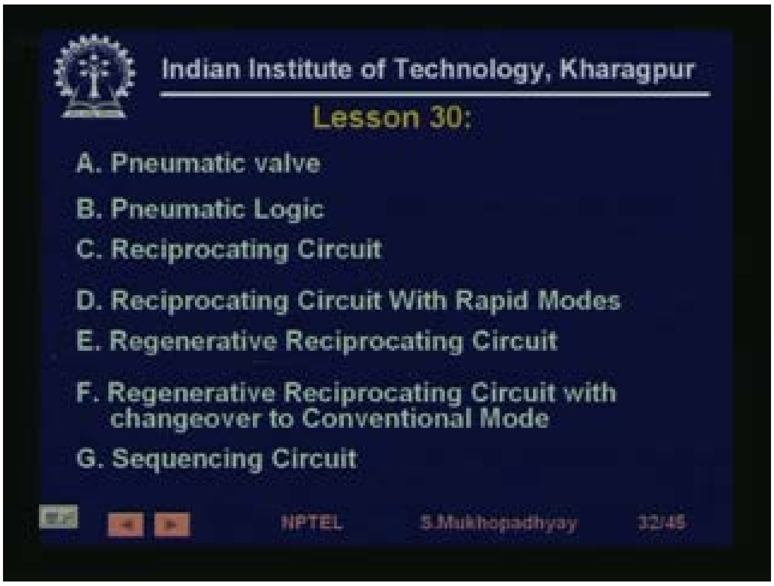

And finally, we took at look at pneumatic logic various kinds of reciprocating and then various kinds of typical pneumatic circuits like reciprocating circuits reciprocating circuits with rapid retracts reciprocating circuit with regeneration. So, that the pressure energy is not wasted and then various kinds of sequencing circuits.

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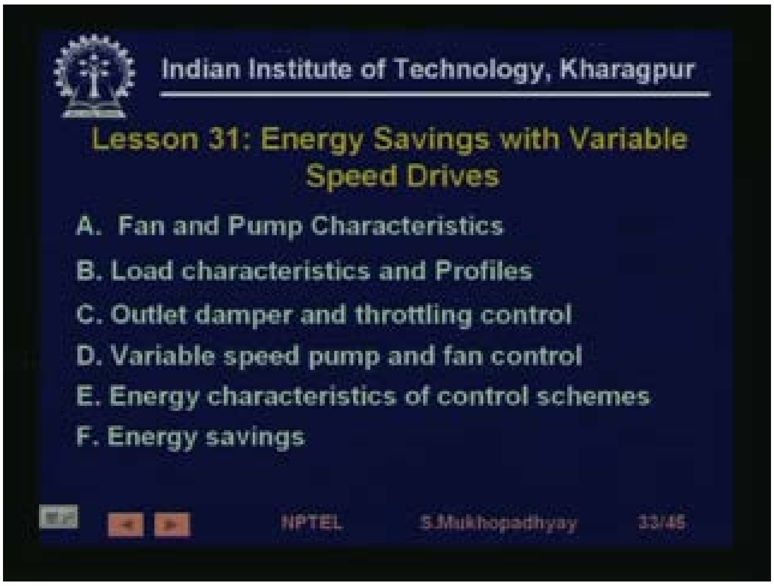

After that, we took a look at electric actuators, but before taking a look at electric actuators, we first understood that why it is a definite trend in among the industrial control or drives that people are going for variable speed drives.

Now, variable speed drives, what is the basic advantage of variable speed drives and showing that variable speed drives can be huge very significant energy savers. So, we first took a look at we actually compared fans and pumps are the predominant devices which are driven by motors.

So, we found out that if the system loads where has a certain amount of variation, then having a variable frequency although it is capital intensive it is actually more expensive and more capital has been has to be invested. But, this capital cost actually is actually coming down as the cost of power electronics is coming down.

And, on the other hand the cost of energy is going up, so it now really makes a lot of sense to have variable speed drive. Since they can save lot of energy and was saw basically from a pump or fan characteristic as to how a variable speed drive can make significant saving of energy to the extent of some sometimes 50 60 percent or even 100 percent.

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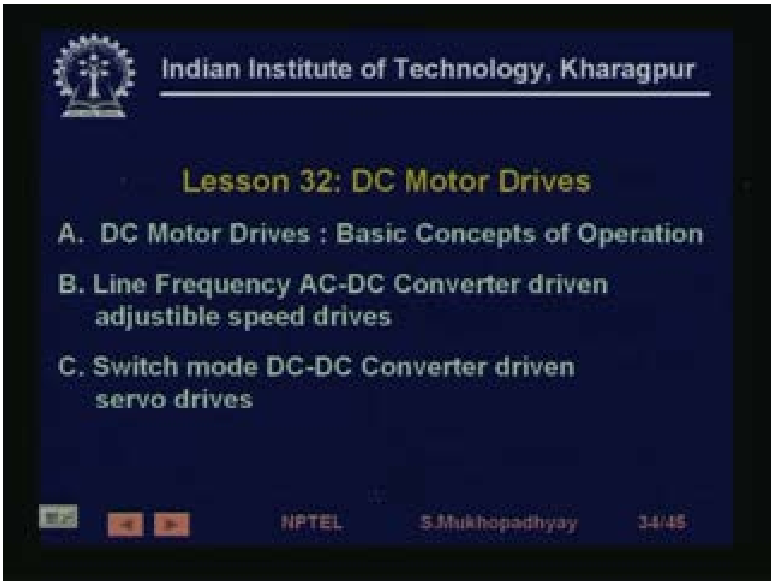

Having convinced ourselves about the requirements for variable speed drives, we took a look at first DC motor drive which is the most common and so we understood the basic concept of operation of DC motors. And then we took two things two different kinds of DC motors drives, one is a line frequency AC DC converted drive there is a rectifier which is used for adjustable speed drive.

Adjustable speed drives and servo drives are two different things in adjustable speed drives speed see its speed can be changed. But, generally the drive is operated for significant amount of time at particular speed reference, while in servo drives the speed continuously keeps changing.

So, we the kinds of power electronic drives that use for adjustable speed drives and servo drives are different. So, we took a look at two different kinds of drives, one with a convertor, one with a rectifier AC-DC convertor and another with a DC-DC convertor.

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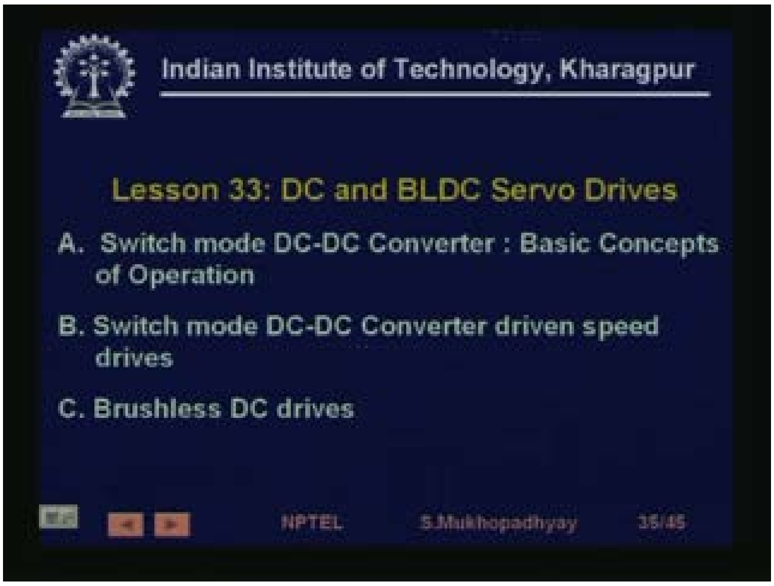

So, we went on this is a continuation lesson number 33 of this switch mode DC-DC convertors. And then we also we have seen these and these are used for BLDC drives, we also took a look at brushless DC drives which are essentially AC motors.

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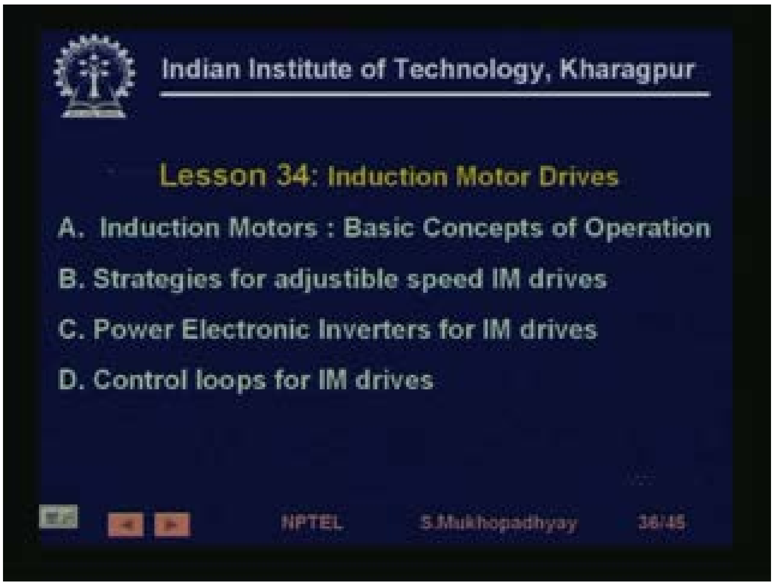

Then, we took a look at induction motor drives and may in the case of induction motors we mainly concentrated towards the adjustable speed drive. Because, induction motors are generally not used for servo drive, so although they can be, but they are much less used for servo drives generally DC and nowadays more BLDC drives are being used.

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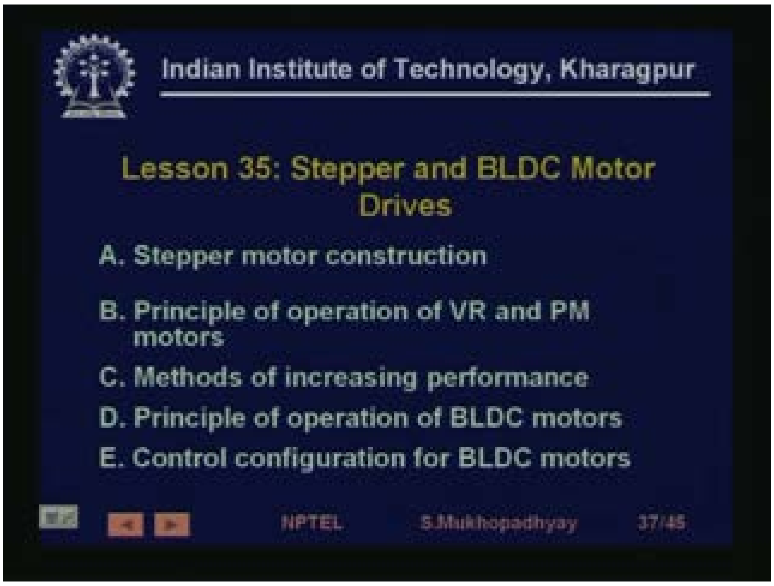

So, then we looked last we took a look at two kinds of motor drives, one are stepper motor which are used for which are very simple very simple and cheap drive electronics and are used for noncritical applications and for smaller applications having smaller power ratings. And then we also took it took a more detailed look at BLDC drives which are becoming very, very popular, basically because of the magnet I mean improvements in magnet technology.

Then, we complete actuation and then it turns out that electronics is making very significant inroads into all areas of technology and also into industrial automation. So, now what is happening is that most of the industrial automation, devices likes sensors, actuators, valves they are having electronics on the field or electronics embedded in them.

So, they are all becoming microprocessor controlled devices which have which give previously I mean huge capability to these mechanical or electromechanical devices. So, now you can have a flow control valve which has electronics on it which can do all sorts of signal processing auto calibration, it can send values it can monitor, it is own failure it can calibrate itself, you can even connect on a network. So, all this is possible because every devices getting is having I mean computing and electronic technology embedded in them. So, we thought that it is a good think to take a look at the basic embedded system technology, because it is so common and all pervasive in all aspects of our life and also industrial automation. So, we took a look at embedded system embed systems.

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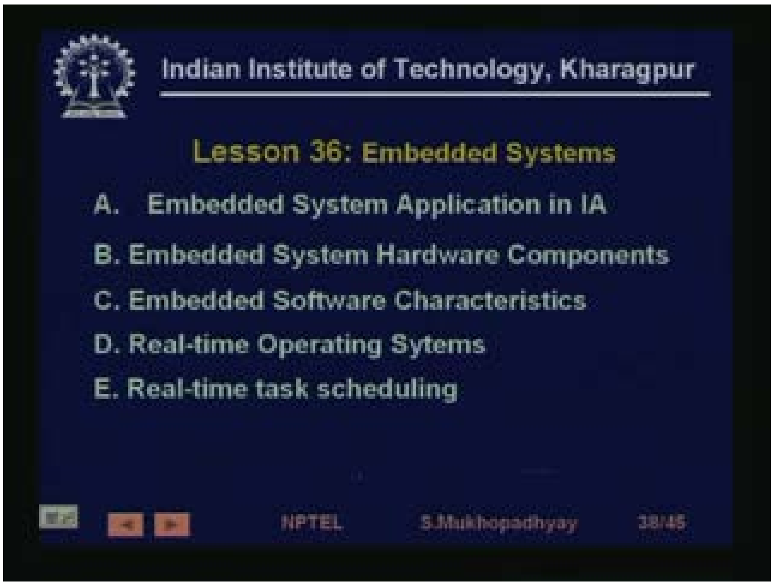

And, understood its basic types of hardware components and basic software characteristics the kind of software that are used in that, then we took a look at many of these systems are actually operated. For example a CNC machine, a CNC machine has various at least three four processors it has axis controller it has PLCs it may also have front end processors which manage the man machine interface.

So, all this multiprocessor complex systems generally work under some short of a real time operating system. So, we took a look at real time operating systems and their features and the one of the essences of real time operating systems is that there are several time critical tasks I mean which are in parallel executed in the system.

So, how to schedule them which one will be computed after what, whether they can be interrupted in the middle or not under what conditions, so these are one of the one of the major aspects of real time computing which is a feature of embedded systems used for industrial automation. So, we took a look at this real time task scheduling the basic principles of it.

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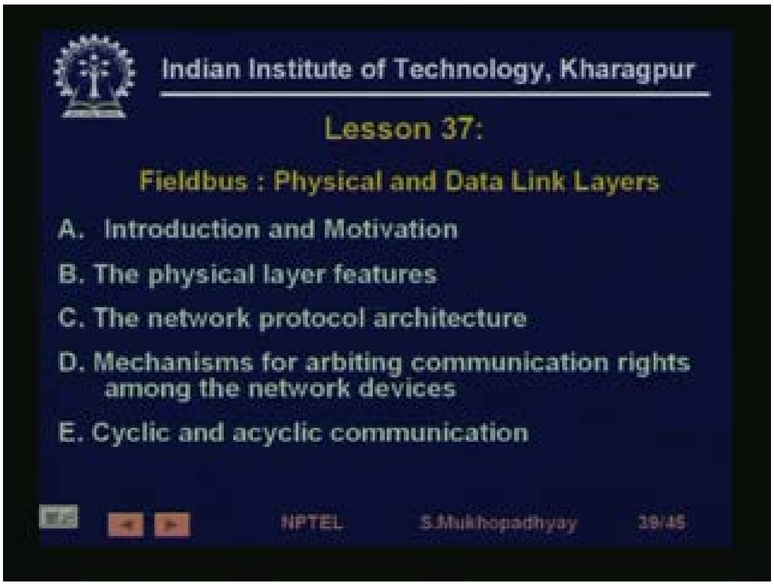

Now, once see you have this embedded, I mean devices with this embedded electronics and embedded processors in them, then the that is I mean the whole new world of opportunity is open up. So, now since you have processors on each of these devices should be able to communicate with each other and that is a very significant benefit that can that can arise out of this communication.

I mean a much more significant coordination would be possible and optimization would be possible, lot of data can be acquired, knowledge can be gained, operations can be always kept in a very tune manner by continuous adaptation. So, all sorts of documentation can be met, so all sorts of benefits can accrue if these intelligent automation devices can be made to communicate. So, it is from this concept that now people are saying that these devices all should be on a network.

So, one of the very emerging and very prominent network standards for the industrial automation marker is the field bus. So, in this lesson and the next in lesson number 37 the field bus protocol network protocol was looked at, so it like all network protocols this is also organized in terms of various kinds of layers, I mean in a network data is the whole the data basically goes I mean get transformed.

You are at the top level, you are generating information and when you are sending it down finally, it is becoming 1’s or 0’s. And, it is at the destination those 1’s or 0’s are being received and they are being processed in various ways, so that finally, you get back the information.

So, this actually carried out through a layers of software’s, so we first talked about, so we started discussing and we in this lesson we talked about the physical and the data link layers the various features and the network protocol architectures. And, also the mechanism of orbiting communication, so one of the problems of having a bus is that the bus is electrically shared. And therefore, a people cannot I mean the devices only one device can talk at a time.

So, there is a need to understand who is going to talk when so there are elaborate rules have to be formulated for that. Otherwise, when somebody is talking or some device is transmitting data on the network if another device start transmitting thus I mean some different data on the same network, then the data can be get corrupted. So, we took a look at some of these modules of you know orbiting communication on the buses and taking a look at how that that actually turns out for cyclic and as cyclic communication.

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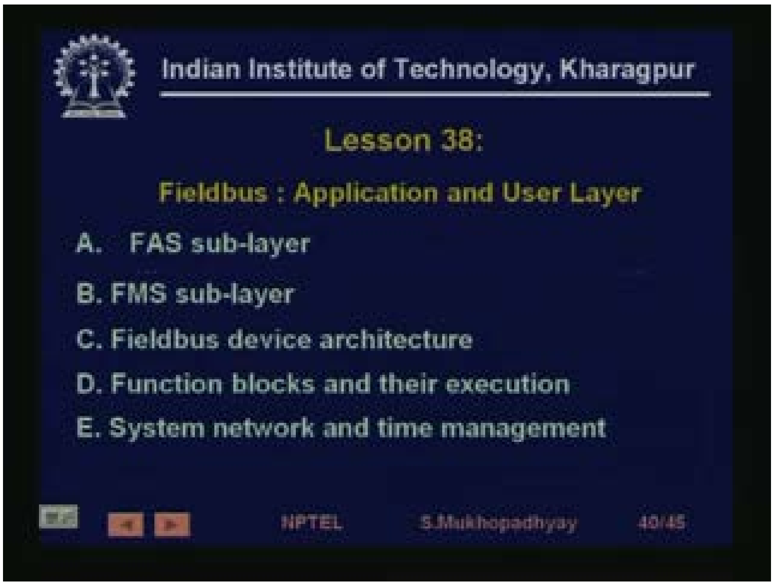

Once the basic, so this will ensure that the basic data packets are the low level they can get transmitted reliably from one point to the other. And then you have to talk about the application and the user layers, so how that is when one device looks at another device how it comes to know that, what is the how that device is made of, what is it doing the interpretation of the variables that one devices sending to the other.

So, all these issues are dealt with at the application and the user layers and we mainly discussed the function blocks which is the obstruct model for any field bus device. And, we also discussed the issue of obtaining synchronization throughout the networks, so doing network management and doing time management over the network.

This more or less completes and so if you go back you have seen that we have discussed a sensor that was in the first module. Then, we have discuss controls both analog controls as well as sequence controls and then we discussed various types of actuators, so we discussed flow control valves we discussed hydraulics we discussed pneumatics and we discussed electrics that is basically motor drives. And, we also discussed that, how these can save lot of power.

So then finally, we discussed the electronics which gives make some intelligent and makes them and enables communication among them. So, once you have all these devices this level 1 and level 0 devices on the network, so all the data are available then it would be possible to do system wide coordination and system wide optimization.

And in fact that, it is precisely this which is done at the automations are at level 2 and level 3. In absence of this electronics and communication, typically these optimizations and then these coordinations are done at a much slower scale basically by the operators. So, these operators just take look at take looks at those values and then they operate the process. But once, these data are available on the computers over the network, then there are possibilities of doing much faster and much more pervasive coordination among in the factory. So, actually that is what is to be done, that is what is done in the case of in level two and level three automations.

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So, in the last in the in the penultimate lesson in very in brief, we actually talked about the higher layers, as we said that we are not going to discuss the higher layers in great depth. Because of various reasons, firstly, it takes time to cover only you know level 0 and level 1, so we did not have enough time.

Secondly higher layers are some often very domain dependent, while level 0 and level 1 technologies are domain independent and they apply to a wide variety of plants. If you want to do how to up to do set point optimization, then you can you have to only talk about set point optimization for either a distillation column or a boiler or a what a whatever. So, they become very process specific and therefore, difficult to discuss in a course.

So in this last penultimate lesson, the basis features of supervisory control and manufacturing management were discussed, so we talked about level two automation functions such that set point optimization and process monitoring. So, one they actually this is a wrong, it should be set point generation and process monitoring this is a typo.

Then, we talked about level three automation functions where we talked about basically planning scheduling and basically planning scheduling. So, how the various we did not go into much depth though, then on top of that we have so we have level two systems and level two systems which are still with the controls.

Then, level some bit of level 2 and basically level three systems are generally decided in different types of computer and their computing and techniques are completely different, so they are called manufacturing execution systems. And then in level four, we have business systems which do which employ technologies like supply chain management enterprise resource planning.

And therefore, and basically they generate long range plans they generate market projections they actually decide how I mean how much how much order has to be taken, what are the commitments deadlines. And then they pass it onto the manufacturing execution systems, which in turn then decide that that with available equipment man power raw material, how exactly production should go such I mean such that all the production deadlines are met.

And then these production sequences and detailed production sequences are passed on to the supervisory controller which then actually gets about producing. So, this is the way it goes on, so in the last lesson we discussed these higher level automation functions.

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So, that brings us to the end of this lesson and so having discussed, what has been covered we should also take a look at, what has not been covered at least we should be aware of some of the things that we have not covered which were also relevant. So, for example, as we have said that we have mainly concentrated on level 0 and 1, so level 2 and 3 have not been covered in great detail that is the first thing. But, even in level at 0 and 1 there are certain parts which could have been covered, but could not be covered you know you have to always leave out certain things.

For example we did not take a take a detailed look of look at metrology or which are widely used for you know quality control we did not take a look at analytical instruments which are used for process product composition testing. We did not look at look in great depth on instrument standards calibration.

Similarly in terms of control, as we said that we while we looked at the PID controllers and some of the standard process control architectures. There are some advanced controls which are coming and which are gradually becoming gradually also being applied in processes and manufacturing, we did not discuss them. Like non-linear model predictive control. The PLC treatment was also kept more or less that there is the standard techniques which PLCs have several programming languages they are so we did not discuss all of them. We only discussed the relay ladder logic in detail and then the sequential function chart in some detail.

So in other word, what I am trying to say is that in case somebody is interested, one can one can go ahead and read other supplementary or advanced level material for knowing the latest in these fields which should be beyond what has been covered in this course.

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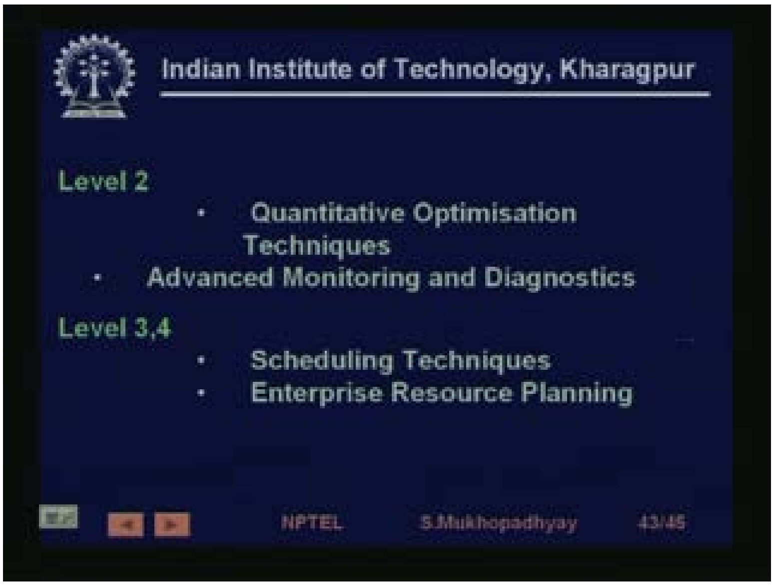

Similarly in level 2, we did not discuss various kinds of quantitative optimization techniques linear non-linear programming. We did not discuss advance monitoring and diagnostic techniques some of which have just started becoming being applied, they are quite advanced. We did not deal with as I said level 3 and 4, we hardly talked about it and there are very detailed scheduling and optimization techniques available which for example, enterprise resource planning can be a course in itself.

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So having said that, I would make the final concluding comments of this course, This course was thought of because such a course actually is rare you have rarely have you do not have books or materials which discuss these, I mean the industrial automation technology is all within one cover. So, that was one of the main motivating factors of having this course.

And this course, it was also felt that can be useful for a various kinds of students backgrounds of I mean for students from I mean engineering under graduate students from mechanical chemical electrical etcetera. So, the major focus and coverage was kept suitable for the major focus and coverage was kept suitable for the undergraduate levels we have just discussed, what has been covered.

So, reference and supplementary materials have been used from a variety of sources several texts, internets my own class notes and books. So, it simply because in fact, they were, but in all while I have I mean we have not within the limits of this course it has not been possible to it would not have been possible to cite all of them.

So, I we have left out left them out altogether, but in all cases while we have I have certainly referred to various kinds of material. I have tried to present them in my own ways, so that way the presentations in many cases I mean all cases are original. We have not been able to give again because of sort of we have not been able to discuss numerical problems

So in fact, one has to find out numerical problems from individual modules like for example, numerical problems and control can be found from process control books. Similarly drives may be from power electronics and drives books and things like that, another thing is that under the same NPTEL program an associated web based course has also been developed by myself and professor S. Sen of IIT Kharagpur.

And we will be able to give some of these refer to say I mean add the some of these problems of numerical problems, questions, answers references in those web courses. So, that is all for today I hope I hope this course would be useful and well yes after recording these courses I am teaching these courses in my own classes using the same set of slides and I discovered a few errors. So, while in the final version some of this errors will get removed I am sure that is some of them might still stay various kinds of errors I hope there are no major errors.

So in case, there are errors and if you declare if you find them and you can inform me I will be I will be grateful, but I will apologize in advance for any errors that may be present here. But, I always feel that you know if one can correct an error in a particular part of any learning material, he probably learns that part of the material the best. So, there you are this is the end of the course.

Thank you very much and bye.